A STUDY OF THE RELATIONSHIP BETWEEN SOIL AND LITTER NUTRIENT STATUS, AND FIRE IN THE FYNBOS ECOSYSTEM

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1. INTRODUCTION

1.1 The aim of the investigation

Originally the basic aim of this investigation was to monitor the changes in soil nutrient status before and after a fire in the Kirstenbosch Botanic Gardens. These results would have been correlated with data obtained on vegetation regeneration after the fire.

Ignition of the vegetation was however unsuccessful due to the fairly wet conditions at the site after early winter rains. The entire approach to the investigation was accordingly restructured to take a much broader approach to the study of nutrient changes occuring in the soil as a result of fire.

Data collected approximately one week after a fire in Orange Kloof and that obtained from a study of fire breaks of various ages on the Table Mountain- Devils Peak saddle were compared with that obtained at Kirstenbosch in the absence of a fire.

1.2 Fire in the fynbos

Workers such as Boucher, (1972) and Taylor, (1969), (see Moll and Campbell, 1976), consider fire to be a natural factor in the fynbos vegetation. The fynbos vegetation accordingly shows a number of adaptations to fire. In many instances this involves adjustment of life cycle so as to coincide with the approximately fifteen year cycle in natural burning. The observed frequency is, however, far greater than this and many areas thought to be able to support forest species have been effectively cleared by frequent burning. Moll and Campbell, (1976) also explain that the frequency of fire has important effects on the spread of aliens such as Hakea, Acacia and Albizia. The spread of these species is assisted by the high frequency of fires.

Regeneration after fire is, therefore, an important factor to be considered when the influence of fire on the fynbos is to be accounted for. McLachlan, (1974) showed that regeneration was better on granite than sandstone soils. Factors important in the amount of regeneration of natural vegetation after a fire, therefore, include the specific nutrient status of the soil after the fire. The most important question is, therefore, how significantly the fire changes the quantity and availability of soil nutrients. It is on this question that this investigation will attempt to throw some light.

1.3 The nature of the fire in relation to the effect it has on the nutrient status of the soil

Many workers have shown that the amount of nutrient release from the soil and litter is directly dependent on the nature of the fire. There are many factors which determine the nature of a fire. These include the age of the vegetation being burnt (Evans and Allen, 1971), and atmospheric conditions prevailing at the time of the fire, (for example, wind, rain or humidity conditions). Fires have been crudely subdivided according to there nature, and canopy, ground and 'totaly destructive' fires may be recognised. The canopy fire may only effect the tops of trees having minimal influence on the soil nutrients. On the other hand, ground, and what I have called 'totaly destructive' fires may significantly influence the soil nutrients. This is because of the very high ground level temperatures that have been associated with these. Ground fires have been associated with temperatures of more than 800 °C and can thus cause extensive volatilization of may nutrients (see Evans and Allen, 1971). 'Totaly destructive' fires, (which include both canopy and ground fire effects), may be even more severe, in that some plants with fairly thick barks, and other protective measures against ground fires may also be killed.

One factor that seems to be very important in limiting the effect of ground and 'totally destructive' fires on the soil mineral status is the presence and thickness of the litter layer. Allen et al, (1969) report almost no nutrient loss when an organic layer of more than 5 cm is present.

Grier, (1975) gives some indication of the extent of nutrient losses that may occur. In studies of wildfires in coniferous ecosystems in Canada, the following nutrient losses were the result of combined volatilization and ash convection:

element	% loss during fire (from Grier, 1975)
N	97
Ca	19
Mg	38
K	80
Na	97

Work of Groves in Australian heathlands should have been mentioned. Some of the classic British work also.

These results clearly indicate just how extensive nutrient losses from burning vegetation may be.

1.4 Description of the sites chosen for the study

1.4.1 Kirstenbosch

(a) Location of the site:

The site originally chosen for the investigation was situated within the Kirstenbosch Botanical Gardens, approximately 250 m north west of the tea room.

(b) Geology and soils

Soils in Kirstenbosch are derived chiefly from Cape Granite and Table Mountain Sandstone (T.M.S.). Granite penetration of the T.M.S. is especially noticable higher up the mountain in the forest. T.M.S. boulders are frequent in the study area.

The site chosen for the study has a fairly gentile slope and erosion seemed to be unimportant.

(c) Climate

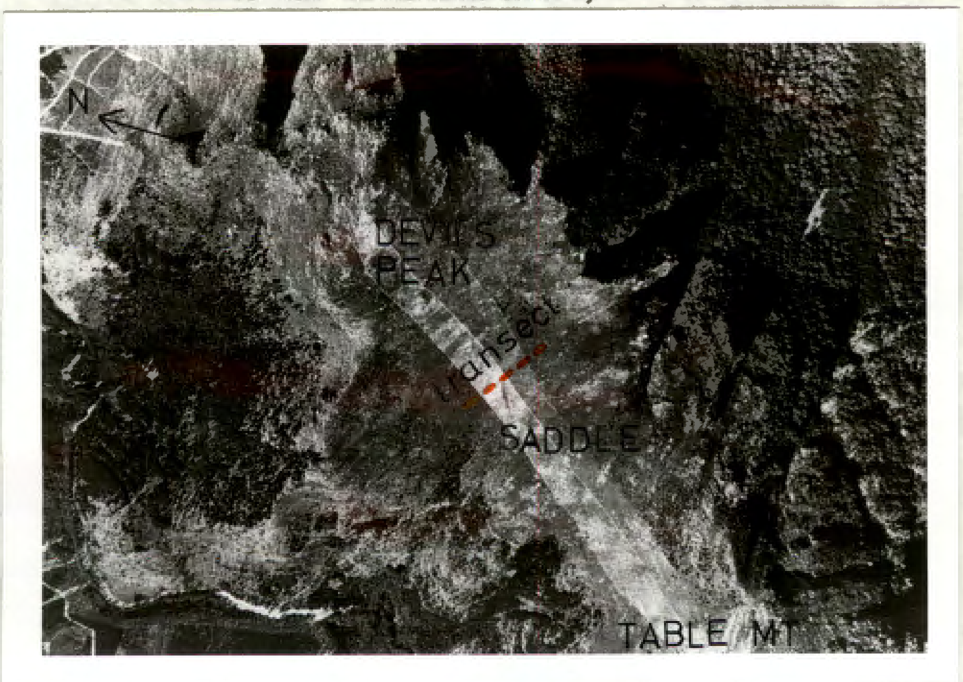
The climate at Kirstenbosch is characterised by a high rainfall compared with other areas on the Cape Peninsula. Botha, (1976) reports that the mean annual precipitation of approximately 1 400 mm, while Campbell, (1975) indicates that little or no frost occurs.

(d) A brief description of the vegetation in the area where the sampling quadrat was established

The site chosen for the study was covered by Pinus pinaster for a period of approximately fifty years (Esterhuizen, 1935, quoted by Botha, 1976). After clearing and felling of the pine trees approximately

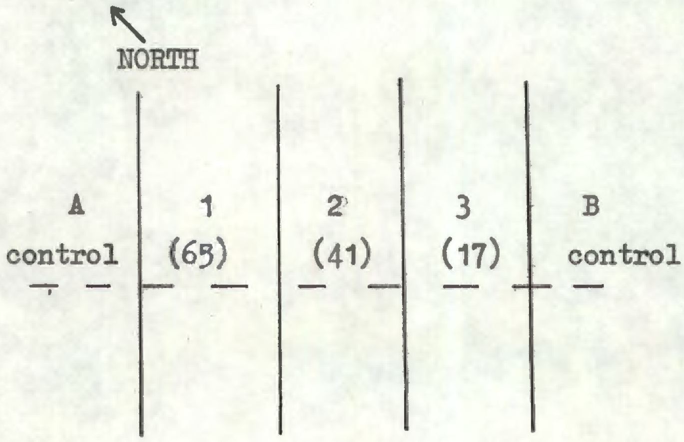
PHOTOGRAPHS 1, 2 and 3: The quadrat established at Kirstenbosch.
Boundary of the 10x10 m area indicated in red.
The three views of the site form a panoramic view.
View is from south to south-east (top to bottom).

