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# THE NITROGEN NUTRITION OF MAIZE

# ON DRYLAND SOILS

# OF THE CENTRAL ORANGE FREE STATE

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# OF THE CENTRAL ORANGE FREE STATE

Thesis submitted in fulfilment of the regulations for the degree of Doctor of Philosophy at the University of Cape Town

by

GERHARD SCHMIDT
(Dr.agr., Halle)

GLEN, June, 1963

University of Cape Town

I, the undersigned, herewith declare that this thesis is entirely my own work and has not been presented for any degree at another University.

Signed by candidate

GERHARD SCHMIDT

GLEN,
15th June, 1963

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Finally I wish to convey my thanks to the Director of the Orange Free State Region for the facilities provided at Glen, to the staff of the Agronomy Section at Glen for assistance with the field experiments, and to Mr. J.B.J.N. Kotzé for his collaboration in co-operative experiments carried out on his farm "Excelsior".

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on research projects carried out

at the

Glen College of Agriculture,

Department of Agricultural Technical Services.

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Permission to incorporate the results
obtained from registered projects in
this thesis is gratefully acknowledged.

## UNITS OF MEASUREMENT

Both metric and South African non-metric units of measurement are used in this thesis. For the reader who is not accustomed to the non-metric units, the following numerical equivalents and approximations are given:

### Length

| | | | |
|---|---|---|---|
| 1 inch (in.) | | = | 2.54 cm |
| 1 English foot (ft.) | = 12 inches | = | 30.48 cm |
| 1 yard (yd.) | = 3 feet | = | 91.44 cm |
| 1 mile | = 1760 yards | = | 1.609 km |

### Area

1 morgen (Cape) = 10,244 square yards = 0.857 hectare
= 2.12 acres (approx.)

It is general practice in field experiments to regard 10,000 square yards as one morgen.

### Weight

| | | |
|---|---|---|
| 1 pound avoirdupois (lb.) | = | 453.6 g |
| 1 bag = 200 pounds for maize | = | 90.72 kg |
| 1 short ton (ton) | = | 0.9072 metric ton |

### Factors for approximate conversion of yields to metric system

Bags per morgen (10,000 square yards)x 1.084 is equivalent to 100 kg units per hectare. Tons per morgen x 1.084 is equivalent to metric tons per hectare. Pounds per morgen x 0.542 is equivalent to kg per hectare.

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## A. ABSTRACT.

1. Central Orange Free State soils vary considerably in the nitrogen supply to dryland maize. In some localities the soil supplies adequate amounts of nitrogen so that nitrogen fertilizer does not lead to any growth response. In other localities soils are poor in nitrogen and require nitrogen fertilizer for maximum grain yields.

2. In the localities investigated surface soils (0 - 1 ft.) did not differ appreciably in nitrogen status and the nitrogen supply to maize was influenced mainly by the nitrogen available in the respective subsoils (1 - 2 and 2 - 3 ft.).

3. Differences in the nitrogen status between localities were evidently caused by appreciable differences in the mineral nitrogen contents of the soils. The ability of the respective soils to liberate mineral nitrogen did not give any indication of the availability of nitrogen to maize in the field. These results may be partially explained by the semi-arid climatic conditions and relatively short periods of soil cultivation.

4. Differences in the nitrogen status of soils were strongly reflected in the nitrogen percentages of the plant material harvested at maturity. Nitrogen determinations in grain or stover seem to be promising as a basis for the prediction of the nitrogen requirement of maize.

5. Weather conditions markedly influenced the response of maize to nitrogen fertilizer. In dry seasons response to nitrogen fertilizer may be low even on soils poor in available nitrogen.

6. When moist conditions allow a vigorous vegetative growth it is important that an adequate nitrogen status of the plants during the generative period be maintained by top-dressings. Limited amounts of nitrogen applied at planting time can lead to increased nitrogen requirement at an advanced stage of development.

7. In the Central Orange Free State the growth and reproduction of maize is limited mainly by moisture supply. A plant population of 15,000 plants per morgen is regarded as optimal for most seasons. A larger number of plants increases the nitrogen requirement of maize and the risk of failure in grain production. With a large number of plants per morgen generally more stover and less grain is produced,

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and/

and more nitrogen is retained in the stover than is the case with a smaller plant density.

8. Planting 15,000 plants per morgen led to only a slightly lower evapotranspiration as compared with 30,000 plants per morgen.

9. The drought resistance of maize can be increased slightly when the proposed number of plants is planted in wide ( 6 or 7 ft.) instead of in narrow ( 3 ft.) rows. Compared with 3 ft. rows, planting in 6 ft. rows resulted in only a slightly retarded evapotranspiration.

0. Compared with early planting (October, November), **delayed** planting (December) increases the probability of a higher soil moisture supply and **may** lead to increased grain yields.

1. Nitrogen fertilization does not seem to affect the drought resistance of maize or to decrease grain yields in dry seasons.

2. In hydroponic experiments, ammonium and nitrate applications led to a nearly equal growth of maize when higher $NH_3$-tensions in the ammonium solutions were avoided.

3. In the physiology of maize the function of nitrates seems to be limited to a storage form of nitrogen. Hydroponic experiments did not indicate a significance of either $NO_3^-$ or $Cl^-$ as antagonists to polyvalent anions in this plant. Maize does not seem to be nitrophile or halophile.

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## B. INTRODUCTION.

In the main crop production areas of the Orange Free State which are concentrated in the semi-arid central, northern and eastern parts, the application of nitrogen fertilizer to dryland crops has only recently been started on a very small scale. At the time when the investigations reported in this thesis were started, the opinion prevailed that only the application of phosphate fertilizer results in a growth response under dryland conditions. The nitrogen status of the soils was believed to be sufficient to meet the nitrogen requirement of crop plants and to ensure optimal yields without nitrogen fertilizer.

There were, however, indications of soil impoverishment due to a decrease in the humus content, resulting from continuous growing of marketing crops. To counter deterioration of the soil fertility, the Government offered subsidies to farmers for improvement of soils by means of ley farming.

A low soil fertility on account of a low humus content mostly finds its expression in a poor nitrogen supply to plants. Decomposing soil organic matter plays a prominent part as a nitrogen source for plants. Since the cultivated lands of the Orange Free State contain little humus (DONALDSON, 1960), it was doubtful whether the nitrogen requirement of crop plants could be met on all the soils of the Central Orange Free State without the addition of nitrogen fertilizer. No systematic investigations on the nitrogen status of dryland soils and the advisability of applying nitrogen fertilizer to crops under dryland conditions had previously been conducted in the Orange Free State Region.

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Investigations on this matter have, however, become imperative due to a general rise in the agricultural production and an increasing availability of nitrogen fertilizer on the market. Knowledge of the possibilities of the application of nitrogen fertilizer may contribute to a judicious use of nitrogen fertilizer and make this growth factor available to a larger community.

The purpose of these investigations was to study the nitrogen requirement of maize on the one hand and the ability of different soils to meet this requirement on the other. Attention was paid to various factors influencing the nitrogen requirement of maize, for example espacement, time of planting as well as the availability of phosphorus and potassium to the plant.

In the course of the investigations other problems emerged from the results obtained. Accordingly, the experimental work was expanded to include studies on the influence of applied nitrogen in combination with various other environmental factors on both the moisture consumption and drought resistance of dry-land maize. In addition, an effort was made to obtain information on the nitrogen requirement of maize during successive growth stages, and on the influence of both the nitrogen status of the soil and the application of nitrogen fertilizer on the nitrogen status of maize plants at different growth stages. In order to facilitate an assessment of the nitrogen fertilizer requirement of maize grown on different soils, it was regarded as essential to investigate various ways of determining nitrogen deficiencies in soils. Finally a study on the physiological function of nitrates in the maize plant was included in the investigations.

## C. EXPERIMENTAL CONDITIONS.

### I. Experimental Sites.

The investigations were concentrated on two experimental sites, each representative of larger surrounding areas. An intensive study on two sites having dissimilar soils was considered preferable to superficial investigations on larger areas.

The sites were situated at the Glen College of Agriculture 16 miles north-east of Bloemfontein and on the farm "Excelsior" about 60 miles north-east of Glen and 8 miles from Theunissen.

At Glen most of the field experiments were conducted on the recently established experimental plots of the Agronomy Section which had been cultivated for periods varying from 2 - 7 years. In one case a field which had been cultivated for about 35 years was also included in the experiments. Soil investigations were carried out on the two lands mentioned as well as on a higher land, named "Topland", situated about 2.5 miles north-west of the experimental plots. It had been cultivated for about 40 years.

On the farm "Excelsior", Theunissen, experiments were carried out on two lands, the first ("Theunissen I") being situated south-west of and bordering the other ("Theunissen II"). The soils of the experiments at "Excelsior", Theunissen, appeared to be uniform and the lands had been under cultivation for more than 35 years.

Pot experiments were conducted outdoors at Glen under bird proof wire-netting.

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Greenhouse facilities were not available, therefore hydroponic experiments were carried out in the laboratories of the Institute of Soil Biology at the University of the Orange Free State. The vessels were placed behind large north facing windows of this newly erected building.

## II. Climate and Weather.

### a. General Climatic Conditions.

The climate of the area investigated has recently been described and discussed in detail (WHITMORE, 1950 a, b and c; KENDREW, 1953 p. 114-133 and MOSTERT, 1958) and only a brief review will be given here.

The air temperature, rainfall and evaporation recorded at Glen and the relative humidity recorded at Bloemfontein are shown in Table 1.

Long term weather records are available for Glen but not for Theunissen.

On account of the relatively small distance and difference in altitude between Glen and Theunissen a good conformity of the general climatic conditions can be assumed.

Records of the relative humidity at 14.00 hours S.A. time have been kept at Glen since October 1957. The monthly figures of the few years available indicate a great variability of the relative humidity. The humidity data at the nearby Weather Office in Bloemfontein are based on long term recordings. These readings are, therefore, considered more representative of the area investigated.

Only 3 years' recordings were available to calculate the mean monthly and yearly evaporation rates. The means may, to a certain extent, be influenced by seasonal deviations. Since the figures for the different months vary greatly and only relatively small annual differences between the evaporation during the same months were found, the mean monthly and annual figures may well reflect the general tendency.

The climate of the specific area seems to be determined mainly by the altitude and the situation in the interior of the Continent. The geographical position (Glen College of Agriculture :- Lat. 28° 57'S, Long. 26° 20'E) could, on account of the latitude, indicate a rather warm climate. However, the climate is, in fact, fairly temperate and this may to a large extent be attributed to the altitude (Glen College of Agriculture 1,310 m).

The position in the interior of the Continent brings about some/

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TABLE 1 : AIR TEMPERATURE, RAINFALL AND EVAPORATION AT THE GLEN COLLEGE OF AGRICULTURE AND RELATIVE HUMIDITY AT THE BLOEMFONTEIN WEATHER OFFICE

| MONTH | Air temperature (°C), period 1914-1950 | | | | | | | | Rainfall (mm), period 1929-1960 | | | | Number of days with rainfall (> 0.2 mm) | | | Evaporation from A-tank (mm) (mean of 3 years) | Relative humidity (%) 1937-1950 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | 08.00 | | 14.00 | |
| | Mean daily maximum | Mean monthly maximum | Highest daily maximum | Mean daily minimum | Mean monthly minimum | Lowest daily minimum | Max. plus min. / 2 | Range : Max. - minimum | Average | Monthly as % of annual mean | Maximum for month and year | Minimum for month and year | Average | Maxim. | Minim. | | Mean | Mean daily maxim. | Mean | Mean daily minim. |
| JULY | 17.2 | 21.6 | 26.1 | -1.8 | -7.4 | -11.7 | 7.7 | 19.0 | 8.4 | 1.6 | 50.3 | 0.0 | 1.6 | 6 | 0 | 89 | 71 | 81 | 32 | 26 |
| AUGUST | 20.4 | 26.1 | 28.2 | 0.7 | -5.3 | -9.4 | 10.5 | 19.7 | 9.8 | 1.8 | 75.4 | 0.0 | 1.5 | 5 | 0 | 141 | 60 | 80 | 29 | 17 |
| SEPTEMBER | 23.7 | 30.4 | 33.2 | 4.9 | -2.1 | -7.5 | 14.3 | 18.8 | 17.9 | 3.4 | 109.1 | 0.0 | 2.6 | 16 | 0 | 223 | 51 | 69 | 25 | 12 |
| OCTOBER | 27.0 | 33.2 | 35.8 | 9.6 | 1.8 | -2.2 | 18.3 | 17.4 | 42.5 | 8.0 | 136.4 | 0.0 | 5.6 | 13 | 0 | 281 | 55 | 68 | 28 | 14 |
| NOVEMBER | 27.9 | 34.0 | 37.2 | 11.9 | 4.6 | -0.6 | 19.9 | 16.0 | 68.5 | 12.9 | 172.0 | 0.0 | 7.4 | 15 | 0 | 282 | 53 | 73 | 27 | 16 |
| DECEMBER | 30.2 | 34.9 | 38.4 | 13.8 | 7.7 | 3.3 | 21.9 | 16.4 | 74.0 | 13.9 | 174.2 | 2.8 | 8.0 | 17 | 2 | 297 | 56 | 72 | 29 | 13 |
| JANUARY | 30.8 | 35.9 | 39.1 | 15.3 | 9.6 | 5.0 | 23.1 | 15.5 | 77.3 | 14.6 | 172.0 | 6.9 | 9.3 | 20 | 3 | 319 | 62 | 78 | 33 | 23 |
| FEBRUARY | 29.3 | 34.3 | 37.2 | 14.4 | 8.9 | 4.0 | 21.8 | 14.9 | 71.9 | 13.6 | 177.3 | 19.3 | 9.4 | 16 | 5 | 242 | 71 | 81 | 42 | 22 |
| MARCH | 27.0 | 31.8 | 36.7 | 12.4 | 6.8 | 1.4 | 19.7 | 14.6 | 84.7 | 16.0 | 233.4 | 8.4 | 9.5 | 16 | 4 | 192 | 73 | 83 | 42 | 28 |
| APRIL | 23.7 | 28.2 | 32.3 | 7.7 | 1.5 | -5.0 | 15.7 | 16.0 | 48.7 | 9.2 | 211.3 | 0.0 | 5.9 | 13 | 0 | 131 | 72 | 84 | 38 | 27 |
| MAY | 20.6 | 24.4 | 28.3 | 2.4 | -4.7 | -8.3 | 11.5 | 18.2 | 19.6 | 3.7 | 88.9 | 0.0 | 4.1 | 10 | 0 | 88 | 75 | 86 | 36 | 25 |
| JUNE | 17.2 | 21.9 | 26.7 | -1.4 | -7.1 | -10.6 | 7.9 | 18.6 | 7.2 | 1.4 | 53.3 | 0.0 | 1.7 | 8 | 0 | 73 | 74 | 81 | 33 | 22 |
| YEAR | 24.6 | - | 39.1 | 7.5 | - | -11.7 | 16.1 | 17.1 | 530.5 | 100 | 822.7 | 215.4 | 66.6 | 106 | 49 | 2358 | 64 | - | 33 | - |

The air temperatures and the relative humidity were taken from the reports of the Weather Bureau, Pretoria

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some climatic properties which are common to the vast continental areas. These properties are great daily and annual temperature fluctuations and a relatively low and erratic precipitation.

The Orange Free State falls within the vast summer rainfall area which takes up the major part of Southern Africa. During summer, when the Continent is strongly heated, a general monsoonal inflow from the north and north-east brings equatorial and maritime air originating mainly from the Indian ocean. Apart from a stronger inflow of moist air into the east, the relief of the Continent also has a marked influence on the distribution of the rains over the western and eastern parts of South Africa. The Orange Free State lies in the rain shadow of the Drakensberg Mountain Range. On this side of the mountain range the land-surface slopes down to the west and with it the rainfall decreases. KENDREW (1953, p. 123) set the altitudes against the precipitation near the 29th parallel:-

| | Alt., ft. | Mean annual rainfall, in. |
|---|---|---|
| Durban | 50 | 45 |
| Pietermaritzburg | 2,243 | 36 |
| Drakensberg | 10,000 | 45 - 75 |
| Bloemfontein | 4,583 | 21 |
| Kimberley | 3,996 | 16 |
| Upington | 2,640 | 7 |
| Pella | 1,500 | 3 |
| Port Nolloth | 22 | 3 |

In the Central Orange Free State 75 - 80 per cent of the rain falls during the six months of the main growth season from October to March. A great part of the rain falls as thunder storms. During winter the inner plateau of Southern Africa is much colder than the coasts and fine, dry weather predominates. Frost occurs only during the night and early morning.

The average first frost date at Glen (over 30 years) is the 3rd of May and the average last date the 24th of September. The extreme dates are the 7th of April for the earliest frost and the 6th of November for the latest.

b. Relationships between Climate and Crop Production.

A consideration of the soil moisture conditions during the year is regarded as important for the understanding of the relationships between climate and crop production. Results

of soil/

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of soil moisture studies conducted by the author during 1956/57 may be helpful for the interpretation of this subject. Figure 1 illustrates the soil moisture content under undisturbed natural vegetation (veld) at Glen for the period from October 1956 to September 1957. Figure 2 shows the soil moisture content during the same period in a maize land, about 25 m distant from the site of Figure 1. The precipitation during the season October 1956 to March 1957 corresponds to the seasonal average for Glen, but the monthly rainfall totals deviated considerably from the corresponding monthly averages.

After relatively dry conditions before and during September 1956, a rainy October followed (192 per cent of the average). During November only 65 per cent of the mean was recorded. With 176 per cent of the mean, a very high precipitation was experienced during December. January 1957 had nearly normal and February (41 per cent), March (62 per cent) and April (55 per cent) subnormal rainfall. The rainfall during the late winter and early spring in 1957 was exceptionally high (August 414 and September 609 per cent of the mean).

On account of winter drought, lands permanently covered with plants (natural vegetation or perennial crop plants) usually have no or only negligible amounts of readily available moisture conserved from the previous rainy season. The plants often grow considerably during autumn until winter dormancy is reached or the above ground parts are killed by frost. During this time the plants may use all or most of the soil moisture gained late in the season.

On the other hand, a certain amount of soil moisture may be conserved towards the termination of a season when the cultivation of an annual crop is followed by winter fallow. The annual crop plants have often reached maturity by late March or early April. In the case of maize and grain sorghums, moisture may be conserved during the period of ripening, when the evapotranspiration is markedly decreased. According to long term weather records, the precipitation during March exceeds that of any other month of the year.

In the investigations no further attention was paid to the late and post seasonal moisture conservation; nevertheless this seems to be of considerable practical significance. Farmers often plant wheat between the rows of maturing maize to obtain grazing during winter. No harmful effect on the ripening maize is to be expected, but the wheat consumes moisture which is lost to the following crop. Farmers often/

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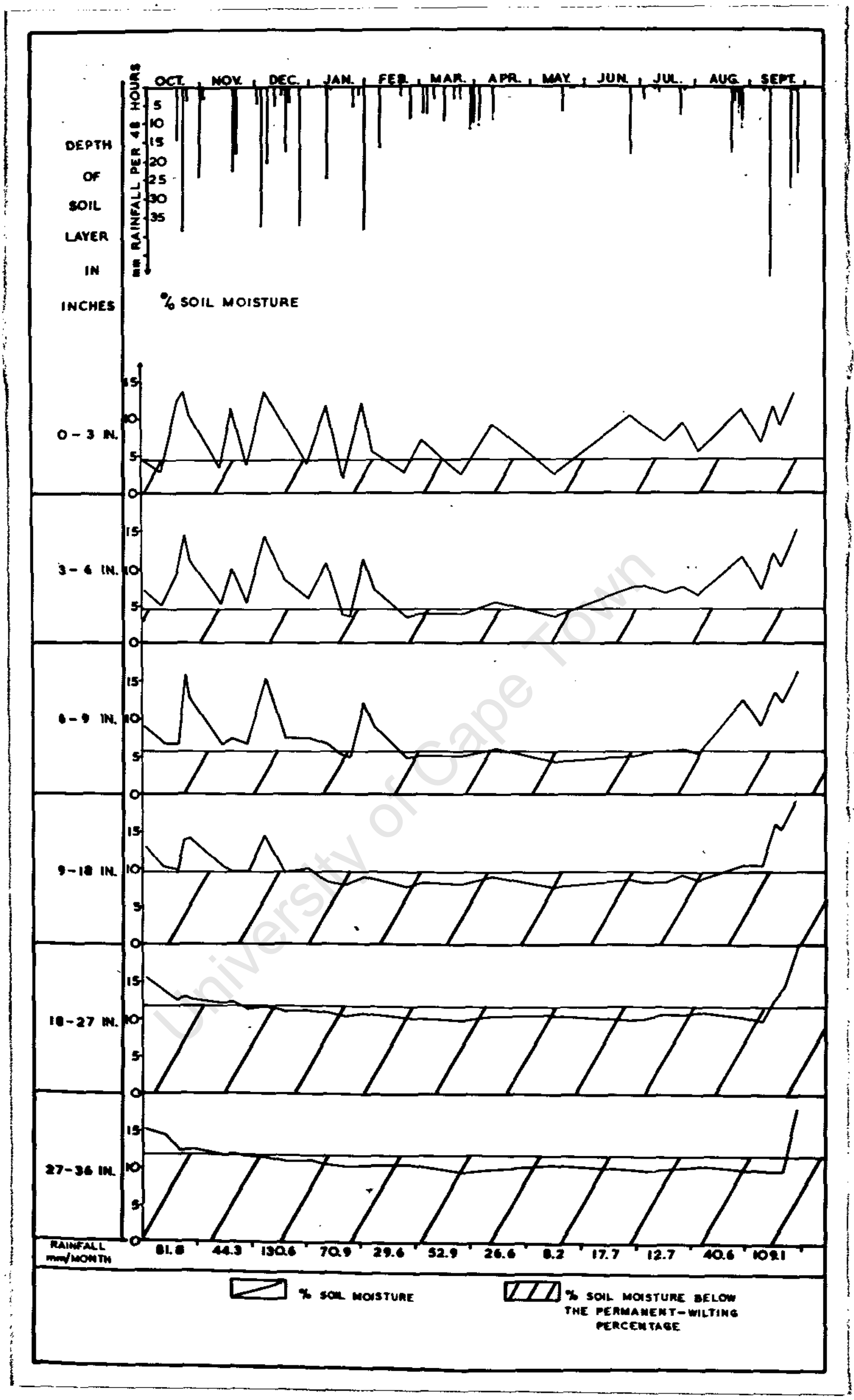


FIGURE 1: SOIL MOISTURE AS A PERCENTAGE OF DRY SOIL DURING TWELVE MONTHS AT SIX DEPTHS UNDER *THEMEDA TRIANDRA* VELD

GLEN, OCTOBER 1956 TO SEPTEMBER 1957

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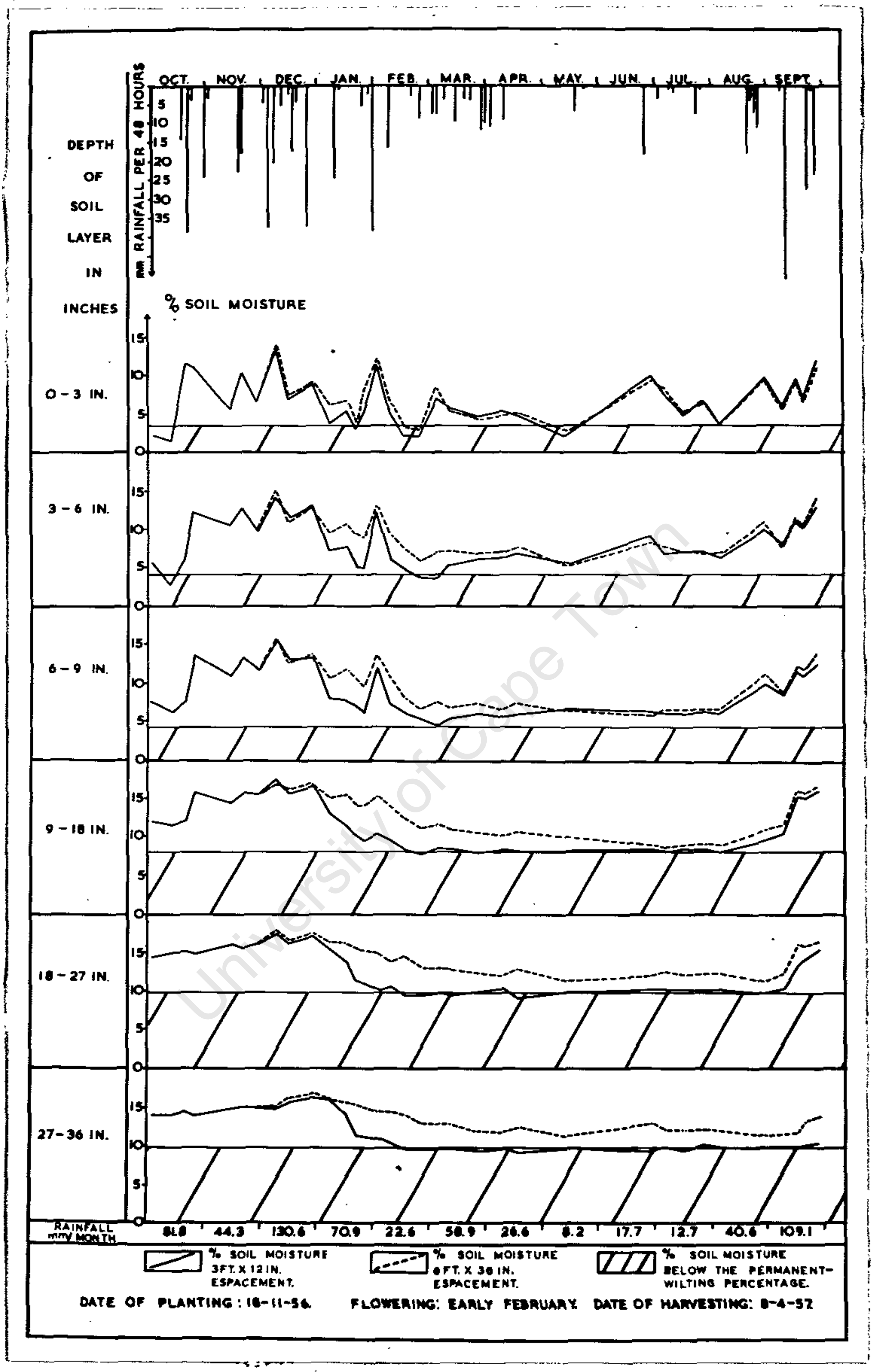


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FIGURE 2: SOIL MOISTURE AS A PERCENTAGE OF DRY SOIL DURING TWELVE MONTHS AT SIX DEPTHS IN A MAIZE LAND WITH NORMAL AND DENSE ESPACEMENT OF MAIZE

GLEN, OCTOBER 1956 TO SEPTEMBER 1957

often leave maize lands unploughed during winter to allow the stover to be grazed. Weeds sometimes appear and waste valuable soil moisture. When switching over from wheat to maize growing, farmers often plant maize immediately after the wheat has been harvested. In most cases such a practice means a failure of the maize because the soil moisture has been depleted.

Often the moisture content of the surface soil only is considered when the moisture supply available to a crop is assessed. The moisture content of the surface soil is important for the germination of seeds. For the moisture supply to a crop during the growth season, the moisture conserved in deeper soil layers is much more important, since it is not exposed to direct evaporation.

The graphs of Figure 1 indicate that also under natural vegetation (veld) a certain amount of moisture was available in the soil before an appreciable rainfall was recorded during October 1956. This, however, is regarded as an exception, caused by a very high precipitation during the period from February to May 1956 which had followed a heavy drought damage during January. The growth had also been terminated by severe frost during the first ten days of May (-9.5° C). In the soil of the maize land (Figure 2) slightly more moisture was available early in October.

As a result of subnormal precipitation from February until May 1957, the soil of the veld remained dry during the winter of 1957. The moisture available in the maize land towards the end of winter 1957 depended on the degree of moisture depletion reached during the previous season. The graphs of Figure 2 indicate an appreciable content of plant available soil moisture in the case of the wide espacement, but not in the case of the narrow espacement of the maize plants.

Later soil moisture investigations (Table 8, following p. 36) indicated conservation of moisture in the soil of a maize land towards the end of the 1957/58 season, from which the maize of the 1958/59 season might have taken benefit.

The commencement of the sowing season is initiated by the spring rains. During spring, larger amounts of rain are necessary to achieve an adequate moisture content of the surface soil which is required for good germination. On account of rapid evaporation, often increased by dry

western/

western winds, the surface soil, moistened by spring rains, dries out rapidly. Thus, the period during which adequate moisture is available in the surface soil for the planting and germination of maize or other annual summer crops may sometimes be limited to a few days. The high operation speed achieved by power mechanization has, however, practically ruled out the difficulty of completing the cultivation of all the lands proposed to carry a crop.

With the advancing season the mean monthly rainfall as well as the evaporative power of the atmosphere increases. During the whole year the potential evaporation generally exceeds the precipitation by far.

On account of the rapid evaporation, light rains cannot be considered of major importance for the moisture supply to plants. Only soaking rains can effect appreciable conservation of moisture, since the moisture then penetrates deeper into the soil and is thereby more protected from evaporation.

Spring and early summer is an important period for conserving soil moisture. The graphs in Figure 2 indicate a considerable moisture conservation before planting and during the early growth of maize. It must, however, be borne in mind that the precipitation experienced during the commencement of the 1956/57 season was exceptionally early and high. During several seasons, little moisture could be conserved before planting. The moisture supply to the plants is mostly supplemented during the early growth stages when the plants still have a relatively small transpiring surface.

WHITMORE (1950 b) showed the evapotranspiration of maize at different growth stages according to data from the Grootfontein Agricultural College. The data show an increasing moisture requirement with advancing growth reaching a peak shortly before tasseling. During the flowering stage a high level of evapotranspiration is maintained. A marked decline takes place only after the flowering stage has occurred and continues with advancing maturity.

The risk of drought damage to maize during the early growth stages (up to about 6 - 7 weeks after planting) is negligible. The seed is always planted into moist surface soil and the transpiration per unit area during the early growth stages is low. Young plants can live on limited amounts of readily available soil moisture and seem to be much more drought resistant than plants at more advanced growth stages. With advancing growth and rising temperature

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the evapotranspiration increases. At the same time, the soil moisture conserved before planting and during the early growth decreases until a negligible amount of moisture is left when the plants are in most need of it, and that is just before and during the flowering stage. As can be seen in Figure 2, in 1957/58 the permanent-wilting percentage with the densely spaced maize was reached as late as the first half of February, that is during the late flowering stage. With wide espacement the permanent-wilting percentage was never reached. During seasons with a fairly normal precipitation densely spaced maize is often severely damaged by drought shortly before tasseling and normally spaced maize during the flowering stage. During January and February severe drought is often experienced, although the mean precipitation and the reliability of the rainfall increases from October to January and decreases only slightly during February. Since the moisture requirement of maize usually cannot be met by conserved soil moisture during the period of the highest evapotranspiration, the plants are mainly dependent on the rainfall during the flowering stage. During January and February short or long periods of drought, accompanied by dry and hot weather, often do extensive damage to the flowering maize.

Late in the season the growth and development of maize is generally fairly slow, probably on account of decreased temperatures and shorter day lengths. Then, moisture is usually not the limiting factor. This can be attributed to a rather reliable and high rainfall during March and a markedly decreased evapotranspiration while the maize is ripening. The growth season is terminated by the occurrence of the first frost. (Average 3rd of May, extreme 7th of April).

Most maize varieties grown by the farmers require 130 - 145 days from planting to maturity. Maize is usually not planted before the middle of September and the planting season can be extended until the middle of December. With fast maturing varieties planting may be delayed until the end of December or the beginning of January. Most of the maize is planted from the middle of October towards the end of November. To decrease the risk possibly attached to one time of planting, often a part of the maize is planted at one time and the rest at one or two other times. The planting operations can thus be extended over a fairly long period.

As mentioned by WHITMORE (1950 b) this long planting season may give the opportunity to regulate the planting so that anticipated periods of drought which are often

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experienced during the second half of January and the first half of February, do not coincide with the most critical growth stadia. It does not, however, often appear possible to evade such drought periods. Most varieties have reached the critical tasseling stage about 65 - 70 days after planting. With fairly late planting (e.g. the end of November) the tasseling and flowering stages just fall into the anticipated period of drought. With early planting on the other hand, the moisture conservation before planting would often be insufficient.

Apart from a possibly slightly higher probability of drought during the period mentioned, it must be kept in mind that rainless periods can occur at any earlier growth stage of maize. In this case the drought seldom becomes evident because damage can only be expected when complete exhaustion of the readily available soil moisture as a result of heavy evapotranspiration up to a certain growth stage, coincides with a rainless period. Such an exhaustion is usually only reached at the peak evapotranspiration stage shortly before and during the time of flowering. Accordingly, the usual interpretation of the relationship between time of planting and drought resistance of maize is not fully convincing. Instead of the assumption that the drought can be evaded with late planting, another explanation seems to be more adequate. When the growth period of maize is delayed by delayed planting, the possibility of conserving soil moisture before planting is increased. At the same time the probability of rains during the growth season is not markedly diminished by late planting in comparison with early planting. Furthermore, the ripening period with late planting is shifted into a period of decreased temperature and increased relative humidity.

The moisture content of the soil during a season may also be of importance for the decomposition of soil organic matter and the nitrogen supply to crop plants. The results of the moisture studies of Figures 1 and 2 may be of some significance from this point of view. If the moisture graphs of Figures 1 and 2 are studied, it becomes evident that, compared with veld, the soil moisture contents take a very different course during the year under maize. This is considered of fundamental importance for the conditions which govern the decomposition of plant residues and thereby influence the humus and nitrogen status of both uncultivated and cultivated soils. At the soil depth 0 - 9 in., under maize as well as under veld, drying out and new moisture infiltration alternated during the period from

October/

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October to February. The graphs indicate a more rapid moisture loss from the veld than from the maize field during spring. From March to July, that means from towards the termination of the growth season until winter, the soil moisture content at 0 - 9 in. soil depth of the cultivated land remained higher than that of the veld. The rain during August and September increased the moisture content of both veld and cultivated land. Assuming that decomposition of organic matter is only hampered when the soil moisture decreases to the permanent-wilting percentage, then under veld as well as under cultivated land during spring and summer conditions prevailed at 0 - 9 in. soil depth which could have favoured decomposition. The low precipitation during winter did not, however, moisten the soil layer at 6 - 9 in. depth in the veld above the permanent-wilting percentage, while the corresponding depth in the cultivated land was moist during the same period.

During October and December heavy rain temporarily increased the soil moisture content at 9 - 18 in. depth under veld. Towards the end of December the permanent-wilting percentage was reached in this soil layer and the moisture content remained below this percentage until August. The soil at 18 - 27 in. and 27 - 36 in. depths reached the permanent-wilting percentage as early as in the middle of November. Thereafter and until the following spring the soil moisture content at these depths remained below the permanent-wilting percentage. During the twelve months the soil moisture content at 18 - 36 in. depth under natural vegetation was above the permanent-wilting percentage for only two months. In the same period and at a corresponding soil depth, the soil moisture content under densely spaced maize remained near the permanent-wilting percentage for approximately six months. Under widely spaced maize it remained well above the permanent-wilting percentage during the twelve months.

Obviously a noticeable infiltration of moisture into the deeper soil horizons of veld can only take place when the veld has not yet passed winter dormancy. As soon as the veld has started growing, the moisture from rains is rapidly consumed. Even heavy rain, as experienced during December 1956, raised only the moisture content of the surface soil.

These relationships may partially be responsible for a relatively vigorous growth of the veld after soaking rain during the early season. This is probably made possible by a moisture conservation before the end of the dormancy period.

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In the deeper soil layers of the veld extremely favourable conditions for the maintenance of a relatively high soil organic matter content may prevail. During the short period when the deeper soil layers are moist an increase in the root material can be assumed. Shortly afterwards the wilting range is reached. For a very long time no new moisture penetration takes place. Therefore it must be reckoned that the decomposition of soil organic matter is limited to a very short period.

The moisture conditions prevailing during the year in the soil under a summer crop followed by winter fallow are very different from those under veld. In this case favourable conditions for the decomposition of soil organic matter at a considerable soil depth predominate during a relatively long period.

c. Weather During the Experimental Period.

This report presents the results of field experiments carried out during the period beginning with the 1957/58 season and ending with the 1960/61 season.

Particulars of the weather conditions during this period are presented in Tables 2, 3, 4 and 5.

The average and absolute maximum and minimum temperatures and the frequency of days with maximum temperatures above 30° C and minimum temperatures below 0° C at Glen College of Agriculture are given in Table 2.

Table 3 presents the mean relative humidity at Glen at 08.00 and 14.00 hours S.A. Time.

The monthly rainfall at Glen and Theunissen is given in Table 4.

Table 5 contains the rainfall per 10 day period and per month during the summer season (October to March), the number of rainy days and the length of the longest periods without precipitation above 2 mm, beginning at any date within each 10 day period.

From Theunissen rainfall figures only are available and it may be assumed that the temperature and the relative humidity at Theunissen took a fairly similar course to that at Glen.

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TABLE 2 : MAXIMUM AND MINIMUM TEMPERATURES AND FREQUENCY OF DAYS WITH TEMPERATURES EITHER ABOVE 30°C OR BELOW 0°C DURING THE YEARS 1957/58 TO 1960/61 AT THE GLEN COLLEGE OF AGRICULTURE

| Temperature (°C) | Year | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean daily maximum | 1957/58 | 18.0 | 20.1 | 23.0 | 23.4 | 30.0 | 30.0 | 29.0 | 30.8 | 29.0 | 25.8 | 21.9 | 17.6 |
| | 1958/59 | 20.0 | 21.5 | 24.0 | 27.4 | 29.6 | 30.3 | 29.6 | 29.5 | 29.0 | 25.8 | 18.2 | 19.0 |
| | 1959/60 | 17.8 | 19.8 | 25.4 | 27.2 | 28.7 | 28.3 | 30.7 | 30.0 | 26.9 | 22.1 | 19.2 | 17.1 |
| | 1960/61 | 17.0 | 22.1 | 25.1 | 27.8 | 28.0 | 30.3 | 29.8 | 31.6 | 27.7 | 24.0 | 19.1 | 16.6 |
| Mean daily minimum | 1957/58 | 1.4 | 1.8 | 6.2 | 8.6 | 11.7 | 14.6 | 16.2 | 12.5 | 11.6 | 8.8 | 3.4 | -2.3 |
| | 1958/59 | -1.3 | -1.2 | 5.2 | 8.7 | 12.5 | 15.6 | 13.5 | 14.2 | 11.9 | 8.2 | 3.1 | -1.0 |
| | 1959/60 | 1.5 | -1.2 | 3.7 | 9.0 | 12.6 | 14.1 | 14.3 | 15.7 | 12.9 | 7.3 | 1.7 | -1.4 |
| | 1960/61 | -1.3 | 4.0 | 6.2 | 9.7 | 13.2 | 14.5 | 13.6 | 15.1 | 14.1 | 8.7 | 4.3 | 3.2 |
| Highest maximum | 1957/58 | 22.6 | 25.5 | 29.5 | 31.0 | 34.1 | 36.0 | 34.4 | 34.6 | 34.0 | 31.8 | 26.2 | 21.8 |
| | 1958/59 | 23.7 | 27.8 | 33.1 | 34.1 | 36.7 | 34.1 | 35.1 | 34.4 | 33.3 | 31.6 | 25.9 | 23.8 |
| | 1959/60 | 22.8 | 27.1 | 32.4 | 37.2 | 35.8 | 33.6 | 36.6 | 35.0 | 32.1 | 27.3 | 23.8 | 22.2 |
| | 1960/61 | 23.2 | 28.5 | 30.6 | 34.2 | 33.2 | 35.4 | 36.6 | 35.3 | 31.0 | 28.6 | 24.5 | 21.8 |
| Lowest minimum | 1957/58 | -5.6 | -7.0 | -0.5 | -1.2 | 4.8 | 8.3 | 13.1 | 6.8 | 4.1 | 2.5 | -2.0 | -8.9 |
| | 1958/59 | -4.5 | -8.3 | -4.6 | 1.1 | 6.4 | 11.7 | 4.6 | 9.1 | 2.6 | 0.0 | -2.2 | -6.2 |
| | 1959/60 | -3.0 | -5.0 | -6.2 | -1.6 | 4.5 | 8.7 | 4.3 | 7.8 | 5.0 | 1.3 | -3.7 | -6.8 |
| | 1960/61 | -7.0 | -2.7 | -1.5 | -1.1 | 8.2 | 10.2 | 5.1 | 7.5 | 7.3 | 3.4 | -2.5 | -0.6 |
| No. of days with max. ≥ 30°C | 1957/58 | 0 | 0 | 0 | 1 | 17 | 15 | 10 | 17 | 16 | 1 | 0 | 0 |
| | 1958/59 | 0 | 0 | 6 | 9 | 15 | 20 | 16 | 16 | 14 | 5 | 0 | 0 |
| | 1959/60 | 0 | 0 | 5 | 10 | 12 | 11 | 20 | 17 | 6 | 0 | 0 | 0 |
| | 1960/61 | 0 | 0 | 2 | 7 | 10 | 18 | 15 | 20 | 4 | 0 | 0 | 0 |
| No. of days with min. ≤ 0°C | 1957/58 | 14 | 12 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 23 |
| | 1958/59 | 26 | 21 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 22 |
| | 1959/60 | 15 | 25 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 22 |
| | 1960/61 | 23 | 3 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 4 |

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TABLE 3 : MEAN MONTHLY RELATIVE HUMIDITY AT 08.00 AND 14.00 HOURS S.A. TIME DURING THE YEARS 1957/58 TO 1960/61 AT THE GLEN COLLEGE OF AGRICULTURE

| | Year | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Relative humidity (%) at 08.00 S.A. time | 1957/58 | 87 | 78 | 76 | 71 | 61 | 65 | 76 | 73 | 77 | 87 | 85 | 87 |
| | 1958/59 | 81 | 66 | 71 | 57 | 61 | 73 | 67 | 80 | 79 | 84 | 88 | 89 |
| | 1959/60 | 87 | 77 | 61 | 59 | 68 | 72 | 66 | 77 | 83 | 86 | 93 | 91 |
| | 1960/61 | 92 | 85 | 69 | 61 | 65 | 65 | 65 | 66 | 78 | 86 | 91 | 90 |
| Relative humidity (%) at 14.00 S.A. time | 1957/58 | - | - | - | 42 | 28 | 41 | 54 | 33 | 36 | 39 | 32 | 28 |
| | 1958/59 | 23 | 15 | 26 | 20 | 29 | 36 | 33 | 41 | 31 | 34 | 42 | 29 |
| | 1959/60 | 36 | 23 | 16 | 27 | 33 | 44 | 32 | 43 | 46 | 47 | 38 | 35 |
| | 1960/61 | 33 | 33 | 23 | 24 | 34 | 31 | 31 | 27 | 39 | 39 | 38 | 45 |

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TABLE 4 : MONTHLY RAINFALL IN mm AT THE GLEN COLLEGE OF AGRICULTURE AND AT THEUNISSEN (x) DURING THE YEARS 1957/58 TO 1960/61

| Season | Place | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1957/58 | Glen | 12.7 | 40.6 | 109.1 | 77.6 | 51.5 | 86.7 | 103.8 | 29.6 | 80.4 | 37.5 | 57.1 | 0.0 | 686.6 |
| | Theunissen | 32.0 | 22.5 | 168.0 | 122.0 | 61.0 | 113.5 | 100.0 | 65.6 | 50.5 | 46.5 | 44.0 | 0.0 | 825.6 |
| 1958/59 | Glen | 0.0 | 0.0 | 27.1 | 52.7 | 66.9 | 105.6 | 71.5 | 61.8 | 31.9 | 69.7 | 34.0 | 0.6 | 521.8 |
| | Theunissen | 0.0 | 0.0 | 15.2 | 36.1 | 12.2 | 73.4 | 69.8 | 53.3 | 41.7 | 40.6 | 60.4 | 0.0 | 402.7 |
| 1959/60 | Glen | 24.7 | 0.0 | 0.0 | 53.6 | 68.7 | 107.2 | 45.7 | 125.3 | 149.5 | 77.2 | 13.2 | 14.0 | 679.1 |
| | Theunissen | 0.0 | 0.0 | 0.0 | 61.4 | 59.2 | 83.1 | 15.2 | 49.6 | 57.8 | 103.4 | 4.1 | 0.0 | 433.8 |
| 1960/61 | Glen | 13.6 | 32.7 | 5.8 | 46.5 | 50.7 | 61.8 | 72.1 | 49.2 | 61.8 | 51.7 | 60.0 | 52.5 | 558.4 |
| | Theunissen | 0.0 | 23.6 | 5.5 | 56.3 | 53.6 | 99.3 | 44.1 | 17.0 | 57.1 | 83.6 | 44.5 | 44.2 | 528.8 |
| Long term average for Glen (1921 - 1961) | | 8.5 | 10.3 | 17.6 | 42.6 | 67.8 | 73.7 | 77.2 | 71.3 | 84.1 | 48.8 | 20.6 | 8.4 | 530.7 |

(x) Until August 1958 at Theunissen and thereafter on the farm "Excelsior", Theunissen

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TABDE 5 : RAINFALL (mm), NUMBER OF DAYS WITH PRECIPITATION ABOVE 0.2 mm AND LONGEST PERIODS WITHOUT PRECIPITATION ABOVE 2 mm FROM 1957/58 TO 1960/61 AT THE GLEN COLLEGE OF AGRICULTURE AND AT THEUNISSEN (x)

| | Rainfall in mm | | | | | | | | Number of days with precipitation above 0.2 mm and, in brackets, longest periods without rain above 2 mm (days) beginning within each period | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | 1957/58 | | 1958/59 | | 1959/60 | | 1960/61 | | 1957/58 | | 1958/59 | | 1958/60 | | 1960/61 | |
| Date | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. |
| Oct. 1-10 | 3.9 | 63.0 | 0.0 | 0.0 | 1.5 | 17.8 | 0.0 | 0.0 | 3( -) | 3( 5) | 0( -) | 0( -) | 1( -) | 2( 9) | 0( -) | 0( -) |
| 11-20 | 46.3 | 38.5 | 30.4 | 5.6 | 42.6 | 33.2 | 43.0 | 51.5 | 6( 4) | 2( 6) | 2( 9) | 1( 9) | 2( -) | 2( 0) | 3( 6) | 1( 6) |
| 21-31 | 27.4 | 20.5 | 22.3 | 30.5 | 9.5 | 10.4 | 3.5 | 4.8 | 4(19) | 2(20) | 2( 6) | 2( 6) | 2( 9) | 2( 9) | 1(15) | 2(13) |
| Total | 77.6 | 122.0 | 52.7 | 36.1 | 53.6 | 61.4 | 46.5 | 56.3 | 13 | 7 | 4 | 3 | 5 | 6 | 4 | 3 |
| Nov. 1-10 | 3.3 | 0.0 | 63.6 | 12.2 | 44.4 | 13.2 | 4.9 | 12.7 | 2( -) | 0( -) | 7( 6) | 1(33) | 3( 3) | 2( 2) | 2((4) | 1(16) |
| 11-20 | 17.6 | 20.0 | 0.2 | 0.0 | 24.3 | 31.5 | 17.7 | 0.0 | 3( 2) | 1( 3) | 0(18) | 0( -) | 2(13) | 3( 5) | 2(11) | 0( -) |
| 21-30 | 30.6 | 41.0 | 3.1 | 0.0 | 0.0 | 14.5 | 28.1 | 40.9 | 3( 9) | 3( 9) | 1( 2) | 0( -) | 0( -) | 2( 5) | 5(13) | 3( 7) |
| Total | 51.5 | 61.0 | 66.9 | 12.2 | 68.7 | 59.2 | 50.7 | 53.6 | 8 | 4 | 8 | 1 | 5 | 7 | 9 | 4 |
| Dec. 1-10 | 60.1 | 113.5 | 52.4 | 27.5 | 70.0 | 34.8 | 5.9 | 34.3 | 9( 2) | 6( 1) | 5( 4) | 2( 3) | 4( 3) | 4( 2) | 3( 0) | 4( 2) |
| 11-20 | 0.5 | 0.0 | 16.1 | 16.5 | 9.3 | 39.9 | 32.2 | 43.2 | 1(16) | 0(32) | 3( 4) | 2( 5) | 4( 4) | 3( 3) | 3( 7) | 2( 8) |
| 21-31 | 26.1 | 0.0 | 37.1 | 29.4 | 27.9 | 8.4 | 23.7 | 21.8 | 4( 1) | 0( -) | 4( 4) | 3( 9) | 4( 8) | 2(16) | 5( 6) | 2( 8) |
| Total | 86.7 | 113.5 | 105.6 | 73.4 | 107.2 | 83.1 | 61.8 | 99.3 | 14 | 6 | 12 | 7 | 12 | 9 | 11 | 8 |
| Jan. 1-10 | 17.5 | 0.0 | 18.4 | 10.4 | 6.9 | 0.0 | 13.7 | 2.5 | 6( 8) | 0( -) | 2(16) | 1(17) | 1( 9) | 0( -) | 1( 8) | 1(11) |
| 11-20 | 43.5 | 89.0 | 0.0 | 0.0 | 18.3 | 2.5 | 42.1 | 37.8 | 6( 3) | 4( 2) | 0( -) | 0( -) | 2( 5) | 1( 5) | 6( 7) | 3( 8) |
| 21-31 | 42.8 | 11.0 | 53.1 | 59.4 | 20.5 | 12.7 | 16.3 | 3.8 | 8( 3) | 1(10) | 6( 2) | 4( 7) | 6(12) | 1(11) | 1(10) | 2(12) |
| Total | 103.8 | 100.0 | 71.5 | 69.8 | 45.7 | 15.2 | 72.1 | 44.1 | 20 | 5 | 8 | 5 | 9 | 2 | 8 | 6 |
| Feb. 1-10 | 17.4 | 15.0 | 9.8 | 27.9 | 25.3 | 17.3 | 19.8 | 17.0 | 4( 6) | 1(10) | 3( 5) | 1( 9) | 3( 3) | 3( 3) | 6( 4) | 2( -) |
| 11-20 | 12.0 | 50.5 | 52.0 | 25.4 | 15.3 | 4.6 | 9.9 | 0.0 | 4(18) | 3(15) | 5(16) | 1(16) | 3( 3) | 1( 9) | 2(10) | 0(20) |
| 21-28/9 | 0.2 | 0.0 | 0.0 | 0.0 | 84.7 | 27.7 | 19.5 | 0.0 | 0( -) | 0( -) | 0( -) | 0( -) | 5( 4) | 3(13) | 2( 2) | 0( -) |
| Total | 29.6 | 65.5 | 61.8 | 53.3 | 125.3 | 49.6 | 49.2 | 17.0 | 8 | 4 | 8 | 2 | 11 | 7 | 10 | 2 |
| Mar. 1-10 | 11.2 | 17.0 | 9.4 | 35.1 | 12.2 | 16.6 | 14.9 | 15.7 | 1( 4) | 2( 5) | 4( 8) | 3( 2) | 3( 5) | 2( 1) | 5( 4) | 1( 8) |
| 11-20 | 65.9 | 19.5 | 20.2 | 6.6 | 108.4 | 36.1 | 31.2 | 29.2 | 5( 5) | 1( 9) | 3(16) | 2(19) | 6( 3) | 3( 4) | 4(10) | 2(11) |
| 21-31 | 3.3 | 14.0 | 2.3 | 0.0 | 28.9 | 5.1 | 15.7 | 12.2 | 1(10) | 1(13) | 2( -) | 0( -) | 5( 5) | 1( 7) | 5( 4) | 1( 4) |
| Total | 80.4 | 50.5 | 31.9 | 41.7 | 149.5 | 57.8 | 61.8 | 57.1 | 7 | 4 | 9 | 5 | 14 | 6 | 14 | 4 |

(x) Up to August 1958 the readings were taken at Theunissen and thereafter on the farm "Excelsior", Theunissen

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TABLE 5 : RAINFALL (mm), NUMBER OF DAYS WITH PRECIPITATION ABOVE 0.2 mm AND LONGEST PERIODS WITHOUT PRECIPITATION ABOVE 2 mm FROM 1957/58 TO 1960/61 AT THE GLEN COLLEGE OF AGRICULTURE AND AT THEUNISSEN (x)

| | | Rainfall in mm | | | | | | | | Number of days with precipitation above 0.2 mm and, in brackets, longest periods without rain above 2 mm (days) beginning within each period | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | | 1957/58 | | 1958/59 | | 1959/60 | | 1960/61 | | 1957/58 | | 1958/59 | | 1958/60 | | 1960/61 | |
| | Date | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. | Glen | Theun. |
| Oct. | 1-10 | 3.9 | 63.0 | 0.0 | 0.0 | 1.5 | 17.8 | 0.0 | 0.0 | 3( - ) | 3( 5) | 0( - ) | 0( - ) | 1( - ) | 2( 9) | 0( - ) | 0( - ) |
| | 11-20 | 46.3 | 38.5 | 30.4 | 5.6 | 42.6 | 33.2 | 43.0 | 51.5 | 6( 4) | 2( 6) | 2( 9) | 1( 9) | 2( - ) | 2( 0) | 3( 6) | 1( 6) |
| | 21-31 | 27.4 | 20.5 | 22.3 | 30.5 | 9.5 | 10.4 | 3.5 | 4.8 | 4(19) | 2(20) | 2( 6) | 2( 6) | 2( 9) | 2( 9) | 1(15) | 2(13) |
| | Total | 77.6 | 122.0 | 52.7 | 36.1 | 53.6 | 61.4 | 46.5 | 56.3 | 13 | 7 | 4 | 3 | 5 | 6 | 4 | 3 |
| Nov. | 1-10 | 3.3 | 0.0 | 63.6 | 12.2 | 44.4 | 13.2 | 4.9 | 12.7 | 2( - ) | 0( - ) | 7( 6) | 1(33) | 3( 3) | 2( 2) | 2((4) | 1(16) |
| | 11-20 | 17.6 | 20.0 | 0.2 | 0.0 | 24.3 | 31.5 | 17.7 | 0.0 | 3( 2) | 1( 3) | 0(18) | 0( - ) | 2(13) | 3( 5) | 2(11) | 0( - ) |
| | 21-30 | 30.6 | 41.0 | 3.1 | 0.0 | 0.0 | 14.5 | 28.1 | 40.9 | 3( 9) | 3( 9) | 1( 2) | 0( - ) | 0( - ) | 2( 5) | 5(13) | 3( 7) |
| | Total | 51.5 | 61.0 | 66.9 | 12.2 | 68.7 | 59.2 | 50.7 | 53.6 | 8 | 4 | 8 | 1 | 5 | 7 | 9 | 4 |
| Dec. | 1-10 | 60.1 | 113.5 | 52.4 | 27.5 | 70.0 | 34.8 | 5.9 | 34.3 | 9( 2) | 6( 1) | 5( 4) | 2( 3) | 4( 3) | 4( 2) | 3( 0) | 4( 2) |
| | 11-20 | 0.5 | 0.0 | 16.1 | 16.5 | 9.3 | 39.9 | 32.2 | 43.2 | 1(16) | 0(32) | 3( 4) | 2( 5) | 4( 4) | 3( 3) | 3( 7) | 2( 8) |
| | 21-31 | 26.1 | 0.0 | 37.1 | 29.4 | 27.9 | 8.4 | 23.7 | 21.8 | 4( 1) | 0( - ) | 4( 4) | 3( 9) | 4( 8) | 2(16) | 5( 6) | 2( 8) |
| | Total | 86.7 | 113.5 | 105.6 | 73.4 | 107.2 | 83.1 | 61.8 | 99.3 | 14 | 6 | 12 | 7 | 12 | 9 | 11 | 8 |
| Jan. | 1-10 | 17.5 | 0.0 | 18.4 | 10.4 | 6.9 | 0.0 | 13.7 | 2.5 | 6( 8) | 0( - ) | 2(16) | 1(17) | 1( 9) | 0( - ) | 1( 8) | 1(11) |
| | 11-20 | 43.5 | 89.0 | 0.0 | 0.0 | 18.3 | 2.5 | 42.1 | 37.8 | 6( 3) | 4( 2) | 0( - ) | 0( - ) | 2( 5) | 1( 5) | 6( 7) | 3( 8) |
| | 21-31 | 42.8 | 11.0 | 53.1 | 59.4 | 20.5 | 12.7 | 16.3 | 3.8 | 8( 3) | 1(10) | 6( 2) | 4( 7) | 6(12) | 1(11) | 1(10) | 2(12) |
| | Total | 103.8 | 100.0 | 71.5 | 69.8 | 45.7 | 15.2 | 72.1 | 44.1 | 20 | 5 | 8 | 5 | 9 | 2 | 8 | 6 |
| Feb. | 1-10 | 17.4 | 15.0 | 9.8 | 27.9 | 25.3 | 17.3 | 19.8 | 17.0 | 4( 6) | 1(10) | 3( 5) | 1( 9) | 3( 3) | 3( 3) | 6( 4) | 2( - ) |
| | 11-20 | 12.0 | 50.5 | 52.0 | 25.4 | 15.3 | 4.0 | 9.9 | 0.0 | 4(18) | 3(15) | 5(16) | 1(16) | 3( 3) | 1( 9) | 2(10) | 0(20) |
| | 21-28/9 | 0.2 | 0.0 | 0.0 | 0.0 | 84.7 | 27.7 | 19.5 | 0.0 | 0( - ) | 0( - ) | 0( - ) | 0( - ) | 5( 4) | 3(13) | 2( 2) | 0( - ) |
| | Total | 29.6 | 65.5 | 61.8 | 53.3 | 125.3 | 49.6 | 49.2 | 17.0 | 8 | 4 | 8 | 2 | 11 | 7 | 10 | 2 |
| Mar. | 1-10 | 11.2 | 17.0 | 9.4 | 35.1 | 12.2 | 16.6 | 14.9 | 15.7 | 1( 4) | 2( 5) | 4( 8) | 3( 2) | 3( 5) | 2( 1) | 5( 4) | 1( 8) |
| | 11-20 | 65.9 | 19.5 | 20.2 | 6.6 | 108.4 | 36.1 | 31.2 | 29.2 | 5( 5) | 1( 9) | 3(16) | 2(19) | 6( 3) | 3( 4) | 4(10) | 2(11) |
| | 21-31 | 3.3 | 14.0 | 2.3 | 0.0 | 28.9 | 5.1 | 15.7 | 12.2 | 1(10) | 1(13) | 2( - ) | 0( - ) | 5( 5) | 1( 7) | 5( 4) | 1( 4) |
| | Total | 80.4 | 50.5 | 31.9 | 41.7 | 149.5 | 57.8 | 61.8 | 57.1 | 7 | 4 | 9 | 5 | 14 | 6 | 14 | 4 |

(x) Up to August 1958 the readings were taken at Theunissen and thereafter on the farm "Excelsior", Theunissen

Since the amount and distribution of rain seems to be the main factor controlling the crop production in this region, reference to the temperatures and the relative humidity data will only be made when the monthly figures differ appreciably from the long term means given in Table 2.

According to the data presented in Tables 2, 3, 4 and 5 the weather conditions during the experimental years were as follows:-

## 1957/58 Season.

The beginning of this season is marked by an exceptionally early and high precipitation.

The highest precipitation recorded at Glen during September since 1929 was in this season (109.1 mm). At Theunissen the September precipitation was even higher than at Glen (168.0 mm). As previously shown, the high precipitation during September 1957 brought about a considerable soil moisture conservation (Figures 1 and 2). As during September, the rainfall recorded during October was at Theunissen (122.0 mm) much higher than that at Glen (77.6 mm), and the precipitation at both places exceeded by far the mean precipitation for October at Glen (42.6 mm). The rainy conditions were accompanied by low temperatures which found their expression in a markedly low mean maximum temperature (23° C, the average is 27.0° C). The relative humidity during October was relatively high (Table 3).

