An investigation of Hawthorn (cratageus monogyna) succession on the magnesian limestone soils of Co Durham

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"AN INVESTIGATION OF HAWTHORN (CRATAGEUS MONOGYNA) SUCCESSION ON THE MAGNESIAN LIMESTONE SOILS OF CO. DURHAM"

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INTRODUCTION

The objectives of this dissertation were to investigate the pedological changes occurring during the process of vegetation succession, the processes and mechanisms involved in these changes, and finally to establish the relevance of these changes to the conservation of the Magnesian Limestone flora of County Durham.

The rendzina soils of the Magnesian Limestone of County Durham have been described in detail by Frisby (1961) and also by McKee (1969) although both studies were concerned with agricultural and landuse problems. Similarly the flora of the Magnesian Limestone has been described by Lousley (1950), whilst the research of Shimwell (1968) was primarily concerned with the application of phyto sociological techniques in the classification of the Limestone communities. There has therefore been a lack of integrated studies concerning the Limestone flora and the associated soils, and it was this situation that this dissertation hoped to rectify.

In recent years it has become apparent that due to continued influence and in some cases intensification of several factors, notably vegetation succession and industrialisation, there exists a situation in which the continued survival of the Magnesian Limestone flora may be endangered (Bellamy, 1970). This study was mainly concerned with the influence of Hawthorn (Crataegus monogyna) (Jacq.) and Gorse (Ulex europaeus) (Linnaeus) succession.

The general processes involved in vegetation succession have been examined by various authors such as Clements (1928), Tansley (1922), and more recently Whittaker (1953). However, despite the existence of a strong theoretical background concerning succession, there is still a noticeable lack of quantative field studies in this aspect of ecology (Burges 1960). Although it must be stated that there are many difficulties encountered in the study of vegetation succession, not least the complications of the time factor, the field remains under-researched.

With reference to the situation under investigation in this dissertation the problem was to assess the possible influence of Hawthorn and Gorse Scrub vegetation on Magnesian Limestone Grassland communities. Hawthorn appears to be a primary colonising species of grasslands and is often associated with a modification in grazing regime. Locket (1946), Tansley (1922) and Salisbury (1952) have reported Hawthorn as being one of the first species to establish in the seral development of woodland from the plagioclimax grassland state. More recently Merton (1970) has stated that the intensity of Hawthorn Scrub communities colonising Limestone Grasslands in Derbyshire was a direct function of the intensity of grazing whilst Pollard (1973) attributes the success of Hawthorn to its ubiquitous distribution as a hedgerow component throughout the British Isles. Thomas (1960, 1963) has drawn attention to the profound effects of altering the grazing regime on the composition of the associated vegetation. Gorse would appear to occupy a similar position to that of Hawthorn in the successional development and its success as a colonising species has been documented by Grubb et al (1969).

Despite the above studies on Hawthorn and Gorse succession, there still exists a lack of information on the precise pedological changes involved during the process of succession. Perhaps the exception to this statement is to be found in the research of Grubb (1970) which concerned the interactions of soil and Gorse during succession on chalk grassland.

The basic premise assumed in this dissertation was that the succession of Hawthorn and Gorse would have detrimental effects on the existing Limestone Grassland flora. It was hypothesised that the colonising species would alter the soil properties to such a degree and in a manner which would prevent the regeneration of the unique grassland communities which existed at the site chosen for investigation. The study was therefore concerned with an autoecological problem which had relevance in a synecological context.

SITE DESCRIPTION

Location

The site chosen for the investigation was Thrislington plantation (Grid Reference NZ 318328) which is situated approximately 12 kilometres due south of Durham City. The site occupied an area of approximately 32 hectacres and was composed of Limestone Grassland interspersed with Hawthorn Scrub.

Geology

Thrislington plantation is situated on an outcrop of Magnesian Limestone of Permian age. This geological formation is highly calcareous in nature being mainly composed of Magnesian and Calcium Carbonates which together usually constitute 90 to 99 percent of the Limestone (Browell and Kirkby, 1866). With regard to the Drift Geology of the site examination of the relevant geological maps indicated that deposits of glacial material had probably been included in the soil.

Soils

In general the calcareous base rock was overlayed by calcareous brown earth soils which varied in depth from approximately 10 to 50 cm. These soils were therefore not of the usual zonal soils expected to be developed over Limestone. The normal soil type developed on Limestone is a rendzina, and the presence of brown earth soils at the site reinforced the hypothesis that glacial material probably in the form of loess had contributed to their development.

Climate

The importance of the climatic factor in soil development has been emphasised by Jenny (1941). The parameters of climate chosen for description were precipitation, temperature and evapo-transpiration. However, due to the lack of a meteorological station on site the data presented is derived from the records of Durham University Observatory which was the nearest station to the site. Therefore, it should be noted that differences in micro-climate between Thrislington and Durham probably exist due to such factors as elevation, distance from sea and vegetation.

The mean annual precipitation for the period 1906-1935 recorded at Durham was 650.2 mm. The distribution of the precipitation is depicted in Figure 2.1. Similarily the distribution of temperature is shown in Figure 2.2. With regard to evapo-transpiration no direct data was available. However, an indication of the annual loss due to this factor was calculated using Holdridge's (1962) formula. The results of this formula indicated that losses due to evapo-transpiration could constitute some 80 percent of the total annual precipitation. Unfortunately this formula cannot be applied to depict monthly evapo-transpiration losses and therefore such information was not available.

<u>Vegetation</u>

The vegetation present at Thrislington has been fully described and classified into communities using phytosociological techniques by Shimwell (1968). The communities recorded by this author were as follows:

FIGURE 2.1

SEASONAL DISTRIBUTION OF TEMPERATURE AT DURHAM OBSERVATORY

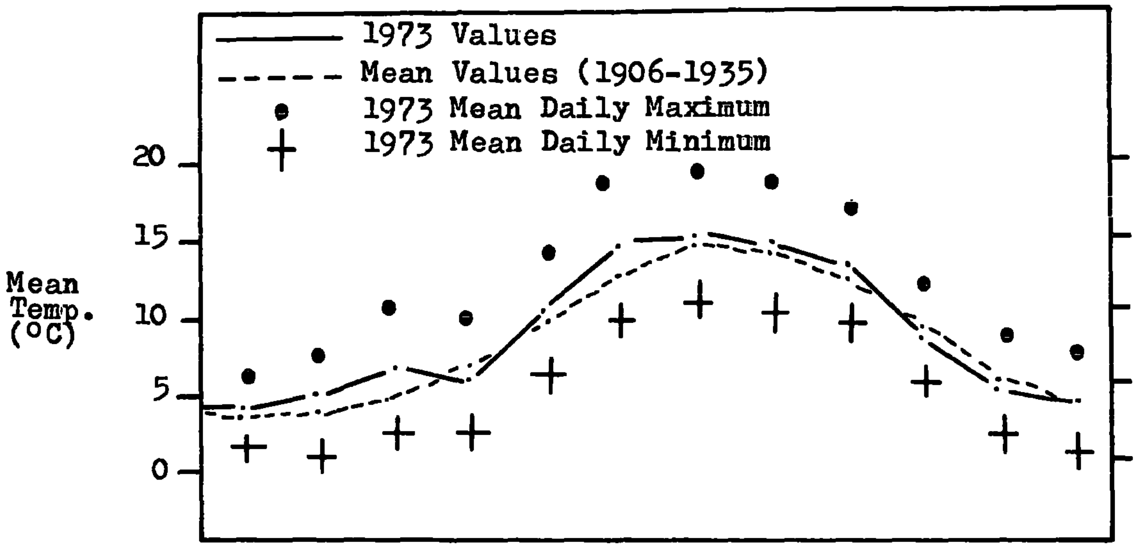
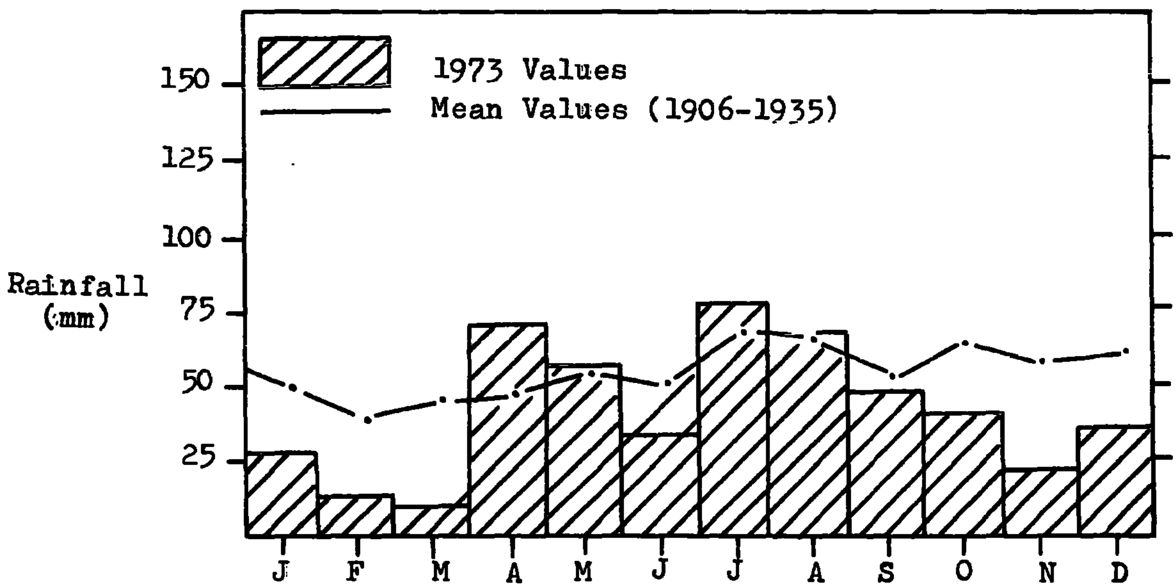


FIGURE 2.2

SEASONAL DISTRIBUTION OF PRECIPITATION AT DURHAM OBSERVATORY



Seslario Helictotrichetum   Sub association typicum

Sub association caucetosum pulicariae

Sub association of Helictotrichetum pubesces, Rosa variant.

Salicetum repenti - nigicantis

Crataegus - Rosa pimpinellifolia Association

Shimwell (1968).

The flora present at Thrislington is of scientific value and the site has been recommended for designation as a national nature reserve.

SAMPLING METHODS

It is proposed to describe the methods used for soil and plant tissue sampling under the following headings:

(a) Preliminary Survey.

(b) Soil Sampling.

(c) Plant Tissue Sampling.

(d) Moisture Content Sampling.

The methods used are fully described below:

(a) Preliminary Survey

A preliminary survey of the site was undertaken to ascertain as to whether Hawthorn did have an acidifying effect on the grassland soil. Samples of soil were extracted from underneath the Hawthorn and also from Limestone Grassland. The location of these sites was random but subjective in that no preconceived procedure, such as the use of random numbers for location, was involved.

Samples of soil were removed using a 5 cm. diameter soil corer. Upon removal from the corer the sample was immediately sectioned into three parts representing their depth in the soil profile. These sections were 0-3 cm., 3-6 cm., and 6-9 cm. Each section was then placed in a separate polythene bag, labelled and transferred to the laboratory for analyses.

On return to the laboratory each sample was carefully removed from the polythene bag and placed on a circle (18 cm.) of filter paper and allowed to air dry for 48 hours. After 48 hours the samples were ground using a mortar and pestle and passed through a 2 mm. sieve. Any fragments of soil retained by the sieve were discarded.

The samples were then analysed for pH and Exchangeable Metallic Cations.

(b) Soil Sampling

After analysis of the preliminary samples for pH and Exchangeable Metallic Cations it was decided that in addition to investigating the effects of Hawthorn on soil properties it would be useful to sample the Gorse present at Thrislington. The two main reasons for this decision were firstly the results of the preliminary survey which indicated that the Hawthorn had no appreciable effect in acidification of the soil. Secondly, it was hypothesised that this failure to detect an acidifying action by Hawthorn was possibly due to the high buffering capacity of the soil and in particular to the effect of the rich base rock of Magnesian Limestone. Gorse has been reported as having a rapid acidifying action on chalk soils (Grubb 1970), and it was thought that the measurement of the changes in soil properties beneath this vegetation would provide a standard of comparison in addition to the standard of comparison provided by the analyses of the soil properties of the Magnesian Limestone Grassland.