PHOTOGRAPH 4: Aerial view of the Table Mountain-Devils Peak Saddle transect. Note that there are only two fire breaks indicated and the age shown by their tone is not what was recorded. This means that the photograph is probably not recent. (see Map 1 for an explanation of the situation noted)



MAP 1: The Table Mountain-Devils Peak saddle fire breaks and position of the transect.

Quadrat number and fire break age is indicated
Each fire break is 60 m wide
Transect was established 100 m up from the footpath that crosses the saddle



fourty years ago, fynbos successfully recolonized the area. Human disturbance is however still obvious and pathways result in the patchy appearance of the vegetation in many places.

The following species are common in or near the quadrat area chosen for the investigation: Erica hispidula (most frequent), Phylica imberbis, Pteridium aquilinium, Erica hirtiflora, Blaera ericoides and Briza maxima. These species are members of the'wet fynbos' (see Bester, 1977). Erica hispidula is however also common on the drier northern slopes of Table Mountain (Moll and Campbell, 1976).

1.4.2 Orange Kloof

(a) Location of the site

The sampling quadrat for this site was established on a fairly small patch of fynbos,(50x50 m), that had been burnt approximately one week before sampling. The site bordered on a pine plantation and was as such fairly disturbed. Site altitude= approx 150 m , aspect= west.

(b) Geology and soils

Soils appear to be derived chiefly from T.M.S. and are fairly sandy, but probably poorly drained. Large T.M.S. bolders are common in this area.

(c) Climate

The characteristics of vegetation in the area of Orange Kloof were the fire took place indicate that rainfall may not be much lower than at Kirstenbosch. Forest species are common lower down in the valley.

(d) Description of the vegetation

Vegetation at the site where the fire took place had been completely destroyed (ashed). Plants in the immediate vicinity appear to be adapted to fairly moist, poorly drained sandy soil. Restionaceae dominate the area.

1.4.3 Table Mountain- Devils Peak saddle

(a) Location of the site

A transect of five sampling quadrats were established across three fire breaks that stretch across the Table Mountain- Devils Peak saddle (see Map 1 and Photograph 4). The altitude at the transect was approximately 800 m and the apect south-east.

Quadrats 1, 2 and 3 were within the youngest to oldest fire breaks respectively. The fire breaks are burnt every two years on a six year rotation. (pers comm Forestry Department). The fire break with quadrat 1 was burnt approximately 17 months ago, meaning that the other two are 41 and 65 months old respectively.

Two control quadrats were established at A and B in the adjacent vegetation, (see Map 1). This would serve to illustrate the significance of results from data collected on 1, 2 and 3.

(b) Geology and soils

The saddle area is exclusively T.M.S. and soils appear much more sandy and well drained when compared with that at Kirstenbosch and Orange Kloof.

(c) Climate

The Table Mountain- Devils Peak saddle is considerably drier than Kirstenbosch or Orange Kloof. The rainfall is probably half of that measured at Kirstenbosch.

(d) A brief description of the vegetation

Dominant species are characteristic of those found on dry sandy sites on Table Mountain. Common species include Leucadendron strobilinum and L. xanthoconus, as well as ericas such as Erica hispidula (which was also recorded at Kirstenbosch in a much wetter environment).

2. METHODS

2.1 Collecting of soil and litter samples

At all three sites chosen for this investigation soil and litter samples were collected at twenty randomly selected points within a 10 x 10 m quadrat. One of these quadrats were established at Kirstenbosch and Orange Kloof respectively, while 5 were established in a transect across the three fire breaks on the Table Mountain - Devils Peak Saddle (see Map 1). Soil and litter samples from sites A and B along the transect were bulked to serve as a control for samples collected within the fire breaks.

Litter and soil samples were collected from the respective sampling sites on the following dates:

Kirstenbosch (a) 11/3/77
Kirstenbosch (b) 12/9/77
Orange Kloof 17/3/77 (approximately one week after a controlled fire)
Table Mountain - Devils Peak Saddle (Transect) - 31/8/77 (approximately 17, 41 and 65 months after fire breaks 1, 2 and 3 had been burnt).

Litter samples were collected within a 10 x 10 cm area at each sampling site in the quadrats. Soil samples were collected in the 10 x 10 cm areas with a soil borer (marked at 5 and 15 cm). All soil and litter samples from each area were bulked, transported in plastic bags and air dried at room temperature.

At the Kirstenbosch site live and dead Erica hispidula samples were collected for analysis of total nitrogen. The terminal 5 cm of live and dead branches were taken.

2.2 Study of the physical characteristics of soil samples

All soil samples were sieved through a series of seven sieves shaken at 30 r.p.m. for 10 minutes. The weight and volume distribution were then determined as a function of particle size.

Soil separates were graded according to the size range limits used by the United States Dept. Agriculture. These are according to Thompson (1952) as follows:

Fraction	Soil separate	Size (mm)
Sand	fine gravel	2 - 1
	coarse sand	1 - 0,5
	medium sand	0,5 - 0,25
	fine sand	0,25 - 0,10
	v. fine sand	0,10 - 0,05
Silt	silt	0,05 - 0,002
Clay	clay	below 0,002

2.3 Determination of organic matter

The method used for determination of organic matter was a modification of that explained by Hess (1971). Six litter and soil samples from each bulked sample were placed in a muffle furnace for 8h at 450°C. The weight loss was expressed as the percentage organic matter.

2.4 Total nitrogen

Total nitrogen was determined by Kjeldahl analysis (Hess, 1971). Six 4g soil and ½g litter or plant samples were used from each bulked sample. Samples were digested in concentrated H_2SO_4 and salicylic acid. Total nitrogen was calculated as ppm.

2.5 Available phosphorus

Available phosphorus was measured for litter and soil samples at Kirstenbosch on the 11/3/77. Five grams soil or 2g litter were used for extraction with Bray No.2 solution. Available phosphorus was then determined colorimetrically by the molybdenum blue method (method recommended by the Fertilizer Society of South Africa (soil analysis methods, Publication No. 37)).

2.6 Determination of total calcium, magnesium, sodium and potassium in litter samples

Total calcium, magnesium, sodium and potassium were measured for litter samples from all sites. One gram of four samples taken from each bulked sample were ashed in a muffle furnace overnight at 500°C (Allan, 1970). For extraction 20ml 0,1 NHCl was taken from each sample before shaking for 30 min with a mechanical shaker. Total cation concentration was determined on a Varian Techron atomic absorption spectrophotometer.

2.7 Determination of available calcium, magnesium in the soil samples

Six 7,5g soil samples were taken from each bulked sample collected at the different sites. Extraction was by shaking for ½h with a N ammonium-acetate solution of pH 7 at a soil/extractant ratio of 1:10 (see soil analysis methods, Publication of the Fertilizer Society). Strontium nitrate was added to counteract the depressing effect that phosphate has on calcium and magnesium determination with atomic absorption.

Available calcium and magnesium was determined on a Varian Techron atomic absorption spectrophotometer.

3. RESULTS

TABLE 3.1: DISTRIBUTION OF SOIL PARTICLE SIZE IN TWO PROFILES AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect) (31/8/77)

Soil Profiles: 1 = 0-5 cm, 2 = 5-15 cm.