The amount of rain recorded at Glen and Theunissen during November did not differ greatly from the long term average at Glen. Periods without precipitation above 2 mm of 19 days at Glen and 20 days at Theunissen were experienced from the end of October until the second 10 days of November.

The monthly precipitation recorded during December and January at Glen (86.7 and 103.8 mm respectively) and Theunissen (113.5 and 100.0 mm respectively) exceeded the average for Glen (73.7 and 77.2 mm respectively). Most of the rain was recorded during the first 10 days of December and during the middle of January. If periods without precipitation over 2 mm are regarded as dry periods, dry conditions were experienced from the middle of December during 16 days at Glen and 32 days at Theunissen. These dry periods were aggravated by temporarily high temperatures which, however, do not find a strong expression in the mean monthly maximum.

February/

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February was a very dry month at Glen (29.6 mm), while a precipitation only slightly below normal was received at Theunissen (65.5 mm). In the second half of February periods without precipitation above 2 mm started and lasted for 18 days at Glen and 15 days at Theunissen. During March a normal precipitation occurred at Glen and a lower than normal one at Theunissen.

A normal precipitation during April was followed by good rains during May.

The 1957/58 season represents a moist season at Glen and an exceptionally moist season at Theunissen. During the twelve months 825.6 mm rain was recorded at Theunissen which is more than the annual maximum ever recorded at Glen. In spite of the high annual precipitation relatively dry periods were experienced during December, January and February.

<u>1958/59 Season.</u>

During September and October a rainfall which does not differ greatly from the mean precipitation at Glen occurred at Glen and Theunissen. The mean maximum temperature of September was below the average.

November brought a normal precipitation at Glen and a very low rainfall (12.2 mm) at Theunissen. A period of 33 days without precipitation above 2 mm, which started during the first 10 days of November, was experienced at Theunissen. At Glen practically all the November precipitation was recorded during the first days of this month.

The December rainfall was also higher at Glen (105.6 mm) than at Theunissen (73.3 mm). The long term mean for December is 74.0 mm at Glen.

During January and February similar amounts of rain were recorded at Glen and Theunissen. These were slightly below the average during January and distinctly below the average during February. Dry periods extending over 16 or 17 days during the middle of January and 16 days beginning in the middle of February, were experienced at both places.

During March less than half of the Glen average rainfall for this month (84.7 mm) was obtained at Glen and at Theunissen. The dry conditions during March found their expression in a relatively low mean relative humidity at

14.00 hours/

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14.00 hours S.A. Time.

April had a fairly normal and May a relatively high rainfall.

The 1958/59 season represents a fairly normal season at Glen and a season marked by a slightly lower than normal rainfall at Theunissen. Long dry periods experienced during the middle of January and the second half of February at Glen and Theunissen must be taken seriously because of the limited possibilities for moisture conservation, especially at Theunissen.

## 1959/60 Season.

The beginning of this season was marked by low relative humidity percentages and a complete absence of rain during September, a slightly above normal precipitation during October and a normal precipitation during November.

During December the precipitation was high at Glen (107.2 mm) and above normal at Theunissen (83.1 mm). High relative humidity percentages, a below normal mean maximum temperature, and relatively few days with temperatures above 30° C also indicate that relatively moist conditions prevailed during December at Glen.

January was a warm and dry month with only 45.7 mm rain at Glen and as little as 15.2 mm at Theunissen (average at Glen 77.2 mm). Relatively dry periods started at the end of December and were also experienced towards the end of January and the beginning of February.

At Glen the drought was broken towards the end of February when good rains occurred which brought the total precipitation for this month up to 125.3 mm (average 71.3 mm). At Theunissen only 49.6 mm were recorded during February, but because of cloudy conditions and an increased relative humidity, the rains during the last days of February brought some relief.

At Glen a very high rainfall was recorded during the middle of March and the total precipitation for this month (149.5 mm) by far exceeded the average (84.1 mm). At Theunissen March was a relatively dry month with only 57.8 mm.

During April an above normal precipitation was received at both Glen (77.2 mm) and Theunissen (103.4 mm).

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It can be assumed that the relatively high precipitation during April brought about some conservation of soil moisture which may have been of significance for the following season's crop.

The 1959/60 season represents a fairly normal season at Glen and a season with a below normal precipitation at Theunissen. Normal weather conditions during October and November were followed by a good precipitation during December, and drought periods during January at Glen and January as well as February at Theunissen. According to the rainfall records the drought was much more pronounced at Theunissen than at Glen.

## 1960/61 Season.

During September only a very small amount of rain was recorded at both Glen (3.5 mm) and Theunissen (4.8 mm). The October rain, although about normal, was concentrated on a few days in the middle of the month, representing the first alternative period which provided suitable soil moisture conditions for planting. On account of dry western winds and high temperatures this period did not last long. Up to the end of November relatively little rain was recorded. The scattered rains did not raise the moisture content of the surface soil sufficiently for planting. The second alternative period for planting occurred during the last days of November and lasted until the beginning of December.

The December rainfall was slightly below the average at Glen (61.8 mm) and higher than normal at Theunissen (99.3 mm). During January a normal precipitation occurred at Glen (72.1 mm) and dry conditions at Theunissen, especially at the beginning and the end of the month (total precipitation 44.1 mm). Periods without precipitation above 2 mm did not exceed 8 to 12 days at both places. The February of 1961 was dry and hot at both Glen (49.2 mm) and Theunissen (17.0 mm). Less than the average rainfall was also obtained during March. The April rainfall was normal at Glen and above normal at Theunissen. The rainfall during May was relatively high at both places.

The 1960/61 season at Theunissen was marked by a fairly normal rainfall supply until December and a sharp decrease during January, February and March. At Glen/

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Glen the rainfall was slightly below normal until January, and considerably below normal during February and March.

Comparison of Seasons 1957/58 to 1960/61.

With regard to the moisture supply to maize plants, the growth stages shortly before and during flowering are regarded as the most sensitive ones. Depending on the date of planting, these growth stages are reached during January or February.

At Theunissen, the January precipitation was above normal in 1957/58, fairly normal in 1958/59, distinctly below normal in 1960/61 and still lower in 1959/60. The February precipitation was slightly below normal in 1957/58, distinctly below normal in 1958/59 as well as 1959/60 and far below normal in 1960/61. Compared with the December rainfall, a decrease in the moisture supply to the plants either in January or in February was thus experienced during each of the experimental seasons. With regard to the moisture supply during the most sensitive growth stages, the 1957/58 and 1958/59 seasons appear to have been more favourable than either the 1959/60 or 1960/61 seasons. In this respect the 1958/59 season differs the least from the normal rainfall distribution.

At Glen the January precipitation was above normal in 1957/58 and fairly normal both in 1958/59 and 1960/61. It was distinctly below normal in 1959/60. The February precipitation was slightly below normal in 1958/59, distinctly below normal in 1960/61 and very low in 1957/58. In 1959/60 a high rainfall only towards the end of February brought the total precipitation for this month considerably above the average. A consideration of the moisture supply during the sensitive growth stages of the three drier seasons would suggest that more favourable conditions prevailed during 1958/59 and 1960/61 than during the 1959/60 season.

With the exception of the 1957/58 season, less rain was recorded at Theunissen than at Glen. This seems to be contradictory to a general tendency of an increased precipitation towards the north and east. It must, however, be borne in mind that the general tendency can only become evident from long term recordings.

The results obtained during the different seasons may, if the exceptionally moist first season (1957/58) is

disregarded,/

disregarded, represent the possibilities of maize growing under fairly normal to slightly below normal rainfall conditions at the Glen experimental site.

For the Theunissen area the results obtained during the 1958/59, 1959/60 and the 1960/61 seasons seem to represent the possibilities for crop production under slightly to fairly subnormal rainfall conditions.

Since the precipitation was not general, a few spots near the experimental sites received a markedly higher precipitation during the same seasons.

Seasons with much drier conditions than those of the experimental period may occur. The absolute annual minimum for Glen is 215.4 mm.

## III. Soils.

In order to make a general classification of the soils included in the experimental work, soil samples were taken at 0 - 1, 1 - 2 and 2 - 3 ft. depths from the cultivated land of each experimental site and the texture, the hydrogen ion concentration and the carbon and nitrogen contents of each sample were determined (references on the methods are given in the section on the experimental procedure). The results of these determinations and a mechanical classification of the soils are set forth in Table 6.

According to the data of Table 6 the soils of the two Theunissen sites are lighter than the soils of the two Glen sites. No marked difference exists between the texture of the soils at the two Theunissen sites. Typical of the soil at Theunissen is a high content of fine sand which is nearly constant at all depths (41.8 - 44.0%). The Glen soils also contain a high percentage of fine sand at all depths investigated, ranging between 37.5 and 50.0%. The surface soil contains more coarse sand at Theunissen than at Glen.

According to finger tests the textures of the Glen and Theunissen soils appear to differ more than the mechanical analyses would suggest. The Theunissen soils have a more sandy and the Glen soils a more clayey appearance. The Theunissen soils tended slightly towards a single grain structure and the Glen soils more towards a crumb structure.

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TABLE 6: MECHANICAL ANALYSES (ATTERBERG) AND CHEMICAL ANALYSES OF THE SOILS INCLUDED IN THE EXPERIMENTS

| Experimental Site | Soil depth, feet | Mechanical composition, per cent | | | | | | Mechanical classification (x) | pH (0.1n KCl) | Soil organic matter, % | Nitrogen, mg per 100 g soil | C : N ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stones >2 mm | Coarse sand 2–0.2 mm | Fine sand 0.2–0.02 mm | Silt 0.02–0.002 mm | Clay < 0.002 mm | Silt plus clay | | | | | |
| Glen College of Agriculture, Experimental Site | 0–1 | 0.0 | 36.0 | 42.7 | 8.3 | 11.9 | 20.2 | Fine sandy loam | 5.7 | 0.98 | 59 | 9.7 |
| | 1–2 | 0.0 | 27.0 | 38.7 | 17.7 | 15.1 | 32.8 | Sandy clay loam | 5.9 | 0.92 | 63 | 8.4 |
| | 2–3 | 0.0 | 31.4 | 41.2 | 18.0 | 8.4 | 26.4 | Fine sandy loam | 6.2 | 0.60 | 48 | 7.2 |
| Glen College of Agriculture, "Topland" | 0–1 | 0.0 | 28.6 | 50.0 | 9.0 | 11.1 | 20.1 | Fine sandy loam | 5.6 | 0.80 | 54 | 8.6 |
| | 1–2 | 0.0 | 24.7 | 37.5 | 15.9 | 21.3 | 37.2 | Fine sandy loam | 5.8 | 0.67 | 49 | 7.9 |
| | 2–3 | 0.0 | 21.6 | 40.2 | 17.6 | 20.0 | 37.6 | Sandy clay loam | 5.9 | 0.33 | 36 | 5.2 |
| "Excelsior", Theunissen, Site I | 0–1 | 0.0 | 41.6 | 42.1 | 3.0 | 12.7 | 15.7 | Loamy fine sand | 5.3 | 0.61 | 44 | 8.0 |
| | 1–2 | 0.0 | 29.6 | 42.9 | 11.4 | 15.1 | 26.5 | Sandy clay loam | 5.4 | 0.52 | 43 | 7.0 |
| | 2–3 | 0.0 | 32.5 | 43.4 | 12.3 | 11.1 | 23.4 | Fine sandy loam | 5.6 | 0.39 | 36 | 6.4 |
| "Excelsior", Theunissen, Site II | 0–1 | 0.0 | 42.0 | 41.6 | 2.7 | 12.0 | 14.7 | Loamy fine sand | 5.0 | 0.60 | 41 | 8.5 |
| | 1–2 | 0.0 | 29.5 | 41.8 | 11.9 | 15.7 | 27.6 | Sandy clay loam | 5.2 | 0.58 | 45 | 7.5 |
| | 2–3 | 0.0 | 31.7 | 44.0 | 11.8 | 12.2 | 24.0 | Fine sandy loam | 5.6 | 0.41 | 39 | 6.0 |

(x) According to an international specification presented by SCHEFFER and SCHACHTSCHABEL (1952)

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The colour of the air dried Glen soils is reddish brown, becoming more reddish with increasing depth. The colour of the air dried Theunissen soils is light brown, sometimes yellowish at the 2 - 3 ft. layer.

At the Glen experimental site, in slightly lower lying localities than the places where the experiments were carried out, a light coloured calcareous and gravel layer was found at 2 - 3 ft. depth. This calcareous layer may underly the experimental site at varying depths.

An exact genetic grouping of the soils does not seem to be possible because too little information on the specific area is available. The only effort to achieve a detailed large scale grouping of the South African soils was undertaken by VAN DER MERWE (1941), and his work is the only source of information on the soil groups existing in the Orange Free State. A preliminary re-classification of South African soils has recently been undertaken (LOXTON, 1962).

If soil forming conditions are taken into account it becomes evident that an exact genetical grouping of the soils is often difficult. The landscape of the Central Free State consists of undulating plains broken by numerous dolerite intrusions which constitute ridges and "koppies". The soil formed by weathering of rocks may be rather rapidly washed down with run-offs sometimes experienced during summer. The soils near the foot of the ridges are to a certain extent always influenced by the parent material of the rocks. The often considerable run-off effects soil erosion which leads to instability and destruction of the soil surface and thus hampers a possible profiliation.

A considerable area of the Free State is mainly covered by aeolian deposits. The factors of water and wind erosion are still working at present. The Glen soils seem to be partially of aeolian and partially of colluvial origin, while a more aeolian origin of the Theunissen soils may be assumed.

According to VAN DER MERWE'S soil map of South Africa (1941), the Glen experimental site falls within the area of the "Aeolian Sandy Soils" which occupies a large portion of the Central Orange Free State, north and north-west of Bloemfontein and Glen.

The mechanical data of Table 6 and the colour of the/

the soils do not fully support a classification as "Aeolian Sandy Soils". MOSTERT (1958, p. 7) also observed that the aeolian soils of this area "have a rather sandy-loam texture which is in contrast to the typical Hoopstad "Sandveld", described by VAN DER MERWE. The properties of the Glen soils resemble more the "Kalahari sand on limestone", described by VAN DER MERWE (1941, p.59) and the closer relationship to this soil group has also been indicated by VAN DER MERWE himself (1941, p.176). According to VAN DER MERWE'S soil map the Theunissen experimental site is situated in the area of the "Alkali Soils" (Soil group : Solonetzic Soils) which extends over a large area in the South and Central Free State and also borders Glen. This soil type seems to occur only in lower lying areas near Theunissen. The area under consideration lies near the western border of the "High Veld Prairie Soils" (Soil group : Podsolic Soils) which occupy practically the whole Eastern Free State and a large portion of Southern Transvaal. On the map the eastern border of the Aeolian Sandy Soils is also situated close to the Theunissen experimental site.

The soils of the high lying areas (Afrikaans : "bulte") in the vicinity of Theunissen, generally have a sandy to loamy texture and seem to be fairly closely related to the Aeolian Sandy Soils towards the west and graduate to the High Veld Prairie Soils towards the east. The soil of the Theunissen experimental site appears to be more closely related to the Aeolian Sandy Soils than to the High Veld Prairie Soils.

The lands of the Central Orange Free State have been cultivated for a relatively short time. The European settlers arrived little more than 100 years ago and for a number of years they mainly practised pastoral farming. Lands which have been under cultivation for more than 35 years can be described as relatively old lands.

Stimulated by the introduction of power mechanization during the past few years, a larger area of land has been ploughed. A considerable portion of the soils have thus been under cultivation for only a few years.

D. EXPERIMENTAL PROCEDURE /

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## D. EXPERIMENTAL PROCEDURE.

### I. Field Experiments.

#### a. Cultivation and Harvesting of Maize.

In all the experiments the maize was planted by hand with the aid of planting lines. Three seeds were planted in each hill. When the plants were about three inches high, surplus plants were removed leaving one plant per hill. On empty hills the seeds were replaced and the plants then also thinned out.

Fertilizer was applied by hand. Great care was taken to achieve an even distribution on the plot area. Phosphorus and potassium fertilizers were applied before planting and ploughed in immediately after being spread. Nitrogen fertilizer was spread at planting time or at different growth stages.

Regular mechanical and chemical weed control and chemical insect control were applied.

When the grain had ripened the plants were cut off just above the soil surface and then stooked for further drying. On account of generally dry conditions during winter efficient wind drying was usually attained. About two months after the maize was cut, the total plant weights were determined and the cobs were removed from the stover and threshed. The wind dry stover yield was calculated by subtraction of the grain weights from the total plant weights. The moisture content of the grain was determined with a Marconi apparatus and the grain yields will always be presented as having a moisture content of 12½%.

In a few instances it was necessary or considered important to determine the dry weight of the stover. Where chemical analyses were done on the stover, the results had to be related to the dry yield. In spite of the relatively long period the stooked maize was left for wind drying, fairly diverging moisture contents of the stover had sometimes to be expected on account of the treatments of an experiment (e.g. different times of planting). In these cases the total weights of the plants were taken either as soon as the plants were cut or after the stooked plants had become fairly dry. The percentage of dry matter in the plants at the time of the determination of the weight was obtained by oven drying of samples.

b./

b. Plot Size and Sampling of Plants.

In most of the experiments conducted at Glen, a plot of 6 x 26 yds. = $\frac{1}{64.1}$ morgen (approx.) was planted, while at Theunissen the plot planted was always 9 x 18 yds. = $\frac{1}{61.7}$ morgen (approx.). In order to exclude border effects the area harvested in most instances was 4 x 22 yds. = $\frac{1}{113.6}$ morgen (approx.) at Glen and 7 x 14 yds. = $\frac{1}{102}$ morgen (approx.) at Theunissen.

There were, however, exceptions to the general plot sizes. In an experiment with extremely strong border effects (different times of planting at Glen, project O-Gl.74) the long and narrow plot shape proved inefficient, and plots with 12 x 13 yds. planting area and 8 x 9 yds. = $\frac{1}{138.9}$ morgen (approx.) harvesting area were used in the following season.

At Glen, samples of ten plants per plot standing in full competition with other plants were taken at different growth stages from a few plots in order to obtain information on the growth and nitrogen uptake up to certain growth stages. This decreased the final harvest size of the plots. In addition to the decreased number of plants, provision had to be made for the new border effect arising from the harvesting at different times. These samples were taken only from densely spaced maize (3 ft. x 12 in.) and the maximum decrease in the final plot size at the grain harvest did not exceed about one-quarter of the original size.

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In order to investigate the growth and nitrogen uptake of maize up to certain growth stages at Theunissen, special experiments were carried out. The general plot size was applied for planting. For the harvesting of the green plants, the plots were sub-divided into four sub-plots, making provision for harvesting at four growth stages. Thirty to forty plants were harvested at early and twenty to thirty at advanced growth stages. The moisture determinations and chemical analyses were based on samples of a minimum of 10 plants each. The harvests were undertaken on the harvesting area of the plots, and provision was also made for the border effects arising from the harvesting on successive dates. In order to eliminate these border effects, two border plants between the harvesting areas were excluded from harvesting during the first experimental season and thereafter three border plants. Because of the

relatively/

relatively small number of plants, only plants standing in full competition with other plants were included in the harvest. As a very high degree of precision was obtained with the espacements, the yields per morgen could be calculated from the number of plants harvested and the theoretical number of plants per morgen.

When sampling at the stage of ripeness, samples of at least ten plants or five to eight pounds of air dry stover were taken. The samples were oven-dried at 100° C until a constant weight was attained. For chemical analyses the entire dry samples were milled and thoroughly mixed.

c. Soil Sampling and Soil Moisture Investigation.

Depending on the purpose, soil samples were taken with Veihmeyer sampling tubes or with spades. Compared with spade sampling, sampling with tubes has the advantage that the soil core which represents the profile on the sampling spot, can easily be obtained. With spade sampling, on the other hand, some effort is required in ensuring that the amount of soil obtained from the different depths of an intersection does not differ. A disadvantage of tube sampling is a relatively small sampling diameter.

Where relatively little soil was required (soil moisture studies and chemical soil survey), the soil samples were usually taken with Veihmeyer tubes.

Soil sampling in order to obtain soil for pot experiments was always done with spades. To investigate the soil of a certain area, samples were taken on a number of spots over the whole area, the area next to the borders being excluded. The number of sampling spots depended mainly on the size of the area, the minimum being four in the case of plots.

For the determination of the soil moisture content, soil samples were placed in tins with closely fitting covers and brought to the laboratory for weighing and oven-drying. As it is desirable to establish the moist weight of soil samples as soon as possible after sampling, with only one or two persons available, the number of soil samples which could be taken at a time was limited. Accordingly, only two to four treatments could be investigated and compared at a time, as provision was made for sampling at four to six soil depths and four replicate sampling spots per treatment.

From/

From a statistical point of view the normal procedure would have been sampling from the soil of each replicate plot at spots picked at random over the experimental area. Sampling on only one or two spots per plot must, in this case, be considered insufficient, since the diameter of the sampling tube is too small to represent a whole plot. In general, replicate plots are also situated relatively far apart which causes a considerable probability of differences in soil texture. The soil moisture content is the finest indicator for differences in soil texture. According to previous experience of the author the results of sampling on relatively distant replicate plots can to such an extent reflect texture differences that treatment effects are overshadowed. On account of these reasons and regarding the available facilities it was attempted to find a solution by the establishment of model conditions.

The model conditions are based on the assumption that the probability of differences in soil texture lessens with decreasing distance between paired sampling spots of two treatments. Therefore, the sampling spots of the treatments were chosen as near to each other as possible, due allowance being made for the border effects (four yds. in the case of maize planted at a row distance of one yard). Furthermore, the uniformity of the soil texture was checked by means of soil moisture studies carried out previous to the experimental sampling.

Thus the sampling was undertaken on adjacent plots representing only one replication of two treatments to be compared. Over the length of the plots four to six pairs of sampling spots were chosen, each pair representing one replication under the model conditions.

In the case of the soil moisture investigations of Figures 1 and 2, the distance between the sampling spots on the veld from those on the maize land amounted to about 25 yds. The soil moisture investigation on veld was part of another comparison not considered in this thesis.

Successive moisture investigations during a season were undertaken in the area next to the prechosen spots, and previous sampling holes were filled with soil and marked.

As the gravimetric method of soil moisture investigation is very laborious, the establishment of model conditions

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seems to be the only promising alternative, if no extreme efforts can be made for sampling on a very large scale. *

Particulars of the distance of the sampling spots from the plants and of the depths of sampling will be given with the results.

With the exception of the soil moisture investigations presented in Figures 1 and 2, soil moisture percentages were always converted into mm soil moisture. In order to obtain the volume weights of the soils, holes were dug into the soils and volume samples from each investigated soil layer were obtained with the aid of 100 $cm^3$ cylinders.

The permanent-wilting percentages of the soils were determined according to the sunflower method described by KRAMER, 1949, p. 87.

## II. Pot Experiments.

### a. Experiment on the Nitrogen and Phosphate Status of the Soils.

In order to determine the nitrogen and phosphorus status of various soils, a pot experiment with two row barley (cv. Swanneck) as test plants was carried out in MITSCHERLICH pots. As purified sand was not available, the soils were not mixed with sand. The quantity of air dry sieved soil used corresponded to 6 kg dry soil per pot. As soils differing in texture were involved in the experiment, it was considered important to note the moisture content of the air dry soils.

The particulars of the fertilizers applied as well as the soils included in the experiment will be given with the results.

At the time when the pots were filled, the fertilizers were mixed with the soil and the moisture content of all the soils was brought to an equal level of 60% of the water-holding capacity. Fifty seeds were planted per pot and after germination the seedlings were thinned out to 25 per pot.

At the beginning of the experiment only the soil surface was kept moist. Thereafter the soil was saturated/

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* The author is indebted to PROFESSOR H. BAUMANN for ideas on sampling for soil moisture investigations.

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saturated with moisture twice a week. In the time between dates of saturation, moisture was supplied according to the weather conditions and all treatments received equal amounts of water. Distilled water was used for watering. The plants were harvested at the flowering stage, oven dried and milled for chemical analysis.

b. Experiment on the Nitrogen Nutrition of Maize.

In order to determine the influence of nitrogen applied at different growth stages, on the growth and nitrogen uptake of maize under conditions with a sufficient moisture supply, a pot experiment was carried out in large MITSCHERLICH vessels. For this experiment 14 kg air dried soil taken from the 0 - 8 inch horizon of the experimental site at "Excelsior", Theunissen (site I) was used per pot.

The following fertilization was applied per pot for all treatments:-

| | | |
|---|---|---|
| 2,00 g | $P_2O_5$ | as Superphosphate |
| 1,00 g | $K_2O$ | as $K_2SO_4$ |
| 0,50 g | MgO | as $MgSO_4 \cdot 7\ H_2O$ |
| 0,10 g | ZnO | as $ZnSO_4 \cdot 6\ H_2O$ |
| 0,03 g | $MnO_2$ | as $MnSO_4 \cdot 4\ H_2O$ |
| 0,21 g | $Na_2$ Fe-EDTA | |

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At the time when the pots were filled, all the fertilizers except nitrogen were mixed with the soils and the soils were moistened to 60 per cent of the water-holding capacity.

On each of four planting hills two seeds of the maize variety PP x K 64 were planted. After germination surplus plants were removed, leaving 2 plants per pot. The seeds had been preselected according to weight (0.5 - 0.6 g). Previous experience had indicated that a greater uniformity of the experimental results can be achieved by selecting the seeds according to weight (SCHMIDT, 1955). Nitrogen fertilizer was applied at different growth stages. The first nitrogen was given as soon as the surplus plants had been removed. The nitrogen treatments will be presented with the results.

At the beginning of the experiment only the soil surface was kept moist. Thereafter the application of water varied according to the size of the plants and the weather conditions.

The/

The soil was saturated with moisture every two to four days. During the time between the saturations all pots obtained the same amounts of water. Care was taken to ensure that the plants of all treatments received a sufficient moisture supply during the whole experimental period. Distilled water was used for watering. To prevent a loss of plant material, dry leaves were cut off and gathered regularly. This plant material was added to the plant material harvested.

### c. Hydroponic Experiments.

Hydroponic experiments were carried out to investigate a possible ion function of nitrate in maize plants and the relative efficiency of nitrate and ammonium nutrition.

Seeds of the variety SA 200 were selected by weighing and germinated in sawdust which had been boiled and washed with distilled water. Only seeds of the weights between 0.35 and 0.40 were used in the experiments. When the roots were about 4 - 5 cm long, the plants were transferred to one gallon polyethylene vegetation vessels containing 4,000 ml nutrient solution. Five plants were grown in each vegetation vessel. The vessels had a cover with six collared holes. Five of the holes held the seed, and a stick placed in the sixth hole (centre) was used to support the plants.

Only distilled water and A.R. quality chemicals were used for the hydroponic experiments. The water losses due to evaporation and transpiration were replaced regularly. From time to time the hydrogen ion concentration of the solution was determined with a METROHM pH meter.

When harvesting, the roots were separated from the herbage. All material was oven-dried at 100° C and the dry weights were determined.

Since both the treatments and the composition of the basic nutrient solution were changed in successive experiments, all the particulars of the solutions will be given with the results.

## III. Soil Incubation Tests.

The mineral nitrogen contents ($NH_4^+$- and $NO_3^-$-N) of the soils of different experimental sites and the liberation of mineral nitrogen in these soils during

incubation/

incubation were determined. The procedure followed was similar to that applied by ZÖTTL (1958, 1960a and 1960c).

The ammonium and nitrate contents of the soils from four experimental sites, sampled at three soil depths, were determined previous to and after incubation for 7, 14 and 21 days at $30^{\circ}$ C. The quantity of soil per sample incubated corresponded to 20 g of dry soil. The moisture content of the soils during incubation amounted to 60 per cent of the water-holding capacity. The liberation of mineral nitrogen in the soils during incubation was obtained by taking the difference between the mineral nitrogen contents previous to and after incubation. The investigations were carried out in duplicate.

## IV. Mechanical and Chemical Analyses. *

### a. Soil Analyses.

The mechanical analyses were conducted according to the ATTERBERG method. Carbon was determined according to the method of KURMIES (MEBIUS, DEKKER and TEN HAVE, 1957). Humus contents (soil organic matter) were always calculated from the carbon contents (factor 1.742). For the determination of total nitrogen, the KJELDAHL-FÖRSTER method was employed. The soil pH was determined electrometrically in 0.1 n KCl-solution with a METROHM pH meter. The dilution was 1 part of soil to 2.5 parts solution.

For the determination of nitrate and ammonium in the soil incubation test, the same methods as applied by ZÖTTL (1958, 1960a and 1960c) were used. A quantity of soil corresponding to 20 g dry soil was shaken for half and hour with 40 ml of one per cent $KAl(SO_4)_2$ solution and then filtered. In the filtrate both nitrate and ammonium were determined photometrically (Zeiss Spectrophotometer), ammonium with NESSLER'S reagent after micro-diffusion (CONWAY, 1950 and BREMNER and SHAW, 1955) and nitrate according to the xylenol method (BLOM and TRESCHOW).

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* When well known, conventional methods are used the original literature will not be cited. In these cases the names will be given without statement of the year. These methods are described in detail by THUN, HERRMANN and KNICKMANN (1949).

b. Plant Analyses.

In order to determine nitrogen in plant material, different methods were used, depending on the presence or absence of nitrates. Previous to any nitrogen determination the presence of nitrates in the plant material was determined by means of the qualitative test with diphenylamine sulphuric acid. If present, the nitrates were reduced with dilute sulphuric acid and ferrum reductum before digestion of the material in sulphuric acid, as proposed by RAUTERBERG and BENISCHKE (1943). The conventional KJELDAHL method was used if no nitrates were present in the material.

In a few instances, various nitrogen fractions were determined separately according to the method applied by ZANDER (1943/44). In these cases, the protein nitrogen was separated from the total soluble nitrogen by coagulation of the protein with tannin solution and subsequent filtration. Both the protein and total soluble nitrogen were determined by the KJELDAHL method, the total soluble nitrogen in an aliquot part of the filtrate after the nitrates had been reduced with dilute sulphuric acid and ferrum reductum.

Nitrates were determined according to the nitroxylenol method applied by ZANDER (1943/44) in aliquot portions of the filtrates.

During the seasons regular determinations were made to find out up to what growth stages the plants contained nitrates. The qualitative test with diphenylamine sulphuric acid was applied according to the plant test described by OHLROGGE (1956).

Phosphates were determined with ammonium vanadate molybdate according to the method of GERICKE and KURMIES (1952).

## V. Design and Evaluation of the Experiments.≁

The designs used in the experiments, depending on the type and object of the experiments, were randomized blocks as well as split plot and factorial designs. The experiments were statistically analyzed according to their design. The standard error (SE) and, where the variance ratio (F) indicated significant differences, the least significant/

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≁ The author is indebted to Professor Saunders as well as to Mr. R. Basson for advice concerning the evaluation of some of the experiments.

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significant difference (LSD) will be presented together with the results. The five per cent level of probability (P = 0.05) has been adopted in the experiments. In some cases a statistical analysis of the data was regarded as unnecessary. Results of factorial experiments will be presented as interaction tables. Correlation coefficients were calculated according to BRAVAIS's formula (MUDRA, 1958, p. 97).

## E. RESULTS AND DISCUSSION OF INDIVIDUAL EXPERIMENTS.

### I. Field Experiments.

#### a. Description.

The following field experiments will be presented and discussed in this thesis :

1. Spacing and Fertilizer Requirement of Maize at Glen (Project O.Gl.54).

The object was to investigate the influence of the espacement and application of fertilizer (nitrogen, phosphorus and potassium) on maize yields.

According to previous experimental results, the optimum plant density is about 15,000 plants per morgen. From other regions reports had been received that yields could be raised considerably when maize was spaced more densely and, in addition to phosphate fertilizer, nitrogen was applied. Special attention was paid to the effects of nitrogen fertilization, as no previous results on the response of maize to nitrogen fertilizer were available in the Central Orange Free State.

The experiments of this project were conducted on the experimental site at Glen during the seasons 1957/58, 1958/59, 1959/60 and 1960/61.

The experiments included two espacements (3 ft. x 12 in. = 30,000 plants per morgen and 3 ft. x 24 in. = 15,000 plants per morgen), three nitrogen fertilizer treatments (none, 200 and 400 lb. ammonium sulphate per morgen, corresponding to 42 and 84 lb. N), two phosphate treatments (300 and 600 lb. superphosphate per morgen in the first season and 200 and 400 lb. superphosphate in the following seasons) and two potassium treatments (none and 400 lb. potassium chloride per morgen in the first and none and 100 lb.

potassium/

potassium chloride per morgen in the first and none and 100 lb. potassium chloride per morgen in the subsequent seasons).

The maize variety S.A. 200 was planted in the 1957/58 and 1958/59 seasons, and the variety PP x K 64 in the 1959/60 and 1960/61 seasons.

A 2 x 3 x 2 x 2 factorial design with 3 replications was employed in the experiments. The position of the plots remained unchanged during the experimental period. The soil had been cultivated for two years when the experiment was started.

In the first season only the yields were determined. In the subsequent seasons the protein content of the grain and the nitrogen content of the stover as well as the nitrogen uptake by the herbage of a number of treatments of the experiments were also investigated. In addition, the nitrogen contents and nitrogen uptake at different growth stages were established by analyses of samples taken during the 1959/60 season. In 1957/58 soil moisture studies were carried out on plots with 3 ft. x 24 in. and 3 ft. x 12 in. espacement of the plants in combination with two fertilizer treatments (without nitrogen fertilization and with 400 lb. ammonium sulphate per morgen).

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• <u>Spacing and Fertilizer Requirement of Maize at "Excelsior", Theunissen (Project O.Gl.55).</u>

The object and duration of the experiments were the same as in the case of project O.Gl.54.

During the 1957/58 season the experimental design and the treatments applied at Glen (O.Gl.54) and Theunissen (O.Gl.55) were exactly the same. As from the second season, special attention was paid to the time of application of the nitrogen fertilizer. A 2 x 7 x 2 factorial design with three replications was used in the 1958/59, 1959/60 and 1960/61 seasons. Two espacements (3 ft. x 12 in. and 3 ft. x 24 in.) were applied in combination with seven nitrogen treatments (without nitrogen fertilizer, 200 lb. ammonium sulphate per morgen applied at planting time, 100 lb. applied at planting plus 100 lb. about four weeks thereafter, 200 lb. applied about four weeks after planting, 200 lb. applied six to eight weeks after planting, 400 lb. applied at planting and 200 lb. applied at planting plus 200 lb. six to

eight/

eight weeks after planting). In addition, two phosphate levels were included in the treatments (200 and 600 lb. superphosphate per morgen).

The maize variety Potchefstroom Pearl was planted in the 1957/58 season and, as from 1958/59, the variety PP x K 64.

In the first season the yields only were determined. In the seasons that followed, the protein content of the grain and the nitrogen content of the stover as well as the nitrogen uptake by the herbage of a number of selected treatments were investigated. An effort was also made to compare the results of corresponding treatments obtained at Glen and Theunissen.

In order to prevent a possible residual effect of nitrogen fertilizer, the experiments were laid out on a new site of the farm "Excelsior", Theunissen, each season. At Glen (O.Gl.54) the available area was limited, so that a change of the experimental site was not possible. The soil at Theunissen had been under cultivation for more than 35 years.

3. Growth, Nitrogen Uptake and Nitrogen Content of Maize at Successive Growth Stages at "Excelsior", Theunissen.

The object was to investigate the influence of nitrogen fertilizer, applied at different stages of growth, on the growth and nitrogen status of the plants during the growth period.

The experiment was carried out during two seasons (1958/59 and 1959/60). In 1959/60 the results obtained from two treatments of this experiment were compared with the results of corresponding treatments obtained by sampling on the experimental area at Glen.

The experiment consisted of six nitrogen fertilizer treatments (without nitrogen fertilizer, 200 lb. ammonium sulphate per morgen applied at planting, 200 lb. applied about four weeks after planting, 200 lb. applied six to eight weeks after planting, 400 lb. applied at planting and 200 lb. applied at planting plus 200 lb. six to eight weeks after planting).

The espacement was 3 ft. x 12 in. = 30,000 plants per morgen, the maize variety PP x K 64. All the plots were provided with superphosphate at a rate of 600 lb./

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600 lb. per morgen. The experimental area was changed after the first season. The soil had been under cultivation for more than 35 years.

Each experimental plot was subdivided for harvests at four growth stages, the first harvest at the date of the application of nitrogen fertilizer about four weeks after planting, the second at the date of the application of nitrogen fertilizer six to eight weeks after planting, the third during the early flowering stage and the fourth during either the late flowering or the milk stage.

The subdivision made it possible to analyse the results as a split plot design. This, however, was only applied for the analysis of the growth intensity and the intensity of the nitrogen uptake between successive harvesting dates.

4. <u>Time of Planting, Spacing and Nitrogen Fertilizer Requirement of Maize at Glen (Project O.Gl.74)</u>.

The object was to investigate the interaction between times of planting, espacements and nitrogen fertilizer treatments with regard to maize yields. Special attention was also paid to the influence of the treatments on the drought resistance of the crop.

In the section on "Relationships between Climate and Crop Production" (p. 6 ), it was pointed out that both the espacement and time of planting **may** have an influence on the drought resistance of maize. Since a decreased danger of drought damage could be expected with both wide espacement and late planting, the possibility had to be considered that an espacement of 15,000 plants per morgen did not represent the optimum espacement at any planting date. Late plantings **may** allow relatively dense plant populations, and early plantings **may** require a wide espacement in order to survive rainless periods without damage to the plants. In addition, interest was taken in the effects of nitrogen fertilizer applied in combination with different times of planting and different espacements.

This report includes the results of two seasons (1959/60 and 1960/61).

In both seasons, two dates of planting, a

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600 lb. per morgen. The experimental area was changed after the first season. The soil had been under cultivation for more than 35 years.

Each experimental plot was subdivided for harvests at four growth stages, the first harvest at the date of the application of nitrogen fertilizer about four weeks after planting, the second at the date of the application of nitrogen fertilizer six to eight weeks after planting, the third during the early flowering stage and the fourth during either the late flowering or the milk stage.

The subdivision made it possible to analyse the results as a split plot design. This, however, was only applied for the analysis of the growth intensity and the intensity of the nitrogen uptake between successive harvesting dates.

Time of Planting, Spacing and Nitrogen Fertilizer Requirement of Maize at Glen (Project O.Gl.74).

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This report includes the results of two seasons (1959/60 and 1960/61).

In both seasons, two dates of planting, a

treatment/

treatment without the application of nitrogen fertilizer and one with the application of 300 lb. ammonium sulphate per morgen (63 lb. N) were included in the experiment. In the first season the plants were planted in three different espacements (3 ft. x 12 in. = 30,000 plants per morgen, 3 ft. x 24 in. = 15,000 plants per morgen and 3 ft. x 36 in. = 10,000 plants per morgen). In the second season both 3 ft. and 6 ft. rows were planted with the same number of plants as were used in the three espacements during the previous season. Thus the espacements 6 ft. x 6 in., 6 ft. x 12 in., and 6 ft. x 18 in. were included in addition to the espacements of the first season.

In both seasons the tillerising of the plants and the yields were established. In the 1960/61 season the protein content of the grain and the nitrogen content of the stover were also determined and the nitrogen uptake calculated for all treatments. In addition, soil moisture investigations were carried out on plots with early and late planting as well as on plots with 15,000 plants per morgen planted in 3 ft. and 6 ft. rows during 1960/61.

A 2 x 3 x 2 factorial design with three replications was applied in the 1959/60 season and a 2 x 3 x 2 x 2 factorial design with three replications in 1960/61. The soil had been under cultivation for four and five years respectively. Superphosphate was applied at a rate of 400 lb. per morgen per season to all treatments. The experimental site was changed after the first season. The maize variety was PP x K 64.

b. Results and Discussion.

Instead of presenting the results of the experiments over the entire duration of each project separately, it was decided to discuss the work season by season, as a discussion of all the results in this way seemed to be more advantageous.

1957/58 Season.

1. Spacing and Fertilizer Requirement of Maize at Glen (O.Gl. 54).

Experimental dates: The maize was planted on November 20th, 1957 and harvested on May 21st, 1958.

Observations: The only visible fertilization effect was observed during the tasseling stage when a

slightly/

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slightly more intense green colour was evident in plants that had received nitrogen fertilizer.

In spite of an exceptionally high rainfall until January, drought during February caused considerable damage to the densely spaced plants (3 ft. x 12 in.). The plants of the normal espacement (3 ft. x 24 in.) also wilted, but only temporarily. During this season normal precautions did not prevent the maize from being infested by stalk borer. The densely spaced plants were more extensively damaged than the normally spaced ones.

Results : The grain and stover yields are summarised in Table 7.

The espacement 3 ft. x 12 in. (30,000 plants per morgen) resulted in lower grain and higher stover yields than the espacement 3 ft. x 24 in. (15,000 plants per morgen). With regard to both grain and stover yields neither fertilizer effects nor interactions between either the treatments with different fertilizers or between each of the fertilizer treatments and the espacements proved significant.

2. Soil Moisture Investigation on Plots of O.Gl.54.

In order to determine the influence of nitrogen fertilizer and of two espacements on the soil moisture depletion during the growth season of maize, soil moisture studies were carried out on plots not provided with nitrogen fertilizer and on plots with the application of 84 lb. N per morgen at 3 ft. x 12 in. as well as 3 ft. x 24 in. espacement of the plants.

The investigations included the soil depths 0 - 4 in., 4 - 8 in., 8 - 12 in., 12 - 24 in. and 24 - 36 in. and were started 15 days after the maize had been planted. The samples were taken about 9 in. from the plants between the rows. Otherwise the procedure described in the section on methods was followed.

Results : In Table 8 the amounts of soil moisture (mm) found at the soil depths 0 - 12, 12 - 24 and 24 - 36 in. are presented for the treatments with dense and normal espacement and the treatments without and with an application of nitrogen fertilizer. Since the results of the combinations between espacements and nitrogen treatments revealed no further information, they are not presented.

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TABLE 7: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS GLEN, 1957/58

| Fertilizer applied, lb./morgen | Grain yield, bags per morgen (12.5% moisture) | | | Stover yield, ton per morgen (air dry) | | |
|---|---|---|---|---|---|---|
| | A. Espacement | | | | | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean |
| B. Ammonium sulphate | | | | | | |
| $b_0$ none | 16.5 | 18.1 | 17.3 | 3.11 | 2.88 | 3.00 |
| $b_1$ 200 | 15.7 | 18.1 | 16.9 | 3.12 | 2.74 | 2.93 |
| $b_2$ 400 | 15.9 | 18.8 | 17.4 | 3.13 | 2.78 | 2.96 |
| C. Superphosphate | | | | | | |
| $c_0$ 300 | 15.6 | 18.1 | 16.8 | 3.08 | 2.82 | 2.95 |
| $c_1$ 600 | 16.5 | 18.6 | 17.6 | 3.16 | 2.77 | 2.97 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 16.9 | 18.4 | 17.6 | 3.13 | 2.74 | 2.94 |
| $d_1$ 400 | 15.1 | 18.3 | 16.7 | 3.11 | 2.86 | 2.98 |
| Mean | 16.0 | 18.3 | 17.2 | 3.12 | 2.80 | 2.96 |

| | B. Ammonium sulphate, lb./morgen | | | | | |
|---|---|---|---|---|---|---|
| C. Superphosphate | $b_0$ none | $b_1$ 200 | $b_2$ 400 | $b_0$ none | $b_1$ 200 | $b_2$ 400 |
| $c_0$ 300 | 16.7 | 17.6 | 16.3 | 2.94 | 3.02 | 2.90 |
| $c_1$ 600 | 17.9 | 16.3 | 18.4 | 3.04 | 2.85 | 3.01 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 17.1 | 17.8 | 18.1 | 2.92 | 2.90 | 2.98 |
| $d_1$ 400 | 17.5 | 16.0 | 16.6 | 3.06 | 2.97 | 2.93 |

| | C. Superphosphate, lb./morgen | | | |
|---|---|---|---|---|
| D. Potassium chloride | $c_0$ 300 | $c_1$ 600 | $c_0$ 300 | $c_1$ 600 |
| $d_0$ none | 17.8 | 17.5 | 2.95 | 2.92 |
| $d_1$ 400 | 15.9 | 17.6 | 2.95 | 3.02 |

| Treatment | SE | LSD (+) | SE | LSD (+) |
|---|---|---|---|---|
| A | 0.454 | 1.3 | 0.0530 | 0.15 |
| B | 0.556 | - | 0.0649 | - |
| C | 0.454 | - | 0.0530 | - |
| D | 0.454 | - | 0.0530 | - |
| AB | 0.787 | - | 0.0917 | - |
| AC | 0.642 | - | 0.0749 | - |
| AD | 0.642 | - | 0.0749 | - |
| BC | 0.787 | - | 0.0917 | - |
| BD | 0.787 | - | 0.0917 | - |
| CD | 0.642 | - | 0.0749 | - |

(+) P = 0.05

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TABLE 8 : DEPLETION OF SOIL MOISTURE UNDER MAIZE AT ($a_0$) 3 ft. x 12 in. AND ($a_1$) 3 ft. x 24 in. ESPACEMENT, ($b_0$) WITHOUT AND ($b_1$) WITH THE APPLICATION OF 84 lb. N PER MORGEN GLEN, 1957/58

| Soil depth | Approximate growth stage | Total soil moisture at three soil depth, mm: Emergence-before flower.-flower.-dough-ripening-fully ripe | | | | | | | | | | Readily available moisture at three soil depths, mm | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dates of investigation | 5.12 | 21.12 | 2.1 | 16.1 | 30.1 | 13.2 | 27.2 | 13.3 | 27.3 | 24.4 | 5.12 | 16.1 | 30.1 | 13.2 | 24.4 |
| 0-12 in. | $a_0$ 3ft.x 12in. | 52.5 | 39.1 | 39.8 | 28.5 | 29.5 | 23.5 | 15.6 | 23.7 | 41.5 | 41.0 | 26.3 | 2.6 | 3.6 | 0.0 | 15.1 |
| | $a_1$ 3ft.x 24in. | 53.6 | 45.0 | 44.6 | 31.0 | 32.9 | 25.3 | 17.3 | 24.2 | 42.9 | 41.7 | 27.7 | 5.1 | 7.0 | 0.0 | 15.8 |
| | $b_0$ no N | 52.6 | 41.4 | 42.1 | 28.3 | 30.5 | 23.8 | 15.5 | 23.4 | 41.1 | 40.4 | 26.7 | 2.4 | 4.6 | 0.0 | 14.5 |
| | $b_1$ 84 lb. N | 54.0 | 42.8 | 41.9 | 31.3 | 31.8 | 25.0 | 17.0 | 24.6 | 43.4 | 42.2 | 28.1 | 5.4 | 5.9 | 0.0 | 16.3 |
| 12-24 in. | $a_0$ 3ft.x 12in. | 76.9 | 72.2 | 62.4 | 52.2 | 51.7 | 48.5 | 44.3 | 47.1 | 58.2 | 57.8 | 28.9 | 4.2 | 3.7 | 0.5 | 9.8 |
| | $a_1$ 3ft.x 24in. | 75.5 | 71.8 | 65.7 | 55.4 | 54.1 | 49.4 | 45.7 | 44.7 | 53.1 | 57.8 | 27.5 | 7.4 | 6.1 | 1.4 | 9.8 |
| | $b_0$ no N | 75.9 | 72.7 | 64.3 | 54.0 | 52.2 | 48.5 | 45.2 | 46.6 | 55.4 | 57.8 | 27.9 | 6.0 | 4.2 | 0.5 | 9.8 |
| | $b_1$ 84 lb. N | 75.9 | 71.8 | 63.8 | 53.1 | 53.6 | 49.4 | 44.7 | 45.7 | 55.9 | 57.3 | 27.9 | 5.1 | 5.6 | 1.4 | 9.3 |
| 24-36 in. | $a_0$ 3ft.x 12in. | 72.2 | 68.5 | 63.3 | 53.0 | 49.7 | 46.0 | 44.5 | 45.0 | 45.0 | 44.5 | 26.7 | 7.5 | 4.2 | 0.5 | 0.0 |
| | $a_1$ 3ft.x 24in. | 70.3 | 67.5 | 66.1 | 56.3 | 52.5 | 46.0 | 44.5 | 46.0 | 45.0 | 44.1 | 24.8 | 10.8 | 7.0 | 0.5 | 0.0 |
| | $b_0$ no N | 72.2 | 68.0 | 64.7 | 54.4 | 50.6 | 45.5 | 43.1 | 46.9 | 45.0 | 44.5 | 26.7 | 8.9 | 5.1 | 0.0 | 0.0 |
| | $b_1$ 84 lb. N | 70.3 | 68.0 | 64.7 | 54.9 | 51.6 | 46.4 | 46.0 | 44.1 | 45.0 | 44.1 | 24.8 | 9.4 | 6.1 | 0.9 | 0.0 |
| mm rain between dates | | | 42.6 | 26.4 | 29.8 | 73.7 | 19.7 | 9.7 | 14.4 | 66.2 | 36.4 | | | | | |
| Evapotranspiration between dates, mm | $a_0$ 3ft.x 12in. | | 64.4 | 40.7 | 61.6 | 76.5 | 32.6 | 23.3 | 3.0 | 37.3 | 37.8 | | | | | |
| | $a_1$ 3ft.x 24in. | | 57.7 | 34.3 | 63.5 | 76.9 | 38.5 | 22.9 | 7.0 | 40.1 | 33.8 | | | | | |
| | $b_0$ no N | | 61.2 | 37.4 | 64.2 | 77.1 | 35.2 | 23.7 | 1.3 | 41.6 | 35.2 | | | | | |
| | $b_1$ 84 lb. N | | 60.2 | 38.6 | 60.9 | 76.0 | 35.9 | 22.8 | 7.7 | 36.3 | 37.1 | | | | | |
| Cumulative evapotranspiration, mm | $a_0$ 3ft.x 12in. | | 64.4 | 105.1 | 166.7 | 243.2 | 275.8 | 299.1 | 302.1 | 339.4 | 377.2 | | | | | |
| | $a_1$ 3ft.x 24in. | | 57.7 | 92.0 | 155.5 | 232.4 | 270.9 | 293.8 | 300.8 | 340.9 | 374.7 | | | | | |
| | $b_0$ no N | | 61.2 | 98.6 | 162.8 | 239.9 | 275.1 | 298.8 | 300.1 | 341.7 | 376.9 | | | | | |
| | $b_1$ 84 lb. N | | 60.2 | 98.8 | 159.7 | 235.7 | 271.6 | 294.4 | 302.1 | 338.4 | 375.5 | | | | | |

| readily available moisture, 0-3ft. | 5.12 | 16.1 | 30.1 | 13.2 | 24.4 |
|---|---|---|---|---|---|
| $a_0$ 3ft.x 12in. | 81.9 | 14.3 | 11.5 | 1.0 | 24.9 |
| $a_1$ 3ft.x 24in. | 80.0 | 23.3 | 20.1 | 1.9 | 25.6 |
| $b_0$ no N | 81.3 | 17.3 | 13.9 | 0.5 | 24.3 |
| $b_1$ 84 lb. N | 80.8 | 19.9 | 17.6 | 2.3 | 25.6 |

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Each figure of Table 8 thus represents the mean obtained from eight sampling holes. In addition to the amount of soil moisture, the evapotranspiration between the dates of investigation, the cumulative evapotranspiration, and, for a few dates, the amount of readily available soil moisture (soil moisture determined minus mm soil moisture below the permanent-wilting percentage) are also given in Table 8.

The moisture investigations of this season are of special interest since the results represent the moisture depletion under relatively high rainfall conditions, in contrast to moisture investigations carried out under relatively low rainfall conditions during the 1960/61 season. On account of a relatively high precipitation during September and October, a relatively large amount of soil moisture was available when the plants emerged (81 mm plant available soil moisture). According to results from previous moisture investigations on fallow land of a bordering site (unpublished), it is estimated that this amount represented about 75% of the field capacity. The rainfall during November was normal. Up to the flowering stage (January 30th) the amount of readily available soil moisture decreased at 0 - 36 in. depth to between 12 and 20 mm in spite of an above normal precipitation during December and January. A dry February brought a complete depletion of the available soil moisture which was followed by wilting of the plants. The soil moisture reserve was increased by a good rainfall only towards the middle of March. The results obtained on April 24th indicate that the moisture had not penetrated deeply into the soil. The soil layer at 24 - 36 in. depth was still dry. The figures also indicate that even considerable amounts of soil moisture conserved before planting were depleted rapidly by the growing plants, with the result that shorter dry periods at advanced growth stages could cause drought damage to the plants.

The intervals between dates of sampling were mostly 14 days, with the exceptions of the first period (5.12 to 21.12 with 16 days), the second period (21.12 to 2.1 with 12 days) and the last period (27.3 to 24.4 with 28 days). The evapotranspiration between dates has not been corrected to equal intervals. Generally, the evapotranspiration per 14 day interval increased slightly up to the flowering/

flowering stage and decreased sharply thereafter. This decrease may to a large extent be attributed to a lack of soil moisture at that stage.

The espacements had only a very slight effect on the soil moisture depletion.

At the early growth stages (5.12 to 2.1) the evapotranspiration was slightly higher with dense than with normal espacement. In contrast, for the period beginning during the flowering stage (30.1 to 13.2) a slightly higher evapotranspiration for normal than for dense espacement was calculated. The probable reason, therefore, was that the densely spaced plants were more severely affected by the drought during the flowering stage and thereafter than the normally spaced ones.

If the cumulative evapotranspiration is considered, it becomes evident that the higher plant population used the soil moisture slightly more readily than the normal plant population only during the early growth stages, while later a more or less equal moisture consumption was obtained with both espacements. This result was not expected and indicates that plant populations of 15,000 and 30,000 plants per morgen may bring about a nearly equal depletion of soil moisture during a season. The growth and development of the plants seemed to be affected only in that the amount of moisture available and used per plant was much higher with normal than with dense espacement. During the previous season where considerable differences were obtained between the soil moisture contents at two espacements (Fig. 2), greatly differing plant populations had been compared (5,000 and 30,000 plants per morgen).

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The nitrogen treatments did not influence the soil moisture depletion to any noteworthy extent. Since the application of nitrogen fertilizer was not followed by any growth reaction this result could be expected.

3. Spacing and Fertilizer Requirement of Maize at Theunissen (O.G1.55).

Experimental Dates : The maize was planted on November 27th, 1957 and harvested on May 1st, 1958.

Observations : No signs of drought damage were observed during the growth season. This may be attributed to an exceptionally high rainfall, which was

higher/

higher than at Glen both before planting and especially during February.

From a relatively early growth stage (about 18 in. height) there was an obvious response to the nitrogen treatments in that the plants developed different intensities of leaf colour. All the plants treated with 400 lb. ammonium sulphate per morgen maintained a dark green colour, while those with 200 lb. became medium green and those without an application of nitrogen fertilizer medium to pale green. At dense espacement the differences between the colour intensity of the plants were greater than at normal espacement. Soon afterwards a considerable growth response to the nitrogen treatments became apparent. The plants which were supplied with nitrogen fertilizer and especially those with the high application, grew more vigorously and developed thicker stalks than the plants without nitrogen fertilization.

With advancing growth the leaf colour generally became paler, especially at dense espacement of the plants. At the tasseling stage all plants supplied with 400 lb. ammonium sulphate per morgen still had a medium to dark green colour, while those with 200 lb. were pale green when densely spaced or medium to pale green when normally spaced. The plants not supplied with nitrogen fertilizer were pale when densely and medium to pale green when normally spaced.

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At the beginning of the milk stage all the densely spaced plants were pale green, while the normally spaced plants with the high application of nitrogen fertilizer were medium green, those with the lower one medium to pale green and those not provided with nitrogen fertilizer nearly as pale as the densely spaced plants without an application of nitrogen. Thereafter, the plants which were not supplied with nitrogen fertilizer changed from pale to medium green again, indicating a new nitrogen uptake from the soil. This indication did not become evident in the plants supplied with nitrogen fertilizer. The result was that the colour of the densely and especially the normally spaced plants not supplied with nitrogen fertilizer was finally darker than that of the densely spaced plants supplied with nitrogen. These symptoms may be explained as follows :-

Nitrogen fertilization had brought about a considerable growth response until a stage was reached when all the nitrogen had been taken up. As a result of vigorous growth and insufficient nitrogen available from the soil, the nitrogen content of the plant material then decreased to such an extent that the densely spaced plants suffered from nitrogen deficiency in spite of a relatively large quantity of nitrogen applied at planting time. When considering the relatively large quantity of material produced by the plants supplied with nitrogen fertilizer, the amount of nitrogen liberated in the soil may not have been sufficient to bring about a visible change of the leaf colour during this late growth stage. In contrast, the amount of nitrogen liberated in the soil during this period of improved soil moisture conditions seemed sufficient to bring about a marked increase in the nitrogen content of the small plants that had not been treated with nitrogen fertilizer. The reduced growth rate at that stage may also have been of importance in that the nitrogen liberated in the soil effected the observed change of the colour of the leaves, as it was not all used for a further growth.

During early growth stages the higher phosphate level brought about a slightly better growth than the lower. Later these differences became indistinct. No distinct potassium reaction on the growth was observed.

The generally heavy attack by stalk borer experienced during the 1957/58 season was even more pronounced at Theunissen than at Glen, in spite of the application of normal precautions. The percentage of infested plants per plot was statistically analysed after transformation of the percentages according to the arc.-sin. transformation. A significantly higher infestation (P = 0.05) occurred at dense espacement (60.7% of the plants were infested) than at a normal one (24.3%). On plots without an application of nitrogen fertilizer the infestation (46.3%) was higher than on those with the application of 200 lb. (40.1%) or 400 lb. ammonium sulphate per morgen (41.0%).

<u>Results</u>:- The grain and stover yields are presented in Table 9. As at Glen during the 1957/58 season, the espacement 3 ft. x 24 in. brought about higher grain and lower stover yields than the espacement

3 ft. x 12 in./

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TABLE 9: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS THEUNISSEN, 1957/58

| Fertilizer applied, lb./morgen | Grain yield, bags per morgen (12.5% moisture) | | | Stover yield, ton per morgen (air dry) | | |
|---|---|---|---|---|---|---|
| | A. Espacement | | | | | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean |
| B. Ammonium sulphate | | | | | | |
| $b_0$ none | 6.1 | 11.9 | 9.0 | 3.34 | 2.74 | 3.04 |
| $b_1$ 200 | 7.2 | 14.1 | 10.6 | 3.80 | 3.22 | 3.51 |
| $b_2$ 400 | 8.7 | 14.3 | 11.5 | 4.18 | 3.61 | 3.90 |
| C. Superphosphate | | | | | | |
| $c_0$ 300 | 7.1 | 13.2 | 10.2 | 3.74 | 3.09 | 3.42 |
| $c_1$ 600 | 7.5 | 13.7 | 10.6 | 3.80 | 3.29 | 3.54 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 7.4 | 13.6 | 10.5 | 3.65 | 3.15 | 3.40 |
| $d_1$ 400 | 7.2 | 13.3 | 10.2 | 3.90 | 3.23 | 3.56 |
| Mean | 7.3 | 13.4 | 10.4 | 3.78 | 3.19 | 3.48 |

| | B. Ammonium sulphate, lb./morgen | | | | | |
|---|---|---|---|---|---|---|
| C. Superphosphate | $b_0$ none | $b_1$ 200 | $b_2$ 400 | $b_0$ none | $b_1$ 200 | $b_2$ 400 |
| $c_0$ 300 | 9.0 | 10.5 | 11.0 | 3.03 | 3.47 | 3.75 |
| $c_1$ 600 | 8.9 | 10.9 | 11.9 | 3.06 | 3.54 | 4.03 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 9.1 | 10.8 | 11.4 | 2.96 | 3.40 | 3.83 |
| $d_1$ 400 | 8.8 | 10.5 | 11.5 | 3.13 | 3.61 | 3.95 |

| | C. Superphosphate, lb./morgen | | | |
|---|---|---|---|---|
| D. Potassium chloride | $c_0$ 300 | $c_1$ 600 | $c_0$ 300 | $c_1$ 600 |
| $d_0$ none | 10.6 | 10.3 | 3.37 | 3.43 |
| $d_1$ 400 | 9.8 | 10.8 | 3.47 | 3.66 |

| Treatment | SE | LSD (+) | SE | LSD (+) |
|---|---|---|---|---|
| A | 0.30 | 0.9 | 0.051 | 0.14 |
| B | 0.37 | 1.1 | 0.062 | 0.18 |
| C | 0.30 | - | 0.051 | - |
| D | 0.30 | - | 0.051 | 0.14 |
| AB | 0.52 | - | 0.088 | - |
| AC | 0.42 | - | 0.072 | - |
| AD | 0.42 | - | 0.072 | - |
| BC | 0.52 | - | 0.088 | - |
| BD | 0.52 | - | 0.088 | - |
| CD | 0.42 | - | 0.072 | - |

(+) P = 0.05

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3 ft. x 12 in. The application of nitrogen fertilizer (200 and 400 lb. of ammonium sulphate per morgen) led to higher grain yields than those obtained when nitrogen had not been applied. The stover yield was increased by increasing amounts of nitrogen. The application of potassium fertilizer resulted in a slightly increased stover yield. The phosphate treatments did not influence the yields. None of the interactions proved significant. The increase in yields resulting from the dressings of nitrogen fertilizer was surprisingly low when one bears the observations in mind. Two factors could have been responsible for nitrogen fertilizer failing to bring about a considerable increase in yields.

