AN ECOLOGICAL STUDY

OF THE

DUNG PATCH

ON

DAIRY PASTURES

by

B. N. MacDIARMID

Thesis presented in Partial Fulfilment of

the Requirements for the

Degree of Master of Agricultural Science

at Massey University

January 1969

ACKNOWLEDGEMENTS

I am most indebted to my supervisor, Professor B.R. Watkin, for his patience, encouragement, understanding and constant interest and guidance in all facets of my work.

To Dr. Jackman and his staff of the Soils Dept, DSIR, Grasslands Division, Palmerston North I am grateful for advice on the soil analyses and the use of their equipment.

I would also like to thank all those at Massey University who helped me one way or another. In particular Professor Hayman for guidance in statistical procedures; our skilled and devoted Library Staff; the various members of the Soils, Dairy Husbandry and Agronomy Departments whom I hindered during chemical procedures; and Mr P. Herbert and the Printing Dept. for reproducing the graphs.

Terry Lynch and the staff of the No. 3 Dairy Unit, Massey University require a special mention for their invaluable assistance during my experiments.

Acknowledgements must also go to Photo Instruments Ltd for compounding the photos; Wills C.A. Ltd for the binding; and Mr R. Mitchell, No. 1 Line, Kairanga for the use of his farm.

My final thanks are reserved for Carol Miers for persevering with the difficult task of assembling the draft copy and for the production of the final typed script.

TABLE OF CONTENTS

TABLE OF CONTENTS - Cont'd

LIST OF PLATES

INTRODUCTION

The fertility cycle is an inherent feature of pasture production. The animal grazes the pasture, retains the digestible energy and small amounts of the plant nutrients it requires and returns the remainder to the sward as excreta. The pasture may then use the nutrients in the excreta for further growth.

In countries such as New Zealand where the animals graze the pasture all the year round the fertility cycle remains intact. The animals excreta is deposited as discrete dung and urine patches on virtually the same pasture from which it was derived, where it is immediately subjected to an environment responsible for its decay and incorporation into the soil.

This fertility cycle is broken, however, in countries where the animal is fed indoors for part of the year. Under this system of management, the excreta becomes mixed with the bedding material of the stalls in which the animals are housed. The mixture, commonly termed "farmyard manure", is eventually redistributed back onto the pasture or mixed with the soil as a manure for crops. Also while in the stalls, the animals are fed meal and conserved fodder which may not necessarily have been grown on land to which the "farmyard manure" is returned. Consequently, although many experiments have been conducted overseas with "farmyard manure", the results have very little relevance to the situation as it exists in New Zealand.

Literature which is relevant to the New Zealand situation is limited to a number of "return" experiments conducted with sheep. For example, Sears (1951) found that returning excreta to a pasture increased yields by up to 40%. He estimated that the manurial value of the excreta returned in these experiments was the equivalent of approximately 24 cwt of Sulphate of Ammonia, 18 cwt of 30 per cent Potash, 6 cwt of Superphosphate and 3 cwt of Carbonate of Lime (Sears 1951).

Although the nutrient content of cattle excreta is recognised (Davies et al 1962) no equivalent return experiments with cattle have been attempted, probably because experiments of this type would be large, costly and time-consuming. Instead, research workers have relied on detailed ecological studies of excretal patches to estimate the manurial value of cattle excreta, and from these have extrapolated to the field situation. Literature on the cattle urine patch is well documented in this respect (During and McNaught 1961, Lotero et al 1965, 1966, Dale 1961, Davies et al 1962). Analagous experiments with dung patches are, however, more limited being confined to the comprehensive study by Norman and Green (1958), the largely theoretical consideration of Petersen et al (1956 I,II) and the limited observations made by several authors during grazing experiments (McLusky 1960, Tayler and Large 1955).

The aim of the experiments presented in this thesis was to attempt to provide further empirical data helpful in determining the ecological significance of the dung patch. A preliminary investigation was made of the distribution and persistence of the dung patch in the field. This was followed by several experiments investigating aspects which arose from observations made during the field study. These included

1. A detailed ecological study on the effect of a dung patch on the soil and surrounding herbage
2. A similar study to the first but including a defoliation treatment to simulate the grazing situation
3. A study of the importance of sight and smell as aids to the animals' selection of herbage in the presence of dung patches

A chapter is devoted to each experiment and includes the aim of the experiment, the methods employed and the results obtained. The results are discussed within the context of the experiment at the end of each chapter. A general discussion in the final chapter attempts to integrate the findings of each experiment and relate them to the field situation.

CHAPTER ONE

REVIEW OF LITERATURE

Cattle dung patches have three distinct characteristics. The first is that, by lying as a discrete patch in the paddock, they foul the herbage beneath them. The second is that animals reject herbage growing around them. These first two characteristics are considered to be detrimental to pasture utilisation. The third is that they represent a source of nutrients to the pasture. This review is concerned with each of these characteristics in turn and the inter-relationships between them.

FAECAL PRODUCTION AND DISTRIBUTION

Cattle deposit 40-60lbs net weight of dung (Waite et al 1951, Petersen et al 1956) in 11 to 16 separate defaecations per day (Table 1.1). Individual estimates for a cow range from 9 (Weeda 1967) to 26 (Wardrop 1963). McLusky (1960) found that the number deposited per day was significantly correlated with intake of dry matter. Thus dry cows with 9 (McLusky 1960) and steers 10.5 (Weeda 1967) tend to have fewer defaecations than their milking counterparts - 12 (Hancock 1953). Elliott et al (1961) in Rhodesia found that the larger Afrikander breed excreted more than the Mashonas cattle. He found that faecal production was relatively constant throughout the year. Some authors, on the other hand, (Hancock 1953, McLusky 1960, Weeda 1967) have found significant variation in the numbers dropped between days and at different times of the year. Hancock (1953) claimed that with the hot weather during the summer, the numbers increased. McLusky (1960) however, could not attribute any of the variation to either the weather or to the yield, botanical composition, dry matter or crude protein content, of the herbage.

TABLE 1.1

DISTRIBUTION OF DUNG PATCHES RECORDED BY AUTHORS

Author	No. Defaecations per day	Area (sq.ft) per patch	% Total No. in Day & Night Pdk	Day Pdk
Johnstone-Wallace & Kennedy (1944)	11.8	0.67		
Wardrop (1963)	16.2		77	34
Castle et al (1950)	11.5		88	41
Hancock (1952)	12.2		98	55
Goodall (1951)	12.0		89	43 (wgt)
McLusky (1960)	11.6	0.55		
Petersen et al (1956 I)	12.0	1.0		
Weeda (1967)	10.5			
Davies et al (1962)	12.0	0.75		

Weeda (1963) measured the height and diameters of dung patches over 12 months and recorded their seasonal variation in consistency. In Spring, dung was wettest and, on a 0 - 5 consistency scale with 5 denoting firm, registered from 0 - 2. In summer, and during the winter when the cows were on hay and silage, the dung was firmest (4 - 5).

The distribution of dung patches within a paddock appears to be uniform provided there are no objects or areas around which the animals may congregate. Thus Dale (1963) found "fairly random" distribution in late Spring, Summer and early Autumn, but non-random distribution in Winter, owing to wet hollows and feeding-out sites. Hancock and McArthur (1951) found droppings to be lowest where feed was short or unpalatable and highest under shelter or on resting sites.

Marten and Donker (1964a) actually noted the location of dung patches within 5ft x 5ft plots marked in the paddock. A typical map produced from three successive grazings illustrated the tendency for fresh dung to be deposited on herbage which had been grazed and to lie between areas occupied by previous dung patches. Since the animals utilise more of the pasture between the patches (Tayler and Rudman 1966) they obviously have more opportunity to drop their faeces there. Combine this evidence with that of Beruldsen and Morgan (1958) who, while observing the dynamics of plant associations within a grazed pasture noted that there was little permacy in the relative positions of the long patches of grass around dung patches, and it becomes apparent that the distribution is more aptly termed uniform, rather than random.

Kydd (1964) and McLusky (1960) both noticed a tendency for faeces to be deposited on herbage which had been already grazed. This tendency could be related to McLusky's (1960) observation that the number and frequency of defaecations is greater during the night whereas the major portion of the grazing was during the day. Castle et al (1950) however, were more concerned that this imbalance between intake and defaecation was responsible for a fertility transfer from "day" to "night" paddocks. Hancock on the other hand (1953) produced evidence to suggest that the number of defaecations were in fact in proportion to the time spent grazing the respective paddocks and that despite observations to the contrary by eminent agronomists in his own country and abroad, considered no fertility transfer was likely to occur, provided the paddock sizes were similar. It was left to

Goodall (1951) to solve the enigma. Whereas Hancock and Castle were both basing their arguments on counts, Goodall measured the weight of individual excretions. He found that there were large variations in the weights (1 - 15 lbs) but that the maximum weight, 5.5 lbs, occurred between 3 - 5 a.m. and that 43% of the dung was deposited in the "day" and 46% in the "night" paddock. Assuming that cows ate 60% of their total intake per 24 hours during the "day" (Sears 1953) this meant that relatively, only 72% of what was being eaten was being returned during the day period, while the "night" paddock was receiving 15% more than was being eaten. At least these results substantiate the results of Stapledon and Davies (1906) who, in an experiment in which paddocks were grazed for three years as separate "day" and "night" paddocks, obtained a 300% increase in dry matter yield from the "night" paddock.

While sheep behaviour will not be discussed in detail in this review, it is interesting to note the observations of Hilder (1964). He found that sheep, and Merinos in particular, tend to congregate their excreta. For example, in one paddock he measured 22% of the total weight of dung on less than 3% of the paddock. Suckling (1951) noted that on hilly country, sheep faeces were concentrated on the ridges although, as the pasture quality improved over the whole paddock, the tendency for the sheep to concentrate their excreta in one area was noticeably reduced.

AREA OF PASTURE AFFECTED BY DUNG PATCHES

Estimates for the average of a dung patch range from 0.55 - 1.0 sq.ft (Table 1.1) or from 7 - 10 sq.ft. per cow per day. However, after a paddock is grazed more than once, a time/space relationship becomes apparent. Petersen (1956a) referred to the relationship as the mean excretal density, Dt, where

$$Dt = \frac{N_t \; a}{A}$$

N_t = No. of defaecations after time t

a = Area individual dung patch

A = Area paddock.

Assuming the dung patches to be uniformly distributed, D_t would give an estimate of the average number of times a point in a pasture is covered by a dung patch after time t. Empirically, it is the proportion of the paddock covered by dung patches. D_t of course, varies with the stocking rate, excretion rate and time span involved. Providing these three factors maintain D_t as a relatively small proportion of the paddock, then the expression above provides an accurate estimate of the actual D_t. As stocking rate or time increases, however, the number of dung patches which may fall on one another before the whole paddock is covered fully causes D_t to over-estimate the empirical relationship. Petersen et al (1956) were able to correct for this "overlap" factor by assuming a Poisson distribution. Finally, as D_t increased still further, above 0.5, they found they could no longer assume the distribution to be uniform and obtained the best fit to their empirical data with a negative binomial function.

Using the empirical relationship obtained by Petersen et al (1956), it can be estimated that it would take 13 animal-years grazing (4745 cow-days) to cover 100% of the pasture with faeces. This estimate compares favourably with McLusky's (1960) estimate of 5000 cow-days.

EFFECT OF PATCH ON GRAZING BEHAVIOUR AND HERBAGE UTILISATION

Having dealt with the dung patch per se, it must next be considered in relation to the grazing situation. Before this is attempted, however, the question which first needs answering is: what is it in the dung patch herbage that makes it objectionable to animals? Tribe (1949) considered that the smell from the faeces was probably the primary cause. He removed the olfactory bulbs from sheep and then fed them herbage from a bin under which a tray of faeces was placed. Initially the treated animals refused to eat any of the herbage, but after about half an hour they became accustomed to the smell and ate readily. Tribe reasoned that "...... the grazing

sheep (and probably the cow also) lives always in an atmosphere saturated by the odour of, say, perennial ryegrass and white clover ...... therefore it might be reasonable to assume that it can smell anything except those plants. If the animal comes in contact with an area contaminated with excreta, olfactory sensations will immediately be received and the animals behaviour will depend on whether these are favourable or otherwise." Tribe also considers however that the opposite may occur "...... if the animal is in a situation in which the herbage is widely contaminated with, say, excreta, then olfactory adaptation will set in for the smell of excreta, and the contaminated plants may be eaten voraciously." This was not

however the case with Marten and Donker (1966). In their experiment they allowed cows to graze pasture which had been heavily manured with 34 tons per acre of cow manure. After 20 - 27 hours of grazing only 20% of the manured pasture had been grazed, compared with 74% for the control paddock. At a second grazing six weeks later, however, 60% of both the treated and control pasture was eaten, presumably because the smell of the manure was no longer evident. When the herbage was cut from the same paddocks and fed indoors, consumption of both the treated and control herbage was similar.

Norman and Green (1958) modified Tribe's view by suggesting that initially the herbage was rejected because of the offensive odour of the faeces, and that subsequently this herbage became mature and unpalatable.

McLusky (1960) however, contends that this would depend on the grazing intensity and management. Plice (1951) presented a very different view when he reported that plants growing around cattle dung contained greater amounts of several substances, including proteins and nitrates, but lower amounts of sugar and phosphorous. His hypothesis was that high N and low available P content in fresh dung provided a source of nutrients to the surrounding herbage which had a P/N imbalance and that this prevented normal sugar formation in the herbage which decreased its palatability. Indeed both he and Marten and Donker (1964a) were able to increase by 60-70% the percentage utilisation of herbage surrounding dung patches by spraying it with sweetening agents (sugar and molasses). However, Marten and Donker (1964a) were not satisfied that a low sugar content within the herbage was necessarily reimbursed by the external application of sugar. They considered that the possibility of a desirable flavour (or even odour) from the sweetening agents being responsible for overcoming an offensive odour instead of or in addition to an offensive flavour could not be ruled out.

Further evidence from Marten and Donker (1964a) continued to refute Plice's "sugar" theory. They could find no difference in consumption of herbage around dung patches with and without phosphate fertilization. Changing the N/P ratio using fertilizer N and P in artificial patches also had no effect on utilisation percentages. A second experiment failed to establish any consistent relationship between forage refusal, P content and sugar content of a brome grass sward fertilised with either sheep faeces, dairy sewerage or various fertilizers.

The actual area of pasture affected by the dung patch is larger than the patch itself, because of the herbage which is "rejected" for one or more of the reasons proposed at the beginning of this section. Norman and Green (1958) and McLusky (1960) found an area 6 times the area of the patch was rejected by grazing cattle, the former author noting the effect lasted for 13 months. Petersen et al (1956a) however, only recorded an area one third this size. McLusky (1960) believes the discrepancy among observations arises from the differences in grazing intensity and management; the higher intensity reducing both the size of the area and the time during which the herbage is rejected. The dominant factor appears to be whether the grazing management allows the herbage around the patch to become rank. For example, Norman and Green (1958) were able to reduce "rejection" from 18 to 13 months by trimming the herbage around the patch. Weeda (1967) found, under a relatively high grazing intensity, that the herbage around the patch was never grazed more than 2 inches higher than the rest of the pasture and that this "rejection" lasted at the most for 5 months. Beruldsen and Morgan (1938) on irrigated pastures and Wardrop (1953) also record the period of "rejection" as being from 3-6 months.

Because this "rejection" of herbage lasts over a number of grazings, the area left affected by dung patches may occupy a significant proportion of the pasture. Tayler and Large (1955) found that after the final grazing at the end of the season, the affected area was 38-40% of the whole paddock and yielded approximately 70% of the remaining herbage. It is interesting to note the difference between grazing patterns on the two swards sown down in this experiment. After grazing the yield of "dung patch" herbage was almost equal for the meadow fescue/timothy and perennial ryegrass swards viz. 1550 and 1600 lbs/ac respectively, yet the yield from the "grazed" areas between the dung patches was 390 and 720lbs per acre. Tayler and Large (1955) suggested that because the vegetative parts of the plants in the meadow fescue/timothy sward were palatable to ground level, there was a tendency for overgrazing to occur in the "grazed" areas of this sward; while on ground contaminated by dung a similar quantity of herbage was left in each sward. It is unlikely from this evidence that "palatability factors" in the herbage itself around the dung patch are likely causes for its rejection during grazing.

Tayler and Rudman (1966) found that the mean area affected by dung patches over a number of grazings was 22%; McLusky (1960) estimated 15%; and Arnold and Holmes (1958) 26%. These estimates are somewhat lower than those of Tayler and Large (1955).

Not only do dung patches cause a "rejection" of herbage but they also appear to be the primary cause of selective grazing within a pasture. Marten and Donker (1964) found that 93% of areas "not grazed" in a pasture contained dung patches while only 1% of the "completely consumed" areas contained them.

The urine patch bears mention here, if only for the fact that for every dung patch there is also a urine patch. A cow's urine patch averages 3-4 sq.ft in area (Lotero et al 1962, Petersen et al 1956 I). Although the response from the urine may be measured in an area averaging 7 sq.ft initially, Lotero et al (1960) have found that this area rapidly diminishes in size from the periphery inwards so that after about 2 months it may have reduced to approximately 2 sq.ft. Effects on herbage growth have, however, still been measurable after 10 months (Lotero et al 1962). During and McNaught (1961) on the other hand seldom found the effect evident for more than 4 months, presumably because of a different environment. With the short term response obtained from urine, the likelihood of it being a major cause of patchy growth in the pasture is limited. This likelihood is further diminished when Norman and Green (1958) report that cows appear to prefer herbage growing from a urine patch, provided it does not suffer from urine burn (Doak 1954, Dale 1961).

FACTORS AFFECTING THE RATE OF DECAY OF DUNG PATCH

Any factor which influences the rate of decay and incorporation of the dung patch into the soil will also influence the availability and effectiveness of the nutrients and the time it remains an influence to the grazing animal. Climate obviously plays some part in the decay process. Dale (1963) noted that dung deposited in the late Winter, Spring and early Summer lasted 4-9 months. In late Summer they survived only 3 months and in Autumn as little as 1-2 months. Weeda (1967) observed that the rate of the deterioration of the patch was related to the formation of a surface crust, the most critical time being the first few days after deposition. When the patch remained soft (such as under rainy conditions) during this critical period, decay was relatively rapid. Dry hot weather hastened the formation of a crust and slowed down deterioration, which then occurred from the bottom upwards.

The number of insect larvae which inhabit a dung patch may be considerable and affect the rate of decay of the patch. Laurence (1954) has reviewed much of the literature on the subject. In his own studies, he identified 18 different genera of coprophagous larvae inhabiting dung patches throughout the year. He concluded that the availability of a patch as a habitat for the larvae of any species appears to depend on the period of the year in which the adult flies can tolerate conditions in the open field (Laurence 1955). However, he also quotes evidence that the temperature and moisture content of the dung itself, which can change considerably within or between days, may also influence the survival of species. Changes in the nutrient composition of the dung during the year may also influence the species present. In general terms Laurence (1954) concludes that the cow leaves in its faeces enough food material to support an insect population, mostly dipterous larvae, equal to at least one-fifth its own weight.

There is little direct evidence suggesting that earthworms are more active near a dung patch compared with the rest of the paddock. However Barley (1964) has shown that the lumbricid Allolobophora caliginosa, from a choice of various types of plant litter, preferred dung, and could ingest 1% of its own weight per day. Since in Adelaide, where the experiments were conducted, this species is active for 150 days at a concentration of 80 gm per square mile, in one year it could consume 1,000-lbs per acre of dung. In New Zealand, Waters (1955) records an earthworm population of varying from 140-300 gm per square mile with a corresponding increase in the consumption of dung. A. caliginosa was the most abundant species (85%) in the pasture also.

Watkin (1954), Watkin and Wheeler (1966) and Waters (1951), all report increases in the number and weight of earthworms in pasture to which dung has been returned. Satchell (1958) has suggested that the supply of readily available organic N, in this case dung, is an important factor limiting earthworm populations. However, Waters (1955) does not consider dung to be a major source of food for these macrobes, while Heath in a discussion on a paper by Guild(1955) considers that the shallow sampling method employed by the above workers may have led to a false estimation of the total population. Furthermore, Satchell (1955) examined the soil beneath the plots of a long-term return experiment and found that, of the factors examined, only pH and exchangeable calcium had any substantial effect on the distribution of the 6 species recovered.

Thus, opinions differ as to the relative importance of dung as a source of nutrients to earthworms and in particular to A.caliginosa, which Waters (1955) believes is primarily a subterranean feeder, feeding mainly on dead roots. Nevertheless, the evidence suggests there is every reason to expect earthworm activity to increase beneath a dung patch. Both the dead and decaying herbage beneath the patch as well as the dung would provide food for the earthworms. They would incorporate this material into the soil either via their excreta, which may contain nitrogenous (Needham 1957) and inorganic nutrients in a more available form than prior to their ingestion (Satchell 1955); or following the death and decay of the earthworm itself (Barley 1964). Waters (1951) was lead to conclude from pot experiments that, because of the process outlined above, earthworms can increase the growth of ryegrass (compared with clover) provided that dung, or probably any nutritive pasture residue be present in the soil. Nielson (1951) also considers earthworms possess "growth factors" which are capable of stimulating plant growth.

Bornemissza (1960) emphasises the importance of coprophagous beetles (Scarabaeidae) in disseminating dung patches. These beetles have the ability to dispose of a dung patch within hours of it being deposited and being prodigious diggers incorporate the dung into the soil rapidly. However, the most efficient species remain confined to the warmer climates of the globe and it appears that the native dung eating insects in New Zealand are not attracted to sheep and cattle dung (Brown 1963). One introduced beetle was apparently ineffective in disposing of dung patches (Thomas 1960).

Cattle dung may contain from 9-20% bacteria by weight, the majority of which are dead cells of the anaerobic rumen bacteria. Faeces from pasture-fed cattle contain 1-4 million bacteria per gm., estimated by the plate count method (Waksman 1932). This author indicated that although fresh manure contained extensive populations of coprophytic bacteria and protozoa, many of these died and were replaced by others characteristic of the soil.

One of the mechanical techniques aimed at increasing the rate of decay and reducing the patchy effect of the dung patch has been to harrow them. However, recently Weeda (1967) has confirmed earlier reports (McLusky and Holmes 1963) that harrowing significantly reduces pasture yield by as much as 2500lb DM per acre. He did notice, however, that the pastures were more evenly grazed and that this may have resulted in better utilisation and offset the depression in yield. No measure was made of utilisation. Assuming that harrowing should produce a more even spread of fertility, Weeda determined the soil levels of N, P and K. At the first sampling, a year after the start of the trial, the standard errors of the N, P and K values were lower than the values for non-harrowed paddocks. However, by the end of 1964, two years later, only the standard error of P was lower. Hignett (1956) has also pointed out that harrowing may help the spread and survival of the larvae of parasitic enterogastric worms voided in the dung. While the dung patch remains intact, the anaerobic conditions in the centre of it preclude development of the larvae. Harrowing increases the amount of dung exposed to the air and may facilitate larval development to the detriment of the stock grazing the pasture.

NUTRIENT CONTENT OF DUNG PATCH

Nitrogen, P, Mg, Ca, S and K are possibly the most important nutrients present in cattle faeces, although most of the micronutrients are present also (Dale 1963). Davies et al (1962) found that 80% of the Mg, 60% of the P, 80% of the Ca, and 10% of the K in the herbage fed to milking cows was recoverable in the faeces. They suggested that with dry cows the proportion of P would be higher as 25% of the P is diverted for milk production.

Barrow and Lambourne (1962) found that the faecal excretion of N, S and organic P per unit of feed eaten by sheep was not affected by the N, S or P content of the feed eaten; nor by the level of intake. Average values were 0.835 gm N, 0.114 gm S, and 0.059 gm organic P, per 100 gm of dry matter eaten. The remainder of the N and S was excreted in the urine and hence the proportion excreted in the urine depended on the N and S content of the feed. Most of the remainder of the P was excreted in the inorganic form in the faeces. No concomitant data is available for P and S in cattle faeces, but Lancaster (1949) and Blaxter and Mitchell (1948) have both shown that the faecal excretion of N per unit of feed eaten tends to remain constant in cattle.

Work at Palmerston North (Sears and Melville 1953) has shown that clover leaves are generally higher in Ca and Mg than grass leaves. Faeces of animals grazing clover dominant sward would then probably contain higher amounts of these two nutrients compared with that returned from grass dominant swards. Potassium, however, tends to be concentrated more in grass leaves (Watkin 1957) and it is likely that the reverse would apply for this element. Barrow and Lambourne (1962) conclude that the output of nutrients per unit of feed eaten is unlikely to fluctuate greatly during the year, but that their concentration in the faeces will depend on their digestibility and the digestibility of the feed. This means that any factors, such as time of harvest, season of year, method of conservation or species of herbage, which is likely to change digestibility (Minson (1963) will also change the concentration of nutrients in the dung patch.

Assuming an average defaecation of 4lbs, covering an area of 1 sq.ft and containing 6.38% N, 0.18% P_2O_5 and 0.22% K_2O, Petersen et al (1956) have calculated that a dung patch contains the equivalent concentration of 760lb N, 350lbs P_2O_5 and 440lbs K_2O per acre. These figures are similar to those calculated by Davies et al (1962) although they assumed an area of 0.75 sq.ft. Their equivalent figures for $MgSO_4$ was 2500lbs per acre.

Although such concentrations in the dung patch represent a substantial application in terms of fertilizer equivalents, there is little evidence to suggest that these nutrients are available for plant growth. Davies et al (1962) found that 62% of the Mg and all the K was water soluble and presumably readily available as plant nutrients. They measured an appreciable rise in the soil K and Mg levels under one dung patch.