Table No.	Size range (mm) of sieves used	Soil separate*
1	2 - 0,84	fine gravel
2	0,84 - 0,42	coarse sand
3	0,42 - 0,25	medium sand
4	0,25 - 0,105	fine sand
5	0,105- 0,074	very fine sand
6	below 0,074	silt and clay

(* size limits of soil separates from U.S. Dept. Agric., see Thompson, 1952)
(w = % weight, v = % volume)

Site, % wt or % vol.		Size Range (see above) 1	2	3	4	5	6
K(a)	1w	3,4	29,4	31,2	26,1	4,1	5,9
	v	2,5	31,2	36,3	23,2	3,0	3,8
	2w	2,6	29,0	31,0	27,7	4,3	5,4
	v	1,9	30,8	36,2	24,6	3,1	3,5
K(b)	1w	3,1	27,6	30,7	28,8	4,8	5,0
	v	2,3	29,3	35,9	25,8	3,5	3,3
	2w	2,7	28,2	31,0	28,2	5,0	4,8
	v	1,9	29,8	36,3	25,1	3,7	3,2
OK	1w	4,2	33,4	32,1	23,0	3,6	3,8
	v	3,2	38,1	31,1	22,2	2,8	2,6
	2w	3,6	31,5	32,0	23,2	4,6	5,1
	v	2,1	33,3	37,3	20,7	3,1	3,6
(A+B)	1w	5,0	33,8	34,0	19,0	3,5	4,8
	v	3,6	35,1	39,1	16,7	2,5	3,0
	2w	18,1	27,2	32,7	18,3	1,9	1,9
	v	13,3	29,1	38,6	16,5	1,4	1,2
(1)	1w	1,7	24,3	36,1	28,1	4,2	5,6
	v	1,2	25,5	41,7	24,9	3,1	3,7
	2w	3,5	31,8	37,1	22,3	2,6	2,8
	v	2,4	32,6	42,0	19,3	1,9	1,7
(2)	1w	3,1	37,7	39,0	14,8	2,0	3,4
	v	2,2	38,1	43,5	12,7	1,5	2,0
	2w	4,6	42,8	36,9	13,0	1,2	1,3
	v	3,1	43,1	33,8	12,0	1,2	1,2
(3)	1w	2,9	25,0	38,6	24,5	3,5	5,5
	v	2,1	26,1	44,4	21,5	2,5	3,4
	2w	2,8	28,1	42,2	23,3	1,9	1,8
	v	2,0	28,6	47,2	19,9	1,3	1,1

TABLE 3.2: AVERAGE PERCENTAGE TOTAL ORGANIC MATTER MEASURED IN TWO SOIL PROFILES AT THE DIFFERENT SAMPLING SITES (see Appendix Table 1).

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect) (31/8/77)
Soil Profiles: 1 = 0-5 cm, 2 = 5-15 cm

Site	Profile	Avg % Total Organic matter
K(a)	1	4,77
	2	2,47
K(b)	1	4,50
	2	3,03
OK	1	3,00
	2	2,17
TM(A+B)	1	8,90
	2	6,46
(1)	1	4,80
	2	4,07
(2)	1	2,83
	2	3,17
(3)	1	6,37
	2	4,70

TABLE 3.3: AVERAGE TOTAL NITROGEN MEASURED IN LITTER AND TWO SOIL PROFILES AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect) (31/8/77)
L = Litter
Soil Profiles: 1 = 0-5 cm, 2 = 5-15 cm.
(see Appendix Table 2)

%L+S = Percentage of litter + two soil profiles

Site	Litter or Soil Profile	Avg Total N (ppm)	%L+S
K(a)	L	3614	78,9
	1	772	16,9
	2	192	4,2
K(b)	L	2344	84,7
	1	212	7,7
	2	211	7,6
OK	L	6791	91,9
	1	396	5,4
	2	201	2,7
TM(A+B)	L	5243	84,5
	1	465	7,5
	2	498	8,0
(1)	L	2919	86,9
	1	268	8,0
	2	172	5,1
(2)	L	2034	72,8
	1	300	10,7
	2	461	16,5
(3)	L	2549	85,6
	1	256	8,6
	2	175	5,9

TABLE 3.4: AVERAGE AVAILABLE PHOSPHORUS MEASURED AT THE KIRSTENBOSCH SITE (11/3/77)

L = Litter
Soil Profiles: 1 = 0-5 cm, 2 = 5-15 cm.
(see Appendix Table 4)

Litter or Profile	Avg available P(ppm)
L	11,3
1	4,3
2	2,2

TABLE 3.5: AVERAGE TOTAL CALCIUM, MAGNESIUM, SODIUM AND POTASSIUM MEASURED IN LITTER AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect) (31/8/77)
(see Appendix Tables 5, 6, 7, 8)

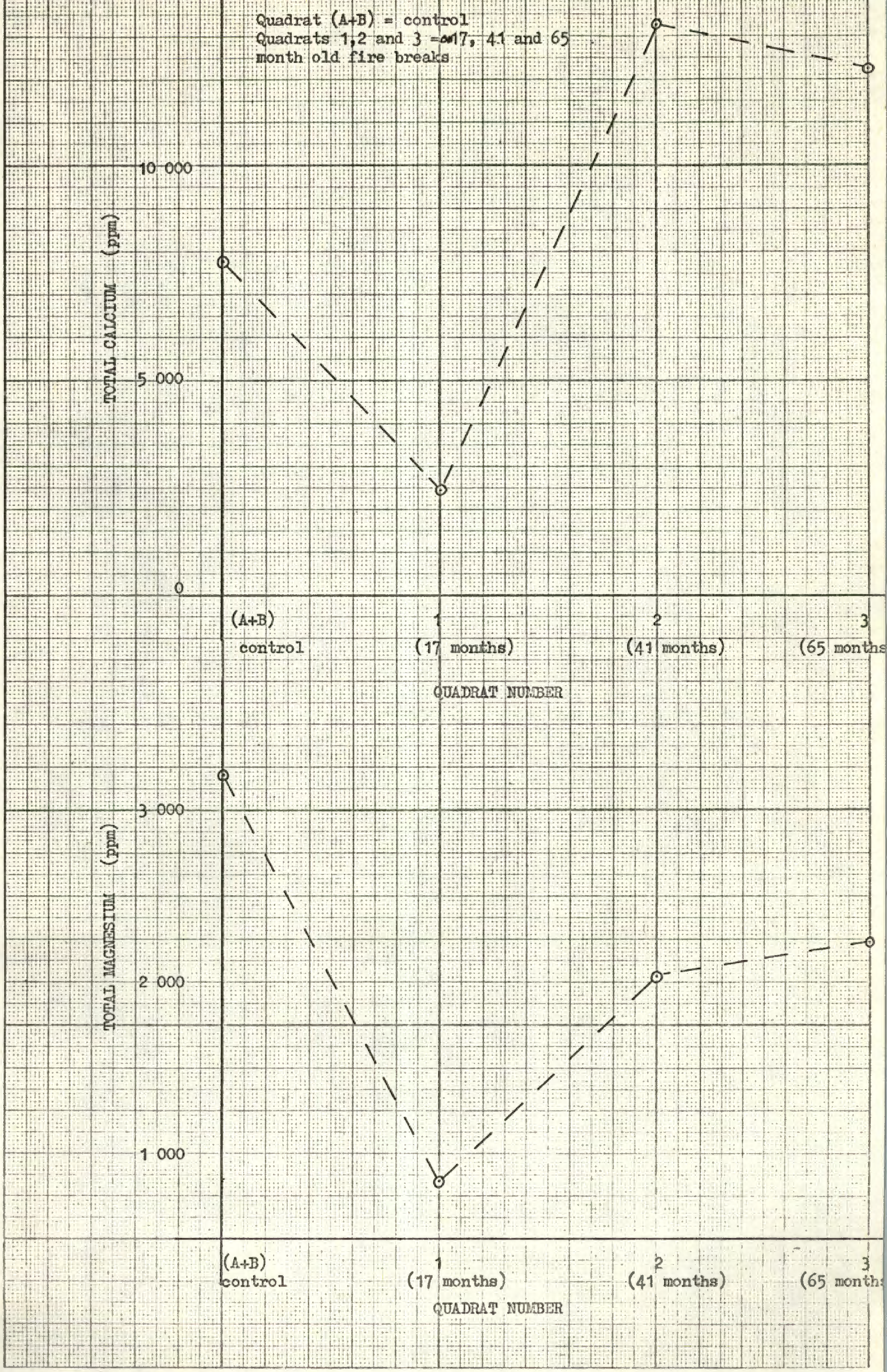
Site	ion concentration (ppm)			
	Ca	Mg	Na	K
K(a)	3375	925	326	259
K(b)	7495	1498	563	340
OK	9025	3480	746	783
TM(A+B)	7575	3420	928	698
1	2450	680	298	171
2	13250	2060	898	545
3	12250	2465	998	843