The soil sampling therefore involved the extraction of samples from three vegetation types. These were the Hawthorn Scrub, the Limestone Grassland and the Gorse. The methods used in sampling the respective vegetation types are described overleaf:

Hawthorn Scrub:

It was decided on a priori considerations that the Hawthorn Scrub would be sampled in a random manner. In order to achieve this objective an overlay grid consisting of two axis with identical scales of 1-16 was constructed. This grid was then placed over a 25 cm/1 km (6 ins/1 mile) map of the area and five locations generated using a table of random numbers (Gregory 1969), as coordinates on the graph. Only five sites were generated owing to the limitations of time. These five locations are presented in Fig. 3.1. In the field these sites were located using a compass and the Hawthorn sampled using the following procedure.

At the sampling site a 50 cm. transect was measured out using a standard tape so that the 25 cm. position was as close to the centre of the Hawthorn bush as possible. Soil cores were extracted from this transect at the following positions:

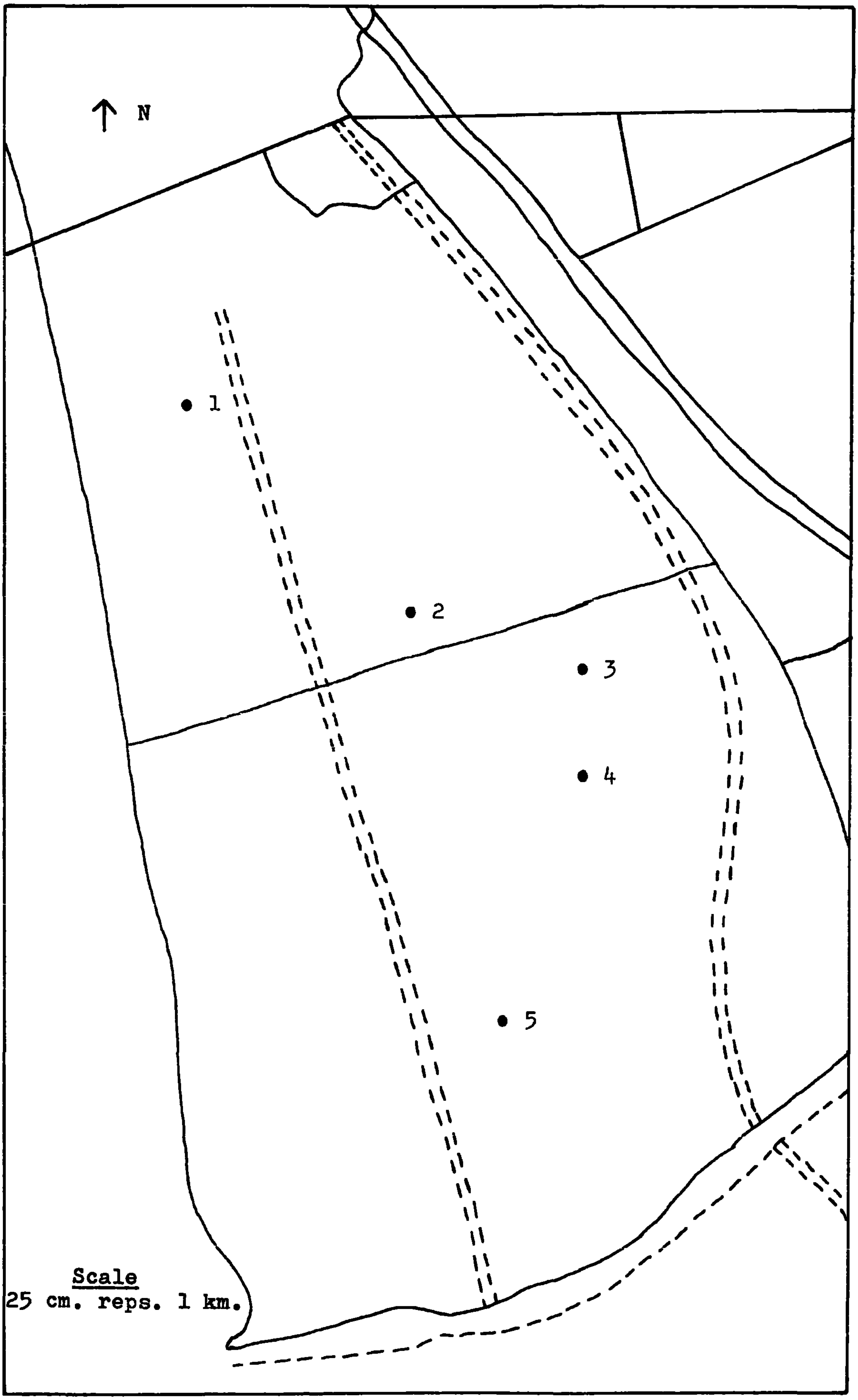
Position 1 - 0-5 cm. along transect.
Position 2 - 15 cm. along transect.
Position 3 - 25 cm. along transect.
Position 4 - 35 cm. along transect.
Position 5 - 50 cm. along transect.

Once the soil core had been extracted from the corer it was sectioned into three parts representing the soil depth 0-3 cm., 3-6 cm. and 6-9 cm. in the profile. The samples were then clearly labelled and placed in separate polythene bags for transport to the laboratory.

Using this procedure a total of 5 Hawthorn sites were

FIGURE 3.1

LOCATION OF RANDOM HAWTHORN SAMPLING SITES



sampled. As each site involved the extraction of five cores each sectioned into three soil depths, a total of 75 samples were removed for laboratory analyses.

Limestone Grassland:

An identical procedure was adopted in the sampling of the Limestone Grassland for soil, as to that used in the sampling of the Hawthorn Scrub Community. The sites were again located at random using identical axis for the overlay graph although a different set of random numbers was used to generate the coordinates of the points. The location of these sites is presented in Fig. 3.2. Five cores, each sectioned into three parts representing identical soil depths as for the Hawthorn sampling, were extracted from each site. This gives a total of 75 samples for laboratory analyses.

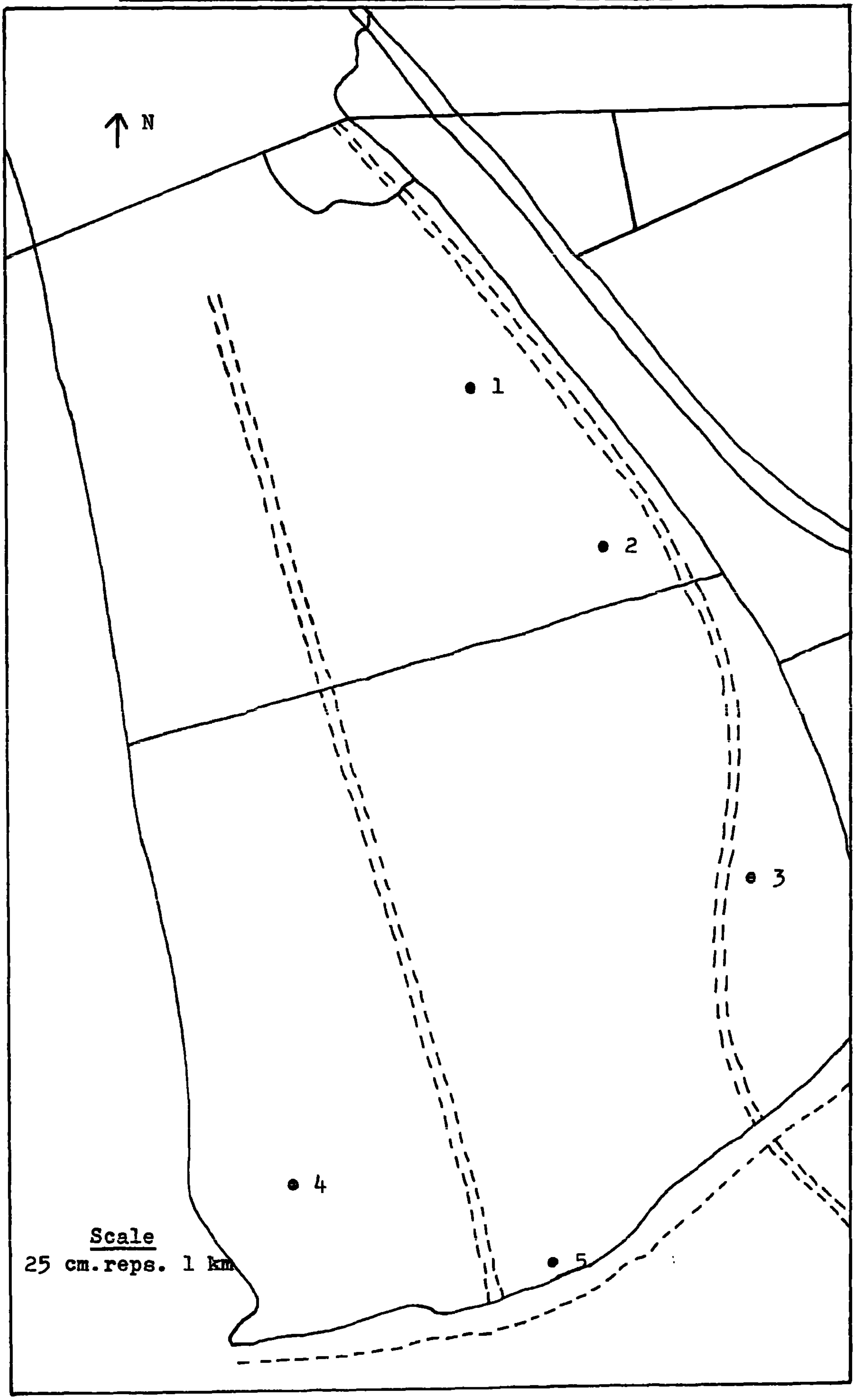
Gorse:

The distribution of Gorse at Thrislington appeared to be confined to one small area. However, for reasons which were stated earlier it was decided to sample this vegetation. Consequently five sites were sampled within this area. The location of these sites was subjective although an attempt was made to randomise the samples. The extraction of the samples followed the procedure already described for Hawthorn Scrub. The 25 cm. point on the transect underneath the Gorse again passed as close to the centre of the bush as possible. A total of 75 samples were extracted from the five sites using these procedures.

In addition to the random samples of Hawthorn Scrub extracted as described previously a further five sites, giving

FIGURE 3.2

LOCATION OF LIMESTONE GRASSLAND SAMPLING SITES



a total of 75 samples, were subjectively sampled. These additional five sites were confined to the same area where the Gorse sampling sites were located. The primary reason for extracting the additional samples was that as the Gorse was confined to such a small area it may have been selecting for particular soil properties and therefore this area could have exhibited deviation from the norm. Therefore, as the Gorse was to be used as a standard of comparison for Hawthorn it was felt necessary that this comparison should be made with Hawthorn sampling from the same area. The location of these samples together with the Gorse samples is presented in Fig. 3.3.