Firstly, the heavy stalk borer infestation might have generally prevented a higher yield. Secondly the fact that even the plants with the higher application of nitrogen obviously suffered from nitrogen deficiency during the flowering and ripening stages, is considered to have influenced the results. It is assumed that the nitrogen content of the plant material of the densely spaced plants supplied with 42 or 84 lb. nitrogen per morgen had decreased to such an extent that the nitrogen taken up by the plants was retained to a large extent in the leaves and stalks and thus prevented from being readily translocated to the grain. This nitrogen retention might have been detrimental to the formation of grain.

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In addition, the differences between yields obtained with and without the application of nitrogen fertilizer may have become smaller because the nitrogen which became available in the soil at an advanced stage of growth, obviously led to a more pronounced improvement of the nitrogen status of the small plants which had not been provided with nitrogen fertilizer than of the nitrogen status of the bigger plants which had been supplied with nitrogen fertilizer at planting time.

## 1958/59 Season.

The observations and results of the previous season nfluenced the approach to the further research work conucted at Theunissen. As from this season great care was aken at both places to prevent any infestation of stalk orer. The potassium treatments were excluded from further experiments/

experiments at Theunissen in favour of more nitrogen treatments. The observations had indicated that the time of the application of nitrogen might be of great importance in ensuring a good nitrogen supply to the plants during the period of grain formation. Special studies on the growth, nitrogen uptake and nitrogen content of the plants at successive growth stages and on the nitrogen composition of the harvested material at the normal harvesting time were undertaken.

1. Spacing and Fertilizer Requirement of Maize at Glen (O.Gl.54).

Experimental Dates : The maize was planted on November 7th, 1958 and harvested on April 13th, 1959.

Observations : In this season with a fairly normal precipitation the maize suffered heavily from drought during rainless periods experienced during January and the second half of February. The densely spaced plants wilted during these periods and large parts of the leaves became dry as early as the flowering stage. No fertilizer effects were observed. The stalks contained nitrates during the whole growth season until harvesting time. Some plants were infected with *Ustilago maydis*. The infection was limited to densely spaced plants and, with very few exceptions, did not occur on normally spaced ones.

Results : The grain and stover yields are given in Table 10. In Table 11 the results of nitrogen analyses are presented which were conducted on the harvested material of the treatments with narrow and normal espacement, without nitrogen fertilizer and the two nitrogen levels, with the higher phosphate level, and with potassium fertilizer.

As in the previous season, the espacement 3 ft. x 12 in. resulted in lower grain and higher stover yields than the espacement 3 ft. x 24 in. The grain yields of the 1958/59 season were much lower than those obtained in the 1957/58 season.

The application of potassium fertilizer resulted in a slightly increased stover yield. Very high percentages of protein in the grain were obtained at Glen. These were very uniform and do not indicate any influence of the treatments.

The quantity of nitrogen in the grain was influenced to a large extent by the grain yield. It was/

TABLE 10: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS GLEN, 1958/59

| Fertilizer applied, lb./morgen | Grain yield, bags per morgen (12.5% moisture) | | | Stover yield, ton per morgen (air dry) | | |
|---|---|---|---|---|---|---|
| | A. Espacement | | | | | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean |
| B. Ammonium sulphate | | | | | | |
| $b_0$ none | 2.93 | 5.85 | 4.39 | 4.01 | 3.01 | 3.51 |
| $b_1$ 200 | 2.60 | 7.04 | 4.82 | 3.89 | 2.87 | 3.38 |
| $b_2$ 400 | 2.58 | 6.66 | 4.62 | 3.79 | 2.84 | 3.32 |
| C. Superphosphate | | | | | | |
| $c_0$ 200 | 2.51 | 6.40 | 4.46 | 3.92 | 2.89 | 3.40 |
| $c_1$ 400 | 2.90 | 6.63 | 4.76 | 3.88 | 2.92 | 3.40 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 3.12 | 6.41 | 4.76 | 3.77 | 2.83 | 3.30 |
| $d_1$ 100 | 2.29 | 6.63 | 4.46 | 4.03 | 2.98 | 3.50 |
| Mean | 2.70 | 6.52 | 4.61 | 3.90 | 2.91 | 3.40 |
| | B. Ammonium sulphate, lb./morgen | | | | | |
| C. Superphosphate | $b_0$ none | $b_1$ 200 | $b_2$ 400 | $b_0$ none | $b_1$ 200 | $b_2$ 400 |
| $c_0$ 200 | 4.35 | 4.38 | 4.64 | 3.54 | 3.42 | 3.25 |
| $c_1$ 400 | 4.43 | 5.26 | 4.60 | 3.47 | 3.34 | 3.38 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 4.24 | 4.91 | 5.13 | 3.35 | 3.28 | 3.27 |
| $d_1$ 100 | 4.53 | 4.73 | 4.11 | 3.67 | 3.48 | 3.37 |
| | C. Superphosphate, lb./morgen | | | | | |
| D. Potassium chloride | $c_0$ 200 | $c_1$ 400 | | $c_0$ 200 | $c_1$ 400 | |
| $d_0$ none | 4.61 | 4.92 | | 3.33 | 3.27 | |
| $d_1$ 100 | 4.30 | 4.61 | | 3.48 | 3.53 | |

| Treatment | SE | LSD (+) | SE | LSD (+) |
|---|---|---|---|---|
| A | 0.286 | 0.81 | 0.0533 | 0.15 |
| B | 0.350 | - | 0.0653 | - |
| C | 0.286 | - | 0.0533 | - |
| D | 0.286 | - | 0.0533 | 0.15 |
| AB | 0.495 | - | 0.0924 | - |
| AC | 0.404 | - | 0.0754 | - |
| AD | 0.404 | - | 0.0754 | - |
| BC | 0.495 | - | 0.0924 | - |
| BD | 0.495 | - | 0.0924 | - |
| CD | 0.404 | - | 0.0754 | - |

(+) $P = 0.05$

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TABLE 11: NITROGEN COMPOSITION OF THE HARVESTED MATERIAL AND AMOUNTS OF NITROGEN GAINED BY MAIZE AS INFLUENCED BY SPACING AND NITROGEN FERTILIZER TREATMENTS

GLEN, 1958/59

| A. Spacing<br>B. Ammonium sulphate applied, lb./morgen | % prot. in dry grain | % N in dry stover | lb. N per morgen contained in grain | stover | total | grain as % of total |
|---|---|---|---|---|---|---|
| $a_0$ 3 ft. x 12 in. | | | | | | |
| $b_0$ none | 12.9 | +) | 11.6 | - | - | - |
| $b_1$ 200 | 12.8 | 1.45 | 5.0 | 99 | 104 | 4.8 |
| $b_2$ 400 | 13.2 | 1.62 | 7.1 | 107 | 114 | 6.2 |
| Mean ($a_0$) | 13.0 | 1.54 | 7.9 | 103 | 109 | 7.2 |
| $a_1$ 3 ft. x 24 in. | | | | | | |
| $b_0$ none | 12.6 | 1.49 | 18.9 | 72 | 91 | 20.8 |
| $b_1$ 200 | 12.8 | 1.45 | 34.5 | 76 | 110 | 31.4 |
| $b_2$ 400 | 12.7 | 1.21 | 21.8 | 62 | 84 | 26.0 |
| Mean ($a_1$) | 12.7 | 1.38 | 25.1 | 70 | 95 | 26.4 |
| Mean values (B) | | | | | | |
| $b_0$ none | 12.8 | - | 15.2 | - | - | - |
| $b_1$ 200 | 12.8 | 1.45 | 19.8 | 88 | 107 | 18.5 |
| $b_2$ 400 | 13.0 | 1.42 | 14.4 | 84 | 99 | 14.5 |
| Mean | 12.9 | 1.46 | 16.5 | 86 | 102 | 16.2 |

| Treatment (P=0.05) | % prot. in grain SE | LSD | lb. N per morgen in grain SE | LSD |
|---|---|---|---|---|
| A | 0.0563 | - | 1.79 | 5.6 |
| B | 0.0688 | - | 2.19 | - |
| AB | 0.0975 | - | 3.09 | 9.7 |

(+) Samples not taken

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was considerably larger at normal than at dense espacement of the plants. The nitrogen content of the stover was also generally high but varied considerably, as did the quantity of nitrogen contained in the stover and the nitrogen uptake by the plants. No statistical analyses were undertaken with these figures, they are presented merely to give a general idea on the nitrogen composition of the harvested material obtained at the Glen experimental site during the 1958/59 season.

The grain nitrogen as a percentage of the nitrogen contained in grain plus stover (Table 11) gives an indication as to what extent the nitrogen taken up by the plants was absorbed by the grain. Since the percentages protein in the grain were very uniform in all treatments, the influence of the treatments on the translocation of nitrogenous compounds to the grain was closely correlated with the influence of the treatments on grain production. The figures indicate that the nitrogen in the plants was used for grain production to a considerably larger extent at 3 ft. x 24 in. than at 3 ft. x 12 in. espacement.

It is believed that the moisture conditions also influenced the extent to which the nitrogen taken up by the plants was translocated to the grain. When only a low percentage of the amount of nitrogen in the plants was absorbed by the grain, this may indicate that dry conditions adversely affected the grain production and with it the translocation of nitrogenous compounds to the grain. The indications obtained from the grain nitrogen expressed as a percentage of the total nitrogen uptake appear to be similar to those which can be obtained by calculating the grain : stover ratio.

2. Spacing and Fertilizer Requirement of Maize at Theunissen (O.Gl.55).

Experimental Dates : On account of dry soil only a few seeds germinated after planting on the 19th November 1958. Rain which occurred on 6th December 1958 effected a good germination on the rest of the experimental site, so that finally a full stand was obtained. On planting hills where plants of both germination dates were present, the older plants were removed when removing surplus plants.

About 98 per cent of the plants in the experiment had started germinating on 6th December 1958. The/

The plants were harvested on 7th April 1959.

Observations : From October to February considerably less rain was recorded at Theunissen than at Glen. In spite of continuous drought during January and February, and in contrast to the plants at Glen, no visible signs of drought damage occurred. On maize lands in the vicinity of the experiment, heavy drought damage was experienced from about the middle of January. Both proper weed control and the late germination of the maize may have contributed to the drought resistance of the plants on the experimental area. A distinct influence of the espacements and nitrogen treatments on the colour of the leaves became evident before the tasseling stage. The plants treated with nitrogen fertilizer had a darker colour and the difference between the colour intensities with and without the application of nitrogen fertilizer were much more pronounced at dense than at normal espacement.

Nitrogen fertilizer effected a distinct growth reaction shortly before and during the flowering stage. The densely spaced plants in particular, showed considerable differences in growth. The top-dressings of nitrogen also resulted in an increased growth and, especially in the cases where no nitrogen had been applied at planting, in a marked change of the colour intensity of the leaves.

In contrast to the previous season, nitrogen deficiency did not occur when nitrogen had been applied at planting time. Distinct nitrogen deficiency symptoms were limited to the treatments without nitrogen fertilizer. The stalks contained nitrates until the tasseling stage.

At early growth stages the plants with the higher phosphate level appeared to grow better than those with the lower one.

Results : The grain and stover yields are given in Table 12 and the results of nitrogen analyses conducted on the harvested material of the treatments with narrow and normal espacement, six of the seven nitrogen treatments and the treatment with the higher phosphate level are presented in Table 13.

In this season during which there was a fairly limited moisture supply, a distinct nitrogen reaction was/

TABLE 12: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS THEUNISSEN, 1958/59

| B. Amm. sulph. in units of 100 lb. per morgen (..) and date of application | Grain, bags per morgen (12.5% moisture) | | | | |
|---|---|---|---|---|---|
| | A. Espacement | | | C. Superphosphate lb./morgen | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean (B) | $c_0$ 200 | $c_1$ 600 |
| $b_0$ none | 14.1 | 21.5 | 17.8 | 17.2 | 18.3 |
| $b_1$ (2)19.11 | 23.9 | 23.5 | 23.7 | 22.9 | 24.5 |
| $b_2$ (1)19.11+(1)30.12 | 19.3 | 23.2 | 21.2 | 20.8 | 21.7 |
| $b_3$ (2)30.12 | 21.1 | 24.6 | 22.3 | 22.1 | 23.6 |
| $b_4$ (4)19.11 | 28.3 | 26.2 | 27.2 | 27.2 | 27.3 |
| $b_5$ (2)19.11+(2)30.12 | 28.9 | 27.4 | 28.2 | 28.1 | 28.2 |
| $b_6$ (2)19.11+(2)14.1 | 26.9 | 26.0 | 26.4 | 26.0 | 26.9 |
| Mean (A and C) | 23.2 | 24.6 | 23.9 | 23.5 | 24.4 |

| C. Superphosphate lb./morgen | $a_0$ | $a_1$ |
|---|---|---|
| $c_0$ 200 | 23.2 | 23.7 |
| $c_1$ 600 | 23.2 | 25.5 |

| Treatment | SE | LSD(+) |
|---|---|---|
| A | 0.438 | 1.2 |
| B | 0.820 | 2.3 |
| C | 0.438 | - |
| AB | 1.16 | 3.3 |
| AC | 0.620 | - |
| BC | 1.16 | - |

| B. Amm. sulph. in units of 100 lb. per morgen (..) and date of application | Stover, ton per morgen (air dry) | | | | |
|---|---|---|---|---|---|
| | A. Espacement | | | C. Superphosphate lb./morgen | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean (B) | $c_0$ 200 | $c_1$ 600 |
| $b_0$ none | 3.05 | 2.98 | 3.02 | 2.97 | 3.07 |
| $b_1$ (2)19.11 | 3.77 | 3.23 | 3.50 | 3.27 | 3.73 |
| $b_2$ (1)19.11+(1)30.12 | 3.53 | 3.12 | 3.32 | 3.32 | 3.33 |
| $b_3$ (2)30.12 | 3.90 | 3.13 | 3.52 | 3.57 | 3.47 |
| $b_4$ (4)19.11 | 4.17 | 3.18 | 3.68 | 3.77 | 3.58 |
| $b_5$ (2)19.11+(2)30.12 | 4.18 | 3.30 | 3.74 | 3.63 | 3.85 |
| $b_6$ (2)19.11+(2)14.1 | 3.97 | 3.35 | 3.66 | 3.67 | 3.65 |
| Mean (A and C) | 3.80 | 3.18 | 3.49 | 3.46 | 3.53 |

| C. Superphosphate lb./morgen | $a_0$ | $a_1$ |
|---|---|---|
| $c_0$ 200 | 3.83 | 3.08 |
| $c_1$ 600 | 3.76 | 3.29 |

| Treatment | SE | LSD(+) |
|---|---|---|
| A | 0.0473 | 0.13 |
| B | 0.0885 | 0.25 |
| C | 0.0473 | - |
| AB | 0.125 | 0.35 |
| AC | 0.0669 | 0.19 |
| BC | 0.125 | - |

(+) P=0.05

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TABLE 13: NITROGEN COMPOSITION OF THE HARVESTED MATERIAL AND AMOUNTS OF NITROGEN GAINED BY MAIZE AS INFLUENCED BY SPACING AND NITROGEN FERTILIZER TREATMENTS
THEUNISSEN, 1958/59

| A. Spacing<br>B. Ammonium sulphate applied, lb./morgen and date | % prot. in dry grain | % N in dry stover | lb. N per morgen contained in: grain | stover | total | grain as % of total | Utilization of N applied, % (+) |
|---|---|---|---|---|---|---|---|
| $a_0$ 3 ft. x 12 in. | | | | | | | |
| $b_0$ none | 5.81 | 0.42 | 22.8 | 21 | 44 | 52 | - |
| $b_1$ 200 : 19.11 | 6.50 | 0.45 | 42.8 | 30 | 73 | 59 | 69 |
| $b_2$ 200 : 30.12 | 6.50 | | 40.3 | | | | |
| $b_3$ 400 : 19.11 | 7.12 | | 55.1 | | | | |
| $b_4$ 200 : 19.11+ 200 : 30.12 | 7.06 | 0.46 | 55.8 | 33 | 89 | 63 | 54 |
| $b_5$ 200 : 19.11+ 200 : 14.1 | 6.50 | | 50.0 | | | | |
| Mean ($a_0$) | 6.58 | 0.44 | 44.5 | 28 | 69 | 59 | |
| $a_1$ 3 ft. x 24 in. | | | | | | | |
| $b_0$ none | 6.56 | 0.38 | 41.9 | 20 | 62 | 68 | - |
| $b_1$ 200 : 19.11 | 7.25 | 0.52 | 52.4 | 31 | 83 | 63 | 50 |
| $b_2$ 200 : 30.12 | 7.50 | | 52.7 | | | | |
| $b_3$ 400 : 19.11 | 7.75 | | 58.1 | | | | |
| $b_4$ 200 : 19.11+ 200 : 30.12 | 7.06 | 0.49 | 55.6 | 29 | 85 | 65 | 27 |
| $b_5$ 200 : 19.11+ 200 : 14.1 | 7.44 | | 55.1 | | | | |
| Mean ($a_1$) | 7.26 | 0.46 | 52.6 | 27 | 77 | 65 | |
| Mean values (B) | | | | | | | |
| $b_0$ none | 6.18 | 0.40 | 32.4 | 20 | 53 | 61 | |
| $b_1$ 200 : 19.11 | 6.88 | 0.48 | 47.6 | 30 | 78 | 61 | 60 |
| $b_2$ 200 : 30.12 | 7.00 | | 46.5 | | | | |
| $b_3$ 400 : 19.11 | 7.44 | | 56.6 | | | | |
| $b_4$ 200 : 19.11+ 200 : 30.12 | 7.06 | 0.48 | 55.7 | 31 | 87 | 64 | 40 |
| $b_5$ 200 : 19.11+ 200 : 14.1 | 6.97 | | 52.6 | | | | |
| Mean | 6.92 | | 48.6 | 27 | 73 | 62 | |

| Treatment (P = 0.05) | % protein in grain: SE | LSD | lb. N/morgen in grain: SE | LSD |
|---|---|---|---|---|
| A | 0.133 | 0.39 | 1.70 | 5.0 |
| B | 0.231 | 0.68 | 2.95 | 8.6 |
| AB | 0.327 | - | 4.17 | - |

(+) Difference between the amounts of nitrogen gained with and without the application of nitrogen, expressed as a percentage of the amount of nitrogen applied

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was again obtained at Theunissen. At normal espacement the response to nitrogen fertilizer was less pronounced than at dense espacement.

The top-dressings of nitrogen applied to plants with or without the application of nitrogen fertilizer at planting time, were well utilized by the plants, and the response to nitrogen fertilizer was almost entirely determined by the quantity of nitrogen applied, and not by the time of application.

Without an application of nitrogen a much higher grain yield was obtained at normal than at dense espacement. When increasing amounts of nitrogen were applied the densely spaced plants had a more pronounced increase in grain yields than the normally spaced ones. At normal espacement only the grain yield obtained without nitrogen fertilizer and that with a total application of 400 lb. ammonium sulphate per morgen differed significantly. The grain yields obtained with dense and normal espacement were nearly equal at the highest nitrogen level. As an average for all fertilizer treatments, the densely spaced plants yielded slightly less grain than the normally spaced ones.

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The stover yields were nearly equal at dense and normal espacement when no nitrogen fertilizer had been applied. Nitrogen fertilizer applied at increasing rates (200 and 400 lb. ammonium sulphate per morgen) brought about a considerable increase in the stover yields of the densely spaced plants only, but not of the normally spaced ones. The mean stover yield at dense espacement was higher than that at normal espacement.

As an average the stover yields obtained from the treatments with 200 and 600 lb. superphosphate per morgen did not differ much. A slightly higher stover yield with 600 lb. of superphosphate than with 200 lb. seemed to be indicated at normal espacement.

The percentage of protein in the grain was generally low. Compared with the treatments without nitrogen fertilizer, all the applications of nitrogen effected an increase in the protein content of the grain.

At normal espacement the protein content of the grain was higher than at dense espacement.

The/

The quantity of nitrogen contained in the grain was larger with the application of 200 lb. ammonium sulphate than without nitrogen fertilization. With 400 lb. ammonium sulphate per morgen (applied at planting time or divided into 200 lb. applied at planting plus 200 lb. applied on December 30th, 1958) the quantity of grain nitrogen was again increased above that obtained with 200 lb. ammonium sulphate applied either at planting or on December 30th, 1958.

The very late top-dressing of nitrogen (January 14th, 1959) does not seem to have influenced the quantity of grain nitrogen to the same extent as the medium late one (December 30th, 1958), especially if the figures for the dense espacement are considered.

At normal espacement considerably more nitrogen was absorbed by the grain than at dense espacement.

The percentages of nitrogen in the stover samples as well as the quantities of nitrogen contained in the stover and the nitrogen uptake by the herbage were generally low.

A considerable portion of the nitrogen taken up by the plants was absorbed by the grain. The nitrogen contained in the grain, expressed as a percentage of the nitrogen contained in grain plus stover, was higher at normal than at dense espacement.

The percentages of nitrogen in the stover and the quantities of nitrogen contained in stover and in grain plus stover (nitrogen uptake) are not statistically analysed. These figures should be used merely to obtain a general idea of the nitrogen composition of the harvested material and the nitrogen supply which had been available in the soil at Theunissen. The figures were presented in order to interpret the reasons for the different results obtained with the application of nitrogen fertilizer at Glen and Theunissen, that is the good response to nitrogen fertilizer at Theunissen and the lack of any nitrogen reaction at Glen. It is, therefore, interesting that the results of the nitrogen analyses indicated a relatively good nitrogen supply to the plants grown on the soil at Glen (high protein contents of grain and high nitrogen contents of stover as well as a high nitrogen uptake by the plants) and a poor nitrogen supply to the plants grown at Theunissen.

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In contrast to Glen, a high percentage of the nitrogen taken up by the plants was found in the grain at Theunissen. This indicates a good use of the nitrogen taken up by the plants for grain production. The drought had a much stronger effect at Glen than at Theunissen during the period when the grain was being formed and this may have contributed to the poor use of the nitrogen for grain production at Glen only. However, the same maize variety was not planted at Glen and Theunissen during this season and the maize was planted at different dates. In subsequent seasons an effort was made to achieve more comparable results.

Influence of the Nitrogen Supply on the Growth, Nitrogen Uptake and Nitrogen Content of Maize at Successive Growth Stages at Theunissen.

Experimental Dates : The seed of this experiment and the experiment O-Gl. 55 were planted on the same date (19th November, 1958) and the maize of this experiment also failed to germinate after planting. The date when germination started is considered to be December 6th, 1958 on which date a rainfall of 17.8 mm was registered. This date was used instead of the planting date when the growth intensity and the intensity of the nitrogen uptake were calculated for the period ending at the first harvest. After the surplus plants had been removed, nearly 100 per cent of the plant population had started germinating on December 6th, 1958. The particulars of the harvesting dates and the dates of nitrogen fertilizer application as well as the number of plants included in the harvests were as follows :-

| Date | Planting, harvesting and application of nitrogen fertilizer | Number of days from germination | Growth stage | Number of plants harvested |
|---|---|---|---|---|
| 9.11.1958 | Planting and first nitrogen fertilization | - | - | - |
| 0.12.1958 | First harvest and medium late nitrogen fertilization | 24 | 8-11 in. height | 50 |
| 4.1.1959 | Second harvest and late nitrogen fertilization | 39 | Before tasseling stage | 50 |
| 2.2.1959 | Third harvest | 68 | Flowering stage | 30 |
| 2.3.1959 | Fourth harvest | 96 | Soft dough stage | 20 |

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Observations : With the exception of the treatment where 200 lb. of ammonium sulphate per morgen was to be applied 6 - 8 weeks after the planting date, all the treatments of this experiment were also represented in the experiment O-Gl.55. The observations on the plants of corresponding treatments in the two experiments were similar, and the discussion of O-Gl.55 is also valid for this experiment which was situated next to the experimental site of O-Gl.55. A uniform plant population was obtained after the removal of surplus plants. The late top-dressing of nitrogen to the plants without a previous application of nitrogen fertilizer, not represented in the experiment O-Gl.55, showed a clear response by an increased growth and change of the leaf colour from a light to a darker green.

Results : The results are given in Tables 14, 15 and 16 and the contents of each table will be dealt with separately. In Table 14 the dry herbage yields, the percentages nitrate and total nitrogen and the quantity of nitrogen in the herbage as obtained on each harvesting date are presented.

Up to the third harvesting date (68 days after germination, flowering) the herbage yield as well as the nitrogen contained in the plants increased considerably during each of the periods from one harvesting date to the next. Between the third and fourth harvesting dates (96 days after germination, soft dough stage) all the plants still increased in herbage weight while an increase in the quantity of nitrogen contained in the herbage was limited to the treatments with either late application of nitrogen fertilizer or the application of the higher amount of ammonium sulphate (400 lb. per morgen) at planting time.

The nitrate and total nitrogen contents decreased with advancing growth and simultaneously the nitrate nitrogen expressed as a percentage of the total nitrogen. This percentage amounted to 12 per cent on the first and 8 per cent on the second harvesting date. With one exception, the plants were free of nitrates from about the flowering stage (third harvest).

The herbage yields of the first harvest (24 days after germination) were nearly equal for all

treatments./

TABLE 14 : GROWTH AND NITROGEN COMPOSITION OF MAIZE AT SUCCESSIVE GROWTH STAGES AS INFLUENCED BY NITROGEN FERTILIZER TREATMENTS
THEUNISSEN, 1958/59

| Amm.sulph. applied, lb./morgen and date | Dry herbage yield, ton/morgen | | | | Nitrate nitrogen in dry matter, % | | | | Total nitrogen in dry matter, % | | | | Total nitrogen in herbage, lb./morgen | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. |
| 1. None | 0.097 | 0.594 | 2.46 | 3.80 | 0.33 | 0.09 | 0 | 0 | 2.98 | 2.02 | 0.94 | 0.54 | 5.78 | 24.0 | 46.2 | 41.1 |
| 2. 200 : 19 Nov. (planting) | 0.098 | 0.630 | 3.54 | 6.14 | 0.48 | 0.22 | 0 | 0 | 3.26 | 2.40 | 1.12 | 0.64 | 6.38 | 30.2 | 79.0 | 78.9 |
| 3. 200 : 30 Dec. | 0.102 | 0.604 | 2.66 | 5.56 | 0.33 | 0.17 | 0 | 0 | 2.98 | 2.24 | 1.11 | 0.67 | 6.08 | 27.0 | 58.8 | 74.2 |
| 4. 200 : 14 Jan. | 0.102 | 0.577 | 2.61 | 5.69 | 0.27 | 0.10 | 0 | 0 | 2.93 | 2.12 | 1.09 | 0.77 | 5.98 | 24.5 | 56.8 | 87.2 |
| 5. 400 : 19 Nov. | 0.096 | 0.619 | 3.56 | 6.76 | 0.49 | 0.21 | trace | 0 | 3.41 | 2.41 | 1.25 | 0.81 | 6.55 | 29.8 | 89.0 | 109.6 |
| 6. 200 : 19 Nov +200 : 14 Jan. | 0.092 | 0.603 | 3.39 | 6.38 | 0.46 | 0.21 | 0 | 0 | 3.29 | 2.40 | 1.20 | 0.80 | 6.06 | 28.9 | 81.5 | 101.8 |
| Mean | 0.098 | 0.604 | 3.04 | 5.72 | 0.39 | 0.17 | 0 | 0 | 3.13 | 2.27 | 1.13 | 0.72 | 6.14 | 27.4 | 68.6 | 82.1 |
| SE | 0.0427 | 0.0178 | 0.119 | 0.157 | 0.030 | 0.024 | | | 0.0540 | 0.0565 | 0.0398 | 0.0296 | 0.278 | 0.813 | 3.90 | 4.57 |
| LSD (P=0.05) | - | - | 0.36 | 0.47 | 0.09 | 0.07 | | | 0.16 | 0.17 | 0.12 | 0.09 | - | 2.4 | 11.7 | 13.8 |

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INCREASE IN HERBAGE WEIGHTS AND IN THE AMOUNTS OF NITROGEN CONTAINED IN MAIZE DURING SUCCESSIVE GROWTH STAGES AS INFLUENCED BY NITROGEN FERTILIZER TREATMENTS

THEUNISSEN, 1958/59

| Ammonium sulphate in units of 100 lb/morgen (..) and date of application | Increase in dry herbage weight, ton per morgen, corrected to 14 day periods | | | | Increase in nitrogen gain, lb. N per morgen, corrected to 14 day periods | | | |
|---|---|---|---|---|---|---|---|---|
| | Actual duration of periods (no. of days) | | | | Actual duration of periods (no. of days) | | | |
| | I (24) germination to 1st harvest | II (15) 1st to 2nd harvest | III (29) 2nd to 3rd harvest | IV (28) 3rd to 4th harvest | I (24) germination to 1st harvest | II (15) 1st to 2nd harvest | III (29) 2nd to 3rd harvest | IV (28) 3rd to 4th harvest |
| 1. None | 0.057 | 0.46 | 0.90 | 0.67 | 3.4 | 17.0 | 10.7 | - 2.5 |
| 2. (2) 19 Nov., planting | 0.057 | 0.50 | 1.41 | 1.30 | 3.7 | 22.3 | 23.6 | - 0.1 |
| 3. (2) 30 Dec., 1st harvest | 0.059 | 0.47 | 0.99 | 1.45 | 3.6 | 19.5 | 15.4 | 7.7 |
| 4. (2) 14 Jan., 2nd harvest | 0.059 | 0.44 | 0.98 | 1.54 | 3.5 | 17.3 | 15.6 | 15.2 |
| 5. (4) 19 Nov., planting | 0.056 | 0.49 | 1.42 | 1.60 | 3.8 | 21.7 | 28.6 | 10.3 |
| 6. (2) 19 Nov., plus (2) 14 Jan. | 0.054 | 0.48 | 1.34 | 1.49 | 3.5 | 21.3 | 25.4 | 10.1 |
| Mean | 0.057 | 0.47 | 1.17 | 1.34 | 3.6 | 19.8 | 19.9 | 6.8 |
| SE | 0.00249 | 0.0158 | 0.0582 | 0.0945 | 0.162 | 0.765 | 2.00 | 3.15 |
| LSD (P=0.05) | - | - | 0.18 | 0.28 | - | 2.3 | 6.0 | 9.5 |

| "Split plot" analysis including all harvests | Mean : Periods | | Periods within each N-treatm. | | Interaction | |
|---|---|---|---|---|---|---|
| | herbage weight | nitrogen gain | herbage weight | nitrogen gain | herbage weight | nitrogen gain |
| SE | 0.0247 | 0.848 | 0.0604 | 2.08 | 0.0563 | 1.90 |
| LSD (P=0.05) | 0.070 | 2.40 | 0.171 | 5.9 | 0.161 | 5.4 |

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TABLE 16 : INFLUENCE OF NITROGEN FERTILIZER ON THE RELATIVE INCREASE IN WEIGHT AND NITROGEN GAIN AT SUCCESSIVE GROWTH STAGES OF MAIZE
THEUNISSEN, 1958/59

| Amm. sulph. in units of 100 lb/morg. (··) and date of application | Dry herbage yields on 1st, 2nd and 3rd harvesting dates as % of that at fourth harvest | | | | Nitrogen gain on 1st, 2nd and 3rd harvesting dates as % of that at fourth harvest | | | | Increase in dry herbage yield per lb. N applied | | | | Increase in nitrogen per lb. N applied | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th. harvest, 12 Mar. |
| 1. None | 2.55 | 15.6 | 64.7 | 100 | 14.1 | 58.4 | 112.4 | 100 | – | – | – | – | – | – | – | – |
| 2. (2) 19 Nov. (planting) | 1.60 | 10.3 | 57.7 | 100 | 8.1 | 38.3 | 100.1 | 100 | 0.048 | 1.71 | 51.4 | 111.4 | 0.0143 | 0.148 | 0.78 | 0.90 |
| 3. (2) 30 Dec. | 1.83 | 10.9 | 47.8 | 100 | 8.2 | 36.4 | 79.2 | 100 | – | 0.48 | 9.5 | 83.8 | – | 0.071 | 0.30 | 0.79 |
| 4. (2) 14 Jan. | 1.79 | 10.1 | 45.8 | 100 | 6.9 | 28.1 | 65.1 | 100 | – | – | 7.1 | 90.0 | – | – | 0.25 | 1.10 |
| 5. (4) 19 Nov. | 1.42 | 9.2 | 52.6 | 100 | 6.0 | 27.2 | 81.2 | 100 | 0.024 | 0.57 | 26.2 | 64.0 | 0.0092 | 0.069 | 0.51 | 0.82 |
| 6. (2) 19 Nov. + (2) 14 Jan. | 1.44 | 9.5 | 53.1 | 100 | 6.0 | 28.4 | 80.1 | 100 | – | – | 22.1 | 61.4 | – | – | 0.42 | 0.72 |
| Mean | 1.71 | 10.6 | 53.1 | 100 | 7.5 | 33.4 | 83.6 | 100 | – | – | – | 82.1 | – | – | – | 0.87 |

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*TABLE 16 : INFLUENCE OF NITROGEN FERTILIZER ON THE RELATIVE INCREASE IN WEIGHT AND NITROGEN GAIN AT SUCCESSIVE GROWTH STAGES OF MAIZE*

THEUNISSEN, 1958/59

| Amm. sulph. in units of 100 lb/morg. (..) and date of application | Dry herbage yields on 1st, 2nd and 3rd harvesting dates as % of that at fourth harvest | | | | Nitrogen gain on 1st, 2nd and 3rd harvesting dates as % of that at fourth harvest | | | | Increase in dry herbage yield per lb. N applied | | | | Increase in nitrogen per lb. N applied | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th harvest, 12 Mar. | 1st harvest, 30 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 12 Feb. | 4th. harvest, 12 Mar. |
| 1. None | 2.55 | 15.6 | 64.7 | 100 | 14.1 | 58.4 | 112.4 | 100 | - | - | - | - | - | - | - | - |
| 2. (2) 19 Nov. (planting) | 1.60 | 10.3 | 57.7 | 100 | 8.1 | 38.3 | 100.1 | 100 | 0.048 | 1.71 | 51.4 | 111.4 | 0.0143 | 0.148 | 0.78 | 0.90 |
| 3. (2) 30 Dec. | 1.83 | 10.9 | 47.8 | 100 | 8.2 | 36.4 | 79.2 | 100 | - | 0.48 | 9.5 | 83.8 | - | 0.071 | 0.30 | 0.79 |
| 4. (2) 14 Jan. | 1.79 | 10.1 | 45.8 | 100 | 6.9 | 28.1 | 65.1 | 100 | - | - | 7.1 | 90.0 | - | - | 0.25 | 1.10 |
| 5. (4) 19 Nov. | 1.42 | 9.2 | 52.6 | 100 | 6.0 | 27.2 | 81.2 | 100 | 0.024 | 0.57 | 26.2 | 64.0 | 0.0092 | 0.069 | 0.51 | 0.82 |
| 6. (2) 19 Nov. + (2) 14 Jan. | 1.44 | 9.5 | 53.1 | 100 | 6.0 | 28.4 | 80.1 | 100 | - | - | 22.1 | 61.4 | - | - | 0.42 | 0.72 |
| Mean | 1.71 | 10.6 | 53.1 | 100 | 7.5 | 33.4 | 83.6 | 100 | - | - | - | 82.1 | - | - | - | 0.87 |

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treatments. The plants supplied with nitrogen fertilizer had slightly higher nitrate and total nitrogen contents than those not provided with nitrogen. There was no noteworthy difference between the nitrogen uptake by the differently treated plants.

The herbage yields of the second harvest (39 days after germination) also did not show any influence of the fertilizer treatments. Compared with the treatment without nitrogen fertilizer, the nitrate and the total nitrogen contents as well as the nitrogen uptake were higher where nitrogen had been applied either at planting time or 24 days after germination. The application of 400 lb. ammonium sulphate per morgen had caused a higher nitrogen gain than the application of 200 lb. at planting time and this treatment again a higher one than the treatment with the same quantity of nitrogen applied 24 days after germination.

A distinct influence of the treatments on the herbage yields became evident on the third harvesting date (68 days after planting, flowering stage). The application of 200 or 400 lb. ammonium sulphate at planting time or 200 lb. at planting time plus 200 lb. at the time of the second harvest, brought about higher herbage yields than the treatments without an application of nitrogen or those with the application of 200 lb. ammonium sulphate either 24 or 39 days after germination. The herbage yields of the last mentioned three treatments were nearly equally low. The percentages of nitrogen in the plants supplied with nitrogen 24 or 39 days after germination were higher than those of the plants without a dressing of nitrogen. The highest percentage of nitrogen was obtained with the application of 400 lb. of ammonium sulphate. The amounts of nitrogen contained in the plants indicate that the nitrogen applied at planting time had been absorbed to a larger extent up to the flowering stage than the nitrogen applied either 24 or 39 days after germination. The latter effected only a slightly increased nitrogen uptake.

The figures from the fourth harvest (96 days after planting, soft dough stage) reflect a much stronger influence of all the nitrogen treatments on the plant weights than those of the third harvest. The plants supplied with 400 lb. ammonium sulphate per morgen at planting time yielded the highest herbage weight./

weight. Smaller harvest weights were obtained with the application of 200 lb. ammonium sulphate at planting time, with or without additional 200 lb. 39 days after germination. These herbage weights were still higher than those obtained with the late application of 200 lb. of ammonium sulphate to the plants not provided with nitrogen at planting time. In contrast to the nitrogen gain up to the third harvest, the nitrogen gain up to the fourth harvest did not reflect any distinct influence of the time of application, but only an influence of the amount of nitrogen applied. This indicates that, by the soft dough stage, the nitrogen of the top-dressing had been taken up to a similar extent as the nitrogen applied at planting time.

The percentages of nitrogen in the harvested material indicate an influence of both the amount of nitrogen applied and the time of application. The plants supplied with 400 lb. ammonium sulphate, either given in one dressing at planting time or divided into two applications, one at planting and the other 39 days after germination, as well as the plants not provided with nitrogen fertilizer at planting time and supplied with 200 lb. ammonium sulphate 39 days after germination, had relatively high nitrogen contents. Lower percentages of nitrogen were found in the plants which had received 200 lb. of ammonium sulphate either at planting time or 24 days after germination. These percentages of nitrogen were still slightly higher than those obtained where nitrogen fertilizer had not been applied.

Table 15 shows the increase in herbage yields and nitrogen from germination until the first harvesting date and during the periods between each two successive harvesting dates, corrected to equal periods of 14 days. The table demonstrates the growth intensity and the intensity of the nitrogen uptake (herbage) during various growth stages.

As an average the growth intensity was very low during the first period (between germination and 24 days thereafter) and about 8 times as high during the second period (from 24 to 39 days after germination). It still increased from the second to the third (68 days after germination) and from the third to the fourth harvesting dates (96 days after germination).

The intensity of the nitrogen uptake as an average/

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average increased only from the first to the second period, remained the same during the third and decreased during the fourth period.

During the first and second periods the growth intensity did not differ between treatments, while the intensity of the nitrogen uptake was higher with than without the application of nitrogen fertilizer during the second period. It is interesting that an equal intensity of nitrogen uptake occurred with the two nitrogen levels of 200 and 400 lb. ammonium sulphate per morgen both during the first and the second periods. Differences in nitrogen uptake between the plants supplied with these two nitrogen levels occurred only later. An influence of the nitrogen applied 24 days after germination on the intensity of the nitrogen uptake becomes evident in the figures for the second period.

During the third and fourth periods the nitrogen treatments distinctly influenced the growth intensities.

Of special interest are the changes in the intensities of growth and nitrogen uptake for each treatment from the third to the fourth period. During the third period the plants not provided with nitrogen fertilizer had a lower growth intensity than the plants supplied with 200 or 400 lb. ammonium sulphate at planting time and an equal low growth intensity as the plants which received a top-dressing of 200 lb. of ammonium sulphate per morgen 24 or 39 days after germination. The plants not provided with nitrogen fertilizer were the only ones which considerably decreased in growth intensity from the third to the fourth period. The figures for the intensity of nitrogen uptake indicate that these plants did not take up any nitrogen from flowering until the soft dough stage. It can be deduced that the growth during this period was strongly reduced by nitrogen starvation, evidence of which was observed before and during this growth stage. Since no nitrogen was taken up after the flowering stage, the nitrogen absorbed by the cobs for grain formation must have originated exclusively from the stalks and leaves which were poor in nitrogen at that growth stage. It is assumed that the vegetative parts of plants can be depleted of nitrogen only to a certain degree. For the treatment without nitrogen fertilizer a supply of nitrogen insufficient for maximum grain production can be assumed.

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average increased only from the first to the second period, remained the same during the third and decreased during the fourth period.

During the first and second periods the growth intensity did not differ between treatments, while the intensity of the nitrogen uptake was higher with than without the application of nitrogen fertilizer during the second period. It is interesting that an equal intensity of nitrogen uptake occurred with the two nitrogen levels of 200 and 400 lb. ammonium sulphate per morgen both during the first and the second periods. Differences in nitrogen uptake between the plants supplied with these two nitrogen levels occurred only later. An influence of the nitrogen applied 24 days after germination on the intensity of the nitrogen uptake becomes evident in the figures for the second period.

During the third and fourth periods the nitrogen treatments distinctly influenced the growth intensities.

Of special interest are the changes in the intensities of growth and nitrogen uptake for each treatment from the third to the fourth period. During the third period the plants not provided with nitrogen fertilizer had a lower growth intensity than the plants supplied with 200 or 400 lb. ammonium sulphate at planting time and an equal low growth intensity as the plants which received a top-dressing of 200 lb. of ammonium sulphate per morgen 24 or 39 days after germination. The plants not provided with nitrogen fertilizer were the only ones which considerably decreased in growth intensity from the third to the fourth period. The figures for the intensity of nitrogen uptake indicate that these plants did not take up any nitrogen from flowering until the soft dough stage. It can be deduced that the growth during this period was strongly reduced by nitrogen starvation, evidence of which was observed before and during this growth stage. Since no nitrogen was taken up after the flowering stage, the nitrogen absorbed by the cobs for grain formation must have originated exclusively from the stalks and leaves which were poor in nitrogen at that growth stage. It is assumed that the vegetative parts of plants can be depleted of nitrogen only to a certain degree. For the treatment without nitrogen fertilizer a supply of nitrogen insufficient for maximum grain production can be assumed.

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The plants supplied with 200 lb. ammonium sulphate at planting time had similar growth intensities during the third and fourth periods. All the nitrogen had been taken up before and during the flowering stage (second and third periods) and no increase in nitrogen was obtained during the fourth period. The growth intensity does not seem to have been decreased by nitrogen deficiency during the last period.

The treatments with a top-dressing of 200 lb. of ammonium sulphate 24 or 39 days after germination represent a case where the growth intensity was relatively low on account of nitrogen shortage during the periods before the tasseling and flowering stages and increased considerably during the period ending with the soft dough stage. On account of a dry period the nitrogen applied 24 days after germination was not taken up shortly after having been applied. The considerable increase in the growth intensity during the late growth stage is remarkable. The general trend experienced with all treatments, that the amounts of nitrogen in the plants increased in advance of the production of plant material, was very pronounced in the treatments with top-dressings of nitrogen. An increased intensity of the nitrogen uptake following the application of nitrogen 24 days after germination became evident during the second period and, following the application of nitrogen 39 days after germination, during the third period. An influence of this nitrogen fertilizer on the growth intensity was observed only during the fourth period. The intensity of nitrogen uptake during the fourth period was higher with the late top-dressing of nitrogen (39 days after germination) than with the medium late one (24 days after germination).

The results from these two treatments (top-dressing of nitrogen to plants not provided with nitrogen fertilizer at planting time) appear to be of special importance when a limited quantity of nitrogen is made available to the plants without the danger of nitrogen deficiency at the important flowering and ripening stages. These conditions of nitrogen deficiency can be induced by a strong vegetative growth during early growth stages in moist seasons and can occur in spite of the application of nitrogen fertilizer at planting time (Theunissen, 1957/58). Nitrogenous top-

dressings/

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dressings may ensure that a favourable nitrogen status of the plants is maintained during the period when the grain is being built up.

The two treatments with 400 lb. ammonium sulphate per morgen applied at planting time and with 400 lb. divided into two applications of 200 lb., one at planting time and the other 39 days after germination, gave similar results. The growth intensity which was already high during the third period did not increase to any noteworthy extent from the third to the fourth period. The intensity of nitrogen uptake reached its highest peak during the third period and was lower during the fourth period.

In contrast to the observations of the previous season (Theunissen, 1957/58), a good nitrogen supply was ensured during all the growth stages by the application of 400 lb. of ammonium sulphate at planting time.

In Table 16 the herbage yields and nitrogen gain of the herbage of each treatment, as determined on each of the first three harvesting dates, are given as percentages of those on the fourth harvesting date. In addition, the increase in herbage yields and in nitrogen, effected by nitrogen fertilizer and calculated per lb. of nitrogen applied, is also presented in Table 16.

The herbage yields and the amounts of nitrogen contained in the plants on the first three harvesting dates, expressed as percentages of the corresponding figures at the fourth harvest, again indicate to what extent the nitrogen uptake preceded the production of plant material. On the second harvesting date, for example, the plants not provided with nitrogen fertilizer had reached 15.6 per cent of the final weight and 58.4 per cent of the final amount of nitrogen taken up. With the application of nitrogen fertilizer, and especially in the cases where top-dressings had been applied, a relatively higher nitrogen uptake and a higher growth intensity became evident during the advanced growth stages.

The figures for the increase in the nitrogen uptake, effected by nitrogen fertilizer and calculated per lb. N applied, give the percentage of fertilizer nitrogen taken up by the plants when multiplied by 100. According to these figures, as an average 87 per cent of the nitrogen applied was absorbed by the plants. Since the utilization of fertilizer nitrogen was assessed by comparing/

comparing the quantities of nitrogen applied with the differences between the quantities of nitrogen taken up with and without the application of nitrogen fertilizer, these figures can be too high and may not reflect the true position. The possibility exists that the plants supplied with nitrogen fertilizer made better use of the soil nitrogen than the plants not provided with nitrogen fertilizer. The latter plants were, especially during the last growth period, much smaller than those supplied with nitrogen and had lost some of the lower leaves at the time of the last harvest. Apart from nitrogen lost with the leaves, a lower growth intensity and weaker development of the roots could also have contributed to the relatively low nitrogen uptake obtained with this treatment.

When the uptake of fertilizer nitrogen by the plants of corresponding treatments of this experiment and the experiment O.Gl.55 are compared, it becomes evident that the fertilizer nitrogen was taken up to a lesser degree in the experiment O.Gl.55 than in this experiment. It must, however, be kept in mind that the harvested material from the stooked plants of experiment O.Gl.55 was gathered in June while the plants of this experiment were oven dried shortly after having been cut. Apart from mechanical losses, as for example loss of leaves through wind, the stover of the plants of experiment O.Gl.55 may have undergone changes through fungi and bacteria during the period of drying. In spite of these reasons for the diverging results, the suspicion may arise that also another methodological shortcoming was involved. It is possible that the border effect which arose from the harvests at successive growth stages was not fully excluded by making provision for one border row either side of the border between the sub-plots established for harvesting at successive dates. The roots of the plants which stood next to the border rows could have reached the soil under the area of the previous harvest and found a relatively good moisture supply on account of lack of vegetation and, where nitrogen had been applied, also additional nitrogen.

The increase in herbage weight per lb. of nitrogen applied was smaller with the application of 400 lb. than with that of 200 lb. ammonium sulphate per morgen, and with the late application of 200 lb. ammonium sulphate slightly lower than with the early one.

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To obtain an indication of the influence of the treatments on the grain yield, the cobs harvested at the fourth harvest were removed from the plants and weighed. The grain of plants in the different treatments had shown no differences in the degree of ripeness. All the grain was in the late soft dough stage. The weight of dry clean cobs differed considerably. It was low where nitrogen fertilizer had not been applied (0.64 ton per morgen), considerably higher with the application of 200 lb. ammonium sulphate per morgen at planting time, 24 or 39 days after germination or with 200 lb. applied at planting time plus 200 lb. 39 days after germination (between 1.46 and 1.65 tons per morgen) and highest with the application of 400 lb. of ammonium sulphate at planting time (2.08 tons).

The results of this experiment indicate that nitrogen fertilizer may be applied to maize up to a fairly late growth stage (in the experiment shortly before the tasseling stage when a nitrogen shortage was indicated by a light leaf colour). The nitrogen applied as a top-dressing effected a high nitrogen uptake during advanced growth stages and increased the growth intensity at a very late growth stage (the flowering stage and thereafter). Compared with the plants not provided with nitrogen fertilizer, the plant and cob weights were increased by the top-dressings and the application of nitrogen fertilizer at planting time to a similar extent.

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## 1959/60 Season.

An effort was made to achieve a good comparability between esults obtained at Theunissen and Glen during the 1959/60 eason. The planting dates of the experiments O.Gl.54, Gl.55 and the experiment on the influence of nitrogen ertilizer on the growth, nitrogen uptake and nitrogen content of maize at successive growth stages were chosen as ear to each other as circumstances allowed. In order to ompare the growth and nitrogen uptake of the plants at en and Theunissen during successive growth periods, plant amples were also taken at successive growth stages from two eatments of O.Gl.54 which were similar to two treatments of he experiment with successive harvesting dates at Theunissen. le influence of the time of planting, spacing and nitrogen ertilization on maize production was during this season investigated for the first time at Glen. The maize variety P x K 64 was planted in all experiments.

Spacing and Fertilizer Requirement of Maize at Glen (O.Gl.54).

Experimental Dates : The maize was planted on November 17th, 1959 and harvested on May 2nd, 1960.

Observations : In spite of a high precipitation during December, a few rainless days towards the end of the month caused the leaves of the densely spaced plants to wilt. Rain on December 30th and 31st brought about a complete recovery for a few days. During the following period drouht damage occurred and large parts of most leaves became dry. The leaves of the normally spaced plants wilted during the period from the beginning of February until towards the end of this month when the drought was broken. These plants recovered to a certain extent after the rain had fallen and no necrosis was observed.

The heavily damaged densely spaced plants also showed signs of recovery towards the end of February and thereafter. The improved moisture conditions led to renewed development with the formation of new inflorescences. The result was that different stages of ear development were obtained during the second half of March. Aside from plants without cobs and with one cob the grain of which had reached the hard dough stage, there were also plants which had developed a second ear which did not yield any grain. This renewed development of inflorescences was not observed among the normally spaced plants. At no stage was any fertilizer effect perceived.

Results : The grain and stover yields are given in Table 17. In Table 18 the results of nitrogen analyses of the harvested material from the treatments with narrow and normal espacement, without nitrogen fertilizer and with the two nitrogen levels, with the higher phosphate level and without potassium fertilizer are presented.

As in previous seasons at Glen, only the espacements had a strong influence on the results. The various fertilizer treatments did not influence either grain or stover yields. The grain yield obtained at dense espacement was exceedingly low, while a reasonable grain yield was obtained at normal espacement if the periods of drought are taken into consideration. The stover yield was higher at dense than at normal espacement.

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TABLE 17: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS GLEN, 1959/60

| Fertilizer applied, lb./morgen | Grain yield, bags per morgen (12.5% moisture) | | | Stover yield, ton per morgen (air dry) | | |
|---|---|---|---|---|---|---|
| | A. Espacement | | | | | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean |
| B. Ammonium sulphate | | | | | | |
| $b_0$ none | 2.28 | 8.40 | 5.34 | 3.53 | 2.96 | 3.24 |
| $b_1$ 200 | 1.72 | 8.12 | 4.92 | 3.73 | 2.88 | 3.31 |
| $b_2$ 400 | 1.66 | 8.13 | 4.90 | 3.50 | 2.91 | 3.20 |
| C. Superphosphate | | | | | | |
| $c_0$ 200 | 1.82 | 8.79 | 5.30 | 3.60 | 2.90 | 3.25 |
| $c_1$ 400 | 1.95 | 7.65 | 4.80 | 3.58 | 2.94 | 3.26 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 2.03 | 7.92 | 5.00 | 3.55 | 2.92 | 3.24 |
| $d_1$ 100 | 1.70 | 8.52 | 5.11 | 3.62 | 2.91 | 3.26 |
| Mean | 1.89 | 8.22 | 5.05 | 3.59 | 2.92 | 3.25 |

| | B. Ammonium sulphate, lb./morgen | | | | | |
|---|---|---|---|---|---|---|
| C. Superphosphate | $b_0$ none | $b_1$ 200 | $b_2$ 400 | $b_0$ none | $b_1$ 200 | $b_2$ 400 |
| $c_0$ 200 | 5.51 | 5.21 | 5.19 | 3.26 | 3.33 | 3.15 |
| $c_1$ 400 | 5.17 | 4.68 | 4.60 | 3.23 | 3.29 | 3.26 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 5.01 | 4.78 | 5.20 | 3.22 | 3.33 | 3.16 |
| $d_1$ 100 | 5.67 | 5.06 | 4.59 | 3.27 | 3.28 | 3.25 |

| | C. Superphosphate, lb./morgen | | | |
|---|---|---|---|---|
| D. Potassium chloride | $c_0$ 200 | $c_1$ 400 | $c_0$ 200 | $c_1$ 400 |
| $d_0$ none | 5.27 | 4.72 | 3.20 | 3.27 |
| $d_1$ 100 | 5.34 | 4.83 | 3.28 | 3.25 |

| Treatment | SE | LSD (+) | SE | LSD (+) |
|---|---|---|---|---|
| A | 0.280 | 0.80 | 0.0444 | 0.13 |
| B | 0.342 | - | 0.0544 | - |
| C | 0.280 | - | 0.0444 | - |
| D | 0.280 | - | 0.0444 | - |
| AB | 0.484 | - | 0.0770 | - |
| AC | 0.395 | - | 0.0628 | - |
| AD | 0.395 | - | 0.0628 | - |
| BC | 0.484 | - | 0.0770 | - |
| BD | 0.484 | - | 0.0770 | - |
| CD | 0.395 | - | 0.0628 | - |

(+) P = 0.05

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TABLE 18: NITROGEN COMPOSITION OF THE HARVESTED MATERIAL AND AMOUNTS OF NITROGEN GAINED BY MAIZE AS INFLUENCED BY SPACING AND NITROGEN FERTILIZER TREATMENTS
GLEN, 1959/60

| A. Spacing<br>B. Ammonium sulphate applied, lb./morgen | % prot. in dry grain | % N in dry stover | lb. N per morgen contained in: grain | stover | total | grain as % of total | Utilization of N applied, % (+) |
|---|---|---|---|---|---|---|---|
| $a_0$ 3 ft. x 12 in. | | | | | | | |
| $b_0$ none | 11.8 | 1.45 | 6.8 | 66.3 | 73.1 | 9.3 | - |
| $b_1$ 200 | 11.9 | 1.65 | 7.1 | 86.0 | 93.1 | 7.6 | 48 |
| $b_2$ 400 | 11.8 | 1.65 | 7.9 | 80.0 | 87.9 | 9.0 | 18 |
| Mean ($a_0$) | 11.8 | 1.58 | 7.3 | 77.4 | 84.7 | 8.6 | - |
| $a_1$ 3 ft. x 24 in. | | | | | | | |
| $b_0$ none | 11.2 | 1.45 | 23.6 | 59.8 | 83.4 | 28.3 | - |
| $b_1$ 200 | 11.4 | 1.49 | 21.4 | 59.0 | 80.4 | 26.6 | 0 |
| $b_2$ 400 | 11.4 | 1.50 | 23.4 | 60.9 | 84.3 | 27.8 | 1 |
| Mean ($a_1$) | 11.3 | 1.48 | 22.8 | 59.9 | 82.7 | 27.6 | 0 |
| Mean values (B) | | | | | | | |
| $b_0$ none | 11.5 | 1.45 | 15.2 | 63.0 | 78.2 | 19.4 | - |
| $b_1$ 200 | 11.6 | 1.57 | 14.3 | 72.5 | 86.8 | 16.5 | 20 |
| $b_2$ 400 | 11.6 | 1.58 | 15.6 | 70.5 | 86.1 | 18.1 | 9 |
| Mean | 11.6 | 1.53 | 15.0 | 68.7 | 83.7 | 17.9 | 14 |

| Treatment (P=0.05) | % prot. in grain: SE | LSD | lb.N/morgen in grain: SE | LSD | stover: SE | LSD | total: SE | LSD |
|---|---|---|---|---|---|---|---|---|
| A | 0.187 | - | 1.72 | 5.4 | 2.62 | 8.3 | 2.46 | - |
| B | 0.229 | - | 2.10 | - | 3.21 | - | 3.01 | - |
| AB | 0.323 | - | 2.97 | - | 4.55 | - | 4.26 | - |

(+) Difference between the amounts of nitrogen gained with and without the application of nitrogen, expressed as a percentage of the amount of nitrogen applied

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The percentages of protein in the grain and nitrogen in the stover were high with all treatments. The quantities of nitrogen contained in the stover and in grain plus stover were also generally relatively high. The nitrogen treatments had not influenced the protein content of the grain and the nitrogen uptake to any noteworthy extent.

The amounts of nitrogen contained in grain plus stover were similar at dense and normal espacement. The densely spaced plants contained considerably less nitrogen in the grain and considerably more in the stover than the normally spaced ones. Accordingly, the grain nitrogen, expressed as a percentage of the nitrogen contained in grain plus stover, was much higher at normal than at dense espacement.

The degree of utilization of fertilizer nitrogen by the plants (difference between nitrogen gain with and without application of nitrogen fertilizer as a percentage of the amount of nitrogen applied) varied considerably. At dense espacement a better utilization of the fertilizer nitrogen seemed to be indicated than at normal espacement. The results of the nitrogen analyses indicate than the soil at Glen was rich in available nitrogen.

<u>Spacing and Fertilizer Requirement of Maize at Theunissen. (O.Gl.55).</u>

<u>Experimental Dates</u> : The maize was planted on November 19th, 1959 and harvested on May 9th, 1960.

<u>Observations</u> : A very uniform plant population was obtained after planting. Pronouncedly dry conditions during January adversely affected the densely spaced plants. Initially the leaves of these plants wilted during the warm hours of the day only. Later permanent-wilting occurred and the plants remained relatively small. In contrast to the experiment O.Gl.54 at Glen, no premature drying of the leaves was observed at any stage at Theunissen. No interaction between fertilizer treatments and degree of drought damage became evident. Apart from occasional wilting, the normally spaced plants survived the dry periods without visible damage.