TABLE 3.6: AVERAGE AVAILABLE CALCIUM AND MAGNESIUM MEASURED IN TWO SOIL PROFILES AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect) (31/8/77)
Soil Profiles: 1 = 0-5 cm, 2 = 5-15 cm.
(see Appendix Tables 9 and 10)

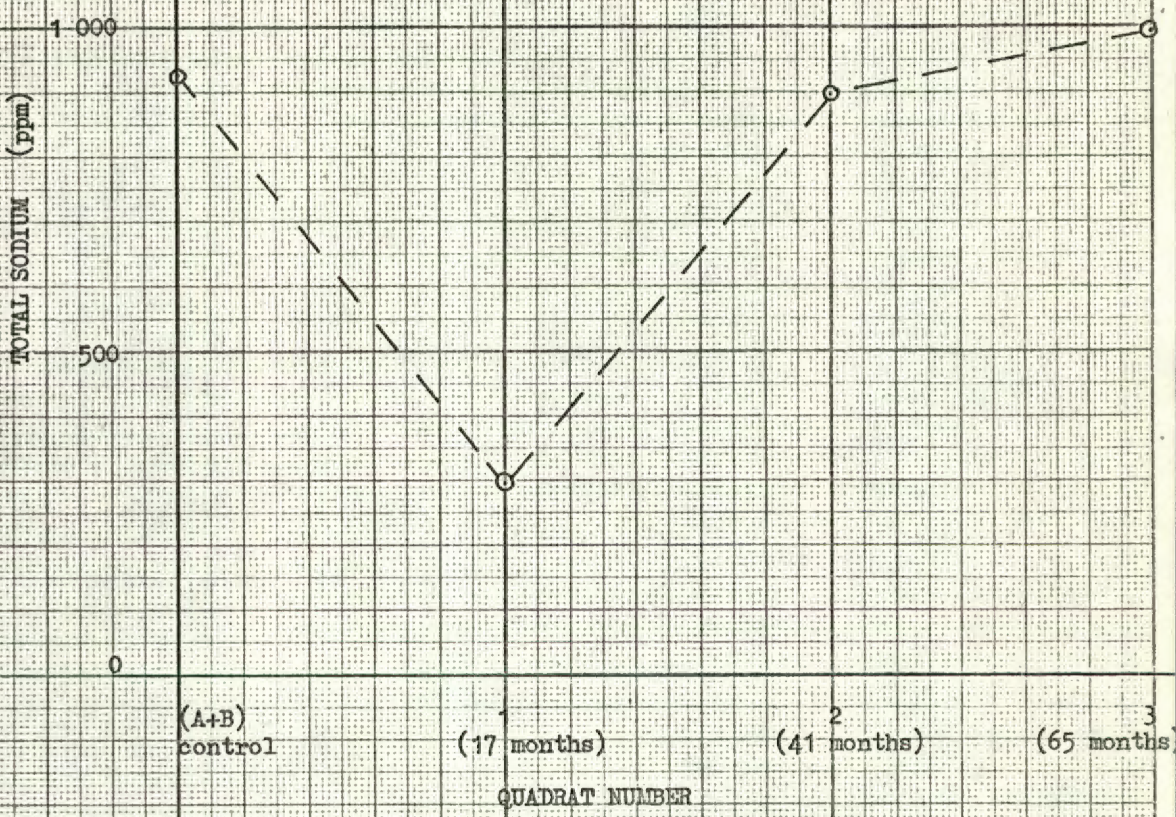
Site	Profile	Ca (ppm)	Mg (ppm)
K(a)	1	396	69
	2	201	39
K(b)	1	375	67
	2	235	54
OK	1	202	82
	2	156	61
TM(A+B)	1	555	142
	2	416	121
(1)	1	295	691
	2	270	811
(2)	1	130	38
	2	73	46
(3)	1	252	88
	2	295	94

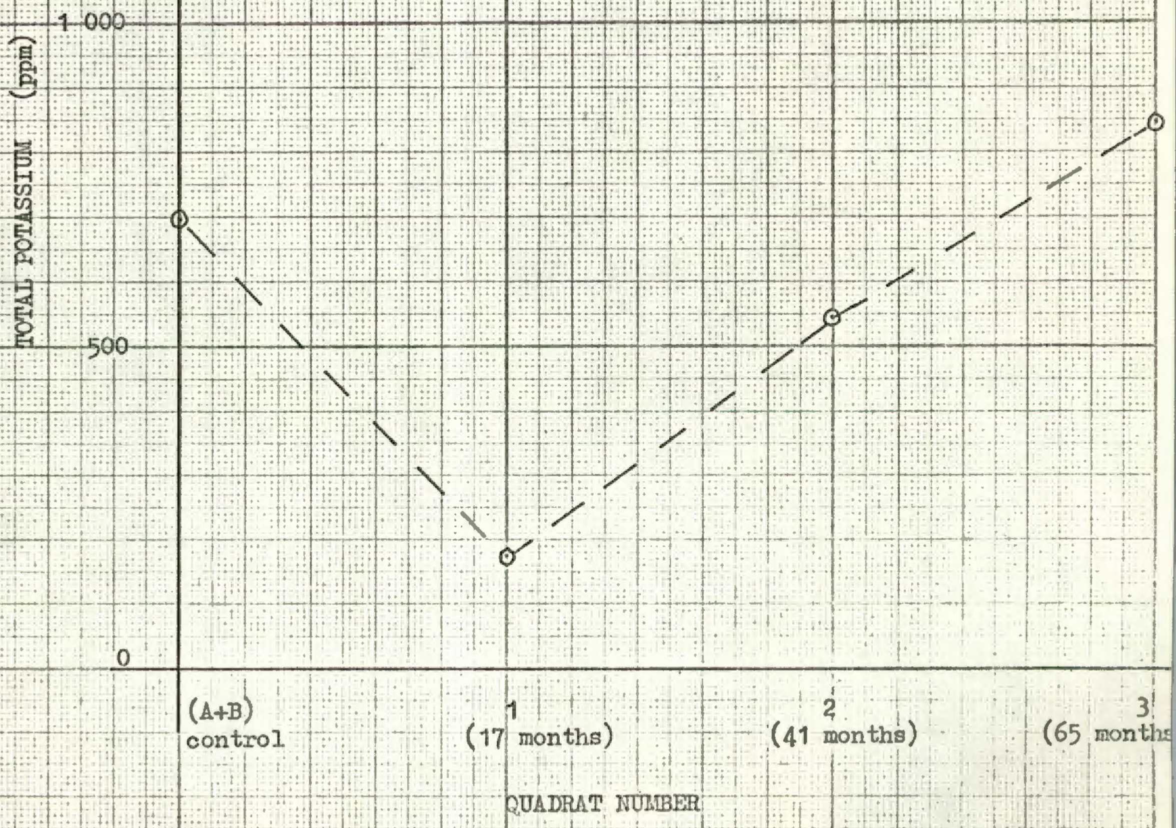
GRAPH 3.1: TOTAL CALCIUM AND TOTAL MAGNESIUM CONCENTRATIONS OF LITTER AT THE THREE FIRE BREAKS ON THE TABLE MOUNTAIN-DEVILS PEAK SADDLE (TRANSECT)