Lancaster (1950) classified the faecal N into two types (a) that derived directly from the feed as undigested N (b) metabolic N derived from secretions from the gut and undigested remnants of gut micro-organisms. Of the 0.72 gm N voided in the faeces per 100 gm of grass eaten, he found that 0.46 gms was metabolic N and would presumably represent the more soluble and readily available proportion of N. Castle and Drysdale (1966) in fact established a strong positive relationship between the proportion of ammonia N in the total N content of dung (and slurry mixtures) and the efficiency of the N in dung relative to fertilizer N.

With regards the availability of P, Bromfield (1961) found that 34% of the inorganic P in sheep faeces could be obtained by prolonged leaching with 100 ml. of water on 8 different occasions over 6 days.

The higher the inorganic P content, the more P in the leachate but the lower the proportion of P removed. Leaching with acid or grinding the dung increased the percentage of P extracted considerably.

The yield of both wheat (Bromfield 1961) and ryegrass (Gunary 1968) was found to be closely related to the content of inorganic P in the sheep dung when incorporated in the soil and this P was just as readily available as the P in Superphosphate applied as other treatments. In both cases it amounted to 70% of the total P. However, when the dung was applied to the surface of the soil and leached, the availability of P to the plants fell to 13-20% of the total P.

In addition to nutrients, Suckling (1951) has shown that cattle dung may spread up to 10.6lbs per acre (3540 seeds) of various clover seeds from improved to unimproved pastures.

EFFECT OF NUTRIENTS FROM DUNG PATCH ON SURROUNDING PASTURES

There is little literature reporting the effects of nutrients contained in the dung patch on the surrounding herbage. The most comprehensive study is that of Norman and Green (1958). They sampled the herbage in rings, varying in diameter, around the patch. However, their data on botanical composition and yield was not analysed statistically. Botanical compositions were determined by eye assessment and conclusions were based on results expressed as "changes in percentage cover, one or two years after application" of the dung. Nevertheless, they concluded that in the 2ft diameter circle around dung patches there was an increase in cocksfoot, creeping bent, red fescue and white clover, and a decrease in herbs. Yield response to dung was still evident after 4 cuts (19 months) and was greater when the dung was applied in the Spring. Chemical analysis showed a rise in the crude protein content from

14 - 18.6% in the herbage sampled after one month from the Spring-applied patches. The authors suggested that an initial response is obtained from readily available N in the dung. The lower response from the Autumn applications they attribute to the higher leaching losses of this readily available N which could occur at this time of the year. However, no yield cuts were taken 1 month after the Autumn-applied patches to compare with the Spring results.

In contrast to the dung patch, the relatively high N and K content in urine (Sears and Newbold 1942) may double or even triple the herbage yield within the patch, although the effect is only apparent for 2-4 months, depending on the climate and soil - the principal factors influencing losses of the N and K compounds (During and McNaught 1961, Lotero et al 1965, Doak 1952). The urine response is also characterised by an increase in grass and decrease in the clover content of the sward (Drysdale 1965).

SIGNIFICANCE OF EXCRETAL RETURN TO GRASSLAND PRODUCTION

The review to this point has been concerned primarily with the dung patch per se, in keeping with the general theme of the thesis. However, the return of excreta to the paddock is a continual, dynamic process, and the review would not be complete without reference to this aspect of excretal return, and in particular to dung return.

Petersen et al (1956 II) used the "steady state" concept to examine the dynamic aspect of excretal return. These workers assumed, and their assumptions are supported by the evidence of Lotero et al (1965), that the loss of nutrients per unit time from a patch was proportional to their concentration in the root zone of the soil. With such an exponential relationship, they suggested that a time would be reached when the level of concentration of nutrients in the patch would be no greater than the mean level for the whole pasture (the "residual" level). A "steady state" would result when the addition of excreta would be balanced by the loss in effective sites, i.e. those which reach the residual level. The factors which would govern the time taken to reach this steady state would be those discussed earlier in relation to distribution and rate of incorporation of nutrients into the soil, viz. Stocking rate, effective area of the patch, decay rates, effects of leaching, the availability of nutrients, etc.. For example, assuming K to be lost at the rate of 10% per month, the time to reach the steady state would be 30 weeks at a stocking rate of 46 animal days per acre. Under these circumstances, 34% of the total pasture area would be 20lbs K per acre above the residual level of fertility. Changing the stocking rate from 1 to 3 cattle per acre would change the area of pasture above a residual of 20lbs K_2O per acre from 34 to 71%.

Opinions differ among workers as to the value of excreta returned to the pasture by the grazing animal. Work in New Zealand, heralded principally by Sears and his co-workers during the 1950's, demonstrated that under fertile conditions return of dung and urine enhanced pasture productivity (Sears 1950). Where no dung and urine was returned, pastures yielded some 10,600lbs DM per acre, were dominated by clover and low fertility-demanding grasses (browntop and danthonia). When urine alone was returned, the proportion of grasses increased by 20% and pasture production rose to 12,200lbs per acre. When only dung was returned, the N in the dung was not sufficiently available or adequate to maintain grass growth, with the result that clovers, which also had a high requirement for the Ca and P returned in the dung (Melville and

Sears 1953 II), initially dominated the sward. As N levels rose under the clover regime, the grasses returned to the sward to support yields similar to those in urine treatments.

When both dung and urine were returned, a well-balanced grass/clover sward producing 14,000lbs per acre persisted. As mentioned before, the nutritional value of the total excreta, as distinct from dung alone, is dependant to a large extent on the nutrient content of the herbage. Sears 1953 VII, (1960) and Green and Cowling (1960) contend that nitrogen is the principal element in this regard within the fertility cycle. Rapidly depleted from the soil by leaching, volatilisation, mineralisation and plant uptake, any source of N is welcomed to maintain fertility. Under the grazing regime clovers persist and in addition to being high in N content, (Melville and Sears 1953 II), themselves raise the level of N in grasses growing in association with them (Washko and Marriott 1960). The result is that the dung and urine return of N is much higher under swards with clover than swards without clover. Thus respective dry matter yields reflect the different amounts of N in the fertility cycle (Sears 1950, 1960).

Watkin (1954) elaborated on this aspect by imposing two nitrogen fertiliser levels on the basic return design used by Sears. Watkin found that in the absence of the grazing animal response to N was poor, although part of the lack of response was probably due to a shortage of K (Wheeler 1948). Combined with urine or the full return of excreta, the highest level of N increased production by up to 120%. There was little response to dung except at the high level of fertilizer nitrogen.

The increase in total nitrogen levels in the soil indicate the changes in fertility status with return of excreta. Both Metson and Hurst (1953) at Palmerston North (Sears 1953) and Wolton (1955) at

Wye (Watkin 1954) found increases in total soil nitrogen during the period of the respective return experiments. Wolton (1955) also found that the full return treatment possessed the highest levels of soil nitrogen. She contends that this addition of readily available nitrogen would decrease the C/N ratio and in so doing would increase the rate of mineralisation of organic matter and the release of available nitrogen. Hence, the nitrogen in the dung may be more efficiently used than that in urine as the latter, once deposited is immediately subjected to losses by leaching (During and McNaught 1961) and volatilisation (Doak 1952). Increase in the earthworm population under the dung treatment (Watkin 1954) may also enhance the availability of organic N. However, Metson and Hurst (1953) were unable to establish that the return of excreta had changed the C/N ratio of the soil.

Walker (1955) considers that the high rate of accumulation of N under a grazing regime established by Metson and Hurst (1953) may also influence the C: N: P: S ratio in the organic matter of the soil. Since evidence suggests that the ratio remains relatively constant at 100: 10: 1: 1 the high accumulation of N would presumably be accompanied byan increase in organic C, P and S. Thus, accumulation of say, 500lbs N returned in the dung and urine to the soil would entail the corresponding addition of 50lb organic P and S, the source of which may have to be inorganic S and P. However, Sears (1953 I and IV) tends to refute this theory by obtaining the only or greater response to applied superphosphate from the non-return series. Walker (1955) also emphasises the part S, an important constituent of dung and urine, and the N/S ratio may play in the initial establishment of legumes in low fertility areas and its value in increasing available P levels.

Herriott and Wells (1963) and Watkin (1954) in the absence of applied N were unable to obtain yield responses to excretal return. Herriott and Wells (1963) claim that assessment of the effect of the animal introduces defoliation method, a major factor in contrasting grazing and mowing regimes. If the legume is depressed by severe management then response to excreta may be significant, but such a relative advantage does not compensate for the low total herbage yield. They also stress the importance of pre-conditioning animals for grazing experiments, a feature not apparent in Sear's and Watkin's work. It was found that approximately three days are needed before fluctuations in faceal output reflect changes in consumption. In view of the fact that Sears (1953 V) was able to obtain a 28% increase in pasture production just by increasing the time animals spent on a pasture, the effect of fertility transfer may be a source of error in some return experiments.

There is evidence that the fertility cycle assists in mobilising K in the soil into more readily available forms. In a duplication of his return experiment at Lincoln, Sears (1953 VI) could establish no difference between the plots grazed with or without excretal return. The high "potassium-supplying power" of the soil, together with the removal of N, enabled the clover in the non-return plots (NR) to flourish to the extent that they were able to compensate for the higher grass production in the full return plots (F.R.) Analysis of the soil, however, showed that, while the exchangeable K levels in the NR plots remained unchanged after four years, the levels in the FR plots increased markedly. Wolton (1955) recorded a similar rise of exchangeable K in urine return plots. She states "...... it appears that urine, as well as redistributing soil potassium in a plant and animal, itself increases the availability of K still in the soil." In contrast, Herriott and Wells (1963) found that the soil in their experiment was incapable of replenishing the loss of K in the NR treatment and the yields fell below those from the F.R.plots. Addition of K fertilizer nullified differences between treatments.

There is no indication that the Mg, P or Ca content of the herbage is in any significant way affected by the return of dung to the sward. Drysdale and Strachan (1966) and Watkin (1957) both point out, though, that since K content of grasses increase markedly when urine is returned, the changes which could occur in the K/Mg, K/Ca and K/Na ratios may affect stock health. Wolton (1955) did, however, notice that dung was responsible for building up the Mg and P content of the soil but that the effect was not immediately apparent.

The yield of crops is probably the best way to guage how effective the return of excreta is in building-up the fertility of the soil. Wheeler (1958) found yields of wheat grown in land which had been in a return experiment (Watkin 1954) ranged from 27.1 to 38.6 cwt. Plots to which faeces were returned during the pasture phase outyielded ($P < 0.01$) those from which they were withheld. Urine was relatively ineffective except in combination with N fertilizer. In the absence of animal return, N fertilizer depressed the straw and grain yields. Because of the large proportion of organic-bound nutrients, particularly N, in the dung treatment, Wheeler considers that only by cropping the land can the residual fertility of dung be exploited fully. Sears (1953 II) obtained a 34% increase in a rape crop grown on his full-return plots compared with his no-return treatment. While N, K and Mg levels were also higher in the rape leaves, he attributes much of the increased yield to the better tilth of the soil brought about by the higher earthworm and organic matter content.

Sears (1950) considers that "......care must be taken to see that plant and animal residues are redistributed back to the soil which originally produced them; only by these means will soil fertility drain by animal production be kept at the desired minimum. Superimposed on this basic cycle of soil fertility is the whole question of soil moisture, temperature, and the suitability of the various species for these environmental factors and for their reaction to different grazing practices."

CHAPTER TWO

A PRELIMINARY INVESTIGATION

The aim of this investigation was to study the distribution of dung patches in a paddock under normal farming conditions; the total area of the paddock covered in dung patches after a grazing; and the time they persist in the pasture as an apparent influence on animal behaviour. Making these measurements also provided an opportunity to observe and decide which particular aspects of the dung patch/pasture complex could best become the subject for more intensive investigation. Later, the data from this preliminary study was used to relate the results of the latter experiments back to the farming situation.

EXPERIMENTAL

The investigation was made in three separate studies during the Winter, Spring and Summer. The Winter study was conducted on four paddocks, between 26th and 31st July, 1967, on Mr R.Mitchell's Farm, No.1 Line, Kairanga. This farm is an intensive town milk supply unit on Kairanga Silt Loam running a herd of 70-75 Friesian cows during the Winter on a 24 hour rotational grazing system. The paddocks chosen were all flat, reasonably square, readily accessible and relatively free from obstacles which could influence the distribution pattern of the dung. Hay was fed in the paddocks at night, and silage in the mornings.

The second (Spring) study was conducted on three paddocks on the No.3 Dairy Unit, Massey University (McQueen 1963). This is an experimental farm on Tokomaru Silt Loam which is very intensively farmed at 1.6 milking cows per acre. Recordings were made on the 28th, 29th and 30th September, 1967.

The third (Summer) study was made on two of the same paddocks used for the Spring study, on 2nd and 3rd February, 1968. The number of paddocks included in each study depended on the varibility of the results. No rain fell on any day measurements were made.

Method:

Each paddock was grazed by the herd during the normal 24 hour rotation of the farm. The day after grazing was completed, each paddock was pegged out into 1-chain blocks in the Winter trial; and into $\frac{1}{2}$-chain blocks in the Spring and Summer trials. The number of dung patches within each block was counted and recorded. Difficulty in defining a single defaecation was sometimes encountered. In each of 10 blocks, chosen at random, 4 to 5 patches were selected on which each of the following measurements were made

Area: A 2ft square quadrat strung with trout line to form an 1" x 1" grid and fitted with 3" legs was placed over the patch. The number of grids which the patch encompassed were counted to establish the area.

Consistency: This was recorded by eye assessment, using an arbitrary scale of 1-5 (1 denoting liquid, 5 firm) (Weeda 1967).

Time of influence: A coloured, numbered plastic disc, the size of a 50c. piece was pushed into the surface of each dung patch. These proved highly successful, remaining in place the whole time the patch remained in the pasture. To aid in relocation of the patch, a white peg 9" long was driven into the ground approximately 2 feet North of the patch. This was considered far enough away so as not to interfere with the animal grazing around the patch, yet close enough to be able to relocate the patch. The paddocks measured were grazed in normal rotation following the initial recordings. After each grazing the numbered patches were relocated and a record was made as to whether they still remained as an influence to the grazing animal, i.e. if the herbage around them was grazed to the same height as the rest of the pasture.

Method of Analysis:

To test the distribution pattern of the dung patches in each paddock, an hypothesis was proposed according to $H(x = \bar{x})$ where x is the number of patches per plot and $\bar{x}$ is the paddock mean. Since the mean of the sample is the "expected" value, for n number of plots the chi-squared value for n-1 degrees of freedom becomes

$$\chi^2_{n-1\ df} = \frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{\bar{x}}$$

This model assumes that the expected distribution is uniform, which is probably not strictly true. However, in this experiment it was used to determine whether the plots with large deviations from the mean were numerous enough not to occur by chance. If they were, then the estimates provided some statistical justification for attempting to explain why the distribution was not uniform.

RESULTS AND DISCUSSION

The distribution of dung patches in five of the eight paddocks measured is shown diagrammatically in figs 2.1 - 2.5. These diagrams were made by making one stroke with a pen for each patch in the plot.

Paddocks in fig 2.1 - 2.3 were recorded in the Winter, during which time hay and silage was being fed from a tractor. In these three paddocks the concentration of dung along the hay and silage "lines" can be clearly seen. In addition, figs 2.2 and 2.3 show the large numbers recorded near trees and hedges. The result of the concentration of dung patches in these areas was that, in all four of the Winter paddocks the χ^2 values (presented in Table 2.1) were two to three times greater than those required for a 95% confidence limit. It should be noted that the weather was fine during the Winter period. Had the cows required shelter

DISTRIBUTION OF DUNG PATCHES IN PADDOCKS GRAZED 24 HRS.

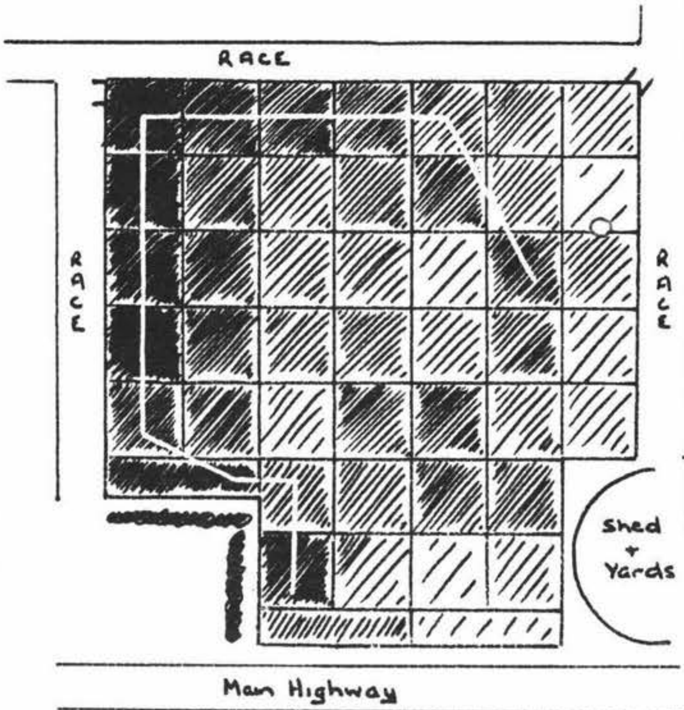


Fig 2.1
Mitchell Farm I

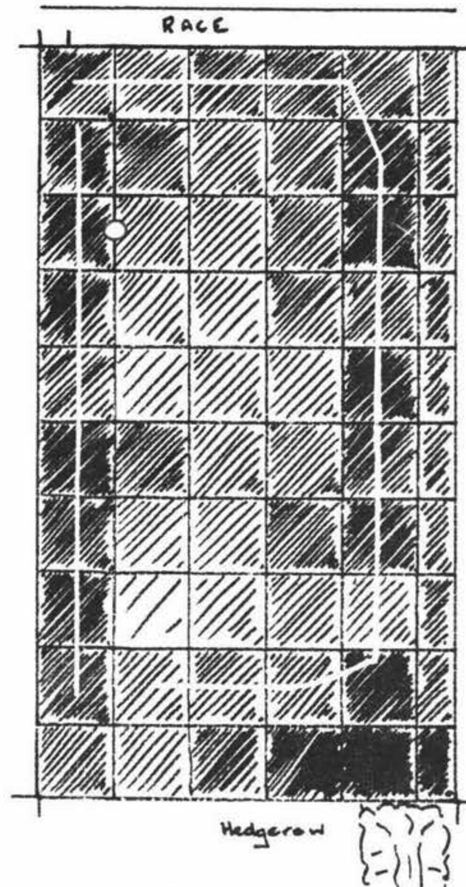


Fig 2.2
Mitchell Farm II

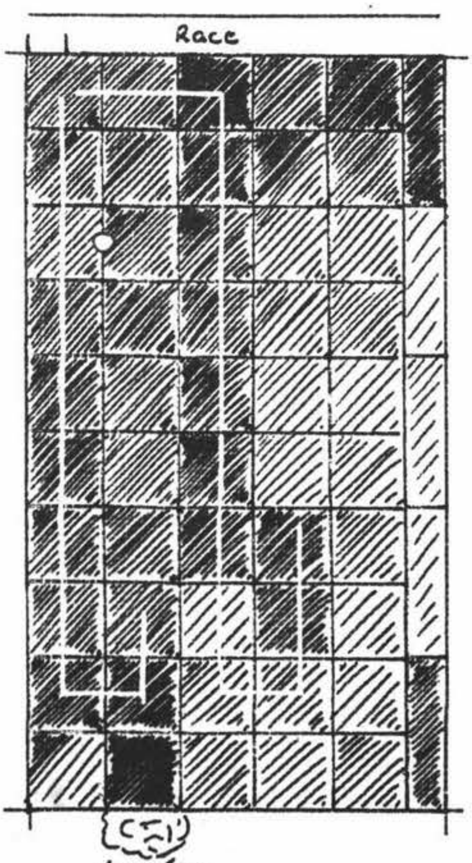


Fig 2.3

Mitchell Farm IV

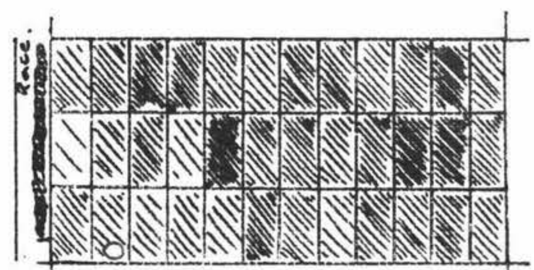


Fig 2.4
No. 3 Dairy Unit II

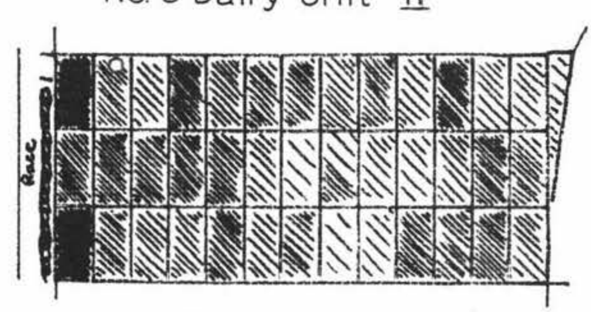


Fig 2.5
No. 3 Dairy Unit I (Summ.)

Gateways. — Hay & Silage lines ● Water troughs.

Chain - square blocks ½ - chain blocks.

from the wind and rain these values might well have been larger.

In both the Spring and Summer recordings the distribution was remarkably uniform. The χ^2 values in brackets for the last two paddocks are calculated after two and one plot, respectively, were removed from the estimate because they detracted from the otherwise uniform distribution. In both cases the plots contributed more than half the χ^2 value yet contained only one tenth of the total number. Fig 2.5 illustrates one of these paddocks. The plot showing highest concentration in this figure had included in it a freshly dug post hole. Whether the dung was concentrated around the earth because the cows were curious and congregated in this area or because they showed some psychological reaction to freshly dug earth is not known.

Fig 2.4 shows a "uniform" distribution typical of those obtained during the Spring and Summer. No doubt the uniformity is a reflection of the fine days experienced during the recording period, and the lack of obstacles and even growth in the paddocks. In none of the paddocks was there any undue concentration of dung around the gateways or troughs.

Estimates for the average number of defaecations per cow per day (Table 2.1) vary from 10.4 to 16.8 which is within the range found by the authors tabulated in Table 1.1. There was little difference between estimates in Winter and Summer, although this comparison may be confounded because of the Friesian herd used for the Winter study.

Estimates for the average area of each defaecation range from 100 - 123 sq.ins. (Table 2.2) which agrees with the 108 square inches Davies et al (1960) used for their calculations under New Zealand conditions (Table 1.1).

TABLE 2.1

Distribution Estimates of Dung Patches in Eight Separate Paddocks

Paddock Description				Dung Patch Data					Distribution Analysis	
Paddock No.	Pegged Blocks per Paddock	Area Padd Acs.	No. Cows Grazed	Total No. in Paddock	Av. No/ Block	S.E.	Av. No/ Acre	Av.No. Cow	χ^2	χ^2 reqd. (95 %)
Mitchells Farm - Winter										
I	46	4.6	72	886	19.3	± 1.9	193	12.3	379	60
II	55	5.2	72	995	17.3	± 1.0	173	13.8	187	73
III	54	5.4	72	1043	19.3	± 1.1	193	14.5	178	72
IV	68	6.8	72	993	14.5	± 0.8	145	13.8	193	88
No. 3 Dairy Unit - Spring										
I	36	1.8	40	416	11.5	± 0.6	230	10.4	41	51
II	36	1.8	40	492	13.6	± 0.6	272	12.3	36	51
III	40	2.0	40	522	12.8	± 1.2	256	13.0	(46) 163	55
		- Summer								
I	36	1.8	40	672	18.7	± 1.3	374	16.8	(50) 110	51
II	Missing Data									

TABLE 2.2

Area Estimates Of Dung Patches

Paddock No.	No. Patches Measured	Av. Area Patch sq.inches	S.E.	Cows Grazed	Patch Area / Cow sq.ft.	Area Paddock Acs.	% Paddock Area Covered By Patches
Winter							
I	48	99.6	± 7.5	72	8.5	4.6	0.31
II	50	100.9	± 7.1	72	9.6	5.2	0.28
III	50	114.6	± 6.8	72	11.5	5.4	0.35
IV	49	123.7	± 7.8	72	11.6	6.8	0.29
							Mean 0.31
Spring							
I	39	113.7	± 7.1	40	8.1	1.8	0.42
II	40	118.6	± 7.5	40	10.1	1.8	0.51
III	39	121.6	± 8.8	40	10.9	2.0	0.50
Summer							
I	40	112.4	± 8.3	40	13.0	1.8	0.67
II	40	117.4	± 7.9	40		1.8	Mean 0.52

In spite of their seeming abundance, the dung patches in fact covered a very small percentage of the pasture. The means for the two farms were 0.31% and 0.52% of the paddock area respectively, the higher stocking rate on the NO.3 Dairy Unit being responsible for the higher excretal density.

While there was a tendency for the number of patches per cow to be higher in the Spring than in the Winter, the area per patch in the former period tended to be lower, with the result that the average area covered per cow remained virtually constant for the three periods.

Probably the greatest difference between the Winter and the other two periods was in the consistency of the dung (Table 2.3). Presumably because of the more fibrous nature of the Winter diet with hay and silage supplementing grass, the proportion of patches of consistency 3, 4 and 5 in the Winter was far greater than the proportion in the other two periods viz. 85% compared with 27%. Yet there was no decrease in total area per patch which one might have expected from the firmer dung. However, if the Firesians do excrete more than the Jerseys (Hancock 1951), then the Winter estimate of area per patch would be an over-estimate by Jersey standards. This may have helped compensate for the firmer consistency.