Towards the end of the growth period, cooler conditions and rain caused a certain recovery of the densely spaced plants. A renewed development was observed in these plants only, presumably because the development/

development of the normally spaced plants was more advanced since it had not been retarded to the same extent by drought. This resulted in different degrees of ripeness of the densely spaced plants towards the end of March. Apart from plants which had formed no grain, there were plants with grain in the soft dough stage, the hard dough stage and with fully ripened grain. Only one cob was formed per plant. The grain of the normally spaced plants was completely ripe.

The reaction of the plants to the nitrogen treatments was far smaller than in previous seasons at Theunissen. Before tasseling the densely spaced plants had a lighter leaf colour than the normally spaced ones. The nitrogen applied had increased the colour intensity. Compared with the plants supplied with the lower phosphate level, the higher phosphate level resulted in a slightly improved growth. The differences caused by the fertilizer treatments disappeared to a large extent during the dry periods.

Results : The grain and stover yields are given in Table 19 and the results of nitrogen analyses of the harvested material from the treatments with narrow and normal espacement, six of the seven nitrogen treatments and the treatment with the higher phosphate level are presented in Table 20.

During this season with sub-normal precipitation and pronouncedly dry conditions during the most important growth periods, a strong spacing effect, only a limited nitrogen effect and, compared with the lower phosphate level, no responses to the higher phosphate level were obtained. The normal espacement yielded on an average 8 bags more grain and 0.6 ton less stover than the dense espacement.

Only the plants supplied with 400 lb. ammonium sulphate per morgen, i.e. those provided with 400 lb. at planting time as well as those with 200 lb. at planting time plus 200 lb. 32 days later, yielded more grain than the plants not supplied with nitrogen fertilizer. Although the interaction spacing by nitrogen treatments did not fully reach the level of significance, the differences between the grain yields obtained with the nitrogen treatments in combination with each of the espacements indicate that the application of

nitrogen/

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TABLE 19: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS
THEUNISSEN, 1959/60

| B. Amm. sulph. in units of 100 lb. per morgen (..) and date of application | Grain, bags per morgen (12.5% moisture) | | | | |
|---|---|---|---|---|---|
| | A. Espacement | | | C. Superphosphate lb./morgen | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean (B) | $c_0$ 200 | $c_1$ 600 |
| $b_0$ None | 9.7 | 16.7 | 13.2 | 13.1 | 13.4 |
| $b_1$ (2)19.11 | 9.6 | 20.5 | 15.0 | 15.2 | 14.8 |
| $b_2$ (1)19.11+(1)21.12 | 12.0 | 17.8 | 14.9 | 14.8 | 15.0 |
| $b_3$ (2)21.12 | 9.3 | 17.7 | 13.5 | 13.2 | 13.8 |
| $b_4$ (4)19.11 | 11.4 | 22.0 | 16.7 | 18.0 | 15.4 |
| $b_5$ (2)19.11+(2)21.12 | 12.9 | 18.5 | 15.7 | 15.6 | 15.8 |
| $b_6$ (2)19.11+(2)14.1 | 10.8 | 18.1 | 14.4 | 14.8 | 14.1 |
| Mean (A and C) | 10.3 | 18.8 | 14.8 | 15.0 | 14.6 |
| C. Superphosphate lb./morgen | | | Treatment | SE | LSD(+) |
| | | | A | 0.410 | 1.2 |
| | | | B | 0.767 | 2.2 |
| $c_0$ 200 | 11.1 | 18.8 | C | 0.410 | - |
| $c_1$ 600 | 10.5 | 18.7 | AB | 1.09 | 3.1 |
| | | | AC | 0.580 | - |
| | | | BC | 1.09 | - |

| B. Amm. sulph. in units of 100 lb. per morgen (..) and date of application | Stover, ton per morgen (air dry) | | | | |
|---|---|---|---|---|---|
| | A. Espacement | | | C. Superphosphate lb./morgen | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean (B) | $c_0$ 200 | $c_1$ 600 |
| $b_0$ none | 2.57 | 2.30 | 2.44 | 2.40 | 2.47 |
| $b_1$ (2)19.11 | 2.86 | 2.34 | 2.60 | 2.62 | 2.59 |
| $b_2$ (1)19.11+(1)21.12 | 2.86 | 2.22 | 2.54 | 2.50 | 2.59 |
| $b_3$ (2)21.12 | 2.75 | 2.22 | 2.48 | 2.48 | 2.49 |
| $b_4$ (4)19.11 | 3.00 | 2.38 | 2.69 | 2.64 | 2.74 |
| $b_5$ (2)19.11+(2)21.12 | 2.95 | 2.26 | 2.60 | 2.60 | 2.60 |
| $b_6$ (2)19.11+(2)14.1 | 2.95 | 2.11 | 2.53 | 2.50 | 2.56 |
| Mean (A and C) | 2.85 | 2.26 | 2.55 | 2.53 | 2.58 |
| C. Superphosphate lb./morgen | | | Treatment | SE | LSD(+) |
| | | | A | 0.0223 | 0.06 |
| | | | B | 0.0418 | 0.12 |
| $c_0$ 200 | 2.83 | 2.24 | C | 0.0223 | - |
| $c_1$ 600 | 2.87 | 2.28 | AB | 0.0591 | 0.17 |
| | | | AC | 0.0316 | - |
| | | | BC | 0.0591 | - |

(+) P=0.05

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TABLE 20: NITROGEN COMPOSITION OF THE HARVESTED MATERIAL AND AMOUNTS OF NITROGEN GAINED BY MAIZE AS INFLUENCED BY SPACING AND NITROGEN FERTILIZER TREATMENTS
THEUNISSEN, 1959/60

| A. Spacing<br>B. Ammonium sulphate applied, lb./morgen and date | % prot. in dry grain | % N in dry stover | lb. N per morgen contained in: grain | sto-ver | to-tal | grain as % of total | Utilization of N applied, % (+) |
|---|---|---|---|---|---|---|---|
| $a_0$ 3 ft. x 12 in. | | | | | | | |
| $b_0$ none | 6.33 | 0.44 | 18.2 | 19.1 | 37.3 | 48.8 | - |
| $b_1$ 200 : 19.11 | 7.98 | 0.49 | 19.8 | 23.3 | 43.1 | 45.9 | 13.8 |
| $b_2$ 200 : 21.12 | 8.12 | 0.52 | 20.3 | 23.1 | 43.4 | 46.8 | 14.5 |
| $b_3$ 400 : 19.11 | 8.29 | 0.62 | 24.3 | 31.4 | 55.7 | 43.6 | 21.9 |
| $b_4$ 200 : 19.11 + 200 : 21.12 | 7.44 | 0.60 | 28.3 | 29.1 | 57.4 | 49.3 | 23.9 |
| $b_5$ 200 : 19.11 + 200 : 14.1 | 8.71 | 0.65 | 23.9 | 32.3 | 56.2 | 42.5 | 22.5 |
| Mean ($a_0$) | 7.81 | 0.55 | 22.5 | 26.4 | 48.8 | 46.1 | 19.3 |
| $a_1$ 3 ft. x 24 in. | | | | | | | |
| $b_0$ none | 6.31 | 0.31 | 29.2 | 13.0 | 42.2 | 69.2 | - |
| $b_1$ 200 : 19.11 | 7.33 | 0.43 | 42.0 | 18.0 | 60.0 | 70.0 | 42.4 |
| $b_2$ 200 : 21.12 | 7.40 | 0.39 | 38.5 | 16.2 | 54.7 | 70.4 | 29.8 |
| $b_3$ 400 : 19.11 | 8.33 | 0.49 | 46.9 | 21.5 | 68.4 | 68.6 | 31.2 |
| $b_4$ 200 : 19.11 + 200 : 21.12 | 7.31 | 0.45 | 36.7 | 18.7 | 55.4 | 66.2 | 15.7 |
| $b_5$ 200 : 19.11 + 200 : 14.1 | 7.17 | 0.46 | 36.8 | 17.7 | 54.5 | 67.5 | 14.6 |
| Mean ($a_1$) | 7.31 | 0.42 | 38.4 | 17.5 | 55.9 | 68.7 | 26.7 |
| Mean values (B) | | | | | | | |
| $b_0$ none | 6.32 | 0.38 | 23.7 | 16.0 | 39.7 | 59.7 | - |
| $b_1$ 200 : 19.11 | 7.66 | 0.46 | 30.9 | 20.6 | 51.5 | 60.0 | 28.1 |
| $b_2$ 200 : 21.12 | 7.76 | 0.46 | 29.4 | 19.6 | 49.0 | 60.0 | 22.1 |
| $b_3$ 400 : 19.11 | 8.31 | 0.56 | 35.6 | 26.4 | 62.0 | 57.4 | 26.5 |
| $b_4$ 200 : 19.11 + 200 : 21.12 | 7.38 | 0.52 | 32.5 | 23.9 | 56.4 | 57.6 | 19.9 |
| $b_5$ 200 : 19.11 + 200 : 14.1 | 7.94 | 0.56 | 30.4 | 25.0 | 55.4 | 54.9 | 18.7 |
| Mean | 7.56 | 0.49 | 30.4 | 21.9 | 52.3 | 58.1 | 23.1 |

| Treatment (P = 0.05) | % prot. in grain SE | % prot. in grain LSD | lb. N/morgen in grain SE | grain LSD | stover SE | stover LSD | total SE | total LSD |
|---|---|---|---|---|---|---|---|---|
| A | 0.131 | 0.38 | 1.27 | 3.7 | 0.254 | 0.7 | 1.35 | 4.0 |
| B | 0.266 | 0.66 | 2.20 | 6.5 | 0.441 | 1.3 | 2.35 | 6.9 |
| AB | 0.320 | - | 3.12 | - | 0.623 | 1.8 | 3.32 | 9.7 |

(+) Difference between the amounts of nitrogen gained with and without the application of nitrogen, expressed as a percentage of the amount of nitrogen applied

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nitrogen fertilizer was followed by increased yields in the case of normal espacement only. It also becomes evident that the nitrogen applied later than at planting time did not or only negligibly influence grain yields. This may be explained by the lack of rain after the top-dressings had been applied. The nitrogen of top-dressings could not be washed into the soil immediately. Presumably there were also no active roots in the dry surface soil. The only appreciable increase in stover yields was caused by nitrogen applied at planting time.

The percentages of protein in the grain and nitrogen in the stover as well as the amounts of nitrogen taken up by the plants were generally low.

The protein content of the grain was slightly higher at dense than at normal espacement of the plants. It was increased by increasing amounts of nitrogen fertilizer applied at planting time.

The grain of the plants which had received a top-dressing of nitrogen only, had a considerably higher protein content than the grain of plants not supplied with nitrogen. In this case, the top-dressing failed to increase the yield, but nevertheless increased the protein content of the grain. This may indicate that the nitrogen of the top-dressing was taken up at a relatively late growth stage.

If the mean quantities of nitrogen contained in the grain and stover of the normally and densely spaced plants are compared, the normally spaced plants contained considerably more nitrogen in the grain, considerably less in the stover and slightly more in grain plus stover. Accordingly, the grain nitrogen as a percentage of the nitrogen contained in the herbage, was higher at normal than at dense espacement. The nitrogen taken up by the plants was used to a larger extent for grain formation by the normally spaced plants than by the densely spaced ones.

Except where nitrogen was applied as top-dressing only, the nitrogen treatments effected an increase in the quantity of grain nitrogen. The amounts of nitrogen contained in the stover and in grain plus stover were increased by all dressings of nitrogen fertilizer. The increase was more pronounced at dense espacement if the stover nitrogen is considered and at normal

espacement/

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espacement if the total nitrogen in the herbage is taken into consideration. The quantities of nitrogen contained in the stover of the densely spaced plants indicate an influence of the amounts of nitrogen fertilizer applied, independently of the time of application. The normally spaced plants, on the other hand, contained more nitrogen in the stover when 400 lb. ammonium sulphate per morgen had been applied at planting time than with either divided application of 400 lb. or application of 200 lb. either at planting time or 32 days thereafter. The latter quantities of stover nitrogen were again higher than that obtained when nitrogen fertilizer had not been applied. The clear effect of the nitrogen level obtained independently of the time of application, which is reflected in the figures for the nitrogen contained in the stover of densely spaced plants only, may be explained by the observation that the development of the densely spaced plants was less advanced than that of the normally spaced ones towards the end of the season. The renewed growth and development of the densely spaced plants only may have allowed a relatively good use of the nitrogen applied as a top-dressing, which became available after the moisture conditions had improved.

These relations also find an expression in the differences between the amounts of nitrogen taken up with and without application of nitrogen fertilizer, expressed as percentages of the amounts of nitrogen applied. At dense espacement, equal total amounts of nitrogen were taken up by the plants whether nitrogen had been applied at planting, as a single top-dressing, or divided into two applications. In contrast to the densely spaced plants, the normally spaced ones took up a larger portion of the nitrogen applied at planting time than of that applied as a top-dressing. Nevertheless, a generally higher degree of utilization of fertilizer nitrogen at normal than at dense espacement became evident. This may be attributed to generally better growth conditions of the normally spaced plants.

The utilization of the nitrogen taken up by the plants for grain production was not noticeably influenced by either the amount of nitrogen applied or the time of application. Only the espacement showed a marked influence on the grain nitrogen expressed as a percentage of the nitrogen in grain and stover. This might

indicate/

indicate that the nitrogen treatments did not markedly influence the readiness with which the nitrogenous compounds were translocated to the grain. As it is assumed that the moisture supply has a strong influence on the translocation of nitrogenous compounds to the grain, the more or less equal use of the nitrogen taken up by the plants for grain production in all nitrogen treatments may indicate that the fertilizer nitrogen did not influence the degree of drought damage suffered by the plants. This concurs with the observation that no relationship could be noticed between fertilizer treatments and drought resistance.

Comparison of Results from Corresponding Treatments at Glen (O.Gl.54) and Theunissen (O.Gl.55).

A comparison of the results obtained at Glen and Theunissen gives information on the nitrogen status of the soils of the experimental sites and explains the different results obtained with the application of nitrogen fertilizer during the previous seasons. It must, however, be pointed out that the experimental conditions at Glen and Theunissen were not exactly the same. The nitrogen treatments compared were nitrogen not applied, 200 lb. of ammonium sulphate applied at planting time and 200 lb. applied at planting time plus 200 lb. 3 to 4 weeks after planting, mentioned as treatment $b_2$ = 400 lb. ammonium sulphate in O.Gl.54. The planting dates, espacements and varieties corresponded in the two experiments. The nitrogen analyses were conducted on material of the treatments with the higher phosphate level and without an application of potassium fertilizer. The phosphate supply to the plants of these treatments may be regarded as optimal on both sites. The main difference is that the experimental site remained unchanged at Glen and was changed annually at Theunissen. Nitrogen fertilizer had been applied to the same plots at Glen for the third season and at Theunissen for the first time during the 1959/60 season. The treatment without an application of nitrogen fertilizer corresponded at Glen and Theunissen. Since nitrogen fertilizer brought a clear response at Theunissen only, the difference between the treatments with the application of nitrogen is of very slight importance in the comparison.

The results compared are those presented in Tables 17, 18, 19 and 20 (following p. 56 and 58). In spite/

spite of a higher rainfall, the maize suffered much more from drought at Glen than at Theunissen. The grain yields obtained at Glen (mean for dense espacement 1.9 bags and mean for normal espacement 8.2 bags per morgen) were accordingly much lower than those obtained at Theunissen (mean for the yields of the corresponding nitrogen treatments : 10.7 bags at dense and 18.6 bags at normal espacement). The stover yields were slightly higher at Glen (3.6 tons at dense and 2.9 tons at normal espacement) than at Theunissen (2.8 tons at dense and 2.3 tons at normal espacement). If the yields of dry grain plus dry stover are calculated for both Glen and Theunissen, the total yield was at both places higher at normal than at dense espacement and at Theunissen higher than that at Glen. It is difficult to decide whether the mechanical composition of the Glen soil was responsible for the comparatively low drought resistance or whether a high nutrient supply might be regarded as a reason for the rapid moisture depletion. Compared with Theunissen, more vigorous vegetative growth during the growth stages before tasseling was observed at Glen during the previous seasons.

The grain and stover yields at Glen were not significantly influenced by the nitrogen fertilizer applied, while at Theunissen the mean grain yield was raised from 13.2 bags (without nitrogen fertilizer) to 15.7 bags by the application of 200 lb. ammonium sulphate at planting time plus 200 lb. 32 days later.

The nitrogen analyses disclosed fundamental differences in the nitrogen composition of the harvested material. At Glen the average percentage of protein in the grain was 11.8 at dense and 11.3 at normal espacement. The corresponding percentages at Theunissen were 7.2 for dense and 7.0 for normal espacement. The difference was particularly distinct when nitrogen had not been applied (6.3 per cent protein at Theunissen and 11.5 per cent at Glen). The application of nitrogen fertilizer raised the protein content of the grain at Theunissen only (6.3% without nitrogen fertilizer and 7.7 and 7.4 with the two nitrogen levels).

The nitrogen contents of the stover differed still more than the protein contents of the grain. The stover from the plants not provided with nitrogen fertilizer contained 1.45% N at Glen and 0.38% N at Theunissen. At

Glen/

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Glen 63 lb. N and at Theunissen only 16 lb. N were returned to the soil with the stover of the maize which had not been supplied with nitrogen fertilizer. As a result of higher grain yields, and in spite of a lower percentage of protein in the grain, the amounts of grain nitrogen were larger at Theunissen (without nitrogen fertilizer and with the applications of 42 and 84 lb. N per morgen, 23.7, 30.9 and 32.5 lb. N per morgen, respectively) than at Glen (15.2, 14.3 and 15.6 lb. N per morgen, respectively). The amounts of nitrogen taken up by the plants were much higher at Glen (78 lb. N without nitrogen fertilizer, 87 lb. N with 42 lb. and 86 lb. N with 84 lb. of fertilizer nitrogen applied per morgen) than at Theunissen (40, 52 and 56 lb. N with the corresponding fertilizer treatments).

All these results indicate a considerably higher supply of nitrogen to the plants at Glen than at Theunissen. Distinct effects of nitrogen fertilizer on the nitrogen contents of the harvested material and the nitrogen uptake of the plants were limited to the Theunissen experimental area. It is possible that the nitrogen supply available in the Glen soil was so high that the comparatively small amounts of nitrogen applied could not bring about a marked growth response under the conditions where the utilization of soil and fertilizer nitrogen was limited on account of drought.

The question arises whether the difference between the nitrogen supply available in the soils at Glen and Theunissen can be attributed to the soil types only or whether it was caused by the different periods the soils had been cultivated. This question will be discussed later.

<u>Influence of the Nitrogen Supply on the Growth, Nitrogen Uptake and Nitrogen Content of Maize at Successive Growth Stages at Theunissen and Glen.</u>

<u>Experimental Dates</u> : The maize at Theunissen was planted on November 20th, 1959. The samples at Glen were taken from the plots of the experiment O.Gl.54 (date of planting, November 17th, 1959). The interval between the two planting dates was only three days. In order to attain a good comparability between the results at Theunissen and Glen, an effort was made to arrange the sampling at each harvesting stage three

days/

days later at Theunissen than at Glen. Small deviations were, however, unavoidable on account of rain on proposed dates of harvesting. The times of harvesting and of the application of nitrogen fertilizer as well as the number of plants included in the harvests are given below.

| Number of days from planting date: Theun. | Glen | Planting, harvesting and application of nitrogen fertilizer | Growth stage at Theunissen (T) and Glen (G) | Number of plants harvested: Theun. | Glen |
|---|---|---|---|---|---|
| 0 | 0 | Planting, first nitrogen fertilization | - | - | - |
| 31 | 31 | First harvest, medium late nitrogen fertilization at Theunissen | 10-12 in. height 6-8 leaves (T) 12-15 in. height 8 leaves (G) | 40 | 10 |
| 55 | 56 | Second harvest, late nitrogen fertilization at Theunissen | 27-30 in. height (T) 36-39 in. height (G), before tasseling | 30 | 10 |
| 83 | 83 | Third harvest | Late flowering-initial soft dough stage | 30 | 10 |
| 119 | 115 | Fourth harvest | Half ripe and fully ripe (T) late flowering and fully ripe (G) | 20 | 10 |

The sampling at Glen was limited to two treatments, the one without nitrogen fertilizer and the other with the application of 200 lb. ammonium sulphate per morgen at planting time. All the sampled plots had been provided with 400 lb. superphosphate per morgen annually. Potassium fertilizer was not applied. The results from these two treatments at Glen were compared with those from the two corresponding treatments at Theunissen.

An optimal phosphate supply could be assumed on both sites. Therefore, a full comparability was given for the treatments without nitrogen fertilizer. The treatment with a dressing of nitrogen at Glen differed from that at Theunissen in that the 200 lb. ammonium sulphate had been applied to the same plots for the third season at Glen, while it was applied for the first time at Theunissen. This was, however, considered/

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considered to be of minor importance since the plants at Glen generally failed to respond to nitrogen fertilizer.

Observations : The observations on the plants of the Theunissen site agreed with those on the plants of the corresponding treatments of experiment O.Gl.55 at Theunissen, which have been described before. The growth of the plants of the two treatments of the experiment O.Gl.54 at Glen, which were included in the comparison, has also been described. The observations at Glen and Theunissen will, therefore, only be briefly compared.

The December rainfall was slightly above normal at Theunissen and relatively high at Glen. Optimal soil moisture conditions can be assumed from planting until the first harvest (31 days later). The plants at Glen grew more vigorously than those at Theunissen.

During the period between the first and second harvests (from 31 to 55 or 56 days after planting) drought adversely affected the plants. At Glen, the generally stronger plants had obviously depleted the moisture supply of the soil rapidly, and a few days without rain caused wilting. At Theunissen, the plants wilted temporarily during the warm hours of the day towards the end of this period.

Further drought, experienced during the period between the second and third harvests (from 55/56 to 83 days after planting), was followed by drying of large parts of most leaves at Glen and, in spite of considerably less rain, by only serious wilting without necrosis at Theunissen. Differences in the soil were reflected in unequal degrees of wilting of the plant population at Theunissen.

During the period between the third and fourth harvests ending 115 days after planting at Glen and 119 days after planting at Theunissen, a certain degree of recovery of the drought damaged plants was observed on both experimental sites. This led to varying degrees of ripeness of the grain at each site as described for the experiments O.Gl.54 and 55.

Results : As the plants sustained heavy drought damage at a fairly early growth stage, no material contribution to the solution of the primary problem to be investigated in this experiment could be expected. Nevertheless, the results were evaluated in the same way as those of

the/

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the previous season, in order to examine the influence of the nitrogen treatments under the abnormally dry conditions of this season. The results are presented in five Tables, 21 to 25, and each table will be dealt with separately.

In Table 21 the dry herbage yields, the percentages nitrate and total nitrogen and the amounts of nitrogen taken up by the plants are given as obtained on each harvesting date at "Excelsior", Theunissen.

The plant weights from all treatments were similar at the first harvest (31 days after the planting date). The plants supplied with ammonium sulphate contained more nitrate and total nitrogen per unit of dry matter and per morgen than those not supplied with nitrogen. An increase in the percentage and amount of nitrogen due to the increase in the fertilizer rate from 200 to 400 lb. ammonium sulphate per morgen is also indicated. The nitrate nitrogen as a percentage of the total nitrogen averaged 8 per cent and was higher with than without the application of nitrogen fertilizer (with 400 lb. ammonium sulphate per morgen 13 per cent, with 200 lb. 8 - 9 per cent, and without nitrogen fertilizer 4 - 6 per cent). Obviously, a considerable amount of the nitrogen fertilizer had been nitrified in the soil before being taken up by the plants.

The plants harvested on the second harvesting date (55 days after the planting date) had suffered from drought. The herbage yield was slightly higher when nitrogen had been applied at planting time than when nitrogen had not been applied. The nitrate and total nitrogen contents of the differently treated plants did not differ to any noteworthy extent. As an average only 2 per cent of the total nitrogen was in the nitrate form. Compared with the plants not supplied with nitrogen fertilizer, more nitrogen was taken up where nitrogen had been applied at planting time. No distinct increase due either to the higher amount of nitrogen applied or to the late application of the smaller amount became evident.

The plants harvested on the third harvesting date (83 days after the planting date) had sustained heavy drought damage. The herbage weights, the percentages of nitrogen in the plant material and the amounts of nitrogen in the plants did not indicate any significant

treatment/

TABLE 21 : GROWTH AND NITROGEN COMPOSITION OF MAIZE AT SUCCESSIVE GROWTH STAGES AS INFLUENCED BY NITROGEN FERTILIZER TREATMENTS
THEUNISSEN, 1959/60

| Amm.sulph. applied, lb./morgen and date | Dry herbage yield, ton/morgen | | | | Nitrate nitrogen in dry matter, % | | | | Total nitrogen in dry matter, % | | | | Total nitrogen in herbage, lb./morgen | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st harvest, 21 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 11 Feb. | 4th harvest, 18 Mar. | 1st harvest, 21 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 11 Feb. | 4th harvest, 18 Mar. | 1st harvest, 21 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 11 Feb. | 4th harvest, 18 Mar. | 1st harvest, 21 Dec. | 2nd harvest, 14 Jan. | 3rd harvest, 11 Feb. | 4th harvest, 18 Mar. |
| 1. None | 0.150 | 1.10 | 2.50 | 3.73 | 0.13 | 0.027 | 0 | 0 | 2.32 | 1.70 | 0.76 | 0.67 | 6.95 | 37.4 | 38.0 | 49.8 |
| 2. 200 : 20 Nov. (Planting) | 0.142 | 1.27 | 2.67 | 3.66 | 0.24 | 0.051 | trace | 0 | 2.81 | 1.74 | 0.87 | 0.83 | 7.97 | 44.3 | 46.7 | 61.0 |
| 3. 200 : 21 Dec. | 0.142 | 1.22 | 2.80 | 3.78 | 0.08 | 0.016 | 0 | 0 | 2.28 | 1.60 | 0.84 | 0.80 | 6.48 | 39.0 | 46.8 | 60.4 |
| 4. 200 : 14 Jan. | 0.150 | 1.06 | 2.74 | 3.40 | 0.13 | 0.019 | trace | 0 | 2.21 | 1.64 | 0.79 | 0.76 | 6.62 | 34.7 | 43.5 | 51.6 |
| 5. 400 : 20 Nov. | 0.152 | 1.38 | 2.99 | 3.68 | 0.36 | 0.054 | 0 | 0 | 2.85 | 1.74 | 0.88 | 0.88 | 8.67 | 47.9 | 52.8 | 64.4 |
| 6. 200 : 20 Nov. +200 : 14 Jan. | 0.141 | 1.24 | 2.87 | 3.71 | 0.21 | 0.020 | trace | 0 | 2.60 | 1.85 | 0.88 | 0.88 | 7.34 | 45.9 | 50.6 | 65.1 |
| Mean | 0.146 | 1.21 | 2.76 | 3.66 | 0.19 | 0.033 | | 0 | 2.51 | 1.71 | 0.84 | 0.80 | 7.34 | 41.5 | 46.4 | 58.7 |
| SE | 0.0107 | 0.0585 | 0.142 | 0.192 | 0.0386 | 0.0200 | | | 0.077 | 0.080 | 0.061 | 0.058 | 0.458 | 2.16 | 3.17 | 3.04 |
| LSD (P=0.05) | - | 0.18 | - | - | 0.12 | - | - | - | 0.23 | - | - | - | 1.38 | 6.5 | - | 9.2 |

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TABLE 22 : INCREASE IN HERBAGE WEIGHTS AND IN THE AMOUNTS OF NITROGEN CONTAINED IN MAIZE DURING SUCCESSIVE GROWTH STAGES AS INFLUENCED BY NITROGEN FERTILIZER TREATMENTS

THEUNISSEN, 1959/60

| Ammonium sulphate in units of 100 lb/morgen (..) and date of application | Increase in dry herbage weight, ton per morgen, corrected to 14 day periods | | | | Increase in nitrogen gain, lb. N per morgen, corrected to 14 day periods | | | |
|---|---|---|---|---|---|---|---|---|
| | Actual duration of periods (no.of days) | | | | Actual duration of periods (no.of days) | | | |
| | I (31) planting to 1st harvest | II (24) 1st to 2nd harvest | III (28) 2nd to 3rd harvest | IV (36) 3rd to 4th harvest | I (31) planting to 1st harvest | II (24) 1st to 2nd harvest | III (28) 2nd to 3rd harvest | IV (36) 3rd to 4th harvest |
| 1. None | 0.068 | 0.55 | 0.70 | 0.48 | 3.1 | 17.8 | 0.3 | 4.6 |
| 2. (2) 20 Nov., planting | 0.064 | 0.66 | 0.70 | 0.39 | 3.6 | 21.2 | 1.2 | 5.6 |
| 3. (2) 21 Dec., 1st harvest | 0.064 | 0.63 | 0.79 | 0.38 | 2.9 | 19.0 | 3.9 | 5.3 |
| 4. (2) 14 Jan., 2nd harvest | 0.068 | 0.53 | 0.84 | 0.26 | 3.0 | 16.4 | 4.4 | 3.2 |
| 5. (4) 20 Nov., planting | 0.069 | 0.72 | 0.80 | 0.27 | 3.9 | 22.9 | 2.5 | 4.5 |
| 6. (2) 20 Nov., plus (2) 14 Jan. | 0.064 | 0.64 | 0.81 | 0.33 | 3.3 | 22.5 | 2.3 | 5.6 |
| Mean | 0.066 | 0.62 | 0.77 | 0.35 | 3.3 | 20.0 | 2.4 | 4.8 |
| SE | 0.00480 | 0.0298 | 0.0518 | 0.0843 | 0.207 | 1.16 | 1.43 | 1.17 |
| LSD (P=0.05) | - | 0.09 | - | - | 0.6 | 3.5 | - | - |

| "Split plot" analysis including all harvests | Mean: Periods | | Periods within each N-treatm. | | Interaction | |
|---|---|---|---|---|---|---|
| | herbage weight | nitrogen gain | herbage weight | nitrogen gain | herbage weight | nitrogen gain |
| SE | 0.0221 | 0.482 | 0.0540 | 1.18 | 0.0510 | 1.08 |
| LSD (P=0.05) | 0.064 | 1.4 | 0.153 | 3.3 | - | - |

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TABLE 24 : INFLUENCE OF NITROGEN FERTILIZER APPLIED AT TWO EXPERIMENTAL SITES ON THE GROWTH AND NITROGEN COMPOSITION OF MAIZE AT SUCCESSIVE GROWTH STAGES
THEUNISSEN AND GLEN, 1959/60

| Exp. site and amm. sulph. applied at planting, lb./morgen | Dry herbage weight, ton/morgen | | | | Nitrate nitrogen in dry matter, % | | | | Total nitrogen in dry matter, % | | | | Total nitrogen in herbage, lb/morgen | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harvest and number of days from planting to harvesting dates at Theunissen (T) and Glen (G) +) | | | | | | | | | | | | | | | |
| | 1st T&G: 31 | 2nd T:55 G:56 | 3rd T&G: 83 | 4th T:119 G:115 | 1st T&G: 31 | 2nd T:55 G:56 | 3rd T&G: 83 | 4th T:119 G:115 | 1st T&G: 31 | 2nd T:55 G:56 | 3rd T&G: 83 | 4th T:119 G:115 | 1st T&G: 31 | 2nd T:55 G:56 | 3rd T&G: 83 | 4th T:119 G:115 |
| THEUNISSEN: | | | | | | | | | | | | | | | | |
| 1. None | 0.150 | 1.10 | 2.50 | 3.73 | 0.13 | 0.027 | 0 | 0 | 2.32 | 1.70 | 0.76 | 0.67 | 6.95 | 37.4 | 38.0 | 49.8 |
| 2. 200 | 0.142 | 1.27 | 2.67 | 3.66 | 0.24 | 0.051 | trace | 0 | 2.81 | 1.74 | 0.87 | 0.83 | 7.97 | 44.3 | 46.7 | 61.0 |
| GLEN: | | | | | | | | | | | | | | | | |
| 3. None | 0.230 | 1.75 | 2.47 | 3.31 | 0.37 | 0.126 | 0.16 | 0.8 | 2.76 | 1.98 | 1.64 | 1.46 | 12.7 | 69.4 | 81.2 | 96.7 |
| 4. 200 | 0.236 | 1.87 | 2.41 | 3.26 | 0.54 | 0.275 | 0.23 | 0.25 | 3.03 | 2.18 | 1.73 | 1.61 | 14.3 | 81.7 | 83.6 | 104.9 |
| Mean | 0.190 | 1.50 | 2.51 | 3.49 | 0.35 | 0.140 | | | 2.76 | 1.94 | 1.24 | 1.12 | 10.5 | 58.2 | 62.4 | 78.1 |
| LSD (P=0.05) to compare 1 or 2 (4 replic.) with 3 or 4 (3 replic.) | 0.031 | 0.19 | n.s. | n.s. | 0.18 | 0.080 | - | - | 0.31 | 0.30 | 0.21 | 0.19 | 1.0 | 8.8 | 9.0 | 9.7 |
| 3 with 4 | 0.033 | 0.21 | n.s. | n.s. | 0.19 | 0.086 | n.s. | 0.16 | 0.33 | 0.32 | 0.22 | 0.20 | 1.1 | 9.2 | 9.6 | 10.3 |
| (n.s.= not significant) | | | | | | | | | | | | | | | | |

+) It was not always possible to harvest after the same number of days from planting at Theunissen and Glen. The second harvest was taken one day later at Glen and the fourth harvest four days later at Theunissen. The influence of the greater deviation of 4 days on the results was negligible on account of the low growth intensity at the advanced growth stage.

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TABLE 25: INFLUENCE OF NITROGEN FERTILIZER APPLIED AT TWO EXPERIMENTAL SITES ON THE INCREASE IN HERBAGE WEIGHTS AND IN THE AMOUNTS OF NITROGEN CONTAINED IN MAIZE PLANTS DURING SUCCESSIVE GROWTH STAGES THEUNISSEN AND GLEN, 1959/60

| Exp. site and amm. sulph. applied at planting, lb./morgen | Increase in dry herbage weight, ton per morgen, corrected to 14 day periods | | | | Increase in nitrogen gain, lb. N per morgen, corrected to 14 day periods | | | |
|---|---|---|---|---|---|---|---|---|
| | Periods and actual duration of periods (number of days) at Theunissen (T) and Glen (G) | | | | | | | |
| | I (T & G : 31) planting to 1st harvest | II (T : 24) (G : 25) 1st to 2nd harvest | III (T : 28) (G : 27) 2nd to 3rd harvest | IV (T : 36) (G : 32) 3rd to 4th harvest | I (T & G : 31) planting to 1st harvest | II (T : 24) (G : 25) 1st to 2nd harvest | III (T : 28) (G : 27) 2nd to 3rd harvest | IV (T : 36) (G : 32) 3rd to 4th harvest |
| **THEUNISSEN:** | | | | | | | | |
| 1. none | 0.068 | 0.55 | 0.70 | 0.48 | 3.1 | 17.8 | 0.3 | 4.6 |
| 2. 200 | 0.064 | 0.66 | 0.70 | 0.39 | 3.6 | 21.2 | 1.2 | 5.6 |
| **GLEN:** | | | | | | | | |
| 3. none | 0.104 | 0.85 | 0.37 | 0.37 | 5.7 | 31.8 | 6.1 | 6.8 |
| 4. 200 | 0.107 | 0.92 | 0.28 | 0.37 | 6.5 | 37.7 | 1.0 | 9.3 |
| Mean | 0.086 | 0.74 | 0.51 | 0.40 | 4.7 | 27.1 | 2.2 | 6.6 |
| LSD (P = 0.05) to compare 1 or 2 (4 replic.) with 3 or 4 (3 replic.) | 0.014 | 0.10 | 0.23 | n.s. | 0.46 | 5.0 | n.s. | 2.1 |
| 3 with 4 | 0.015 | 0.11 | 0.24 | n.s. | 0.49 | 5.3 | n.s. | 2.2 |

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treatment effect. Only traces of nitrate nitrogen were found in the material of some of these plants.

During the period between the third and fourth harvesting dates (from 83 to 119 days after the planting date) the plants recovered a little from the heavy drought damage.

The herbage weights obtained from the fourth harvest were similar for all treatments. The percentages of nitrogen in the plant material did not differ to any noteworthy extent. The material of all plants was free from nitrates. The plants supplied with nitrogen fertilizer at either planting time or 31 days thereafter had taken up more nitrogen than the plants supplied with nitrogen 55 days after planting or those not supplied with nitrogen fertilizer. The reappearance of the treatment effect on the amount of nitrogen contained in the plants at the fourth harvest (it had disappeared from the second to the third harvest), may be explained by improved soil moisture conditions during the period between the third and fourth harvests. However, the nitrogen applied 55 days after the planting date had obviously remained inefficient. It is possible that the results were influenced by a difference in level between the active root zone and most of the fertilizer nitrogen. Early in the season there was enough rain to wash the ammonium sulphate into the soil, and the small plants having a relatively shallow root system could readily take up the nitrogen from the moist surface soil. The surface soil dried out during the periods of extended drought, and the active root zone presumably went deeper with advancing growth. The amount of rain which would be necessary to wash nitrogen down to the active root zone after a dry period, would have to increase with advancing growth. Only little rain was recorded after the late top-dressing of nitrogen. This could explain why most of the nitrogen applied 55 days after planting was not taken up, in spite of slightly improved soil moisture conditions during a late stage of plant development.

Table 22 shows the increase in herbage yields and in the amounts of nitrogen in the plants from planting until the first harvesting date and during the periods between each two successive harvesting dates, corrected to equal periods of 14 days at "Excelsior", Theunissen. As an average for all treatments, the highest growth

intensity/

intensity was recorded for the period between the second and third harvests (from 55 to 83 days after planting, i.e. from before tasseling until the late flowering stage). The growth intensity was not much lower during the preceding period (from 31 to 55 days after planting), but considerably lower during the period that followed (from 83 to 119 days after planting). It was very low during the period from planting up to the first harvest.

By far the highest intensity of nitrogen uptake was recorded during the period between the first and second harvests. Only small and not widely differing amounts of nitrogen were taken up during the other three periods. The highest growth intensity during the period starting before tasseling (second harvest) and ending at the late flowering stage (third harvest) coincided with the lowest intensity of nitrogen uptake, if the means for all treatments are considered. This again indicates that the nitrogen uptake preceded the production of plant material. The exceptionally low intensity of nitrogen uptake during the period between the second and third harvesting dates indicates a retarding influence of the drought on the nitrogen uptake. A slightly improved moisture supply during the last period (from late flowering up to the stage of full ripeness) brought about a higher average nitrogen uptake than that obtained during the preceding period.

The figures for the first period (from planting up to the first harvest) may be misleading as the time taken by the seed to germinate was included in this period. The figures calculated for the second period show an influence of the fertilizer treatments on the growth intensity and those for the first and second periods, on the intensity of nitrogen uptake. As from the second harvest no marked differences were obtained between the intensities of growth and nitrogen uptake if the results from the different treatments are compared within each period. The nitrogen applied later than at planting affected neither the growth intensity nor the intensity of nitrogen uptake.

In Table 23 the herbage yields and the amounts of nitrogen contained in the plants of each treatment, as determined on each of the first three harvesting dates, are given as percentages of those on the fourth harvesting date. In addition, the increase in herbage yields and/

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and in nitrogen uptake, as affected by the application of nitrogen fertilizer and calculated per lb. of nitrogen applied, are also presented in Table 23.

The figures in the first part of this table again indicate to what extent the nitrogen uptake preceded the production of plant material. As an average for all treatments, e.g. only 33.1 per cent of the final weight (fourth harvest) was reached on the second harvesting date, while the amount of nitrogen taken up amounted to 70.7 per cent of the final one. Generally, a higher percentage of the final weight was reached on the dates of the second and third harvests when nitrogen fertilizer had been applied at planting time than when nitrogen fertilizer had not been applied. On the second harvesting date, relatively higher percentages of the final nitrogen uptake were found both without a dressing of nitrogen and with nitrogen applied at planting time than with top-dressings of nitrogen. On the third harvesting date, the percentages indicate a relatively delayed nitrogen uptake when the nitrogen had been applied as a top-dressing. It must be borne in mind that these figures, expressed as percentages, are to a certain extent independent of the absolute figures.

The second part of Table 22 demonstrates the increase in herbage yields and in the amounts of nitrogen due to equal amounts of fertilizer nitrogen. The figures for the increase in the amounts of nitrogen, caused by fertilizer nitrogen and calculated in lb. N per lb. of nitrogen applied, could indicate the percentage of fertilizer nitrogen utilized by the plants, if multiplied by 100. This, however, is based on the assumption that the plants supplied with nitrogen fertilizer and those not supplied with nitrogen took up equal amounts of nitrogen originating from the soil. The results obtained from the corresponding experiment during the previous season (p.47) led to the suspicion that this assumption is not always correct. Therefore, these figures must be interpreted cautiously, although the possible methodological shortcoming of an insufficient elimination of border effects, arising from harvesting at different growth stages, was eliminated as far as possible. The figures indicate a weak growth response and poor utilization of the nitrogen applied to the plants.

In Table 24 the dry herbage yields, the percentages nitrate/

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nitrate and total nitrogen in the plant material and the amounts of nitrogen contained in the plants from two corresponding treatments at "Excelsior", Theunissen and at Glen are presented.

Most striking is the considerably higher herbage yield at Glen than at Theunissen at the time of the first harvest. Since optimal soil moisture conditions for the young plants can be assumed on both sites, it can be taken for granted that the soil at Glen allowed a better growth than the soil at Theunissen. This agrees with the observations made during several seasons. Although the higher herbage yields at Glen were accompanied by higher total nitrogen and nitrate nitrogen contents as well as a higher nitrogen uptake, the better growth is not attributed to a superior nitrogen supply in the Glen soil. All the previous results at Theunissen and Glen had shown that the nitrogen supply does not affect herbage yields at very early growth stages. Some unknown fertility factor must be responsible for the different growth at Theunissen and Glen. On the other hand, the more vigorous growth at Glen might have been directly responsible for the higher sensitivity to drought, since a more rapid depletion of the soil moisture supply might have resulted from the more vigorous growth. In spite of a higher rainfall, the plants at Glen suffered more from drought than the plants at Theunissen during the period that followed the first harvest. On the second harvesting date the differences between the results at Glen and Theunissen were similar to, but less pronounced than those on the first harvesting date. During the period between the first and second harvesting dates the nitrate nitrogen contents decreased more rapidly at Theunissen than at Glen.

On the third and fourth harvesting dates, the herbage weights obtained at Glen and Theunissen did not differ appreciably. The plant material at Glen contained nitrate nitrogen during the entire growth period. Except for traces of nitrate in the plants of one treatment at the third harvest, the plants at Theunissen were free from nitrate nitrogen on the third and fourth harvesting dates. The percentages of total nitrogen also show a considerable influence of the experimental site. The difference between the nitrogen contents of the material harvested at Glen and Theunissen was much larger at the time of the third and

fourth/

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fourth harvests than at the first and second harvests. The nitrogen uptake of the plants up to the third and fourth harvests was also much higher at Glen than at Theunissen.

Table 25 presents the increase in herbage yields and in the quantities of nitrogen taken up from germination until the first harvesting date and during the periods between successive harvesting dates, corrected to periods of 14 days.

The higher growth intensity during the early growth stages recorded at Glen is clearly shown by the figures for the first and second periods. The differences between the growth intensities at Glen and Theunissen were smaller during the second period than during the first. From the second to the third period the growth intensity did not change noticeably at Theunissen, but decreased sharply at Glen, with the result that it was much lower at Glen than at Theunissen during the third period. This result may be explained by the phenomenon that the plants at Glen suffered earlier and more heavily from drought than those at Theunissen. From the third to the fourth period the growth intensity decreased at Theunissen and remained nearly constant at Glen, so that similar growth intensities were obtained during the fourth period on both sites.

The figures for the intensity of nitrogen uptake reveal the same tendencies as mentioned when the previous table was discussed, namely a high intensity during the second period only, with a higher nitrogen uptake at Glen than at Theunissen, a sharp decrease towards the third period and a slight recovery during the fourth period caused by improved moisture conditions.

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Time of Planting, Spacing and Nitrogen Fertilizer Requirement of Maize at Glen (O.Gl.74).

Experimental Dates : The early maize was planted on October 24th, 1959 and the late maize on December 3rd, 1959. The harvesting dates were March 17th, 1960 for the early planted maize, and May 2nd, 1960 for the late planted maize. The harvested material of all treatments was gathered on June 16th, 1960. It was suspected that the moisture content of the stover was not uniform on account of the different planting dates. Therefore, the moisture content of the stover was determined and the stover weights were calculated on a dry weight basis.

Observations : When the early maize was planted the soil moisture content was insufficient for a good germination and a number of seeds failed to germinate. It was initially believed that the germination of these seeds was retarded and the replacement was, therefore, arranged only on November 11th, 1959. Adjacent to the planting hills where the seed had germinated after the first planting on October 24th, there were thus a number of planting hills where the seed had germinated after the date of replacement, 16 days after the regular planting date.

A uniform plant population was obtained on the plots with late planting (December 3rd). The early planted maize grew vigorously, as adequate moisture was available until the second half of December. Towards the end of this month, about 50 per cent of the plants had reached the tasseling stage. All the plants had a dark green colour and no nitrogen reaction was observed.

Towards the end of December, the early planted and densely spaced (3 ft. x 12 in.) maize wilted after a few days without rain. Later these plants were heavily damaged by drought and large parts of most leaves dried up. The normally spaced (3 ft. x 24 in.) and, especially the widely spaced (3 ft. x 36 in.) maize of the early planting, withstood the drought for a considerably longer period but also wilted slightly towards the middle of January.

According to observations, the normally and especially the widely spaced plants tillered more than the densely spaced ones and thereby lost the advantage of the wider espacement with regard to drought resistance.

The plants of the late planting grew vigorously during January. At normal as well as at wide espacement the tasseling stage was reached early in February. During the second half of January wilting occurred only at dense espacement. Thereafter the densely spaced plants were heavily damaged by drought. The leaves dried up partially and the plants remained smaller than those of the wider espacements. The drought also retarded the development of the densely spaced plants. The result was that towards the end of March some of the ears had reached the soft dough stage, others only the late flowering stage. In contrast, the grain of the wider spaced plants was in the hard dough stage at that time. On the borders between plots with early and late planted maize, a strong border effect occurred. The plants of the late planting, growing in border rows next to plots with early maize, failed to grow higher than about 1 ft. to 1 ft. 6 in. The leaves remained strongly rolled inward during an extended period but did not become necrotic. After good rain during the second half of February, the retarded plants immediately developed inflorescences and formed ears. The impression was obtained that young plants can endure heavy drought much better than older plants without being damaged. In the case of young plants, only the vegetative growth seemed to have been retarded.

The maize was infected with Ustilago maydis. The infection was practically limited to the heavily drought stricken, densely spaced plants.

With planting at different times, the question arises whether the rate of development is influenced by the time of planting. To answer this question, the number of days from planting until the beginning of tasseling was estimated for the normally spaced early and late planted maize of this experiment and for the maize of the experiment O.Gl.54, which had the same variety and grew on plots adjacent to those of this experiment. With the planting dates October 24th, November 17th and December 3rd, 1959, the period from planting until the beginning of tasseling varied between 59 and 62 days. No influence of the time of planting on the rate of development until tasseling became evident.

Results : The grain and stover yields are presented in Table 26. In order to determine the influence of the treatments on the tillering of the plants, the number of tillers higher than 15 in. was determined during the flowering stage. The results are also given in Table 26.

The grain yields of the early planted maize (October 24th, 1959) were very low, while those of the late planted maize (December 3rd, 1959) were appreciably higher. There was a considerable variation in grain yields. The main reason for this is considered to be drought during the growth season. It has always been found that drought increases the variation in grain yields. The plot size harvested was also rather small. The plot shape proved unfavourable for this experiment where allowance had to be made for a strong border effect. The transformed grain yields indicate a significant/

TABLE 26: INFLUENCE OF PLANTING DATE, SPACING AND THE APPLICATION OF NITROGEN FERTILIZER ON GRAIN AND STOVER YIELDS AND ON THE TILLERING OF MAIZE

GLEN, 1959/60

| A. Planting date<br>B. Distance of plants within 3 ft. rows<br>C. N applied, lb./morgen | | Grain (12.5 % moisture), bags per morg. (x) | log 10x +) | Stover (dry) ton per morgen | Plants (1) without (2) with one, (3) with > one tiller higher than 15 in., % (1) | (2) | (3) | No. of stems plus tillers higher than 15 in. per plant | per morgen |
|---|---|---|---|---|---|---|---|---|---|
| $a_0$ 24 Oct. | $b_0$ 12 in. | 1.3 | 1.12 | 1.95 | 89 | 7 | 4 | 1.17 | 35,003 |
| | $b_1$ 24 in. | 1.8 | 1.22 | 1.93 | 35 | 29 | 36 | 2.02 | 30,226 |
| | $b_2$ 36 in. | 3.7 | 1.55 | 1.80 | 24 | 25 | 51 | 2.37 | 23,669 |
| | Mean | 2.3 | 1.30 | 1.89 | 49 | 20 | 30 | 1.85 | 29,643 |
| $a_1$ 3 Dec. | $b_1$ 12 in. | 11.5 | 2.04 | 3.29 | 95 | 3 | 2 | 1.08 | 32,303 |
| | $b_2$ 24 in. | 15.1 | 2.17 | 2.78 | 49 | 27 | 24 | 1.75 | 26,260 |
| | $b_3$ 36 in. | 13.2 | 2.11 | 2.12 | 29 | 27 | 44 | 2.19 | 21,874 |
| | Mean | 13.3 | 2.11 | 2.73 | 58 | 19 | 23 | 1.67 | 26,812 |
| $b_0$ 12 in. | $c_0$ 0 | 7.0 | 1.60 | 2.68 | 92 | 5 | 3 | 1.13 | 33,853 |
| | $c_1$ 63 | 5.8 | 1.58 | 2.56 | 92 | 6 | 2 | 1.12 | 33,453 |
| | Mean | 6.4 | 1.59 | 2.62 | 92 | 5 | 3 | 1.12 | 33,653 |
| $b_1$ 24 in. | $c_0$ 0 | 8.4 | 1.70 | 2.31 | 42 | 28 | 30 | 1.89 | 28,394 |
| | $c_1$ 63 | 8.6 | 1.70 | 2.39 | 43 | 28 | 29 | 1.87 | 28,093 |
| | Mean | 8.5 | 1.70 | 2.35 | 42 | 28 | 30 | 1.88 | 28,243 |
| $b_2$ 36 in. | $c_0$ 0 | 9.0 | 1.86 | 1.93 | 27 | 28 | 45 | 2.26 | 22,578 |
| | $c_1$ 63 | 7.9 | 1.80 | 1.98 | 26 | 24 | 49 | 2.30 | 22,994 |
| | Mean | 8.4 | 1.83 | 1.96 | 26 | 26 | 47 | 2.28 | 22,786 |
| $c_0$ 0 | $a_0$ 24 Oct. | 2.5 | 1.31 | 1.88 | 51 | 21 | 28 | 1.82 | 22,080 |
| | $a_1$ 3 Dec. | 13.7 | 2.12 | 2.74 | 56 | 20 | 24 | 1.70 | 27,469 |
| | Mean | 8.1 | 1.72 | 2.31 | 54 | 20 | 26 | 1.76 | 28,275 |
| $c_1$ 63 | $a_0$ 24 Oct. | 2.1 | 1.29 | 1.90 | 49 | 19 | 32 | 1.88 | 30,205 |
| | $a_1$ 3 Dec. | 12.8 | 2.09 | 2.72 | 59 | 19 | 22 | 1.64 | 26,155 |
| | Mean | 7.4 | 1.69 | 2.31 | 54 | 19 | 27 | 1.76 | 28,180 |
| Mean | | 7.8 | 1.70 | 2.31 | 54 | 20 | 27 | 1.76 | 28,227 |

| Treatments | A | B | C | AB | AC | BC |
|---|---|---|---|---|---|---|
| SE, grain (+) | 0.0344 | 0.0421 | 0.0344 | 0.0596 | 0.0486 | 0.0596 |
| LSD (P=0.05) | 0.10 | 0.12 | - | 0.17 | - | - |
| SE, stover | 0.0353 | 0.0433 | 0.0353 | 0.0612 | 0.0499 | 0.0612 |
| LSD (P=0.05) | 0.10 | 0.13 | - | 0.18 | - | - |

+) In the case of grain yields the analysis of variance was carried out on transformed data. Indications were that logarithmic transformation was most appropriate. The SE and LSD for grain yields apply to the transformed data.

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significant interaction between dates of planting and espacements. With early planting the treatment with 10,000 plants per morgen yielded slightly more grain than the treatments with 15,000 or 30,000 plants per morgen. The differences were, however, small and it is obvious that the wide espacement could eliminate the adverse effect of a poor moisture supply to the early planted maize to only a slight extent. The grain yields obtained from the densely, normally and widely spaced plants of the late planting did not differ to an appreciable extent.

Similar grain and stover yields were obtained whether or not nitrogen fertilizer had been applied. The stover yields of the late planted maize were generally higher than those of the early planted maize. The condition of the stover from the plants of the two planting dates was not the same when the weights and moisture contents were determined (June 16th, 1960). The stover of the early planted maize had a darker colour and was more brittle. A larger loss of weight by decomposition during the longer period the early maize was left stooked, is regarded as possible.

The three espacements in combination with early planting gave similar stover weights. From the late planted maize the smallest stover weight was obtained in combination with the wide espacement, a higher one in combination with the normal and the highest in combination with the dense espacement.

It was contrary to expectation that the grain yield obtained from the widely spaced maize of the early planting was very poor and not appreciably higher than that from the early planted and normally or densely spaced maize. It had been expected that both wide espacement and late planting would have increased the drought resistance of the plants with the result that not only late planting would generally yield more grain than early planting, but also that early planting would yield considerably more grain in combination with wide espacement than with normal or dense espacement. This was not the case, and the widely spaced plants of the early planting also suffered from drought, assumedly because the strong tillering led to a detrimentally high moisture consumption. In this respect the particulars on the tillering of the plants, which are presented in Table 26, are of special interest.

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significant interaction between dates of planting and espacements. With early planting the treatment with 10,000 plants per morgen yielded slightly more grain than the treatments with 15,000 or 30,000 plants per morgen. The differences were, however, small and it is obvious that the wide espacement could eliminate the adverse effect of a poor moisture supply to the early planted maize to only a slight extent. The grain yields obtained from the densely, normally and widely spaced plants of the late planting did not differ to an appreciable extent.

Similar grain and stover yields were obtained whether or not nitrogen fertilizer had been applied. The stover yields of the late planted maize were generally higher than those of the early planted maize. The condition of the stover from the plants of the two planting dates was not the same when the weights and moisture contents were determined (June 16th, 1960). The stover of the early planted maize had a darker colour and was more brittle. A larger loss of weight by decomposition during the longer period the early maize was left stooked, is regarded as possible.

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The tillering appears to have been slightly lower with late than with early planting. The nitrogen treatments do not seem to have influenced the tillering and the strongest influence came from the espacements. Assumedly, the competition between the plants was strong at dense espacement, resulting in a high percentage of plants in which the tillers could not develop. In contrast, a weak competition between the widely spaced plants favoured tillering. With the three different plant populations of ten, twenty and thirty thousand plants per morgen, as an average about 22.8, 28.2 and 33.7 thousand stems and tillers were counted per morgen. While the tillers of the densely planted maize generally did not grow high and dried up early, the majority of the tillers of the widely spaced plants grew as high as the main stems so that it was difficult to distinguish between main stems and tillers. The advantage of a greater drought resistance, attributable to a thin plant population, had obviously been decreased by the strong tillering of the widely spaced plants. This had a detrimental effect on the early planted maize, as the soil moisture reserves had been depleted when the strongly developed plants entered the drier period.

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## 1960/61 Season.

The investigations of the previous season were continued. In addition, an effort was made to determine whether the different results obtained at Theunissen and Glen are to be attributed to the soil type or to the period the soils had been under cultivation. It was, however, difficult to find a suitable experimental site which allowed a comparison of soils identical except for the period of cultivation.

In addition it was tried to reduce the tillering in a thin plant population in order to enable the plants to take full advantage of a wide espacement as regards drought resistance.

1. Spacing and Fertilizer Requirement of Maize at Glen (O.Gl.54).

Experimental Dates : The maize was planted on December 1st, 1960 and harvested on April 19th, 1961.

Observations : During this season with a subnormal precipitation at Glen, the fertilizer treatments did not influence the growth and leaf colour of the plants.

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The maize started tasseling towards the beginning of February, and at that time the first wilting symptoms occurred among the densely spaced plants. Shortly afterwards the normally spaced plants also started wilting. After the middle of February the leaves of all plants were strongly wilted and partially dried up. In contrast to the previous seasons, the degree of wilting of the normally and densely spaced plants did not differ much. Towards the beginning of March practically all the leaves had dried up.

Results : The grain and stover yields are given in Table 27. The results of nitrogen analyses of the harvested material from the densely and normally spaced plants without an application of nitrogen and with the two nitrogen levels, with the higher phosphate level and without an application of potassium fertilizer are presented in Table 28.

The grain yields were very low. As in the previous seasons, the plants of the normal espacement yielded more grain and less stover than the plants of the dense espacement. The effect of espacements on the grain yields was considerably smaller than in previous seasons. The prolonged drought had affected the normally and densely spaced plants to a similar degree. From the results of this dry season a tendency can be noticed for phosphate fertilizer to decrease the drought resistance of the plants, thereby affecting the grain production. At normal espacement the higher phosphate level caused a lower grain yield than the lower phosphate level.

The percentage protein in the grain was relatively high and varied little. It was slightly higher at normal than at dense espacement. The percentage of nitrogen in the stover was generally high. The quantity of grain nitrogen varied to an exceptional degree. This was caused by the great variation in grain yields, since the protein contents of the grain varied only slightly. The stover as well as the total herbage contained more nitrogen at dense than at normal espacement.