GRAPH 3.2: TOTAL SODIUM AND TOTAL POTASSIUM CONCENTRATIONS OF LITTER LITTER AT THE THREE FIRE BREAKS ON THE TABLE MOUNTAIN-DEVILS PEAK SADDLE (TRANSECT)

Quadrat (A+B) = control
Quadrats 1, 2 and 3 = on 17, 41 and 65 month old fire breaks

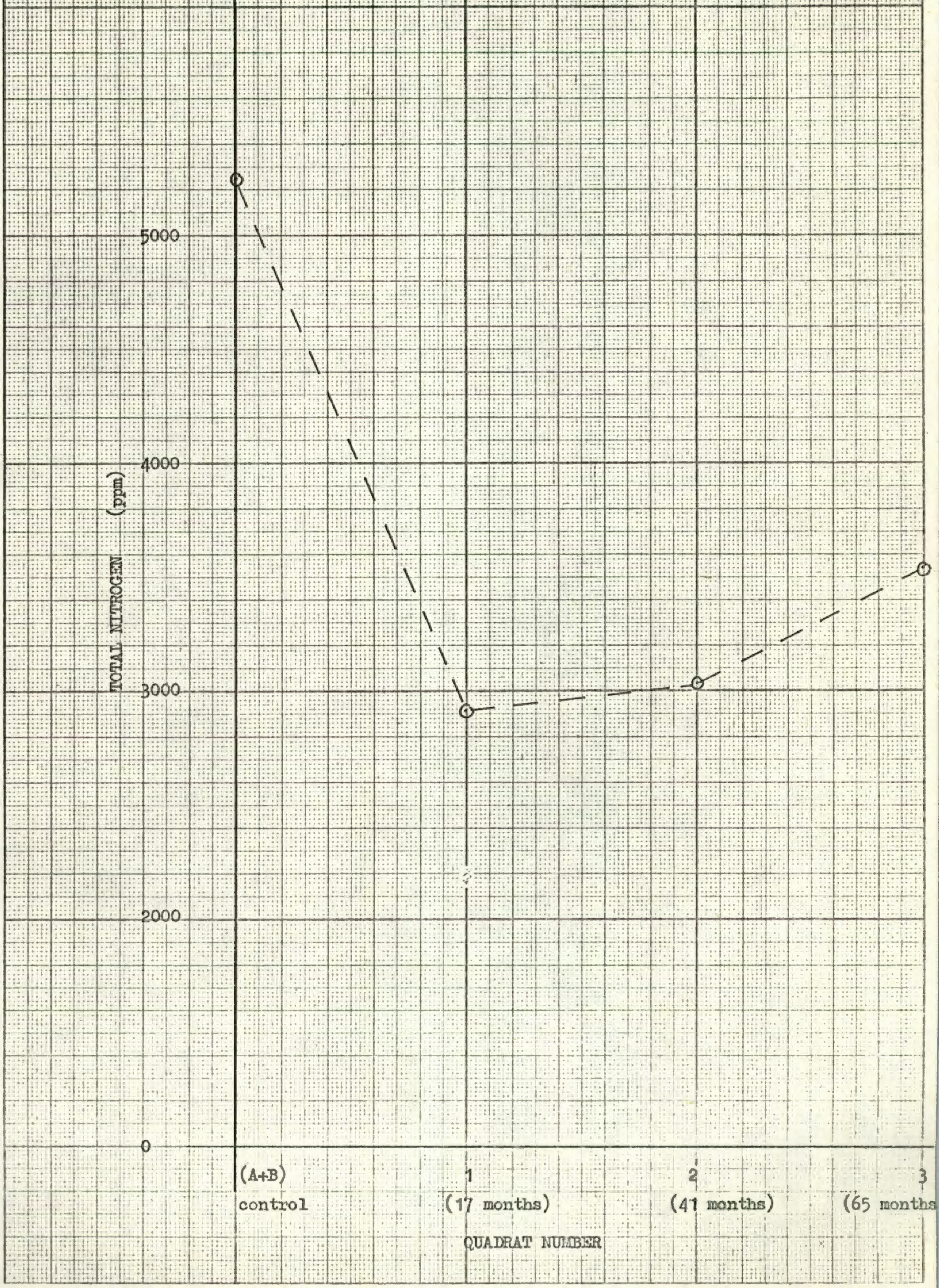




GRAPH 3.3: TOTAL NITROGEN CONCENENTRATION OF LITTER AT THE THREE FIRE BREAKS ON THE TABLE MOUNTAIN-DEVILS PEAK SADDLE (TRANSECT)