(c) Plant Tissue Sampling

Samples of the leaf tissue of Hawthorn, Gorse, Limestone Grassland and the Grassland Communities present underneath the Hawthorn Scrub were extracted in order to estimate the approximate nutrient removal of these vegetation types, and also for use in the experimental leaching columns. The sampling procedure is described below:

Hawthorn Tissue:

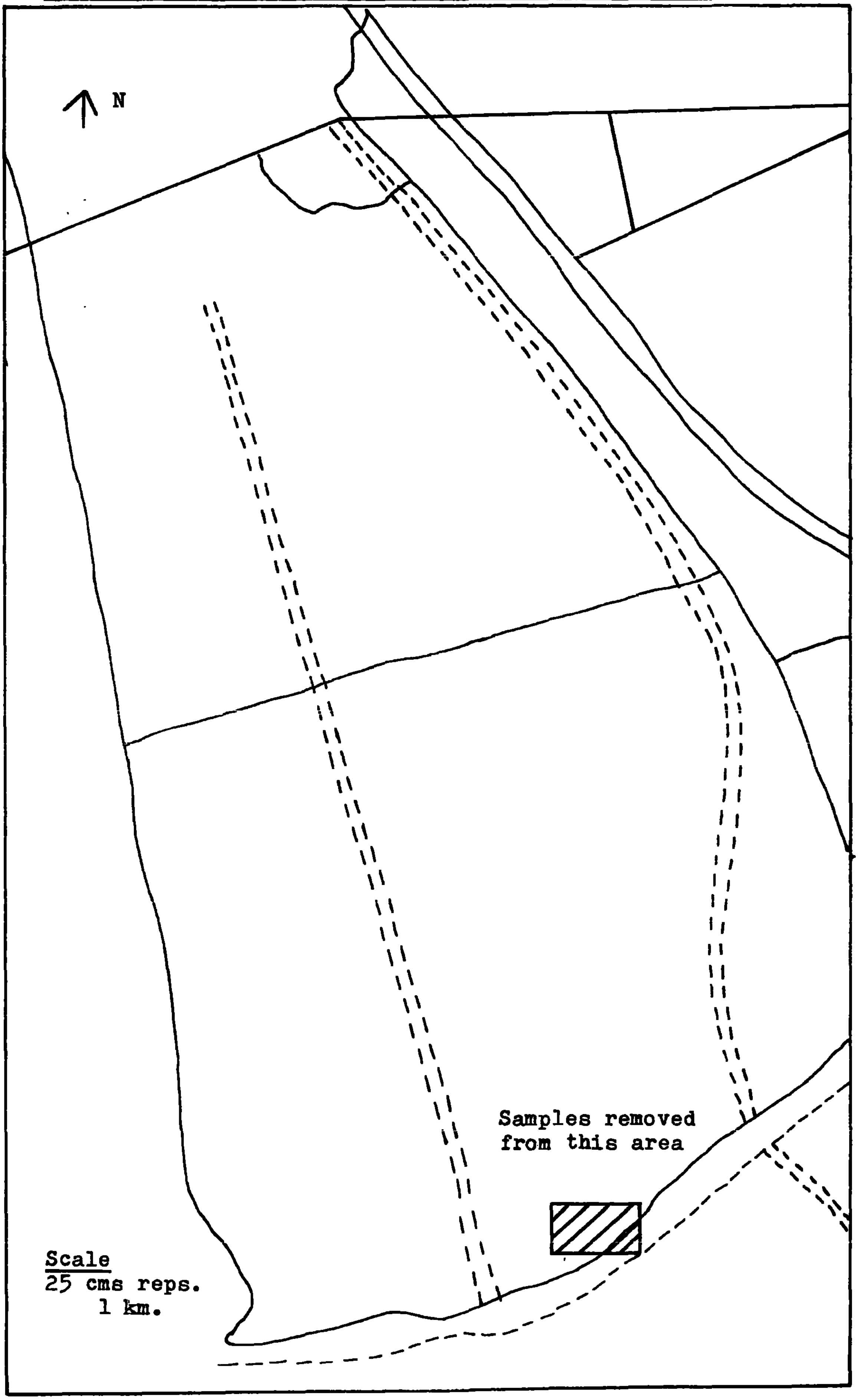
At each of the five sites used for the extraction of Hawthorn soil samples located randomly, the leaf tissue of each Hawthorn Bush was sampled randomly and approximately 4 grams fresh weight of leaf tissue collected per plant.

Gorse Tissue:

At each of the five locations used for the extraction of Gorse soil samples, the leaf tissue of each Gorse Bush was sampled and approximately 4 grams fresh weight of leaf tissue per bush collected for chemical analyses.

FIGURE 3.3

LOCATION OF SUBJECTIVELY SAMPLED HAWTHORN AND GORSE SITES



Limestone Grassland:

At each of the five locations used for the extraction of Limestone Grassland soil samples, the Grassland vegetation was cropped. Approximately 4 grams fresh weight of Grassland vegetation per site was collected for chemical analyses.

Hawthorn Grassland:

At each of the five sites used for the extraction of Hawthorn soil samples located randomly, the Grassland vegetation directly underneath the centre of the Hawthorn Bush was cropped. Approximately 4 grams fresh weight of Hawthorn Grassland vegetation per site was collected for chemical analyses.

All the plant tissue samples were composite samples and were collected in paper bags, labelled and oven dried in the laboratory for a period of 48 hours prior to analyses.

(d) Moisture Content Sampling

The procedure for the extraction of soil cores for moisture content determination is given below:

Using the overlay graph as described for Hawthorn Scrub previously a total of twenty sites were generated using random numbers. Of these twenty sites, ten were located underneath Hawthorn bushes and the remainder on the Limestone Grassland. The samples were extracted using the soil corer, only one core per site was taken, placed in a polythene bag, labelled and transported to the laboratory for analyses.

ANALYTICAL TECHNIQUES

Studies of the processess involved in vegetation succession by several authors, notably, Clements (1928) and Salisbury (1925), indicated that the soil properties most influenced were pH, Exchangeable Cation Capacity and Organic Matter Content. It was therefore decided to analyse for these properties and in addition to measure other properties which were hypothesised as being important in the Limestone Grassland habitat. The following soil properties were therefore measured:

(1) pH.

(2) Exchangeable Metallic Cation Capacity.

(3) Exchangeable Cations - Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg).

(4) Organic Matter Content.

(5) Free Carbonate Content.

(6) Moisture Content.

However, in order to obtain an indication of the amounts of nutrients removed by the vegetation and the possible losses due to chelation and leaching from the soil further analysis were undertaken.

The samples of leaf tissue collected from the various types of vegetation were analysed for their geochemical content. Similarly in order to estimate differences between sites due to the effect of litter a series of experimental leaching columns were constructed and the leachates obtained analysed for Calcium, Magnesium, Sodium, Iron, Aluminium and Carbonate.

The analytical techniques used in the dissertation are described below:

(1) pH Determination:

The pH of the soil samples was determined electrometrically using a glass and a reference electrode after the method of Jackson (1958). The procedure was as follows:

To a carefully weighed 5 gram sample of air dried soil in a beaker was added 25 ml of distilled water. The soil-water solution was allowed to equilibrate for an hour and stirred at intervals. A glass electrode was then inserted into the solution and the pH read directly and recorded.

The pH meter was calibrated before operation using standard buffers of pH4 and pH9 and recalibrated after every tenth sample to ensure maximum accuracy.

A total of 300 samples were measured using this technique.

(2) Total Exchangeable Metallic Cations:

The Total Exchangeable Metallic Cations of the soil samples was determined using Brown's (1943) method of Acetic Acid Titration. This technique was chosen in preference to the alternative Barium Chloride Leaching on the criterion of time available for analyses. However, some difficulty was experienced in the use of the technique although the alternative was not considered to be ideal due to the limitations of time. The procedure used is given below:

To a carefully weighed 1 gram sample of air dried soil was added 100 ml of exactly 1N Acetic Acid. The soil-acid solution was left for a period of 12-16 hours in order for the solution to equilibrate.

The change in pH of the solution was then determined, using the Delta pH scale on the pH meter, to two decimal places. The change in pH was measured using a blank solution of 1N Acetic Acid as a standard reference point. The Total Exchangeable Cation Capacity was then calculated using the following formula:

$$\text{meq exchangeable metallic cations per 100 gm of soil} = (\text{pH observed} - 2.31) \times 220$$

(Jackson 1958).

The main difficulty encountered in this technique was the lack of accuracy which arose from two main sources. Firstly, the Delta pH scale on the pH meter available was not as sensitive to the micro changes involved as had been first expected. The second source of inaccuracy involved the conversion factor. This multiplicative factor of 220 (or 440 in the case of Limestone Grassland samples) was necessarily high due to the high amounts of metallic cations present in the soil. Ideally this method is more applicable to soils of low-moderate metallic cation capacity.

(3) Exchangeable Cations - Calcium, Magnesium, Sodium and Potassium:

The determination of Exchangeable Calcium, Magnesium, Sodium and Potassium was carried out on the solution resulting from the determination of Exchangeable Metallic Cations (see above (2)).

The soil-acetic acid solution resulting from the measurement of total metallic exchangeable cations was filtered using Whatman's No. 42 filter paper and the filtrate made up to 100 ml with distilled water.

Calcium and Magnesium were then determined using a Perkin Elmer Atomic Absorption Spectrophotometer using the following procedure:

A 4 ml sub sample of the solution was placed in an acid washed phial and 6 drops of Lanthanum Chloride added to suppress interference effects. The Spectrophotometer was calibrated on a suitable scale using Standard Solutions of the element to be determined. The sample was then aspirated into the machine and the readings obtained recorded. The procedure was repeated for each sample and also for the samples of plant tissue and the experimental leachates.

The Sodium and Potassium content of the soil samples only was measured using an identical procedure but using an Eel Flame Photometer.

Blanks were run with each batch of samples in order to assess possible operator contamination and the readings obtained corrected for this source of error.

(4) Organic Matter Content:

Due to the limitations of time only 120 soil samples were analysed for Organic Matter Content. The procedure adopted was the Walkley-Black method based on spontaneous heating by dilution of H_2SO_4 (Sulphuric Acid) (Black 1965). The procedure is described below:

The soil sample was ground using a mortar and pestle and passed through a 0.5 mm sieve. To a carefully weighed 1 gram sample of sieved soil was added 10 ml of 1N Potassium Dichromate ($K_2Cr_2O_7$). The flask containing the soil and dichromate was swirled gently to disperse the soil. 20 ml of concentrate Sulphuric Acid (H_2SO_4) were rapidly added to the solution and the flask swirled to ensure complete contact of the reagent with the soil. The reaction was allowed to proceed for a period of thirty minutes after which the soil-acid-dichromate solution was made up to 200 ml with distilled water and the resultant solution titrated with 0.5 N Ferrous Sulphate ($FeSO_4$) using Diphenylamine as indicator. A blank containing no soil but all reagents was run with each set of samples in order to standardise the Potassium Dichromate. The Organic Matter Content was calculated as follows:

$$\% \text{ OM} = 10(1-\frac{T}{S}) \times 1.34$$

were S = standardisation blank titration, ml ferrous solution

T = sample titration, ml ferrous solution

The factor 1.34 and its use are described by Jackson (1958).

(5) Free Carbonate Content:

The analysis for Free Carbonate Content was performed on 120 soil samples. These samples were derived from the same position in the soil profile as those used for Organic Matter Determination.

The procedure used was modified from Black (1965) and is described below:

To 5 grams of carefully weighed, air dried, soil were added 100 ml of 1N Hydrochloric Acid (HCl). The soil-acid solution was shaken at intervals and finally left to equilibrate for a period of 12 hours.

Subsequently a 20 ml aliquot of the solution was placed in a 100 ml Erlenmeyer flask and titrated with 1N Sodium Hydroxide (NaOH) using Bromo-Thymol Blue as indicator. The Free Carbonate of the sample was calculated as follows:

% Free Carbonate = (ml of NaOH in blank - ml of NaOH in sample) x 5

Some difficulty was encountered in several samples in the location of the endpoint of the titration (Green - Blue endpoint). This was probably due to the suspension of clay from the soil samples in the aliquot removed.

(6) <u>Moisture Content</u>:

The moisture content of 30 samples collected at random from the study site was determined gravimetrically using the following procedure:

A porcelain crucible was numbered and weighed to 4 decimal places on a fine balance. 5 grams of soil at field moisture were then placed in the crucible and the weight of the crucible and soil noted.

The crucible and contents were transferred to an oven and heated at $105^{o}C$ for a period of 24 hours. After 24 hours had elapsed the crucible and contents were removed from the oven and placed in a dessicator and allowed to cool. Subsequently the crucible and contents were removed and their weight determined to 4 decimal places. The difference between the two weighings was calculated and the moisture content found using the following formula:

$$\text{Moisture Content \%} = \frac{\text{Loss in Wt. of Sample}}{\text{Initial Weight of Sample}} \times 100$$

In addition to the soil samples, leaf tissue analysis of Gorse and Hawthorn was performed. The procedure for tissue analysis was a modification of Jackson's (1958) method and is described below:

After collection in the field the tissue was allowed to dry in an oven at 80°C for a period of 48 hours. Subsequently the tissue was passed through a laboratory grinder which reduced it to a fine powder form.

Three 1 gram samples of each vegetation type (Hawthorn, Gorse, Limestone Grassland and Hawthorn Grassland) were carefully weighed and transferred to digestion flasks. 20 ml of concentrated Nitric Acid (HNO_3) were added to each flask and the tissue-acid solution left to digest for a period of 24 hours. Subsequently 5 ml of concentrated Perchloric Acid ($HClO_4$) was added to the samples and the flasks heated on a sand bath. The solutions were evaporated until a clear solution residue was obtained. This residue was filtered to remove insoluble silica (SiO_2), and then made up to 100 ml with distilled water.