TABLE 2.3

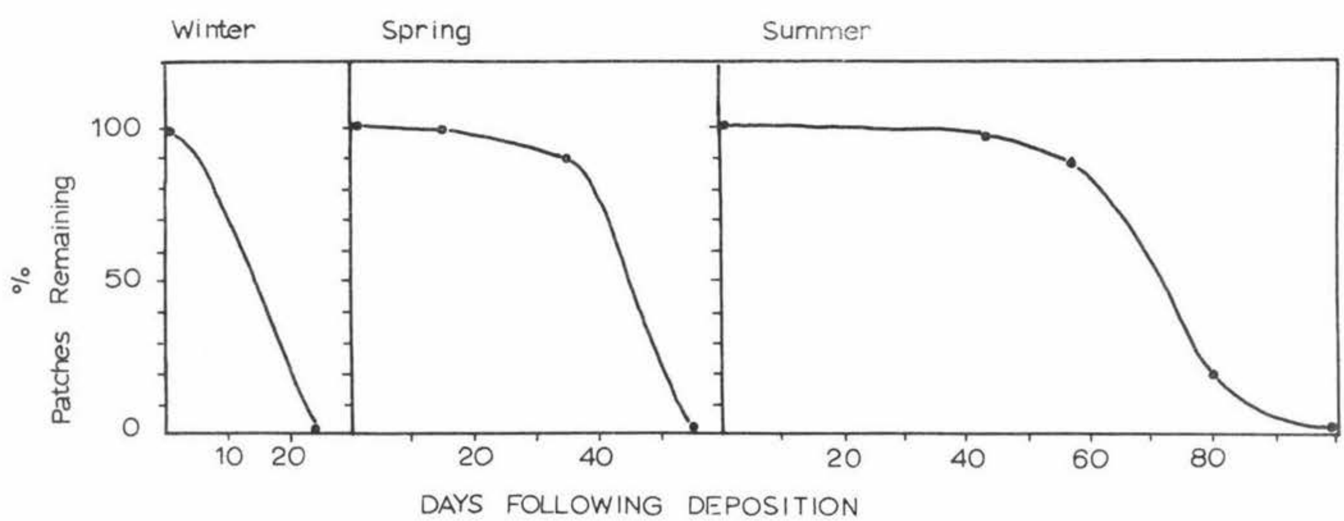
Consistency of Dung in Patches

(Percentages in each category) and percentages classified discrete and scattered

Season	Winter					Spring				Summer		
Paddock	I	II	III	IV	Mean	I	II	III	Mean	I	II	Mean
Consistency 1			2	2	1	8	5	15	9	15	15	15
2	24	14	14	12	14	67	68	58	64	55	60	58
3	49	54	56	54	53	23	27	27	26	30	23	26
4	33	26	26	32	29	2			1		2	1
5	4	6	2	0	3							
Discrete %	77	66	68	74	72	77	57	70	69	90	90	90
Scattered %	34	32	26	22	28	22	42	30	31	10	10	10

The graphs in Fig 2.6 show the percentages of patches which remained an influence in the pasture after each grazing. In the Winter, there was rapid disappearance of the patches, all of them having disappeared on return to the paddock after one month. The very high rainfall of 7.2 inches, recorded during August, together with heavy stocking of the paddocks and pugging must have been contributing factors to their rapid disappearance.

FIG. 2.6 RATE OF DISAPPEARANCE OF DUNG PATCHES



In the Spring period, the weather was considerably drier and warmer (3.7" of rain in 2 months) and the patches became hard and crusted. They remained like this for 5 weeks, during which time the cows "rejected" the herbage around them. After the third grazing the crust began to crack and the patch then disintegrated over the following 3 weeks.

The Summer decay patterns were very similar to those in the Spring, except that the patches persisted longer (7 weeks) before beginning to disintegrate. By the end of the fourth grazing (8 weeks), however, the cows were completely grazing the grass around the patches, although the patches themselves did not disappear completely for a further 4 weeks.

There was no correlation between the rate of disappearance of the patches and the consistency of the dung. Weeda (1967) noticed patches consisting of firm dung (4-5 category) tended to persist longer than patches of more liquid consistency (1-3) provided a surface crust did not form. If a crust did form, rate of disappearance was independant of consistency. In the Winter trial in this experiment, the patches disappeared too quickly for any correlation to be made while in the Spring and Summer trials, crusts formed and all patches disappeared at a similar rate.

CHAPTER THREE

ECOLOGICAL EXPERIMENT I

During the study described in the previous chapter it was noticed that the herbage surrounding the dung patch appeared to be taller than the rest of the pasture before each grazing. The main aim of this experiment was to determine whether the dung patch could have been the cause of the apparent increase in growth. In addition, several related aspects were also investigated.

EXPERIMENTAL

The experiment was designed as shown in fig 3.1. Each individual square in the figure represents a plot. The treatments (A, B, C and D) were as follows:

Treatment A: Each plot in this treatment acted as a control

Treatment B: The plots in this treatment had, in their centre, a rubber pad. The purpose of the rubber pad was to simulate a dung patch but without nutrient return.

Treatment C: A dung patch was centred in the middle of each plot in this treatment.

Treatment D: This was the same as C, except that at each harvest date the patch was lifted and the whole plot mown to 1 inch in height. The plot was then allowed to grow to grazing height before it was harvested. As well as providing data on any residual effect the dung patch may have had, it also allowed the regrowth of the herbage beneath the patch to be followed.

Each treatment was on a plot four feet square and each plot was harvested in three concentric circles 2, 3 and 4 feet in diameter around the patch - designated R2, R3 and R4.

Sixteen plots per replication of each treatment were laid to allow for sequential harvests to be taken to cover the expected period of growth

FIG. 3.1 DESIGN OF FACTORIAL EXPERIMENT I.

Race — I — Race

B	16	10	12	7	13	2	9	8	6	3	5	11	14	4	15	1
A	13	4	9	7	6	15	10	8	14	11	16	12	2	3	1	5
C	14	5	11	9	12	8	7	3	2	4	16	13	15	6	1	10
D	2	11	3	6	13	12	7	1	10	4	15	16	5	9	8	14

II

A	9	6	15	12	2	16	7	5	8	13	3	11	10	4	1	14
D	6	10	7	11	13	4	8	15	5	3	9	12	14	16	1	2
B	1	7	8	16	6	10	3	9	5	15	2	4	14	12	11	13
C	11	2	15	14	3	6	7	13	10	4	12	9	5	1	8	16

III

D	3	16	1	4	8	12	2	15	6	5	14	11	7	10	9	13
B	2	8	13	5	7	9	4	15	11	3	12	14	10	1	6	16
C	9	6	3	13	5	2	16	12	15	8	4	7	10	11	1	14
A	8	16	9	6	15	12	2	1	7	5	13	3	14	11	4	10

IV

C	2	4	5	3	1	12	6	9	16	14	11	15	10	7	13	8
A	1	2	13	14	12	16	4	8	11	3	9	5	15	6	10	7
B	8	6	10	9	12	16	15	14	4	7	5	3	1	13	2	11
D	10	5	1	16	13	3	14	12	11	8	7	9	6	15	2	4

A - Control plots
B - Artificial patch
C - Dung patch
D - Regrowth

1 - 16 Sequential harvest
I - IV Blocks

to a plateau.

Materials and Method:

In the middle of October, 1967, a $\frac{1}{4}$ acre section was fenced off in the corner of one of the paddocks on the No. 3 Dairy Unit, Massey University (McQueen 1963 - See Chap 2). The soil type on the site was Tokomaru Silt Loam. The paddock had been sown down in the Autumn of 1964 following a summer crop of chou moellier, and had subsequently received 3 cwt per annum of superphosphate. The last application before the trial was in March, 1967.

In an endeavour to remove as much variability in the pasture as possible, the experimental area was mown twice with an Allen reciprocating blade mower over the 6 week period prior to the start of the experiment and the clippings, together with any dung patches present, were removed. This treatment established a relatively uniform sward. However, as the trial progressed, a distinct fertility gradient became obvious from the race, which bordered one end (fig 3.1) toward the centre of the paddock. This problem was anticipated, but apart from fencing off a portion in the middle of the paddock, could not be avoided. Placing the replications with the gradient allowed some of the variability to be removed statistically.

The final pre-cut was made on November 28th. The experiment was laid out and the treatments applied on December 1st.

Dung for the trial was collected from the Massey herd after milking at night and again in the morning and thoroughly mixed. Obviously, some urine was present with the mixture but collecting from the yard minimised pollution from this source as most of it drained away.

From the population study (Chap 2), the average size of a patch was 113 sq.ins. In this experiment, a dung patch of similar size, 12 inches in diameter (113 sq.ins), was used. In order to determine the weight of dung to use, several patches in a nearby paddock which were of similar consistency to the dung collected (viz. 3 on the consistency scale), and approximately 12 inches in diameter were collected and weighed. These averaged 4lbs wet weight.

To make a patch similar to those in the paddock, 4lbs (±) 2 oz of dung was weighed in a plastic bowl and emptied into a 12 inch circular rim of 2 inch iron and the mixture spread from the middle outwards. The patch was centred in the middle of each plot.

The rubber pads for Treatment B were made from 3/16th inch thick industrial rubber, cut in 12 inch circles and held in place with four galvanised steel spikes.

Sampling Procedure

Harvests were made on each of the following days:

Harvest No.	0	1	2	3	4	5	6	7	8	9	10
Date 1967/68	1/12	2/12	4/12	7/12	11/12	16/12	21/12	26/12	31/12	10/1	25/1
Interval (days)		1	2	3	4	5	5	5	5	10	15

Herbage Samples:

At each harvest, Treatments A, B and C were cut to ground level using a Sunbeam Shearmaster electric handpiece. (see Plate 1)

On Treatment A, two 12 inch circular quadrats were cut at random. On the other two treatments, the sampling rings (R2, R3 and R4) were centred around the patch and the herbage in each ring harvested, bagged and weighed.

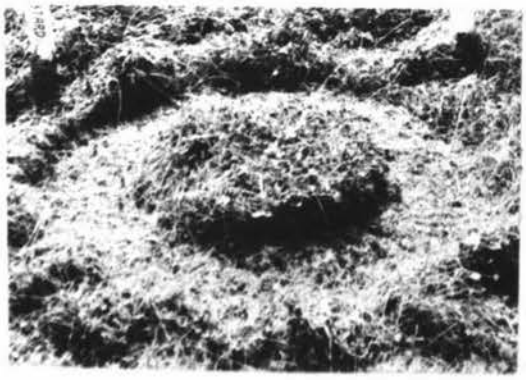
The samples obtained were subsequently sub-sampled for dry matter determinations (100gms) and on alternative harvests for botanical compositions (at least 100 gms or 1/10th of the sample). Botanical samples were hand separated into Ryegrasses (*Lolium* species), Cocksfoot

PLATE 1

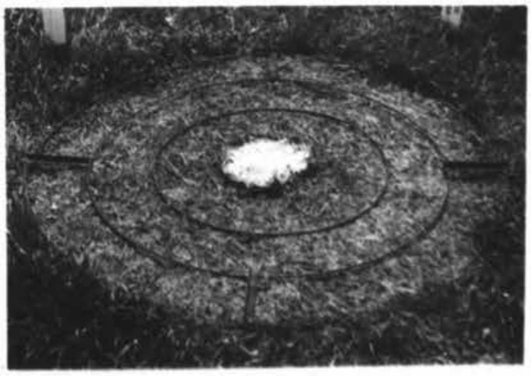
Two views of the layout of Experiment I, taken at the 5th harvest. Each plot, 4 ft. square, is shown bordered by the white pegs.

The "Shearmaster" clippers, run from a 240 V. generator, used for harvesting plots.

The outer 6" ring (R_4) was harvested first.



This was followed by the harvest of R_3.



Finally, the inner 6" ring (R_2) was harvested. Photo shows the rings used for harvesting centred around dung patch

(Dactylis glomerata), Yorkshire fog (Holcus lanatus), other grasses (predominantly Poa species) and Timothy (Phleum pratense), Clovers (principally Trifolium repens), Weed species and Dead Matter; dried and weighed.

Harvests in Treatment D were made when the regrowth herbage from plots at the 2nd, 3rd, 5th and 7th harvest reached "grazing height" (5-6 inches). Ring 1, R2, R3 and R4 were sampled as described above. Botanicals were made on bulked samples.

Dung Patch Sampling:

At each harvest the dung patch from C was lifted, weighed, dried at 100°C, ground through a 2mm sieve and stored in a screw-top jar and later analysed for Acid Detergent Fibre content (App 3.12).

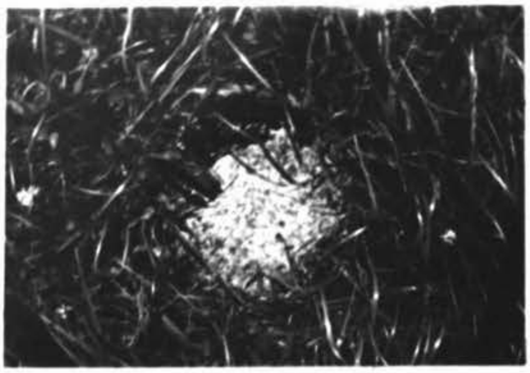
In addition, three 2 inch diameter tiller cores were taken from the area beneath the patch and the remaining material was clipped and collected (Plate 1). The procedure was repeated on the area beneath the pads in Treatment B. The tiller cores were examined for total live tillers which were counted, cut and weighed dry. This weight was added to the weight of herbage remaining beneath the patch. Clover stolons were also separated and the number of rooted nodes counted.

The material collected from beneath the patches was sorted into clover petiole, grass stem, grass leaf and dead matter. Each component was dried and weighed. On harvest 2, 3 and 4 in treatment C this material had to be washed on a ¼" sieve to remove contamination from the dung. After harvest 4 the dung patch separated easily from the material beneath.

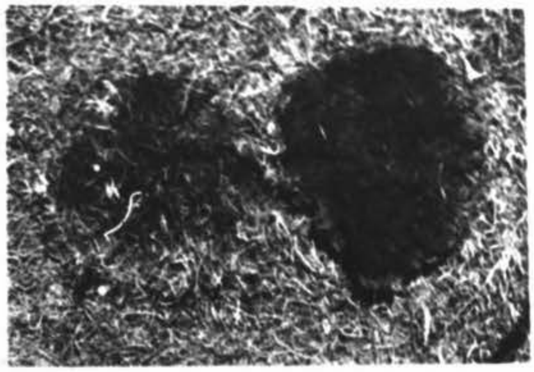
Soil Samples:

Using a ½ inch diameter cork borer, five soil samples 3 inches

PLATE 2



A dung patch shown in situ before harvest of surrounding herbage.



After harvest the dung patch was lifted. Note dark, burnt appearance of herbage beneath patch.

Photo shows where tiller cores were taken ex patch area. The small holes show where soil cores were taken at 0, 3, 6, 9, 12 & 18" ex centre of patch.

The artificial patch shown in situ.

Herbage beneath artificial patch. Note the dried, lighter appearance c/f that beneath dung patch.

deep were taken from C plots at 0, 3, 6, 9, 12 and 18 inches from the centre of the dung patch. Sampling times alternated with herbage botanical samples and were taken in each of the four blocks. (Plate 2). Unfortunately, on harvest 2, samples at 9", 12" and 18" were omitted.

The soil cores were then taken to the laboratory where the top 1 inch and remaining 2 inch length was cut from each core. Any adhering dung was removed from the 1 inch sample. The five lengths thus obtained at each depth were bulked for each radius and dried at 100°C. The samples were then ground through a 2 mm sieve and stored in 25 ml. stoppered plastic phials. On harvest 2 and 3 soil moisture percentages were calculated on the soil beneath the patches.

Soil Chemical Analysis

The following chemical determinations were made on each soil sample.

1. Available Soil Nitrogen:

The method employed was that described by Keeney and Bremner (1966 a), involving the extraction of exchangeable ammonium, nitrate and organic nitrogen by boiling the soil in distilled water. Kjeldahl determination of the extract excludes most of the nitrate. The nitrogen extracted by this method has a highly significant ($p<0.01$) correlation with the N uptake by ryegrass (Keeney and Bremner 1966b). In addition, it was considered more applicable than the conventional biological methods for detecting the N compounds mobilised from the dung patch. Ball (pers.comm.) has found when using the former method that oven-drying the soil at 80°C increased the soil N values by 100% and the correlation of these values with determination of the same soil air-dried was 0.610 ($p<0.05$). Since only qualitative values were of interest in this experiment, the fact that the samples were oven-dried seemed of no great consequence.

The only samples in which drying could have had an effect were the original pre-experimental samples taken on the day the patches were laid. These samples gave values of available N which were more than 200 ppm. higher than samples taken at the second harvest. Since it is doubtful that losses of this magnitude could have occurred between the three days between samplings (Ball, pers.comm.), it was considered that some extraneous experimental error, perhaps drying of the excessively wet soil, lead to the high values in these initial samples. For this reason these samples were not included in the results. Instead, the average for the 18" samples was used, since these were relatively uniform throughout the experiment.

2. Exchangeable Potassium Determination:

The method employed for the extraction of exchangeable potassium was the centrifugation method described by Bower et al (1952) for use with soils of low permeability. The NH_4OAC extractant was then run directly through a Technicon Flame Photometer with Autoanalyser system attached. The Ca manifold was used because of the relatively high dilution factor involved. Results were read against a standard curve made from standard samples of 0, 2.5, 5.0, 7.5, 10, 20 and 30 ppm K (as KCl) in NH_4OAC.

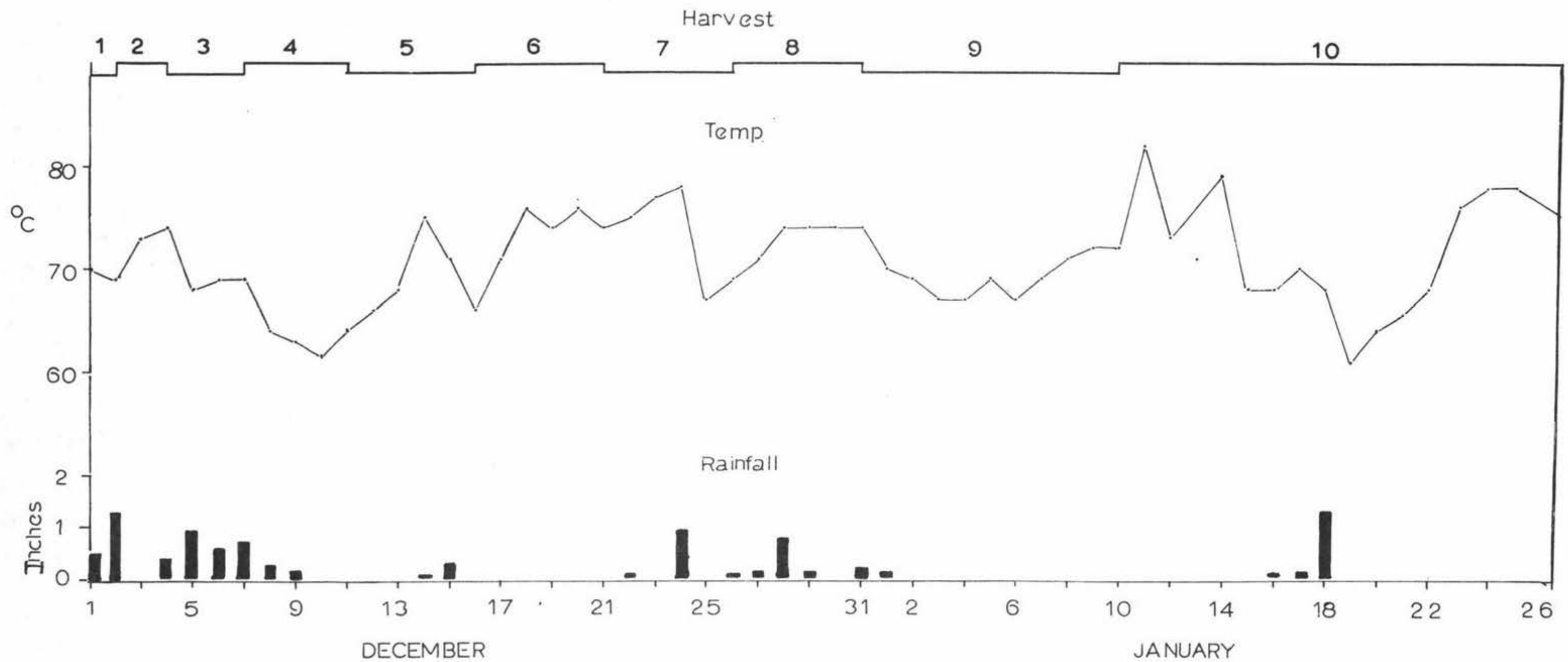
3. Available Phosphorous Determination:

Available phosphorous was extracted by Truog solution (Truog 1930) and the P in this extract developed and determined colorimetrically by the ascorbic acid/antimony method described by Watanable and Olsen (1965). It is likely that oven-drying of the soil may have released a portion of the organic P (Jackson 1958) but the contamination from this source was considered unlikely to affect qualitative results.

Climate Data

Fig 3.2 shows the temperature and rainfall on each day of the

CLIMATE DATA THROUGHOUT EXPERIMENT – FIG. 3.2



experiment. The period between each harvest is graphically presented in the staggered line above the data. Of particular note is the deluge which occurred the day after the dung patches were laid (1.23 inches) and the high rainfall (4.37 inches) over the first 9 days of the experiment. The relevance of this rain to the results obtained in the experiment is referred to in the discussion.

Conditions were generally excellent for growth, the temperatures on average ranging not more than 5F^{o} either side of 70^{o}F while rainfall appeared sufficient and frequent enough to maintain soil moisture around field capacity, although no actual measurements were made.

ANALYSIS OF DATA

The experiment included 4 dung treatments, 3 ring samplings and 4 blocks (fig 3.1) in a 4 x 3 x 4 random factorial design repeated 16 times to allow for sequential harvests. Only 10 harvests were taken. Harvest time was also randomised within each treatment. Because of the different time period involved, treatment D was analysed separately.

The analysis of total dry weight of herbage (TDM) as well as each botanical component including a total grass component, was performed for the other three treatments (A, B and C) at each harvest separately using a generalised multi-factorial analysis of variance program on the IBM 1620 model 2 computer installed at Massey University. Table 3.1 shows the expectation of the mean squares for the analysis compiled following the direction by Henderson (1963). The F ratiosused are shown. In the case of treatment effects (t), the approximate degrees of freedom used for determining the required F-values were calculated according to Snedecor (1959) (App 3.1).

TABLE 3.1

Expectation of Mean Squares and F-ratio Test in Analysis of Variance of Herbage Date from each Harvest

B = Blocks	number (n) of each item
T = Treatments	$n_b = 4$
R = Ring Samples	$n_t = 3$
	$n_r = 3$
	$n_w = 1$

Source of Variation	df	Expectation of Mean Squares	F-ratio
B	3	$\sigma^2_w + \cancel{\sigma^2_{btr}} + 3\sigma^2_{br} + 3\cancel{\sigma^2_{bt}} + 9\sigma^2_b$	B/BR
T	2	$\sigma^2_w + \sigma^2_{btr} + 3\sigma^2_{bt} + 4\sigma^2_{tr} + 12\sigma^2_t$	T/BT + TR - BTR
BT	6	$\sigma^2_w + \sigma^2_{btr} + 3\sigma^2_{bt}$	
R	2	$\sigma^2_w + \cancel{\sigma^2_{btr}} + \cancel{3\sigma^2_{br}} + 4\sigma^2_{tr} \quad 12\sigma^2_r$	R/BR
BR	6	$\sigma^2_w + \cancel{\sigma^2_{btr}} + 3\sigma^2_{br}$	
TR	4	$\sigma^2_w + \sigma^2_{btr} + 4\sigma^2_{tr} +$	TR/BTR
BTR	12	$\sigma^2_w + \sigma^2_{btr}$	

T was assumed to be fixed, giving as the true components of the analysis those which are not crossed out.

All the herbage data was converted to a common factor viz. lbs /ac before being analysed statistically. This conversion was also performed with the computer and the punch-out of the raw data is tabled in App 3.20. Although all the data was analysed, only that which showed significant treatment variation is tabulated with mean squares and significance levels (See App 3.5 - 3.9). It may be noted that for the convertion of the raw data, the ratio of R2 : R3 : R4 used was 2.66 : 4.10 : 5.33. These were estimated by measurement and vary slightly from the theoretical because the sampling rings were difficult to construct in a perfect circle (see Plate 1).

The results are expressed in the main body of the text in graphical form with the appropriate Least Significant Difference (LSD - App 3.2) around those means which show significant variation from one another. The values from which each graph was derived are tabulated in the appropriate appendix together with the results of the analysis of variance. Results from the soil chemical determinations were analysed at each harvest also and expressed similarly.

Analysis of the herbage data as described above gave alternating significant and non-significant results between harvests (see fig 3.3). Consequently, the data for the whole experiment was analysed. This necessitated pooling all the error variance. However, as shown in Table 3.2 this variance was independant of the mean particularly over the latter stages of the experiment when the herbage in the plots became stalky and dense making it difficult to place the rings accurately in position for sampling. The non-additivity of the variance was partly overcome by transforming all the data (x) to $\log_e x$. This reduced the range of the ratio of the Error Mean Square/Grand Mean from between 4.7 - 36.3 to between 1.2 - 6.4 (Table 3.2).

TABLE 3.2

The Ratio of Error Mean Square (EMS) to Grand Mean for each harvest using Raw and Transformed (X-$\log_e X$) Data

Harvest		2	3	4	5	6	7	8	9	10
Raw Data	EMS	15678	13112	9727	21199	64324	40401	23018	16958	272225
	Mean	2294	2244	2054	2808	3339	4148	4414	5641	7482
EMS/Mean		6.8	5.8	4.7	7.5	19.3	9.8	5.2	30.0	36.3
Transf. Data	EMS x 10^4	31	27	21	23	55	25	10	56	49
	Mean	7.73	7.71	7.62	7.93	8.10	8.31	8.38	8.63	8.91
EMSx10^4/Mean		4.0	3.6	2.8	2.9	6.8	3.0	1.2	6.4	5.6

Having established that the effect of the treatment was significant (see Results section) it then seemed justifiable to proceed with analysis of the remainder of the data, which included botanical components, within each harvest. In this way the analysis was not restricted by the non-additivity of the variance between harvests.