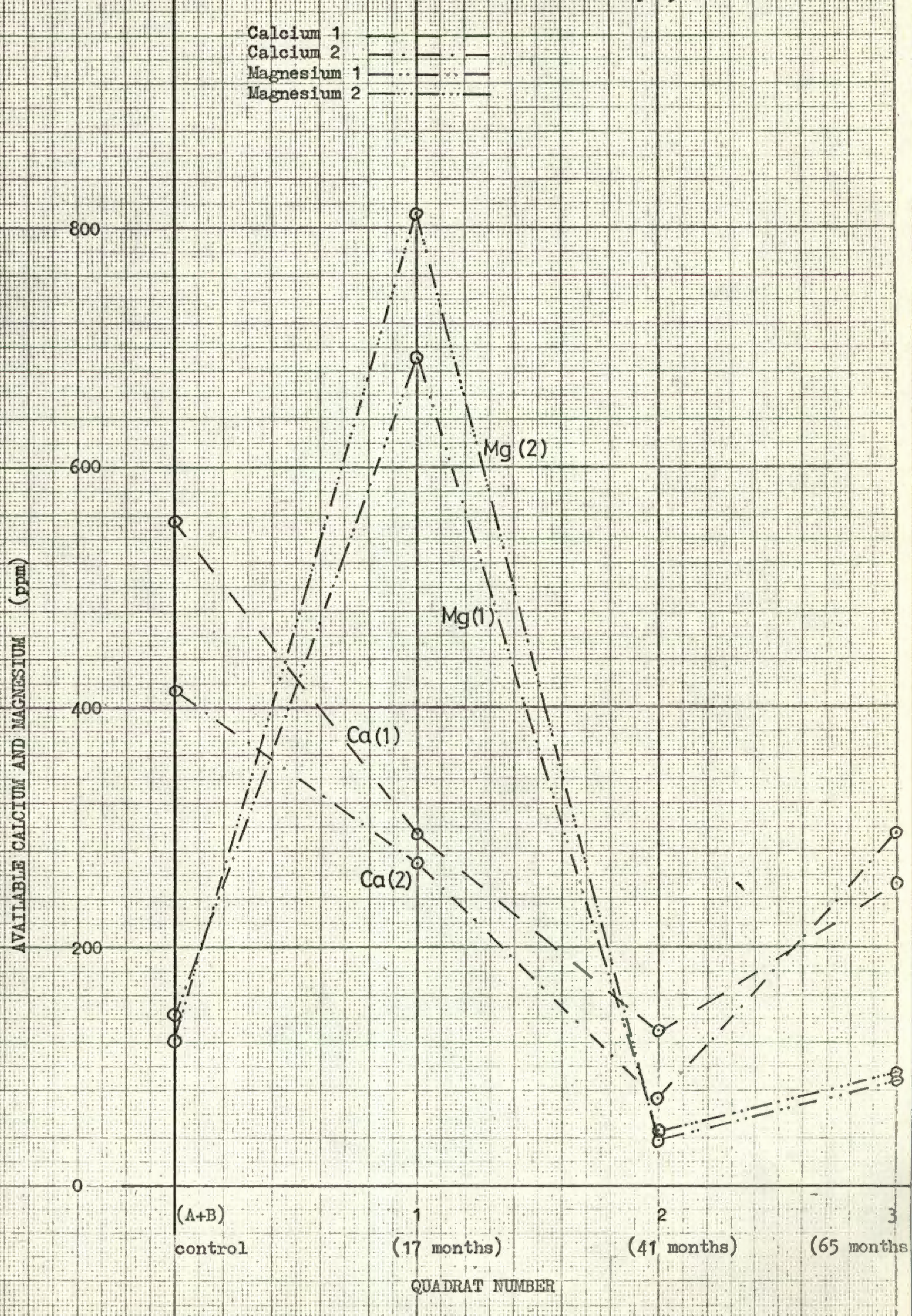
Quadrat (A+B) = control

Quadrats 1, 2 and 3 = 17, 41 and 65 month old fire breaks



GRAPH 3.4: CONCENTRATIONS OF AVAILABLE CALCIUM AND MAGNESIUM MEASURED IN THE SOIL AT THREE FIRE BREAKS ON THE TABLE MOUNTAIN-DEVILS PEAK SADDLE. (TRANSECT)

Quadrat (A+B) = control
Quadrats 1, 2 and 3 = 17, 41 and 65 month old fire breaks
available cation measurements in two profiles: 1- 0-5 cm
2- 5-15 cm



3. RESULTS

3.1 Study of the physical characteristics of soil samples

Results obtained from measurements of the distribution of soil particle size (% weight or % volume) in samples obtained from the three study areas show some interesting trends (see Table 3.1). The size range 0,105 - 0,84 mm seems to be characteristic of all sampling sites. This range includes coarse, medium and fine sand separates and generally consitutes 85-95% total weight or volume in each sample.

The sampling site at the Table Mountain-Devils Peak Saddle appears to have significantly more coarse and medium sand, but less very fine sand and silt and clay than Kirstenbosch or Orange Kloof. Little difference was noted between the particle size range in samples from the control quadrat (A+B) and 1, 2 and 3 on the fire breaks.

Considering the percentage weight and percentage volume values obtained for the two profiles at each site, those obtained at Orange Kloof and Kirstenbosch appear to be very similar, (that is, profiles 1 and 2 for a specific size range does not differ significantly). Some interesting trends are, however, noticeable in the profiles of the Saddle. Considering the most important size ranges (2, 3 and 4) for quadrats 1, 2 and 3, there seems to be a shift towards higher values for profile 2 in the size ranges 2 and 3 in quadrat 3. This means that there seems to be a slight increase in soil particle size in profile 2 from fire break 1 to 3. This would not be expected, as the plant cover increases from quadrat 1 to 3 according to the age of the respective fire breaks. Erosion factors would favour the reverse of what was noted.

Soil samples from the (A+B) control profile 2 show a marked difference to the normal trend for the rest of Table 3.1. The fine gravel separate is very much larger here than recorded at the other quadrats.

Percentage weight and percentage volume of soil sample ranges 5 and 6 at the Saddle show a constant decrease from profiles 1 to 2 for all quadrats.

3.2 Measurement of percentage total organic matter in the soil samples

The percentage total organic matter measured at Kirstenbosch on the 11/3/77 and that on 12/9/77 do show a slight increase in organic matter in profile 1 in the latter (Table 3.2). The value for profile 2 increases slightly over this period. This could be an indication of autumn to spring shift in organic matter content, than a seasonal trend.

Organic matter values for Orange Kloof are very interesting as they are still fairly high (but significantly lower than Kirstenbosch). Most important is the closeness of the values for profiles 1 and 2 when compared with the values from Kirstenbosch. The closeness of the measurements may be an indication of how much organic matter has been lost. It should, however, also be remembered that there is an organic matter gain from partially burnt plants.

Organic matter content of the soil samples from the Saddle appears to be almost twice as high as those measured at Kirstenbosch and Orange Kloof. Values obtained from quadrats 1 to 3 appear to differ significantly from those of (A+B), and are much higher than those from Orange Kloof. The trend of organic matter from quadrat 1 to 3 shows a much lower value at 2 than may be expected when considering the vegetation cover increase.

3.3 Average total nitrogen measured in litter and soil samples

Values obtained for total nitrogen generally show a fairly large standard deviation. This is probably as a result of experimental error and variations in the micro-organism population of the soil (see Appendix Table 2).

The average total nitrogen measured in litter samples ranges between approximately 70 and 85 percent of the total soil + litter (see Table 3.3). Profile 1 contains 5-16% of the total soil + litter nitrogen while approximately 3-16% is found in the lowest profile.

Total nitrogen measured at Kirstenbosch on 12/9/77 was significantly lower than the 11/3/77. This could be related to a seasonal fluctuation. The distribution of nitrogen however changes and there is a 6% increase in the amount found in litter on the 12/9/77 (see Table 3.3).

Total nitrogen measured in soil profiles 1 and 2 at Kirstenbosch shows a good correlation with the percentage total organic matter in Table 3.2.

Measurements of live and dead Erica hispidula at Kirstenbosch show that live plants contain 50% more nitrogen than dead plants (see Appendix Table 3). It also appears that litter, on the other hand, contains significantly more total nitrogen than dead plants.

A very large difference between soil and litter total nitrogen was noticed at Orange Kloof, (litter samples collected here consisted of pieces of partially burnt vegetation). Approximately 90 percent of total nitrogen is now present in the litter. This may suggest that the additional gain was from the burnt plants.

Total nitrogen measured at the Devils Peak Saddle also shows a good correlation with the percentage organic matter recorded here. Considering the values obtained for litter, quadrats 1, 2 and 3 show a marked difference to that from (A+B). The value for quadrat 2 is again lower than may be expected when considering the vegetation cover abundance trend from 1 to 3. The percentage nitrogen present in litter (see Table 3.3) is, however, fairly consistent for all quadrats except 2, where it is much lower.

Total nitrogen distribution in the soil profiles at the Saddle shows an interesting difference to that measured at Kirstenbosch. It appears that the nitrogen content of profile 2 (A+B) is slightly higher than that of profile 1. That is 8,0% total nitrogen present in profile 2 as opposed to 7,5% in profile 1. This trend could be very significant when considering the effects of burning. The nitrogen reserves in profile 2 may be almost unaffected and again become available to the plant by the action of, for example, micro-organisms after the fire.

3.4 Measurement of available phosphorus at Kirstenbosch (11/3/77)

The measurements of available phosphorus at Kirstenbosch are only a relative indication of what is available to plants. That is, it is by no means an indication of what plants will ultimately use.

Litter contains almost three times the amount of available phosphorus than is present in the first soil profile (see Table 3.4). Profile 1 in turn contains almost twice as much available phosphorus than that present in profile 2.

It appears that burning of the area would result in a considerable loss in available phosphorus, if litter (which contains 2/3 of the total available P) is burnt.