The samples were then analysed using the Perkin Elmer Spectrophotometer for Calcium, Magnesium, Sodium and Potassium. Iron and Aluminium were also analysed using the Graph Recorder due to the trace amounts present and the print outs obtained are included in Appendix A.

The solutions derived from the experimental leaching columns were also analysed using the Perkin Elmer Spectrophotometer for Calcium, Magnesium, Sodium, Iron and Aluminium. In addition these solutions were tested for the presence of Free Carbonate (CO_3)

using Phenopthalein as indicator. No Free Carbonate was found in these solutions.

RESULTS

The results of the analyses performed on the soil and plant tissue samples together with the data collected from the experimental leaching columns are presented in Tables 5.1 - 5.11. The tables are arranged according to the parameter measured and it is proposed to discuss briefly some aspects of these results below.

Soil Analysis Results

(1) Soil pH

The variation in soil pH both within and between the different vegetation types sampled can be seen in Table 5.1. The highest pH values recorded were associated with the Limestone Grassland sites whilst the lower values of soil pH tended to be associated with Gorse and also with the Hawthorn which grew in proximity to the Gorse. The Hawthorn samples extracted randomly occupied an intermediate position between the Limestone Grassland and the Gorse.

In all the profiles analysed there was a noticeable trend for the soil pH to decrease with increasing depth in the profile, although this varied in intensity between and within the vegetation types.

The soil pH values obtained for the Limestone Grassland sites and the variation exhibited in these values suggests that the Limestone Grassland exhibits a mosaic pattern in soil pH. Such a conclusion would tend to negate the hypothesis that the establishment of Hawthorn is dependent on a reduction of soil pH by other vegetation.

(2) Exchangeable Metallic Cation Capacity

The results of the analyses for Exchangeable Metallic Cation Capacity are presented in Table 5.2. From this it can be seen that apparent significant differences existed between the vegetation types and statistical analyses were performed to validate this assumption. These statistical analyses will be presented at a later stage.

The highest values of Exchangeable Metallic Cation Capacity were recorded from the Limestone Grassland samples. The situation as regards the other vegetation sites was similar to that of the pH results in that the randomly sampled Hawthorn occupied an intermediate position between the Limestone Grassland and the Gorse.

All the sites sampled with the exception of the Limestone Grassland again exhibited a strong tendency towards the reduction of Exchangeable Metallic Cation Capacity with increasing depth in the profile.

(3) Exchangeable Cations - Calcium, Magnesium, Sodium, Potassium

The results of the soil analyses for Exchangeable Calcium, Magnesium, Sodium and Potassium are presented in Tables 5.3 - 5.6.

The results to a large degree parallel the results obtained for Exchangeable Metallic Cation Capacity. Calcium and Magnesium were the dominant cations in the soil system and this was to be expected owing to the nature of the base rock. Sodium and Potassium exhibited a more uniform distribution between sites.

Calcium and Magnesium tended to decrease in abundance with increasing depth in the profile with the exception of the

Limestone Grassland sites. Sodium and Potassium again exhibited this characteristic tendency in all the vegetation types.

(4) Organic Matter

The results of the soil analyses for organic matter content are presented in Table 5.7. At all sites there was a strong trend towards a reduction of organic matter with increasing depth in the soil. Unfortunately due to the limitations of time it was not possible to fractionate samples in order to assess any possible qualatative differences between sites.

However, the results indicated a general increase in organic matter under Gorse vegetation. There did not appear to be significant quantitative differences in organic matter between the Limestone Grassland and the Hawthorn sites.

(5) Free Carbonate

The results of the soil analyses for Percentage Free Carbonate are presented in Table 5.8.

These results indicated that there was a general inverse relationship between the Free Carbonate present and the depth of soil, although the Limestone Grassland exhibited a general uniformity with little variation of Free Carbonate with depth. However, as the samples taken did not exceed 10 cm. depth in the profile it is possible that the amount of Free Carbonate may increase at greater depths. This situation could be expected owing to the nature of the base rock and the probable increase in Free Carbonate due to weathering of the base rock/soil interface.

The orders of magnitude involved in the amounts of Free Carbonate present in the soil between the different vegetation types was approximately similar to the differences in magnitude exhibited between the sites in respect of Exchangeable Metallic Cation Capacity. This suggested that these two variables could be correlated and statistical evidence will be presented at a later stage to validate this assumption.

(6) Soil Moisture

The results of the soil moisture analyses are presented in Table 5.9.

Only samples extracted from sites independent from the sites used in the other soil analyses were used and analyses was confined to Limestone Grassland and Hawthorn. However, results would seem to indicate that the Limestone Grassland soils possessed a greater moisture holding capacity than the Hawthorn sites. It is possible that this difference in moisture content between the two types of vegetation was due to differences in organic matter content although it is possible that the combination of micro-meteorlogical and hydrological factors could be operative. This aspect will be discussed more fully at a later stage.

Plant Tissue Analysis

The results of the leaf tissue analysis performed on the different types are presented in Table 5.10.

The chemical analyses of the leaf tissue indicate that Hawthorn possessed a higher content in all elements analysed compared to the Limestone Grassland. In particular there appears to be a loss of Calcium from the soil system due to enhanced uptake by Hawthorn. It is also interesting to note the generally higher level of nutrients present in the Hawthorn

Grassland compared to the levels found in the Limestone Grassland. However, it should be stressed that general conclusions based on these results are tentative as only leaf tissue was analysed.

Experimental Leaching Columns

The results of the Experimental Leaching Columns are presented in Table 5.11.

These results give some indication of the losses which could take place due to the variation in the vegetation. It should be noted that the nutrient content of the leachates analysed may be a function of the nutrient content of the vegetation included in the experimental operations. However, in certain cases the leachates do contain nutrients derived from the soil, in excess of those levels possible from complete leaching of the included vegetation.

TABLE 5.1 - SOIL pH RESULTS

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
pH Mean	7.92	7.44	7.66	7.67
0-3 cm Mean	8.01	7.62	7.81	7.73
S.D.	0.15	0.50	0.14	0.14
3-6 cm Mean	7.88	7.42	7.61	7.66
S.D.	0.17	0.65	0.22	0.14
6-9 cm Mean	7.87	7.27	7.55	7.63
S.D.	0.21	0.68	0.25	0.21

TABLE 5.2 - SOIL METALLIC EXCHANGEABLE CATIONS RESULTS*

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
Sample Mean	209.32	39.78	36.34	96.99
0-3 cm Mean	210.82	49.40	43.82	114.8
S.D.	35.57	5.74	12.81	27.04
3-6 cm Mean	206.13	38.28	34.41	89.58
S.D.	38.31	7.93	10.39	34.03
6-9 cm Mean	211.02	31.68	30.8	86.59
S.D.	41.96	7.93	11.55	43.40

*Results expressed in milliequivalents/100 grams air dried soil.

1 - Hawthorn from Gorse site sampled subjectively.

2 - Randomly sampled Hawthorn.

TABLE 5.3 - EXCHANGEABLE CALCIUM RESULTS*

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
Sample Mean	496.48	80.78	81.92	192.63
0-3 cm Mean	506.88	113.28	106.68	298.73
S.D.	201.90	49.10	20.46	134.87
3-6 cm Mean	481.36	69.48	75.28	240.28
S.D.	204.13	33.33	33.49	149.99
6-9 cm Mean	501.20	59.58	63.80	238.88
S.D.	214.59	30.61	17.10	175.46

* Results expressed in ug/gram air dried soil.

TABLE 5.4 - EXCHANGEABLE MAGNESIUM RESULTS**

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
Sample Mean	295.65	30.39	32.77	151.44
0-3 cm Mean	289.36	42.72	42.96	167.21
S.D.	108.63	14.95	11.64	83.26
3-6 cm Mean	295.28	26.55	29.42	143.92
S.D.	121.99	13.05	12.44	95.43
6-9 cm Mean	302.32	21.92	25.92	143.20
S.D.	121.72	14.93	10.43	106.59

** Results expressed in ug/gram air dried soil.

1 - Hawthorn from Gorse site sampled subjectively.

2 - Randomly sampled Hawthorn.

TABLE 5.5 - EXCHANGEABLE SODIUM RESULTS*

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
Sample Mean	7.65	6.62	3.73	7.91
0-3 cm Mean	7.74	7.48	4.03	8.46
S.D.	2.96	0.98	0.93	1.78
3-6 cm Mean	7.50	6.42	3.71	7.65
S.D.	2.72	1.20	1.19	1.75
6-9 cm Mean	7.71	5.97	3.45	7.62
S.D.	3.12	1.65	0.78	1.52

* Results expressed in ug/gram air dried soil.

TABLE 5.6 - EXCHANGEABLE POTASSIUM RESULTS**

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
Sample Mean	3.34	4.55	4.53	3.74
0-3 cm Mean	4.19	5.22	6.12	4.82
S.D.		1.26	1.32	2.63
3-6 cm Mean	3.07	4.62	4.43	3.57
S.D.		1.36	1.28	0.84
6-9 cm Mean	2.76	3.82	3.03	2.82
S.D.		1.31	0.62	0.91

** Results expressed in ug/gram air dried soil.

1 - Hawthorn from Gorse site sampled subjectively.

2 - Randomly sampled Hawthorn.

TABLE 5.7 - SOIL ORGANIC MATTER RESULTS*

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
Sample Mean	8.18	9.72	10.32	7.64
0-3 cm Mean	9.05	11.31	11.80	8.59
S.D.	1.34	1.18	0.65	0.82
3-6 cm Mean	8.16	9.91	10.46	8.27
S.D.	1.74	1.73	1.45	1.65
6-9 cm Mean	7.34	7.96	8.70	6.07
S.D.	1.48	1.68	1.16	1.35

* Results expressed in percentage basis.

TABLE 5.8 - SOIL FREE CARBONATE RESULTS**

Vegetation	Limestone Grassland	Hawthorn[1]	Gorse	Hawthorn[2]
Sample Mean				
0-3 cm Mean	33.66	4.35	7.60	17.43
S.D.				
3-6 cm Mean	34.65	3.44	6.15	13.33
S.D.				
6-9 cm Mean	33.38	3.35	6.85	12.40
S.D.				

** Results expressed in percentage basis.

1 - Hawthorn from Gorse site sampled subjectively.

2 - Randomly sampled Hawthorn.

TABLE 5.9 - SOIL MOISTURE CONTENT RESULTS*

Vegetation	Limestone Grassland	Hawthorn[1]
Sample Mean	30.71	26.01
S.D.	5.23	1.56

* Results expressed on percentage weight basis.

1 Random sample independent of previous random samples.

TABLE 5.10 - PLANT TISSUE ANALYSIS RESULTS**

Vegetation	Limestone Grassland	Hawthorn	Gorse	Hawthorn
Calcium Mean	49.13	104.63	37.53	75.30
Magnesium Mean	22.60	35.90	32.20	32.70
Potassium Mean	111.70	120.03	118.60	179.03
Sodium Mean	3.40	4.60	29.73	6.00
Iron Mean	3.04	3.21	2.03	4.30
Aluminium Mean	1.26	1.37	0.72	1.88

** Results expressed in ug/gram dry weight.

TABLE 5.11 - EXPERIMENTAL LEACHING RESULTS*

Vegetation	Limestone Grassland	Hawthorn	Gorse	Hawthorn	Control
Calcium Mean	79.09	62.03	96.96	110.80	17.36
Magnesium Mean	33.69	26.66	45.96	45.49	7.33
Sodium Mean	4.53	4.59	31.26	8.60	3.29
Iron Mean	0.84	Trace	0.88	1.08	Trace
Aluminium Mean	0.28	Trace	0.40	0.63	Trace

* Results expressed in ug/100 ml leachate.

STATISTICAL TECHNIQUES AND ANALYSES

The results obtained from the analyses of the soil samples were subjected to selected statistical tests in order to establish (a) any differences within the sites in respect of the soil properties measured, (b) any differences between the sites in respect of the soil properties measured and (c) any relationships which existed between the parameters measured.

The statistical tests chosen for the above purposes were Analyses of Variance, Students t Test, Spearman's Rank Correlation Coefficient and Regression Analyses. The results of the various statistical tests are described below:

Analyses of Variance

A total of thirty-eight null hypotheses were generated and tested using this technique. The data was computed using a Olivetti 101 Programma. The null hypotheses were accepted or discarded according to the significance of the F value obtained in the print out.