Coefficient of Variation:

The coefficient of variation for the whole experiment, obtained from the transformed data (App 3.3) was 31%.

RESULTS

The analysis of the total dry weight of herbage (TDM) harvested over the experimental period from each of the treatments, using the transformed data, is shown in App 3.4. The transformed means are shown in Table 3.3. The result was a highly significant ($p<0.01$) increase in the yield of herbage from treatment C, inwhich the dung patch was present, compared with the yield from the other two treatments. However, there was no significant difference between yields from treatment B which contained the artificial patch and the control treatment (A). The significant differences between Blocks I, II and IV indicated a fertility gradient, the Blocks yielding progressively more as their distance from the fence bordering the race and Block I increased (see fig 3.1).

TABLE 3.3

Mean Yield of TDM over the Experimental Period - Transformed Data Means ($X = \log_e X$)

Treatment Means

A	B	C
8.1298	8.1415	8.1854

LSD (0.05) = 0.028

Block Means

I	II	III	IV
8.056	8.153	8.194	8.206

LSD (0.05) = 0.053

Harvest Means

Harvest	2	3	4	5	6	7	8	9	10
	7.7340	7.7119	7.6223	7.9337	8.1052	8.3155	8.3879	8.6300	8.9150

LSD (0.05) = 0.025

FIG. 3.3 TOTAL DRY WEIGHT OF HERBAGE. (Mean of three rings & four blocks).

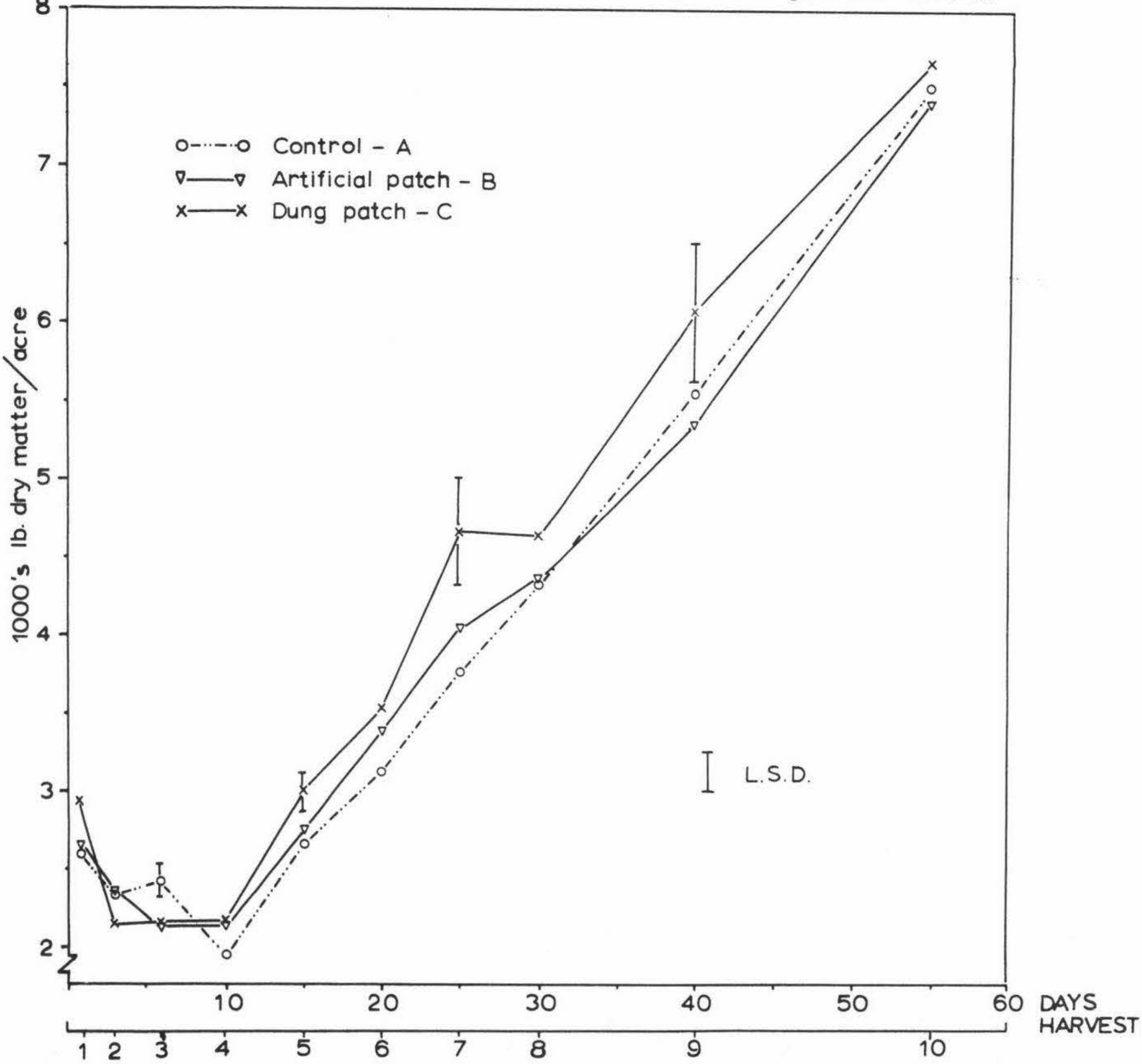


Fig 3.3 shows the total dry weight of herbage at each harvest graphed for the whole experimental period, and the results of the analysis of variance for each harvest (App 3.5). Apart from the result from the 3rd harvest, which probably occurred by chance, there was no significant differences between treatments A and B.

The effect of the dung patch (treatment C) first became significant at the 5th harvest, 15 days after the start of the experiment and was still significant at the 9th harvest, 25 days later. However, the effect appeared to radiate progressively from the inner ring (R2) outwards. This affect is illustrated in figs 3.4, 3.5 and 3.6 for R2, R3 and R4 respectively. The effect occurred first in the 6 inch ring of herbage surrounding the dung patch (R2), (fig 3.4a), the response coming entirely from the total grass component (fig 3.4b) which included ryegrass species, cocksfoot and "other grasses" (timothy, Yorkshire fog and poa species). Of the total grass component, "other grasses" showed a significant increase ($p<0.05$) in C at the 5th harvest while ryegrass species were significantly greater, ($p<0.05$) at the 7th harvest (fig 3.4c). Ryegrass species also yielded significantly more at the 9th harvest in the R2 ring of treatment C, despite the fact that total dry weight and "total grasses" were not significantly greater (fig 3.4).

The response in the two outer rings of herbage R3 and R4, extending up to 18 inches from the periphery of the dung patch, did not become significant until after the 6th harvest (20 days) but was still apparent, though not significantly so, at the end of the experiment (55 days) in R4 (fig 3.5a, fig 3.6a). By this stage, the ryegrasses had run to seed, making them difficult to sample accurately and therefore making differences between treatments difficult to measure statistically (App 3.5 et seq.) As for R2, there was also a significant increase in total grass species

FIG. 3.4 HERBAGE WEIGHTS IN FIRST 6 INCH RING (R_2) AROUND DUNG PATCH & CONTROLS.

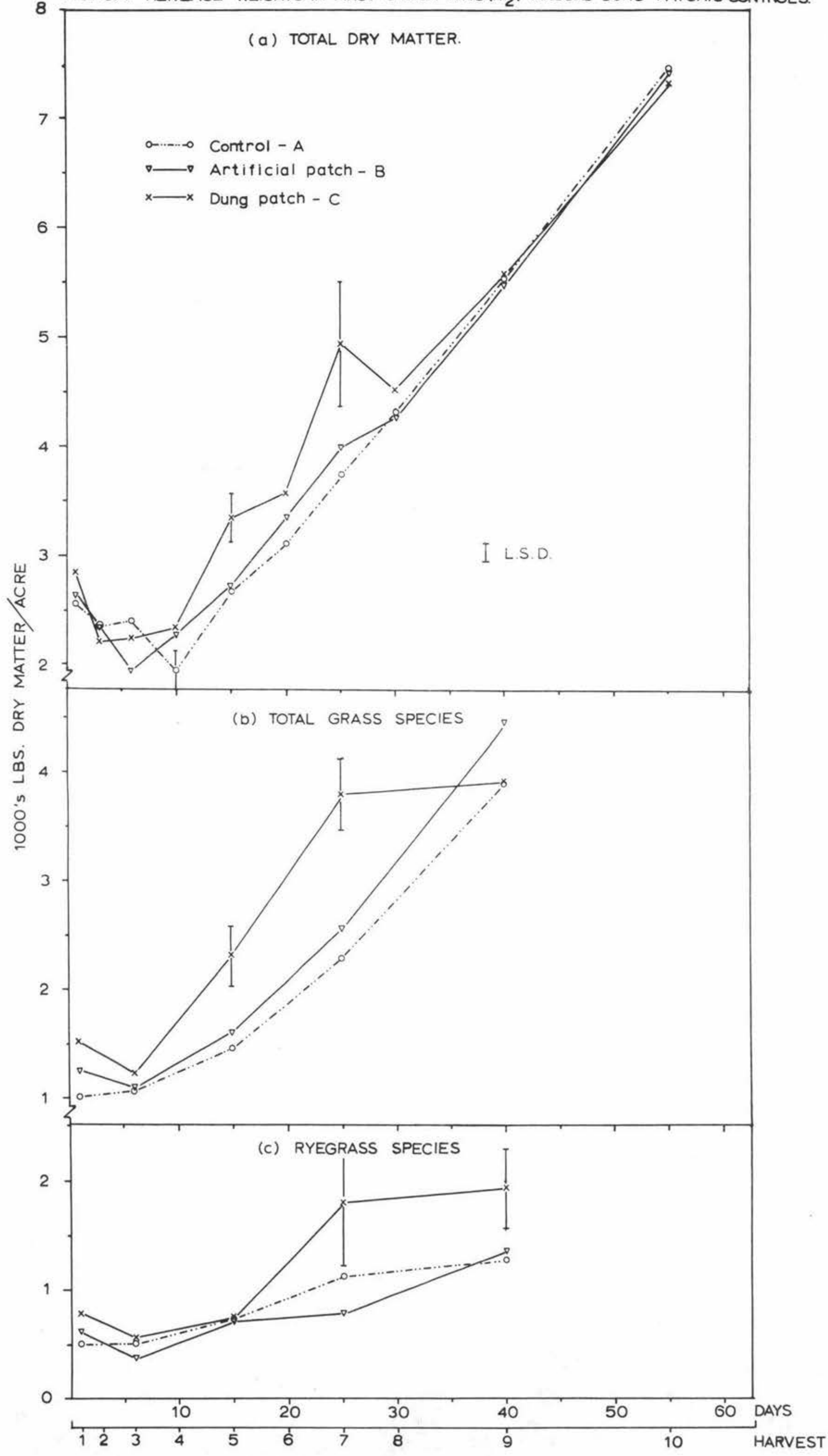


FIG. 3.5 HERBAGE WEIGHTS IN SECOND 6 INCH RING (R_3)

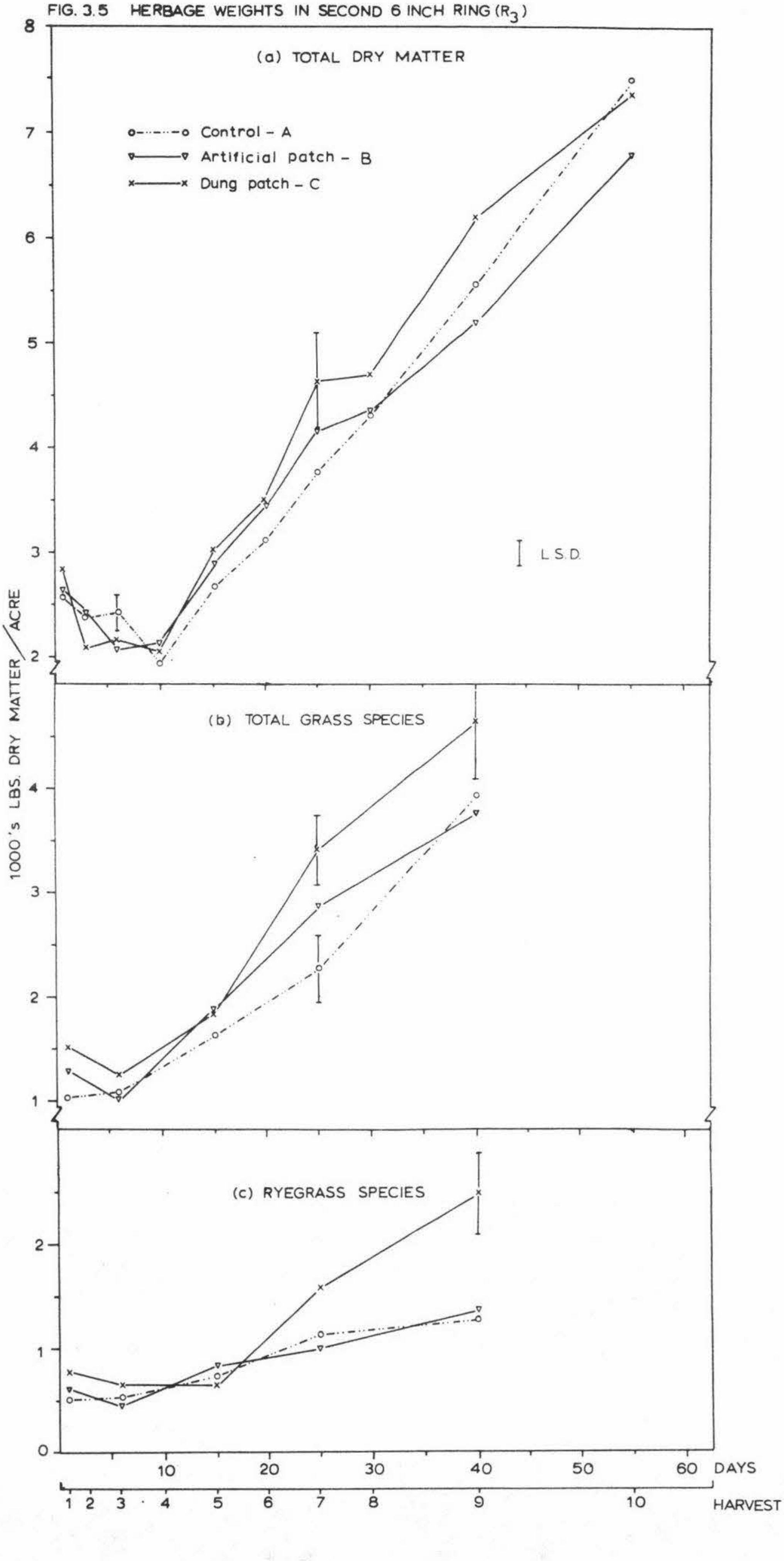
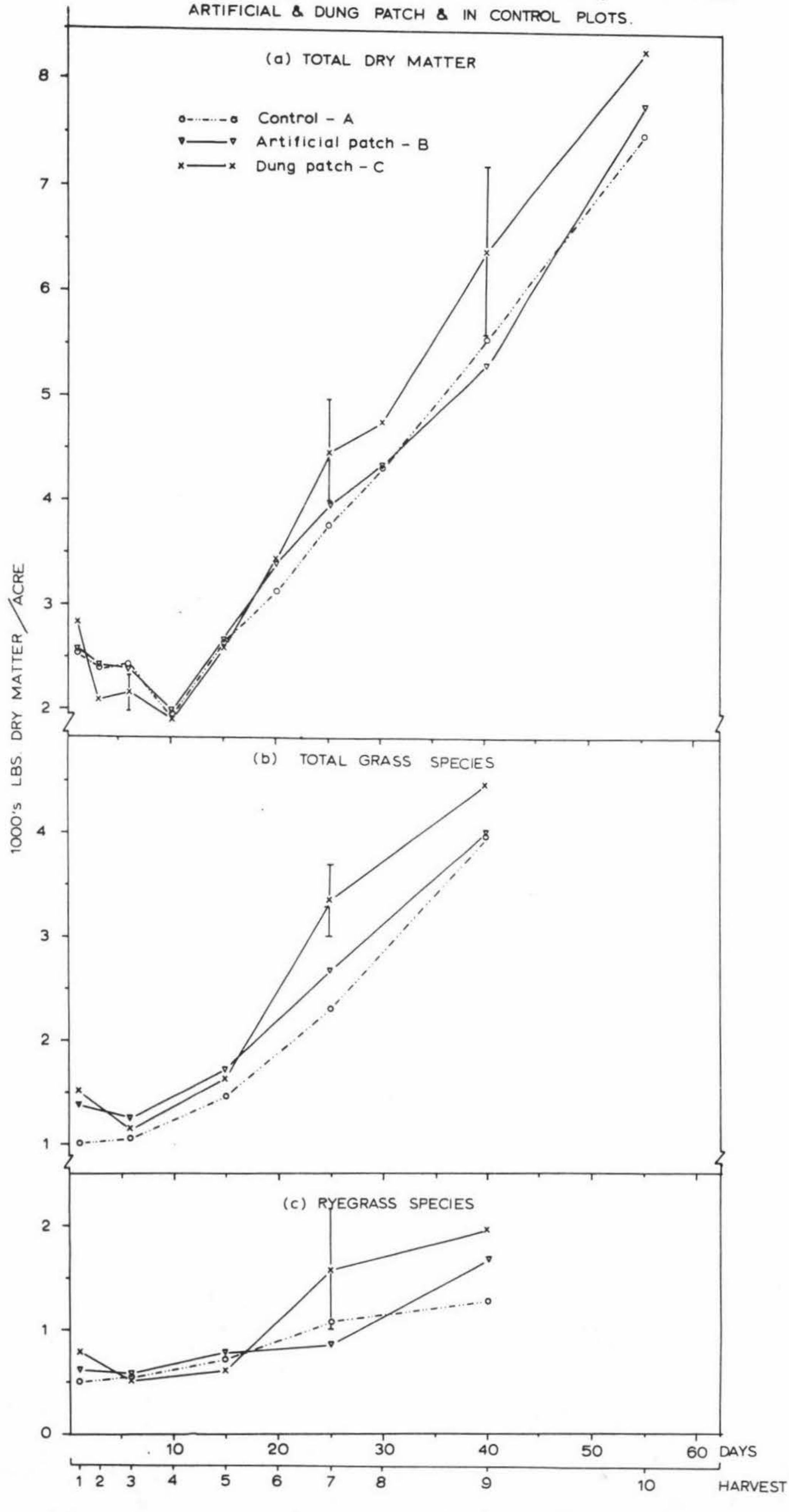
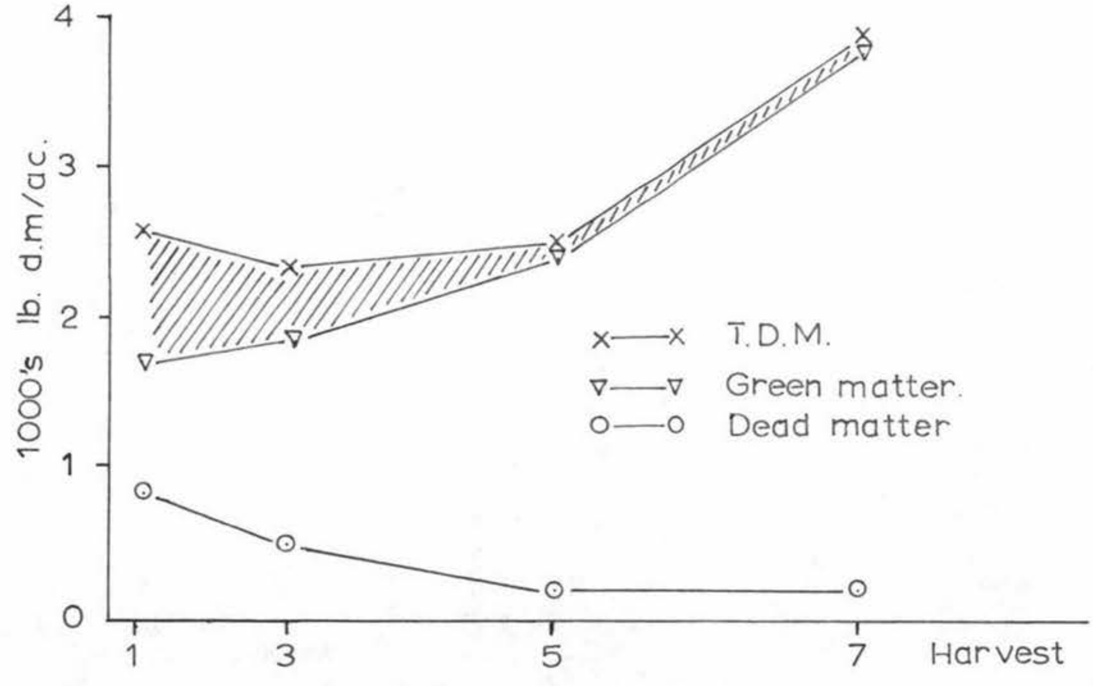


FIG. 3.6 HERBAGE WEIGHTS IN THE THIRD 6 INCH RING (R_4) AROUND THE ARTIFICIAL & DUNG PATCH & IN CONTROL PLOTS.



in R3 and R4 (fig 3.5b, 3.6b) of which ryegrass was a significant component (fig 3.5c, 3.6c).

There was no significant difference between the three treatments at each harvest in either the yields of clover species (predominantly white clover), weed species (predominantly dandelion) or the content of dead matter. However, the high proportion of dead matter in the sward at the start of the experiment was probably a contributing factor to the U-shaped nature of the total dry weight (TDM) curve over the first 10 days (fig 3.3). The regular cutting of the plots with a rotary mower prior to the start of the experiment resulted in a lot of dry, heavy stubble as well as some clippings in the sward. After the rain, concomitant with the start of the experiment there was a period of lush, leafy growth which, with its high moisture content "weighed light". If this growth was largely the result of mobilisation of the reserves in the stubble, the TDM of the sward would not change appreciably. Furthermore, while this mobilisation was occurring, the dead matter which had accumulated in the sward during the mowing, consisting mainly of clippings and the sheath surrounding the stubble, would be decaying and this was probably the cause of the depression in the curve. This effect is shown in the figure below.



Soil Moisture

The moisture content in the first 1 inch of soil beneath the dung patch at both the 2nd and 4th harvest was higher than that of the surrounding soil, whereas the moisture content was not altered in the soil beneath the rubber pad (Table 3.7). The effect was probably a combination of added moisture from the dung and prevention of evaporation from the soil.

TABLE 3.7

Soil Moisture Content (%) of Samples taken at two depths at H2 and H4

Sampling Site	Beneath Dung Patch	Beneath Art. Patch	Control Level
Harvest 2			
Depth 0 - 1"	42.7	31.8	31.8
1 - 3"	32.6	28.5	27.5
Harvest 4			
Depth 0 - 1"	39.7	33.0	34.5
1 - 3"	31.2	30.1	31.0

Regrowth following Defoliation

The intervals between when the patches were lifted and the plots cut to 1" and their subsequent harvest (Treatment D) are shown below:

Harvest (D)	1	2	3	4
Harvest Patch Lifted	2	3	5	7
Date Patch Lifted - 1967	4/12	7/12	16/12	26/12
Duration of Patch - Days	3	6	15	25
Date Plots Harvested - 1968	9/1	24/1	5/2	17/2
Regrowth Period - Days	36	48	51	53

The relatively long period allowed for regrowth in the last three harvests was because of very dry weather. However, the average yield from each harvest was similar, which was the designed objective.

TABLE 3.4

Yield of Regrowth (lbs DM/ac) from Plots cut to 1"

at the same time as the Dung Patch was removed. (Mean of 4 Blocks)

Harvest (D)	1	2	3	4
Duration of Dung Patch (days)	3	6	15	25
Patch Area	2439	2703	1379	305
Ring 2	3296	3889	4689	4427
3	3684	4073	3601	3446
4	3389	3766	3362	3056
LSD (0.05)	569	795	747	764

Analysis - App 3.10

Table 3.4 gives the results of the regrowth treatment. It is evident from these that at the first harvest, even though the patch had been present for only three days before being lifted the regrowth from the area, although it provided substantial cover, yielded significantly less than the surrounding herbage. A similar situation was still apparent after the patch had been left for 6 days. Regrowth in the area after the dung patch had been left a further 9 days however was considerably reduced (32% of surrounding herbage). By the time the patch had remained in position for 25 days the ground beneath it was virtually bare, and remained so throughout the time allowed for regrowth. The small yield (305lbs/ac) was from surrounding pasture encroaching the patch area. There was no indication of clover stolons creeping in from surrounding pasture as noticed by Weeda (1967), at least not during the period of the experiment.

The ability of the herbage beneath the dung patch to regrow again depends on the live tillers and stolons still present. It is therefore interesting to note the number of these recorded in tiller cores taken from beneath patches in Treatments B and C, and in A at the same time the dung patches in D were lifted (Table 3.5). The figures in this table support the regrowth data, since they show that up to 6 days there was little reduction in the number of grass tillers or rooted stolon nodes beneath the dung patch (C). Subsequently these numbers fell considerably corresponding to the fall in regrowth from the area.