3.5 Measurements of total calcium, magnesium, sodium and potassium in litter

A comparison of the average total calcium, magnesium, sodium and potassium measured in the litter at Kirstenbosch shows a marked increase from March to September (see Table 3.5). The increases for calcium and magnesium appear to be most significant.

A comparison of the cation concentrations measured at Orange Kloof with those from Kirstenbosch shows that the latter has much lower concentrations. The most significant difference is noted for magnesium.

Cation values obtained for litter samples collected at the Saddle Transect and control quadrats are illustrated in Graphs 3.1 and 3.2 (from Table 3.5). It appears that the general trend across the transect is remarkably similar for all cations. Values obtained for quadrat 1 are significantly lower than those for the other quadrats. This could be related to the relatively low vegetation density on this fire break.

The values for total nitrogen in the litter (see Graphs 3.3 and Table 3.2) show a general decreasing trend from (A+B) to 1, 2 and 3.

The values obtained for quadrats 1, 2 and 3 are significantly lower than that from (A+B).

3.6 Measurement of available calcium and magnesium in soil samples

Values obtained for available calcium and magnesium at Kirstenbosch indicate that the concentration of each is significantly lower in profile 1 on the 12/9/77 than on the 11/3/77. Interestingly the values in profile 2 increase during this period. This trend could indicate that some leaching of calcium and magnesium may occur during the winter.

Measurements of available calcium and magnesium at the Orange Kloof site show that there is a smaller difference in their respective concentrations here than at Kirstenbosch.

Available calcium and magnesium present in soil at the Saddle site show markedly different trends across the transect (see Graph 3.4). The values obtained for profiles 1 and 2 follow the same trend.

The trend of available calcium is one of marked decrease till quadrat 2 (where the lowest value is noted). The values obtained for quadrat 3 for available calcium and magnesium are significantly higher than those for quadrat 2.

The trend for available magnesium is interesting in that very high values are obtained from quadrat 1. This means that high available magnesium is at the site with the lowest vegetation cover.

4. DISCUSSION

A study of the physical characteristics of fynbos soils shows that they are almost exclusively coarse to fine sand. This property could be important in determining the soil nutrient loss during a fire, as well as the significance of erosion afterwards. Well aerated sandy soils are probably more likely to lose a significant percent of their nutrients, (in the upper 0-5 cm), than clay or silt rich soils. This is because the latter have better insulation properties.

A comparison of the amount of organic matter recorded at Orange Kloof after a fire, with that measured at Kirstenbosch (unburnt), appear to indicate that a decrease in the 0-5 cm soil profile organic matter content occured during burning. The decrease in organic matter content is reflected by the closeness of the measurements obtained for the two profiles.

Measurements of the percentage total organic matter at the Table Mountain-Devils Peak saddle indicate that more recently burnt fire breaks do contain significantly less than the control quadrats. This could be related to poor vegetation cover and factors such as erosion, (which is frequent on steeper slopes), rather than the direct effects of burning. It must also be remembered that the youngest fire break was 17 months old.

As would be expected, values obtained for total nitrogen in the soil at all sampling sites show a close correlation with the percent total organic matter present. Total nitrogen levels recorded for soil at the three sites are significantly lower than those measured by Botha, (1976) in forest soils. Total nitrogen levels of between three and seven thousand ppm were noted for the Kirstenbosch forests. The values recorded at the sites for this project ranged between 3,5 and 15 percent of the average forest value. This indicates that fynbos soils are associated with very low levels of nitrogen.

Interestingly the percentage total nitrogen present in the litter at Orange Kloof appears to have been significantly increased during the fire. This may be related to the contribution made to litter by partially burnt vegetation. After a fire litter therefore consists of ash + partially burnt vegetation + partially burnt litter that was present before the fire. It must be remembered that the Orange Kloof measurements are for a particular fire of a particular nature and burning specific vegetation of a specific age. These variables have not been accounted for in this survey.

Measurements of available phosphorus in the soil at Kirstenbosch are slightly lower than those recorded by Botha, (1976). The amount of available phosphorus in the litter is similar to that measured in the 0-5 cm profile by this worker.

When the total cation content of litter from Orange Kloof is compared with that measured at Kirstenbosch, it appears to be significantly higher. This may be associated with the fire, in that the extensive nutrient losses recorded in vegetation during burning, (Evans and Allen, 1971 and Grier, 1975), may be accounted for in an increase in litter nutrient concentration. It must be noted that no clear indication of the relative amount by which the concentraion of each cation in the litter and soil change during burning can be made. This is obviously due to the fact that no measurements were obtained from one site before, as well as after a fire.

Comparison of the total cation concentrations in litter at the youngest fire break with that present at the control quadrats, indicate that, after 17 months had elapsed since burning, values for total calcium, magnesium, sodium and potassium, were still significantly low. Because of the long period of time that had elapsed since burning, this observation could be more closely related to low vegetation cover and soil erosion, etc., than direct effects due to fire.

The relatively small differences in available calcium and magnesium concentrations measured in the two soil profiles at Orange Kloof, compared with that recorded at Kirstenbosch, may indicate, that while the total calcium and magnesium concentrations in the litter have increased, (as has been noted), the available concentration in the 0-5 cm profile has decreased. This decrease could be related to nutrient loss during the fire and is similar to that noted for organic matter.

Measurements of available calcium on the Table Mountain saddle, indicate that significantly lower concnetrations are associated with the fire breaks (compared to the control quadrats). Available magnesium does not follow the same trend as calcium and is highest at the youngest fire break. Both calcium and magnesium values do not correlate with an increase in fire break age.

5. CONCLUSIONS

A comparison of measurements of nutrient concentrations in litter and soil 1 week after a fire at Orange Kloof, with those obtained from the unburnt site at Kirstenbosch, indicate that a redistribution of nutrients may occur during a fire.

Concentrations of total nitrogen, calcium, magnesium, sodium, and potassium measured in the litter layer appear to increase during burning. This may account for a significant amount of the high nutrient losses associated with burning of vegetation.

There are indications that the total nitrogen and available calcium and magnesium concentrations of the top 5 cm of soil may decrease with respect to the concentrations in the 5-15 cm profile. This observation may be related to volatilization of nitrogen, calcium and magnesium during burning.

The low nutrient status associated with soil and litter from the seventeen month old fire break on the Table Mountain-Delvils Peak saddle may largely be due to factors associated with low vegetation abundance, (such as soil erosion), rather than direct effects due to burning. The original soil nutrient status has apparently not been reestablished on the 65 month old fire break. This may indicate that regeneration of vegetation and reestablishment of the soil nutrient status is very slow in the fynbos.

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APPENDIX

TABLE 1: PERCENTAGE TOTAL ORGANIC MATTER MEASURED IN TWO SOIL PROFILES AT THE DIFFERENT SAMPLING SITES

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle(Transect)(31/8/77)
Soil Profiles: 1 = 0-5cm, 2 = 5-15cm.
Six samples, average and standard deviation indicated.