Students t Test

A total of one hundred and forty two null hypotheses were generated and tested using this technique. This test was used as an alternative to the analyses of variance technique described above. The test was calculated manually and corrected for sample size using Yate's correction (Bishop, 1966). According to the value of 't' obtained and the degrees of freedom the hypotheses were either accepted or discarded. These two tests were used to indicate differences in soil properties within and between sites. The results of the statistical analyses are presented in Tables 6.1 and 6.2.

TABLE 6.1

RESULTS OF STATISTICAL ANALYSIS OF DATA

WITHIN SITE VARIATION

Vegetation Type	Soil Horizons Compared (cms.)	Soil Property Compared					
		pH	Exc.Cat.	Ca	Mg	Na	K
Hawthorn Random	0-3, 3-6	0	0	0	0	0	1
	3-6, 6-9	0	0	0	0	0	1
	0-3, 6-9	0	0	0	0	0	1
Limestone Grassland	0-3, 3-6	0	0	0	0	0	1
	3-6, 6-9	0	0	0	0	0	0
	0-3, 6-9	0	0	0	0	0	1
Gorse	0-3, 3-6	1	1	1	1	0	1
	3-6, 6-9	0	0	0	0	0	1
	0-3, 6-9	1	1	1	1	1	1
Hawthorn Subjective	0-3, 3-6	0	1	1	1	1	0
	3-6, 6-9	0	1	0	0	0	1
	0-3, 6-9	1	1	1	1	1	1

0 = No significant difference.

1 = Significant difference ($p > 1\%$).

TABLE 6.2

RESULTS OF STATISTICAL ANALYSIS OF DATA

BETWEEN SITE VARIATION

Vegetation Type Compared	Soil Horizons Compared	Soil Property Compared					
		pH	Exc.Cat.	Ca	Mg	Na	K
Hawthorn Random/ Limestone Grassland	0-3 cm.	1	1	1	1	0	0
	3-6 cm.	1	1	1	1	0	0
	6-9 cm.	1	1	1	1	0	0
Hawthorn Subjective/ Gorse	0-3 cm.	1	1	0	0	1	1
	3-6 cm.	0	0	0	0	1	0
	6-9 cm.	0	0	0	0	1	1
Hawthorn Subjective/ Hawthorn Random	0-3 cm.	0	1	1	1	1	0
	3-6 cm.	0	1	1	1	1	1
	6-9 cm.	1	1	1	1	1	1
Hawthorn Subjective/ Limestone Grassland	0-3 cm.	1	1	1	1	0	0
	3-6 cm.	1	1	1	1	0	1
	6-9 cm.	1	1	1	1	1	1
Hawthorn Random/ Gorse	0-3 cm.	0	1	1	1	1	1
	3-6 cm.	0	1	1	1	1	1
	6-9 cm.	0	1	1	1	1	1
Gorse/ Limestone Grassland	0-3 cm.	1	1	1	1	1	1
	3-6 cm.	1	1	1	1	1	1
	6-9 cm.	1	1	1	1	1	0

0 = No significant difference.

1 = Significant difference ($p > 1\%$).

Spearman's Rank Correlation Coefficient

In order to ascertain the relationships, if any, which existed between the variables which had been measured a correlation matrix was generated. This matrix together with the relevant correlation coefficients is presented in Table 6.3. From this table it can be seen that various parameters were related significantly and these are described below:

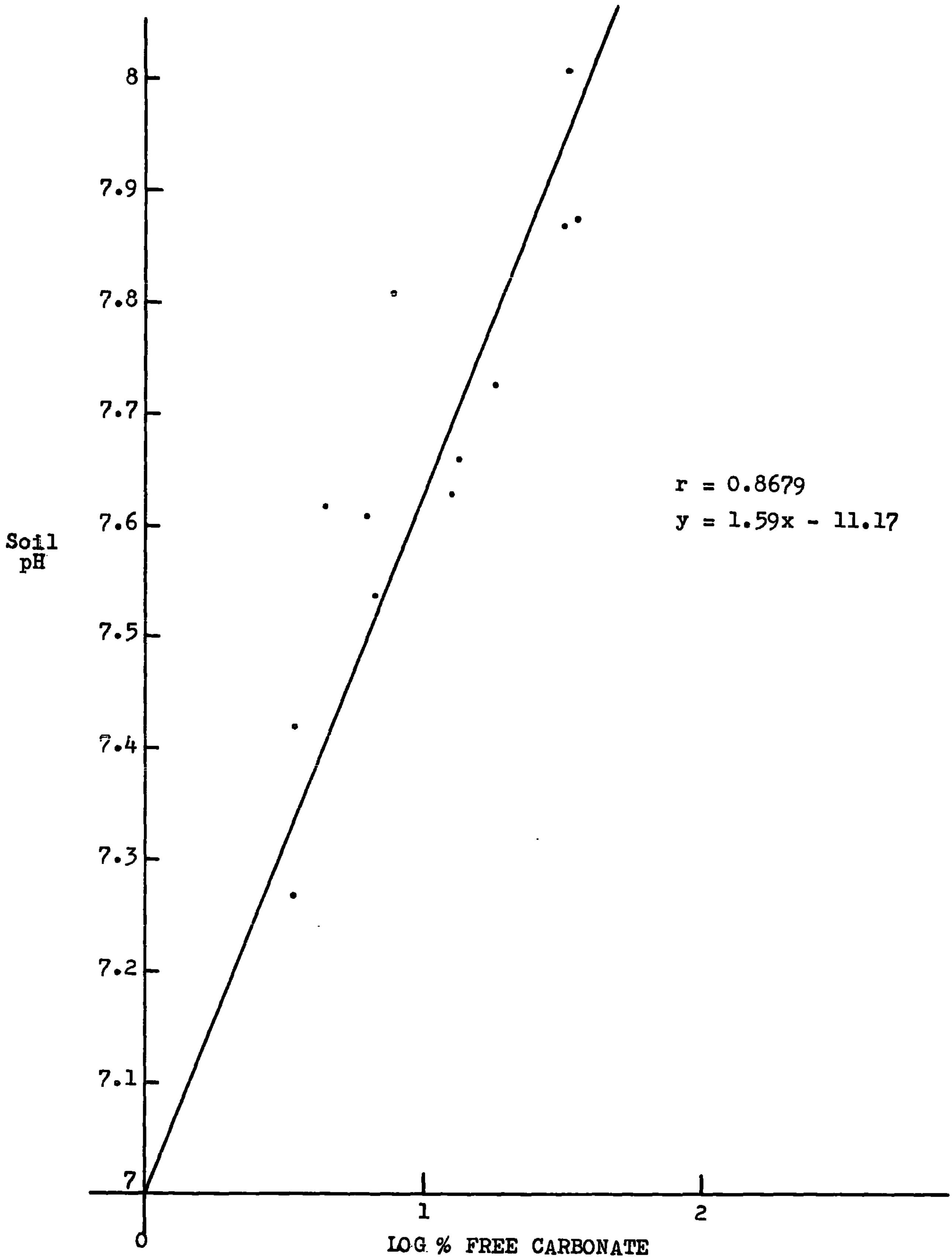
TABLE 6.3 - RANK CORRELATION MATRIX

	% Organic Matter (O.M.)	Exc. Metallic Cation Capacity	% Free Carbonate	Exc. Calcium	Exc. Magnesium
EMCC	-0.45	-	-	-	-
% F.C.	-0.45	0.85	-	-	-
Ex.Ca	-0.37	0.97	0.92	-	-
Ex.Mg	-0.43	0.97	0.92	0.97	-
pH	-0.18	0.86	0.91	0.91	0.91

(i) % Free Carbonate

This variable was highly correlated with Exchangeable Metallic Cation Capacity, Exchangeable Calcium, Exchangeable Magnesium, and pH. It was therefore considered that the presence and quantity of Free Carbonate present in the soil was of prime importance with regard to the soil properties under investigation. It was therefore decided to compute a series of regressions of this variable on the variables with which it had been correlated using the Rank method. The relationship of Free Carbonate to soil pH is presented graphically in Fig. 6.1.

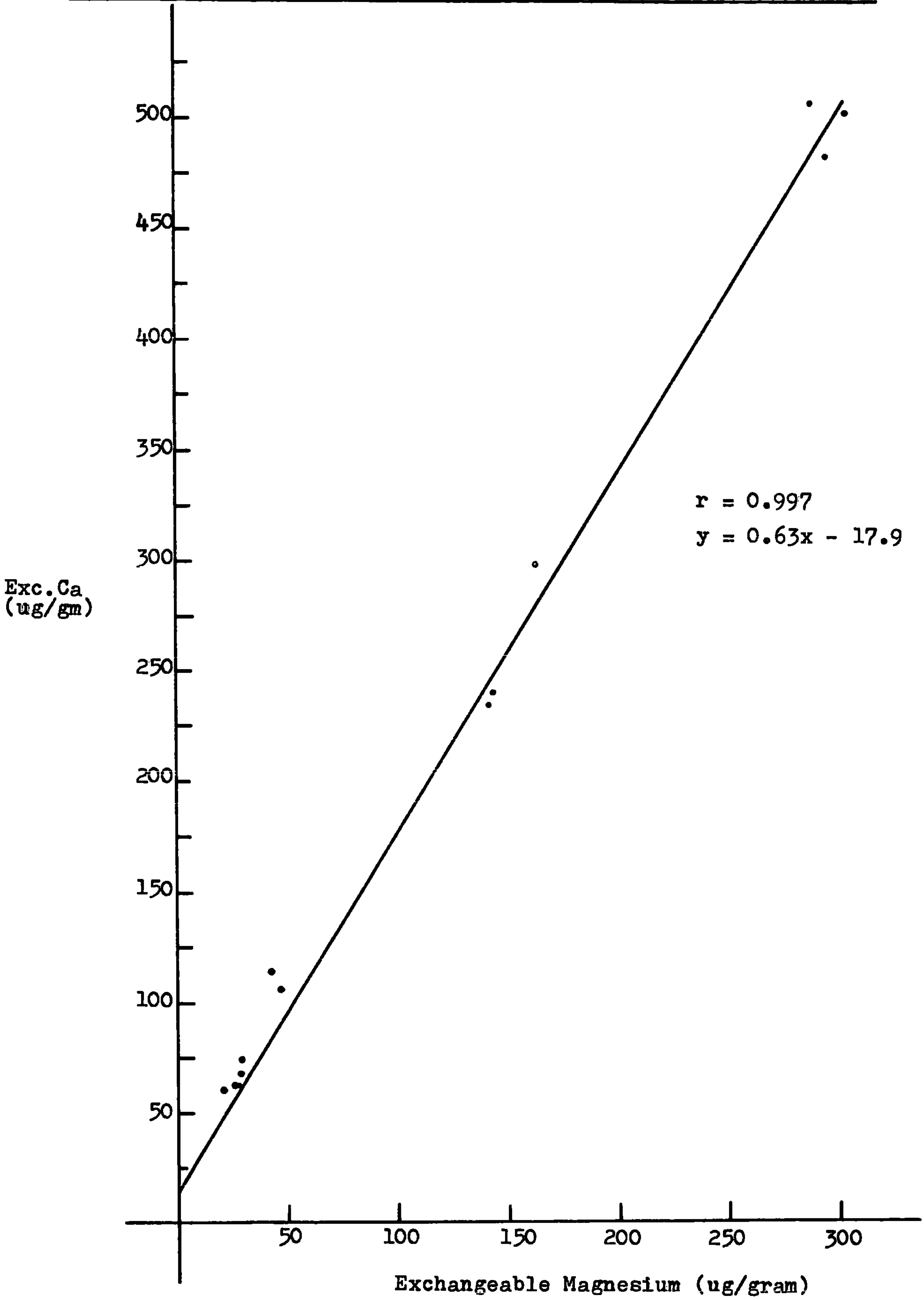
FIGURE 6.1 - RELATIONSHIP OF LOG FREE CARBONATE/SOIL pH



Each point represents the mean value of 25 observations.

FIGURE 6.2

RELATIONSHIP OF EXCHANGEABLE CALCIUM TO EXCHANGEABLE MAGNESIUM



Each point represents the mean value of 25 observations.