TABLE 3.5

Numbers of Grass Tillers and Rooted Clover Stolon Nodes

	Grass Tiller Numbers (mean of 12 Cores)						
Duration of Patch - Days		3	6		15		25
Harvest	1	2	3	4	5	6	7
Treatment A	12.9	15.1	17.7	22.6	20.6	13.7	12.7
B	13.9	14.2	12.0	13.8	13.3	8.3	5.8
C	19.7	22.6	16.5	13.4	7.6	11.0	2.3
	Rooted Stolon Nodes						
A	15.0	13.1	17.4	15.2	17.7	26.2	17.4
B	15.3	19.4	16.1	15.1	6.7	4.0	1.7
C	15.7	13.0	13.2	3.9	6.1	5.4	0.3

App 3.18, 3.19

The numbers of each beneath the artificial patch (B) do not appear to decline as rapidly possibly because of lower decay rates in the absence of dung. In the control plots an increase in tiller numbers accompanied the phase of vegetative growth. However, as the grass in the plots went to seed the tiller numbers declined.

With regards the herbage surrounding the dung patch, there was a significant "residual" response to the dung in the first 6 inch ring (R2).

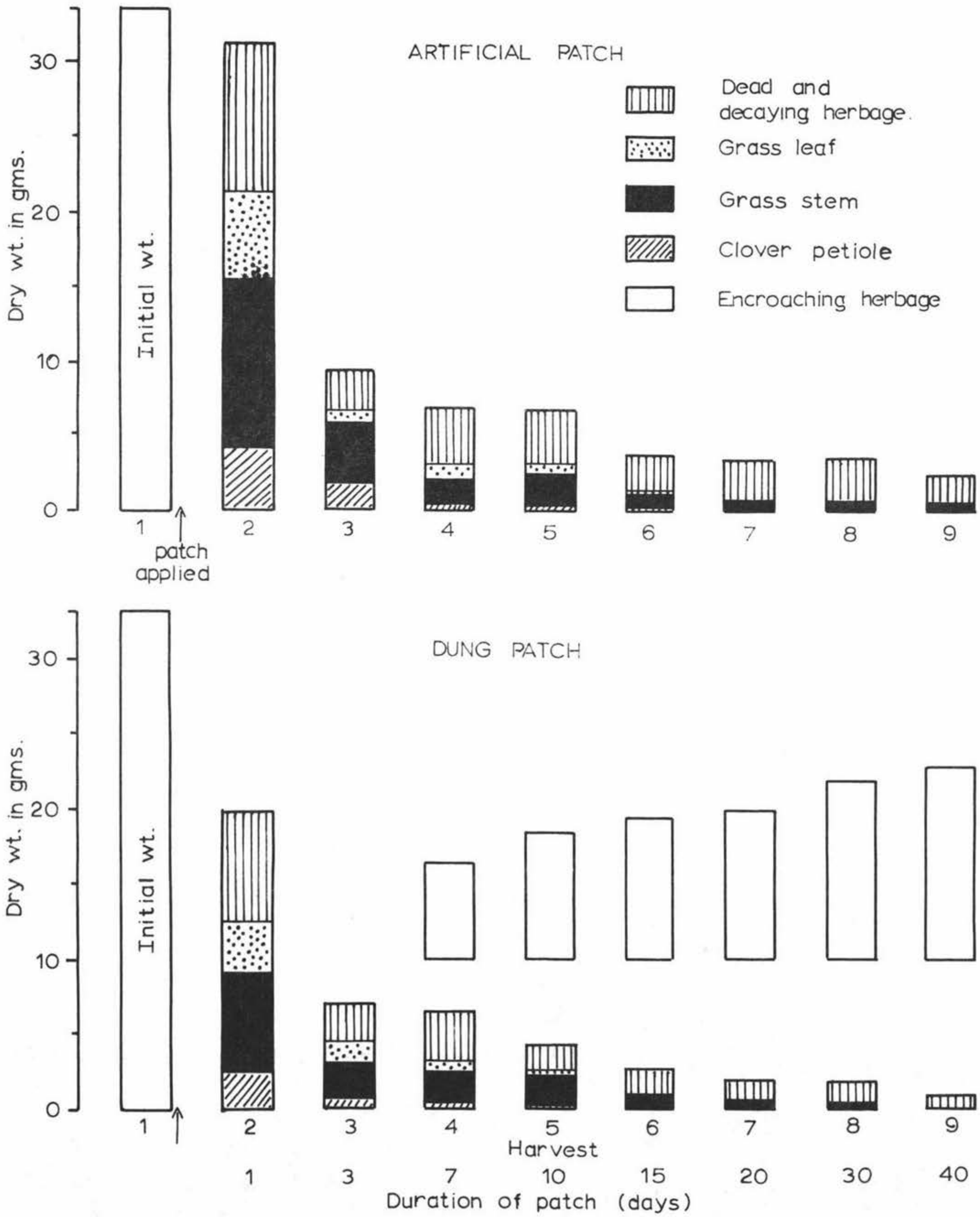
This occurred in the last two harvests (Table 3.4) which corresponds to regrowth from harvests 5 and 7 of Treatment C. Since in this treatment, a response in R2 was not evident after the 5th harvest (fig 3.4), the results indicate that by cutting the plots, the response was extended. This effect suggested lines for possible further investigation, the result of which were the defoliation treatments incorporated in the Second Ecological Experiment (Chap 5).

Decay of Herbage Beneath Dung Patch

Fig 3.7 shows the pattern of decay of the herbage beneath both the artificial patch and the dung patch. Each histogram is the mean of 4 replications. Over the first 3 days, there was a marked fall in the total weight of this herbage, although the rate of decay initially was considerably higher for the herbage under the dung patch. It was noticed that the material beneath the dung was limp, dark and showed signs of burning, whereas the material beneath the rubber pads became bleached and dry and decayed less rapidly/ Plate 2. Clover petiole and grass leaf decayed relatively quickly, in contrast to grass stem which persisted for up to 50 days. The dead material which accumulated under the dung patch appeared to decay more rapidly, presumably because of the more favourable microclimate and increased micro fauna and flora associated with the decay of the dung patch. As has been observed by other authors (Weeda 1967, Laurence 1954) the dung patch dried out from the top and harboured a pocket of air beneath it. In this aerobic environment fungi and spiders were seen to thrive.

As the periphery of the patch receded, owing to decay, herbage from the surrounding sward invaded the space which was left. This herbage was not included in harvests of the R2 ring. Instead it was kept separate and is shown separately in the histrogram (fig 3.7)

FIG. 3.7 TOTAL WEIGHT & COMPOSITION OF HERBAGE BENEATH ARTIFICIAL & DUNG PATCH LIFTED SEQUENTIALLY DURING EXPERIMENT. (Included is herbage which encroached into patch area as periphery of dung patch receded).



Decay of Dung Patch

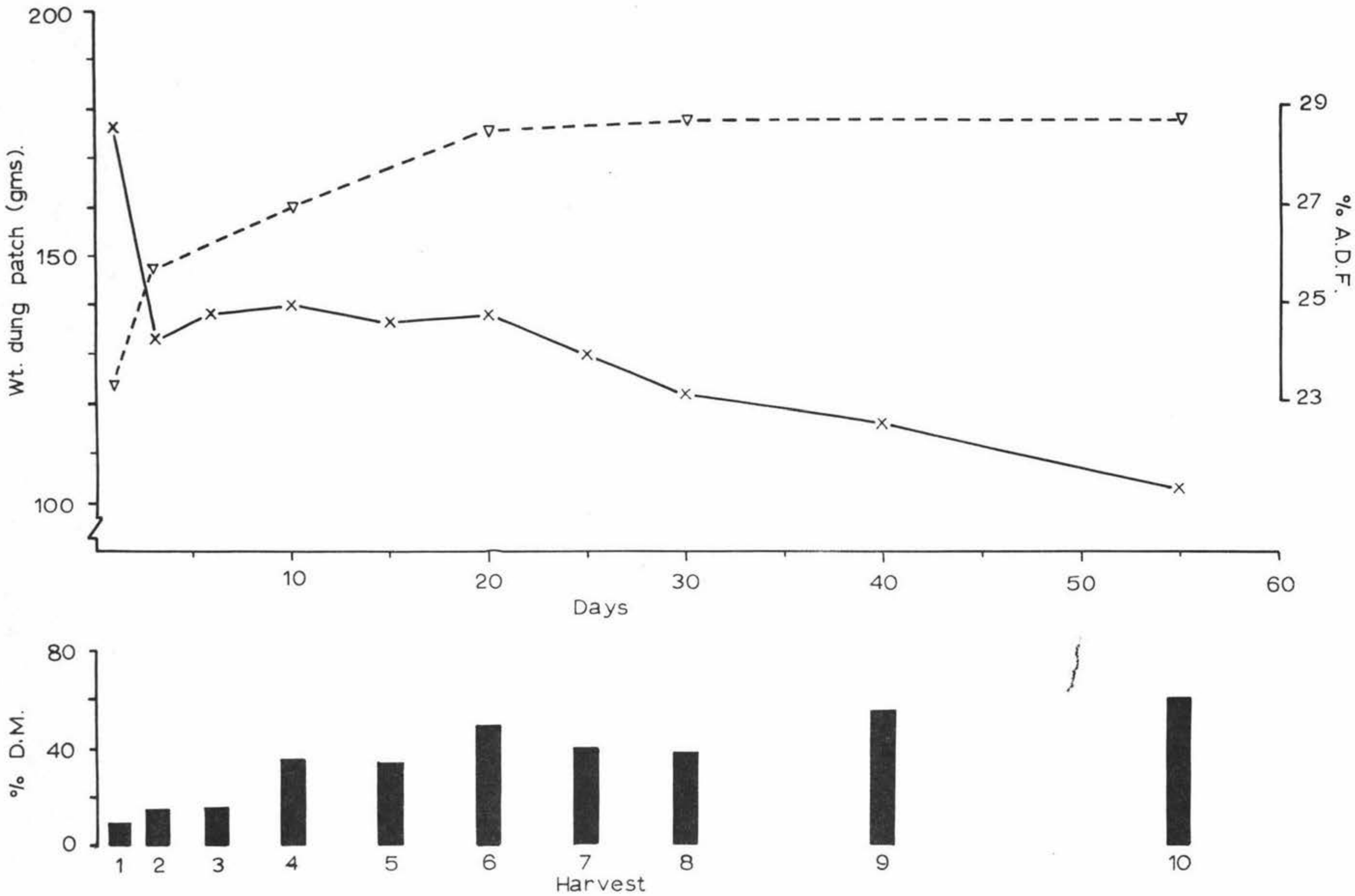
The dung patches in this experiment showed remarkable resistance to decay. Even after 5 mths, they were still present as 10 inch diameter fibrous mats in the plots which had not been harvested.

Fig 3.8 shows the weight of the patches lifted at each harvest. During the first 3 days, the dry weight fell sharply. Part of this loss must be credited to the inability to recover all the dung from the plots. However, by no means all the loss, amounting to 27 gms dry weight (270 gms wet weight) could be attributed to a sampling loss. The major reason for the loss is most likely leaching by the heavy rain which fell over this period, (fig 3.2). Dung could be seen being washed from the surface of the patch, which did not have a chance to dry out until after the third harvest.

Fig 3.8 also shows the dry matter content of the patch. Once the dung dried out, loss in weight was relatively small. Rain which fell during the 7th and 8th harvest (fig 3.2) is reflected in the lower dry matter content at these harvests.

The relatively slow rate of decay may be explained in part by the change in Acid Detergent Fibre content of the dung. This fraction is probably a measure of the carbohydrates which would be relatively resistant to microbiological attack, viz. hemi-cellulose and lignin. The proportion of this fraction rises over the first 25 days (fig 3.8). Presumably during this period the carbohydrates which were not fermented by rumen micro organisms, but which were, nevertheless, readily available, either fermented or were leached out of the dung. Once this material had been disposed of the fibre, which remained as a constant proportion of the dung patch, represented the fraction resistant to rapid decay and was the "fibrous mat" of material, referred to earlier, which remained in the

FIG. 3.8 DRY WEIGHT, % ACID DETERGENT FIBRE (A.D.F.) & % DRY MATTER (D.M.) OF DUNG PATCH THROUGHOUT EXPT. (Mean 4 patches).



plots for up to 5 months.

Chemical Analysis of Soil

The levels of available N in the soil at four of the six sites sampled are shown at the 0-1 inch depth in fig 3.9a. The notations 3, 9, 12 and 18 refer to the radii in inches from the centre of the patch at which the samples were taken, i.e. 3 represents soil sampled beneath the dung patch, 9 and 12 are samples 3 and 6 inches from the periphery of the dung patch while 18 refers to samples taken 12 inches from the patch and are considered to reflect control levels of N.

The results indicate that, throughout the experimental period, the level of available N in the top 1 inch of soil beneath the dung patch was significantly higher ($p<0.05$) than corresponding samples taken from the control sites. In addition, for 10 days after the start of the experiment the N levels in the first 6 inches around the dung patch were also higher than the control level. This increase in available N level remained detectable ($p<0.05$) for a further 10 days in the first 3 inches around the patch.

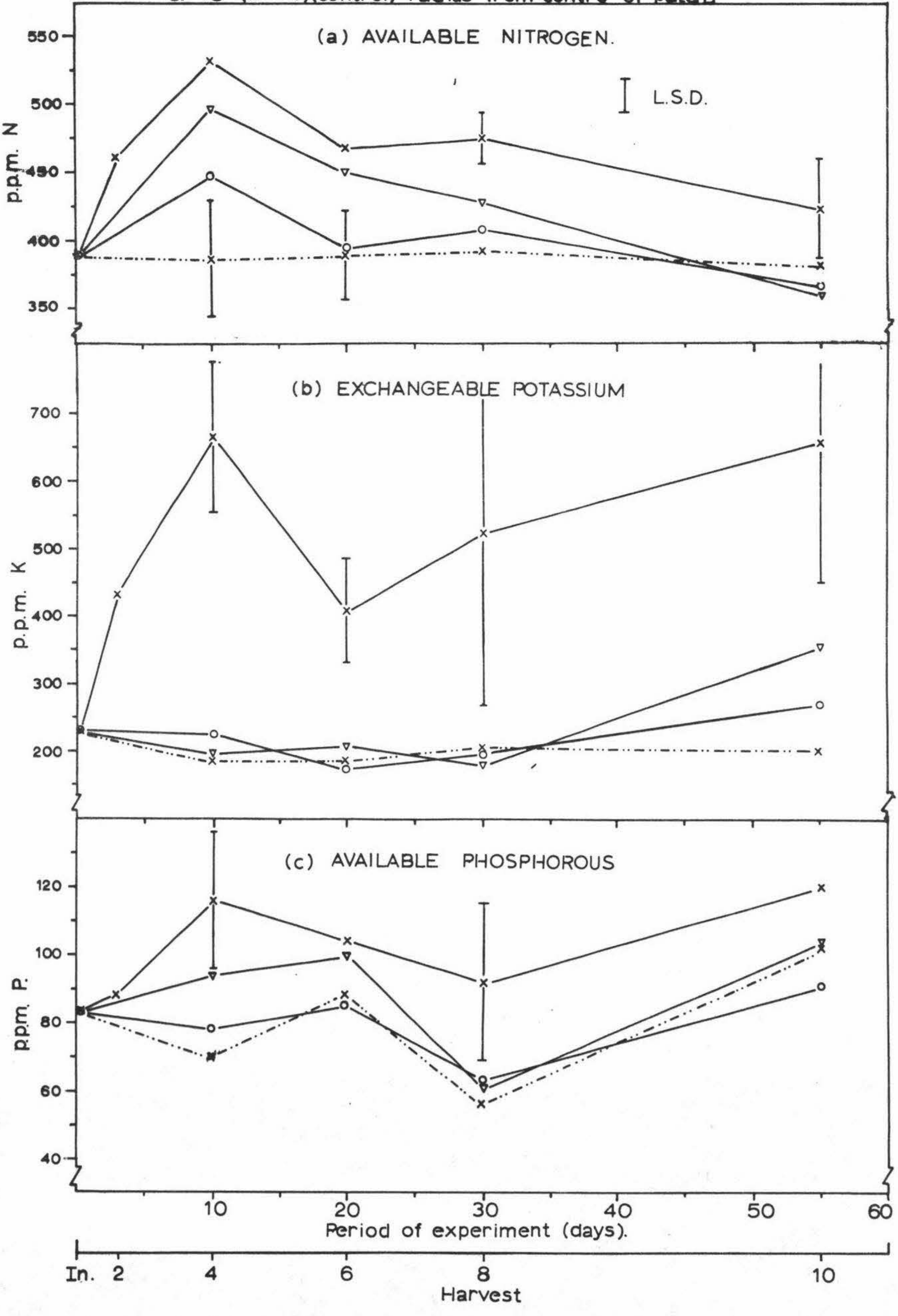
The level of available N measured at the 1-3 inch depth was significantly ($p<0.01$) lower than the top 1 inch at each sampling, but the difference between the two depths was greater at the beginning of the experiment than at the end owing mainly to the relatively higher levels for the 1 inch samples (Table 3.6)

TABLE 3.6

Level of Available N in ppm at 0-1" and 1-3" Depth
(mean of 3 replicates)

Harvest	0	2	4	6	8	10
Sample Depth 0-1"	670	561	465	427	428	383
1-3"	475	321	350	339	314	265
Difference	213	240	115	88	114	118

FIG. 3.9 LEVELS OF N, K, & P IN SOIL SAMPLES TAKEN AT 0—1" DEPTH FROM BENEATH DUNG PATCH & SURROUNDING SOIL. [Samples were taken at 3"(x—x)(beneath patch), 9"(▽—▽), 12"(o—o) & 18" (x-···-x)(control) radius from centre of patch]



None of the sampling sites at the 1-3 inch depth showed any significant difference from one another. However, at the sixth harvest the standard error was considerably greater than at any other and the "radius" component of the analysis of variance almost reached the 5% level of significance (App 3.14). The inference from this is that a portion of the N compounds which had evidently moved from the dung patch into the top 1 inch of soil over the first 10 days, passed into the next 2 inches of soil over the following 10 days.

Fig 3.9b illustrates the substantial ($p<0.05$) rise in exchangeable potassium levels in the soil beneath the dung patch and the complete lack of lateral movement of this element. The 1-3 inch soil samples were lower in exchangeable K than the top 1 inch and showed no significant rise beneath the dung patch when compared with the levels in the soil at the same depth 3 inches outside the patch (App 3.17).

Fig 3.9c illustrates the levels of available phosphorous in the soil at the same four sampling sites for which available N determinations were made. The results indicate a significant ($p<0.05$) but transient rise in the level of available P in the soil beneath the dung patch at the 4th and again at the 8th harvests. As with K, there was no evidence of any lateral or downward movement of this nutrient.

DISCUSSION

Despite the variability inherent within the experiment, the results presented in this chapter indicate that following the deposition of a dung patch on pasture, there is likely to be an increase in the subsequent growth of the pasture around it. The response is likely to be only from the grass component and in particular from the ryegrass species in the pasture and may be detectable up to 18 inches from the periphery of the patch. However, the indication from this experiment is that a response as extensive as this is likely only to be transient - in this particular experiment it was 40 days; and that any long term or residual effect which the dung patch may have will be limited to a response in regrowth herbage in the first 6 inches surrounding the patch.

The exceedingly heavy rain which flooded the surface of the soil at the beginning of the experiment, before the dung had had a chance to dry and form a surface crust, was no doubt partly responsible for the extensive response obtained. Soil N figures suggest that N compounds from the dung patch were distributed into the soil up to 6 inches away from its periphery during the first 10 days and even after 20 days the effect was still detectable. This does not, however, explain the response obtained in the herbage up to 18 inches from the patch.

Of the other two nutrients determined, potassium appeared the more mobile, its concentration beneath the patch rising to more than three times that of the control sites after only 3 days. This apparent mobility of K is not surprising, since Davies et al (1962) report that all the K in dung exists as KCl. What is surprising, however, is that considering its high solubility, K was not detected in the soil around the dung patch as was N. There appear to be two explanations for this.

The first is that the K was contained in the organic fraction of the dung which was readily soluble and during the heavy rain was leached into the soil beneath the patch giving it little chance to spread; whereas the N was principally from the organic fraction of the dung which would not penetrate into the soil and was able to be spread in the surface water. The N in this organic matter could then be mineralised to become available for plant growth. The rapid loss in weight of the dung patch over the first two days supports this theory as there is little doubt that a considerable portion of the loss constituted both organic matter and inorganic compounds which were washed away. However, in view of the fact that a herbage response was evident within 10 days it is doubtful that organic matter was a significant source of readily and rapidly available N.

The other explanation is that although there was an increase in N under and around the dung patch, this N was not, in fact, directly from the patch but was the result of some indirect effect associated with it. For example, the higher N values obtained beneath the patch could have resulted from decay of the herbage onto which the patch was placed. The results indicated that the weight of this herbage fell by over half during the first three days. This loss could have been due, at least in part, to the release of soluble cell constituents and the decay of readily decomposable material. Similarly the rapid decay of dead matter in the sward which was recorded could have contributed to the increased N values in this region. However, this latter fact would not explain the relatively low N figures from the control sites.

There is also the possibility that increased microbial activity under and around the patch may have resulted in a relatively greater release of N from the organic fraction of the soil. This is unlikely, however, to be of consequence in this experiment since the procedure of boiling the soil for an hour releases the readily available organic N, so that differences between the form of N (mineralised or organic) in the soil around the patch and in the control sites would not be detectable. Whatever the explanation, the evidence suggests that an increase in the levels of available N in the soil in the vicinity of the dung patch was responsible, at least in part, for the increase in the grass growing around it.

There is little doubt that the relatively high clay content of the soil was responsible for fixing K from the dung patch in the top 1 inch of soil. This is reflected both in the high levels of K which persisted beneath the dung patch throughout the experiment and in the inability to detect any increase in K in the 1-3 inch samples.

Barrow and Lambourne (1962) report that the organic P in dung remains relatively constant per unit of feed and only the inorganic P content of the dung varies with factors such as the physiological state of the animal. Since the dung for this experiment was collected from milking cows, which have a high requirement for P (Davies et al 1962) it is likely that its organic P content was relatively low. The results indicate that the P which was present moved into the soil under the same circumstances as did N and K, i.e. by leaching. These results agree with Bromfield (1961) who leached 34% of the inorganic P in sheep faeces over 6 days. There was some evidence in the present experiment of a later release which could have come from organic P mineralised in the dung patch.

The dung patch appeared very effective in destroying the herbage beneath it. Leaving it on top of the pasture for more than 15 days apparently killed all the plants beneath it. When it was removed, the area where the patch had been remained bare for up to 3 months. The death of the plants was presumably a combination of the burning effect of the dung, the exclusion of light and air, and the development of an environment which was ideal for the decay of material by soil and dung macro and micro organisms.

CHAPTER FOUR

ANIMAL BEHAVIOUR STUDY

In the last chapter, it was established that, under the conditions of the experiment, the dung patch caused an increase in the growth of the pasture surrounding it, primarily by way of the grass component.

In the field, also, it is common to see longer grass surrounding the dung patch. The question arising is whether this observation is owing largely to the plant response or whether it is influenced by the behaviour of the grazing animal in avoiding these sites.

Much of the literature suggests that the smell of the dung is the primary cause for the rejection of this herbage. The experiment in this chapter attempts to investigate this aspect by measuring the grazing pattern of two groups of cows on a pasture in which both artificial and dung patches are laid, the cows in one group being blinkered in order that they rely to a greater extent on smell for the selection of herbage; the cows in a second group being without blinkers as a normal control.

EXPERIMENTAL

The trial was laid down on 14th March, 1968, on the No.3 Dairy Unit, Massey University (see Chap 2). Following a spell of dry weather the pasture on the paddock chosen was short, even and had been grazed the previous day. Existing dung patches were removed and an area 27 x 60 yards ($\frac{1}{3}$ acre) was fenced off electrically and divided into two 1/6th acre sections.

The grazing pressure adopted in the study viz. 24 cows per acre, was that practised with the No.3 herd grazing Autumn-saved pasture in adjacent paddocks. This gave 4 cows per section and since dung patch density had been estimated at approximately 13 per cow per day (Chap 2)

52 patches per section (26 dung and 26 artificial) were laid. The artificial patches were included to examine whether the cows would react to something lying in the pasture similar to a dung patch but with no apparent smell. They were the rubber pads used for Treatment B, Chap 3.

Dung was collected and patches laid down in the method similar to that described in Chapter 3.

Areas of pasture which were undisturbed and had an even growth were chosen as sites for laying down both the artificial and dung patches. The patches were distributed evenly over each section.

The grazing periods for both sections are shown in Table 4.1. Cows were removed from the paddock while it was being measured and also, to prevent pugging, after heavy rainfall on the evening of the 17th and 18th March.

TABLE 4.1

Grazing Schedule for Both Groups of Cows

Date	Cows On	Cows Off	Length Grazing Period (hrs)	Cumulative Grazing Time (Hrs
April 16	3 pm			0
17		3pm	24	24
18	8 am	6pm	10	34
19	8 am			
20		8 am	24	58

Measurements:

The following measurements were made on the day the trial commenced and at the end of each grazing period throughout the trial.

a) "Unaffected" Herbage:- A line transect, (a rope knotted with white tape every three feet) was strung diagonally from corner to corner of each section in turn. The height of the herbage in the vicinity of each knot was measured with a ruler and recorded in inches. Care was taken to ensure that subsequent measurements coincided with the sites established initially.

b) "Dung Patch" Herbage:- The height of herbage in the first 6 inches surrounding each patch was measured at three places, the average taken and recorded. In addition it was noted whether this herbage had been grazed completely (G), partially (P), or nibbled at (N). To assist in relocation of each patch, each was labelled with a wire pin, looped at one end, through which a piece of insulating tape had been folded and numbered.

c) Artificial Patches:- Measurements in (b) were repeated around the artificial patch.

BLINKER DESIGN

The blinkers for the cows were designed and fitted in such a way that the cows were unable to see what they were eating but at the same time were able to see some distance ahead to prevent them from becoming restless.