All the stover samples contained nitrates. The amounts of nitrogen in the grain, expressed as percentages of the nitrogen in grain plus stover, were generally low and varied considerably. These figures demonstrate that the translocation of nitrogenous

compounds/

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TABLE 27: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS
GLEN, 1960/61

| Fertilizer applied, lb./morgen | Grain yield, bags per morgen (12.5% moisture) | | | Stover yield, ton per morgen (air dry) | | |
|---|---|---|---|---|---|---|
| | A. Espacement | | | | | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean |
| B. Ammonium sulphate | | | | | | |
| $b_0$ none | 2.75 | 5.23 | 3.99 | 4.46 | 3.09 | 3.78 |
| $b_1$ 200 | 2.57 | 4.87 | 3.72 | 4.09 | 3.03 | 3.56 |
| $b_2$ 400 | 1.21 | 4.62 | 2.92 | 3.92 | 2.99 | 3.46 |
| C. Superphosphate | | | | | | |
| $c_0$ 200 | 1.80 | 5.68 | 3.74 | 4.16 | 3.07 | 3.62 |
| $c_1$ 400 | 2.56 | 4.13 | 3.35 | 4.15 | 3.00 | 3.58 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 2.05 | 4.82 | 3.44 | 4.03 | 2.95 | 3.49 |
| $d_1$ 100 | 2.31 | 4.99 | 3.65 | 4.28 | 3.12 | 3.70 |
| Mean | 2.18 | 4.91 | 3.54 | 4.16 | 3.04 | 3.60 |

| | B. Ammonium sulphate, lb./morgen | | | | | |
|---|---|---|---|---|---|---|
| C. Superphosphate | $b_0$ none | $b_1$ 200 | $b_2$ 400 | $b_0$ none | $b_1$ 200 | $b_2$ 400 |
| $c_0$ 200 | 3.95 | 4.37 | 2.89 | 3.84 | 3.64 | 3.37 |
| $c_1$ 400 | 4.03 | 3.07 | 2.94 | 3.72 | 3.47 | 3.54 |
| D. Potassium chloride | | | | | | |
| $d_0$ none | 3.58 | 3.63 | 3.11 | 3.65 | 3.51 | 3.32 |
| $d_1$ 100 | 4.41 | 3.81 | 2.73 | 3.90 | 3.61 | 3.59 |

| | C. Superphosphate, lb./morgen | | | |
|---|---|---|---|---|
| D. Potassium chloride | $c_0$ 200 | $c_1$ 400 | $c_0$ 200 | $c_1$ 400 |
| $d_0$ none | 3.91 | 2.97 | 3.59 | 3.39 |
| $d_1$ 100 | 3.57 | 3.73 | 3.64 | 3.76 |

| Treatment | SE | LSD (+) | SE | LSD (+) |
|---|---|---|---|---|
| A | 0.316 | 0.90 | 0.083 | 0.24 |
| B | 0.387 | - | 0.102 | - |
| C | 0.316 | - | 0.083 | - |
| D | 0.316 | - | 0.083 | - |
| AB | 0.547 | - | 0.144 | - |
| AC | 0.447 | 1.27 | 0.117 | - |
| AD | 0.447 | - | 0.117 | - |
| BC | 0.547 | - | 0.144 | - |
| BD | 0.547 | - | 0.144 | - |
| CD | 0.447 | - | 0.117 | - |

(+) P = 0.05

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TABLE 28: NITROGEN COMPOSITION OF THE HARVESTED MATERIAL AND AMOUNTS OF NITROGEN GAINED BY MAIZE AS INFLUENCED BY SPACING AND NITROGEN FERTILIZER TREATMENTS
GLEN, 1960/61

| A. Spacing<br>B. Ammonium sulphate applied, lb./morgen | % prot. in dry grain | % N in dry stover | lb. N per morgen contained in | | | |
|---|---|---|---|---|---|---|
| | | | grain | stover | total | grain as % of total |
| $a_0$ 3 ft. x 12 in. | | | | | | |
| $b_0$ none | 9.9 | 1.51 | 8.2 | 88 | 96 | 8.5 |
| $b_1$ 200 | 10.6 | 1.84 | 16.4 | 107 | 123 | 13.3 |
| $b_2$ 400 | 9.8 | 1.74 | 3.0 | 93 | 96 | 3.1 |
| Mean ($a_0$) | 10.1 | 1.70 | 9.2 | 96 | 105 | 8.8 |
| $a_1$ 3 ft. x 24 in. | | | | | | |
| $b_0$ none | 10.4 | 1.50 | 10.5 | 71 | 82 | 12.8 |
| $b_1$ 200 | 10.6 | 1.73 | 8.4 | 72 | 80 | 10.5 |
| $b_2$ 400 | 10.9 | 1.80 | 13.7 | 83 | 97 | 14.1 |
| Mean ($a_1$) | 10.6 | 1.68 | 10.9 | 75 | 86 | 12.7 |
| Mean values (B) | | | | | | |
| $b_0$ none | 10.2 | 1.50 | 9.4 | 80 | 89 | 10.6 |
| $b_1$ 200 | 10.6 | 1.64 | 12.4 | 90 | 102 | 12.2 |
| $b_2$ 400 | 10.4 | 1.77 | 8.4 | 88 | 96 | 8.8 |
| Mean | 10.4 | 1.64 | 10.1 | 86 | 96 | 10.5 |

| Treatment (P=0.05) | % prot. in grain | | lb. N per morgen in | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | grain | | stover | | total | |
| | SE | LSD | SE | LSD | SE | LSD | SE | LSD |
| A | 0.139 | 0.44 | 2.45 | - | 2.92 | 9.2 | 4.47 | 14.1 |
| B | 0.170 | - | 3.00 | - | 3.58 | - | 5.47 | - |
| AB | 0.240 | - | 4.25 | - | 5.06 | - | 7.47 | - |

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compounds to the grain had been decreased by drought at both normal and dense espacement.

Spacing and Fertilizer Requirement of Maize at Theunissen (O.Gl.55).

Experimental Dates : The maize was planted on November 28th, 1960 and harvested on April 25th, 1961.

Observations : This season was marked by a fairly normal moisture supply until December and a considerably below normal rainfall during the rest of the growth season. The seed germinated uniformly. The young plants were adversely affected by dust storms. The surface of the experimental plots was very even and this contributed to the dust storms being able to damage the plants to a considerable extent. The plants recovered quickly, but a portion of the nitrogen fertilizer might have been blown from one plot to another or away from the experimental area.

Drought during January and especially during February caused visible damage to the densely spaced plants from about the second half of February (late flowering stage). Not all the densely spaced plants, however, were affected at that time. The plants had suffered visibly only in patches. No relationship could be found between the fertilizer treatments and the appearance of dry patches. The influence of drought increased with advancing development until the stage of maturity. Many of the normally spaced plants showed marked wilting symptoms from after the flowering stage.

Shortly before tasseling one could observe an effect of the nitrogen treatments on the growth and the leaf colour of the plants. Mainly at dense espacement a slightly lighter leaf colour and a slightly poorer growth could be noted on the plots where nitrogen had not been applied. The leaf colour of the densely spaced plants was generally lighter than that of the normally spaced ones. After tasseling the leaf colour of all the plants not supplied with nitrogen fertilizer became still lighter, so that the plants supplied with nitrogen at planting time or 37 days after the planting date could easily be distinguished from the plants not supplied with nitrogen. Compared with the previous seasons, the nitrogen reaction was considerably less pronounced. It was assumed that the drought was responsible for the relatively poor effect of nitrogen fertilizer.

During/

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During the earlier growth stages until tasseling, the plants supplied with the higher quantity of phosphate grew more vigorously than those supplied with the smaller quantity. Outside the border of the experimental area Crotalaria nubica Benth was found. The roots had numerous and well developed nodules.

As was the case with most of the maize in the Theunissen district, the plants dried up early during this season. At the time of improved moisture conditions during March, the roots and stems of many plants rotted near the crown and many plants fell over. In some places other than the experimental area, this occurred even before the grain was fully developed. It is assumed that the preceding drought was responsible for this early termination of the growth. As a result of wilting, a decreased photosynthesis and insufficient nutrition of the roots and thereby, in turn, a decreased use of possibly still available soil moisture may be assumed. This might have contributed to the rapid desiccation of the plants under the conditions of extended drought. The possibilities of fungi entering the dead plant material can be regarded as optimal after the moisture conditions had improved.

Results : The grain and stover yields are given in Table 29 and the results of nitrogen analyses of the harvested material from the densely and normally spaced plants of six of the seven nitrogen treatments and the treatment with the higher phosphate level are presented in Table 30.

In this dry season, the application of nitrogen fertilizer did not influence either grain or stover yields at Theunissen. As in previous seasons, a strong effect of the espacements was obtained and the normally spaced plants yielded more grain and less stover than the densely spaced ones. The grain and stover yields were about equal at the two phosphate levels.

The reason for the lack of a response to nitrogen fertilizer during this season, in contradiction to three previous seasons, cannot be ascribed to the poor moisture conditions during the flowering stage and thereafter alone. The percentages of protein in the grain and nitrogen in the stover as well as the amounts of nitrogen taken up by the plants were higher than in the previous seasons. This indicates that more

nitrogen/

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TABLE 29: GRAIN AND STOVER YIELDS OF MAIZE AS INFLUENCED BY SPACING AND FERTILIZER TREATMENTS
THEUNISSEN, 1960/61

| B. Amm. sulph. in units of 100 lb. per morgen(..) and date of application | Grain, bags per morgen (12.5% moisture) | | | | |
|---|---|---|---|---|---|
| | A. Espacement | | | C. Superphosphate lb./morgen | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean (B) | $c_0$ 200 | $c_1$ 600 |
| $b_0$ none | 10.6 | 14.4 | 12.5 | 13.0 | 12.0 |
| $b_1$ (2)28.11 | 9.3 | 14.4 | 11.8 | 12.8 | 10.9 |
| $b_2$ (1)28.11+(1)4.1 | 10.6 | 16.4 | 13.5 | 15.0 | 12.1 |
| $b_3$ (2)4.1 | 8.3 | 14.1 | 11.2 | 11.4 | 11.0 |
| $b_4$ (4)28.11 | 11.9 | 17.8 | 14.8 | 14.3 | 15.4 |
| $b_5$ (2)28.11+(2)4.1 | 11.0 | 16.8 | 13.9 | 12.7 | 15.2 |
| $b_6$ (2)28.11+(2)26.1 | 9.8 | 16.2 | 13.0 | 13.8 | 12.2 |
| Mean (A and C) | 10.2 | 15.7 | 13.0 | 13.3 | 12.7 |
| C. Superphosphate lb./morgen | | | | | |
| $c_0$ 200 | 10.2 | 16.4 | | | |
| $c_1$ 600 | 10.2 | 15.1 | | | |

| Treatment | SE | LSD(+) |
|---|---|---|
| A | 0.497 | 1.4 |
| B | 0.930 | - |
| C | 0.497 | - |
| AB | 1.32 | - |
| AC | 0.703 | - |
| BC | 1.32 | - |

| B. Amm. sulph. in units of 100 lb. per morgen (..) and date of application | Stover, ton per morgen (air dry) | | | | |
|---|---|---|---|---|---|
| | A. Espacement | | | C. Superphosphate lb./morgen | |
| | $a_0$ 3ft. x 12 in. | $a_1$ 3ft. x 24 in. | Mean (B) | $c_0$ 200 | $c_1$ 600 |
| $b_0$ none | 3.60 | 2.76 | 3.18 | 3.10 | 3.26 |
| $b_1$ (2)28.11 | 3.84 | 2.72 | 3.28 | 3.22 | 3.34 |
| $b_2$ (1)28.11+(1)4.1 | 3.83 | 2.71 | 3.27 | 3.28 | 3.27 |
| $b_3$ (2)4.1 | 3.66 | 2.68 | 3.17 | 3.16 | 3.18 |
| $b_4$ (4)28.11 | 4.05 | 2.88 | 3.46 | 3.46 | 3.47 |
| $b_5$ (2)28.11+(2)4.1 | 3.98 | 2.82 | 3.40 | 3.34 | 3.47 |
| $b_6$ (2)28.11+(2)26.1 | 3.94 | 2.70 | 3.32 | 3.40 | 3.24 |
| Mean (A and C) | 3.84 | 2.75 | 3.30 | 3.28 | 3.32 |
| C. Superphosphate lb./morgen | | | | | |
| $c_0$ 200 | 3.79 | 2.77 | | | |
| $c_1$ 600 | 3.89 | 2.74 | | | |

| Treatment | SE | LSD(+) |
|---|---|---|
| A | 0.0441 | 0.12 |
| B | 0.0824 | - |
| C | 0.0441 | - |
| AB | 0.117 | - |
| AC | 0.0623 | - |
| BC | 0.117 | - |

(+) P=0.05

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TABLE 30: NITROGEN COMPOSITION OF THE HARVESTED MATERIAL AND AMOUNTS OF NITROGEN GAINED BY MAIZE AS INFLUENCED BY SPACING AND NITROGEN FERTILIZER TREATMENTS

THEUNISSEN, 1960/61

| A. Spacing<br>B. Ammonium sulphate applied, lb./morgen and date | % prot. in dry grain | % N in dry stover | lb. N per morgen contained in: grain | stover | total | grain as % of total | Utilization of N applied, % (+) |
|---|---|---|---|---|---|---|---|
| $a_0$ 3 ft. x 12 in. | | | | | | | |
| $b_0$ none | 8.73 | 0.61 | 22.9 | 34.7 | 57.6 | 39.8 | - |
| $b_1$ 200 : 28.11 | 9.69 | 0.71 | 23.6 | 44.3 | 67.9 | 34.8 | 25 |
| $b_2$ 200 : 4.1 | 9.50 | 0.73 | 25.8 | 45.2 | 71.0 | 36.3 | 32 |
| $b_3$ 400 : 28.11 | 10.00 | 0.72 | 36.1 | 44.9 | 81.0 | 44.6 | 28 |
| $b_4$ 200 : 28.11+ 200 : 4.1 | 9.73 | 0.66 | 32.7 | 41.6 | 74.3 | 44.0 | 20 |
| $b_5$ 200 : 28.11+ 200 : 26.1 | 10.12 | 0.68 | 25.9 | 40.7 | 66.6 | 38.9 | 11 |
| Mean ($a_0$) | 9.63 | 0.68 | 27.8 | 41.9 | 69.7 | 39.9 | 23 |
| $a_1$ 3 ft. x 24 in. | | | | | | | |
| $b_0$ none | 9.54 | 0.52 | 37.7 | 25.7 | 63.4 | 59.5 | - |
| $b_1$ 200 : 28.11 | 9.81 | 0.72 | 35.6 | 32.6 | 68.2 | 52.2 | 11 |
| $b_2$ 200 : 4.1 | 10.40 | 0.67 | 42.1 | 29.2 | 71.3 | 59.0 | 19 |
| $b_3$ 400 : 28.11 | 10.19 | 0.69 | 50.2 | 34.1 | 84.3 | 59.5 | 25 |
| $b_4$ 200 : 28.11+ 200 : 4.1 | 10.27 | 0.71 | 51.3 | 34.8 | 86.1 | 59.6 | 27 |
| $b_5$ 200 : 28.11+ 200 : 26.1 | 9.87 | 0.69 | 41.3 | 31.1 | 72.4 | 57.0 | 11 |
| Mean ($a_1$) | 10.01 | 0.67 | 43.0 | 31.3 | 74.3 | 57.9 | 19 |
| Mean values (B) | | | | | | | |
| $b_0$ none | 9.14 | 0.56 | 30.3 | 30.2 | 60.5 | 50.1 | - |
| $b_1$ 200 : 28.11 | 9.75 | 0.72 | 29.6 | 38.4 | 68.0 | 43.5 | 18 |
| $b_2$ 200 : 4.1 | 9.95 | 0.70 | 34.0 | 37.2 | 71.2 | 47.8 | 25 |
| $b_3$ 400 : 28.11 | 10.10 | 0.70 | 43.2 | 39.5 | 82.7 | 52.2 | 26 |
| $b_4$ 200 : 28.11+ 200 : 4.1 | 10.00 | 0.68 | 42.0 | 38.2 | 80.2 | 52.4 | 23 |
| $b_5$ 200 : 28.11+ 200 : 26.1 | 10.00 | 0.68 | 33.6 | 35.9 | 69.5 | 43.3 | 11 |
| Mean | 9.82 | 0.67 | 35.4 | 36.6 | 72.0 | 49.2 | 21 |

| Treatment (P= 0.05) | % prot. in grain SE | % prot. in grain LSD | lb. N/morgen in grain SE | grain LSD | stover SE | stover LSD | total SE | total LSD |
|---|---|---|---|---|---|---|---|---|
| A | 0.151 | - | 1.82 | 5.3 | 0.771 | 2.3 | 1.92 | - |
| B | 0.262 | - | 3.15 | 9.2 | 1.33 | 3.9 | 3.32 | 9.7 |
| AB | 0.370 | - | 4.46 | - | 1.89 | - | 4.69 | - |

(+) Difference between the amounts of nitrogen gained with and without the application of nitrogen, expressed as a percentage of the amount of nitrogen applied

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nitrogen had been available in the soil during this season than during the previous seasons. Apart from a possible seasonal difference, the higher nitrogen supply might have been caused by nitrogen fixation by Crotalaria nubica Benth which grew on the area of the 1960/61 experiment.

The fertilizer treatments did not bring about any noticeable differences between the protein contents of the grain. The nitrogen content of the stover was slightly higher with than without the application of nitrogen fertilizer.

At wide espacement, more nitrogen was contained in the grain and less in the stover than at dense espacement, while the amounts of nitrogen contained in grain plus stover were similar at dense and normal espacement. These relations are also reflected in the figures for the grain nitrogen, expressed as a percentage of the nitrogen contained in grain plus stover. This percentage was higher at normal than at dense espacement. As a result of more pronouncedly dry conditions, the translocation of nitrogen to the grain was hampered at dense espacement to a higher degree than at normal espacement.

A significant influence of the nitrogen fertilizer applied on the quantity of nitrogen contained in the grain, was obtained only with the higher nitrogen level (400 lb. ammonium sulphate per morgen) either applied as a single dressing at planting time or divided into two applications, at planting and about 5 weeks thereafter.

The difference between the amounts of nitrogen taken up with and without a dressing of nitrogen fertilizer, expressed as a percentage of the quantity of nitrogen applied, gives an indication of the degree of utilization of fertilizer nitrogen by the plants. The figures show that the nitrogen applied about 8½ weeks after the planting date was practically not taken up by the plants.

Comparison of Results from Theunissen and from two Experimental Sites at Glen.

The results compared are those obtained with normal espacement and three nitrogen treatments at Theunissen (O.Gl.55, on soil cultivated for more than 35 years), at Glen on soil cultivated for 5 years (O.Gl.54) and at Glen on soil which had been under cultivation for about 35 years.

Previous results had indicated a richer supply of

nitrogen/

nitrogen in the soil on which the experiments at Glen (O.Gl.54) were carried out than in the Theunissen soil (O.Gl.55). As the periods which these lands had been cultivated differed so widely, it was decided to lay out a trial on an older land at Glen, so as to be able to determine whether this larger nitrogen supply was an inherent property of the Glen soil or only limited to relatively new lands.

As in a previous comparison between the results from Glen and Theunissen, the experiments were not fully comparable. An optimal phosphate supply could be assumed in the soils of all sites. Nitrogen fertilizer had been applied for the fourth successive season to the same plots of the experiment O.Gl.54 at Glen and for the first time to the plots of both the experiment O.Gl.55 at Theunissen and the old land at Glen. The treatments without nitrogen fertilizer corresponded on the three sites. On the old land at Glen, Velvet Sorghum had been grown for two years previous to the maize planting and mostly maize before that time. Nitrogen had never before been applied to this land. The Sorghum had been ploughed early in 1960.

<u>Experimental Dates</u> : The maize at Theunissen was planted on November 28th, and the maize of the experiment O.Gl.54 at Glen and on the old land at Glen on December 1st, 1960. The harvesting dates were April 25th, 1961 at Theunissen, April 19th, 1961 for the experiment O.Gl.54 at Glen and April 12th, 1961 for the experiment on the old land at Glen. The results obtained with normal espacement, without nitrogen fertilizer and with the two nitrogen levels of 200 and 400 lb. ammonium sulphate per morgen are presented in Table 31.

The grain yields obtained at Theunissen were much higher than those obtained from the experiment O.Gl.54 at Glen, in spite of considerably less rain at Theunissen. The maize at Theunissen was not affected to the same extent by drought and endured more pronounced drought with less damage. The maize of the experiment on the old land at Glen also suffered less from drought than that of the experiment O.Gl.54 and brought considerably higher grain yields. Possibly, the treatment of the lands prior to planting was of importance, as the previous crop was ploughed under relatively early in the case of the old land. This may have contributed to a larger soil moisture supply.

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TABLE 31: COMPARISON OF YIELDS AND NITROGEN CONTENTS OF MAIZE HARVESTED AT THEUNISSEN AND ON TWO EXPERIMENTAL SITES AT GLEN 1960/61

| Exp. site and period of cultivation, years | Amm. sulph. applied, lb. per morgen | Grain (12.5% moist.) bags/morgen | Stover (dry), ton/morgen | % prot. in dry grain | % N in dry stover | lb. N/morgen contained in gr. | stover | total |
|---|---|---|---|---|---|---|---|---|
| Theunissen, > 35 (O.Gl.55) | 0 | 14.3 | 2.47 | 9.5 | 0.52 | 38 | 26 | 64 |
| | 200 | 13.1 | 2.28 | 9.8 | 0.72 | 36 | 33 | 69 |
| | 400 | 18.2 | 2.48 | 10.3 | 0.71 | 52 | 35 | 87 |
| | Mean | 15.2 | 2.41 | 9.9 | 0.65 | 42 | 31 | 73 |
| Glen, 5 (O.Gl.54) | 0 | 3.6 | 2.36 | 10.4 | 1.50 | 10 | 71 | 81 |
| | 200 | 2.8 | 2.09 | 10.6 | 1.73 | 8 | 72 | 80 |
| | 400 | 4.5 | 2.30 | 10.9 | 1.80 | 14 | 83 | 97 |
| | Mean | 3.6 | 2.25 | 10.6 | 1.67 | 11 | 75 | 86 |
| Glen, about 35 | 0 | 10.6 | 2.45 | 10.5 | 1.78 | 31 | 87 | 118 |
| | 200 | 10.9 | 2.39 | 10.5 | 1.61 | 32 | 77 | 109 |
| | 400 | 9.9 | 2.32 | 11.1 | 1.57 | 31 | 73 | 104 |
| | Mean | 10.5 | 2.39 | 10.7 | 1.65 | 31 | 79 | 110 |

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The stover yields from the three experimental sites did not differ much. Nearly equal percentages of protein were found in the grain from the two sites at Glen. Without the application of nitrogen fertilizer the protein content was slightly higher at Glen than at Theunissen.

The percentage of nitrogen in the stover from the two sites at Glen was very high and varied only slightly. The percentage of nitrogen in the stover sampled at Theunissen was found to be low. As a result of higher grain yields, the quantities of nitrogen contained in the grain harvested at Theunissen and from the old land at Glen were much higher than in the case of the experiment O.Gl.54 at Glen.

The quantities of nitrogen contained in the stover from both Glen sites were much higher than those of the Theunissen experimental site. The old land at Glen brought the highest total nitrogen uptake, followed by the experiment O.Gl.54 at Glen, while the experiment at Theunissen had the lowest. This becomes even more evident if the yields obtained with the most comparable treatments, namely those without the application of nitrogen fertilizer, are compared. Although the moisture supply to the plants might have differed to a certain extent at the three sites, the results may indicate that the type of soil and not the period of cultivation was the predominating factor determining the amount of nitrogen available to the plants.

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## Time of Planting, Spacing and Nitrogen Fertilizer Requirement of Maize at Glen (O.Gl.74).

Apart from the treatments which were included in this experiment during the previous season, 6 ft. and 3 ft. rows were taken up as a factor in the experiment of this season. In addition to the harvest weights, the protein contents of the grain and the nitrogen contents of the stover were determined.

Experimental Dates : The early maize was planted on October 17th, 1960 and the late maize on December 3rd, 1960. The harvesting dates were March 6th, 1961 for the early and April 18th, 1961 for the late maize. The weights and samples for moisture determination were taken shortly after the plants had been harvested.

Observations : Early in December the leaves of the early planted maize showed signs of wilting. At first this occurred among the densely spaced plants in 3 ft.

rows/

rows (3 ft. x 12 in.) only and later, less pronouncedly, also among the plants of the 3 ft. x 24 in. and 6 ft. x 6 in. espacements. After rain during the middle of December all the plants recovered.

The plants in 3 ft. rows tillered more than those in 6 ft. rows. At wide espacement more tillers developed than at dense espacement. On December 22nd, 1960 (tasseling stage), the height of the plants was measured. In 3 ft. rows the densely spaced plants (3 ft. x 12 in.) had an average height of 37 in., while the normally spaced plants (3 ft. x 24 in.) and the widely spaced plants (3 ft. x 36 in.) were between 41 and 42 in. high. The average plant height in 6 ft. rows was 44 in. for all plant densities. The growth of the densely spaced plants in 3 ft. rows had been adversely affected by drought. The plants in 6 ft. rows probably grew higher because they did not tiller as much as those in 3 ft. rows.

Severe drought damage was noted during January. At the beginning of this month many leaves of the plants in 3 ft. rows, with the exception of the widely spaced ones (3 ft. x 36 in.), dried up. Relatively little drought damage was observed among the plants in 6 ft. rows, with the exception of the densely spaced ones (6 ft. x 6 in.) which suffered severely from the drought. As regards drought damage, the plants of the replications of identical treatments exhibited a considerable variation.

Until the milk stage (middle January) a further increase in drought damage was observed. The plants of the 3 ft. x 12 in., 3 ft. x 24 in. and 6 ft. x 6 in. espacements were most severely affected, but the plants of the 3 ft. x 36 in. and 6 ft. x 12 in. espacements had also suffered. On account of extended drought, all the plants of the early maize dried up early, so that towards the middle of February no green leaves could be found any more. Thereafter a number of the root crowns and stems near the soil surface started rotting. It was assumed that saprophytic fungi attacked the plant material of the drought stricken plants after the soil moisture content had increased.

The observations on the late planted maize were generally similar to those described for the early planted maize. The plants tasseled towards the beginning of February. At this time the first wilting occurred among the plants of the 3 ft. x 12 in. espacement.

Shortly/

Shortly afterwards, the plants of the 3 ft. x 24 in. and 6 ft. x 6 in. espacements were also affected by drought. Towards the end of February all the leaves of the densely spaced plants in 3 ft. rows, and most of the leaves of the normally spaced plants in 3 ft. rows and the densely spaced plants in 6 ft. rows had dried up. Wilting also occurred among the widely spaced plants in 3 ft. rows and the normally spaced plants in 6 ft. rows.

With both plantings a markedly higher drought resistance was observed with planting in 6 ft. rows than with planting in 3 ft. rows, when treatments with the same number of plants per morgen were compared. The impression was obtained that 6 ft. rows were superior to 3 ft. rows as regards drought resistance, even when 30,000 plants per morgen in 6 ft. rows were compared with 15,000 plants per morgen in 3 ft. rows.

Results : In order to determine the influence of the treatments on the tillering of the plants, the number of tillers higher than 15 in. was determined during the flowering stage. The results are presented in Table 32. The grain and stover yields and the results of nitrogen analyses of the harvested material are presented in Table 33.

For the figures of Table 32, which are not statistically analysed, a fair degree of variation must be assumed, although each figure represents the average of countings on a minimum of 12 plots. As in the previous season, not all the relationships could be expressed by figures. The widely spaced plants often had equally high and equally developed stems and tillers. In contrast, the densely spaced plants had mostly one strong main stem and varying numbers of short tillers. Some of the tillers withered before they had reached the height of 15 in., the lowest limit taken into account. The impression was obtained that all the plants tillered to a more or less equal extent, with the exception of the plants of the 6 ft. x 6 in. spacing. The moisture supply assumedly determined to a large extent to what height the tillers could grow and whether they could reach the flowering stage.

The percentages of plants without tillers, with 1 - 2 tillers and with more than 2 tillers higher than 15 in. indicate that the number of plants per morgen strongly influenced the tillering. With a decreasing number/

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TABLE 32: INFLUENCE OF PLANTING DATE, SPACING AND THE APPLICATION OF NITROGEN FERTILIZER ON THE TILLERING OF MAIZE
GLEN, 1960/61

| A. Planting date<br>B. No of plants/ morgen<br>C. Row distance<br>D. lb. N/morgen applied | | Plants (1) without, (2) with 1-2, (3) with >2 tillers higher than 15 in., % (1) | (2) | (3) | Tillers tasseling, % | No. of stems plus tillers higher than 15 in. per plant | per morgen |
|---|---|---|---|---|---|---|---|
| $a_0$ 17 Oct. | $b_0$ 30,000 | 72 | 28 | 0 | 17 | 1.36 | 40868 |
| | $b_1$ 15,000 | 40 | 58 | 2 | 50 | 1.92 | 28770 |
| | $b_2$ 10,000 | 27 | 64 | 9 | 79 | 2.31 | 23138 |
| | Mean | 46 | 50 | 4 | 49 | 1.86 | 30925 |
| $a_1$ 3 Dec. | $b_0$ 30,000 | 74 | 25 | 1 | 1 | 1.35 | 40492 |
| | $b_1$ 15,000 | 43 | 53 | 4 | 39 | 1.86 | 27911 |
| | $b_2$ 10,000 | 25 | 68 | 7 | 73 | 2.27 | 22708 |
| | Mean | 47 | 49 | 4 | 38 | 1.83 | 30370 |
| $a_0$ 17 Oct. | $c_0$ 3 ft. | 38 | 58 | 4 | 43 | 2.01 | 33677 |
| | $c_1$ 6 ft. | 55 | 42 | 3 | 54 | 1.72 | 28173 |
| $a_1$ 3 Dec. | $c_0$ 3 ft. | 40 | 54 | 6 | 35 | 1.97 | 32766 |
| | $c_1$ 6 ft. | 55 | 43 | 2 | 40 | 1.69 | 27975 |
| $b_0$ 30,000 | $c_0$ 3 ft. | 65 | 35 | 1 | 1 | 1.49 | 44752 |
| | $c_1$ 6 ft. | 82 | 18 | 0 | 14 | 1.22 | 36608 |
| | Mean | 74 | 26 | 0 | 8 | 1.36 | 40680 |
| $b_1$ 15,000 | $c_0$ 3 ft. | 32 | 64 | 4 | 41 | 2.03 | 30476 |
| | $c_1$ 6 ft. | 51 | 47 | 2 | 49 | 1.75 | 26205 |
| | Mean | 42 | 56 | 3 | 45 | 1.89 | 28340 |
| $b_2$ 10,000 | $c_0$ 3 ft. | 20 | 69 | 11 | 72 | 2.44 | 24436 |
| | $c_1$ 6 ft. | 31 | 63 | 6 | 80 | 2.14 | 21410 |
| | Mean | 26 | 66 | 8 | 76 | 2.29 | 22923 |
| $b_0$ 30,000 | $d_0$ 0 | 77 | 23 | 1 | 6 | 1.30 | 38925 |
| | $d_1$ 63 | 70 | 30 | 0 | 9 | 1.41 | 42435 |
| $b_1$ 15,000 | $d_0$ 0 | 42 | 54 | 4 | 36 | 1.88 | 28170 |
| | $d_1$ 63 | 41 | 57 | 2 | 54 | 1.90 | 28511 |
| $b_2$ 10,000 | $d_0$ 0 | 26 | 66 | 8 | 74 | 2.26 | 22610 |
| | $d_1$ 63 | 25 | 66 | 9 | 78 | 2.32 | 23235 |
| $c_0$ 3 ft. | $d_0$ 0 | 41 | 54 | 5 | 39 | 1.96 | 32298 |
| | $d_1$ 63 | 37 | 58 | 5 | 39 | 2.02 | 34145 |
| | Mean | 39 | 56 | 5 | 39 | 1.99 | 33222 |
| $c_1$ 6 ft. | $d_0$ 0 | 56 | 41 | 3 | 39 | 1.67 | 27506 |
| | $d_1$ 63 | 53 | 45 | 2 | 56 | 1.74 | 28642 |
| | Mean | 54 | 43 | 3 | 48 | 1.70 | 28074 |
| $d_0$ 0 | $a_0$ 17 Oct. | 46 | 50 | 4 | 46 | 1.86 | 31128 |
| | $a_1$ 3 Dec. | 51 | 45 | 4 | 32 | 1.76 | 28676 |
| | Mean | 48 | 48 | 4 | 39 | 1.81 | 29902 |
| $d_1$ 63 | $a_0$ 17 Oct. | 46 | 50 | 4 | 51 | 1.87 | 30722 |
| | $a_1$ 3 Dec. | 44 | 52 | 4 | 43 | 1.89 | 32065 |
| | Mean | 45 | 51 | 4 | 47 | 1.88 | 31394 |

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TABLE 33: GRAIN AND STOVER YIELDS, NITROGEN COMPOSITION OF THE HARVESTED MATERIAL, AND AMOUNTS OF NITROGEN GAINED BY MAIZE AS INFLUENCED BY THE DATE OF PLANTING, SPACING, AND THE APPLICATION OF NITROGEN FERTILIZER GLEN, 1960/61

| A. Time of planting<br>B. No. of plants/morgen<br>C. Row distance<br>D. lb. N/morgen applied | | grain, bags/morg. (12.5% moist.) | stover, ton/morg (dry) | % prot. in dry grain | % N in dry stover | lb. N per morgen contained in | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | grain | stover | total |
| $a_0$ 17 Oct. | $b_0$ 30,000 | 6.5 | 2.51 | 10.4 | 1.11 | 19.0 | 55.5 | 74.5 |
| | $b_1$ 15,000 | 11.4 | 2.21 | 10.5 | 1.04 | 33.4 | 45.8 | 79.2 |
| | $b_2$ 10,000 | 14.0 | 2.43 | 10.6 | 1.01 | 41.4 | 49.1 | 90.5 |
| | Mean | 10.6 | 2.38 | 10.5 | 1.05 | 31.3 | 50.1 | 81.4 |
| $a_1$ 3 Dec. | $b_0$ 30,000 | 4.7 | 4.18 | 10.7 | 1.16 | 14.1 | 97.3 | 111.4 |
| | $b_1$ 15,000 | 9.7 | 2.55 | 10.6 | 1.05 | 28.9 | 53.5 | 82.4 |
| | $b_2$ 10,000 | 11.6 | 2.45 | 10.7 | 1.05 | 34.8 | 51.6 | 86.4 |
| | Mean | 8.7 | 3.06 | 10.6 | 1.10 | 25.9 | 67.5 | 93.4 |
| $a_0$ 17 Oct. | $c_0$ 3 ft. | 8.3 | 2.20 | 10.5 | 1.15 | 24.4 | 50.7 | 75.1 |
| | $c_1$ 6 ft. | 12.9 | 2.56 | 10.6 | 0.97 | 38.2 | 49.6 | 87.8 |
| $a_1$ 3 Dec. | $c_0$ 3 ft. | 7.8 | 2.90 | 10.6 | 1.10 | 23.2 | 64.0 | 87.2 |
| | $c_1$ 6 ft. | 9.6 | 3.22 | 10.6 | 1.10 | 28.6 | 70.9 | 99.5 |
| $b_0$ 30,000 | $c_0$ 3 ft. | 3.7 | 3.15 | 10.8 | 1.21 | 11.2 | 76.2 | 87.4 |
| | $c_1$ 6 ft. | 7.5 | 3.55 | 10.4 | 1.08 | 21.9 | 76.7 | 98.6 |
| | Mean | 5.6 | 3.35 | 10.6 | 1.14 | 16.6 | 76.4 | 93.0 |
| $b_2$ 15,000 | $c_0$ 3 ft. | 8.6 | 2.12 | 10.5 | 1.09 | 25.2 | 46.1 | 71.3 |
| | $c_1$ 6 ft. | 12.5 | 2.63 | 10.6 | 1.01 | 37.1 | 53.2 | 90.3 |
| | Mean | 10.5 | 2.38 | 10.6 | 1.04 | 31.2 | 49.6 | 80.8 |
| $b_3$ 10,000 | $c_0$ 3 ft. | 11.8 | 2.39 | 10.6 | 1.04 | 35.0 | 49.7 | 84.7 |
| | $c_1$ 6 ft. | 13.8 | 2.49 | 10.7 | 1.02 | 41.2 | 51.0 | 92.2 |
| | Mean | 12.8 | 2.44 | 10.6 | 1.03 | 38.1 | 50.3 | 88.4 |
| $b_0$ 30,000 | $d_0$ 0 | 5.0 | 3.21 | 10.6 | 1.09 | 14.8 | 69.9 | 84.7 |
| | $d_1$ 63 | 6.1 | 3.48 | 10.7 | 1.19 | 18.3 | 82.9 | 101.2 |
| $b_1$ 15,000 | $d_0$ 0 | 9.1 | 2.27 | 10.4 | 1.10 | 26.6 | 50.0 | 76.6 |
| | $d_1$ 63 | 11.9 | 2.48 | 10.7 | 0.99 | 35.7 | 49.3 | 85.0 |
| $b_2$ 10,000 | $d_0$ 0 | 12.4 | 2.42 | 10.6 | 1.03 | 36.9 | 49.8 | 86.7 |
| | $d_1$ 63 | 13.3 | 2.46 | 10.5 | 1.03 | 39.3 | 50.8 | 90.1 |
| $c_0$ 3 ft. | $d_0$ 0 | 7.5 | 2.46 | 10.6 | 1.11 | 22.3 | 54.8 | 77.1 |
| | $d_1$ 63 | 8.6 | 2.64 | 10.5 | 1.13 | 25.3 | 59.9 | 85.2 |
| | Mean | 8.0 | 2.55 | 10.6 | 1.12 | 23.8 | 57.4 | 81.2 |
| $c_1$ 6 ft. | $d_0$ 0 | 10.2 | 2.80 | 10.5 | 1.04 | 30.0 | 58.3 | 88.3 |
| | $d_1$ 63 | 12.4 | 2.98 | 10.6 | 1.04 | 36.8 | 62.2 | 99.0 |
| | Mean | 11.3 | 2.89 | 10.6 | 1.04 | 33.4 | 60.2 | 93.6 |
| $d_0$ 0 | $a_0$ 17 Oct. | 9.7 | 2.40 | 10.5 | 1.08 | 28.4 | 51.7 | 80.1 |
| | $a_1$ 3 Dec. | 8.0 | 2.87 | 10.6 | 1.07 | 23.8 | 61.5 | 85.3 |
| | Mean | 8.8 | 2.63 | 10.6 | 1.08 | 26.1 | 56.6 | 82.7 |
| $d_1$ 63 | $a_0$ 17 Oct. | 11.6 | 2.37 | 10.5 | 1.03 | 34.2 | 48.6 | 82.8 |
| | $a_1$ 3 Dec. | 9.3 | 3.25 | 10.7 | 1.13 | 28.0 | 73.4 | 101.4 |
| | Mean | 10.4 | 2.31 | 10.7 | 1.09 | 31.1 | 61.0 | 92.1 |
| Mean | | 9.6 | 2.72 | 10.6 | 1.08 | 28.6 | 58.8 | 87.4 |

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TABLE 33 continued

| Treatment | | grain yield | stover yield | % prot. in grain | % N in stover | lb.N/morgen in grain | stover | total |
|---|---|---|---|---|---|---|---|---|
| A. Date of planting | SE | 0.527 | 0.0681 | 0.0585 | 0.0280 | 1.52 | 2.06 | 1.75 |
| | LSD+) | 1.5 | 0.19 | - | - | 4.3 | 5.9 | 5.0 |
| B. No. of plants | SE | 0.645 | 0.0831 | 0.0719 | 0.0342 | 1.86 | 2.52 | 2.14 |
| | LSD+) | 1.8 | 0.24 | - | - | 5.3 | 7.2 | 6.1 |
| C. Row distance | SE | 0.527 | 0.0681 | 0.0585 | 0.0280 | 1.52 | 2.06 | 1.75 |
| | LSD+) | 1.5 | 0.19 | - | 0.08 | 4.3 | - | 5.0 |
| D. N-treatments | SE | 0.527 | 0.0681 | 0.0585 | 0.0280 | 1.52 | 2.06 | 1.75 |
| | LSD+) | 1.5 | - | - | - | 4.3 | - | 5.0 |
| AB | SE | 0.912 | 0.118 | 0.101 | 0.0484 | 2.63 | 3.56 | 3.03 |
| | LSD+) | - | 0.34 | - | - | - | 10.1 | 8.6 |
| AC | SE | 0.745 | 0.096 | 0.0825 | 0.0395 | 2.15 | 2.91 | 2.48 |
| | LSD+) | - | 0.27 | - | 0.11 | - | - | - |
| AD | SE | 0.745 | 0.096 | 0.0825 | 0.0395 | 2.15 | 2.91 | 2.48 |
| | LSD+) | - | 0.27 | - | - | - | 8.3 | - |
| BC | SE | 0.912 | 0.118 | 0.101 | 0.0484 | 2.63 | 3.56 | 3.03 |
| | LSD+) | - | - | 0.3 | - | - | - | - |
| BD | SE | 0.912 | 0.118 | 0.101 | 0.0484 | 2.63 | 3.56 | 3.03 |
| | LSD+) | - | - | - | - | - | - | - |
| CD | SE | 0.745 | 0.096 | 0.0825 | 0.0395 | 2.15 | 2.91 | 2.48 |
| | LSD+) | - | - | - | - | - | - | - |

+) P = 0.05

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number of plants, the percentage of plants without tillers decreased and the percentage of plants with 1 - 2 and more than 2 tillers increased. The time of planting had no marked influence on the tillering. Six ft. rows brought about a higher percentage of plants without tillers than 3 ft. rows. This result was very distinct in the treatments with 30,000 and 15,000 plants per morgen, but not in the treatment with 10,000 plants. The nitrogen treatments had no appreciable influence on the tillering. The number of stems plus tillers per plant gives similar indications of the treatment effects on the tillering.

The percentage of tillers which reached the tasseling stage was strongly influenced by the plant population. With a decreasing number of plants per morgen, the percentage of tillers which reached the tasseling stage increased appreciably. In 6 ft. rows relatively more tillers reached the tasseling stage than in 3 ft. rows, especially in the case of the plant population of 30,000 plants per morgen.

The number of stems plus tillers per morgen indicates to what extent the plant density, as determined by the espacements, had been changed by tillering. In combination with 30,000, 15,000 and 10,000 plants per morgen, 3 ft. rows brought about considerably higher numbers of stems plus tillers than 6 ft. rows. The difference between 3 ft. and 6 ft. rows was relatively greatest with 30,000 plants per morgen and greater with 15,000 than with 10,000 plants.

As in the previous season, the advantage of a low plant population as regards drought resistance, was lost to a certain degree by a strong tillering of the widely spaced plants. The reduced tillering, where 6 ft. rows had been planted instead of 3 ft. rows, is regarded as of considerable importance for the drought resistance of these plants.

The grain yields (Table 33) were slightly higher with the early than with the late planting. On account of little rain during the period between the early and the late planting dates, no appreciable moisture conservation could have taken place. The drought continued until late in the season and affected the late planted maize to a similar extent as the early planted maize. The late planted maize had suffered severely

from/

from high temperatures and little precipitation during February.

Of all treatments the plant population had the most influence on the yields. Under normal weather conditions higher grain yields can be expected with about 15,000 plants per morgen than with either 10,000 or 30,000 plants. In this season the highest grain yield was obtained with 10,000 plants, a lower one with 15,000 and a very low grain yield with 30,000 plants per morgen. The grain yield from 6 ft. rows was considerably higher than that from 3 ft. rows.

The application of nitrogen fertilizer effected a slight increase in grain yields. None of the interactions proved significant. As is usual in dry seasons, the grain yields varied considerably.

The late planted maize yielded more stover than the early planted maize. If the interaction between times of planting and number of plants per morgen is considered, it becomes evident that an appreciable difference between the stover yields obtained with early and late planting was limited to the plant population of 30,000 plants. With 10,000 plants per morgen equal stover yields were obtained with early and late planting. The stover yields from 6 ft. rows were higher than those from 3 ft. rows. The application of nitrogen fertilizer brought about a slight increase in the stover yield from the maize of the late planting.

Nearly equal percentages of protein were found in the grain of all treatments. The variation was extraordinarily small. With 30,000 plants per morgen, the percentage protein in the grain was slightly higher in combination with 3 ft. rows than in combination with 6 ft. rows. Compared with the grain of the other spacings, the grain of the 3 ft. x 12 in. spacing was smaller and shrunken. This morphological difference might have been the reason for the higher protein content.

The percentage nitrogen in the stover varied considerably. The only noteworthy difference occurred at early planting, where 6 ft. rows brought about a lower percentage of nitrogen in the stover than 3 ft. rows. The reason for this is sought in an early drying up of the plants in 3 ft. rows, which had probably prevented a further increase in the lignin content.

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The percentages of nitrate nitrogen in the stover varied to a high degree. All the stover samples contained nitrates. It was not possible to dry all the stover samples in a drying oven immediately after the harvest. The possibility of a biological conversion of nitrates to protein existed during the air drying of the samples before oven drying. Therefore, no conclusions were drawn from the nitrate contents. It may only be mentioned that about 11 per cent of the stover nitrogen (average for all treatments) was found to be in the form of nitrates.

Since the grain of all the plants had approximately equal protein contents, the nitrogen treatments had similar effects on the grain yields and the quantities of grain nitrogen.

The quantities of stover nitrogen varied considerably. With late planting these were slightly higher than with early planting. The interactions time of planting with number of plants and time of planting with nitrogen treatments, indicate that the higher quantity of nitrogen contained in the stover of the late planted maize did not apply to all combinations. Only the combinations between late planting and 30,000 plants, and late planting with the application of nitrogen fertilizer, yielded noticeably more stover nitrogen than the remaining combinations of the two mentioned interactions.

The nitrogen contained in grain plus stover varied less than either the quantity of grain nitrogen or the quantity of stover nitrogen. This indicates that low or high amounts of nitrogen contained in either the grain or the stover were compensated for by low or high amounts of nitrogen in the respective stover or grain.

With 30,000 plants per morgen more nitrogen was taken up by the plants in combination with late than in combination with early planting. The reason may be methodological, since a number of the small tillers of the early planted and densely spaced maize had rotted on the soil surface when the plants were harvested.

Six ft. rows resulted in a higher nitrogen uptake than 3 ft. rows. This higher nitrogen uptake of the plants in 6 ft. rows was due to a higher amount of nitrogen in the grain and not to a higher one in the stover.

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The amount of nitrogen contained in grain plus stover was also slightly higher with than without the application of nitrogen fertilizer. The figures obtained from the combinations between nitrogen treatments and times of planting indicate that the increased nitrogen uptake resulting from nitrogen fertilization, was limited to the late planting.

Soil Moisture Investigations on Plots of Experiment O.Gl.74.*

In order to determine the influence of the row distance and the time of planting on the soil moisture status during the season, soil moisture investigations were carried out on plots with 6 ft. and 3 ft. rows of the early planted maize (6 ft. x 12 in. and 3 ft. x 24 in. = 15,000 plants per morgen) and on plots with early and late planted maize (espacement 3 ft. x 24 in.) at 5 soil depths and on seven dates.

In the case of the comparison between the soil moisture contents under 3 ft. and 6 ft. rows, the samples were taken 6 in. from the plants within the rows as well as in the middle between the rows. In the case of the comparison between the soil moisture contents with early and late maize planting, the samples were taken 6 in. from the plants within the rows only. Otherwise the procedure as described in the chapter on methods was followed.

Results : The soil moisture contents (mm) and the evapotranspiration for each of the two row distances are presented in Table 34. Only the average moisture contents for each row distance (8 sampling spots per treatment) are presented. Differences between moisture contents when sampling 6 in. from the plants within rows and in the middle between rows occurred only in the surface soil (0 - 1 ft.) and were practically limited to six ft. rows. The surface soil is regarded as of little importance for moisture conservation. It was felt that the averages will represent the moisture contents of the soil with six ft. rows more truly than the figures obtained by either the sampling in the rows or in the middle between rows. Table 35 shows the mm soil moisture and the evapotranspiration with early and late planting (four sampling spots per treatment).

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The sampling for these soil moisture investigations was carried out by Mr. J.H.P. Kellerman, and the author is indebted to him for his collaboration.

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TABLE 34: INFLUENCE OF TWO ROW DISTANCES OF MAIZE ON THE DEPLETION OF SOIL MOISTURE: mm SOIL MOISTURE AT FIVE DEPTHS AND EVAPOTRANSPIRATION BETWEEN SUCCESSIVE DATES OF INVESTIGATION GLEN, 1960/61

| Treatments: | a. 3 ft. rows (3 ft. x 24 in.) | | | | | b. 6 ft. rows (6 ft. x 12 in.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates and approximate growth stage | October 17th, planting | | December 3rd, before flowering | | December 29th, flowering | | February 6th, dough stage | | March 7th, ripening stage | |
| Treatment | a | b | a | b | a | b | a | b | a | b |
| Depth, in. | | | | | | | | | | |
| 0 - 4 | 8.6 | 8.1 | 5.7 | 6.8 | 10.7 | 9.3 | 6.1 | 5.7 | 6.5 | 6.4 |
| 4 - 8 | 13.9 | 12.7 | 6.7 | 7.8 | 7.8 | 6.8 | 4.9 | 5.9 | 6.0 | 5.4 |
| 8 - 12 | 18.8 | 17.9 | 10.5 | 12.7 | 10.6 | 8.4 | 9.2 | 9.5 | 9.1 | 9.6 |
| 0 - 12 | 41.3 | 38.7 | 22.9 | 27.3 | 29.1 | 24.5 | 20.2 | 21.1 | 21.6 | 21.4 |
| 12 - 24 | 61.4 | 62.7 | 46.0 | 52.4 | 39.6 | 40.0 | 36.0 | 38.1 | 36.0 | 37.1 |
| 24 - 36 | 52.9 | 53.6 | 46.8 | 47.9 | 36.7 | 39.2 | 31.7 | 33.8 | 32.3 | 33.5 |
| 0 - 36 | 155.6 | 155.0 | 115.7 | 127.6 | 105.4 | 103.7 | 87.9 | 93.0 | 89.9 | 92.0 |
| mm rain between dates | - | - | 56.4 | 56.4 | 57.4 | 57.4 | 77.9 | 77.9 | 53.2 | 53.2 |
| Evapotranspiration between dates, mm | - | - | 96.3 | 83.8 | 67.7 | 81.3 | 95.4 | 88.6 | 51.2 | 54.2 |
| Cumulative evapotranspiration, mm | - | - | 96.3 | 83.8 | 164.0 | 165.1 | 259.4 | 253.7 | 310.6 | 307.9 |

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TABLE 35: INFLUENCE OF TWO PLANTING DATES OF MAIZE ON THE DEPLETION OF SOIL MOISTURE: mm SOIL MOISTURE AT FIVE DEPTHS AND EVAPOTRANSPIRATION BETWEEN SUCCESSIVE DATES OF INVESTIGATION
GLEN, 1960/61

| Treatments: | a. Early planting (October 17th) | | | | | b. Late planting (December 3rd) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates | October 17th | | December 3rd | | December 29th | | February 6th | | March 7th | |
| Treatment | a | b | a | b | a | b | a | b | a | b |
| Approx. growth stage | plant-ing | before plant-ing | before flower. | plant-ing | flower-ing | before flower. | dough stage | flower-ing | ripe | soft dough |
| Depth, in. | | | | | | | | | | |
| 0 - 4 | 8.6 | 9.7 | 6.2 | 11.6 | 13.0 | 13.9 | 6.0 | 7.7 | 6.7 | 6.0 |
| 4 - 8 | 13.9 | 15.8 | 6.6 | 13.7 | 8.0 | 16.4 | 4.7 | 7.4 | 5.8 | 6.1 |
| 8 - 12 | 18.8 | 19.1 | 10.1 | 19.6 | 10.4 | 21.5 | 9.1 | 12.1 | 9.7 | 9.9 |
| 0 - 12 | 41.3 | 44.6 | 22.9 | 44.9 | 31.4 | 51.8 | 19.8 | 27.2 | 22.2 | 22.0 |
| 12 - 24 | 61.4 | 60.6 | 45.9 | 63.4 | 38.2 | 65.9 | 35.0 | 43.1 | 36.2 | 36.7 |
| 24 - 36 | 52.9 | 52.3 | 46.4 | 56.9 | 36.1 | 58.0 | 31.4 | 43.2 | 32.6 | 33.8 |
| 0 - 36 | 155.6 | 157.5 | 115.2 | 165.2 | 105.7 | 175.7 | 86.2 | 113.5 | 91.0 | 92.5 |
| mm rain between dates | - | - | 56.4 | 56.4 | 57.4 | 57.4 | 77.9 | 77.9 | 53.2 | 53.2 |
| Evapotrans-piration be-tween dates, mm | - | - | 96.8 | 48.7 | 66.9 | 46.9 | 97.4 | 140.1 | 48.4 | 74.2 |
| Cumulative evapotranspira-tion, mm | - | - | 96.8 | 48.7 | 163.7 | 95.6 | 261.1 | 235.7 | 309.5 | 309.9 |

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At planting time equal moisture reserves were found in the soils of the plots where 3 ft. and 6 ft. rows were to be planted (Table 34). Before the flowering stage (46 days after planting), the plants of the 6 ft. rows had a larger soil moisture reserve than those of the 3 ft. rows. The reason may be sought in the stronger tillering of the maize in 3 ft. rows. The moisture content of the deepest soil layer (24 - 36 in.) had decreased to a similar extent with both row distances. A more pronounced moisture depletion under 3 ft. than under 6 ft. rows was indicated for the layers 0 - 12 in. and 12 - 24 in. During the next period (ending during the flowering stage) the evapotranspiration was higher with 6 ft. than with 3 ft. rows, probably because more moisture had still been available for the plants in 6 ft. rows. The plants in 3 ft. rows had been adversely affected by drought. No very pronounced differences were obtained during the last two periods.

It is of interest that the maize in 6 ft. rows depleted the moisture content of the deepest investigated soil layer (24 - 36 in.) to the same extent as the maize in the 3 ft. rows, but only at a slightly later growth stage.

The total evapotranspiration for the two treatments was equal. Under the dry conditions, the soil moisture was obviously completely depleted by the maize in both 3 ft. and 6 ft. rows. During the last period the amount of rain recorded and the calculated evapotranspiration were similar.

The moisture contents of the soils from the plots reserved for early and late maize planting did not differ appreciably when each investigated depth and the whole profile were compared at the time of the early planting (Table 35). During the period from the early planting date to the late planting date the soil of the early planted maize lost a considerable amount of the soil moisture which had been available at planting time. Especially the soil layers at the soil depths between 0 and 24 in. were depleted.

During the same period the plots reserved for late planting gained only a negligible amount of soil moisture, as only a little rain occurred. The amount of moisture which evaporated from the bare soil was only slightly less than the amount of moisture obtained from rain. Thus, the moisture reserve of the soil for

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the early maize at the early planting date, and that of the soil for the late maize at the late planting date, did not differ appreciably.

The moisture contents as determined until the flowering stage indicated a better moisture supply to the plants of the late than to those of the early planting up to flowering. High temperatures and drought during January and February brought a considerable increase in the evapotranspiration, particularly on the plots of the late planted maize which was not damaged by drought during the growth stages before flowering. The result was that the soil moisture contents decreased during the flowering stage to a very low level with this treatment as well. At the same time a stronger wilting occurred.

The total evapotranspiration over the period of investigation was equal for the plots with early and late maize planting, although the early planted maize had reached the stage of ripeness and the late maize only the soft dough stage when the investigations were suspended. This may be explained by a complete depletion of the readily available moisture by the plants of both planting dates. No substantially different supplies of moisture to the plants were obtained with the two planting dates during this season. The late planting only delayed the growth period and with it the depletion of moisture in the soil.

The possibility of the pre-planting moisture reserve being increased during the period from the first to the second planting dates, was not realised. Therefore, the late planting was not advantageous when compared with the early planting.

In spite of this result, the following ideas must be kept in mind when choosing the planting date : Although the probability of an increased moisture conservation by delayed planting was not fulfilled during this season, it is assumed to be of importance during normal seasons. The conservation of additional soil moisture before planting may be achieved by late planting without the probability of rain during the growth period being diminished. Therefore, it can generally be assumed that relatively late planting of maize will normally ensure a higher moisture supply than early planting.

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## II. Pot Experimentson the Nitrogen Nutrition of Maize.

### a. Pot Experiment with Applications of Nitrogen Fertilizer at Different Growth Stages. /)

The observations during the moist 1957/58 season at Theunissen led to the conclusion that the application of 42 or 84 lb. N per morgen at planting time does not always ensure a sufficient nitrogen supply to the plants during the reproductive period of growth. In this moist season the application of nitrogen fertilizer resulted in a strongly increased growth up to the flowering stage. Indications were that the percentage of nitrogen in the plant material decreased to a very low level on account of vigorous growth during the vegetative period of growth. It is assumed that the leaves and stalks can be depleted of nitrogen only to a certain minimum percentage when the grain is being formed and that the translocation of nitrogenous compounds to the grain as well as the setting of grain is hampered when the nitrogen content of the plant material has reached a low level.

To ensure an adequate nitrogen supply during the reproductive period of growth, a knowledge of the most suitable time for the application of nitrogen fertilizer appears to be of considerable importance, particularly in a region with erratic precipitation where only a limited quantity of nitrogen is applied on account of an uncertain yield response to nitrogen fertilizer. Special attention was, therefore, paid to the time of application of nitrogen fertilizer in the experiments carried out at Theunissen during the 1958/59, 1959/60 and 1960/61 seasons. The results of the 1958/59 season with an only slightly below normal precipitation suggested that fertilizer nitrogen may be taken up and favourably utilized by the plants up to a fairly late growth stage. A moist season did not occur again and it was, therefore, not possible to investigate in field experiments the influence of a late application of nitrogen fertilizer under high rainfall conditions.

The pot experiment was carried out to elucidate the influence of the time of application of an equal total quantity of ammonium nitrate (2 g N per two plants) on the uptake and utilization of nitrogen for grain formation under optimal moisture conditions. Only a limited nitrogen supply should be offered and, therefore, a relatively small total quantity of ammonium nitrate was chosen.

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/ In this pot experiment the author was assisted by the Technical Officer, Mr. R. B. van der Merwe.

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Apart from a treatment without an application of ammonium nitrate, treatments were included in the experiment where the total application of 2 g N per pot was applied either shortly after planting or before tasseling, or divided and applied at two times : the first portion shortly after planting (1 g N or 0.5 g N) and the rest (1 g N or 1.5 g N) either before tasseling or during the tasseling stage. During the tasseling stage the plants of two pots per treatment were harvested, in order to obtain information on the nitrogen status of the plants at that stage.

The number of replicate pots planted were ten in the case of the treatments with the application of ammonium nitrate and six in the case of the treatment without nitrogen. After the early harvest alternatively eight and four replicate pots were left for the harvest at the stage of ripeness. In the cases where nitrogen had been applied, the analyses were conducted on mixed material from each two replicate pots, leaving four replicate samples per treatment for the nitrogen analyses of the material from the late harvest.

<u>Experimental Dates</u> : The maize was planted on November 7th, 1960. The surplus plants were removed on November 17th. The 17th of November was also the date of the application of nitrogen "shortly after planting". The nitrogen to be applied before tasseling was applied on December 23rd, and the nitrogen to be applied during the tasseling stage, on January 20th, 1961. At this date the early harvest was taken and the harvest at the stage of maturity on March 16th, 1961.

<u>Observations</u> : A very uniform plant population was obtained after the surplus plants had been removed. All the plants had a dark green colour until about 28 days after planting. The impression was obtained that the growth of the plants supplied with the larger quantity of ammonium nitrate at planting time was slightly retarded when compared with that of the other plants. Thereafter the leaves of the plants which were not supplied with nitrogen rapidly became light green. The growth was retarded and the older leaves then became yellow and dry, probably on account of a translocation of nitrogenous compounds to the younger leaves. About 36 days after planting no differences between the leaf colours of the plants supplied with ammonium nitrate were observed. At the same time, the growth intensity of these plants was markedly influenced by the quantity of nitrogen made available to the plants, while differences between the leaf colour could be noted only later.

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The second date of ammonium nitrate application was 14 days before the expected beginning of tasseling (46 days after planting). According to experience in field experiments, it takes about 60 days from planting until the maize variety PP x K 64 starts tasseling. An influence of the nitrogen applied before tasseling on the colour of the leaves was visible within four days. A strong increase in the growth intensity followed soon. However, after a short period the colour of the leaves of these plants became lighter again.

With the exception of the plants not supplied with nitrogen and those only supplied with 0.5 g N shortly after planting, the tasseling began between 65 and 70 days after planting. The tasseling was retarded when compared with the period determined in field experiments. It also became evident that the plants which had not suffered from nitrogen shortage tasseled earlier than the other plants. The plants which had not been provided with nitrogen reached the tasseling stage only 90 days after planting.

At the time of the first harvest (74 days after planting) all the plants supplied with ammonium nitrate shortly after planting only, exhibited a strong nitrogen deficiency colour of the leaves. In contrast, a darker leaf colour prevailed when nitrogen had been applied before tasseling. In this case the colour differed in accordance with the quantity of ammonium nitrate given to the plants.

The application of nitrogen during the period of tasseling (74 days after planting) also caused a rapid change of the leaf colour. Compared with the nitrogen offered, the quantity of plant material was large at this stage. Therefore, in no case was a dark green colour obtained after the very late application of nitrogen. In spite of the advanced development of the plants, this very late application of ammonium nitrate caused a considerable increase in the growth intensity.

The majority of the plants not supplied with nitrogen failed to form ears. The ear development of the other plants was extremely retarded, especially where a pronounced nitrogen deficiency still prevailed at the stage of ear development. In order to ensure a full pollination, the plants were pollinated with pollen from other plants.

Towards the end of the experimental period, the colour of all plants was light, with the exception of those which had received 0.5 g N shortly after planting plus 1.5 g N at tasseling. These plants also had the best cob development.