(ii) Calcium/Magnesium

There appeared to exist a significant correlation between Exchangeable Calcium and Exchangeable Magnesium. It was inferred that this correlation related basically to the chemical composition of the Magnesian Limestone bedrock, and therefore also to the Free Carbonate in the soil. The ratio of Calcium/Magnesium was approximately 2:1 and this figure would not suggest any toxic effects due to high levels of Magnesium and low levels of Calcium as found by Proctor (1971). The ratio of Calcium/Magnesium would appear to be optimal for the Limestone Grassland communities. This relationship is presented graphically in Fig. 6.2.

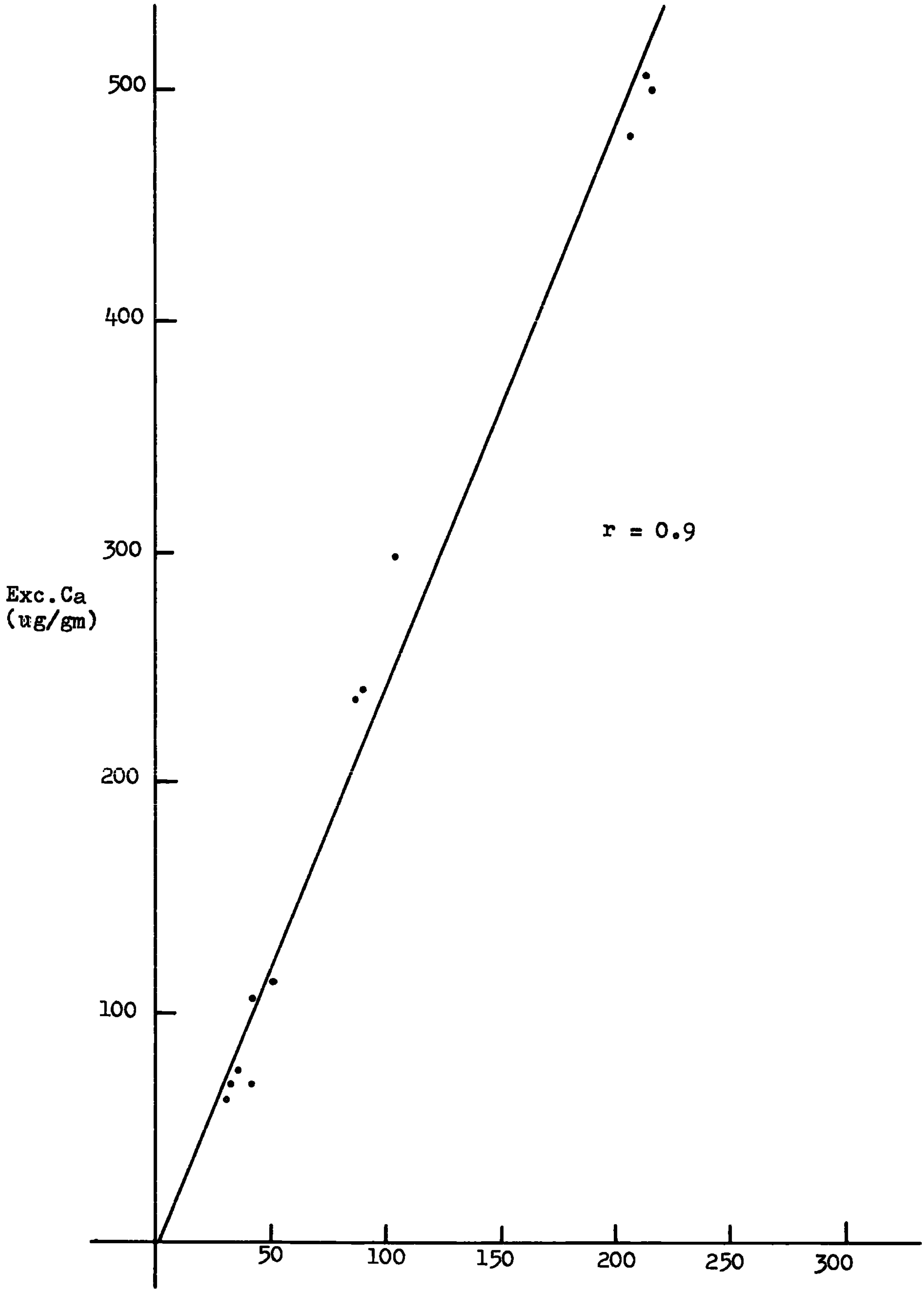
(iii) Exchangeable Metallic Cation Capacity

This variable was highly correlated with Exchangeable Calcium and also Exchangeable Magnesium. It would appear therefore that the Exchangeable Calcium and Magnesium was present in the same ratio at all the sites although there were quantative differences between sites in absolute terms. Graphs of the relationships is presented in Fig. 6.3 and Fig. 6.4.

(iv) pH

Significant correlation coefficients were obtained for this variable with Exchangeable Calcium, Exchangeable Magnesium and Free Carbonate. In the case of the correlation with Free Carbonate it is difficult to assess which variable is dependent and which is independent. It is therefore concluded that this relationship was of a "cause/effect" type, and there was therefore reciprocal interactions between these two variables.

FIGURE 6.3 - RELATIONSHIP OF EXCHANGEABLE CALCIUM TO METALLIC CATION EXCHANGE CAPACITY

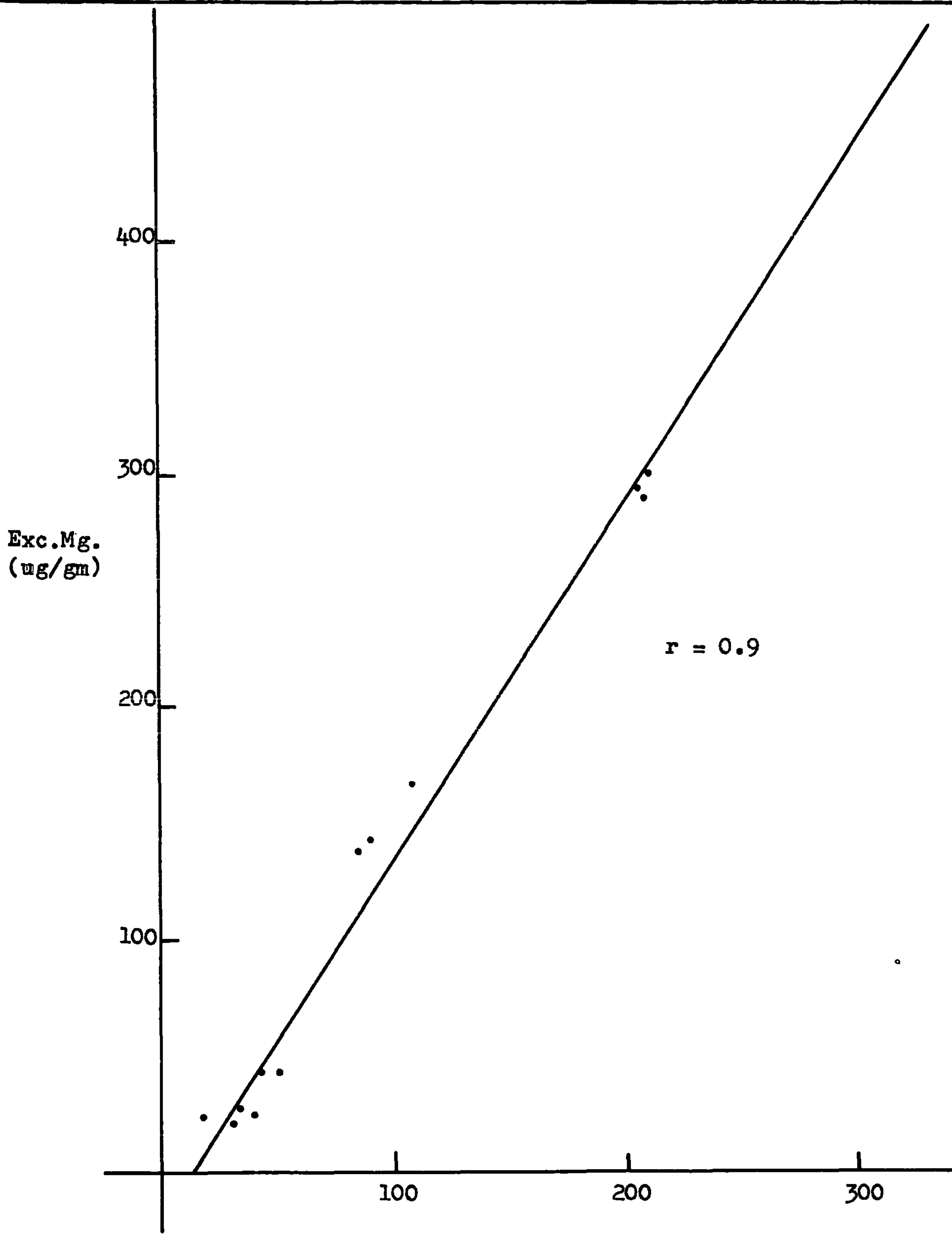


Exchangeable Metallic Cation Capacity (m.e./100 gm soil

Each point represents the mean value of 25 observations.

FIGURE 6.4

RELATIONSHIP OF EXCHANGEABLE MAGNESIUM TO METALLIC CATION EXCHANGE CAPACITY



Exchangeable Metallic Cation Capacity (m.e./100 gm soil)

Each point represents the mean value of 25 observations.

(v) Organic Matter

This variable was not significantly correlated with any of the other factors measured. However it should be noted that all the correlation coefficients obtained were negative (Table 6.3) suggesting that Organic Matter contributed to acidification of the soil.

Regression Analysis

Regression equations were computed to establish the exact relationships between those variables which had already been correlated using the Ranking technique. The relationships together with the regression lines are presented below:

(i) Regression line of pH/Free Carbonate.

$$\log x = 1.5 \log y - 11.17$$

(ii) Regression line of Exc. Calcium/Exc. Magnesium.

$$x = 0.63\ y - 17.92$$

$$(Mg = 0.63\ Ca - 17.92)$$

(iii) Regression line of Free Carbonate/Exc.Metallic Cation Capacity.

$$x = 5.9\ y + 7.99$$

$$(\text{Ex. Cat. Cap.} = 5.9 \times (\text{Free Carbonate}) + 7.99$$

(iv) Regression line of Free Carbonate/Exc. Calcium.

$$x = 14.3\ y + 18.5$$

$$(\text{Exc.Ca} = 14.3 \times (\text{F.C.}) + 18.5)$$

(v) Regression line of Free Carbonate/Exc. Magnesium.

$$x = 9.09\ y - 6.28$$

$$(\text{Exc.Mg} = 9.09 \times (\text{F.C.}) - 6.28)$$

DISCUSSION

For convenience and clarity it is proposed to discuss the results obtained in this study under the following sub-headings:

(a) Variation within sites.

(b) Variation between sites.

(c) Pedological effects of scrub succession.

(d) Possible mechanisms involved in acidification.

(e) Relevance of the results for the conservation of the Magnesian Limestone flora.