The basic component was a ladies black, padded brassiere (size 32B). The material connecting the two cups of the brassiere was cut down the centre and string was tied top and bottom to both the exposed edges. The respective ends of the string were tied in a bow to give a gap of some 4-6 inches between the cups. The shoulder straps were cut where they attached to the top of the brassiere and an 18 inch length of ½ inch tape was sewn in its place. Finally, approximately two-thirds of the top section of rubber making up the cup was removed. Care was taken not to remove too much initially, nor to cut the stitching joining the sections.

The blinkers were then fitted to the animal so that a brassiere cup covered each eye - the length of the strings being adjusted to fit individual cows. (These strings were then later replaced by a permanent piece of $\frac{1}{2}$ inch tape of similar length). The clips of the brassiere were fastened under the chin, the shoulder straps tied over the neck and the tapes tied around the horn (see photos, fig 4.1). Tied this way, the blinkers remained firmly in position and the elastic body of the brassiere enabled it to stretch with the jaw movements of the cow and in this way prevented chafing.

(If the blinkers had to be left on for more than a fortnight it would be desirable to sew a stiffener around the cut edge of the cup to prevent it fraying).

To test the effectiveness of the blinkers a small observation trial was carried out. In the stock yards was a grassed pen some 30 ft square, from which a small race led away to the main yard. Each cow was led into the race. To accustom them to the taste of hay, a forkfull was fed in the race. Another forkfull of hay was also placed in the middle of the pen. The blinkers were then fitted to the cow and the gate to the pen opened. If the cow refused to move then the eye was being shaded too much by the blinker and a small piece of the offending material would be cut away. This procedure was repeated until the cow could see well enough over the top of the blinker to give it the confidence to walk out of the race.

Once in the pen the cows soon began nibbling tentatively at the grass. However, they would not recognise that the hay was in the pen until they had accidentally grazed to within 6 inches of it or touched it with their nose. Yet when the blinkers were removed the cows would walk straight from the race to the hay and start eating it.

It was concluded from these observations that with the blinkers on the cows were unable to see less than approximately 15 ft ahead of them

Fig 4.1

The Blinkers Shown Fitted to Cows for the Grazing Behaviour Trial

while their heads were down.

While the blinkers were fitted the cows were confined to paddocks which were fenced electrically. This precaution was taken in case any cow had the notion to rub its blinkers off on the fence. However, no discomfort was apparent and this precaution may not have been necessary. Except in showing some reluctance to negotiate races and gateways, the cows behaved quite normally.

METHOD OF ANALYSIS

Thirty-eight sites along the line transect ("unaffected area") and 29 dung patches were measured at four different occasions during the experiment. These sets of measurements were analysed separately according to the analysis of variance in Table 4.2. The degrees of freedom for the dung patch measurements appear in the brackets.

TABLE 4.2

Analysis of Variance for Height Measurements

Source of Variation:	d.f.	
Blinkered v Control Group of cows	1	(1)
Between Grazing Periods	3	(3)
Interaction	3	(3)
Error	296	(225)

To analyse both sets of data together would have necessitated a disproportionate sub-class analysis. However, this method was considered unnecessary when it was obvious from the data that the dung patch herbage was higher, at each sampling, than the unaffected herbage. Instead, an unparied t-test between mean height for each treatment at each sampling was performed, according to the model below.

Standard Error of the difference between the means

$$S_{(\bar{x} - \bar{y})} = \left[\frac{SSX + SSY}{(k + n - 2)} \cdot \left[\frac{1}{k} + \frac{1}{n} \right] \right]^{\frac{1}{2}}$$

t - test comparing the two means

$$t_{(k + n - 2)\,df.} = \frac{(\bar{x} - \bar{y})}{S_{(\bar{x} - \bar{y})}}$$

Where $\bar{x}$ = mean height of "unaffected" sites with k df.

$\bar{y}$ = mean height of dung patch sites with n df.

RESULTS

From observations, as well as from the measurements made, it appears that the blinkers made no significant difference to the grazing pattern of the animals wearing them. This is borne out from the figures in Table 4.3 showing the reduction in height of the herbage both around the dung patch and in the rest of the section. In both sections the reduction is similar. For example, in the section in which the blinkered herd was grazing, the herbage between the patches was reduced initially from 5.5" to 2.5", i.e. 3"; in the non-blinkered herd the reduction was from 4.9" to 2.0", i.e. 2.9".

TABLE 4.3

Height (inches) of Herbage at Successive Grazings

	"Unaffected" herbage				"Dung Patch" Herbage			
Hrs Grazing	Initial	24	34	58	Initial	24	34	58
Blinkered	5.50	2.50	1.71	1.24	6.65	5.30	3.62	2.86
Control	4.90	2.00	1.31	1.11	6.96	4.72	3.44	2.62
Mean	5.21 a +	2.27 b	1.51 c	1.17 c	6.81 a +	5.02 b	3.53 c	2.74 c

LSD (p 0.05) = 0.62 LSD (p 0.05) = 1.40

+ Means with different subscripts differ significantly.

(Analysis of Data App 4.3)

With the dung patch herbage also, the grazing pattern was similar for both groups of cows, as evidenced by the non-significant treatment grazing period interaction component of the analysis. (App 4.2)

This experiment does, however, help to confirm the "rejection" response by the animals to the herbage around the dung patch. T-tests between means of the "unaffected" and dung patch herbage at all samplings were highly significant (p 0.001). The means for these two areas of herbage are presented in Table 4.3. It shows that for the first 24 hours the cows in both groups confined their grazing mainly to the areas between the patches, reducing the height of this herbage by over 50%. This feature is emphasised in Fig 4.3 which shows that of the total herbage height reduced over the whole grazing period, 74% of this reduction was achieved in the first 24 hours. In contrast, the comparable figure for the patch herbage was 40%. When one considers that the greatest density of herbage is in the lower regions of the pasture the amount grazed from the patch areas would probably represent an even smaller proportion in weight.

Possibly the only reaction of the blinkered cows was shown in this first grazing period. Fig 4.2 indicates that during this period the "blinkered" cows were more apt to "partially" graze the dung patch herbage - indicated by the high score for herbage in this category. This suggests that these cows were unable to distinguish herbage around a dung patch until their heads came close enough for them to smell it, or in some other way realise its presence.

During the second grazing period, up to 34 hours after the beginning of the experiment, the cows devoted more attention to grazing the dung patch herbage. Over half the dung patches were grazed around (fig 4.2), reducing this herbage by approximately $1\frac{1}{2}$ inches. Meanwhile, the herbage in the rest of the pasture was only reduced by approximately 0.8" and 71% of the sites had been closely and fully grazed (App 4.1).

By the end of the last grazing period the herbage on offer was obviously very limited and the cows were restless and apparently hungry. They had reduced virtually all the sites along the string to

FIG. 4.2 SCORE OF HERBAGE AROUND DUNG PATCH
(% each category)

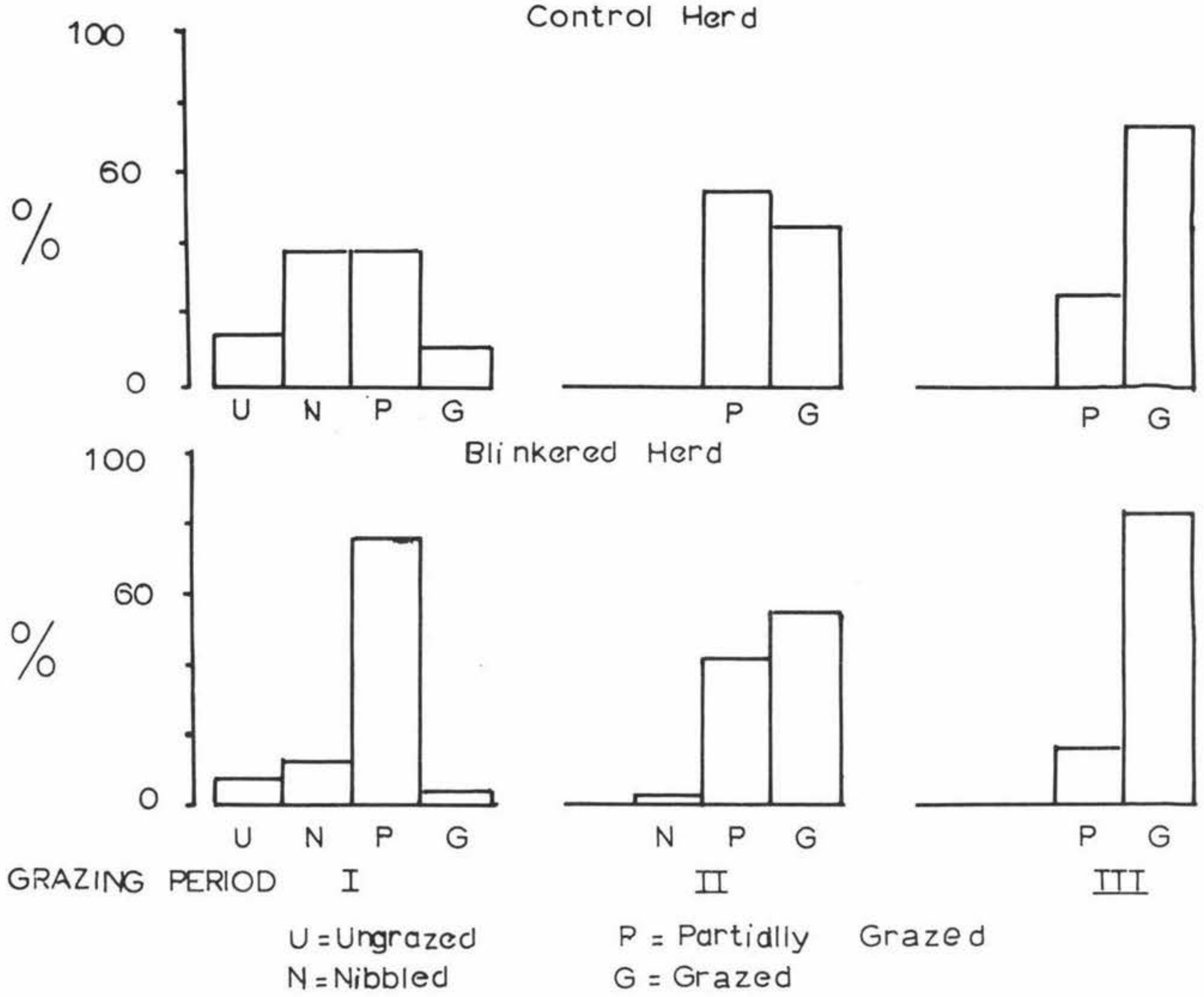
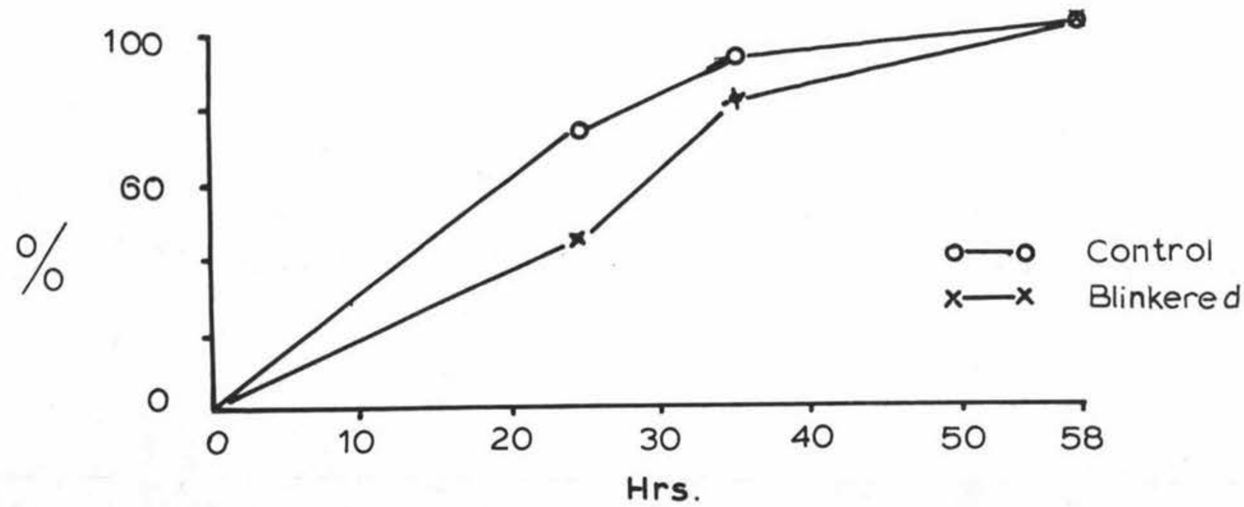


FIG. 4.3 HERBAGE REMOVED
(% total removed)



1", the only remaining high spots occurring where rank, coarse, but nevertheless lush ryegrass had been growing in clumps. Seventy-five percent of the dung patches had been grazed around completely (fig 4.2) to an average height $1\frac{1}{2}$ inches higher than the rest of the paddock. It is worth noting that the cows tended to return to those patches which they had grazed down previously rather than eat the more rank growth left around the remaining patches.

Both groups of cows showed an interesting reaction to the artificial pads. After twenty-four hours, 21 and 25 of the initial 27 pads in each section had been grazed around completely to approximately $1\frac{1}{2}$". They became quite distinctive in the pasture (see photo, fig 4.1). By the end of the second period, all herbage surrounding the 27 pads in both sections had been grazed completely. Presumably any smell that the pads had was not objectionable. Whether they had an attractive smell is obviously not known. Probably the best explanation for their relative popularity is that the cows were curious of them, and found it easy to graze around them. The fact that the blinkered cows "found" almost as many of these pads in the first grazing period as the control group helps to confirm that the former did not labour under any great handicap with regards selection and movement around the paddock.

DISCUSSION

This experiment served to confirm the "rejection" response cows have to dung patch herbage, and also suggested the animal senses involved.

The cows seemed to follow a definite grazing pattern. On entering the plots, they roamed about taking snippets of grass from the tips of leaves irrespective of whether the grass was situated near dung patches or not. It appeared that the choice of these sampling sites was mainly made by sight, the cows charging ahead to an area which looked appealing. This behaviour would explain why nearly all the artificial pads were grazed early in the experiment, since they were strange objects in the pasture, were it not for the fact that the blinkered cows showed similar behaviour. One cannot, however, discount that these cows may also have been able to see the pads over the tops of their blinkers. However it would be unlikely that, once having seen them, they could then walk virtually blind to them. Certainly behaviour of this kind was not obvious from observation.

The "blinkered" cows differed from the control group when they were let onto the plots for the first time. They wandered much more slowly over the pasture, their nostrils twitching continuously as they tentatively selected small mouthfulls to eat.

Once this initial "tasting period" was complete both groups of cows assumed a similar grazing pattern. For lengthy periods, lasting sometimes many minutes, the cows would graze almost continuously, moving forward in small steps as they did so. Once the general vicinity in which to graze had been chosen, the cows appeared to rely on smell, touch and/or taste as their aids to selection of herbage.

The observations made from the preliminary trial with hay - that cows appear to have a very short range of smell - was confirmed during the experiment. The cows would graze as described above, unaware of the presence of a dung patch until they were about to, or had already taken a bite of the grass growing immediately around it. Once they realised the patch was there, presumably by smell as they did not appear to touch it, they would move away to another area to graze. This reaction resulted in the areas between the patches being grazed first. However, selection within these areas was also apparent. The most preferred areas appeared to be those in which both grass and clover were growing not more than about 5 inches high. It was also observed that dung patches which had pasture similar to this growing around them were also the first to be grazed intensively.

It is probable that, had the cows been removed from the paddock at an early stage, while the herbage around the patches was only partially grazed, then by the next grazing this herbage would have become very rank and unpalatable. In the work of McLusky (1960), although it is difficult to determine the stocking rate or intensity of grazing used, it is probable that the above situation was the reason for the rank and unpalatable growth which persisted around the dung patches for 13 months in his experiment. Certainly, limiting the grazing to 4 times a year as he did would do little to alleviate the condition. With the emphasis toward high stocking rate and frequent, short spells of grazing, this situation is unlikely to prevail in New Zealand.

As the experiment progressed, the cows turned their attention to the herbage surrounding the dung patches, the pasture between the patches becoming extremely short. Nevertheless, even with their intake probably limited from the latter source, the cows still continued to graze the herbage around the patches with caution, and at the end of the experiment left it on average $1\frac{1}{2}$" higher than the rest of the pasture.

CHAPTER FIVE

ECOLOGICAL EXPERIMENT II

The main aim of the experiment described in this chapter was to investigate the response of herbage around a dung patch when a cutting treatment, which more closely emulated the grazing situation, was imposed; the cutting treatments being the height at which the cows a) left the herbage in the "unaffected" areas, b) left the herbage around the dung patch, at the end of the grazing experiment in the previous chapter (4). The experiment also provided for the opportunity to assess the ecology of the dung patch under different climatic conditions, viz. the Summer.

EXPERIMENTAL

The experiment was sited on an area immediately adjacent to the first ecological study, Chap 3. The design of the experiment included a 3 x 2 x 5 random factorial in four replications layed out as in fig 5.1.

Plots in C and D were cut to a uniform 1 inch in height after each sampling. For plots in E and F, the first 6 inch ring (R2) was cut to $2\frac{1}{2}$ inches and the remainder of the plot was cut to 1 inch. This treatment emulated the "rejection" of herbage by the animal (Chap 4).

Each treatment had 5 sequential harvests, H1 - H5. Only four harvests were made, however, as adverse weather conditions prevented adequate samples being taken beyond this point. A harvest was made when the herbage on the plots C and D reached a "grazing height" of approximately 5 inches.

As it was established in Chap 3 that the artificial patch appeared to exert no significant influence, it was included in E as an aid to cutting the herbage to a differential height in these plots.

FIG. 5.1 DESIGN OF FACTORIAL EXPERIMENT II

I

D	4	1	3	5	2
A	1	5	4	2	3
B	2	5	1	4	3
E	1	3	4	5	2
C	4	2	3	1	5
F	5	4	2	3	1

III

A	3	2	5	4	1
F	4	2	1	5	3
D	1	4	5	2	3
B	5	3	2	1	4
C	5	1	4	3	2
E	1	3	5	4	2

II

C	1	3	5	2	4
D	2	1	5	4	3
B	4	2	5	3	1
F	2	1	5	3	4
A	1	4	5	3	2
E	2	5	3	4	1

IV

A	5	3	4	2	1
B	3	1	4	5	2
C	2	1	4	5	3
D	1	3	4	2	5
E	4	2	5	3	1
F	3	5	1	2	4

NO CUTTING

A - Control

B - Dung patch

UNIFORM CUTTING HEIGHT - 1"

C - Control

D - Dung patch

DIFFERENTIAL CUTTING HEIGHT - 2½"

E - Control

F - Dung patch

1 - 5 Sequential harvest

I - IV Blocks

Materials and Method:

The herbage was harvested in a manner similar to that described in Chap 3 using the 4, 3, 2 and 1 foot rings and the Shearmaster clippers.

Since to harvest by rings in all the plots would have meant duplicating some harvests, the following harvest sequence and sampling procedure was followed:

Treatment	A	B	C	D	E	F
Ring No.:	4	4*	4	4*		
:	3*	3*	3*	3*		
:	2	2*	2	2*	2*	2*
:	1		1			

* Denotes samples from which botanical compositions were made.

The assumption necessary to sample in this manner was that R3 and R4 in E and F were represented by the same rings in C and D, regardless of the differential cutting height in the former treatment. It will be explained later that it was only necessary, anyway, to consider R2 in the two treatments concerned.

On H1, harvest samples were only taken from A and B as at this stage no cutting treatment had been imposed. On H3, owing to the lack of growth, botanicals were restricted to R2 for all plots.

Dry weights and botanical analyses were performed as described in the first ecological study (Chap 3).

Once the appropriate plot in C and D had been harvested, the plots still to be harvested were cut to 1 inch. In an attempt to measure the amount that was being removed at each cut, the herbage from the plots to be harvested at the next harvest was bagged and weighed. For example, at the first harvest, H1 would be harvested at ground level, H2 at 1 inch and H3, H4 and H5 mown to 1 inch. The herbage harvested in this manner was termed "utilisation" herbage, representing that which could have been grazed from the plots.

On plots E and F, a drum 2 feet in diameter from which the bottom had been removed, was placed over the patch. The rest of the plot was mown to 1 inch. The drum was then removed and the R2 herbage harvested. R2 of the remaining plots was cut to 2½ inches, "utilisation" herbage being recorded for this treatment also. As can be seen from Plate 3, this method simulated the grazing situation reasonably well.

The study commenced on January 23rd, 1968 and terminated on the 30th April, 1968. The interval between each harvest is shown in Table 5.1.

CLIMATE

The climate data is also presented in Table 5.1. Five days elapsed after the beginning of the experiment before rain fell and then it was only 0.14 inches over two days. This was in direct contrast to the first experiment in which heavy and continuous rain fell for the first four days. Throughout a 7 week period in the middle of the experiment drought conditions prevailed, the temperatures averaging 75°F while rain was limited to 0.11 inch. The lack of rain in this experiment will be discussed later in the light of the responses obtained.

TABLE 5.1

Climate Data

Growth Period (Date, 1968)	23/1 to 13/2	13/2 to 4/3	4/2 to 6/4	6/4 to 30/4
Interval (Days)	21	20	33	24
Max. Temp. °F	78	83	85	78
Mean Temp. °F	67	75	75	63
Rainfall - Inches	2.05	0.11	0.97	3.99

PLATE 3

Two views of Experiment II at completion of 3rd harvest.

Before.

After.

One cutting treatment involved cutting plots to a uniform height of 1".

Before.

After.

The other cutting treatment involved cutting the herbage in R_2 around a patch $1\frac{1}{2}$" higher than the rest of the plot.

Despite the relatively dry conditions, the high clover content of the pasture and the 2 inches of rain which fell during the first period were sufficient to maintain reasonably rapid growth at the beginning of the experiment. However, the clover appeared to be adversely affected by the dry conditions which prevailed during the middle two periods while the grass which remained became very dry (up to 47% dry matter) and virtually stopped growing.

The third cut was made not because the pasture was at "grazing height", but rather because rain was imminent. Two days after the cut, the drought did break and growth over the last period was rapid and pronounced for its rich green colour, indicating high nitrogen content.

ANALYSIS OF RESULTS

The complete random factorial design of the experiment, including a control for each treatment, allowed the cutting treatments to be analysed separately at each harvest, using a split-plot design (with rings as a sub-class) similar to that used in Chap 3. The analysis of A versus B by this method enabled a direct comparison to be made with the results from Chap 3.

A similar analysis of C versus D established that response to the dung under this cutting treatment was only evident in R2. This, then, meant that analysis between C, D, E and F, could be confined to R2 without concern for the omission of the harvests of R3 and R4 in E and F, mentioned earlier.

A comparison could not be made between AB and CDEF using the raw data because data from the former treatment consisted of cumulative growth, whereas data from the latter represented growth between successive cuttings. To overcome this enigma, the "utilisation" herbage was used to assemble cumulative growth curves for C, D, E and F. The general form of the calculations is revealed below. The graphs so formed are shown in figures 5.3 and 5.4.

$$W_n = W_{n-1} + dW$$

Where $dW = W_{(n+1)} - W_n + H_n$

W_n = weight of herbage at nth harvest

H_n = "utilisation" herbage at nth harvest

dW = growth between successive harvests

If DW represents the total growth over the experimental period, i.e.

$n = 1 - 4$ then

$$DW = W_4 - W_1 + \sum_{4}^{1} H$$

This was the basis for the data in the App 5.4.

There was no "base line" measurement made of the herbage present at the beginning of the experiment. Since the analysis was only concerned with relative growth under the different treatments an approximation of the base line was calculated from $(W_1 - H_1)$. The resultant figure, amounting to 1730lbs per acre TDM, was adopted (see figs 5.2 - 5.4).

RESULTS

In the treatments in which the plots remained uncut (A and B), at all harvests except the first, the total dry weight of herbage (TDM) in the first 6 inch ring (R2) around the dung patch was significantly greater ($p<0.05$) than either of the other two rings on the control plot. Figure 5.2 illustrates the mean TDM for the control plot (A) and for each of the three rings cut from around the dung patch (B - R2, R3 and R4). (B - R2 was significantly greater than A at the first harvest at the 7.5% level of significance).

TABLE 5.2

Yield of Total Grass Species, (Tot.Gr.) and Ryegrass Species (Rye) from the Uncut Treatments in Ring 2 around Dung Patch (B) and in Control Plots (A)

(Mean of 4 Blocks - lbs/ac).

Harvest	1		2		3		4	
	Tot.Gr.	Rye	Tot.Gr.	Rye	Tot.Gr.	Rye	Tot.Gr.	Rye
Control (A)	1385	612	1803	571	896	349	1252	474
Dung Patch (B)	1982	960	2704	1476	1453	620	1993	972
B - A	597	348	901	905	557	271	741	498

LSD (0.05) between Total Grass means = 566 (App 5.2)

LSD (0.05) between Ryegrass means = 398 (App 5.3)

The total grass yield, of which ryegrass was the only significant component ($p<0.05$), was significantly greater ($p<0.05$) in the first 6 inches around the dung patch at all harvests (Table 5.2). This increase in grass growth was not accompanied by any change in clover content; nor did treatments differ in their amounts of weed species or dead matter. There was, however, a considerable accumulation of dead matter (up to 50%) in the plots for A and B, particularly once a "ceiling yield" was obtained and during the dry conditions which prevailed in the middle of the experiment (App 5.9).

Following the rain after the third harvest, the herbage in both A and B became noticeably greener and the grass content increased during the final period (Table 5.2). Over the same period the dead matter content decreased, the warm humid conditions presumably being conducive to the decay of this material.