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The plants supplied with ammonium nitrate during the tasseling stage, generally had more cobs than those supplied with nitrogen at earlier stages. Only about one-third of the plants not provided with nitrogen formed cobs. The plants with applications of ammonium nitrate shortly after planting or before flowering formed between 106 and 112 cobs per 100 plants, while those supplied with nitrogen during the tasseling stage formed between 144 and 169 cobs per 100 plants. None of the plants tillered.

The water consumption was very distinctly influenced by the nitrogen supply. Before the first harvest, the plants with the higher application of nitrogen required much more water than those with the lower or those without the addition of nitrogen. The late applications of nitrogen were also followed by a strong increase in water consumption. During the experimental period it was generally observed that plants which had a darker leaf colour required more water than those which had a lighter leaf colour.

Results : The results of the first harvest are presented in Table 36 and those of the second harvest in Table 37.

The figures for the first harvest (Table 36) indicate that all the applications of ammonium nitrate were followed by increased herbage yields. The nitrogen level available to the plants also influenced the production of plant material. The increase, calculated per gram nitrogen applied, was smaller in the case of the high application than in the case of the lower ones. The application of all the nitrogen (2 g) before tasseling, brought about a relatively small herbage yield per g N applied.

The additional nitrogen applied before tasseling to the plants which had been supplied with nitrogen shortly after planting, only raised the herbage yields by about half, when compared with early application (difference between herbage yields with early as well as late application of nitrogen and the herbage yields with early application only, corrected to one g N applied). The percentage of nitrogen in the plants not supplied with nitrogen and in those supplied with only 0.5 g N shortly after planting had decreased to a very low level. The nitrogen contents of 0.44 or 0.50 per cent assumedly did not allow a ready translocation of nitrogenous compounds for the development of grain, although the absolute minimum level which can be achieved at a later stage of plant development and under conditions of nitrogen deficiency, is lower. Whole maize

plants/

TABLE 36 : *INFLUENCE OF AMMONIUM NITRATE APPLIED AT DIFFERENT GROWTH STAGES ON THE YIELD AND NITROGEN* COMPOSITION OF MAIZE HARVESTED AT THE TASSELING STAGE

POT EXPERIMENT, 1960/61

| g N per pot applied as $NH_4NO_3$ and date of application | Dry herbage yield, g/pot | Nitrogen in herbage % | Nitrogen in herbage g/pot | Increase due to the application of $NH_4NO_3$: in herbage yield, g per g N applied early and late | in herbage yield, g per g N applied early or late | in nitrogen gain as percentage of N applied |
|---|---|---|---|---|---|---|
| 1. None | 32 | 0.44 | 0.14 | - | - | - |
| 2. 2 g - 17 Nov. | 188 | 0.72 | 1.35 | 78 | 78 (early) | 60 |
| 3. 2 g - 23 Dec. | 110 | 1.22 | 1.34 | 39 | 39 (late) | 60 |
| 4. 1 g - 17 Nov. + 1 g - 23 Dec. | 160 | 0.84 | 1.35 | 64 | 41 (late) | 60 |
| 5. 1 g - 17 Nov. | 119 | 0.56 | 0.67 | 87 | 87 (early) | 53 |
| 6. 0.5 g - 17 Nov. + 1.5 g - 23 Dec. | 154 | 0.81 | 1.24 | 61 | 47 (late) | 55 |
| 7. 0.5 g - 17 Nov. | 84 | 0.50 | 0.42 | 104 | 104 (early) | 56 |
| Mean | 121 | 0.77 | 0.93 | 72 | - | - |
| SE | 6.04 | 0.0263 | 0.0793 | | | |
| LSD (P=0.05) | 21 | 0.09 | 0.27 | | | |

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OF MAIZE AND ON THE NITROGEN COMPOSITION OF THE HARVESTED MATERIAL
POT EXPERIMENT, 1960/61

| g N per pot applied as $NH_4NO_3$ and date of application | Dry weight, g pot grain | Dry weight, g pot stover | Dry weight, g pot total | % N in grain | % N in stover | g nitrogen per pot contained in grain | g nitrogen per pot contained in stover | g nitrogen per pot contained in total | Increase due to N applied in dry weight, g per g N applied grain | Increase due to N applied in dry weight, g per g N applied stover | Increase due to N applied in dry weight, g per g N applied total | Increase due to N applied in N gain as % of N applied | Grain N as % of N in gr. plus stover | Difference: Second minus first harvest in herbage weight g/pot | Difference: Second minus first harvest in nitrogen gain g N/pot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. None | 0+) | 45+) | 45+) | - | 0.27 | 0.00+) | 0.12 | 0.12 | - | - | - | - | 0 | 13 | -0.02 |
| 2. 2 g 17 Nov. | 52 | 198 | 250 | 0.77 | 0.29 | 0.40 | 0.57 | 0.97 | 26 | 76 | 102 | 42 | 41 | 62 | -0.38 |
| 3. 2 g 23 Dec. | 49 | 165 | 214 | 0.86 | 0.33 | 0.42 | 0.55 | 0.97 | 24 | 60 | 84 | 42 | 43 | 104 | -0.37 |
| 3. 1 g 17 Nov.+ 1 g 23 Dec. | 53 | 166 | 219 | 0.77 | 0.30 | 0.41 | 0.49 | 0.90 | 26 | 61 | 87 | 39 | 46 | 60 | -0.45 |
| 4. 1 g 17 Nov.+ 1 g 20 Jan. | 76 | 161 | 237 | 0.88 | 0.34 | 0.67 | 0.55 | 1.22 | 38 | 58 | 96 | 55 | 55 | 118 | 0.55 |
| 5. 0.5 g 17 Nov+ 1.5 g 23 Dec. | 49 | 172 | 221 | 0.78 | 0.30 | 0.38 | 0.52 | 0.90 | 24 | 64 | 88 | 39 | 42 | 67 | -0.34 |
| 6. 0.5 g 17 Nov.+ 1.5 g 20 Jan. | 81 | 128 | 209 | 0.91 | 0.36 | 0.74 | 0.46 | 1.20 | 40 | 42 | 82 | 54 | 62 | 125 | 0.78 |
| Mean | 60 | 165 | 225 | 0.83 | 0.32 | 0.50 | 0.47 | 0.90 | 30 | 60 | 90 | 45 | | 78 | -0.23 |
| SE | 4.99 | 5.24 | 5.27 | 0.032 | 0.0126 | 0.0433 | 0.0238 | 0.0443 | | | | | | | |
| LSD(P=0.05) | 14 | 15 | 15 | 0.096 | 0.037 | 0.013 | 0.071 | 0.13 | | | | | | | |

+) Not included in the statistical analysis and the calculation of the mean

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plants at the early tasseling stage from a farm in the Theunissen district had an average nitrogen content of 0.38 per cent in this season.

The plants which had not been supplied with ammonium nitrate shortly after planting and received 2 g N before tasseling, had the highest nitrogen content, obviously because the amount of nitrogen applied was high when compared with the small quantity of plant material produced on account of previous nitrogen shortage. The late applications of nitrogen to the plants which had received nitrogen shortly after planting were not as efficient with regard to an increase in the percentage of nitrogen. Less nitrogen fertilizer was applied and, in particular, the quantity offered per unit of plant material produced before the date of application, was considerably less.

The nitrogen taken up per pot was only influenced by the quantity of nitrogen applied and not by the time of application. The average utilization by the herbage of the nitrogen applied amounted to 57 per cent.

Plants not supplied with nitrogen did not yield any grain (second harvest : Table 37). The grain yields obtained with the application of ammonium nitrate shortly after planting, before tasseling or at both times did not differ appreciably. Higher grain yields than these were obtained from the plants which had been supplied with the second portion of the nitrogen during the tasseling stage. This indicates that under conditions of a limited nitrogen and a sufficient moisture supply to the plants, nitrogen applied as late as during the tasseling stage may, as regards grain yields, be superior to nitrogen applied shortly after planting or before tasseling.

In the treatments with the application of ammonium nitrate, the highest stover yield was obtained when all the nitrogen (2 g N) had been given shortly after planting, and the lowest when 0.5 g N had been applied shortly after planting plus 1.5 g N at tasseling. The stover yields of the other plants did not differ noticeably.

The average nitrogen content of the grain from all treatments was exceptionally low (0.83% N = 5.2% protein). The two treatments with the application of a portion of the nitrogen during the tasseling stage which brought the highest grain yields, also effected the highest nitrogen content of the grain.

All/

All the percentages of nitrogen in the stover were extremely low and indicated that the plants of all treatments had suffered from nitrogen deficiency. The lowest content to which the stover nitrogen may decrease up to the stage of ripeness is considered to be about 0.30 per cent. Such a low nitrogen content of the plant material was reached by the plants which had not been supplied with nitrogen and which had yielded no grain. The stover of the plants supplied with ammonium nitrate had similarly low nitrogen contents. In this case, however, a considerable portion of the nitrogen, taken up by the plants, had been translocated to the grain.

The amount of nitrogen contained in the grain was highest with the application of 1.5 g N during the tasseling stage. This very late application ensured a higher availability of nitrogen for grain formation than any of the earlier applications. The plants of the remaining treatments did not differ much with regard to the utilization of the applied nitrogen for grain production.

The plants not supplied with ammonium nitrate contained very little nitrogen in the plant material. With the exception of two treatments, no distinctly different quantities of nitrogen were found in the stover of the plants which had been supplied with nitrogen. The exceptions were the plants provided with 2 g N shortly after planting, where the stover contained slightly less nitrogen, and the plants provided with 0.5 g N shortly after planting plus 1.5 g N at tasseling, where the stover contained slightly more nitrogen than the stover of the remaining plants.

All the plants supplied with ammonium nitrate had received equal total quantities of nitrogen. It is, therefore, surprising that the amounts of nitrogen taken up during the whole growth period were not equal. Where a portion of the nitrogen was given during the tasseling stage, the plants contained more nitrogen than where all the nitrogen was applied at earlier growth stages. The possibility exists that the plants supplied with a relatively high amount of ammonium nitrate at early stages formed an extensive root system. A relatively large portion of the nitrogen could have been fixed in the material of the roots. However, if the results of the second harvest are compared with those of the first harvest, it becomes evident that the possibility of nitrogen losses cannot be excluded. At the second harvest the plants which had received all the nitrogen before the date of the first harvest contained less nitrogen than the corresponding plants at the first harvest. It is difficult/

lifficult to explain the nitrogen losses. The leaves were gathered regularly. Losses of plant material may have occurred, especially during the tasseling stage with the tassels and pollen. A leaching of nitrogenous compounds from drying leaves through rain is also regarded as possible.

The plants which received the second portion of nitrogen luring the tasseling stage, about doubled their weight from asseling until the stage of ripeness, whereas most of the plants supplied with nitrogen at earlier stages, gained much less in weight during the same period. This indicates that a considerable growth intensity of maize plants can be achieved as late as during the reproductive period.

The figures for the increase in yields due to nitrogen fertilizer and the grain nitrogen expressed as a percentage of the nitrogen contained in the plants, demonstrate the facts discussed before. These figures also indicate that nitrogen applied during the tasseling stage ensured a higher availability of nitrogen for grain formation than nitrogen applied at earlier stages. The results of this experiment suggest that special care should be taken to ensure the maintenance of a sufficient nitrogen status of the plants during the reproductive period of growth. In the case where only a limited amount of nitrogen is to be made available to the plants, an early application of nitrogen fertilizer may be followed by a considerable increase in the early growth, with the result that the nitrogen content of the plants decreases to a very low level and that the nitrogen contained in the plant material is not readily available for translocation at the time when the grain is being formed. Therefore a late application of nitrogen can be more advantageous than an early one. When the moisture supply is adequate, nitrogen fertilizer made available during the tasseling stage, is rapidly taken up by the plants and causes a considerable increase in growth and grain production.

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b. Hydroponic Experiments on the Functions of Nitrate in the Maize Plant and on the Ammonium and Nitrate Nutrition of Maize.

Depending on the growth stage, the nitrogen status of the soil and the application of nitrogen fertilizer, various amounts of nitrates were found in maize plants in field experiments. It is known that nitrate nitrogen can be accumulated in the plant material of various species, where it fulfils the function of a storage form of nitrogen and is reduced as required for the synthesis of protein.

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In some cases, as for example Beta vulgaris, Spinacia oleracea and Triticum sativum, nitrates can be stored in larger amounts without being used for protein synthesis. Apart from a limited reducing ability, a particular requirement for monovalent anions is attributed to such nitrophile or halophile plants. This requirement can be met by either nitrate or chloride ions, since the monovalent anions $Cl^-$ and $NO_3^-$ can replace each other to a certain extent and in accordance with HOFMEISTER'S series, similarly as the cations $K^+$ and $Na^+$. It is further known that nitrates can be extruded from an ion function in Beta plants (especially in fodder beet varieties)by chloride ions and thereby freed for reduction and utilization for the synthesis of protein (SCHMALFUSS,1954 and SCHMALFUSS,1955, p.204). Therefore, the application of chloride salts to Beta vulgaris and Spinacia oleracea was followed by a distinct increase in yields and decrease in the nitrate content of the plant material (SCHMALFUSS,1945, 1950 and 1954). In general, nitrate nutrition is superior to ammonium nutrition in its effect on the growth of halophile or nitrophile plants (SCHMALFUSS, 1954).

With these investigations on other plant species in mind, investigations were conducted on the reaction of maize plants to nitrate nutrition in the absence and presence of chlorides in the nutrient solutions.

The purpose of the hydroponic experiments was to indicate whether nitrates fulfil the function of a storage form of nitrogen only or whether the function of monovalent anions, as antagonists to polyvalent anions for the maintenance of an optimal hydration of the protoplasm colloids may possibly be ascribed to nitrates also in the case of maize. In addition, the efficiency of ammonium and nitrate nutrition of maize should be compared.

Hydroponic Experiment 1.

The purpose of this experiment was to determine the influence of chloride and sulphate on the nitrogen metabolism of maize, with special reference to the rate of reduction and the use of nitrate nitrogen for the synthesis of protein.

Experimental Dates and Treatments : Maize was germinated in saw dust and the seedlings were transferred to a nutrient solution containing no chlorides and with nitrate as nitrogen source on August 17th, 1960. The composition of this solution was as follows :-
2.126 g $KNO_3$, 1.736 g $Ca(NO_3)_2 \cdot 4H_2O$, 1.213 g $CaHPO_4$ ·

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$\cdot 2H_2O$, 1.223 g $MgSO_4 \cdot 7H_2O$, corresponding to 500 mg N, 500 mg $P_2O_5$, 990 mg $K_2O$, 807 mg CaO and 200 mg MgO per vessel per 4000 ml. The solution of each vessel also contained 5 ml Hoagland A-Z solution in which the $Cl^-$ salts had been replaced by $SO_4^{--}$ salts, and 200 mg $Na_2$ Fe-EDTA. All the plants of 12 vessels were grown in this solution for 31 days.

On September 17th, 1960, the plants of three vessels were harvested in order to obtain an indication of the nitrogen uptake up to that growth stage and of the nitrogen composition of the harvested material. On the same date the plants of the nine remaining vessels were transferred into three different nitrogen free solutions. The first of these solutions was free from chlorides and contained 1.213 g $CaHPO_4 \cdot 2H_2O$, 1.850 g $K_2SO_4$, 0.921 g $CaSO_4 \cdot 2H_2O$ and 1.223 g $MgSO_4 \cdot 7H_2O$, corresponding to 500 mg $P_2O_5$, 1000 mg $K_2O$, 695 mg CaO and 200 mg MgO per vessel. In the second solution 50% and in the third 90% of the sulphates of the first solution were replaced by equivalent amounts of the corresponding chlorides. Iron and trace elements were added to these three solutions in the same forms and amounts as were used during the first experimental period. The plants were left in the new solutions for only eight days and then harvested.

Results : The results of hydroponic experiment 1 are presented in Table 38.

At the time of the early harvest a considerable amount of nitrate nitrogen had accumulated in the plants. The nutrient solutions still contained a small amount of nitrates. The percentage nitrate nitrogen in the roots was considerably higher than that in the herbage. In the whole plant about 8.5 per cent of the total nitrogen was in the nitrate form.

During the final eight days of growth in the three nitrogen free solutions, the herbage and total plant weights increased considerably. This gain was accompanied by a general decrease in the nitrogen percentages from all nitrogenous fractions investigated.

The three different nutrient solutions did not bring about different herbage and total plant weights, but the root weights were different. The roots of the plants grown in the sulphate solution did not increase in weight during the final eight days of the experiment, while a slight increase in the root weights was obtained/

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TABLE 38: INFLUENCE OF SULPHATE AND CHLORIDE SOLUTIONS ON THE NITROGEN METABOLISM OF MAIZE HYDROPONIC EXPERIMENT 1

| Commencement of experiment 17.8.1960 | Dates of harvesting and equivalent weights $SO_4$:Cl in the nutrient solution | | | | SE | LSD (P= 0.05) |
|---|---|---|---|---|---|---|
| | 1. 17 Sept. 100:0 | 2. 25 Sept. 100:0 | 3. 25 Sept. 50:50 | 4. 25 Sept. 10:90 | | |
| Dry weight, g | | | | | | |
| herbage | 9.4 | 16.5 | 17.0 | 15.7 | 0.613 | 2.1 |
| roots | 1.06 | 1.07 | 1.45 | 1.48 | 0.096 | 0.33 |
| total | 10.5 | 17.6 | 18.4 | 17.2 | 0.597 | 2.1 |
| Protein N, % | | | | | | |
| herbage | 1.73 | 1.19 | 1.13 | 1.25 | 0.0456 | 0.16 |
| roots | 2.15 | 1.69 | 1.54 | 1.48 | 0.171 | – |
| Soluble N, % | | | | | | |
| herbage | 1.16 | 0.29 | 0.35 | 0.40 | 0.069 | 0.24 |
| roots | 1.43 | 0.46 | 0.39 | 0.37 | 0.069 | 0.24 |
| $NO_3$-N, % | | | | | | |
| herbage | 0.227 | 0.008 | 0.010 | 0.012 | 0.0185 | 0.064 |
| roots | 0.49 | 0.000 | 0.000 | 0.002 | – | – |
| Total N, % | | | | | | |
| herbage | 2.89 | 1.48 | 1.48 | 1.65 | 0.104 | 0.36 |
| roots | 3.58 | 2.15 | 1.93 | 1.85 | 0.218 | 0.75 |
| mgN/vessel in | | | | | | |
| herbage | 272 | 244 | 252 | 259 | 21.4 | – |
| roots | 38 | 23 | 28 | 27 | 1.68 | 5.8 |
| total | 310 | 267 | 280 | 286 | 20.7 | – |
| pH values minimum - maximum | | | | | | |
| a. Initial | 6.2-6.4 | 6.0-6.0+) | 6.0-6.1+) | 6.1-6.4+) | | |
| b. At harvests | 6.9-7.0 | 4.3-4.9+) | 5.2-5.8+) | 5.5-6.1+) | | |

+) pH values of the new solutions used after the harvest on 17 September

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obtained in the solutions containing chlorides. The composition of the new solutions had no appreciable influence on the nitrogen metabolism of the plants.

At the termination of the experiment only little nitrate nitrogen was found in the herbage and practically none in the roots. This is in contrast to the results of the first harvest, where the percentage of nitrate nitrogen was lower in the herbage than in the roots. The total amounts of nitrogen in the roots decreased during the final experimental period. A translocation of nitrogenous compounds to the herbage can be assumed as a possible reason, but the possibility of nitrogen losses due to leaching of the roots cannot be excluded.

The results of this experiment indicate that nitrates, which are accumulated in maize plants, are readily reduced when the plants grow without an additional nitrogen supply, even when no chlorides and considerable amounts of sulphates are present in the solution and an antagonistic function of the nitrates as monovalent anions can be regarded as important. It may, therefore, be assumed that nitrates represent mainly a storage form of nitrogen in the metabolism of maize.

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Hydroponic Experiment 2.

The influence of nitrate and ammonium nutrition in combination with sulphate and chloride nutrient solutions on the growth and nitrogen metabolism of maize was investigated.

Experimental Dates and Treatments : The experiment commenced on August 17th, 1960 and terminated on October 9th, 1960. Two nutrient solutions were used. The one solution contained the sulphates of potassium, magnesium and calcium and no chlorides. It contained 1.093 g $Ca_3(PO_4)_2$, 1.227g $K_2HPO_4$, 0.622 g $K_2SO_4$, 1.223 g $MgSO_4 \cdot 7H_2O$, 0.921 g $CaSO_4 \cdot 2H_2O$, 0.300 g $Na_2$ Fe-EDTA and 5 ml Hoagland A-Z solution per 4000 ml per vessel. In the other solution 90 per cent of the sulphates of the first solution were replaced by equivalent amounts of the corresponding chlorides. For the rest the two solutions were identical. These solutions were used in combination with two nitrogen treatments in which small amounts of nitrogen were repeatedly applied to the plants as either $HNO_3$ or $NH_4HCO_3$. The dates of application and the amounts of/

of nitrogen applied at a time as well as the pH values determined at intervals during the experimental period are presented in Table 39. The number of replicate vessels was four.

The reasons for the application of nitrogen in small portions and in the form of $HNO_3$ or $NH_4HCO_3$ are as follows :- A great methodological obstacle in the determination of the relative efficiency of nitrate and ammonium as nutrients for a number of plants has been the influence of ammonium and nitrate salts on the hydrogen ion concentration (cH) of the nutrient solutions. As ammonium salts of strong acids increase and nitrate salts of strong bases decrease the cH in the solutions with advancing growth and nitrogen uptake, it has been difficult to compare the effects of ammonium and nitrate nutrition at equal pH levels. Many efforts have been made by various scientists to avoid a divergent development of the cH after the use of nitrate and ammonium salts. A comparison of nitrate and ammonium effects at nearly equal pH in the nutrient solutions was achieved by PIRSCHLE (1930 and 1931) by the use of flowing nutrient solutions. By this method equal pH values could be attained with ammonium and nitrate nutrition and also constant pH values over whole experimental periods. Since the assimilation rate of nitrate and ammonium nitrogen can differ (MEVIUS and ENGEL, 1930), and only a small portion of the nitrogen supplied by flowing solutions is taken up by the plants, flowing nutrient solutions do not ensure an equal nitrogen uptake by the plants from nitrate and ammonium solutions.

In the investigation under review it was, therefore, attempted to achieve a comparison of the effects of nitrate and ammonium nutrition at nearly equal cH and at an equal nitrogen uptake by the plants. For this purpose ammonium was offered in the form of $NH_4HCO_3$ and nitrate in the form of $HNO_3$, both by small successive applications.

By the successive application of small amounts of $HNO_3$ and $NH_4HCO_3$ it was endeavoured to achieve a complete uptake of the nitrogen offered during the experimental period. It was further tried to meet a probable increase in the need of nitrogen with advancing growth by increasing the amounts of nitrogen applied at a time. It was assumed that only negligibly divergent cH could develop in the solutions if only relatively/

TABLE 39: DATES OF APPLICATION AND AMOUNTS OF NITROGEN APPLIED, AND pH VALUES OF NUTRIENT SOLUTIONS DURING THE EXPERIMENTAL PERIOD OF HYDROPONIC EXPERIMENT 2.

Commencement of experiment: 18.8.1960 Harvest: 9.10.1960 Experimental duration: 52 days

| Application of nitrogen | | | pH values of solutions, range minimum - maximum, or of one replication | | | | |
|---|---|---|---|---|---|---|---|
| Dates | mg N per vessel: at each date | mg N per vessel: cumulative | Date of determination | 1. $NO_3^-$ nutrition, $SO_4^{--}$ solution | 2. $NO_3^-$ nutrition, $Cl^-$ solution | 3. $NH_4^+$ nutrition, $SO_4^{--}$ solution | 4. $NH_4^+$ nutrition $Cl^-$ solution |
| 29.8 | 2 | 2 | 18.8 | 7.1 - 7.2 | 7.1 - 7.1 | 7.1 - 7.1 | 7.1 - 7.1 |
| 31.8 | 2 | 4 | 26.8 | 6.9 - 7.0 | 7.0 - 7.1 | 7.0 - 7.1 | 6.9 - 7.0 |
| 2.9 | 2 | 6 | 7.9 | 6.8 | 7.0 | 6.9 | 7.0 |
| 5.9 | 2 | 8 | 9.9 | 6.6 - 6.7 | 6.7 - 6.8 | 6.7 - 6.7 | 6.7 - 6.8 |
| 7.9 | 5 | 13 | 14.9 | 6.3 - 6.4 | 6.4 - 6.5 | 6.5 - 6.7 | 6.7 - 6.8 |
| 9.9 | 5 | 18 | 17.9 | 6.1 - 6.4 | 6.2 - 6.4 | 6.4 - 6.7 | 6.3 - 6.5 |
| 10.9 | 5 | 23 | 25.9 | 5.2 - 5.7 | 5.4 - 5.7 | 6.5 - 6.8 | 6.5 - 6.9 |
| 12.9 | 7 | 30 | 28.9 | 6.2 - 6.5 | 6.0 - 6.5 | 6.2 - 6.6 | 6.1 - 6.4 |
| 14.9 | 10 | 40 | 10.10 | 5.2 - 5.7 | 6.1 - 6.3 | 7.2 - 7.5 | 6.9 - 7.2 |
| 15.9 | 5 | 45 | | | | | |
| 16.9 | 10 | 55 | | | | | |
| 17.9 | 20 | 75 | | | | | |
| 18.9 | 20 | 95 | | | | | |
| 19.9 | 20 | 115 | | | | | |
| 20.9 | 20 | 135 | | | | | |
| 21.9 | 20 | 155 | | | | | |
| 22.9 | 20 | 175 | | | | | |
| 29.9 | 20 | 195 | | | | | |
| 4.10 | 5 | 200 | | | | | |

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relatively small quantities of ammonium and nitrate were offered at a time and both nitrogenous compounds were completely taken up by the plants. Constant pH values over the whole experimental period were not expected, because a tendency of the nitrogen free solutions to change their cH under the influence of the growing plants had to be reckoned with. On account of this tendency the possibility that different growth intensities in different treatments might have led to divergent cH could not be excluded.

While $HNO_3$ was applied in small amounts at a time in order to prevent noticeable changes in the cH of the solutions, ammonium was applied in this way mainly in order to prevent high $NH_3$ - tensions in the solutions. It is known that high $NH_3$ - tensions can have very harmful effects on plants. The $NH_3$ - tension in a solution depends mainly on the ammonium concentration and the cH in the solution. With decreasing pH the $NH_3$ - tension in solutions decreases (MEVIUS and ENGEL, 1930). As the prevention of a decrease in the pH of the solutions with applications of $HNO_3$ was considered to be the greater problem in this experiment, a neutral solution was used which was buffered against the decrease in the pH. In this way higher $NH_3$ - tensions were countered only be means of small ammonium applications at a time and not by a high cH.

<u>Observations and Discussion of pH Values</u> : From about 30 days after the commencement of the experiment, the plants with nitrate nutrition grew slightly better than those with ammonium nutrition. Only slightly higher pH values (Table 39) in the solutions with ammonium than in those with nitrate application were obtained at that stage. Thereafter the applications of ammonium caused a darkening of the colour of the leaves, but not an appreciable increase in the growth intensity. In contrast, the applications of nitrate were followed by a considerable increase in the rate of growth.

A bluish-green colour of the plants supplied with ammonium was suspected to have been caused by a high $NH_3$ - tension in the solution and, accordingly, a high ammonia uptake by the plants. Therefore, the nitrogen applications were suspended for a few days to allow the plants to consume all the nitrogen offered. Distinct differences between the pH values of the solutions with

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the addition of ammonium and nitrate, determined 38 days after the experiment had commenced, seemed to prove the suspicion of an incomplete uptake of the nitrogen offered to the plants. These differences between the pH values disappeared after a few days without an application of nitrogen. During the last experimental period, the growth was much more vigorous with nitrate than with ammonium nutrition.

With nitrate nutrition both sulphate and chloride solutions resulted in a similar plant growth. In contrast, the plants supplied with ammonium showed a better growth in the chloride than in the sulphate solution.

Towards the end of the experiment the plants with ammonium nutrition in combination with the sulphate solution developed dry leaves and root decay. Discoloured roots and a few dry leaves were also observed among the plants supplied with ammonium in chloride solutions.

An inability of the decayed plants supplied with ammonium to take up the nitrogen offered during the final period of the experiment, evidently had an influence on the pH of the solutions, determined at the termination of the experiment. With nitrate nutrition, the final pH of the chloride solutions were higher than those of the sulphate solutions. This may indicate a more complete uptake of nitrate by the plants grown in chloride solutions shortly before the experiment terminated.

The plants were not able to use ammonium nitrogen as efficiently as nitrate nitrogen. It is suspected that the detrimental effects of ammonium nitrogen on the plants can be ascribed to high ammonia tensions in the solutions. Temporarily high ammonia tensions may have occurred, in spite of the successive applications of ammonium in small amounts, because the pH values of the solutions were relatively high.

Results : The results are presented in Table 40. The observations during the last experimental period are well reflected in the yields. In both chloride and sulphate solutions much higher plant yields were obtained with nitrate than with ammonium nutrition. With nitrate nutrition in combination with either sulphate or chloride solution similar herbage, root and total plant weights were obtained. In contrast, ammonium nutrition led to slightly higher herbage, root and total plant weights in combination with chloride

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TABLE 40 : INFLUENCE OF NITRATE AND AMMONIUM NUTRITION IN COMBINATION WITH SULPHATE AND CHLORIDE SOLUTIONS ON THE GROWTH AND NITROGEN METABOLISM OF MAIZE
HYDROPONIC EXPERIMENT 2

| Treatments: Nitrogen form and kind of nutrient solution | Dry weight, g/vessel | | | Protein N, % | | Soluble N, % | | Nitrate N, % | | Total N, % | | mg N/vessel in | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | herb. | roots | total | herb. | roots | herb. | roots | herb. | roots | herb. | roots | herb. | roots | total |
| 1. $NO_3^-$ nutrition, sulphate solution | 9.36 | 1.36 | 10.7 | 1.29 | 1.10 | 0.34 | 0.31 | 0.024 | 0.000 | 1.63 | 1.41 | 153 | 19.2 | 172 |
| 2. $NO_3^-$ nutrition, chloride solution | 9.69 | 1.18 | 10.9 | 1.22 | 1.25 | 0.32 | 0.34 | 0.012 | 0.000 | 1.54 | 1.59 | 149 | 18.8 | 168 |
| 3. $NH_4^+$ nutrition, sulphate solution | 2.91 | 0.58 | 3.5 | 1.17 | 1.33 | 1.30 | 0.52 | – | – | 2.47 | 1.85 | 72 | 10.7 | 83 |
| 4. $NH_4^+$ nutrition, chloride solution | 4.80 | 0.83 | 5.6 | 1.33 | 1.40 | 1.06 | 0.76 | – | – | 2.39 | 2.16 | 115 | 17.9 | 133 |
| SE | 0.488 | 0.0746 | 0.522 | 0.0495 | 0.0744 | 0.0690 | 0.0574 | – | – | 0.0697 | 0.095 | 9.66 | 1.39 | 10.2 |
| LSD (P=0.05) | 1.56 | 0.24 | 1.7 | – | - | 0.22 | 0.18 | – | – | 0.22 | 0.30 | 31 | 4.4 | 33 |

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solution than in combination with sulphate solution.

With nitrate as nitrogen source, the nitrate content of the herbage tended to be slightly higher when the sulphate than when the chloride solution was used. Generally, however, the results with nitrate nutrition do not indicate any appreciable influence of the kind of solution ($SO_4^{--}$ or $CL^-$) on the content of the different nitrogen fractions and of total nitrogen. Of interest is the absence of nitrate in the roots and its presence in the herbage.

With ammonium as nitrogen source, the chloride solution resulted in a lower percentage soluble nitrogen in the herbage and a higher percentage soluble nitrogen in the roots than the sulphate solution. Leaching of soluble N-compounds from the more decayed roots of the sulphate solution, or ammonium uptake up to a later growth stage from the chloride solution, may have caused this higher content of soluble nitrogen of the roots grown in the chloride solution.

The plants supplied with ammonium contained more nitrogen in both herbage and roots when grown in chloride than when grown in sulphate solution. A higher nitrogen uptake from the chloride than from the sulphate solution is thereby indicated. This may be due mainly to a better health and higher growth intensity of the plants grown in chloride solution during the final experimental period.

If the results with nitrate and ammonium nutrition are compared with regard to the nitrogen fractions, it becomes evident that the two sources of nitrogen did not influence the percentage protein nitrogen to any appreciable extent. The plants supplied with ammonium contained considerably more soluble nitrogen per unit of dry matter than the plants supplied with nitrate. The figures for the herbage show the greatest difference. The particularly high percentage of soluble nitrogen in the plant material of the plants supplied with ammonium indicates that these plants were unable to convert all the available nitrogen to protein. Obviously, a degree of ammonia poisoning of the plants had taken place. The nitrogen taken up seems to have been readily transferred to the herbage. Possibly the rate of $CO_2$ assimilation was also hampered by the adverse effects of an excessive supply of ammonia, caused by the relatively high pH of the solutions, in spite of the application of ammonium

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in relatively small amounts on successive dates. This, in turn, may have caused an insufficient carbohydrate supply for the detoxication of the ammonia taken up by the plants.

With nitrate nutrition, on the other hand, there was no difficulty in a conversion of the nitrogen taken up by the plants. The nitrate nitrogen was well utilized and the healthy plants were also able to take up more nitrogen from the solutions than the plants supplied with ammonium.

According to the experimental evidence maize did not prove to have as comparatively a halophile character as have some other plant species (Beta, Chenopodium). Nitrate can accumulate temporarily in the plant tissue, but is readily and quantitatively reduced and utilized for the synthesis of protein. Traces of nitrate nitrogen found in the herbage probably originated from nitrate applied shortly before the plants were harvested. A tendency towards a slightly higher nitrate content of the herbage with sulphate than with chloride solution may, according to the final pH of the solutions, be related to a higher nitrate uptake during the final experimental period, and not to a higher rate of reduction in the plants grown in chloride solution.

There were no signs of a better growth in chloride than in sulphate solution when the plants were given nitrate. With ammonium nutrition, on the other hand, the chloride solution led to higher plant yields than the sulphate solution. This result was, however, obtained at an advanced degree of decay of the plants. A better resistance against unfavourable growth conditions, caused by temporarily high $NH_3$-tensions in the solutions, might possibly be attributed to the plants grown in the chloride solution.

It would appear risky to make the conclusion that the favourable effect of chloride in the case of ammonium nutrition can be attributed to the function of chloride as a monovalent anion and as an antagonist to the polyvalent anions in the plant. In the same way, the lack of any distinct chloride effect in the case of nitrate nutrition cannot simply be attributed to the presence of nitrates in the plants which might have functioned as antagonists to polyvalent anions in the case of the sulphate solution containing no chlorides. The general growth conditions with ammonium and nitrate nutrition differed too much to allow such conclusions

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which are based on the absence of a chloride effect with nitrate nutrition and its presence with ammonium nutrition.

Hydroponic Experiment 3.

This experiment served the solution of the same problems as Experiment 2. In order to avoid harmful $NH_3$-tensions in the case of ammonium nutrition, a nutrient solution with a higher cH and a tendency towards a stronger increase in the cH with advancing growth was used in this experiment. The sulphate solution was similar to that used by SCHMIDT (1955) in experiments with *Vicia faba*. It contained 500 mg $P_2O_5$ as $CaHPO_4 \cdot 2H_2O$, 1000 mg $K_2O$ as $K_2SO_4$, 300 mg CaO as $CaSO_4 \cdot 2H_2O$, 200 mg MgO as $MgSO_4 \cdot 7H_2O$, 300 mg $Na_2$ Fe-EDTA and 5 ml Hoagland A-Z solution in 4000 ml solution per vessel. In addition to this solution, three solutions were used in which 10, 50 or 90 per cent of each of the sulphates had been replaced by equivalent amounts of the corresponding chlorides. For the nitrogen nutrition $HNO_3$ and $NH_4HCO_3$ were applied in combination with each of the four nutrient solutions. Similarly as in the previous experiment, the nitrogenous compounds were applied in small amounts on successive dates. Four replicate vessels were provided per treatment. The dates of application and the quantities of nitrogen applied at a time as well as the pH values determined at intervals during the experimental period are presented in Table 41. The experiment commenced on February 27th, 1961 and was terminated on April 14th, 1961.

Observations and Discussion of the pH values.

The plants generally grew more vigorously than in the previous experiment, which may indicate that the nutrient solution of this experiment was more suitable to maize than the previous ones. Since the nutrient solutions of this experiment were buffered against an increase in the cH to a lesser degree than the previous ones, greater changes in the pH values had to be expected. The chloride solutions tended to have slightly higher pH values than the sulphate solutions. No distinct treatment effects were observed during the early period of the experiment. Later the plants supplied with nitrate differed slightly in appearance when compared with those supplied with ammonium. The plants supplied with nitrate had slightly thinner stems and were slightly taller than the plants supplied with ammonium. The latter were slightly darker and greyish-green in colour. In general the differences were very small and it was difficult to decide whether nitrate and ammonium nutrition had in-

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TABLE 41 : DATES OF APPLICATION AND AMOUNTS OF NITROGEN APPLIED, AND pH VALUES OF NUTRIENT SOLUTIONS DURING THE EXPERIMENTAL PERIOD OF HYDROPONIC EXPERIMENT 3

Commencement of experiment : 27.2.1961 Harvest : 14.4.1961

Experimental duration : 46 days

| Application of nitrogen | | | pH-values of solutions, range minimum - maximum | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $a_0$ nitrate nutrition | | | | $a_1$ ammonium nutrition | | | |
| | | | | Equiv. weight $SO_4^{--}$:$Cl^-$ in solutions = | | | | Equiv. weight $SO_4^{--}$:$Cl^-$ in solutions = | | | |
| Dates | mg N per vessel at each date | mg N per vessel cumulative | Date of determination | $b_0$ 100:0 | $b_1$ 90:10 | $b_2$ 50:50 | $b_3$ 10:90 | $b_0$ 100:0 | $b_1$ 90:10 | $b_2$ 50:50 | $b_3$ 10:90 |
| 28.2 to 15.3 | 2 at 1-2 day intervals | | 28.2 | 5.9-6.2 | 5.9-6.0 | 5.8-6.0 | 6.1-6.3 | 5.8-5.9 | 5.8-5.9 | 5.9-6.3 | 6.2-6.4 |
| | | 20 | 9.3 | 5.6-5.8 | 5.7-5.8 | 5.9-6.0 | 6.3-6.4 | 5.8-5.8 | 5.8-6.0 | 6.0-6.2 | 6.1-6.4 |
| 16.3 to 30.3 | 5 at 1-2 day intervals | | 20.3 | 4.9-5.0 | 5.2-5.3 | 5.3-5.5 | 5.8-6.0 | 5.1-5.5 | 5.3-5.6 | 5.8-6.0 | 6.0-6.2 |
| | | 85 | 25.3 | 4.7-5.0 | 4.9-5.1 | 5.1-5.3 | 5.4-5.9 | 4.8-5.1 | 5.2-5.4 | 5.1-5.9 | 5.7-6.0 |
| 31.3 to 11.4 | 10 at 1-3 day intervals | | 10.4 | 3.6-3.9 | 3.4-3.8 | 3.9-4.3 | 3.8-4.4 | 3.5-4.1 | 3.9-4.3 | 4.2-5.0 | 4.1-5.2 |
| | | 150 | 14.4 | 3.4-3.6 | 3.5-3.8 | 3.9-4.3 | 3.5-4.5 | 3.6-4.3 | 3.9-4.5 | 4.1-5.2 | 4.2-4.9 |

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fluenced the growth in a different way. The plants were harvested earlier than intended because mucilage appeared in some of the solutions where ammonium had been applied. The roots of the plants concerned decayed slightly during the last days of the experimental period.

Results : The results of the third hydroponic experiment are presented in Table 42.

The water content of the green herbage was determined in this experiment. It was influenced by both the form of nitrogen nutrition and the kind of solution. The solutions containing chlorides resulted in higher water contents of the herbage than the solution containing sulphates and no chlorides. An increased water content became evident when 10% of the sulphates of the sulphate solution had been replaced by chlorides. Increasing portions of chlorides were not followed by a further increase in the water content. A similar influence of chloride on the water content of plant material was also found by SCHMALFUSS and REINICKE (1960) in the case of Spinacia oleracea. The results obtained with maize demonstrate the hydrophile character of the chloride ions and their contribution to the hydration of the protoplasm colloids.

The water content of the green herbage was also higher with nitrate than with ammonium nutrition. This result, however, may not be ascribed simply to an anion function of the nitrates similar to that of the chlorides, although an equal growth under all treatments which was generally obtained, would seem to allow conclusions on the nitrate and ammonium effects on the water content of the plant material. It must be borne in mind that no nitrates were found in the plant material harvested. Shortly before the date of harvesting, a slight decay of the roots of the plants supplied with ammonium was observed, which might have effected a different water uptake with nitrate when compared with ammonium nutrition. It appears, therefore, that this experiment does not allow a conclusion on the influence of nitrate and ammonium nutrition on the water content of the plant material.

The herbage, root and total plant weights as well as the quantity of nitrogen in the herbage and the total nitrogen uptake from the solutions did not differ appreciably between the treatments. The treatments affected

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TABLE [illegible]: INFLUENCE OF NITRATE AND AMMONIUM NUTRITION IN COMBINATION WITH INCREASING LEVELS OF CHLORIDE AND DECREASING LEVELS OF SULPHATE IN THE SOLUTIONS ON THE GROWTH, WATER CONTENT OF THE HERBAGE AND THE NITROGEN METABOLISM OF MAIZE
HYDROPONIC EXPERIMENT 3

| A. N applied as | B. Equiv. weight $SO_4$:Cl= | $H_2O$ in herbage, % | Dry weight, g/vessel | | | Protein N, % | | Soluble N, %+) | | Total N, % | | mg N/vessel in | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | herb. | roots | total | herb. | roots | herb. | roots | herb. | roots | herb. | roots | total |
| $a_0HNO_3$ | $b_0$ 100 : 0 | 83.3 | 11.0 | 1.65 | 12.6 | 0.68 | 0.92 | 0.32 | 0.47 | 1.00 | 1.39 | 110 | 23.0 | 113 |
| | $b_1$ 90 : 10 | 85.6 | 11.6 | 1.93 | 13.5 | 0.79 | 0.80 | 0.25 | 0.35 | 1.04 | 1.15 | 121 | 22.2 | 143 |
| | $b_2$ 50 : 50 | 84.8 | 12.2 | 2.20 | 14.4 | 0.70 | 0.90 | 0.19 | 0.29 | 0.89 | 1.19 | 108 | 26.1 | 134 |
| | $b_3$ 10 : 90 | 84.2 | 9.8 | 1.18 | 11.0 | 0.67 | 1.07 | 0.31 | 0.22 | 0.98 | 1.29 | 96 | 15.2 | 111 |
| | Mean | 84.5 | 11.2 | 1.74 | 12.9 | 0.71 | 0.92 | 0.26 | 0.33 | 0.97 | 1.24 | 109 | 21.6 | 130 |
| $a_1NH_4HCO_3$ | $b_0$ 100 : 0 | 82.2 | 12.1 | 1.86 | 14.0 | 0.71 | 0.84 | 0.29 | 0.46 | 1.00 | 1.30 | 121 | 24.2 | 145 |
| | $b_1$ 90 : 10 | 83.8 | 11.2 | 2.00 | 13.2 | 0.69 | 0.72 | 0.33 | 0.48 | 1.02 | 1.20 | 114 | 23.9 | 138 |
| | $b_2$ 50 : 50 | 83.8 | 11.4 | 1.97 | 13.4 | 0.72 | 0.73 | 0.29 | 0.53 | 1.01 | 1.26 | 115 | 24.9 | 140 |
| | $b_3$ 10 : 90 | 83.2 | 11.8 | 1.73 | 13.5 | 0.90 | 1.02 | 0.10 | 0.30 | 1.00 | 1.32 | 118 | 22.8 | 141 |
| | Mean | 83.2 | 11.6 | 1.89 | 13.5 | 0.76 | 0.83 | 0.25 | 0.44 | 1.01 | 1.27 | 117 | 24.0 | 141 |
| Mean | $b_0$ 100 : 0 | 82.8 | 11.6 | 1.76 | 13.3 | 0.70 | 0.88 | 0.30 | 0.46 | 1.00 | 1.34 | 116 | 23.6 | 139 |
| | $b_1$ 90 : 10 | 84.7 | 11.4 | 1.96 | 13.4 | 0.75 | 0.76 | 0.29 | 0.41 | 1.04 | 1.17 | 118 | 23.0 | 140 |
| | $b_2$ 50 : 50 | 84.3 | 11.8 | 2.08 | 13.9 | 0.71 | 0.82 | 0.24 | 0.41 | 0.95 | 1.23 | 112 | 25.5 | 137 |
| | $b_3$ 10 : 90 | 83.7 | 10.8 | 1.46 | 12.3 | 0.78 | 1.04 | 0.21 | 0.26 | 0.99 | 1.30 | 107 | 19.0 | 126 |
| | Mean | 83.8 | 11.4 | 1.82 | 13.2 | 0.74 | 0.88 | 0.26 | 0.38 | 0.99 | 1.25 | 113 | 2.28 | 136 |
| SE | A | 0.195 | 0.400 | 0.127 | 0.504 | 0.0174 | 0.0484 | 0.0133 | 0.0302 | 0.0196 | 0.0531 | 4.28 | 0.88 | 4.68 |
| | B | 0.276 | 0.565 | 0.179 | 0.712 | 0.0246 | 0.0685 | 0.0187 | 0.0427 | 0.0277 | 0.0751 | 6.05 | 1.24 | 6.61 |
| | AB | 0.391 | 0.799 | 0.254 | 1.01 | 0.0348 | 0.0969 | 0.0265 | 0.0604 | 0.0391 | 0.106 | 8.55 | 1.76 | 9.35 |
| LSD (P=0.05) | A | 0.57 | - | - | - | - | - | - | 0.09 | - | - | - | 2.6 | - |
| | B | 0.81 | - | - | - | - | - | 0.06 | 0.13 | - | - | - | 3.6 | - |
| | AB | - | - | - | - | 0.10 | - | 0.08 | 0.18 | - | - | - | - | - |

+) The plants contained no nitrate

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TABLE [illegible] INFLUENCE OF NITRATE AND AMMONIUM NUTRITION IN COMBINATION WITH INCREASING LEVELS OF CHLORIDE AND DECREASING LEVELS OF SULPHATE IN THE SOLUTIONS ON THE GROWTH, WATER CONTENT OF THE HERBAGE AND THE NITROGEN METABOLISM OF MAIZE

HYDROPONIC EXPERIMENT 3

| A. N applied as | B. Equiv. weight $SO_4$:Cl= | $H_2O$ in herbage, % | Dry weight, g/vessel | | | Protein N, % | | Soluble N, % +) | | Total N, % | | mg N/vessel in | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | herb. | roots | total | herb. | roots | herb. | roots | herb. | roots | herb. | roots | total |
| $a_0HNO_3$ | $b_0$ 100 : 0 | 83.3 | 11.0 | 1.65 | 12.6 | 0.68 | 0.92 | 0.32 | 0.47 | 1.00 | 1.39 | 110 | 23.0 | 113 |
| | $b_1$ 90 : 10 | 85.6 | 11.6 | 1.93 | 13.5 | 0.79 | 0.80 | 0.25 | 0.35 | 1.04 | 1.15 | 121 | 22.2 | 143 |
| | $b_2$ 50 : 50 | 84.8 | 12.2 | 2.20 | 14.4 | 0.70 | 0.90 | 0.19 | 0.29 | 0.89 | 1.19 | 108 | 26.1 | 134 |
| | $b_3$ 10 : 90 | 84.2 | 9.8 | 1.18 | 11.0 | 0.67 | 1.07 | 0.31 | 0.22 | 0.98 | 1.29 | 96 | 15.2 | 111 |
| | Mean | 84.5 | 11.2 | 1.74 | 12.9 | 0.71 | 0.92 | 0.26 | 0.33 | 0.97 | 1.24 | 109 | 21.6 | 130 |
| $a_1NH_4HCO_3$ | $b_0$ 100 : 0 | 82.2 | 12.1 | 1.86 | 14.0 | 0.71 | 0.84 | 0.29 | 0.46 | 1.00 | 1.30 | 121 | 24.2 | 145 |
| | $b_1$ 90 : 10 | 83.8 | 11.2 | 2.00 | 13.2 | 0.69 | 0.72 | 0.33 | 0.48 | 1.02 | 1.20 | 114 | 23.9 | 138 |
| | $b_2$ 50 : 50 | 83.8 | 11.4 | 1.97 | 13.4 | 0.72 | 0.73 | 0.29 | 0.53 | 1.01 | 1.26 | 115 | 24.9 | 140 |
| | $b_3$ 10 : 90 | 83.2 | 11.8 | 1.73 | 13.5 | 0.90 | 1.02 | 0.10 | 0.30 | 1.00 | 1.32 | 118 | 22.8 | 141 |
| | Mean | 83.2 | 11.6 | 1.89 | 13.5 | 0.76 | 0.83 | 0.25 | 0.44 | 1.01 | 1.27 | 117 | 24.0 | 141 |
| Mean | $b_0$ 100 : 0 | 82.8 | 11.6 | 1.76 | 13.3 | 0.70 | 0.88 | 0.30 | 0.46 | 1.00 | 1.34 | 116 | 23.6 | 139 |
| | $b_1$ 90 : 10 | 84.7 | 11.4 | 1.96 | 13.4 | 0.75 | 0.76 | 0.29 | 0.41 | 1.04 | 1.17 | 118 | 23.0 | 140 |
| | $b_2$ 50 : 50 | 84.3 | 11.8 | 2.08 | 13.9 | 0.71 | 0.82 | 0.24 | 0.41 | 0.95 | 1.23 | 112 | 25.5 | 137 |
| | $b_3$ 10 : 90 | 83.7 | 10.8 | 1.46 | 12.3 | 0.78 | 1.04 | 0.21 | 0.26 | 0.99 | 1.30 | 107 | 19.0 | 126 |
| | Mean | 83.8 | 11.4 | 1.82 | 13.2 | 0.74 | 0.88 | 0.26 | 0.38 | 0.99 | 1.25 | 113 | 2.28 | 136 |
| SE | A | 0.195 | 0.400 | 0.127 | 0.504 | 0.0174 | 0.0484 | 0.0133 | 0.0302 | 0.0196 | 0.0531 | 4.28 | 0.88 | 4.68 |
| | B | 0.276 | 0.565 | 0.179 | 0.712 | 0.0246 | 0.0685 | 0.0187 | 0.0427 | 0.0277 | 0.0751 | 6.05 | 1.24 | 6.61 |
| | AB | 0.391 | 0.799 | 0.254 | 1.01 | 0.0348 | 0.0969 | 0.0265 | 0.0604 | 0.0391 | 0.106 | 8.55 | 1.76 | 9.35 |
| LSD (P=0.05) | A | 0.57 | - | - | - | - | - | - | 0.09 | - | - | - | 2.6 | - |
| | B | 0.81 | - | - | - | - | - | 0.06 | 0.13 | - | - | - | 3.6 | - |
| | AB | - | - | - | - | 0.10 | - | 0.08 | 0.18 | - | - | - | - | - |

+) The plants contained no nitrate

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TABLE 42 : INFLUENCE OF NITRATE AND AMMONIUM NUTRITION IN COMBINATION WITH INCREASING LEVELS OF CHLORIDE AND DECREASING LEVELS OF SULPHATE IN THE SOLUTIONS ON THE GROWTH, WATER CONTENT OF THE HERBAGE AND THE NITROGEN METABOLISM OF MAIZE

HYDROPONIC EXPERIMENT 3

| A. N applied as | B. Equiv. weight | $SO_4$:Cl= | $H_2O$ in herbage, % | Dry weight, g/vessel | | | Protein N, % | | Soluble N, %+) | | Total N, % | | mg N/vessel in | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | herb. | roots | total | herb. | roots | herb. | roots | herb. | roots | herb. | roots | total |
| $a_0$ $HNO_3$ | $b_0$ | 100 : 0 | 83.3 | 11.0 | 1.65 | 12.6 | 0.68 | 0.92 | 0.32 | 0.47 | 1.00 | 1.39 | 110 | 23.0 | 113 |
| | $b_1$ | 90 : 10 | 85.6 | 11.6 | 1.93 | 13.5 | 0.79 | 0.80 | 0.25 | 0.35 | 1.04 | 1.15 | 121 | 22.2 | 143 |
| | $b_2$ | 50 : 50 | 84.8 | 12.2 | 2.20 | 14.4 | 0.70 | 0.90 | 0.19 | 0.29 | 0.89 | 1.19 | 108 | 26.1 | 134 |
| | $b_3$ | 10 : 90 | 84.2 | 9.8 | 1.18 | 11.0 | 0.67 | 1.07 | 0.31 | 0.22 | 0.98 | 1.29 | 96 | 15.2 | 111 |
| | Mean | | 84.5 | 11.2 | 1.74 | 12.9 | 0.71 | 0.92 | 0.26 | 0.33 | 0.97 | 1.24 | 109 | 21.6 | 130 |
| $a_1$ $NH_4HCO_3$ | $b_0$ | 100 : 0 | 82.2 | 12.1 | 1.86 | 14.0 | 0.71 | 0.84 | 0.29 | 0.46 | 1.00 | 1.30 | 121 | 24.2 | 145 |
| | $b_1$ | 90 : 10 | 83.8 | 11.2 | 2.00 | 13.2 | 0.69 | 0.72 | 0.33 | 0.48 | 1.02 | 1.20 | 114 | 23.9 | 138 |
| | $b_2$ | 50 : 50 | 83.8 | 11.4 | 1.97 | 13.4 | 0.72 | 0.73 | 0.29 | 0.53 | 1.01 | 1.26 | 115 | 24.9 | 140 |
| | $b_3$ | 10 : 90 | 83.2 | 11.8 | 1.73 | 13.5 | 0.90 | 1.02 | 0.10 | 0.30 | 1.00 | 1.32 | 118 | 22.8 | 141 |
| | Mean | | 83.2 | 11.6 | 1.89 | 13.5 | 0.76 | 0.83 | 0.25 | 0.44 | 1.01 | 1.27 | 117 | 24.0 | 141 |
| Mean | $b_0$ | 100 : 0 | 82.8 | 11.6 | 1.76 | 13.3 | 0.70 | 0.88 | 0.30 | 0.46 | 1.00 | 1.34 | 116 | 23.6 | 139 |
| | $b_1$ | 90 : 10 | 84.7 | 11.4 | 1.96 | 13.4 | 0.75 | 0.76 | 0.29 | 0.41 | 1.04 | 1.17 | 118 | 23.0 | 140 |
| | $b_2$ | 50 : 50 | 84.3 | 11.8 | 2.08 | 13.9 | 0.71 | 0.82 | 0.24 | 0.41 | 0.95 | 1.23 | 112 | 25.5 | 137 |
| | $b_3$ | 10 : 90 | 83.7 | 10.8 | 1.46 | 12.3 | 0.78 | 1.04 | 0.21 | 0.26 | 0.99 | 1.30 | 107 | 19.0 | 126 |
| | Mean | | 83.8 | 11.4 | 1.82 | 13.2 | 0.74 | 0.88 | 0.26 | 0.38 | 0.99 | 1.25 | 113 | 2.28 | 136 |
| SE | A | | 0.195 | 0.400 | 0.127 | 0.504 | 0.0174 | 0.0484 | 0.0133 | 0.0302 | 0.0196 | 0.0531 | 4.28 | 0.88 | 4.68 |
| | B | | 0.276 | 0.565 | 0.179 | 0.712 | 0.0246 | 0.0685 | 0.0187 | 0.0427 | 0.0277 | 0.0751 | 6.05 | 1.24 | 6.61 |
| | AB | | 0.391 | 0.799 | 0.254 | 1.01 | 0.0348 | 0.0969 | 0.0265 | 0.0604 | 0.0391 | 0.106 | 8.55 | 1.76 | 9.35 |
| LSD (P=0.05) | A | | 0.57 | - | - | - | - | - | - | 0.09 | - | - | - | 2.6 | - |
| | B | | 0.81 | - | - | - | - | - | 0.06 | 0.13 | - | - | - | 3.6 | - |
| | AB | | - | - | - | - | 0.10 | - | 0.08 | 0.18 | - | - | - | - | - |

+) The plants contained no nitrate

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only the quantity of nitrogen contained in the roots. With ammonium nutrition the roots contained more nitrogen than with nitrate nutrition. Where 90 per cent of the sulphates had been replaced by chlorides, there was less nitrogen in the roots than in the case of the solution containing sulphates only or where either 10 or 50 per cent of the sulphates had been replaced by chlorides.

In the solution with the highest chloride content, the roots contained slightly more protein nitrogen and slightly less soluble nitrogen per unit of dry matter than the roots grown in the solutions containing considerable amounts of sulphates.

If all the results are considered it becomes evident that nitrate nutrition can be substituted by ammonium nutrition and that both nitrogen forms can lead to a very similar growth response in the case of maize. Similar conclusions were made by MEVIUS and ENGEL (1930) and PIRSCHLE (1931). Maize can also grow in the absence of both nitrate and chloride as well as in the presence of one or both of these anions. Although an anion function of chloride was indicated by an influence on the water content of the plants, the results of this experiment do not prove that chloride is of importance as a plant nutrient for maize.

## III. Investigations on the Nitrogen and Phosphate Status of Various Soils.

In the field experiments widely divergent results had been obtained with the application of nitrogen fertilizer at the two experimental sites situated at Theunissen and at Glen. There had been indications that the soil at Glen is much richer in available nitrogen than the soil at Theunissen. The results of the field experiments had, however, always been obtained under different rainfall conditions, so that in the comparisons not only the soil had differed, but also the weather. Consequently, it was desirable to compare the availability of nitrogen in the soils which had been involved in the field experiments and of other soils in the vicinity by the means of pot and laboratory experiments.

The approach to these investigations was influenced by results of previous investigations on the humus and nitrogen contents of cultivated and veld soils of various sites (SCHMIDT and SCHMIDT, 1963). These results had indicated that/

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that greater differences between the humus and nitrogen contents of cultivated and adjacent veld soils existed at 2 - 3 ft. but not at 0 - 1 ft. soil depth. At 2 - 3 ft. depth veld soils were richer in both humus and nitrogen than the soils under cultivated lands. The liberation of considerable amounts of mineral nitrogen in the deep soil layers after ploughing veld and cultivating annual crop plants was assumed and explained by the soil moisture conditions prevailing under veld and cultivated lands. After cultivation of veld, soil moisture is conserved at a considerable depth during fallowing and the early growth of annual crop plants, whereas moisture only rarely penetrates to the deeper soil layers of veld (Figs. 1 and 2, following p. 7 ).

These indications gave rise to the idea that the nitrogen status of surface soils does not give a proper indication of the nitrogen status of a whole soil profile and that the contribution of deeper soil layers to the nitrogen nutrition of crop plants can be of a greater importance. As a result, special attention was paid to the question of the contribution of different soil layers to the nitrogen and phosphate supply of plants.

a. Pot Experiment on the Nitrogen and Phosphate Status of Soils from Four Sites at Three Depths.

This experiment was designed on the lines of a Mitscherlich experiment for the determination of plant nutrient contents of soils (THUN, HERRMANN and KNICKMANN, 1955, p.160), which is mainly used for the nutrients $P_2O_5$ and $K_2O$. The Mitscherlich experiment is based on a comparison between the herbage yields of test plants when one growth factor is lacking and the yields when all growth factors are supplied. The yields obtained in the first case are expressed as percentages of those obtained in the second case. If the quantity of fertilizer applied, the yield and the empirical efficiency factor for the respective nutrient are known, the amount of the investigated nutrient available in the soil can be estimated by calculation. If the yield obtained when one of these nutrients is not applied is expressed as a percentage of that when all nutrients are applied, the quantities of $P_2O_5$ or of $K_2O$ available in soils can be read from existing tables.