(a) Variation within sites

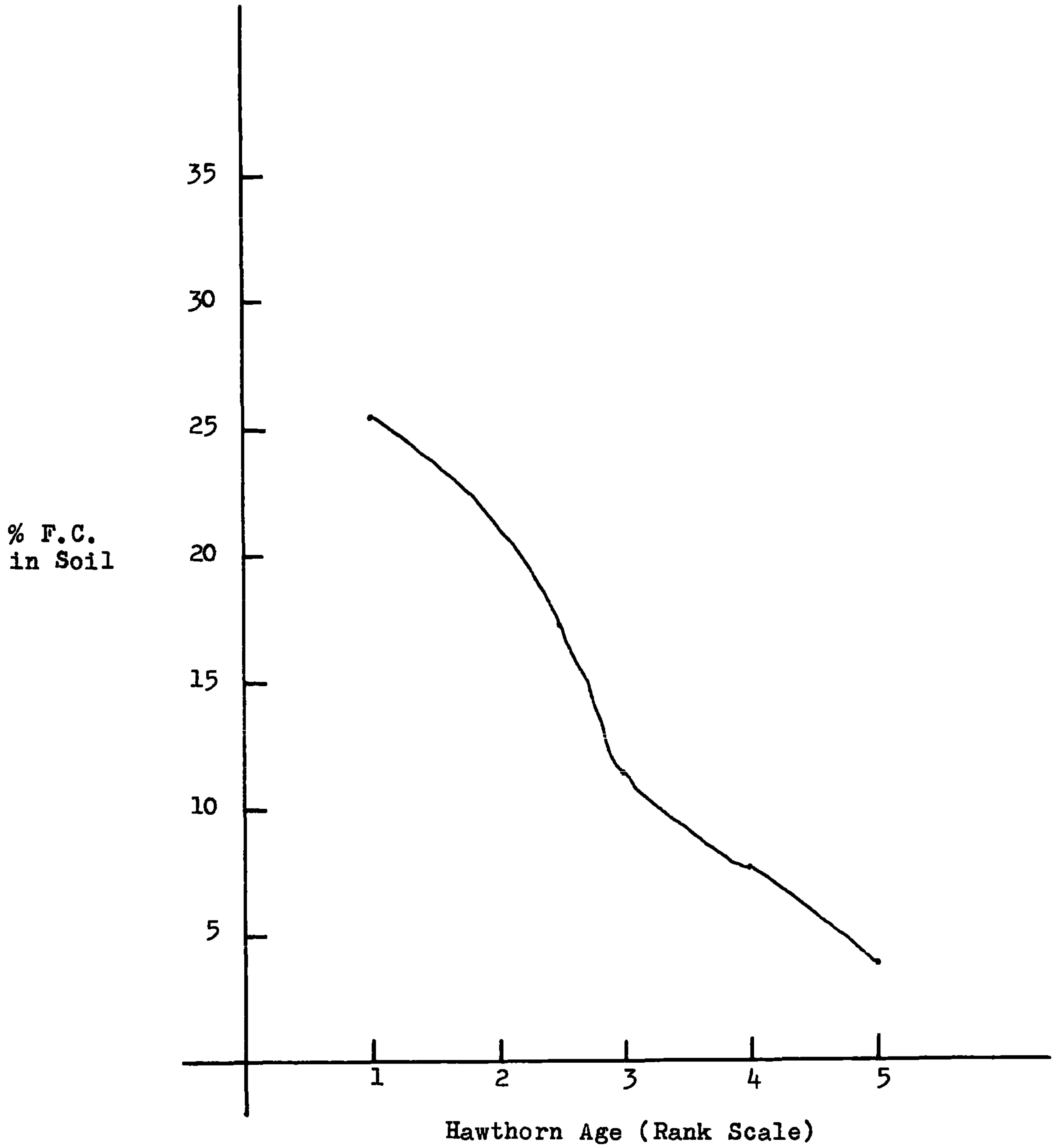
As previously mentioned the results were subjected to statistical analyses to establish within site variation in the properties measured. Attention was focused on the depth variation in soil properties within sites. The horizontal variation within sites was not analysed statistically for two reasons. Firstly there seemed no general variation in the horizontal distribution within sites for the properties analysed. Secondly the time involved in testing the variation of the horizontal component would have been prohibitive.

In the case of the Magnesian Limestone grassland samples there were no significant differences with depth of soil. In contrast to the grassland sites the Hawthorn and Gorse from the subjectively sampled sites exhibited marked differences in practically all the soil properties analysed. In the case of Gorse pH the 0-3 cm. level was significantly less alkaline than the other depths. This difference within the Gorse was attributed to the effects of the input of Gorse litter although no significant correlation between these two variables was obtained. In both Hawthorn and Gorse there were statistically significant reductions in Exchangeable Metallic Cation Capacity with increasing depth in the soil. This gradient was paralleled in the Gorse and Hawthorn with respect to Exchangeable Calcium and Exchangeable Magnesium.

The random Hawthorn samples analysed did not exhibit any significant differences between depth for the properties measured although the values recorded showed a marked reduction by comparison with those obtained for the Limestone Grassland. However, there seemed to exist a general correlation between the age of the bushes of random Hawthorn with the percentage Free Carbonate recorded from the soil beneath these bushes. This would seem to indicate a progressive removal of Free Carbonate from beneath the Hawthorn with growth of the Hawthorn - Fig. 7.1.

The samples of Hawthorn collected subjectively were also aged using a Ranking method but no general correlation of age and Free Carbonate was visible. This tended to reinforce the view that the Gorse and Hawthorn site was a-typical of the area generally. It is possible that the reasons for the differences exhibited by the Gorse and Hawthorn from the subjectively sampled sites were firstly the intensity of development of Hawthorn and Gorse which both reached their highest density at this site. However, the situation was also complicated by the presence of larch trees (Larix decidua) which could possibly have influenced the soil properties at this site.

FIGURE 7.1 - RELATIONSHIP OF HAWTHORN AGE TO % FREE CARBONATE



(b) Variation between sites

The main emphasis of the study was to establish the differences between the Limestone Grassland and the Hawthorn whilst the comparison with Gorse was a subsidiary investigation. Therefore this section of the discussion will mainly be concerned with the between sites variation of Hawthorn and the Limestone Grassland.

There existed statistically significant differences between the Limestone Grassland and the randomly sampled Hawthorn in respect of pH, Exchangeable Metallic Cation Capacity, Exchangeable Calcium, Exchangeable Magnesium and Free Carbonate. The quantative differences between the sites have been presented previously in Tables 6.1 and 6.2. In general the Grassland sites exhibited higher levels in all properties measured.

Several hypotheses have been invoked in an attempt to explain the observed variation. Firstly, it is possible that the Hawthorn was actively selecting for those sites which were less alkaline and nutritionally poorer. The existence of a mosaic of soil properties over an area of grassland is probably a more valid conception than that of a uniform situation. Grubb (1969) has argued for the existence of such a mosaic pattern on chalk grassland although he concluded that scrub succession was not necessarily dependent on this.

In the case of Thrislington it would appear that the most important factor controlling Hawthorn succession was not the existence of a mosaic pattern but rather the influence of the grazing regime. The evidence presented would seem to indicate that once established the Hawthorn drastically alters the soil properties underneath its canopy and ultimately results in an acidification of the soil. Two lines of evidence tend to support this view. Firstly, there is a general although by no means certain indication of progressive reduction in Free Carbonate content with increasing age of Hawthorn scrub. Secondly, the Free Carbonate is highly correlated ($r = 0.98$ $p = 0.001$) with pH. The rate of acidification will ultimately be dependent on the density of the Hawthorn scrub and the age of the Hawthorn. It is hypothesied that once the Free Carbonate is removed from the soil with a concomitant reduction in the buffering capacity of the soil that the rate of acidification will increase. Unfortunately no evidence is presented to validate this hypothesis as all the samples collected contained Free Carbonate although in variable quantities.

The differences between the Grassland sites and the Hawthorn have therefore been attributed directly to the influence of Hawthorn on the soil and not to the existence of localised less alkaline areas of soil. The differences between the sites in respect of Exchangeable Calcium and Exchangeable Magnesium can also be partially attributed to the removal of these nutrients at the respective sites. The evidence from the plant tissue analyses indicated that the Hawthorn removed substantially greater amounts of Calcium and Magnesium from the soil as compared to the Limestone Grassland. However, when one considers the nutrient removal by both the Hawthorn and the Grassland growing directly underneath the Hawthorn it is obvious from the results of Table 5.10 that large amounts of these elements have been incorporated into plant tissue at the Hawthorn sites.

A comparison of the subjectively sampled Hawthorn and Gorse also reveal significant differences between these two vegetation types in respect of pH, Exchangeable Metallic Cation Capacity, Exchangeable Sodium and Exchangeable Potassium. In the case of Sodium and Potassium it was thought that the differences between the sites could be explained by the physiological differences between the plants. From Table 5.10 it is obvious that Gorse has a very high soil/plant enrichment ratio for these two elements as compared to the Hawthorn.

The situation with respect to the pH differences between these two sites is interesting. Grubb (1969) has characterised Gorse as a rapid acidifier on chalk grassland yet in the situation under investigation at Thrislington it would appear that the Hawthorn produces a more acidic micro-enrironment than Gorse. It is therefore possible that Hawthorn is also a rapid soil acidifier under less alkaline conditions than those present at Thrislington and it would be worthwhile to investigate the effect of Hawthorn under such conditions. It is also possible that the differences in pH between the Gorse and Hawthorn may be partially dependent on the age structure of the two populations, however, no ageing of the Gorse was carried out to examine this possibility.

(c) Pedological effects of scrub succession

From the results obtained in this study it would appear that the colonisation of Limestone Grassland by Hawthorn in particular and to a lesser degree Gorse, results in a deterioration of soil properties with respect to the requirements of the calcicole Limestone Grassland flora. The scrub sites were characterised by low Free Carbonate levels, low pH, reduced Exchangeable Metallic Cation Capacity, reduction in Exchangeable Calcium and Magnesium and an increase in Organic Matter. In general these results are in agreement with previous research on vegetation succession. Salisbury (1921), Olson (1958) and Grubb et al (1969) have reported similar effects during vegetation succession. However, it should be emphasised that this deterioration in soil properties is only such in relation to the requirements of Magnesian Limestone Grassland and also it should be considered that other soil properties, not investigated in this study, such as the Nitrogen economy, may be improved by succession.

(d) Possible mechanisms involved in acidification

Simonson (1958) has classified the processes involved during soil development as additions, transfers, removals and transformations and this classification has been adopted for the discussion of the possible mechanisms in the alteration of soil properties by Hawthorn succession.

Additions to the soil from vegetation resulting in acidification of the soil could occur via the contribution of mineral and or organic acids. Such a situation was investigated with respect to Gorse by Grubb (1970) who concluded that this mechanism was not operative in the situation which he studied. In the case of Hawthorn and Gorse in the situation at Thrislington no specific experimentation was undertaken in an attempt to identify possible contributions of acids by the vegetation. However, the results of the experimental leaching columns appeared to indicate enhanced removal of nutrients from the soil system underneath Gorse and Hawthorn Grassland and it is therefore possible that organic acids and mineral acids could be operative. Another possible mechanism contributing to acidification of the soil at Thrislington is the addition of hydrogen (H^{++}) ions from the root systems of Hawthorn and Gorse. This mechanism is operative during the process of ion exchange between root hairs and the colloid fraction of the soil. Finally the additions to the soil system contributed by possible pollution fallout could be an important factor in acidification. The concentration of industry at Teeside, Wearmouth and Tyneside could possibly have acidifying effects through the contribution of atmospheric sulphur and sulphuric acid. Similarily it is recommended that the possible pollution from the nearby quarries should also be investigated. Personal observations at the site indicated that appreciable quantities of dust, probably calcareous, were being deposited on the site from this source.

The removal from the soil of individual cations of Calcium, Magnesium, Sodium and Potassium may also be an important mechanism in the deterioration of the soil and in the process of acidification. In this respect the removal of free carbonate from the soil is regarded as a critical parameter in determining the rate of acidification of the soil. It would appear that the removal and or reduction in free carbonate has repercussions on many other soil properties such as Exchangeable Metallic Cation Capacity. In addition to the removal of cations via plant uptake the evidence from the leaching columns tentatively indicates accelerated leaching under Gorse and Hawthorn vegetation.

In the case of the transfer component of acidification it is likely that the removal of geochemicals by scrub and associated scrub grassland is an important factor in acidification. The tissue analyses results indicate the syngernistic effect of Hawthorn and Hawthorn Grassland on the nutrient economy of the soil as compared to the Limestone Grassland. Considering the above points it became apparent that some research on specific rates of removal, addition and transfer would be a useful adjunct in any future studies at Thrislington. However, despite the above explanations of the variation between and within sites and the mechanisms involved in acidification it appeared possible upon consideration of the facts that some other processes could be operative in relation to mineral nutrition of the Limestone Grassland.