Site,	Profile	% Total Organic Matter							
		1	2	3	4	5	6	Avg	St Dev
K(a)	1	4,8	4,8	4,8	4,6	4,8	4,8	4,77	0,08
	2	2,4	2,4	2,4	2,4	2,6	2,6	2,47	0,10
K(b)	1	4,2	4,6	4,8	4,2	4,6	4,6	4,50	0,25
	2	2,8	3,2	3,0	2,8	3,2	3,2	3,03	0,20
OK	1	2,8	3,2	3,2	3,0	3,0	2,8	3,00	0,03
	2	2,2	2,2	2,0	2,0	2,2	2,4	2,17	0,15
TM(A+B)	1	8,6	8,8	9,2	9,0	9,0	8,8	8,90	0,21
	2	6,0	6,8	7,0	6,8	6,2	6,0	6,46	0,41
(1)	1	4,6	4,8	4,8	4,8	4,8	5,0	4,80	0,13
	2	3,8	4,2	4,2	4,2	4,0	4,0	4,07	0,16
(2)	1	2,6	3,0	2,6	2,6	3,2	3,0	2,83	0,27
	2	3,2	3,0	3,4	3,0	3,4	3,0	3,17	0,20
(3)	1	6,2	6,6	6,4	6,2	6,4	6,4	6,37	0,15
	2	4,4	5,0	4,8	4,4	5,0	4,6	4,70	0,28

TABLE 2: TOTAL NITROGEN MEASURED IN LITTER AND TWO SOIL PROFILES AT THE DIFFERENT SAMPLING SITES

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect)(31/8/77)
L = Litter
Soil Profiles: 1 = 0-5cm, 2 = 5-15cm.
Six samples, average and standard deviation indicated.

Site, Litter or Soil Profile		TOTAL N (ppm) 1	2	3	4	5	6	Avg	St Dev
K(a)	L	3829	3542	3486	3598	3695	3535	3614	127
	1	775	802	734	792	775	752	772	25
	2	186	177	211	195	178	204	192	14
K(b)	L	2100	2340	2562	2445	2231	2385	2344	162
	1	187	236	214	222	189	226	212	20
	2	207	185	239	225	198	211	211	19
OK	L	6622	6818	6433	6993	7000	6880	6791	224
	1	379	399	416	426	373	384	396	21
	2	179	229	195	212	183	205	201	19
TM(A+B)	L	5115	5180	5383	5225	5280	5275	5243	92
	1	446	443	490	481	476	452	465	20
	2	425	483	516	515	453	534	498	55
(1)	L	2893	3178	2639	2850	2920	3035	2919	181
	1	242	296	253	298	288	233	268	29
	2	170	152	145	184	196	184	172	20
(2)	L	2032	2128	2055	1946	2019	2025	2034	59
	1	273	329	331	273	312	280	300	28
	2	446	436	494	490	460	438	461	26
(3)	L	2598	2503	2639	2450	2577	2525	2549	69
	1	256	224	200	266	301	286	256	38
	2	175	186	147	188	192	160	175	18

TABLE 3: TOTAL NITROGEN MEASURED IN LIVE AND DEAD *ERICA HISPIDULA* AT THE KIRSTENBOSCH SITE (11/3/77)

Six samples, average and standard deviation indicated.

Plant Condition	TOTAL N (ppm)							
	1	2	3	4	5	6	Avg	St Dev
Live	5740	5390	5530	5615	5635	5443	5559	130
Dead	2772	2898	2807	3010	2541	2450	2746	213

TABLE 4: AVAILABLE PHOSPHORUS MEASURED AT THE KIRSTENBOSCH SITE (11/3/77)

L = Litter
Soil Profiles: 1 = 0-5cm, 2 = 5-15cm.
Values for six samples, average and standard deviation indicated.

Litter or Profile	AVAILABLE P (ppm)							
	1	2	3	4	5	6	Avg	St Dev
L	15,0	10,0	10,2	9,5	10,2	13,0	11,3	2,2
1	5,1	4,2	4,2	4,2	3,8	4,1	4,3	0,4
2	2,5	2,3	2,2	2,1	2,2	2,0	2,2	0,2

TABLE 5: TOTAL CALCIUM MEASURED IN LITTER AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect)(31/8/77)
Four samples, average and standard deviation indicated.

Site	TOTAL Ca (ppm)					
	1	2	3	4	Avg	St Dev
K(a)	3300	3400	3300	3500	3375	96
K(b)	7460	7560	7500	7460	7495	47
OK	8600	8800	9700	9000	9025	479
TM(A+B)	7100	8300	7400	7500	7575	512
1	2400	2500	2500	2400	2450	58
2	13000	13600	13000	13400	13250	300
3	12300	12300	12000	12400	12250	173

TABLE 6: TOTAL MAGNESIUM MEASURED IN LITTER AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain- Devils Peak Saddle (Transect)(31/8/77)
Four samples, average and standard deviation indicated.

Site	TOTAL Mg (ppm)					
	1	2	3	4	Avg	St Dev
K(a)	900	950	900	950	925	29
K(b)	1490	1540	1500	1460	1498	33
OK	3520	3400	3500	3500	3480	54
TM(A+B)	3320	3520	3400	3440	3420	83
1	680	690	660	690	680	14
2	1940	2200	2000	2100	2060	114
3	2480	2400	2480	2500	2465	44

TABLE 7: TOTAL SODIUM MEASURED IN LITTER AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect)(31/8/77)
Four samples, average and standard deviation indicated.

TOTAL Na (ppm)

	1	2	3	4	Avg	St Dev
K(a)	350	305	320	330	326	19
(b)	600	550	600	500	563	48
OK	720	785	750	730	746	29
TM(A+B)	900	940	950	920	928	22
1	290	305	300	295	298	6
2	900	870	940	880	898	31
3	1070	940	1000	980	998	54

TABLE 8: TOTAL POTASSIUM MEASURED IN LITTER AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect)(31/8/77)
Four samples, average and standard deviation indicated.

Site	TOTAL K (ppm)					
	1	2	3	4	Avg	St Dev
K(a)	280	232	240	284	259	27
(b)	310	320	368	360	340	29
OK	724	770	810	828	783	46
TM(A+B)	640	700	742	710	698	43
1	170	180	160	175	171	9
2	540	580	500	560	545	34
3	830	820	880	840	843	26

TABLE 9: AVAILABLE CALCIUM MEASURED IN TWO SOIL PROFILES AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect)(31/8/77)
Soil Profiles: 1 = 0-5cm, 2 = 5-15cm.
Four samples, average and standard deviation indicated.

Site,	Profile	Available Ca (ppm)					
		1	2	3	4	Avg	St Dev
K(a)	1	405	390	395	395	396	6
	2	208	203	200	193	201	6
K(b)	1	355	375	388	380	375	14
	2	230	240	243	225	235	8
OK	1	200	200	193	213	202	8
	2	140	170	165	150	156	14
TM(A+B)	1	540	575	545	560	555	16
	2	400	420	435	410	416	15
(1)	1	295	295	290	300	295	4
	2	270	270	270	268	270	1
(2)	1	140	120	125	135	130	9
	2	60	80	75	75	73	9
(3)	1	255	248	255	248	252	4
	2	290	290	295	305	295	7

TABLE 10: AVAILABLE MAGNESIUM MEASURED IN TWO SOIL PROFILES AT THE DIFFERENT SAMPLING SITES.

K(a) = Kirstenbosch (11/3/77)
K(b) = Kirstenbosch (12/9/77)
OK = Orange Kloof (17/3/77)
TM = Table Mountain-Devils Peak Saddle (Transect)(31/8/77)
Soil Profiles: 1 = 0-5cm, 2 = 5-15cm.
Four samples, average and standard deviation indicated.

Site,	Profile	Available Mg (ppm)					
		1	2	3	4	Avg	St Dev
K(a)	1	73	70	65	68	69	3
	2	35	40	40	42	39	3
K(b)	1	65	68	65	70	67	2
	2	51	51	58	56	54	4
OK	1	73	81	85	87	82	6
	2	58	65	60	60	61	3
TM(A+B)	1	142	142	142	140	142	1
	2	118	126	120	120	121	3
(1)	1	725	650	675	715	691	35
	2	810	810	820	805	811	6
(2)	1	35	35	42	40	38	4
	2	51	42	46	43	46	4
(3)	1	88	88	88	86	88	1
	2	88	103	95	90	94	7