For the purpose of this investigation, it was preferred to assess the relative nitrogen and phosphate status of the soils investigated only on the yields obtained without the application of nitrogen or phosphate fertilizer, expressed as

percentages/

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percentages of those obtained with addition of N, $P_2O_5$, $K_2O$, CaO and MgO.

In addition to the herbage yields of the test plants, the nitrogen and phosphate contents of the herbage were also determined and the nitrogen and phosphate gained by the herbage were calculated.

The soils at the depths 0 - 1, 1 - 2 and 2 - 3 ft. of the following sites were included in this investigation :-

1. A land situated adjacent to the plots of the field experiment O.Gl.54 at Glen which had been cultivated for two years and never been supplied with any fertilizer (Glen, new site).

2. A land of the experimental area at Glen which had been cultivated for about 35 years and had since 1945 been supplied annually with about 200 lb. superphosphate per morgen (Glen, old site).

3. The "Topland" at Glen, which had been under cultivation for about 40 years. According to information obtained, it had been supplied with superphosphate at a rate of about 150 lb. per morgen annually for a number of years (Glen, "Topland").

4. Site I of the farm "Excelsior", Theunissen, which had been cultivated for more than 35 years and supplied with superphosphate at a rate of 150 lb. per morgen about every second year since 1945 (Theunissen).

The quantity of fertilizer provided in the case where all the growth factors should be supplied was 0.5 g N as $NH_4NO_3$, 0.5 g $P_2O_5$ as $CaHPO_4 \cdot 2H_2O$, 0.3 g $K_2O$ as $K_2SO_4$, 0.1 g MgO as $MgSO_4 \cdot 7H_2O$, and 0.1 g CaO as $CaSO_4 \cdot 2H_2O$ per pot per 6 kg soil, calculated on a dry soil basis. Three replicate pots per treatment were provided.

<u>Experimental Dates</u> : The soil was sampled from maize lands during the period between the 3rd and the 13th of November, 1960, and then air dried. The test plant (two row barley) was planted on the 4th of March, 1961, and harvested on the 4th of May 1961, when the plants of some of the treatments had reached the flowering stage.

<u>Observations</u> : The germination of the seed was slightly retarded where nitrogen fertilizer had been applied to Theunissen soil. However, in general, a good germination was achieved. The differences in growth observed during the growth period, are well shown by the results of/

of the harvest.

The development of the plants was appreciably influenced by the treatments. With the exception of the plants grown in surface soil (0 - 1 ft.) from the old site at Glen, the development of the plants not supplied with phosphate fertilizer was strongly retarded. At harvesting time these plants had scarcely reached the piping stage, whereas all other plants had reached the flowering stage.

Results : In Table 43 the dry herbage yields and the amounts of nitrogen and phosphate contained in the herbage are presented for all the treatments.

In Table 44 the herbage yields in the absence of nitrogen fertilizer and those in the absence of phosphate fertilizer are given as percentages of the respective yields obtained with both nitrogen and phosphate fertilizer applied. In addition, the amounts of nitrogen gained by the herbage when nitrogen was not applied and of phosphate when phosphate was not applied, are presented as percentages of the respective amounts of nitrogen or phosphate taken up when both nitrogen and phosphate fertilizer were applied.

The herbage yields obtained from the various soils with complete fertilization were generally high and did not differ much. The highest yields were obtained on the soils from the new site at Glen and the lowest from the soils of the site at Theunissen. It is regarded as possible that 0.5 g N was not sufficient to ensure the maximum yield in the case of all the soils. Therefore, the yields obtained with the addition of all the nutrients could have been influenced by differences in the amounts of soil nitrogen available to the plants. The same does not seem to apply to phosphate, since similar herbage yields were obtained with complete fertilization in soils where widely differing contents of available phosphate were indicated by the herbage yields obtained without the application of phosphate fertilizer. The choice of the optimal nitrogen supply appears to be problematical. Owing to a low efficiency factor of nitrogen ("Wirkungsfaktor" according to MITSCHERLICH), a relatively large amount of nitrogen fertilizer would be necessary for maximum yields. However, damage to the plants can easily occur when all the nitrogen is given at the same time and at a relatively high concentration in a pot experiment with a short growth

period/

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TABLE 43 : NITROGEN AND PHOSPHATE STATUS OF SOILS AS INDICATED BY A POT EXPERIMENT WITH BARLEY AS TEST PLANT

| Fertilizer treatment | Soil depth, ft. | Dry herbage yield, g/pot | | | | | Nitrogen in herbage, mg N/pot | | | | | Phosphate in herbage, mg $P_2O_5$/pot | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Glen, new land | Glen, old land | Glen, "Top-land" | Theu-nis-sen | Mean | Glen, new land | Glen, old land | Glen, "Top-land" | Theu-nis-sen | Mean | Glen, new land | Glen, old land | Glen, "Top-land" | Theu-nis-sen | Mean |
| No nitrogen applied | 0-1 | 7.69 | 6.34 | 7.35 | 6.08 | 6.86 | 61 | 45 | 46 | 49 | 50 | 73.2 | 57.6 | 64.6 | 69.6 | 66.2 |
| | 1-2 | 8.11 | 4.69 | 7.00 | 2.98 | 5.70 | 62 | 37 | 61 | 28 | 47 | 57.6 | 46.5 | 34.8 | 30.5 | 42.4 |
| | 2-3 | 11.60 | 4.46 | 4.70 | 2.25 | 5.75 | 90 | 30 | 36 | 23 | 45 | 49.8 | 26.5 | 26.7 | 21.6 | 31.2 |
| | Mean | 9.13 | 5.16 | 6.35 | 3.77 | 6.10 | 71 | 37 | 48 | 33 | 47 | 60.2 | 43.5 | 42.0 | 40.6 | 46.6 |
| No phosphate applied | 0-1 | 4.06 | 23.47 | 4.81 | 6.27 | 9.65 | 172 | 267 | 197 | 199 | 209 | 10.1 | 98.8 | 12.6 | 12.8 | 33.6 |
| | 1-2 | 2.25 | 2.64 | 1.79 | 1.29 | 1.99 | 106 | 107 | 71 | 60 | 86 | 4.2 | 4.8 | 3.0 | 2.8 | 3.7 |
| | 2-3 | 2.44 | 2.56 | 1.44 | 1.30 | 1.94 | 113 | 100 | 57 | 57 | 82 | 4.8 | 4.1 | 2.3 | 2.7 | 3.5 |
| | Mean | 2.92 | 9.56 | 2.68 | 2.95 | 4.53 | 130 | 158 | 108 | 105 | 126 | 6.4 | 35.9 | 6.0 | 6.1 | 13.6 |
| Nitrogen and phosphate applied | 0-1 | 26.04 | 24.24 | 24.13 | 20.57 | 23.74 | 304 | 264 | 301 | 298 | 292 | 153.1 | 231.8 | 132.5 | 153.8 | 167.8 |
| | 1-2 | 26.07 | 23.26 | 20.39 | 19.17 | 22.22 | 329 | 272 | 314 | 295 | 302 | 124.4 | 112.8 | 76.9 | 84.6 | 99.7 |
| | 2-3 | 28.83 | 24.30 | 22.17 | 20.32 | 23.90 | 303 | 257 | 295 | 296 | 288 | 120.5 | 137.8 | 88.2 | 75.2 | 105.4 |
| | Mean | 26.98 | 23.93 | 22.23 | 20.02 | 23.29 | 312 | 264 | 303 | 296 | 294 | 132.7 | 160.8 | 99.2 | 104.5 | 124.3 |

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TABLE 44: NITROGEN AND PHOSPHATE STATUS OF SOILS AS INDICATED BY HERBAGE YIELDS, NITROGEN OR PHOSPHATE UPTAKE WHEN EITHER NITROGEN OR PHOSPHATE WERE NOT APPLIED, EXPRESSED AS PERCENTAGES OF THOSE WHEN BOTH NITROGEN AND PHOSPHATE WERE APPLIED

POT EXPERIMENT WITH BARLEY AS TEST PLANT

| | Soil depth, ft. | Origin of soils | | | | |
|---|---|---|---|---|---|---|
| | | Glen, new land | Glen, old land | Glen, "Top-land" | Theunissen | Mean |
| Dry material when no N applied as % of that when N applied | 0-1 | 30 | 26 | 30 | 30 | 29 |
| | 1-2 | 31 | 20 | 34 | 16 | 26 |
| | 2-3 | 40 | 18 | 21 | 11 | 24 |
| | Mean | 34 | 22 | 29 | 19 | 26 |
| N gain when no N applied as % of that when N applied | 0-1 | 20 | 17 | 15 | 16 | 17 |
| | 1-2 | 19 | 14 | 19 | 9 | 16 |
| | 2-3 | 30 | 12 | 12 | 8 | 16 |
| | Mean | 23 | 14 | 16 | 11 | 16 |
| Dry material when no $P_2O_5$ applied as % of that when $P_2O_5$ applied | 0-1 | 16 | 97 | 20 | 30 | 41 |
| | 1-2 | 9 | 11 | 9 | 7 | 9 |
| | 2-3 | 8 | 11 | 6 | 6 | 8 |
| | Mean | 11 | 40 | 12 | 15 | 19 |
| $P_2O_5$ gain when no $P_2O_5$ applied as % of that when $P_2O_5$ applied | 0-1 | 7 | 43 | 10 | 8 | 20 |
| | 1-2 | 3 | 4 | 4 | 3 | 4 |
| | 2-3 | 4 | 3 | 3 | 4 | 3 |
| | Mean | 5 | 22 | 6 | 6 | 11 |

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period of the test plant. The slightly retarded germination of the seed observed in the case of the Theunissen soil, seems to indicate that 0.5 g N was a relatively heavy application when applied at planting time.

The herbage yields and the amounts of phosphate taken up in the absence of phosphate fertilizer indicated considerable differences in the phosphate status of the soils. By far the highest amount of phosphate was available in the surface soil (0 - 1 ft.) from the old site at Glen. The subsoil from this site contained much less available phosphate, and the figures for the phosphate uptake from the soil from the two layers at 1 - 2 and 2 - 3 ft. depths were similar to those of the soils sampled at corresponding depths from the other sites. According to the evidence obtained, the surface soil layer (0 - 1 ft.) at each site contained more available phosphate than the deeper soil layers (1 - 2 and 2 - 3 ft.). The subsoils from the "Topland" at Glen and from the experimental site at Theunissen were particularly poor in available phosphate.

The herbage yields and the amounts of nitrogen in the herbage obtained without nitrogen fertilizer indicated considerable differences in the nitrogen status of the soils. The results obtained with soils from the new site at Glen show that the amount of available nitrogen in the soil was considerably higher at 2 - 3 ft. than at both 0 - 1 and 1 - 2 ft. depths. In the soil from the old site at Glen, however, the available nitrogen decreased with increasing depth. In the case of the "Topland" at Glen, the soil from the layer at 1 - 2 ft. depth contained more available nitrogen than that from the layers at both 0 - 1 and 2 - 3 ft. depths. The surface soil from Theunissen contained similar amounts of available nitrogen as the surface soils from the old site at Glen and from the "Topland". The two subsoil layers at Theunissen were poorer in available nitrogen than any of the other investigated subsoils.

The phosphate and nitrogen status of the different soils is also clearly reflected in the yields obtained without nitrogen or phosphate fertilizer, expressed as percentages of the respective yields with the application of both nitrogen and phosphate (Table 44). These figures also indicate a fairly similar supply of available nitrogen in the surface soils from the four sites. In contrast to the surface soils, the nitrogen available in the subsoils differed largely.

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According to all these results the nitrogen status of the surface soil does not necessarily give a true indication of the nitrogen supply available to a crop grown in the land. An investigation of both surface and subsoil is necessary when information on the amount of nitrogen available to a crop is required. The reason for the relatively high amount of available nitrogen in the soil from the 2 - 3 ft. soil layer of the newly established land at Glen is not seen in a translocation of mineral nitrogen through percolation, but rather in a particularly strong mineralization of soil organic matter in this specific layer.

At 0 - 3 ft. depth, the average supply of available nitrogen was highest in the soil of the new site at Glen and lowest at Theunissen. The nitrogen supply in the old land at Glen approached that of the Theunissen site and the nitrogen status of the "Topland" soil was close to that of the soil of the new site at Glen.

The difference between the nitrogen status of the soils from the old and new sites at Glen neither found its expression in the nitrogen composition of the harvested material nor in the nitrogen uptake in field experiments with maize during the 1960/61 season. (Table 31, following p.80 ). The nitrogen available in the soil of the old site at Glen probably ensured an adequate nitrogen supply to the plants and the larger amounts of nitrogen available in the soil of the new site could, on account of drought, not be used to a correspondingly increased extent in the field experiments. It must also be borne in mind that soil layers deeper than 3 ft. might have been of importance to the nitrogen nutrition of the crop.

When the nitrogen status of the soils from all the sites is considered, it becomes evident that the number of years a soil has been cultivated does not necessarily determine the amount of available nitrogen in a soil. In this respect, natural differences between the soils can be of greater importance than the number of years under cultivation. This also found its expression in previous investigations (SCHMIDT and SCHMIDT, 1963). The humus and nitrogen contents of veld soils at Theunissen proved to be considerably lower than those of veld soils at Glen, and the amounts of mineral nitrogen estimated to have been liberated during the period of cultivation were particularly low only in the case of the Theunissen experimental site.

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As regards the phosphate supply, the results from the soil of the new site at Glen are of special interest insofar as this soil had never been supplied with phosphate fertilizer. The surface soil contained more available phosphorus than the subsoil. Since this site was fenced off and not grazed for many years, the residues from the vegetation had not been removed. An improvement of the phosphate content of the surface soil could thus have taken place. According to the information obtained, all the other soils had been fairly regularly fertilized with superphosphate. The results, however, suggest that phosphate fertilizer had been applied regularly only in the case of the old site at Glen, where the cultivation measures were well supervised. Without the application of phosphate fertilizer to the surface soil from the old site at Glen, the herbage yield was 97 per cent, and the quantity of $P_2O_5$ taken up 43 per cent of the respective yield or phosphate uptake obtained with the application of both nitrogen and phosphate fertilizer. A good phosphate status of this particular soil was thereby indicated.

This demonstrates that a regular application of phosphate fertilizer leads to an enrichment of available phosphorus in the soil. Generally, however, the phosphate content of the farm soils has not been enriched by regular applications of fertilizer, as it has been the practice prevailing under better moisture conditions, e.g. in Central Europe. There, phosphate fertilizer is mainly applied in order to improve the phosphate status of the soil or to maintain it at a high level, and not so much to provide only the following crop with sufficient phosphate (SELKE, 1955, p.201). In the area under consideration in this thesis, a yield response to phosphate fertilizer does not often occur owing to the dry conditions and the small plant population per soil surface unit, *in spite of an extremely low phosphorus content* of the soil. Therefore, it appears dubious whether a general and substantial improvement of the phosphate status of the soils would be economically justified.

The results obtained with the soils from the three layers of the old land at Glen clearly demonstrate the well known fact that phosphate does not move in the soil to any appreciable extent. In spite of a particularly high phosphate content of the surface soil layer, the subsoil was poor in phosphate.

With regard to the interpretation of the nitrogen or phosphate status of the soils, the nitrogen uptake obtained without an application of phosphate fertilizer and the phosphate uptake where nitrogen fertilizer had not been applied (Table 43), are not of any significance. If these figures are compared with those obtained with the application of both nitrogen and phosphate fertilizer, it becomes evident to what extent the nitrogen uptake may be hampered by a shortage of phosphate and the phosphate uptake also be decreased if there is a lack of nitrogen. This depressive action of a deficiency of one nutrient on the uptake of the other may be explained by an influence of the deficiency on the growth, the root development and the root activity in the absorption of nutrients. For the same reasons, OLSON and DREIER (1956) found nitrogen to be a key factor in phosphorus efficiency.

It is probable that the uptake of a nutrient from the soil is decreased not only when another nutrient is deficient, but also when the same nutrient is available in an inadequate amount. The growth of the plant is also retarded in this case and a full use of the available amount of the nutrient concerned is not possible. In this respect it is of interest that several scientists found an increased use of soil phosphorus when an increase in yields took place as a response to the application of phosphate fertilizer (STRZEMIEŃSKI, 1948, and MATTINGLY, 1957). For these reasons it is probable that field and pot experiments overstate nutrient deficiencies.

). <u>Determination of the Mineral Nitrogen Content of the Soils and Soil Incubation Test</u>.

The nitrogen uptake in the pot experiment was influenced y the amounts of nitrogen available in the soils previous to lanting, as well as by the amounts which became available to he plants during the growth period. It was of particular interest to determine whether the mineral nitrogen present in he soils previous to planting, or that liberated in the soils uring the experimental period, had the greater effect on he nitrogen uptake of the test plant in the pot experiment. It was assumed that different amounts of mineral nitrogen, ccumulated in the different soils, had been of considerable importance for the results of the pot experiment, since an ppreciable accumulation of mineral nitrogen could be assumed t the deeper soil layers of the newly established land. This as indicated by the results of both the pot experiment and a

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6. <u>Determination of the Mineral Nitrogen Content of the Soils and Soil Incubation Test.</u>

The nitrogen uptake in the pot experiment was influenced by the amounts of nitrogen available in the soils previous to planting, as well as by the amounts which became available to the plants during the growth period. It was of particular interest to determine whether the mineral nitrogen present in the soils previous to planting, or that liberated in the soils during the experimental period, had the greater effect on the nitrogen uptake of the test plant in the pot experiment. It was assumed that different amounts of mineral nitrogen, accumulated in the different soils, had been of considerable importance for the results of the pot experiment, since an appreciable accumulation of mineral nitrogen could be assumed at the deeper soil layers of the newly established land. This was indicated by the results of both the pot experiment and a previous/

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previous soil investigation (SCHMIDT and SCHMIDT, 1963).

The mineral nitrogen contents of soils may be influenced by the weather conditions prevailing previous to sampling (BAUMANN and SCHENDEL, 1952 and BAUMANN and MAASS, 1957). An effort was made to secure fairly similar initial conditions by sampling during a short period and from lands having been similarly treated before sampling.

The mineral nitrogen contents of the same soils as used in the pot experiment and the liberation of mineral nitrogen in these soils during incubation under controlled conditions were investigated.

The liberation of mineral nitrogen in a soil during incubation was given by the difference between the mineral nitrogen contents of samples previous to and after incubation. This method of determining the liberation rate of mineral nitrogen was preferred to methods involving leaching of the soils previous to incubation and determining the mineral nitrogen after incubation only, as applied by STANFORD and HANWAY (1955), HANWAY and DUMENIL (1955), MUNSON and STANFORD (1955), and LENHARD (1957). It was suspected that leaching might influence the ability of the soils to liberate mineral nitrogen. The determination of both nitrate and ammonium would have required leaching with a salt solution. The soils differed considerably in texture, and it was not possible to prevent clay from passing through a number of filters used when some of the soils were leached with distilled water. Colourless filtrates were obtained in these cases only when the soils had been shaken up with $KAl(SO_4)_2$ or KCl-solutions.

HARMSEN and LINDENBERG (1949) extracted the mineral nitrogen from the soils by growing a fast growing crop previous to incubation. In the experiment of this thesis, a relatively low rate of liberation of mineral nitrogen was expected in the soils, and the growth and root development of the plants grown in the various soils differed visibly (observations after harvesting the pot experiment). An incomplete removal of root material from the soils would have influenced the liberation of mineral nitrogen in the soils. Owing to considerable differences in soil texture, especially between the soils from different depths, it was regarded as improbable that the roots could be removed to a similar extent from all soils.

Results : The results of the soil analyses and the differences between the ammonium, nitrate and total mineral nitrogen contents of the soils previous to and after incubation for 7, 14 and 21 days are presented

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in Table 45.

In order to determine relationships existing between the results of the pot experiment (Table 43, following p.110) and the soil analyses presented in Table 45, a number of correlation coefficients were calculated. The level of significance in all cases amounted to r = 0.708 at P = 0.01(++) and r = 0.576 at P = 0.05(+).

As expected, there was a close correlation (r = 0.861++) between the total mineral nitrogen contents of the soils (Table 45) and the amounts of nitrogen taken up by the herbage in the pot experiment (Table 43). The nitrate contents of the soils previous to incubation were also closely correlated with the nitrogen uptake (r = 0.856++), but not the ammonium contents (r = 0.489). The nitrogen uptake in the pot experiment (Table 43) was neither correlated with the total C and N contents of the soils (r = 0.404 and 0.318 respectively), nor with the C : N ratio (r = 0.463), nor with the increase in mineral nitrogen during incubation for 21 days ($NH_4^+$ : r = -0.336; $NO_3^-$ : r = 0.206 and $NH_4^+$-N plus $NO_3^-$-N : r = 0.011). These figures suggest that the nitrogen uptake in the pot experiment had been determined nearly exclusively by the mineral nitrogen contents of the soils previous to planting, but not by the nitrogen liberated in the soils during the vegetation period.

The C and N contents of the soils and the C : N ratio were not distinctly correlated with either the total mineral nitrogen contents (r = 0.426, 0.354 and 0.480 respectively), or with the liberation of mineral nitrogen during 21 days of incubation (r = 0.453, 0.390 and 0.443 respectively). The C and N contents of the soils and the C : N ratio were also not distinctly correlated with either the $NH_4^+$ or $NO_3^-$ contents of the soils ($NH_4^+$ : r = 0.257, 0.201 and 0.258, and $NO_3^-$ : r = 0.415, 0.352 and 0.485 respectively). The higher the C and N contents of the soils and the wider the C : N ratio, the stronger was the nitrification of ammonium during incubation. This found its expression in a negative correlation of the C contents and the C : N ratio with the increase in ammonium during incubation for 21 days (r = -0.647+ and -0.669+) and a positive correlation for C, N and C : N with the increase in the $NO_3^-$ contents during incubation (r = 0.781++, 0.674+ and 0.783++ respectively). The ammonium contents

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TABLE 45: CARBON, TOTAL NITROGEN AND MINERAL NITROGEN CONTENTS OF SOILS AND LIBERATION OF MINERAL NITROGEN DURING 7, 14 AND 21 DAYS OF INCUBATION

| Exp. site | Soil depth, ft. | C, % | N, % | C:N ratio | Mineral N, ppm., before incubation | | | Mineral N, ppm., difference after 7, 14 and 21 days of incubation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 7 days | | | 14 days | | | 21 days | | |
| | | | | | $NH_4^+$ | $NO_3^-$ | Tot. | $NH_4^+$ | $NO_3^-$ | Tot. | $NH_4^+$ | $NO_3^-$ | Tot. | $NH_4^+$ | $NO_3^-$ | Tot. |
| Glen, new land | 0-1 | 0.54 | 0.056 | 9.6 | 10.1 | 6.2 | 16.3 | -0.1 | +4.7 | +4.6 | -1.1 | +10.2 | +9.1 | +0.3 | +8.2 | +8.5 |
| | 1-2 | 0.50 | 0.057 | 8.8 | 13.3 | 5.6 | 18.9 | -2.9 | -0.4 | -3.3 | +0.5 | + 1.6 | +2.1 | +2.7 | +1.4 | +4.1 |
| | 2-3 | 0.32 | 0.043 | 7.4 | 9.8 | 13.6 | 23.4 | 0.0 | -3.3 | -3.3 | +1.6 | - 0.6 | +1.0 | +2.0 | -0.7 | +1.3 |
| | Mean | 0.45 | 0.052 | 8.7 | 11.1 | 8.5 | 19.6 | -1.0 | +0.3 | -0.7 | +0.3 | +3.7 | +3.8 | +1.7 | +3.0 | +4.7 |
| Glen, old land | 0-1 | 0.50 | 0.054 | 9.3 | 8.2 | 6.6 | 14.8 | +0.2 | +6.4 | +6.6 | -0.2 | +6.7 | +6.5 | -0.2 | +5.4 | +5.2 |
| | 1-2 | 0.38 | 0.047 | 8.1 | 7.2 | 3.6 | 10.8 | +3.7 | +0.8 | +4.5 | +3.4 | +0.2 | +3.6 | +3.8 | +0.6 | +4.4 |
| | 2-3 | 0.33 | 0.048 | 6.9 | 6.5 | 4.2 | 10.7 | +4.3 | -0.5 | +3.8 | +4.9 | +1.2 | +6.1 | +3.1 | -0.2 | +2.9 |
| | Mean | 0.40 | 0.050 | 8.0 | 7.3 | 4.8 | 12.1 | +2.7 | +2.2 | +5.0 | +2.7 | +2.7 | +5.4 | +2.2 | +1.9 | +4.2 |
| Glen, "Top-land" | 0-1 | 0.48 | 0.055 | 8.7 | 10.0 | 9.0 | 19.0 | +0.6 | +2.8 | +3.4 | +1.4 | +3.1 | +4.5 | +1.1 | +4.7 | +5.8 |
| | 1-2 | 0.40 | 0.049 | 8.2 | 13.1 | 10.9 | 24.0 | -5.1 | -0.7 | -5.8 | -0.3 | -1.5 | -1.8 | +1.6 | -0.1 | +1.5 |
| | 2-3 | 0.21 | 0.039 | 5.4 | 9.0 | 1.3 | 10.3 | +4.6 | +1.1 | +5.7 | +4.3 | +0.5 | +4.8 | +5.5 | -0.5 | +5.0 |
| | Mean | 0.36 | 0.048 | 7.5 | 10.7 | 7.1 | 17.8 | 0.0 | +1.1 | +1.1 | +1.8 | +0.7 | +2.5 | +2.7 | +1.4 | +4.1 |
| Theu-nissen | 0-1 | 0.37 | 0.046 | 8.0 | 10.0 | 5.0 | 15.0 | +1.4 | -0.8 | +0.6 | +4.6 | 0.0 | +4.6 | +5.0 | +4.4 | +9.4 |
| | 1-2 | 0.32 | 0.047 | 6.8 | 8.1 | 2.6 | 10.7 | -0.1 | -0.4 | -0.5 | +4.5 | -0.8 | +3.7 | +3.9 | -0.9 | +3.0 |
| | 2-3 | 0.22 | 0.036 | 6.1 | 10.6 | 1.2 | 11.8 | -3.5 | -0.4 | -3.9 | +1.2 | +0.3 | +1.5 | +2.1 | -0.3 | +1.8 |
| | Mean | 0.30 | 0.043 | 7.0 | 9.6 | 2.9 | 12.5 | -0.7 | -0.5 | -1.3 | +3.4 | -0.2 | +3.3 | +3.7 | +1.1 | +4.7 |

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of the soils previous to incubation had no pronounced influence on the increase in the nitrate contents of the soils during 21 days of incubation (r = 0.050).

The amounts of mineral nitrogen ($NH_4^+$ plus $NO_3^-$ - N) found in the soils previous to incubation were generally low. Calculated per morgen, the quantity of mineral nitrogen which was present at 0 - 3 ft. soil depth would, however, be considerably larger than the maximum quantity of nitrogen taken up by maize from the soil under dryland conditions during a season. Theoretically, the nitrogen uptake by maize plants could thus have been fully covered by the mineral nitrogen present in the soils at the time of sampling and, in addition, a considerable amount of mineral nitrogen could have been left for subsequent crops.

After incubation for 7 and 14 days, some soils contained less mineral nitrogen than previous to incubation. After 21 days of incubation either about equal or higher amounts of mineral nitrogen were found in the soils than before incubation. Several authors pointed out that the mineral nitrogen, accumulated in soils after incubation, does not represent all the nitrogen mineralized. Decomposition of organic matter is accompanied by a building up of the microbe population, which fixes a portion of the nitrogen mineralized. ZÖTTL (1958, 1960a and 1960c) distinguished between the total mineralization of nitrogen and the net mineralization. Only the latter is determined by soil incubation tests. The net mineralization of nitrogen was negative in some of the soils after a relatively short period of incubation, especially in the soil from the subsoil layers of the new site at Glen, the soil from the 1 - 2 ft. soil layer of the "Topland" at Glen and the soil from the 2 - 3 ft. layer of the experimental site at Theunissen. In most of these cases the net mineralization of nitrogen became either about zero or positive after 14 days of incubation.

An appreciable increase in nitrate contents after incubation was limited to the soils from the surface soil layers (0 - 1 ft.). The increase in the ammonium contents, on the other hand, tended to be more pronounced in the subsoils than in the surface soils. This suggests that the nitrification of ammonium was retarded in the subsoils. In contrast to the subsoils, the ammonium in the surface soils was readily converted to nitrate nitrogen.

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Considerable differences between the rate of liberation of mineral nitrogen were determined in the soils sampled at different depths from each site. The average amount of nitrogen liberated in the soils from the four sites (0 - 3 ft. depth) during 21 days of incubation did not differ appreciably. The incubation test thus failed to indicate the differences between the nitrogen status of the soils of the experimental sites at Glen and Theunissen as found in the field experiments.

The subsoil of the new site at Glen which proved to be particularly rich in mineral nitrogen previous to incubation, showed only a slight increase in mineral nitrogen after 21 days of incubation. It is regarded as possible that a portion of the mineral nitrogen was fixed biologically after a short period of incubation (7 and 14 days) and released to only a slight extent after 21 days of incubation. The surface soil from Theunissen gained a considerable amount of mineral nitrogen during incubation. Experience, not cited in this thesis, suggested that the nitrogen status of the soil at Theunissen also decreased pronouncedly from the soil surface to only 1 ft. depth. Possibly the surface soil is of minor importance for the nitrogen supply to crop plants, since it remains dry during extended periods.

It appears that the amounts of mineral nitrogen available in the soils were very important for the nitrogen supply to maize and determined the nitrogen fertilizer requirement of the various soils to a considerable extent. Under the prevailing climatic conditions which rarely allow a thorough leaching of the soils and require that a relatively large amount of soil is available per plant, the amount of mineral nitrogen available in the soil may be of considerably greater importance for the nitrogen supply to plants than the amount of mineral nitrogen released from the soil organic matter during the growth period. This conclusion may apply mainly to soils which have been cultivated for only a relatively short period and have accumulated certain amounts of mineral nitrogen during the period when the higher humus level of the uncultivated soil decreased due to changed conditions after cultivation.

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<u>F. FINAL DISCUSSION...../</u>

# F. FINAL DISCUSSION AND CONCLUSIONS.

## I. The Nitrogen Status of Some Central Orange Free State Soils and the Total Nitrogen Requirement of Dryland Maize.

The nitrogen status of the soils should be considered in conjunction with the dynamics of the formation and decomposition of soil organic matter, which, apart from fertilizer nitrogen and nitrogen fixed by legumes, represents the main source of nitrogen for the nutrition of plants.

The total humus and nitrogen contents of both uncultivated and cultivated Orange Free State soils are low. This applies to both lighter and to heavier soils. The reasons may be sparse vegetation under the relatively dry conditions and the rapid decomposition of soil organic matter on account of high temperatures during the greater part of the year.

It can be assumed that fairly constant conditions for the formation and decomposition of soil organic matter during an extended period, have led to the adjustment of certain humus and nitrogen levels in uncultivated soils which are typical of the climate and the type of soil. ALLISON (1957) stated that the nitrogen content of virgin soils is "stabilized". In this connection the comments on humus and climate made by WELTE (1949) may also be referred to.

The cultivation of a virgin soil usually brings about a considerable decrease in the soil organic matter and nitrogen contents (THERON, 1961, and others). This became evident in investigations on the organic matter and nitrogen contents of cultivated and veld soils sampled near the experimental areas of the maize experiments (SCHMIDT and SCHMIDT, 1963). The results of these investigations are of special interest as they are complementary to the investigations cited here. It was found that the soil organic matter content at 0 - 1 ft. depth differed relatively slightly between veld and cultivated soils in various sites at Glen and Theunissen, whereas cultivated soils contained considerably less organic matter at 2 - 3 ft. depth. This phenomenon was explained in conjunction with the results of the soil moisture studies cited before (Figs. 1 and 2, following p. 7 ). In veld, favourable conditions for the maintenance of a relatively high organic matter content can be/

be expected in soil layers below 18 in.. Occasional moisture penetration to these soil layers during the rainy season is followed by rapid moisture consumption, so that the moisture content at 18 - 36 in. is seldom above the permanent-wilting percentage. The decomposition of root material built up after occasional moisture penetration may be prevented by the subsequent drought. When veld is ploughed for the production of annual crop plants, moisture penetrates and is conserved in deep soil layers during the periods of fallowing and the early growth of the plants. As a result, the soil organic matter content in these layers decreases and considerable amounts of mineral nitrogen are liberated at an appreciable soil depth within a few years after the first cultivation (SCHMIDT and SCHMIDT, 1963).

If this is borne in mind, it becomes evident that the number of years a soil has been under cultivation may be of considerable importance for the availability of nitrogen to crop plants. The soils referred to in this thesis had been under cultivation for either relatively long (between 35 and 40 years) or short periods (two to six years). The soil of the experimental site at Theunissen had been under cultivation for more than 35 years. At Glen, an effort was made to compare the nitrogen status of soils which had been under cultivation for different periods (2 years and more, and about 35 and 40 years).

The evidence revealed by the pot experiment on the nitrogen status of the soils sampled at 0 - 3 ft. depth from three sites at Glen and from the experimental area at Theunissen, indicated that the soil at Theunissen was poorer in available nitrogen than the soils at Glen. However, the average mineral nitrogen content (ammonium plus nitrate nitrogen) of the soils at 0 - 3 ft. depth, was as low in the old land at Glen as in the experimental site at Theunissen. It is assumed that the analytical determination of ammonium in the soils was complicated by differences in soil texture, in that the degree of extraction of ammonium depended on the clay content. The assessment of the nitrogen status of the soils will, therefore, be based mainly on the results of the pot experiment. The nitrogen uptake in the pot experiment was positively correlated with the mineral nitrogen contents of the soils.

The deep soil layers (2 - 3 ft.) of the various sites

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showed the largest differences in nitrogen status, while the soils at 0 - 1 ft. depth did not differ much in available nitrogen. The influence of the period of cultivation of the soils from the various sites was reflected mainly in the nitrogen status of deep soil layers. The investigations indicated a particularly high content of mineral nitrogen in the soil of the newly established land at Glen at 2 - 3 ft. depth. This particular soil layer contained much more available nitrogen than the corresponding soils sampled from lands at Glen which had been cultivated for about 35 or 40 years. The soil of the experimental site at Theunissen proved to be particularly poor in available nitrogen at both 1 - 2 and 2 - 3 ft. depths. Previous investigations had indicated that the nitrogen status of both cultivated and uncultivated soils is particularly poor at Theunissen (SCHMIDT and SCHMIDT, 1963).

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In the investigations of this thesis the liberation of mineral nitrogen during soil incubation was determined in addition to the mineral nitrogen contents of the soils previous to incubation and the nitrogen uptake of test plants from the same soils. The liberation of mineral nitrogen during 21 days of incubation under controlled conditions was not correlated with the organic matter and total nitrogen contents of the soils, nor with the mineral nitrogen contents previous to incubation, nor with the nitrogen uptake of barley in the pot experiment. The incubation test failed to give any indication of the availability of nitrogen to maize grown in the field. On the other hand, the mineral nitrogen contents of the soils previous to incubation and, in particular, the nitrogen uptake in the pot experiment, showed considerable differences in nitrogen status between lands at Glen and Theunissen which also became evident in field experiments. This led to the conclusion that the mineral nitrogen contained in the soils was of greater importance for the nitrogen supply to maize than the mineral nitrogen liberated in the soils during the growth season.

However, the influence of the period of cultivation on the nitrogen status of the soils at Glen, as indicated by the soil investigations, failed to become evident under field conditions. According to the observations and results of the field experiments, the period of cultivation had no influence on the nitrogen uptake of maize at Glen.

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The quantities of nitrogen contained in grain and stover were determined in 3 of the 4 experimental seasons. The soil of the newly established experimental site at Glen always allowed a considerably higher nitrogen uptake than the soil of the experimental site at Theunissen which had been under cultivation for more than 35 years. The higher nitrogen uptake at Glen was not limited to the newly established site. In 1960/61, the highest nitrogen uptake was obtained on a land near the new site at Glen which had been under cultivation for about 35 years.

Tissue tests for the presence of nitrate in the plants grown on various lands, also indicated that the soils at Glen supplied more nitrogen to maize than the soils at Theunissen, irrespective of the period the soils at Glen had been under cultivation. Maize grown at Glen always contained nitrates in the stalks up to the stage of ripeness, while maize grown on the Theunissen experimental site and in the vicinity was generally free of nitrate from about the flowering stage. Pronounced nitrogen deficiency symptoms were observed in the maize of the experimental site at Theunissen and occurred on many lands in the Theunissen district. At Glen and on farms near the College of Agriculture, maize generally failed to show any signs of nitrogen deficiency at any growth stage.

The fact that the period during which the Glen soils had been under cultivation had no influence on the nitrogen status of maize may be explained as follows. On dryland where the growth is often adversely affected by drought for shorter or longer periods, soils which vary considerably in available nitrogen may lead to a similar nitrogen uptake in the course of a season, because the soils can supply the limited requirement of the plants, provided that the nitrogen status is not excessively low, as at Theunissen. In the case of the Glen soils, a cultivation period of about forty years does not seem to have been long enough to bring about so great a decrease in the nitrogen status that an insufficient supply to maize would have resulted. According to the soil investigations it would, however, be desirable to check the nitrogen status of the older lands at Glen at regular intervals in the future. On the other hand, the generally low fertility level of the soils at Theunissen would necessitate the application of nitrogen fertilizer after relatively short periods of cultivation.

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There were indications that the differences in nitrogen status between the soils at Theunissen and Glen were more pronounced than was suggested by the nitrogen uptake of maize under field conditions. The maize at Glen was more severely affected by drought and started suffering earlier during the growth seasons than the maize at Theunissen. In 1959/60, the total nitrogen uptake by the plants was determined at four successive growth stages. Where nitrogen fertilizer had not been applied, the nitrogen uptake up to each date of sampling was considerably higher at Glen than at Theunissen. Compared with Glen (100 per cent), it amounted to only between 47 and 55 per cent at Theunissen. The intensity of the nitrogen uptake during each of the periods between two successive sampling dates indicated that the nitrogen uptake at Glen was appreciably higher than at Theunissen only during the growth stages before tasseling, but not thereafter. This is of particular significance since an optimal moisture supply to the plants at both sites could be assumed for the early growth stages only. At Glen, severe drought damage to the densely spaced plants did not allow an appreciable nitrogen uptake from the soil after tasseling. At Theunissen, where the plants suffered from drought to a lesser degree than at Glen, the absence of an appreciable nitrogen uptake after tasseling was probably due mainly to a depletion of the reserves of available nitrogen in the soil.

It is also assumed that the liberation of mineral nitrogen in the soils was hampered when the soil moisture contents had reached the permanent-wilting percentage. During the three drier seasons at Glen (1958/59, 1959/60 and 1960/61), densely spaced plants either wilted or were more or less damaged by drought during the period from shortly before tasseling until the flowering stage. Even in the moist 1957/58 season, normally as well as densely spaced plants had, at the late flowering stage, depleted the soil moisture reserve at 0 – 3 ft. soil depth to about the permanent-wilting percentage. At Theunissen, soil moisture was apparently available to the plants up to later growth stages than at Glen. The plants at Theunissen were considerably less affected by drought. It appears improbable that nitrogen can be taken up by the plants when the soil moisture content has reached the permanent-wilting percentage.

All these points of view suggest that the potential nitrogen supply to plants grown in the soils at Glen was

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higher than was indicated by the nitrogen uptake of dry land maize. On the other hand, the ability of the Theunissen soils to provide maize plants with nitrogen may have been reflected fairly accurately in the nitrogen uptake during three experimental seasons.

The general conditions which led to different fertility levels in both cultivated and uncultivated soils at Glen and Theunissen are not known. A similar climate at both places can be assumed. The soils at Theunissen were only slightly lighter than those at Glen. A more productive use of soil moisture at Theunissen than at Glen became evident in the field experiments. The removal of grain nitrogen was, on account of higher grain yields and in spite of lower nitrogen contents of the grain, higher at Theunissen than at Glen. Under similar conditions heavier soils usually contain more organic matter and nitrogen than lighter soils. According to ALLISON, SHERMAN and PINCK (1949) the nature of the inorganic colloids may also have an appreciable influence on the humus level of a soil.

At Glen, the nitrogen requirement of maize was not only fully met by a sufficient nitrogen supply in the soils, but there was even a luxurious nitrogen supply when the growth conditions are taken into account. In none of the four experimental seasons did any appreciable influence of nitrogen fertilizer on either grain or stover yields become evident. The protein content of the grain was either normal (about 10 - 11%) or slightly higher than normal, and the nitrogen content of the stover was mostly high, in some cases extremely high. The stover always contained nitrates. These indications suggested that more nitrogen had been taken up than was necessary for grain formation. Under better growth conditions, this nitrogen could have been utilized for higher grain production. The plants had a considerable nitrogen reserve at their disposal, which could not be utilized.

According to the results obtained at Glen, it can be estimated that the herbage of dryland maize can take up a maximum of about 100 lb. nitrogen per morgen from the soil. This quantity is low when compared with the potential nitrogen uptake of maize grown either under more favourable climatic conditions or under irrigation. If the growth conditions of dryland maize in this area are taken into account, the amount of nitrogen the Glen soil can supply to maize must be regarded as high.

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On account of the prevailing climatic conditions, the plant population must be kept small in order to ensure an efficient utilization of the limited soil moisture. Consequently, a relatively large amount of soil is available per plant, and the amount of available soil nitrogen can be adequate or even relatively high, in spite of an absolutely poor nitrogen status of the soil. In addition, the growth and grain production of maize were often reduced by drought damage of varying degrees, although the espacement was relatively wide.

In contrast to Glen, the amounts of nitrogen the soils at Theunissen supplied to maize were insufficient for an optimal growth and grain production. The plants which had not been supplied with nitrogen fertilizer yielded grain with a very low protein content in the 1958/59 and 1959/60 seasons and stover with a very low nitrogen content in all the seasons from 1958/59 to 1960/61. Most of the nitrogen available in the leaves and stalks for translocation to the ears was absorbed by the grain. During 1958/59 and 1959/60, the nitrogen status of the plants was even insufficient for the achievement of a normal protein content of the grain. This shows that the growth and grain production at Theunissen was to a large extent limited by an insufficient supply of available nitrogen in the soil.

From the results obtained at Glen, it can be deduced that the application of nitrogen fertilizer to dryland maize would be unnecessary on soils with a nitrogen status similar to that of these lands. At Theunissen, on the other hand, the application of nitrogen fertilizer led to increased grain and stover yields. In the moist 1957/58 season, nitrogen applied at planting time (42 and 84 lb. N per morgen) caused a considerable growth response and a considerable increase in stover yields, but only a relatively small increase in grain yields. Subnormal conditions in the availability of nitrogen for grain formation, as well as stalk borer infestation may have contributed to the failure of nitrogen fertilizer to effect a substantial increase in grain production during this exceptionally moist season. According to the observations, the vegetative growth had been strongly stimulated by the application of nitrogen. Marked signs of nitrogen deficiency in most plants indicated low percentages of nitrogen in the plant material during the reproductive period of growth. The nitrogen deficiency was not limited to the plants which were not supplied with nitrogen fertilizer

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but also occurred in the plants with the lighter or heavier applications of nitrogen fertilizer, particularly at dense espacement. A ready translocation of nitrogenous compounds to the grain could assumedly not take place because the nitrogen content of the leaves and stalks had reached a very low level previous to the period of grain formation.

In the 1958/59 season a fairly normal rainfall distribution was obtained during advanced growth stages. Nitrogen applied at planting time as well as top-dressings of nitrogen fertilizer led to substantial increases in grain and stover yields. The distribution of the rain during the critical months of January and February was in 1959 closer to the supposed normal distribution at Theunissen than in any other of the experimental seasons. Therefore, the results of the 1958/59 season are considered to be the most applicable is assessing the possibilities of the application of nitrogen fertilizer to maize. It is one of the characteristics of the climate in this area that great deviations from the normal rainfall and its distribution are to be expected during most seasons. The results obtained from experiments conducted in a limited number of seasons may, therefore, vary considerably, and it is difficult to obtain results which are representative for the majority of seasons.

In comparison with the 1957/58 and 1958/59 seasons, the distribution of rain during the 1959/60 season was pronouncedly more unfavourable for maize production. Nitrogen fertilizer, accordingly, did not bring about the same response as in 1958/59. The increases in grain and stover yields were considerably smaller. On account of dry weather conditions during advanced growth stages, the nitrogen of top-dressings did not influence the grain yields.

In 1960/61, the plants at Theunissen suffered from drought at an earlier stage than during any of the previous seasons. Notwithstanding the dry conditions, nitrogen deficiency symptoms were observed. The nitrogen deficiency was less pronounced than in the previous seasons and the application of nitrogen fertilizer did not have any noticeable effect on either grain or stover yields.

When considering the evidence from the field experiments, it may be deduced that the application of nitrogen fertilizer may lead to appreciable increases in grain yields at Theunissen when the rainfall conditions are

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about normal or better than normal. The effect of nitrogen fertilizer on the yields may be either small or entirely lacking when the rainfall is either considerably below normal or very unfavourably distributed over the growth period, particularly during advanced growth stages.

In some seasons the maize yield will be limited by drought, in others by nitrogen deficiency. From the farmer's point of view it is considered desirable that the low grain yields of dry seasons be compensated for by higher ones in normal or better than normal seasons. This compensation appears to be possible only when the plants are provided with sufficient nitrogen. Therefore the application of nitrogen fertilizer is considered essential for a successful maize production on soils poor in nitrogen, in spite of the risk that yields in isolated dry seasons might fail to justify the expenditure on fertilizer. In order to reduce this financial risk to a minimum, the quantity of nitrogen fertilizer to be applied should not exceed about 40 to 80 lb. fertilizer nitrogen per morgen per season. The experimental evidence suggests that this application would ensure that more or less full advantage can be taken of fairly normal or better than normal seasons at Theunissen. On account of a large variation in the nitrogen requirement of maize during seasons with varying rainfall conditions, the optimal application of nitrogen fertilizer will vary from one season to another.

In the future, allowance must also be made for a further impoverishment of the nitrogen status of the soils due to continuous crop production. A regular application of nitrogen fertilizer may counteract this tendency and may even lead to an improvement in the nitrogen status of the soil, since the amounts of crop residues from herbage and roots and of nitrogen being returned to the soil are increased. The nitrogen cycle of a land, consisting of the nitrogen uptake by the plants and the return to the soil of the nitrogen contained in crop residues, may be brought to a higher level as far as the quantities of nitrogen involved are concerned. SCHMALFUSS (1960) demonstrated that an increased return of crop residues and of root material after the application of fertilizer may lead to increased humus contents of soils.

Larger nitrogen losses through leaching are improbable under the prevailing climatic conditions. Therefore, a certain portion of the fertilizer nitrogen not taken up by

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the plants during a dry season, may still be available for the crop of the following season (see PEARSON and ENSMINGER, 1957).

As far as an assessment of the fertilizer requirement of various crops is concerned, it is of interest that a dressing of ammonium sulphate to wheat, grown on soils near the experimental area at Theunissen, failed to affect either grain or straw yields during a number of seasons (unpublished).

<u>The Nitrogen Status and Nitrogen Requirement of Maize and the Utilization of Fertilizer Nitrogen at Different Growth Stages.</u>

The nitrogen status of maize plants is reflected in the percentage of nitrogen in the plant material, in the colour of the leaves, and in the absence or presence of nitrates in the plant tissue. When assessing the percentage of nitrogen in the plant material, the growth stage must be considered. The uptake of nitrogen generally precedes the production of plant material. Since protoplasm is formed most rapidly in young plants, these are relatively richer in nitrogen than older plants. With advancing growth, nitrogen free compounds are produced at an increased rate, and the nitrogen content of the plant material consequently decreases. When the seed is formed, nitrogenous compounds are translocated from the vegetative to the generative parts of the plants. The nitrogen content of the leaves and stalks decreases when this loss of nitrogen is not compensated for by nitrogen uptake.

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These generally accepted relationships were evident in both the field experiments and the pot experiment on the nitrogen nutrition of maize. In the 1958/59 and 1959/60 seasons, it was found that the nitrogen contents of plants harvested at a height of 8 - 15 in. (6 - 8 leaves) were generally high at both Glen and Theunissen, although the young plants had taken up only relatively little nitrogen. The low nitrogen requirement of the young plants was sufficiently met by an adequate nitrogen supply in the soil. No influence of nitrogen fertilizer on the plant weight became evident at early harvesting dates. The plants in the pot experiment showed no difference in growth intensity or leaf colour for about 28 days after planting, irrespective of the nitrogen supply. Distinct differences in the growth intensity were evident only at a later stage.

Although the nitrogen supply did not affect the growth

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intensity during the early growth stages, it was reflected in the nitrogen content of the plant material. In 1958/59 and 1959/60, it was found that the application of nitrogen fertilizer increased the nitrate and total nitrogen contents of young plants at Theunissen. In 1959/60, young plants at Glen contained more nitrate and total nitrogen than plants of the same age from corresponding fertilizer treatments at Theunissen. Nitrogen fertilizer also effected a slight increase in the nitrogen content of the plants at Glen.

The nitrogen uptake and the nitrogen content of the plants during early growth stages may be of importance to the growth intensity and the nitrogen supply to the plants at later growth stages. An improved nitrogen status of young plants (harvested 39 days after germination in 1958 and 31 days after planting in 1959) was followed by an increased production of plant material during more advanced growth stages at Theunissen. A relatively high nitrogen content of young plants may prolong the period during which sufficient nitrogen is available for optimal growth. This was reflected in both the observations and results of the field experiments at Theunissen and of the pot experiment on the nitrogen nutrition of maize. A relatively high nitrogen supply to young plants may also bring about a more vigorous growth before tasseling, and in this way improves the chances of a reasonable grain yield.

The stimulation of the growth by nitrogen fertilizer applied at an early stage may, however, also lead to an increase in the nitrogen requirement of maize. A limited amount of nitrogen available at an early stage of growth, will be fully taken up and used to increase the production of plant material. As a result, a low nitrogen content of the plant material and severe nitrogen deficiency may be reached at an advanced stage of growth even when a small quantity of fertilizer nitrogen had been available to the young plants.

The amount of nitrogen required to improve the nitrogen status of plants increases with the quantity of plant material formed. More nitrogen is required to raise the nitrogen status of plants which have built up a considerable quantity of material after an early application of a small amount of nitrogen, than in the case of limited early growth resulting from nitrogen deficiency. These relationships were reflected in the observations and results of the field experiments at Theunissen and in those of the pot experiment on the nitrogen nutrition of maize. During the moist 1957/58 season at Theunissen, nitrogen fertilizer applied at planting time resulted in a vigorous growth response before tasseling. The date on which nitrogen deficiency occurred varied in accordance with the quantity of nitrogen applied. Even 84 lb. of nitrogen applied at planting time did not prevent nitrogen deficiency during or after the flowering stage. Late in the season, increased availability of nitrogen in the soil brought about an improved nitrogen status of the smaller plants not provided with nitrogen fertilizer, but not of bigger plants which had been supplied with nitrogen fertilizer. In the pot experiment, relatively small applications of ammonium nitrate at different growth stages led to only a temporarily improved nitrogen status of the plants. Plants which suffered from severe nitrogen deficiency at an advanced growth stage, rapidly took up the nitrogen applied as ammonium nitrate, resulting in a marked increase in growth. A similar degree of nitrogen deficiency appeared again soon afterwards. This applied particularly to the plants which had been provided with nitrogen shortly after planting. In this case, the amount of plant material formed during early growth stages was relatively high. The nitrogen applied at advanced growth stages could not be considered as very efficient in improving the nitrogen status of the plants, because relatively little nitrogen had been applied in relation to the plant material produced by the plants.

During the 1958/59, 1959/60 and 1960/61 seasons at Theunissen, which were drier than the 1957/58 season, distinct symptoms of nitrogen deficiency were mostly limited to the plants which had not been supplied with nitrogen fertilizer. More or less distinct differences between the leaf colour of the plants provided with various dressings of nitrogen fertilizer indicated that the quantity of nitrogen applied had also influenced the nitrogen status of the plants. The drier conditions of these seasons did not allow as vigorous a vegetative plant growth as the moist conditions of 1957/58. It is assumed that the percentage nitrogen in the plant material, therefore, could not decrease to the same low level. Notwithstanding the drier conditions, all the plants were free of nitrates at about the flowering stage or even earlier.

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The nitrogen fertilizer applied at planting influenced the nitrogen uptake pronouncedly from 8 - 12 in. plant height until flowering. After flowering, the plants on plots which had received little (42 lb. N per morgen) or no nitrogen fertilizer at planting time, showed no further gain in nitrogen. When 84 lb. nitrogen per morgen had been given at planting time or 42 lb. shortly before flowering, appreciable amounts of nitrogen were taken up during the period from flowering until the soft dough stage. These results were obtained under conditions where no visible drought damage occurred. CARLES, SOUBIÈS and GARET (1956) also found that the maximum nitrogen uptake of maize was reached by the flowering stage when nitrogen fertilizer had not been applied, and that the nitrogen contained in maize plants increased after flowering when sufficient nitrogen fertilizer had been provided.

Under conditions of more limited moisture supply in 1959/60, the nitrogen uptake at Glen and Theunissen was highest during the growth stages from about 10 - 15 in. plant height (6 - 8 leaves) until shortly before tasseling. Thereafter a dry period without any appreciable nitrogen uptake followed. Improved moisture conditions after flowering led to a certain degree of recovery of the plants and a late increase in nitrogen uptake. During the period of the most intense nitrogen uptake, the plants at Glen took up much more nitrogen than the plants at Theunissen.

As discussed in the previous section, the growth and nitrogen uptake of the plants at Glen was obviously not limited by the nitrogen supply of the soil, but only by lack of moisture during advanced growth stages. Dry weather conditions possibly also decreased the nitrogen supply to the maize plants at Theunissen. Soil analyses had indicated that the surface soil at Theunissen contributes more nitrogen to maize than the subsoil. When the surface soil dries out during extended drought, the mineralization of soil organic matter and the liberation of mineral nitrogen as well as the uptake of available nitrogen may be stopped in the surface soil. The nitrogen supply to the plants would then depend on the subsoil only, which is poor in nitrogen. Soil moisture investigations at Glen showed that the surface soil may remain dry during extended periods. When a land has been cultivated for a number of years, the surface soil will in most cases be more fertile than the subsoil since the crop residues are ploughed into the surface soil only. These general

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relationships may have contributed to the results of SOUBIES, GADET and LENAIN (1960) in the South West of France (Toulouse). Nitrogen deficiency at an advanced growth stage under dry conditions is explained by a rise of nitrates to the soil surface at a time when the roots penetrate deeper into the soil in search of moisture. In order to ensure sufficient nitrogen supply during the reproductive period of growth, deep (15 - 20 cm) placement of nitrogen fertilizer three to four weeks before flowering is recommended. Under Central Orange Free State conditions, deep disturbance of the surface soil at an advanced growth stage by soil implements may lead to a pronounced wilting of maize, even if only dry soil is moved.

During three of four experimental seasons at Theunissen attempts were made to maintain an adequate nitrogen supply to the plants during advanced growth stages by top-dressings. During the moist 1957/58 season, nitrogen fertilizer had been applied at planting time only. No further moist seasons in which top-dressings could have proved superior to nitrogen applied at planting time were experienced. In the 1958/59 season which provided a fairly normal rainfall distribution, nitrogen fertilizer applied as late as shortly before tasseling was readily taken up by the plants. The nitrogen status of the plants was improved during the tasseling stage and thereafter, and a substantial increase in the production of plant material occurred during the period from flowering until the soft dough stage. In the 1959/60 season, pronouncedly dry periods during advanced growth stages resulted in top-dressings of nitrogen fertilizer being less effective than applications at planting time. The increase in grain yields, brought about by nitrogen fertilizer applied at planting time was, however, small in this season. In 1960/61, a season with a very unfavourable rainfall distribution, nitrogen fertilizer applied at planting time and/or as top-dressing failed to increase either grain or stover yields.

From the experimental evidence at Theunissen it may be deduced that nitrogen applied as top-dressing before tasseling may be advantageous to the plants when normal or better than normal rainfall conditions prevail during a season.

Applications of nitrogen at advanced growth stages would be of particular importance when the nitrogen status of the soil is poor and only a limited quantity of nitrogen fertilizer is to be applied on account of the irregular growth response under erratic rainfall conditions. When the

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rainfall is normal or better than normal, small amounts of nitrogen available in the soil or applied at planting time, are taken up by the plants at a relatively early growth stage. The nitrogen content of the plant material may decrease to a very low level at the time when the nitrogen requirement of the plants reaches its peak. For grain production of maize it appears to be of particular importance that sufficient nitrogen is available during the reproductive period of growth. This was also indicated by results reported by NELSON (1956), SOUBIES, GADET and LENAIN (1960), and the results of the pot experiment discussed hereafter.

In the pot experiment on the nitrogen nutrition of maize, sufficient moisture, but a limited nitrogen supply was available to the plants. Under these conditions maize readily took up nitrogen applied as late as towards the end of the flowering stage. This late application ensured that a considerable portion of the nitrogen in the plant material was readily available for translocation to the grain. As a result, higher grain yields were obtained than with earlier applications. CARLES, SOUBIÈS and GADET (1956) obtained similar results. When nitrogen fertilizer had not been applied until flowering, almost all the nitrogen subsequently absorbed, passed into the ear. These indications are of particular importance for an assessment of the possibilities of applying nitrogen to maize grown under irrigation in the newly developed irrigated area near Theunissen.

Under dryland conditions, a heavy application of nitrogen fertilizer at planting time would probably ensure a sufficient nitrogen supply to the plants during the entire growth period in the majority of seasons at Theunissen. In order to decrease the financial risk of an inadequate return for the expenditure during seasons with an insufficient moisture supply, the rate of application of nitrogen fertilizer should, however, be relatively low. When only a small quantity of nitrogen fertilizer is to be applied, it is of great significance that a favourable nitrogen status during the critical advanced growth stages can be achieved by delayed application. It may, therefore, be suggested that at least a portion of the nitrogen to be supplied be given to the plants as a top-dressing about 6 - 8 weeks after planting.

With regard to the assessment of the advisability of applying nitrogen fertilizer at advanced growth stages of crops, the results with small grain cereals obtained by

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SELKE (1955) may also be mentioned. Under Central European conditions, a certain amount of nitrogen fertilizer should be applied at planting time. Top-dressings were given in addition to nitrogen applied at planting time. According to SELKE (1955, p.282), fertilizer nitrogen applied from the beginning of flowering until shortly after flowering, is readily taken up by small grain cereals and increases the protein content of the grain. Nitrogen applied at an advanced stage of growth generally improved the grain quality and increased grain yields. The nitrogen requirement of maize is higher than that of small grain cereals. In addition, maize has a longer period of active growth and especially a longer period from flowering until the grain is ripe. Therefore, a top-dressing of nitrogen at an advanced growth stage appears to be at least as promising in the case of maize as in the case of small grain cereals.

In the experiments reported here, attention was paid to the limit to which the nitrogen content of the plant material can decrease while maize is growing, or while the nitrogen of the vegetative parts is absorbed by the cobs. At Theunissen, the nitrogen content of the plants not supplied with nitrogen fertilizer reached 0.94 per cent during the flowering stage in 1958/59 and 0.76 per cent between late flowering and the soft dough stage during the 1959/60 season. At these percentages distinct signs of nitrogen deficiency were present. Up to the soft dough stage in 1958/59 and about the half ripe stage in 1959/60, the nitrogen contents of the whole plants decreased further to respectively 0.54 and 0.67 per cent.