As previously stated the Limestone Grassland appears to be relatively intensively grazed by both wild and domesticated herbivores in comparison to the Hawthorn scrub and Hawthorn Grassland. Although no quantative data was available on the quantities of nutrients removed or redistributed via animal faeces by this factor it was hypothesied that the amount was significant. Assuming a stable equilibrium state in the Limestone Grassland therefore becomes a logical necessity that this loss via grazing must be accompanied by an equal addition. Apart from the meteorological input of nutrients via precipitation it was hypothesied that the removal of nutrients via grazing and leaching could be compensated by an addition by capillary rise of carbonate rich water from the bedrock. This process of eluviation or calcification has been documented as an important soil process under more extreme climatic conditions to those generally associated with Britain (Bridges 1970, Marshall (1959). However, it is possible that due to soil water deficits, evapo-transpiration and radiation effects that this process could be operative at Thrislington. Although as previously stated there was no available data on evapo-transpiration losses which could be related to the site it is likely in view of the comparatively low rainfall experienced at Thrislington that potential water deficits (PWD) exist at Thrislington. Meteorological data available for York which is situated some 90 kilometres south of Durham indicates the existence of potential water deficits in the north-east (Ground Water Year Book 1963). If this hypothesis was to be substantiated it could also account for the variation encountered between sites as one would also expect a variation in the intensity of the capillary rise process beneath the different vegetation types present at Thrislington. Continuing this line of argument Perring (1960) has correlated variations in humidity with variations in pH, Exchangeable Cation Capacity and other parameters on chalk grassland. Although Perring's study was concerned with macro-climatic variations its results would still be applicable in a micro-climatic situation such as exists at Thrislington provided that differences in humidity were present between the scrub communities and the Limestone Grassland. It would therefore be valuable to institute research on micro-meteorological differences between the Limestone Grassland and the Hawthorn at Thrislington in an attempt to substantiate the above hypothesis.

(e) Relevance of the results for the conservation of the Magnesian Limestone flora

The results of this study would seem to indicate that the continued existence of the Limestone Grassland flora at Thrislington may be endangered by the succession of scrub communities of Hawthorn and Gorse. This conclusion has been reached on the basis of the changes in soil properties beneath Hawthorn and Gorse and the continued expansion of the scrub populations at the site. Various authors notably Steele (1955), De Silva (1934), and Rorison (1960) have stated that the most important factor controlling the regeneration of calcicole vegetation in chalk and Limestone Grassland is the presence of Free Carbonate in the soil. Undoubtedly there has been a reduction in the soil Free Carbonate content at Thrislington which is attributed to the action of Hawthorn and Gorse. Apart from the obvious shading effects of the scrub communities this removal of Free Carbonate must be detrimental in the long term to the regeneration of the Limestone Grassland flora. Another important parameter for the regeneration of the calcicole Limestone flora is soil pH (Steele 1955). Various specific values of soil pH have been quoted as representing the critical limit for the regeneration of calcicole vegetation although Ferreira (1963), has distinguished between calciphilous and baciliphous species and it is therefore possible that two or more threshold values exist of soil pH in the conservation of Limestone and Chalk Grassland. However, despite Ferreira's distinction and Steele's classification between 'very exacting' and 'less exacting' calcicoles, the general range quoted for the regeneration of calcicole vegetation is in the range pH 5 to pH 6.3. With regard to the situation at Thrislington it would appear that these threshold levels of soil pH have not yet been reached. However, it has been shown that there is a significant correlation between soil pH and Free Carbonate and as previously stated this suggests that the rate of acidification underneath Hawthorn and Gorse could increase rapidly once the Free Carbonate has been removed.

In conclusion it appears that the succession of Hawthorn and Gorse could prevent the regeneration of the Limestone Grassland flora through its effect on soil properties. However, if the capillary rise hypothesis is correct the Limestone Grassland flora could be conserved by the removal of the scrub communities if this proved necessary. Theoretically the removal of Hawthorn and Gorse would allow the capillary recharge of Free Carbonate by carbonated water from the bedrock and negate the adverse effects of Hawthorn succession. It is interesting to compare this suggestion with that of Grubb's concerning management policy for the conservation of chalk grassland following Gorse succession. Grubb (1970) recommended the removal of Gorse followed by a dressing of lime on the top soil to negate the acidifying effects of the Gorse. It is hypothesied that such a method of restoring alkaline conditions would be unnecessary at Thrislington. The removal of Hawthorn and the accompanying recharge of soil Free Carbonate by capillary rise being sufficient to restore soil conditions. Apart from the consideration of the mechanism involved in the capillary rise hypothesis it should also be stated that this phenomena is not necessarily annual in occurrence but may be random in nature depending upon the existence of suitable climatic conditions, which themselves occur at random intervals. It is recommended that investigations should be mounted at Thrislington on the effect of Hawthorn removal on soil properties. Such research could also be used to substantiate the capillary hypothesis.

SUMMARY

An investigation of the effect of Hawthorn succession on the Limestone Grassland flora of Thrislington plantation revealed that the successional process led to a reduction in various soil parameters. The mechanisms involved in the achievement of these changes have been briefly outlined and recommendations for further research suggested. A hypothesis involving capillary rise of carbonated water has been suggested as being responsible for much of the variation found between sites. This process of calcification of the soil has previously been reported for more extreme climatic conditions and it is postulated that this process could have further applications particularly in those areas of Britain subjected to more extreme continental type climates, e.g. Each Anglia. The relevance of the results for the conservation of the Magnesian Limestone Grassland has been outlined and recommendations made to achieve this goal.

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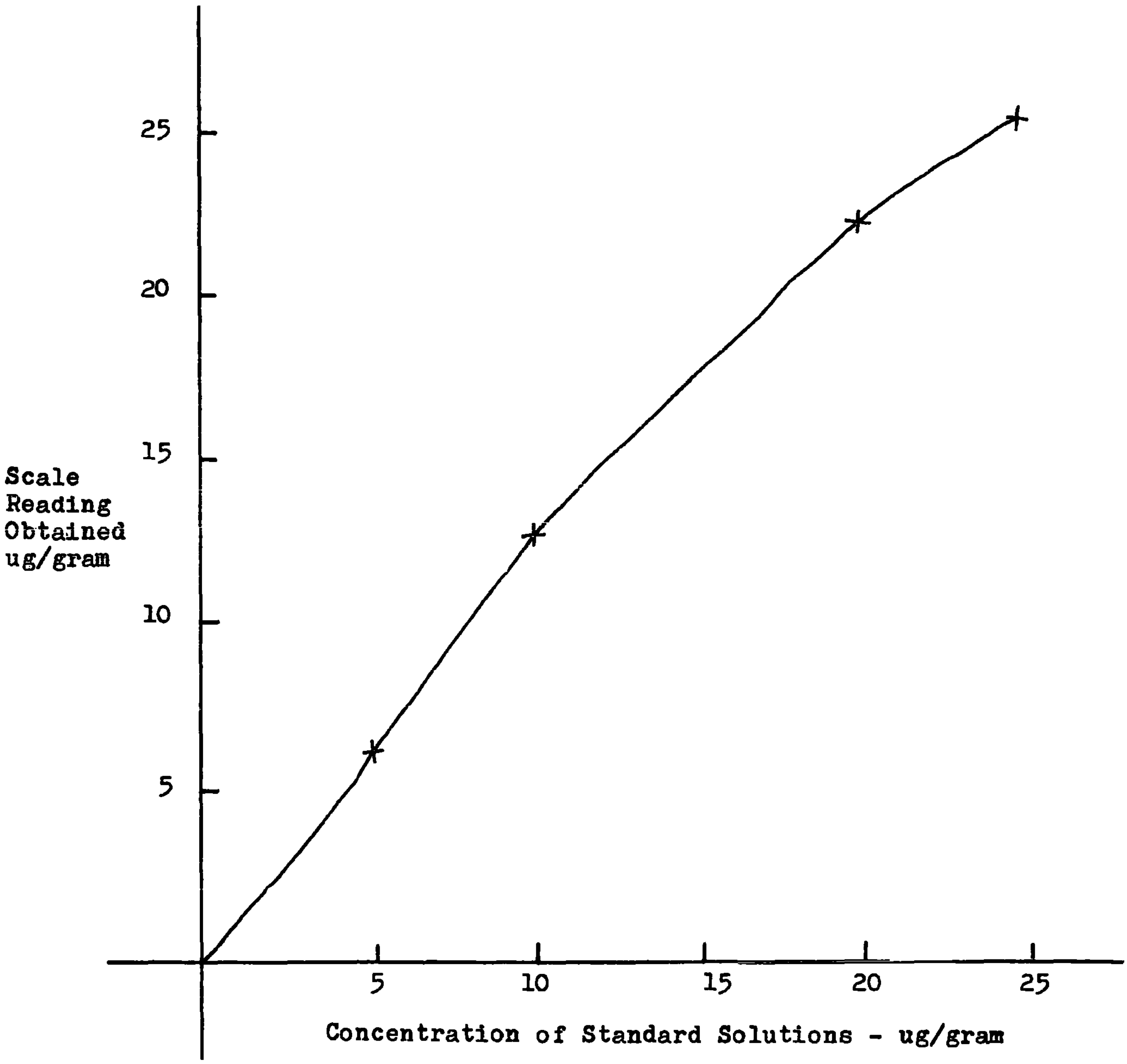
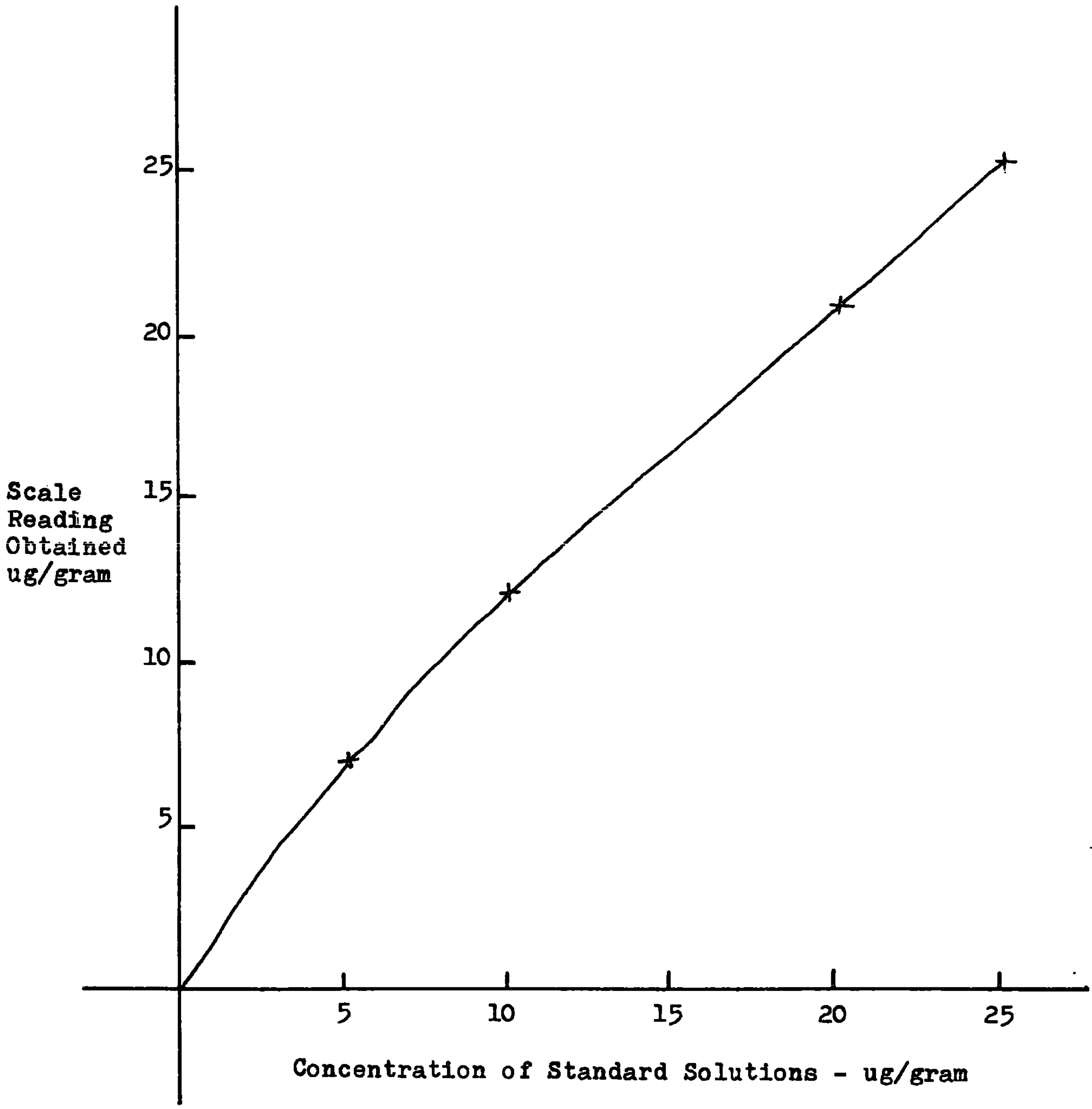
APPENDIX

CALIBRATION CURVE - POTASSIUM



CALIBRATION CURVE - SODIUM

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