FIG. 5.2 DRY WEIGHT OF HERBAGE IN THREE 6 INCH RINGS (R_2, R_3, R_4) SURROUNDING DUNG PATCH & IN CONTROL PLOTS UNDER NO-CUTTING REGIME.

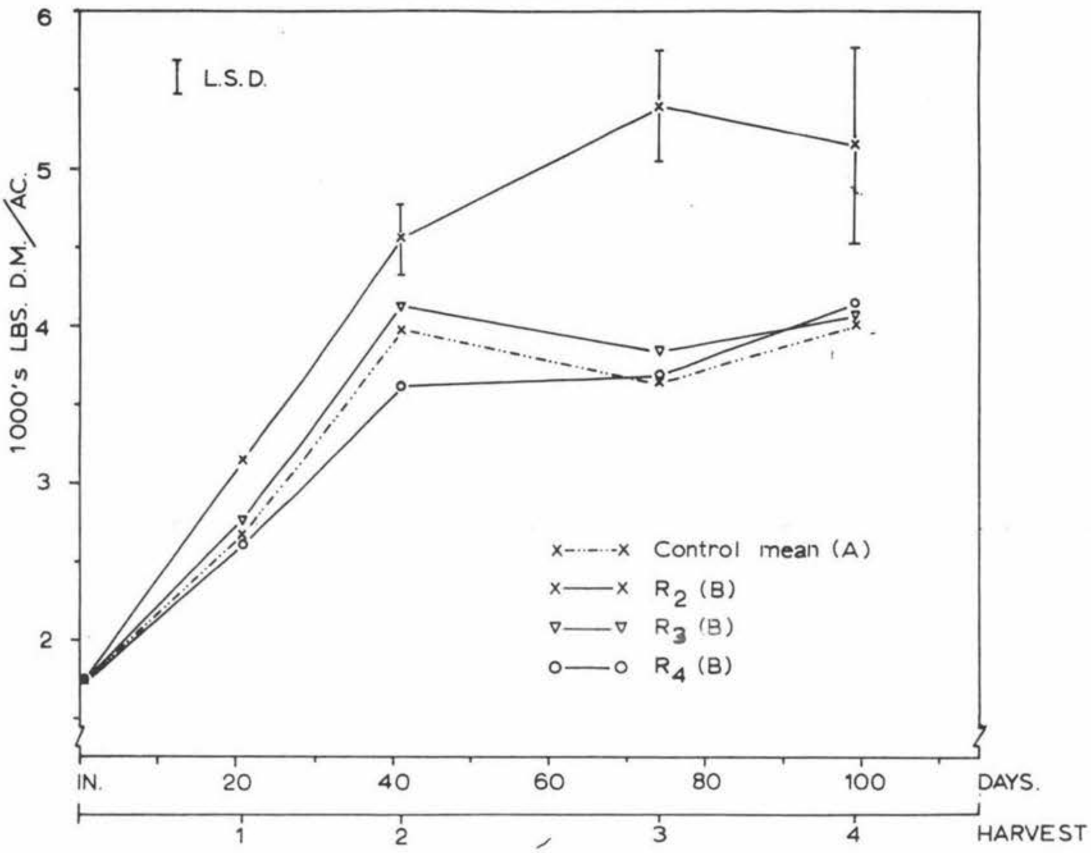
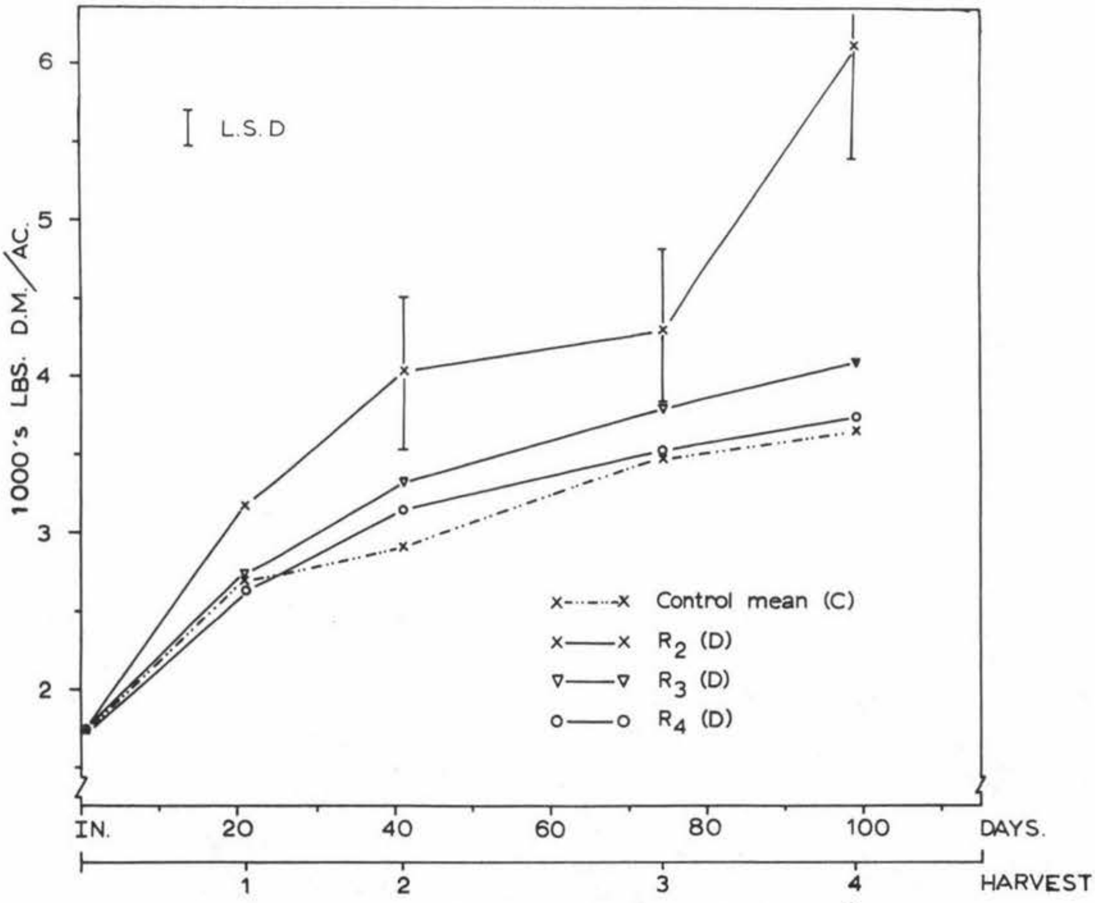


FIG. 5.3 CUMULATIVE DRY WEIGHT IN THREE 6 INCH RINGS (R_2, R_3, R_4) SURROUNDING DUNG PATCH & IN CONTROL PLOTS CUT TO UNIFORM HEIGHT OF 1" AFTER EACH HARVEST.



EFFECT OF CUTTING TREATMENTS

1. Cutting to a Uniform Height

Fig 5.3 illustrates the effect the dung patch had when the herbage surrounding it was cut to a uniform height of 1 inch after each harvest. The graph comprises the cumulative growth curves of the three rings around the dung patch (D) and the mean for the three rings of the control plot (C).

In spite of the fact that these plots were cut, while A and B were not, the response to the dung was again confined to R2, the first 6 inch ring around the patch. Obviously, however, because of the plots being cut at each harvest, the yield of the herbage did not reach a ceiling level as it did in A and B. Also, the herbage was at a similar stage of growth at the beginning of each growth period. These factors appeared to influence the response obtained.

The first harvest in fig 5.3 is, of course, the same as that in fig 5.2 since at this stage no cutting treatment had been imposed.

The second growth period shows the R2 growing at a greater rate than either of the other two rings outside it, or the control. At this stage the yield from R2 was significantly greater at the 5% level (fig 5.3). The response was again owing to a significant ($p<0.05$) increase in the total grass component (Table 5.4), but unlike B, at this stage was not attributable to any particular species, although Yorkshire fog yields were greater but not significantly so, from the D plots.

Under the conditions which prevailed, growth during the third period was barely noticeable in C and D. Because the herbage was short, the ground became hard and dry, and the herbage itself became very dry and began to brown off. Owing to the difficulty of harvesting the relatively small amount on the plots, the sampling error at the third cut was greater than for previous cuts and this, accompanied by a slightly greater growth rate in the control plots, led to a non-significant difference in the R2 ring at this harvest (App 5.4).

TABLE 5.4

Yield of Grass Components of Herbage in R2

under the two Cutting Treatments (mean 4 Blocks, lbs/ac)

Harvest	1		2		3		4		
Component / Treatment	Total Grass	Rye	Tot Grass	Rye	Tot Grass	Rye	Tot Grass	Rye	Y/shire Fog
Control - C	1385	612	602	398	760	395	916	500	359
Dung Patch - D			1277	441	997	322	2341	1060	1082
Control - E	1982	960	1326	448	1482	507	1696	573	914
Dung Patch - F			2226	990	1970	779	2484	888	1341
LSD (0.05) between Treatment Means	566	398	425	360	537	NS	617	562	538

Analysis App 5.5, 5.6, 5.7

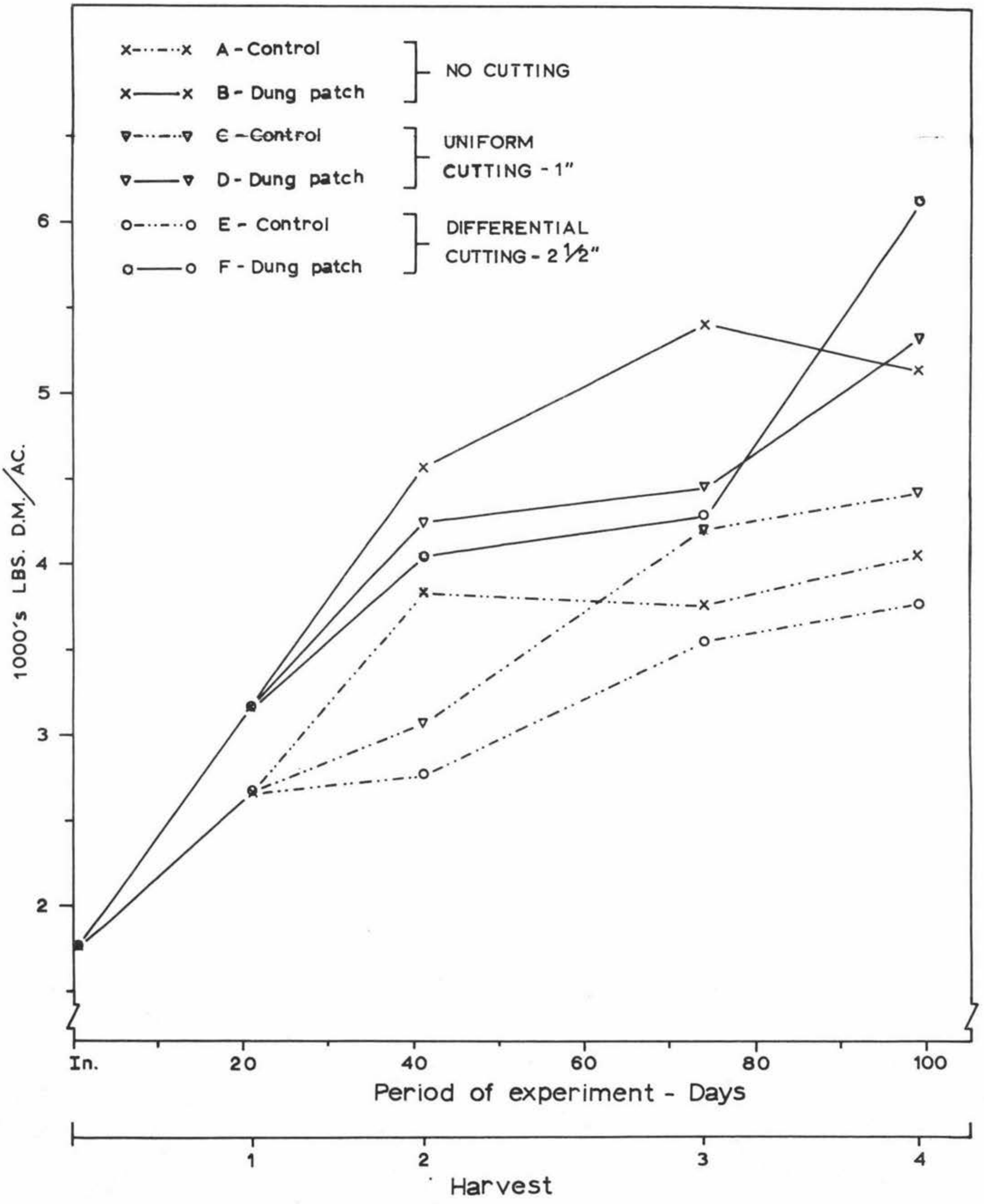
It was during the final period, when the drought broke that the most pronounced response occurred. There was a phenomenal increase (in all replications) in growth around the dung patch (R2), the yield of TDM almost doubling that of the control plots (fig 5.3). The response was as before, confined to the grass component, in which both ryegrass and fog were the significant ($p<0.05$) species (Table 5.4).

2. Cutting to a Differential Height

The response to the dung patch under the third cutting treatment, where the herbage in R2 was cut to 2½ inches after each harvest, was intermediate between the other two treatments. Figure 5.4 shows the cumulative growth curves for R2 in E and F, as well as in A, B, C and D. Their interaction will be discussed later.

By the second harvest, the yield of TDM was significantly greater ($p<0.05$) around the dung patch than the yield of the control plots. The

FIG. 5.4 DRY WEIGHT OF HERBAGE FROM FIRST 6 INCH RING SURROUNDING DUNG PATCH (R_2) & IN RESPECTIVE CONTROL PLOTS.



response around the patch was again, due entirely to an increase in the total grass content, of which ryegrass was a significant ($p<0.05$) component (Table 5.4).

Growth over the third period was negligible, and, as was experienced with C and D, at the third harvest there was no significant difference between the growth in E and in F.

Over the final period there was a significant ($p<0.05$) increase in the yield of TDM around the dung patch similar to the response obtained in D, except that the increase was not as great. Analysis of the herbage growing around the patch showed that the laxer cutting regime had encouraged the growth of both Yorkshire fog and Ryegrass ($p<0.05$), which, by the end of the experiment, persisted as a dense ring of grass in which a considerable amount of dead matter had accumulated. Analysis of the percentage dead matter in R2 under the three cutting regimes gives figures of 44%, 24%, and 2% for AB, EF and CD respectively, which helps confirm the above observation (App 5.8). Suggestions as to how this may have affected the response are in the discussion.

Cutting/Dung Interaction

Fig 5.4 combines the data of R2 from A, B, C, D, E and F in an effort to illustrate the interaction between cutting regime and the dung patch.

Over the first three periods, in the presence of the dung patch, the advantage of maintaining the herbage near optimum LAI is evident, the most lax cutting treatment B, outyielding F which in turn tends to have a greater yield than D. However, once a ceiling yield was attained in B, the advantages of keeping the herbage cut became obvious, D and to a lesser extent F at the final harvesting outyielded B. Under the three cutting treatments however, the yield of herbage around the dung patch was always greater than from the control plots.

DISCUSSION

In the absence of the dung patch (A, C and E), there was little growth after the first period regardless of the cutting regime. This is particularly evident over the last period, when although climatic conditions were ideal for rapid growth of the cut plots they showed little response. It can only be assumed that once the plants had used the readily available nutrients in the soil during the first period, further growth was limited. The most probable limiting element would be N if the pretreatment conditions of the plots are considered. During the first ecological experiment which lasted three months, the land for the present experiment remained idle. Climatic conditions were ideal for the rapid mineralisation of organic matter in the soil, high leaching losses of N and rapid grass growth. In addition, the rank growth which was allowed to develop on the area would have had the effect of limiting clover growth and its subsequent contribution to the N economy of the soil. It is likely, then, that at the beginning of the experiment the level of N and possibly the level of some other nutrients also in the soil area was relatively low. The substantial clover growth, amounting to 50% of the herbage which was measured in all plots over the initial stages of the experiment tends to support this contention (App 5.9). The effect of this relatively low fertility level of the soil would be to enhance the relative response around the dung patch; the nutrients from the dung helping to alleviate the level of the limiting nutrients; while growth in the control plots would be restricted. Fig 5.4 seems to bear this out.

With respect to the dung patch, the results from this experiment confirm those already obtained in the previous ecological experiment (Chap 3), viz. that the dung patch substantially increases the growth of the grasses and in particular the ryegrass species which surround it. In contrast to the first experiment, however, the response was confined to only 6 inches beyond the periphery of the patch. The apparent limited spread in response can probably be explained by the dry weather which occurred at the beginning of the experiment. No doubt, this had the effect of drying out the dung in the patch and also caused the formation of a hard crust on its surface. This would prevent rain, which fell subsequently, washing nutrients from the patch as appeared to occur in the first experiment; while the proportion of nutrients passing into the soil beneath the patch would also be reduced. In addition, it is possible that the high temperatures may have volatilised ammoniacal N from the patch. This may have represented a loss of N which could have, under the conditions which prevailed in the first experiment, been leached into the soil and become available for plant growth. The experiment in the next chapter investigates whether in fact N lost in this matter is of importance.

When the herbage around the patch was cut, the response obtained from the dung appeared to be enhanced. This was particularly so when conditions were ideal for growth. The results indicate that during the dry weather in the middle of the experiment, inorganic and organic nutrients from the patch were present in the soil in available forms, but the plants were unable to utilise them until the final growth period, when the soil moisture returned to a level favourable for nutrient uptake and plant growth.

The results of cutting height experiments (Brougham 1959) indicate that the herbage in the more laxly cut treatment (F) should have been at a more favourable stage of growth to respond to the nutrients available from the dung compared with the more closely cut treatment (D), particularly during the last growth period. This was, in fact, not so. The reason appears to be that a combination of the influence of the dung patch, the higher cutting height and the dry weather encouraged both a dense growth of Yorkshire fog and an accumulation of dead matter. Consequently, over the last period, although moisture was not limiting growth, light energy was. The explanation is probably that the photosynthetic efficiency of the "old" leaves in the upper layers of the canopy in F, the leaves which appeared to be interpreting the majority of light, was lower compared with the photosynthetic efficiency of the shorter "young" leaves in treatment D. In this treatment (D), there was very little (2%) dead matter present and light appeared to be intercepted at all layers of the canopy.

CHAPTER SIX

RELEASE OF AMMONIA FROM A DUNG PATCH

The aim of this experiment was to investigate whether ammonia was a significant source of loss of nitrogen from the dung patch.

The method employed was to absorb the ammonia released onto a glass wool pad soaked in sulphuric acid and contained in a cage placed over the patch. One of the difficulties encountered with the technique, however, was that moisture evaporating from the patch condensed inside the cage, thereby preventing the patch from drying out as quickly as it would were it left in the open. It was considered this effect could influence the amount of ammonia released.

In an effort to cope with this problem, the measurements were made following several pretreatments which consisted of leaving the patches out in the open to dry for a specified time before the cages were placed over them. Table 6.1 gives the times the cages were placed and the interval allowed for drying. The treatments were duplicated.

TABLE 6.1

Pretreatment of Dung Patches Measuring NH_3 Release

Treatment	Control	1	2	3	4	5
Date - March	27	27	27	27	28	28
Time Cage Applied	8 am	8 am	2 pm	8 pm	8 am	2 pm
Drying Interval (hours)	0	0	6	12	24	30

Materials and Method:

Dung was collected as described in Chap 2. Three rows of ten patches were laid down on a strip of pasture previously mown to 1 inch in height. Over each patch in two of the rows, five rectangular hoops of plastic-coated wire (plastic to prevent the wire being attacked by the acid) were placed so that they formed a platform 12" x 6" in size about 1 inch above the patch. Onto this platform a pad of glass wool 8" x 6" weighing from 5-6 gms was placed. Each arrangement was then covered by a cage. The third row of patches was left exposed.

The cages were semi-circular in shape, 18 inches long and 5 inches high made from clear, perspex, wire-reinforced sheeting ("Windowlite")(Plate 4) To prevent them from being disturbed, the cages were suitably pinned to the ground.

Ammonia Collection:

The glass wool pad was placed on the wire platform. Twenty ml. of 10% sulphuric acid was pipetted carefully onto the pad. The pad had to be thin enough for the acid to spread through it, but not so thin that it dripped. The thin stream from the pipette enabled the acid to be applied evenly. Each morning at 8 am on the 1st, 2nd, 3rd, 4th, 5th, 7th, 9th and 13th day after the experiment started, the pad was transferred to 200 ml. distilled water in a 250 ml. conical flask, and a new pad was replaced. The amount of ammonia in the pad was determined and expressed in mgm NH_3 per 24 hours (App 6.1).

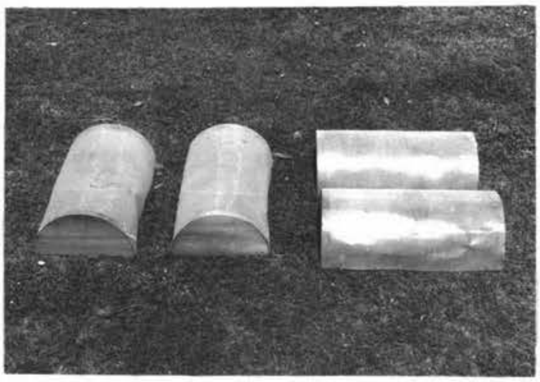
Total Nitrogen:

Each sampling day, one of the patches from the third row was lifted, weighed and a wet sample taken and analysed for total N by the Kjeldahl method described by Hiller et al (1948). A further 100 gms was dried overnight at 100°C, ground through a 2 mm. sieve and a sample also analysed for total N.

Temperature Measurements:

A measure of the microclimate inside the cage was provided from thermometers, inserted through the end of the cage. Recordings were taken for the first 6 days at 8 am and 2 pm. In addition, corresponding temp-

PLATE 4



The cages used for the collection of ammonia from a dung patch.

A view, using a transparent cage, showing glass-wool pads in position on the plastic-coated wire platform.

eratures were taken outside the cage to gauge how closely these followed the cage temperatures.

Table 6.2 illustrates the temperature measurements obtained over the first five days of the experiment. The temperatures within the cages were up to 11°C higher than the corresponding temperatures outside, the biggest discrepancy occurring on the hottest day. Within either environment, the patch temperature during the day was lower than the ambient air temperature although on all but the hottest day the two temperatures returned to similar levels at night.

TABLE 6.2

Temperature Measurements (°C) Inside and Outside Cages During the First Five days of Trial

Therm. Place	Day / Time	1 8 am	1 2 pm	2 8 am	2 2 pm	3 8 am	3 2 pm	4 8 am	4 2 pm	5 8 am	5 2 pm
Ground Level	Outside Cage (O)	22	34	20	25	21	22	18	29	21	34
	Inside Cage (I)	25	33	21	30	23	23	21	34	32	42
Differences (I-O)		3	-1	1	5	2	1	3	5	11	8
Inside Patch	Outside Cage (O)	24	26	17	27	18	22	18	32	20	35
	Inside Cage (I)	30	34	19	29	20	24	21	35	24	34
Difference (I-O)		6	8	2	2	2	2	3	3	4	-1

Apart from light rain (0.06") on the third day, the weather was very hot and fine until 2" rain fell during the last three days. An attempt was made to reflect some of the heat, using aluminium foil, to equilibrate the temperatures within and without the cages, but this was unsuccessful mainly because of the changing position of the sun. Shading the morning sun gave excessive afternoon temperatures and vice versa.

RESULTS

Fig 6.1 shows the mean production of ammonia in mgms. per 24 hours from each of the treatments. Unfortunately, considerable variation between replicates and lack of adequate replication prevented quite large treatment differences reaching significance (App 6.2). Nevertheless, the results did suggest that drying could lead to a considerable depression in ammonia release.

Table 6.3 shows the total ammonia released over the experimental period and its percentage of the total N content of the dung patch (dry sample). (Total N determinations of the wet dung gave levels similar to those for the dry samples).