The lowest nitrogen contents of stover from field experiments occurred on the Theunissen experimental site at normal espacement of plants not supplied with nitrogen fertilizer. These nitrogen percentages in the dry stover amounted to 0.38 in the 1958/59 season, 0.31 in 1959/60 and 0.52 in 1960/61. In the pot experiment, a nitrogen content of 0.44 per cent was reached as early as at tasseling, and the nitrogen content decreased to 0.27 per cent up to the end of the experiment, without grain being formed. Similarly low nitrogen percentages were determined in the stover of plants which had been supplied with nitrogen fertilizer and which had formed grain. It is assumed that about 0.3 per cent nitrogen represents the minimum to which the vegetative parts of maize plants can be depleted of nitrogen until maturity.



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In all experiments, the nitrogen supply available to the plants had a considerable influence on the nitrogen content of the stover and protein content of the grain. The influence of the nitrogen supply available in the soil was always more evident than that of nitrogen fertilizer applied. During the 1958/59 season at Theunissen, the application of nitrogen increased the nitrogen content of the stover only slightly. The fairly normal rainfall distribution during the advanced growth stages had allowed relatively high grain yields. Consequently, the nitrogen of the plants could readily be absorbed by the grain during this season. Drier conditions during 1959/60, and in particular during 1960/61, prevented efficient utilization of the nitrogen taken up by the densely spaced plants of the experiments.

At Glen, nitrogen fertilizer as a rule did not affect the nitrogen contents of the stover to any noteworthy extent. These were generally high, and varied between 1.21 and 1.62 in the 1958/59 season, between 1.45 and 1.65 in 1959/60 and between 1.43 and 1.84 in 1960/61. The percentages of nitrogen in the stover from the plants with 3 ft. x 12 in. spacing were always slightly higher than those in the stover from the plants with 3 ft. x 24 in. spacing. This may be due to the lower grain yields at dense espacement and poorer utilization of the nitrogen, taken up by the plants, for the formation of grain. The early drought damage at dense espacement may also have contributed to this result as it decreased the production of nitrogen-free compounds.

In 1960/61, nitrogen percentages were determined in the stover of two other experiments at Glen. On an old land of the Glen experimental site high percentages of nitrogen (between 1.57 and 1.78) were found in stover from maize that had given a relatively high grain yield in this dry season. On an experimental site which was situated near to that of the experiment on spacing and nitrogen requirement of maize and which had been cultivated for the same period, stover nitrogen percentages between 0.97 and 1.21 were obtained. The treatments of this experiment (Time of Planting, Spacing and Nitrogen Requirement of Maize) had a considerable influence on the grain yields but not on the nitrogen content of the stover.

It is assumed that the nitrogen content of the stover is of importance for the availability of nitrogen to the crop of the next season. If stover of a poor nitrogen content, as obtained at Theunissen, is ploughed into the soil shortly before the crop of the next season is planted, a

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pronounced nitrogen negative period may be experienced.

The stover in this area is often grazed. The results of the nitrogen determinations suggest that the nutritive value of the stover may vary appreciably depending on the protein supply to the animals.

As in the case of the stover, the protein contents of the grain were also strongly influenced by the nitrogen supply to the plants. As a rule the protein contents of the grain were lower at Theunissen than at Glen. At Theunissen, protein contents of 5.8 per cent at dense and 6.6 per cent at normal espacement were obtained without an application of nitrogen fertilizer in 1958/59. Applications of 42 or 84 lb. of nitrogen raised the protein contents to between 6.5 and 7.1 per cent at dense and between 7.2 and 7.7 per cent at normal espacement. During the same season average protein contents ranging from 12.6 to 13.2 per cent were obtained at Glen, where neither espacements nor nitrogen fertilizer treatments affected the protein content of the grain to any noteworthy extent.

A marked influence of nitrogen fertilizer on the protein content of the grain was limited again in 1959/60 to the Theunissen experimental site (grain protein percentages between 6.3 and 8.7 were obtained). The protein contents at Glen varied between 11.2 and 11.9 per cent.

In 1960/61, however, similar protein contents were determined in the grain from Theunissen (between 8.7 and 10.3 per cent) and Glen (between 9.9 and 10.9 per cent in three experiments).

It appears to be impossible to achieve a further increase in the protein content of the grain by the application of nitrogen fertilizer if the protein content is high on account of a relatively high supply of nitrogen in the soil. It is interesting that the protein contents of the grain obtained in each season at Glen were often similar within each experiment, in spite of great differences between the grain yields obtained at different espacements.

On the other hand, the application of nitrogen fertilizer increased both grain yields and the protein contents of the grain during two seasons at Theunissen. It can be assumed that the protein content of the grain can be appreciably increased by nitrogen fertilizer only when the soil is poor in nitrogen. A top-dressing of nitrogen appeared to be more effective in increasing the protein content of the grain than an application at planting time,

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provided that the weather conditions allowed a fairly complete uptake of the nitrogen applied at an advanced stage of growth.

The relationship between the nitrogen content of the stover and the protein content of the grain also indicates whether the nitrogen in the plant material had been readily available for the formation of grain. Evidently, the leaves and stalks of maize plants can be depleted of nitrogen until a stover nitrogen percentage of about 0.60 per cent is reached, without the development of a depressing effect of nitrogen shortage on the protein content of the grain. On the other hand, much higher stover nitrogen percentages are not accompanied by appreciably increased grain protein contents.

The protein content of the grain is important in that it determines the nutritive value of maize products. It is, therefore, of interest that it may vary between 6.2 per cent and 12.8 per cent in a single season, mainly on account of the nitrogen available in the soil.

<u>Possibilities of Determining and Predicting Nitrogen Deficiency</u>.

In comparison with the nutrients phosphorus and potassium, little attention has been paid to the nitrogen status of soils with the object of predicting the nitrogen fertilizer requirements of crop plants. In Central Europe, the majority of soils are relatively poor in available nitrogen and the optimal fertilization is determined more by the nitrogen requirement of each specific crop than by the nitrogen the soil may contribute (SELKE, 1955, p.205). As a result of dense plant populations and luxurious plant growth, both the mineral nitrogen applied and that liberated in the soil, are generally depleted during a single season. Depending on the weather conditions, the contribution of soil nitrogen to the nutrition of crop plants varies (BAUMANN and SCHENDEL, 1952) and cannot be easily assessed. The nitrogen requirement of crop plants under humid conditions or under irrigation is generally high.

In the low rainfall areas of Southern Africa, on the other hand, a prediction of the nitrogen fertilizer requirement is important for the judicious use of nitrogen fertilizer. Limited soil moisture allows only a low plant density. Consequently, relatively large amounts of soil are available per plant, and relatively little nitrogen

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being or becoming available per unit of soil can be sufficient to meet the nitrogen requirement of a crop. In the Central Orange Free State, drought damage often decreases the nitrogen uptake of plants. Many soils have been under cultivation for short periods, and the available soil nitrogen is often more than sufficient to cover the relatively low nitrogen requirement of dryland crops.

The field experiments at Glen and in the Theunissen district had indicated that the soils in this semi-arid continental area may differ considerably from place to place in the amount of nitrogen available to maize. It was found that the application of nitrogen fertilizer increases the growth and reproduction of maize only on soils poor in nitrogen. An assessment of the nitrogen status of various Orange Free State soils in order to predict nitrogen deficiency in maize is, therefore, of primary importance. The results obtained from the field, pot and laboratory experiments may contribute to an assessment of the possibilities of predicting nitrogen deficiency in maize grown on various soils in this area.

The pot experiment on the nitrogen status of soils sampled at 0 - 1, 1 - 2 and 2 - 3 ft. depths from four sites gave an indication of the amounts of mineral nitrogen present in the soils before planting plus those liberated during the experimental period. Where nitrogen fertilizer had not been applied, the amounts of nitrogen contained in the harvested material (herbage) of the pot experiment were closely correlated with the mineral nitrogen contents (ammonium plus nitrate nitrogen) of the soils previous to sowing barley as test plant, but not with the liberation of mineral nitrogen in the soils during incubation under controlled conditions. The results suggested that the nitrogen uptake in the pot experiment was nearly exclusively determined by the mineral nitrogen contents of the soils previous to planting and not by nitrogen liberated during the growth period of the test plants.

The assessment of the nitrogen status of the soils was similar, but not exactly the same, when based on either the nitrogen uptake by the test plants or on the mineral nitrogen contents of the soils. The results of both investigations clearly indicated a large difference in soil nitrogen status between the new land at Glen and the experimental area at Theunissen. A difference in nitrogen status between the old land at Glen and the experimental site at Theunissen, which became evident in field experiments, was

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not reflected in the mineral nitrogen contents of the soils. To a certain extent this difference was, however, indicated by the results of the pot experiment, especially when the amounts of nitrogen gained from the subsoils (1 - 2 and 2 - 3 ft.) were compared. This suggests that the pot experiment showed the nitrogen status of the soils more accurately than the mineral nitrogen contents of the soils sampled at 0 - 3 ft. depth. The determination of ammonium may have been complicated because the texture of the soils differed, especially at different depths. The degree of extraction of ammonium from soils can apparently depend on the texture. In addition to this possible analytical complication, it must also be borne in mind that a considerable quantity of soil was used in the pot experiment (6 kg dry soil per pot), while only a small quantity was used for the determination of ammonium and nitrate (10 g). The experimental error decreases with increasing sample size.

The results obtained suggest that a pot experiment, conducted on the lines of a MITSCHERLICH experiment, may indicate the availability of nitrogen to maize grown on various Central Orange Free State soils fairly accurately. On the other hand, a determination of the mineral nitrogen content would reveal larger differences in nitrogen status as existed between the soils sampled at different depths from one site, but not always smaller differences, as were found between total investigated soil profiles (0 - 3 ft. depth) at various sites.

The differences in soil nitrogen status between the horizons at 0 - 1, 1 - 2 and 2 - 3 ft. depths proved to be particularly important for the assessment of the availability of soil nitrogen to maize. Surface soils (0 - 1 ft.) from Glen and Theunissen provided fairly equal amounts of nitrogen to the test plants in the pot experiment, while the soils at 1 - 2 and 2 - 3 ft. depths differed widely in this respect. The new land at Glen was particularly rich in available nitrogen and the land at Theunissen particularly poor at 1 - 3 ft. soil depth. A consideration of the nitrogen status of surface soil only, would have led to a completely misleading assessment of the availability of nitrogen to maize at Glen and Theunissen. For an accurate indication of the nitrogen requirement of maize grown on various soils, it is, therefore, absolutely essential that the sampling includes the subsoil. Sampling to 3 ft. depth may be regarded as sufficient. The nitrogen status of the soils at Glen and Theunissen, as indicated by the

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results of the field experiments, was fairly accurately reflected in the results of the pot experiment obtained with the soils sampled at 0 - 3 ft. depth from the respective localities.

With regard to the essential depth of sampling it is of interest that the conditions discussed for the nutrient nitrogen, do not apply to the nutrient phosphorus. The pot experiment indicated that all the subsoils from the four investigated sites were poor in available phosphorus and that the phosphate status of the surface soils differed widely, depending on the application of phosphate fertilizer. Phosphates do not move in the soil to any appreciable extent and are generally placed in the soil to the depth ploughed. Sampling at ploughing depth only would, therefore, generally be sufficient for a determination of the phosphate status of a land as influenced by the application of phosphate fertilizer. The majority of soils in this area are regarded as originally poor in phosphorus (WHITMORE, 1950c), and differences in the phosphate supply will result mainly from the application of phosphate fertilizer.

In contrast to phosphorus, mineral nitrogen can move relatively easily in soils. In addition, changed conditions for decomposition of soil organic matter after ploughing veld may lead to a very different contribution of different soil horizons to the nitrogen nutrition of maize. Experimental evidence suggested that ploughing veld brings about a more pronounced change in the conditions for the decomposition of organic matter in subsoils than in surface soils (SCHMIDT and SCHMIDT, 1963). Due to these reasons, a larger soil depth must be covered for a determination of available nitrogen in soils than for a determination of available phosphorus.

Contrary to the results of the pot experiment, the soil incubation test failed to indicate differences between the nitrogen status of the soils at Glen and Theunissen which had become evident in field experiments. The amounts of mineral nitrogen liberated in the soils were generally small. The mean liberation of mineral nitrogen in the soils sampled at 0 - 3 ft. depth did not differ appreciably between sites. Neither the relatively poor nitrogen status of the soil at Theunissen, nor the relatively rich supply in the soils at Glen was indicated. In the subsoil of the new land at Glen, which was proved to be rich in available nitrogen by both the pot experiment and the determination of the mineral

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nitrogen content, relatively little mineral nitrogen was liberated in the incubation test. The liberation of mineral nitrogen in this soil did not exceed that of the subsoil sampled at Theunissen, which supplied very little nitrogen to the test plant in the pot experiment. The results of the field, pot and laboratory experiments suggested that the mineral nitrogen available in the soils was of much greater importance for the nitrogen supply to maize than the nitrogen liberated during the growth period. This is contrary to the findings of a number of authors :

According to HARMSEN and LINDENBERGH (1949) and LENHARD (1957), an accurate indication of the nitrogen fertilizer requirement of plants grown in various localities cannot be obtained by a determination of the mineral nitrogen present in the soils. This is explained by the fact that the field conditions governing the decomposition of organic matter in soils may vary considerably, so that appreciable seasonal and local differences in the content of soluble nitrogenous compounds may occur. The mineral nitrogen contents, therefore, often do not reflect the ability of soils to liberate mineral nitrogen under controlled conditions and to provide crop plants with nitrogen. The rate of liberation of mineral nitrogen per unit of soil during incubation under controlled conditions is generally regarded as of much greater importance for an assessment of the nitrogen supply available to crop plants during a season than the mineral nitrogen content. HARMSEN and LINDENBERGH (1949) stated that it is impossible to accumulate enough mineral nitrogen in soils under natural conditions to cover the total nitrogen requirement of any crop during a whole season. Only an incubation method would, therefore, give a correct indication of the nitrogen fertilizer requirement. These authors, as well as FITTS, BARTHOLOMEW and HEIDEL (1955), STANFORD and HANWAY (1955), HANWAY and DUMENIL (1955) and MUNSON and STANFORD (1955), found that methods involving measurements of the liberation rates of mineral nitrogen are promising in the assessment of the nitrogen fertilizer needs of various soils.

This discrepancy between the results of the investigations of this thesis and those of other authors may be explained by the low rainfall in the Central Orange Free State and the short periods the soils have been under cultivation. Relatively dry climatic conditions allow only a low plant density which, in turn, results in a relatively small nitrogen requirement of crop plants per morgen. Little nitrogen

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available at 0 - 3 ft. soil depth can be sufficient to ensure an adequate supply to maize during a season or even a number of seasons. Mineral nitrogen is accumulated after the cultivation of virgin soils when the higher humus content decreases under the changed conditions for decomposition of organic matter. The soils are only rarely thoroughly leached. Therefore, appreciable nitrogen losses from the soils due to leaching are improbable.

The rate of liberation of mineral nitrogen in an incubation test may give an accurate indication of the nitrogen requirement of crop plants in various localities only when the climatic conditions allow a fairly complete depletion of the mineral nitrogen in the soil during a season, and when the soils have been cultivated for a relatively long period.

Surface and subsoil sampling of a large number of sites is laborious and the determination of the nitrogen status of soils requires special equipment. In the discussions of the previous chapters it was repeatedly pointed out that the nitrogen status of maize plants depends largely on the nitrogen status of the soil. The question arises as to whether the nitrogen content of plant material can serve for an assessment of the soil nitrogen status and for a prediction of the chances of a successful application of nitrogen fertilizer to maize.

Several authors, e.g. OHLROGGE (1956) and HANWAY and ENGLEHORN (1958), assessed the nitrogen status of maize plants during the growth season from the presence or absence of nitrates in the tissue of maize stems. The presence of nitrate, a storage form of nitrogen, may indicate an adequate nitrogen supply to the plants. Apart from the intensity of the colour after the application of diphenylamine sulphuric acid, also the height where a positive reaction to this reagent can be obtained in the stem, gives an indication of a poor or rich nitrogen status of the plant. The more nitrate is present, the higher nitrate can be found in the stem.

Qualitative nitrate tests as well as nitrate analyses revealed that the plants at Glen were sufficiently provided with nitrogen during the entire growth season. In each of the experimental seasons the plants still contained nitrate nitrogen at the stage of ripeness. At Theunissen, on the other hand, all the nitrate present in young plants was readily reduced before or during the flowering stage, so that nitrates were never found in the plant material when

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the plants had reached the stage of maturity. The height of the stem to which nitrates were found shortly before tasseling varied from plant to plant. With some experience, the result of the qualitative nitrate test could be predicted according to the colour of the leaves.

Absence of nitrate in the plant tissue as early as before tasseling would indicate that strong nitrogen deficiency has already been reached or can be expected during the reproductive period of growth. Under these circumstances top-dressings of nitrogen can still be applied with a good chance of increasing grain yields if sufficient soil moisture is available (results of the 1958/59 season at Theunissen).

The nitrogen content of plant samples taken shortly before tasseling may also reveal the nitrogen status of maize plants and may possibly help to decide whether or not a top-dressing of nitrogen should be applied. However, the percentage of nitrogen in the material of whole plants depends largely on the growth stage and changes rapidly with advancing growth. At Theunissen, the nitrogen content of maize rarely decreased to the minimum level, clearly indicating a poor nitrogen status, earlier than at tasseling. A consideration of the colour of the leaves or of the absence or presence of nitrates in maize stems, appears to be more promising for an assessment of the nitrogen status of maize plants shortly before tasseling than the results of nitrogen analyses of the plant material.

At the beginning of tasseling, a nitrogen content of the plant material of less than about 1.0 per cent would indicate fairly strong nitrogen deficiency. However, it is doubtful whether nitrogen fertilizer can still be successfully applied to maize in the field when the plants have reached the tasseling stage. In 1960/61, even less than 1.0 per cent nitrogen was found in the plant material of tasseling maize on farms in the Theunissen district. As the plants had already suffered from drought, a top-dressing of nitrogen was not recommended.

In the light of the experimental evidence obtained from the field experiments, a determination of the nitrogen content of the plant material harvested at the stage of ripeness, may be of considerable practical importance for an assessment of the nitrogen status of the soil, and may be helpful in deciding whether nitrogen fertilizer should be applied in subsequent seasons. In this respect, the

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percentages of nitrogen in both grain and stover may give valuable information. Less than 0.50 per cent stover nitrogen would indicate that the nitrogen supply to the plants had been poor during the season. A medium supply would be indicated by stover nitrogen percentages between 0.60 and 0.80 per cent. When these levels are reached in a dry season with low grain yields, it may be expected that the supply of nitrogen to maize will be insufficient during subsequent seasons in which the rainfall allows increased grain production. An adequate soil nitrogen status would be suggested by stover nitrogen percentages between 0.80 and 1.10, and a rich nitrogen supply when the stover contains more than 1.10 per cent nitrogen. It is doubted whether the very high stover nitrogen percentages obtained under fairly dry conditions at Glen (often about 1.50%) can occur unless the growth and grain production is decreased by drought.

The protein contents (N x 6.25) of the grain indicated whether the plants had suffered from pronounced nitrogen deficiency or whether the nitrogen status of the plants had allowed a fairly normal protein content. Protein contents of the grain between about 6 and 8 per cent would indicate a poor nitrogen status of plant and soil. In two experiments where the application of nitrogen fertilizer had resulted in increased grain yields, the grain obtained from the treatment without a dressing of nitrogen had such low protein contents. During another season, only a slightly improved nitrogen status of the plants, as indicated by slightly increased percentages of nitrogen in the stover, allowed a protein content of the grain of about 10 per cent. Since sampling of, and nitrogen determination in grain is comparatively simple, this possibility of determining pronounced nitrogen deficiency in Orange Free State soils appears to be of particular interest. This determination may indicate soils of poor nitrogen status which should be considered first when nitrogen fertilizer is to be applied on an increased scale.

<u>Influence of the Nitrogen Supply, the Plant Density and the Time of Planting on the Drought Resistance of Dryland Maize and the Utilization of Nitrogen by the Plants.</u>

In four experimental seasons, a considerable variation in growth and grain production of dryland maize occurred at Glen and Theunissen. This was largely due to rainfall conditions which were erratic in both the totals for the

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seasons and the seasonal distribution. Erratic moisture conditions brought an irregular yield response to the application of nitrogen fertilizer at Theunissen.

A failure in the dryland maize production in the Central Orange Free State results most frequently from insufficient moisture during advanced growth stages. By this time, the soil moisture reserves are usually more or less depleted, and the moisture supply to the plants depends mainly on the amount and distribution of rain.

Maize grown on the soils of the experimental sites at Glen and Theunissen showed striking differences in drought resistance. Apparently, differences between the soils at the two sites in texture and water-holding capacity are too small to explain this phenomenon.

The extent of tillering and the growth intensity during early growth stages on each of the two sites, is considered to be the major contributary factor to this difference in drought resistance. In 1959/60, maize grew more vigorously at Glen than at Theunissen until drought limited the growth (harvests before the tasseling stage, 31 and 55 days after planting). This agreed with the observations during the other experimental seasons. Obviously, the reserve of available soil moisture had been depleted earlier at Glen than at Theunissen. Considering the rainfall and its distribution during the three seasons from 1958/59 to 1960/61, the opposite would be expected. The plant weights increased less at Glen than at Theunissen during the growth stages that followed the harvest shortly before tasseling in 1959/60. This was due to drought damage which was experienced earlier at Glen than at Theunissen.

The difference in growth intensity during the very early growth at Glen and Theunissen was not attributed to the nitrogen supply. Observations on the plants in the pot and field experiments and the results from harvests at about 8 - 12 in. plant height showed that considerable differences in the nitrogen supply had no noticeable influence on the growth intensity of young plants.

As a rule the plants tillered excessively at Glen but less at Theunissen. This is considered to be as important for the soil moisture consumption as the more vigorous growth at Glen. In the pot experiment on the nitrogen nutrition of maize tillers were laid out but failed to grow on the soil from the experimental site at Theunissen. At an early growth stage the nitrogen supply provided with

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the treatments varied from poor to rich. Phosphorus, potassium, magnesium and trace elements had been added to the soil. In a further pot experiment with the same maize cultivar, carried out in 1961/62 (not previously described in this thesis), the soil was obtained from the experimental area at Glen. Irrespective of the application of ammonium nitrate, most of the plants formed relatively long tillers. It is possible that the stronger tillering at Glen is due to the presence of some or other soil factor. If this is so, the same factor may also be responsible for the more vigorous growth. Excessive tillering of maize increases the plant density and is, therefore, detrimental to the plants when the moisture supply is limited. A knowledge of factors which influence the tillering would consequently be of considerable value to dryland maize production.

Due to the limited and erratic rainfall in this area, it was particularly important to obtain information about the effect of nitrogen fertilizer on the moisture consumption and on the ability of maize to survive dry periods. PEARSON and ENSMINGER (1957) reported that field experiments throughout the South-Eastern Uplands of the U.S.A. failed to show a depressing effect of high dressings of nitrogen fertilizer on maize yields in dry seasons. In the pot experiment on the nitrogen nutrition of maize it was observed that the moisture consumption depended greatly on the nitrogen status of the plants, in that plants suffering from nitrogen deficiency consumed little, and plants sufficiently supplied with nitrogen consumed much more moisture.

With regard to the effect of various nutrients on the moisture consumption of crops, the results of field experiments with maize including different levels of phosphate supply may also be mentioned (unpublished). During the dry 1960/61 season, the application of phosphate fertilizer led to markedly increased stover and decreased grain yields. A growth response during early growth stages had evidently led to an increased moisture consumption, resulting in pronounced moisture deficiency during the stage of grain setting.

Nitrogen fertilizer did not have an effect similar to that of phosphate fertilizer. Soil moisture investigations on plots with and without the application of nitrogen fertilizer, carried out at Glen in 1957/58, did not reveal any influence of nitrogen on the depletion of soil moisture. However, it must be borne in mind that nitrogen fertilizer had no appreciable influence on either the growth or grain production of maize during four experimental seasons at Glen.

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The similar soil moisture depletion which occurred irrespective of the application of nitrogen fertilizer, may have been due to the absence of any growth response. During the seasons that followed the 1957/58 season, observations were made on the degree of wilting of maize in various fertilizer treatments at Glen. No influence of nitrogen fertilizer on the drought resistance of the plants could be seen. According to these observations and results, the application of nitrogen fertilizer has no appreciable effect on the moisture consumption and wilting of maize when the applied nitrogen fails to affect the growth.

At Theunissen, where an influence of nitrogen fertilizer on the moisture consumption could have resulted from an increase in growth, soil moisture investigations could not be included in the experiments. During dry periods special attention was paid to the influence of fertilizer on the degree of wilting. A marked wilting occurred at dense espacement during the 1959/60 and 1960/61 seasons. No distinct relationship between nitrogen treatments and the degree of wilting of the plants was observed.

The grain yields obtained in the drier seasons at Theunissen did not reveal any depressing effect of nitrogen fertilizer on the grain production. In spite of severe drought damage to the densely spaced plants, the application of nitrogen fertilizer increased both grain and stover yields in 1959/60. In 1960/61, the driest of the four experimental seasons, nitrogen fertilizer failed to increase grain or stover yields at either normal or dense espacement.

When assessing these results it must be remembered that abnormally dry conditions usually bring about a great variation in growth and grain production. The soil moisture content is a sensitive indicator for variation in texture, and slight differences in texture are reflected in a considerable variation in the grain yields during a dry season. It is, therefore, difficult to prove that fertilizer affects the drought resistance of plants adversely.

The results obtained at Theunissen suggest that drought can reduce the beneficial effect of nitrogen fertilizer on grain yields. The danger of a depressing action on the drought resistance and grain formation during dry seasons, which was predicted by several farmers, does not seem to occur in practice under field conditions. This is in agreement with the findings of PEARSON and ENSMINGER (1957) in the South-Eastern Uplands of the U.S.A.

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If this conclusion is related to the strong influence/ of the nitrogen supply on the moisture consumption shown in the pot experiment with maize, two factors must be considered. On account of the limited quantity of soil and relatively heavy applications, the nitrogen treatments differed much more in the amounts of nitrogen temporarily available to the plants in the pot experiment than in field experiments at Theunissen. In addition, a growth response to fertilizer nitrogen may be accompanied by increased root development. Root penetration through larger soil volume in the field may increase the moisture supply to the plants.

Both at Glen and at Theunissen, the drought resistance and grain yields were strongly influenced by differences in espacement. The moisture supply during the most important growth stages (from shortly before until after flowering) varied from particularly moist during 1957/58 to dry during 1960/61. Notwithstanding appreciable differences in rainfall from one season to the other, the annual grain yields per morgen obtained with a plant population of 15,000 plants were always higher than those from a plant population of 30,000 plants per morgen.

At Glen where the nitrogen supply in the soil had always been adequate, the densely spaced maize suffered from varying degrees of drought damage even during a relatively moist season (1957/58). At normal espacement, severe drought damage was limited to the drier seasons (1958/59 to 1960/61). The grain yields and the differences between the grain yields from densely and normally spaced plants depended mainly on the moisture supply. During the relatively moist 1957/58 season, a high grain yield was obtained. In this season the difference between the grain yields at normal and dense espacement was slight. The grain yields, particularly at dense espacement, were much lower in the other three seasons. The grain yields at normal and dense spacing in the three drier seasons differed greatly in 1959/60 and less in 1958/59 and 1960/61.

During the four experimental seasons, the stover yields were always higher at dense than at normal espacement. Nitrogen analyses of the material harvested in the seasons from 1958/59 to 1960/61 revealed that the stover of densely spaced plants always contained more nitrogen than that of normally spaced ones. In contrast, the amounts of grain nitrogen were always higher at normal espacement.

The relationships between the grain and stover yields, as/

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as well as between the amounts of nitrogen contained in grain and stover at dense and normal espacement, are regarded as important in the interpretation of the general effects of espacement on the utilization of nitrogen taken up by the plants. When both nitrogen and moisture were adequate, the dense espacement of the plants allowed the formation of more vegetative plant material per morgen than the normal one. It is assumed that during the early growth stages at Glen both nitrogen and moisture were sufficiently available to all plants. At advanced growth stages, moisture deficiency especially retarded the development of the densely spaced plants. Despite the more pronounced adverse effect of drought, the ability of the denser plant population to form more plant material per morgen in the form of leaves and stalks was clearly reflected in higher stover yields.

An increased production of plant material during the vegetative growth period is accompanied by an increased nitrogen requirement of the crop. When the production of plant material is increased, the nitrogen gained by the plants is distributed throughout an increased amount of plant material. As a result, the nitrogen percentage in the plants is decreased. This can lead to nitrogen deficiency when the nitrogen supply is relatively poor. However, the soil at Glen provided enough nitrogen to meet the requirement of both densely and normally spaced plants.

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The amounts of nitrogen contained in grain plus stover of the normally and densely spaced plants did not differ appreciably in 1958/59 and 1959/60. In 1960/61 it was higher at dense than at normal espacement. It is believed that drought during 1958/59 and 1959/60 decreased the nitrogen uptake of mainly the densely spaced plants. In 1960/61 a more severe drought decreased the nitrogen uptake of both densely and normally spaced plants to a larger extent.

The diverging moisture supply to the plants, induced by the two planting densities, greatly affected the utilization of the nitrogen taken up for the setting of grain. The relatively larger moisture supply available per plant at normal espacement allowed higher grain yields and the translocation of a larger portion of the nitrogen to the grain than at dense espacement.

In contrast to Glen where only the moisture supply to the plants seems to have determined the growth and grain production, the results obtained at Theunissen suggest the influence of both moisture and nitrogen supply. In the

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moist 1957/58 season at Theunissen, dense espacement resulted in a marked increase in the nitrogen requirement of maize. Both the plants supplied with nitrogen fertilizer and those not provided with nitrogen suffered from varying degrees of nitrogen deficiency shortly before and during the reproductive growth period. Nitrogen deficiency symptoms were more severe at dense than at normal spacing. A considerable growth response to nitrogen, experienced during early stages, had obviously led to an early depletion of the available nitrogen. This was followed by pronounced nitrogen deficiency of the densely spaced plants, which occurred irrespective of the application of nitrogen at planting time during the reproductive growth period. The relatively greater deficiency in the densely spaced plants may have contributed to a large difference between the grain yields which, in spite of exceptionally moist conditions during this season, were considerably higher at normal than at dense espacement. As in four seasons at Glen, the stover yields were higher at dense than at normal espacement. Nitrogen fertilizer applied at planting time increased both grain and stover yields, although it failed to ensure the maintenance of an optimal nitrogen status during reproduction.

Increased nitrogen requirement at dense, compared with normal espacement, was especially evident in 1958/59 at Theunissen. The results were obtained under a fairly normal rainfall distribution during advanced growth stages, and are, therefore, considered to be important in the general assessment of the combined effects of different plant densities and different nitrogen fertilizer treatments. Neither densely nor normally spaced plants were visibly affected by drought during this season, and the application of nitrogen fertilizer caused a considerable increase in yields. A significant interaction between espacements and nitrogen treatments with regard to both grain and stover yields was obtained. Without the application of nitrogen, the grain yield from densely spaced plants was considerably lower than that from normally spaced ones (14 and 22 bags per morgen respectively). Applications of 42 and 84 lb. of nitrogen per morgen either at planting or at different stages of the vegetative growth period, increased the grain yields of the densely spaced plants much more than those of the normally spaced ones, and thereby largely equalized the grain yields obtained from both espacements. At dense espacement 42 lb. N per morgen applied at planting time brought about an increase of 10 bags, and 84 lb. N per

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morgen an increase of 14 bags of grain per morgen. At normal espacement the corresponding increase amounted to only 2 and 6 bags respectively. When the actual grain yields obtained are compared, it becomes evident that dense planting increased the nitrogen requirement without allowing a larger grain production when equal quantities of nitrogen fertilizer per morgen had been applied.

Nitrogen analyses indicated that, where nitrogen had not been provided, the stover of both densely and normally spaced plants had been depleted of nitrogen to a similar extent. Compared with the densely spaced plants, more nitrogen had been absorbed by the grain of the normally spaced ones.

In 1958/59, in those cases where nitrogen fertilizer had not been applied, the espacements failed to bring about a difference in stover yields. This is in contrast to the results obtained with the application of nitrogen fertilizer in the same season at Theunissen and in all nitrogen treatments in the other seasons at both Glen and Theunissen. It may be related to pronounced nitrogen deficiency in the densely spaced plants even before tasseling. From this stage, the plants concerned failed to show any appreciable growth. It is assumed that this retarded growth was accompanied by a retarded uptake of soil nitrogen. The corresponding normally spaced plants took up more nitrogen per morgen from the soil. Nitrogen deficiency may have affected the root development and the activity of the roots in absorbing soil nitrogen.

The mutual relationships between the effects of espacement and nitrogen fertilizer treatments on the amounts of nitrogen available in the plants for the formation of grain were, in 1958/59, also reflected in the results obtained with different quantities of nitrogen applied. When 42 lb. fertilizer nitrogen per morgen was given to the densely spaced plants, less nitrogen could be translocated to the grain than when it was given to normally spaced ones. The higher application (84 lb. N per morgen) resulted in the absorption of similar amounts of nitrogen by the grain of both normally and densely spaced plants.

Under the rainfall conditions of the 1958/59 season, equal total quantities of nitrogen fertilizer brought about similar grain yields whether applied at planting time or at different growth stages before flowering. According to the results, either 42 or 84 lb. nitrogen per morgen applied at

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planting time, ensured that an adequate nitrogen status for considerable grain production was maintained during the entire growth period at both normal and dense espacement.

The results obtained in the two seasons at Theunissen with pronouncedly dry conditions during either January or February (1959/60 and 1960/61) were fairly similar. At dense espacement, severe drought damage occurred at an advanced stage of growth during both seasons. As a result, the densely spaced plants generally yielded considerably less grain and appreciably more stover than the normally spaced ones.

During 1959/60, nitrogen fertilizer applied at planting time increased both grain and stover yields. The increase in stover yields was greater at dense than at normal spacing. Accordingly, the dense espacement during this season increased the nitrogen requirement of the plants. Where nitrogen fertilizer had not been applied, the nitrogen status of the densely spaced plants appeared to have been poorer than that of the normally spaced ones. Assumedly, severe drought damage did not allow a beneficial effect of nitrogen fertilizer on the grain production of the densely spaced plants.

In 1960/61, dressings of nitrogen fertilizer affected neither grain nor stover yields, nor the quantities of either grain or stover nitrogen. As in previous seasons, the densely spaced plants contained more nitrogen per morgen in the stover and less in the grain than the normally spaced ones. Compared with dense espacement, a considerably larger portion of the nitrogen contained in the plants at normal spacing had been absorbed by the grain.

As a result of indications from areas of higher precipitation, the local farming community and agricultural publications recently discussed the possibility of increasing grain yields by increasing the plant population in combination with heavier fertilization. In the light of the experimental evidence from Theunissen, where the soil provided a relatively poor nitrogen supply to the plants, this does not seem advisable under the low rainfall conditions of this area. A dense espacement, apart from increasing the risk of drought damage, also increases the nitrogen requirement of maize. An increased number of plants must share a limited quantity of nitrogen available in the soil. Densely spaced plants form more plant material in the form of stalks and leaves than widely spaced ones. It is accepted

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that the plant material can be depleted of nitrogen to a certain minimum nitrogen percentage only. Consequently, more leaves and stalks retain more nitrogen which is not available for translocation to the grain. Provided that the plants are not damaged by drought, dense espacement may be superior to a wider one when the effects of nitrogen fertilizer are to be demonstrated. For practical dryland maize production, a plant density of about 15,000 plants per morgen is to be preferred, although the plants do not respond to nitrogen fertilizer to the same extent as at a denser spacing. At the normal espacement the risk of drought damage is smaller, and the yields are as a rule higher.

As demonstrated by the results, the risk of drought damage is considerably higher at Glen than at Theunissen. Due to frequent drought damage, grain yields are generally lower at Glen. Therefore, additional efforts were made to investigate factors which may bring about an improvement in the moisture supply to the plants at Glen and thereby help to decrease the risk of drought damage.

Apart from espacement, the time of maize planting is important for the moisture supply to the plants. Compared with relatively early planting, the probability of accumulating soil moisture before planting is increased when the maize planting is delayed. Consequently, an increased moisture supply per plant may be achieved by delayed planting as well as by decreasing the plant density. As the moisture supply to the plants is influenced by both factors, the optimal plant density may vary depending on the time of planting. It may thus be possible to counter a higher susceptibility to drought of early planted maize by relatively wide spacing, or to take advantage of improved soil moisture conditions at delayed planting by planting more plants per morgen. With these ideas in mind, experiments on the time of planting, spacing and nitrogen fertilizer requirement were carried out during the 1959/60 and 1960/61 seasons at Glen.

In 1959/60, the grain yield with early planting (October 24th) was a failure (2 bags of grain per morgen), while a reasonable grain yield was obtained when the maize was planted on the 3rd of December (13 bags). The rainfall recorded between the two dates of planting amounted to 89 mm and could not have caused a substantial increase in soil moisture before the delayed planting. A relatively high

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rainfall during December led to an increased moisture content of the soil under the maize of the late planting, as compared with the land of the early planted maize. The small plants of the delayed planting did not consume the available soil moisture as readily as the bigger plants of the early planting, so that some accumulation of soil moisture was achieved by delayed planting. During this season, severe drought damage was avoided by delayed planting where no more than 15,000 plants had been planted per morgen.

The assumed interaction between the influence of time of planting and espacement on the moisture supply to the plants was suggested by the results, but it was impossible to substantially increase the grain yield of the early maize by planting only 10,000 instead of 15,000 or 30,000 plants per morgen.

The reason for the failure of early planted maize to produce reasonable grain yields at wide espacement is mainly seen in the strong tiller development. Instead of the proposed plant densities of 10,000, 15,000 and 30,000 plants per morgen respectively, 22,786, 28,243 and 33,653 stems plus tillers (15 in. or longer) were found. In addition, the tillers of the widely spaced plants were much stronger than those of the normally and densely spaced plants. At 10,000 plants per morgen it was often difficult to discriminate between stems and tillers, whereas, where 30,000 plants had been planted per morgen, many tillers were not much longer than 15 in. It is believed that the excessive tillering prevented an efficient use of soil moisture by the widely spaced maize at early planting.

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The results of the tiller counting also suggested that the competition between the plants had a marked influence on the tiller development. According to observations, the numbers of tillers formed per plant were similar at all espacements. Whether or not the tillers reached a height of more than 15 in., the limit at which they were counted, depended mainly on the moisture status of the soil as induced by the different plant densities. The average number of stems plus tillers counted per plant amounted to 1.1, 1.9 and 2.3 at the plant densities of 30,000, 15,000 and 10,000 plants per morgen respectively.

In 1959/60 all the plants had been planted in 3 ft. rows, a relatively narrow row distance. The results and observations of this season led to the idea that the tillering of the plants may be reduced without increasing the

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plant population per morgen by planting 6 ft. instead of 3 ft. rows and providing only half the space per plant within the rows. It was assumed that decreasing the distance between the plants within the rows would increase competition from an early growth stage and therefore decrease the tiller development, resulting in a more economical use of the available soil moisture.

In 1960/61, plants in 6 ft. rows proved superior to those in 3 ft. rows with regard to drought resistance. At equal numbers of plants per morgen, the plants in 3 ft. rows were earlier and more severely affected by drought than the plants in 6 ft. rows. Counting stems plus tillers longer than 15 in. revealed that the tillering was reduced when 6 ft. rows were used in place of 3 ft. rows. At a planting density of 10,000 plants per morgen, this difference was smaller than at 15,000 or 30,000 plants per morgen. Apart from this distinct effect of the row distance, the influence of the plant density on the tillering of the plants was similar to that in 1959/60. Neither the time of planting nor the application of nitrogen fertilizer markedly affected the tillering.

The higher drought resistance, ascribed to the reduced tiller development in 6 ft. rows, was accompanied by increased grain yields, in particular where more than 10,000 plants had been planted per morgen. In this dry season, the smallest plant population yielded more grain than the normal one, which, in turn, yielded more than the dense plant population.

In contrast to the previous season, early and late planting did not affect grain yields greatly. These were slightly lower following early than following late planting. The amount of rain recorded between the two dates of planting (October 17th, 1960 and December 3rd, 1960) was exceptionally low and did not cause any appreciable increase in the soil moisture content of the land, which had been fallowed until the 3rd of December. During the same period, the moisture content in the soil under early planted maize decreased considerably. Subnormal rainfall conditions during the entire growth season adversely affected the plants of both planting dates. Compared with planting on October 17th, planting on December 3rd led to a correspondingly delayed growth and soil moisture depletion, without appreciably affecting the degree of soil moisture depletion or of drought damage incurred. This may explain why grain yields obtained with early and late planting in this season were similar.

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The results of both seasons suggest that the influence of the time of planting on the drought resistance may vary. Delayed planting prolongs the period during which sufficient rain can be expected to increase the soil moisture content before planting. Compared with early planting, the chances for good rain during the growth period is not diminished when the maize planting is delayed. Therefore, delayed planting will increase the chance of a better moisture supply to the plants and, within limits, of a higher grain yield. Deviations from this general rule may occur, as demonstrated in 1960/61, when the expected increase in soil moisture was not realized.

Compared with dense espacement, normal or wide espacement increases the amount of soil moisture available per plant. In soil moisture investigations during 1957/58 soil moisture was lost by evapotranspiration at a fairly similar rate under both 30,000 and 15,000 plants per morgen. The soil moisture depletion by 15,000 plants was only slightly less rapid. This unexpected result indicates that the moisture consumption per plant was much higher at a normal than at a dense espacement. It further suggests that the main advantage of a normal espacement is not the increased amount of moisture left in the soil at critical growth stages but rather the extension of the growth period before permanent drought damage occurs. This means that the chance of dry periods being broken by rain before severe damage to the plants occurs is increased. The superiority of a wide over a dense espacement will be limited when lasting drought finally causes a collapse of the widely spaced plants as well. In 1960/61, the difference between the grain yields at the plant densities of 30,000 and 15,000 plants per morgen was determined mainly by the slight difference between the moisture consumption per morgen and not by partial evasion of drought damage in the case of the wider espacement.

As in the case of the two plant densities, the soil moisture content at the same number of plants per morgen in 3 ft. and 6 ft. rows differed surprisingly little. Compared with 3 ft. rows, 6 ft. rows prolonged the period of growth before severe drought damage occurred. The difference between the soil moisture supply available at critical growth stages was not large in 1960/61. This suggests that the advantage of 6 ft. over 3 ft. rows was mainly the improved chance of termination of drought before the plants were damaged. Extended drought finally severely affected the

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plants of even the 6 ft. rows. It can be assumed that the difference in yields obtained from 3 and 6 ft. rows would have been much larger if the drought had terminated when only the plants in 3 ft. rows were permanently damaged.

In farming practice either 3 or 7 ft. rows are planted. Seven ft. rows would be impractical in experiments, when equal plant populations are to be compared at a wide and a narrow row distance. Apart from an increased drought resistance of the plants, wider row distances have the advantage that weeds can be more easily controlled mechanically. In addition, relatively wide rows more or less exclude the danger of a too large plant population. On account of these reasons, preference should be given to a wide row distance (6 or 7 ft.).

These measures which may improve the moisture supply to the plants or increase utilization of the available moisture, were not followed by nearly as high grain yields as can be obtained under irrigation or under higher rainfall conditions. At Glen, in particular, the grain yields in all treatments were rather low. Owing to the seasonal distribution of rain in this area and heavy evapotranspiration, soil moisture accumulation is in practice limited to the short period from maturity of summer crops to the beginning of winter and another short period before planting. Deep moistening of the soil rarely occurs. The soil moisture in the upper layers is exposed to rapid evaporation. Due to increased tillering, relatively wide espacement does not always ensure a substantially improved moisture supply per plant. When a limited soil moisture supply is available at a relatively shallow depth only, it will be depleted by densely and normally spaced plants at a fairly similar rate. It seems, therefore, that the risk of drought damage followed by low yields at Glen, can be decreased but not excluded by the measures discussed.

The only method of achieving moisture conservation in deep soil layers at Glen may be to fallow the lands during the rainy season. The possibility of improving the moisture supply by means of cultivating maize every second season and accumulating soil moisture during the summer seasons in between, will be investigated at Glen. At Theunissen, this method of increasing the moisture supply appears to be less promising since the role played by drought is not as important as at Glen.

On account of the lengthy growth period of maize and

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the low humidity in this area, even a large soil moisture reserve available at planting time may not compensate for a poor rainfall distribution during the season. According to BAUMANN (1949 and 1951) and BAUMANN and CLAUSS (1956), an abundant supply of moisture during the early growth stages of a plant may bring about a luxurious moisture consumption during the vegetative period of growth and a relatively high susceptibility to drought. Dry conditions during early growth stages, on the other hand, may induce the plants to develop a more drought resistant constitution. Similarly, increased drought resistance may have followed planting of the same number of plants per morgen in 6 ft. in place of 3 ft. rows. The increased drought resistance may have been induced by increased competition for soil moisture between the plants within the rows during early growth stages. The achievement of grain yields which are as high as those obtained under more humid conditions or under irrigation would be impossible if increased consumption of moisture followed an abundant supply at planting.

## V. Functions of Nitrate in the Metabolism of Maize and the Relative Efficiency of Nitrate and Ammonium in the Nitrogen Nutrition of Maize.

Depending on the growth stage and the nitrogen supply to the plants, varying amounts of nitrate nitrogen were found in the plant material of maize grown under field conditions. Nitrates, which were accumulated in the plant tissue during early growth stages, were readily and completely reduced and utilized for the synthesis of protein, as soon as the nitrogen requirement of the plants was no longer met by an adequate supply of fertilizer or soil nitrogen.

During the early growth, the nitrogen supply available in the soil was supposedly relatively large as compared with the quantity of plant material formed by the plants. Both at Theunissen and at Glen young maize plants invariably contained a considerable portion of the nitrogen in the form of nitrates. The nitrate content of the plant material, as well as nitrate nitrogen expressed as a percentage of the total nitrogen in the plants, decreased with advancing growth. At Theunissen, nitrates were mostly absent from plants at about the flowering stage and, owing to a relatively poor nitrogen supply in the soil, the plants were obviously in need of nitrogen at this stage. Application of ammonium sulphate at a rate of 42 or 84 lb. N per morgen had only a relatively slight effect on the nitrate content of the plant material

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and did not prevent a complete reduction of all the nitrates in the plant material when the flowering stage was reached.

On the other hand, the plants grown at Glen always contained nitrates in the stover. The supply of available soil nitrogen was relatively high and a conversion to protein of the nitrates taken up by the plants was apparently limited on account of an abundant nitrogen supply. Under these conditions, a portion of the nitrogen in the plant material remained in the nitrate form until the harvest and thus could not be incorporated in the nitrogen metabolism of the plants. Drought, which affected the growth of the plants may have contributed to the relatively poor conversion of the nitrates, in that it affected the carbohydrate synthesis and reduced the nitrogen requirement of the plants.

The assumption that nitrates in the plant material are readily and completely reduced when the plant is in need of nitrogen for the synthesis of protein, was confirmed by the results of a hydroponic experiment. A considerable quantity of nitrate which had been accumulated in the plant material previous to an exposure to nitrogen-free nutrient solutions, was readily reduced within a few days.

The investigations on the functions of nitrates in maize, described in this paper, may be regarded as complementary to investigations of other authors, whose work deals mostly with plant species other than maize. According to SCHMALFUSS (1954 and 1955), nitrates can be accumulated in the plant tissue of some plant species, for example Beta vulgaris, Spinacia oleracea and Triticum sativum, without being used for protein synthesis. Apart from a limited ability for reduction, such nitrophile or halophile plants obviously have a particular requirement for monovalent anions, which can be met by either $NO_3^-$ ions or $Cl^-$ ions. A large supply of chlorides can effect a decrease in the nitrate content of Beta vulgaris, in that more of the accumulated nitrate is made available for the protein synthesis (SCHMALFUSS, 1954 and 1955, p. 204). Variations in the nitrophile or halophile character may occur even between different varieties of one species, as indicated by a pronounced halophile character in Beta vulgaris, var. rosea and lutea and a less pronounced one in Beta vulgaris, var. altissima (SCHMALFUSS, 1954).

Both nitrates and chlorides may influence the water balance of these plants and contribute to the maintenance of/

of an optimal hydration of the protoplasm colloids. These anions are in this respect of significance as antagonists to polyvalent anions in the plant and can replace each other to a certain extent, in accordance with HOFMEISTER's series and similar to K and Na in the case of the cations (SCHMALFUSS, 1954).

With these investigations on other plant species in mind, it was of particular interest to see whether any indications could be obtained which would suggest that maize plants have a similar requirement for the monovalent anions $Cl^-$ and $NO_3^-$, and that an anion function of nitrate is of importance to maize plants in addition to the function as a storage form of nitrogen.

Experimental evidence from a hydroponic experiment suggested that the nitrates which were accumulated in the plant tissue were readily reduced and utilized for the synthesis of protein, irrespective of the presence or absence of chloride in the nutrient solutions. This corresponds with the results obtained in another hydroponic experiment (SCHMIDT and SCHMIDT, 1962).

Further experiments included nitrate and ammonium nutrition of plants grown in either chloride-free nutrient solutions or in nutrient solutions where varying portions of the sulphate salts had been replaced by equivalent amounts of the corresponding chlorides. The nitrogen sources were $HNO_3$ and $NH_4HCO_3$, and small amounts of nitrogen were applied on successive days during the whole growth period. In this way noteworthy differences in the hydrogen ion concentration (cH) between solutions with ammonium and nitrate addition were avoided, since the small amounts of nitrogen could readily be taken up.

Nitrate nutrition proved to be greatly superior to ammonium nutrition when the cH of the nutrient solution was relatively low. In this case, the plants supplied with ammonium were severely damaged, probably on account of a high $NH_3$-tension in the solution which presumably occurred in spite of the successive applications of small amounts of $NH_4HCO_3$ at a time. The roots decayed and the plants contained considerable amounts of soluble nitrogenous compounds. The adverse effect of high $NH_3$-tensions on plants is known and described by MEVIUS and ENGEL (1930).

By choosing a nutrient solution with a higher hydrogen ion concentration, higher $NH_3$-tensions in the nutrient solutions could be avoided. In this case, nitrate and ammonium nutrition/

nutrition proved to have a similar effect on the herbage, root and total plant weights as well as on the nitrogen uptake by the plants. Nitrate nutrition caused a higher water content of the green herbage than ammonium nutrition. This could not be related to a possible ion function of nitrate, since no nitrates were found in the plant material at harvesting time, and a slight decay of the roots in the case of ammonium nutrition may have led to a decreased water uptake.

Chloride in the nutrient solution had no influence on either plant weights or the nitrogen uptake by the plants when nitrate was used as a nitrogen source. When ammonium was applied, a solution containing chlorides led to higher plant weights than a solution containing no chlorides. This difference occurred in the experiment where the nutrient solutions with the lower cH were used but not in the experiment where the cH of the solutions was higher. No conclusions on a possible monovalent anion requirement of the plants could, however, be made, since this result was obtained after the plants had been affected adversely by the application of $NH_4HCO_3$. Compared with the plants of the chloride-free solution, the plants grown in the solutions containing chloride showed a better resistance to unfavourable growth conditions induced by ammonium nutrition at relatively low cH.

In the experiment which included the nutrient solution with higher cH, sulphate and chloride solution led to different water contents of the green herbage. Compared with the plants of the solution containing no chlorides, the solutions containing chlorides increased the water content of the green herbage. Increasing amounts of chloride, were not accompanied by a further increase in the water content. It is known that chlorides may increase the water content of various plants (SCHMALFUSS, 1955). SCHMALFUSS and REINICKE (1960) found this to be the case in Spinacia oleracea. This effect demonstrates the hydrophile character of the $Cl^-$ ions and their contribution to the hydration of the protoplasm colloids.

The experimental evidence suggests that maize cannot be considered as a plant having an obviously nitrophile character. It may grow in the absence of both nitrates and chlorides as well as in the presence of one or both of these anions. It is doubtful whether $Cl^-$ fulfils the function of a nutrient in the case of maize. Nitrogen, being

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accumulated in the plant tissue, represents a storage form of nitrogen and is readily and completely reduced as soon as the plants are in need of nitrogen.

Nitrate and ammonium seem to be similarly efficient in the nitrogen nutrition of maize, provided that a high $NH_3$-tension of the substratum is avoided in the case of ammonium nutrition. MEVIUS (1928), MEVIUS and ENGEL (1930) and PIRSCHLE (1931) came to similar conclusions.

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## G. SUMMARY.

In dryland experiments on a farm in the Theunissen district, the nitrogen requirement of maize could not be met by the nitrogen available in the soil. The response to applications of 42 and 84 lb. of nitrogen per morgen per season depended greatly on the moisture supply to the plants during advanced stages of growth.

In a moist season (1957/58), nitrogen fertilizer applied at planting time effected a marked increase in the growth intensity up to the flowering stage, but did not prevent pronounced nitrogen deficiency during the reproductive growth period, especially when the plants were densely spaced. Both grain and stover yields were increased by the application of nitrogen fertilizer.

In a season with a fairly normal distribution of a slightly subnormal rainfall (1958/59), the nitrogen requirement was considerably influenced by the number of plants per morgen. Compared with a normal plant population (15,000 plants per morgen), a denser population (30,000) resulted in a considerably increased nitrogen requirement and accordingly increased the effect of fertilizer nitrogen on grain yields. When no nitrogen fertilizer had been applied, the densely spaced plants yielded considerably less grain than the normally spaced ones. The application of nitrogen fertilizer equalized, to a large extent, the grain yields in that it caused a greater increase at dense than at normal espacement. Nitrogen which was applied as a top-dressing at different growth stages before flowering was utilized to an extent similar to that of nitrogen applied at planting time. The grain and stover yields as well as the nitrogen uptake were determined mainly by the quantity of nitrogen applied, and not so much by the time of application. Nitrogen fertilizer applied shortly before tasseling brought about a substantial improvement in the nitrogen status of plants during reproductive growth, followed by a considerable increase in the growth intensity during this advanced stage of development. The percentage of protein in the grain was exceptionally low when the plants had not been provided with nitrogen fertilizer, and was increased when nitrogen fertilizer was applied. The percentage of nitrogen in the stover was generally low.

In two seasons with severe drought (1959/60 and 1960/61), visible drought damage occurred at dense espacement during

an advanced stage of growth. In one of these seasons (1959/60), nitrogen applied at planting time increased both grain and stover yields as well as the protein content of the grain and the nitrogen uptake by the plants. Top-dressings of nitrogen increased the protein content of the grain and the nitrogen uptake by the plants without appreciably affecting grain yields. Both the protein content of the grain and the nitrogen content of the stover were low, especially when no nitrogen fertilizer had been applied. In the other season (1960/61), fertilizer nitrogen failed to increase either grain or stover yields. The protein content of the grain was normal and considerably higher than in the previous seasons. It was not affected by the nitrogen fertilizer applied. The nitrogen content of the stover was only slightly higher than in the previous seasons and was slightly increased by the application of nitrogen.

In both dry seasons, normally spaced plants yielded considerably more grain and less stover than densely spaced ones. At normal espacement, the plants contained more nitrogen in the grain and less in the stover than at dense espacement.

The plants at Theunissen were generally free of nitrates from about the flowering stage. On account of a low percentage of nitrogen in the stover, the amount of nitrogen returned to the soil or made available for grazing was small.

According to the evidence obtained, application of nitrogen at a rate of forty to eighty lb. N per morgen should increase grain yields at Theunissen in seasons with a normal or a better than normal moisture supply. In moist seasons, a top-dressing of nitrogen before flowering would maintain an optimal nitrogen status of the plants during advanced growth stages. Top-dressings may also be applied in normal seasons, especially when nitrogen deficiency becomes evident.

Planting at more than about 15,000 plants per morgen unduly increases the risk of drought damage to the plants and of a failure in grain production.

In contrast to the results obtained at Theunissen, no appreciable influence of nitrogen fertilizer (42 and 84 lb. N per morgen) on either grain or stover yields, or on the nitrogen content of either grain or stover, was obtained during four seasons on the experimental site at the Glen College of Agriculture. In addition, nitrogen fertilizer

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did not noticeably affect the nitrogen uptake by the crop. The nitrogen contents of both grain and stover as well as the nitrogen uptake were relatively high. Nitrates were always present in the stover.

Normally spaced maize plants yielded more grain but less stover than densely spaced plants. The difference between the grain yields at normal and dense espacement varied according to the rainfall conditions. In a moist season (1957/58), this difference was smaller than in three drier seasons (1958/59 to 1960/61). Compared with dense espacement, normal espacement ensured that a larger portion of the nitrogen, taken up by the plants, was translocated to the grain. Densely spaced plants contained more nitrogen in the stover than normally spaced ones. The amounts of nitrogen contained in the stover and thus returned to the soil, were relatively large at Glen.

In comparison with the plants at Theunissen, those grown at Glen proved to be much more susceptible to drought. This difference was largely attributable to a higher growth intensity during early growth stages and a stronger tillering of the plants at Glen.

The degree of wilting or of drought damage was not visibly influenced by the application of nitrogen fertilizer at either Glen or Theunissen. Investigations during one season at Glen did not indicate any influence of nitrogen fertilizer on evapotranspiration, and nitrogen fertilizer did not influence tiller development.

At Glen, normal and wide espacement (15,000 and 10,000 plants per morgen respectively) brought about a stronger tiller development than a dense one (30,000 plants) and thus decreased the advantage of a larger moisture supply per plant. When the plants were grown in 6 ft. rows, the tiller development was decreased, the drought resistance increased and a higher grain yield was obtained than when equal numbers of plants were planted in 3 ft. rows. Compared with 3 ft. rows, there was only a slight reduction in evapotranspiration when the same number of plants per morgen were planted in 6 ft. rows.

These slight reductions in evapotranspiration increased the probability of termination of drought before the plants were severely damaged which seems to be more important for the superiority of either normal spacing or six feet rows over dense spacing or three feet rows than the slightly

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increased available moisture.

Compared with relatively early planting, delayed planting resulted in a considerable increase in grain yields in a season with adequate early summer rainfall, but, in a season with generally poor moisture conditions, it failed to affect the yields appreciably. Delayed planting increases the probability of an improved moisture supply to the plants.

A pot experiment with maize indicated that nitrogen fertilizer can still cure nitrogen deficiency and bring about a strong increase in herbage weight and grain yield even if applied as late as during the flowering stage. This late application was superior to earlier ones as regards the utilization of the nitrogen for grain production.

A pot experiment on the nitrogen status of soils sampled from various sites at three depths revealed that the soils at Glen were richer in available nitrogen than the soils of the experimental site at Theunissen. This applied to all the Glen soils investigated whether they had been cultivated for shorter or for longer periods, although an influence of the duration of the period of cultivation on the nitrogen status of the soils was indicated. It was found that the supply of available nitrogen in the surface soils (0-1 ft) at Glen and Theunissen differed only slightly. Larger differences were found between the subsoils (1-2 and 2-3 ft). A newly established land at Glen was particularly rich in available nitrogen at a depth of 2-3 ft.. Less pronouncedly, these indications were also obtained from a determination of the mineral nitrogen content of the soils. All the results from the soil investigations demonstrated that sampling to a depth of at least three feet is of particular importance when the nitrogen status of a soil is to be determined by means of soil analyses.

The amounts of mineral nitrogen released from the soils during incubation were not related to either the mineral nitrogen contents of the soils previous to incubation or to the nitrogen uptake by test plants from the same soils. The experimental evidence suggested that the mineral nitrogen contents of the soils were more important for the nitrogen nutrition of maize than the nitrogen liberated in the soils during a growth season. In the case of the soils investigated, a soil incubation test failed to show differences between the nitrogen available to maize grown on different lands.

Pronounced nitrogen deficiency in soils was also re-

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flected in a low protein content of the grain as well as a low nitrogen content of the stover from dryland maize.

The results of hydroponic experiments indicated that ammonium and nitrate nitrogen may be utilized fairly equally by maize when precautions are taken to avoid high ammonia tension in the ammonium solutions.

The significance of nitrates for maize plants appeared to be limited to the function of nitrates as a storage form of nitrogen. No indication was obtained which would suggest an importance of an anion function of either nitrates or chlorides. Maize does not seem to be nitrophile or halophile as are some other species.

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