TABLE 6.3

Total mgm NH_3 released and its % total

N Content of the Dung

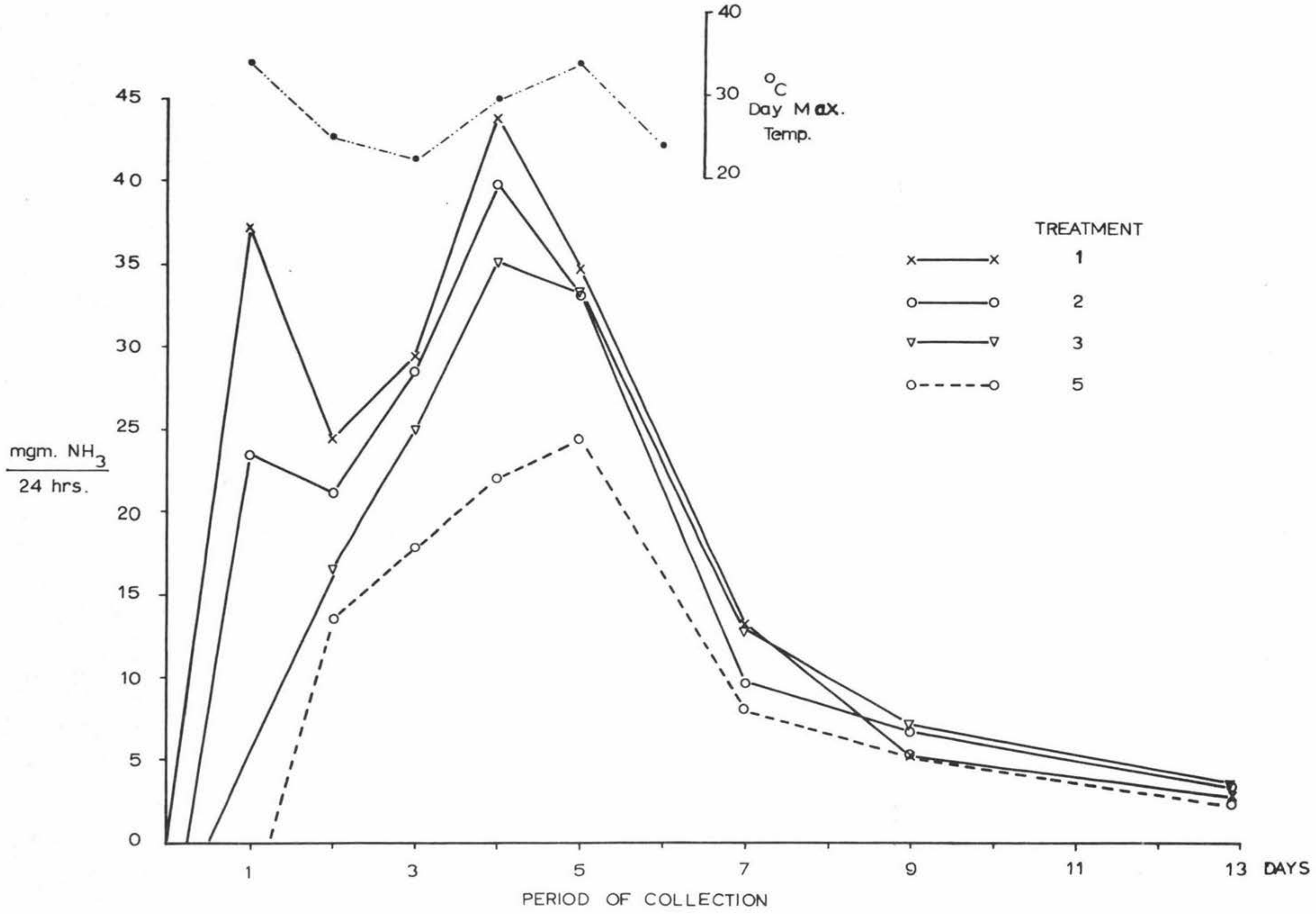
Treatment	1	2	3	4	5
Rep. I	247.7	196.8	127.8	137.8	104.9
II	188.2	176.9	213.6	184.3	120.3
Mean	217.9	186.8	171.2	161.1	112.7
% Total N	5.2	4.0	4.1	3.8	2.7

The majority of the ammonia (78% of the total) was lost during the first 5 days, the peak releases occurring on the warmer days (Fig 6.1).

After the fifth day the rate of release fell considerably until at the end of the experiment it was only 3 mgm per 24 hours. Even this rate, however, was considerably higher than the 0.4 mgm per 24 hours obtained under the control cages which had no dung patch.

Table 6.4 shows the data collected from the dung patches left to dry in the open. Under the very hot conditions which prevailed during the experiment, reaching $34^{o}C$ ($93^{o}F$) in the open, 1086 gms of moisture, i.e.

FIG. 6:1. PRODUCTION OF AMMONIA FROM A DUNG PATCH (Mean 2 reps.)



60% of the original weight was lost in 13 days. Seventy-two percent of this loss occurred in the first four days. During the 13 days of the experiment the dry matter rose from 13 - 33%.

TABLE 6.4

Dry Weight and Total Nitrogen Content of Dung Patches Lifted Throughout Experiment

Sample Day	Dung Patch Data				Nitrogen Analysis	
	Total Wet Wgt. (gms)	Dry %	Total Dry wgt. (gms)	Loss in Moisture (gms)	N.Content %	Total N in Patch (gms)
0	1816	12.9	234		2.05	4.80
1	1479	15.7	232	335	1.91	4.44
2	1271	16.5	210	186	2.05	4.30
4	1106	18.6	206	161	2.07	4.26 4.40
5	899	21.8	196	97	1.98	3.88
7	884	22.1	195	14	1.76	3.44
9	755	26.9	203	121	1.82	3.70
13	568	33.1	188	172	1.83	3.44 3.82

The total N determinations have to be viewed with some caution, as they were taken from successive patches. Although duplicate determinations gave almost no variation within patches, there was some variation between patches other than that caused by changes within, or losses from, the patch. A tendency does show, however, for the N content to fall, which when accompanied by a fall in the dry weight of the patch itself, caused a decline in the total N in the patch. If the differences between the mean for the first four and last four samples is taken as a measure of this decline, it amounts to 0.48 gms N. This is equivalent to 581 mgm NH_3, of which as much as 218 mgm (37%) was recovered under the cages in this experiment as free NH_3. The balance of the N was apparently lost into the soil or utilised during decay processes.

CONCLUSIONS

The rapid release of ammonia (NH_3) over the first five days probably results primarily from the volatilisation of ammoniacal N in the dung, together with the hydrolysis of any urea present. Martin and Chapman (1951) reported that the amount of NH_3 volatilised from N fertiliser applied to the soil surface depended on the humidity of the atmosphere, and losses were recorded only when moisture was being lost at the same time. Their observation appears relevant to dung also, as in this experiment the major loss of NH_3 occurred with the major loss of moisture.

It is also likely that the highest humidity occurred within the cages which were placed first over the dung patches (Treatment 1). This would account for the tendency for this treatment to give the highest ammonia value. The drying out of the surface of the patch would decrease the release of moisture and hence NH_3. Thus, although the pretreatments applied were not effective statistically, there is every indication that the method employed for the collection of ammonia from dung in this experiment will give maximum figures for ammonia if the cage is positioned immediately the patch is laid.

Once the volatile ammonia has been released, the production of further ammonia is probably from that released during the decomposition of plant and microbial protein in the dung. Since microbial decomposition of the cellulose and pentosans in the dung will probably also have begun (Waksman 1932 Chap.IIV) some of the ammonia being produced will be required by the micro-organisms themselves. Although this will prevent the ammonia from being lost to the atmosphere, it will, nevertheless, convert it to an organic form which would not be as readily available to the plants once it became incorporated in the soil.

To conclude, it appears that, under the conditions which prevailed in this experiment, ammonia is a potential source of loss of N from the dung patch. Although it only amounted to approximately 5% of the total N in the patch, it probably represented the portion which would be most available to plants and would certainly be the most soluble should leaching of N from the dung occur. It may be calculated that if the entire 218 mgm of ammonia were available to plants, this would represent an equivalent application of some 22 lbs N per acre in the patch area. Trials in the autumn, on plots adjacent to this experimental area, have obtained 12 % increase in herbage growth from a similar rate of fertiliser N (MacDiarmid - Unpublished data).

CHAPTER SEVEN

GENERAL DISCUSSION

The preliminary investigation in Chap 2 provided information on the distribution of the dung patch and its relative importance as a discrete patch in the pasture. The distribution patterns suggested that provided paddocks are free from objects under or around which cows may congregate, then the dung patches will be distributed uniformily at each grazing.

The results showed that cows, on average, defaecate 13 times during a 24-hour grazing period, the defaecations covering 9 sq.ft of pasture. These estimates lie within the values obtained by other authors (Table 1.1). There was no indication that the area covered per cow per grazing varied between seasons of the year as found by some authors (Hancock 1953, McLusky 1960). The area covered by dung patches at each grazing as a proportion of the whole paddock varied with the stocking rate and ranged between 0.28 and 0.67%.

The grazing records for the 1968 season on the No.3 Dairy Unit recorded an average of 500 animal grazing days per acre for the paddocks used in the investigation. From this it can be estimated that 10% of pasture would be covered by dung patches during the same season. At the stocking rate practiced on the farm at present (1.4 cows per acre) it could, therefore, take almost 10 years (5000cow-days) for 100% of the pasture to be covered with dung. Moreover, the calculations by Petersen et al (1956 a) indicate that patches overlapping one another would likely become an important factor after the first 5 years, increasing the period for 100% of the pasture to be covered accordingly. However, the estimate agrees with Petersen et al - 4745 cow-days, and McLusky (1960) - 5000 cow-days.

The length of time the dung patch covers the pasture beneath it depends on its rate of decay and subsequent disappearance. One of the major factors which appears to determine the rate of disappearance of the patch is the climatic conditions which prevail immediately following the deposition of the dung (Weeda 1967). Rain appears to accelerate the rate, while dry weather appears to prolong it. However, observations made during the experiments described in this thesis suggest that other factors may be equally as important.

The dung patches observed in the Spring and Summer field study (Chap 2) and also in the second Ecological Experiment (Chap 5) decayed in a manner similar to that described by Weeda (1967) in accordance with the dry weather which prevailed. The patches formed a surface crust and decay was from underneath. However, the patches laid down in the behavioural study (Chap 3) were also laid during dry weather in the Autumn, yet these patches lasted for only about 6 weeks and did not form a surface crust. Furthermore, in the first Ecological Experiment (Chap 3), heavy rain fell over the first 9 days producing conditions which, according to Weeda, should have been ideal for the rapid disappearance of the dung patch. This did not, however, occur as the patches were still apparent in the unharvested plots after 4 months.

A possible explanation for this variation in the decay pattern may be found in the composition of the dung itself and in earthworm activity throughout the year.

The dung used in the first experiment rapidly formed a dense mat which appeared to consist mainly of long, leathery-like fibres resistant to decay. It is possible that the relatively high digestibility of herbage in the Spring results in the dung having a high proportion of this fibrous material. Having already resisted decay by rumen micro organisms, this fibre may also be relatively resistant to decay by soil and coprophytic micro organisms. If at this time of the year micro organisms are the principal agents responsible for the decay of the dung patch then this would explain the relative persistence of the patches. Furthermore, the effect of rain leaching soluble nutrients from the dung may have been to deprive the micro organisms of growth factors essential for their activity.

In the Autumn, on the other hand, earthworms and other soil macrobes may be the primary agents responsible for incorporating the dung patch into the soil. Supporting evidence for this are the results of Barley (1959) and Waters (1955). They found that Allolobophora caliginosa, the most abundant earthworm in New Zealand pastures (up to 86% of all species) were active for about 26 weeks in the year, the main factors controlling their activity being the soil temperatures and moisture. During the late Summer, Autumn and Winter, their activity was greatest. As the soil dried out in the Spring, and soil temperatures increased the worms tunnelled more deeply until by the Summer had aestivated at depths of from 15 - 60 cm. Since earthworms prefer dead material (Barley 1964) and have a supplementary source of nutrients from e.g. plant litter and soil, the leaching of nutrients from the patch would not deprive them of a source of growth factors which, as mentioned earlier, may occur with micro organisms.

A further factor contributing to the rapid decay of the dung in the Autumn may have been that the dung used at that time was from cows fed hay, silage and grass high in dry matter. The fibre in this dung had the appearance of being "brittle" and "broken" into small pieces, quite unlike the fibre in the Spring dung. The earthworms may have found this dung easy to ingest and the type of fibre may also explain the reluctance for the Autumn dung to form a surface crust.

Further investigation is required on the factors responsible for the rate of disappearance of the dung patch, with emphasis not only on the effect of climate, but also on the effect of changes in the composition of the dung and the occurrence of coprophytic macro and micro-organisms in the dung patch throughout the year.

The measurements made on the herbage beneath the patch suggest that, under the conditions which prevailed in the experiment, decay was rapid. The longer the patch remained in position, the more complete the decay, until after approximately 3 weeks all the plants beneath the patch were dead. It must be assumed that once this stage is reached, restoration of plant cover to the patch area must be either from surrounding herbage or from the germination of seeds in the dung and/or in the soil. Hence, not only does the dung patch prevent the area beneath it from being grazed, but it also renders portions of the paddock bare providing the opportunity for the introduction of weed species.

It has been suggested that one of the aims of harrowing is to prevent this bare patch from occurring. However, results in this thesis suggest that the benefits from this practice may be debateable.

In the first ecological experiment (Chap 3) the whole dung patch was completely removed. Even so, leaving the patch on the pasture for more than 6 days resulted in a 30% depression in the regrowth from the area. Leaving the patch for 15 days resulted in a 70% depression. Since harrowing the patches appears to do little more than spread the top half, at the most regrowth is not likely to be greater than that recorded in the experiment. Whether harrowing increases the "effective area" of the dung patch or its rate of decay has not been ascertained. Weeda (1967) has indicated that harrowing does reduce the amount of rejected herbage. In view of the fact that harrowing may reduce the yield of the pasture as a whole by as much as 16% (Weeda 1967) and may also increase the survival of parasite larvae in the dung (Hignett 1956) it is unlikely that the benefits which may accrue from harrowing justifies the time involved.

Not only is the pasture beneath the dung patch affected, but the results suggest that the pasture surrounding it is affected also. In each of the two ecological experiments, in the absence of a defoliation treatment, the yield of herbage in the first 6 inch ring around the dung patch was up to 30% greater than in the control plots, the response confining itself to the grass component of the sward. In the first of these experiments the outer 2 rings, extending up to 18 inches from the patch, also yielded as much as 18% more than the control plots although the response was progressive from the inner ring outwards. In the second experiment the response was confined to the first 6 inches.

When the herbage around the patch was cut, the response was prolonged considerably but confined to the first 6 inch ring. In the regrowth treatment (D) of the first experiment the herbage in this ring was still yielding 20 - 25% more after 4 months, while three months after the start of the second experiment, the yield from both cutting treatments was up to 60% greater than their controls, the response again being confined to the grass species, in particular ryegrass and Yorkshire fog.

The only results in the literature with which these results may be compared are those of Norman and Green (1958). They applied 10 inch diameter dung patches in the middle of 3 foot square plots in both the Autumn and Spring. Cattle were allowed to graze around the plots and at the end of each year for2 years the botanical composition of the pasture was measured by eye assessment in the first 8 inch ring around the patch.

Results were not analysed statistically, but their conclusions were that after two years, there was an increase in cocksfoot, creeping bent, red fescue and white clover around the patch, although the only consistent response was in cocksfoot and creeping bent. In a second experiment they measured the yield of herbage in an 8 inch ring around the patch. Their results are shown in Table 7.1.

TABLE 7.1

Influence of Cattle Dung upon Herbage Yield

Number of Months after dung		Yield of Herbage - 100's lbs/ac		
Autumn Appln	Spring Appln	Autumn Appl.	Spring Appl.	Control
7	1	14.6	9.7	9.6
9	3	11.7	16.4	10.0
12	6	10.9	13.1	7.2
19	13	8.8	12.9	6.3

The persistent and quite dramatic responses obtained in this experiment, particularly to the Spring-applied dung, was no doubt in part due to the poor fertility level of the soil. The experimental area was on a chalk escarpment of 1 in 10 gradient, had last been sown in grass two years after World War II and up to the time of the trial had received no fertiliser and carried few stock. Twenty-seven percent of the pasture was in plantain, daisy and buttercup; white clover was 2%. Highest yield of herbage, after 2 months growth and cut to ground level, was only 1640 lbs/ac. By comparison, yields after almost 2 months growth in the present experiment (Chap 3) were 7700 lbs/ac. The inapplicability of Norman and Green's results to the New Zealand situation illustrates the need for more experiments of this nature to be conducted.

It may be estimated from the results in this thesis that it would take from 3 - 5 years for 100% of the pasture to be "affected" by dung patches, the time depending on the stocking rate and "effective" area of the dung patch. The "affected" areas would yield on average 20% more than the "unaffected" areas and the effect would persist for at least 4 months.

If it is assumed that the herbage response is due to nutrients from the dung patch, then there are three major routes by which these nutrients may have become available. They include

a) movement through the soil

b) uptake by roots from beneath the patch

c) mobilisation by soil organisms.

a) Movement through the soil:

Inorganic nitrogenous fertilisers are mobile in soil moisture and surface dressings are washed into the root zone by rain (Cooke 1956). There is every indication from the soil analysis that a similar movement occurred with the N compounds from the dung patch. Following the rain at the beginning of the experiment, the level of available N both beneath and up to 6 inches around the patch rose significantly higher ($p<0.05$) than levels in the "control" areas during the first 20 days. In view of the response obtained during and after this period in the herbage, it may be assumed that this N was at least partly responsible for the increase in grass growth around the dung patch. Nitrogen from the dung may have moved even further laterally in the soil water, but by the time the soil samples were taken the N was not present in sufficient quantities to be detectable.

Cooke (1956) considers that particularly on heavy soils, K and soluble P fertilisers combine with clay colloids and may not move very far in the soil water. This lack of movement of K and P was certainly evident from the results obtained on the heavy silt loam soil on which these experiments were conducted. Only in the first 1 inch of soil immediately beneath the dung patch was there significant rise in the exchangeable K and available P levels, the former nutrient showing higher mobility and persisting longer than the latter.

b) Uptake by Roots from Beneath the Patch:

Measurements made in pasture swards indicate that from 60 - 80% of the roots of grasses and clovers are present in the top 2 inches of soil (Goedewaagen and Schuurman, 1950 a). The breadth of the root system of grasses in various pasture swards range from 16 - 24 inches (Linkola and Tiirikka 1936). Assuming that, in the presence of sufficient moisture, these roots are partly responsible for the nutrition of the plant, then plants up to 8 inches away from the dung patch would be able to derive nutrients from the top 1 inch of soil beneath the dung patch, the region into which it appears the largest proportion of nutrients from the dung patch pass. There is little doubt that the consistent and persistent response obtained from herbage in the first 6 inch ring is the result of plants in this region deriving their nutrients via roots which pass into the soil beneath the patch.

The confinement of the response around the patch to the grasses and in particular to ryegrass, rather than the clovers, may be due to the grass species having more extensive root systems which could extend further into the patch area. Furthermore, evidence suggests grasses posses a better ability to take up and a high requirement for K and N (Russell 1963), the nutrients which appeared the most mobile from the dung patch.

It is interesting to note that Edmond (1965) obtained a significant increase ($p < 0.05$) in the ryegrass content of pasture plots one month after they had been fertilised with "N and K" (4 cwt Sulphate of Ammonia + 4 cwt muriate of potash). The plots were situated on a paddock of the No.3 Dairy Unit adjacent to the paddock used for the two ecological experiments in this thesis. The response to P (10 cwt Superphosphate) applied with N and K was also significant but not until 4 months after application.

Norman and Green (1958) obtained an initial response in the grass component of the sward surrounding a dung patch which they suggested was due to readily available N from the dung. The crude protein content in this herbage rose from 14% to 18.6% after 1 month. However, in a separate experiment in which the surrounding herbage was cut frequently, these authors still obtained a response after 13 months, the surrounding herbage at this stage containing more white clover than control plots. This increase in the clover over a long term in the patch area has also been noticed by Weeda (1967) and Sears (1953) It is probable that the effect is due to the slow mineralisation and release of organic P in the dung and also to the invasion of the area by stolons of clover plants adjacent to the patch. This effect was not, however, noticed in the relatively short-term experiments in this thesis.

c) Mobilisation by Soil Organisms:

The literature available suggests that soil macrobes, and earthworms in particular, are capable of ingesting considerable amounts of dung (Barley 1964). It is probable that the dung patch, together with the decaying herbage beneath it, may also be readily incorporated into the soil by the earthworm and become available as plant nutrients either via the earthworm's excreta or from the death and decay of the organism itself (Barley 1964, Waters 1951, 1955, Watkin and Wheeler 1966). Stockdill (priv.comm) found the earthworm

Allolobophora caliginosa was responsible for incorporating dung, plant residues, lime and DDT into the topsoil.

The increased activity of micro-organisms in the vicinity of the patch may also increase the rate of mineralisation of the organic fraction of the soil, raising the nutrient status accordingly, (Waksman 1932, Russell 1963).

It is likely that a combination of all three factors listed above is responsible for the mobilisation of nutrients from the dung patch into the soil and their subsequent uptake by the roots of surrounding plants, the relative importance of each depending on the environmental conditions prevailing.

As the evidence suggests that the nutrients N and K were primarily responsible for the increase in grass growth around the patch, then perhaps the results research workers have obtained in sheep return experiments may not be particularly relevant to the cattle situation, where the dung is returned in larger, fewer and more discrete patches. From the plots to which only sheep dung was returned, Sears (1953 I) obtained an initial increase in the clover content of the sward, which he attributed to the relatively high P, Ca and Mg content of dung. In the present experiment the dung patch caused an increase in the grass content of the sward. The reason for the different results is probably that where sheep are used for grazing plots the dung, because of its spherical shape and greater dispersal, has a greater surface area making the nutrients in it more susceptible to leaching. Also, the inorganic P content in dung from wethers, the usual animal used for return experiments, is likely to be higher than in dung from ewes or milking cows, the latter animals diverting much of the P in feed to milk production, (Davies et al 1962). Any experiments in which the dung is dried and returned evenly over the sward is also likely to increase the relative importance of P, by making it more susceptible to leaching and releasing some of the organic P (Bromfield 1961). Furthermore, the nutrients are much less concentrated per unit area when spread than when applied in a patch.

It is suggested, therefore, that although the content of N and K in dung is relatively low when compared e.g. with urine, by virtue of these nutrients being concentrated in a discrete patch of solids they are released relatively slowly and are protected against the excessive leaching losses such as those likely to occur in the urine patch by nature of their being in a liquid medium (During and McNaught 1961, Lotero et al 1966, Davies et al 1962). Furthermore, under hot, dry conditions, urine may only penetrate into the soil about 0.1 inches and up to 35% of the N may be liberated as ammonia in the first 24 hours (Doak 1953). In contrast, the results from Chap 6 suggest that, under similar conditions loss from N as ammonia from the dung patch is unlikely to exceed a total of 5%, the greatest portion of this loss occurring over the first 7 days.

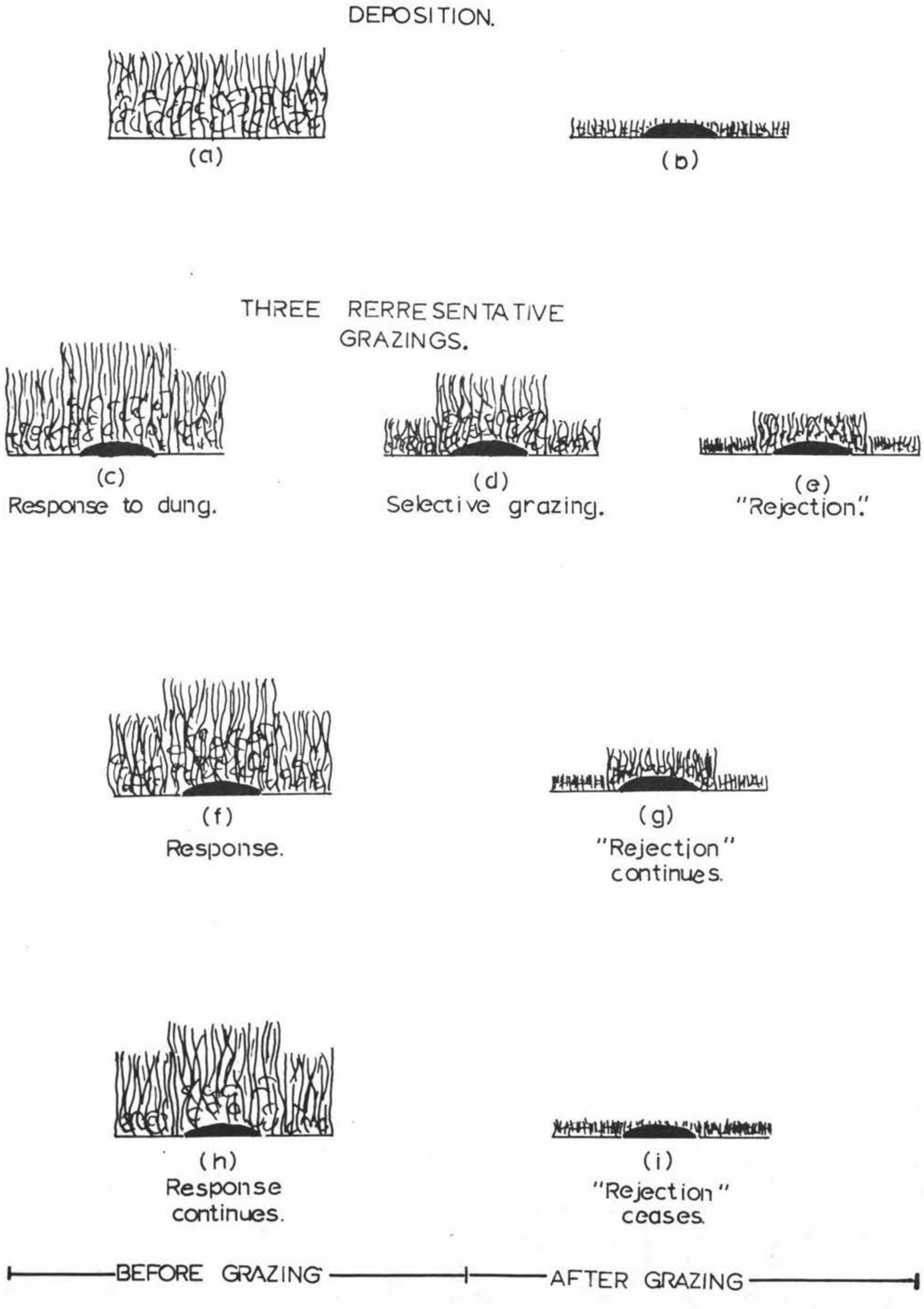
Because of the characteristics of the cattle dung patch that have been outlined in this discussion which distinguish it from sheep excreta, it is unlikely that the results from sheep return experiments relate to the cattle situation with any degree of certainty. The need for cattle return experiments, to asses the farm situation, appears justifiable in lieu of the variable responses obtained from "excretal patch" experiments such as those presented in this thesis, and the difficulty in extrapolating the results to the farm situation.

The results from the behavioural study (Chap 4) indicate that the reason the cows did not graze the herbage around the dung as intensively as the remainder of the paddock was because of some objectionable smell that the dung possessed. This observation substantiates claims by other authors (Tribe 1949, Marten and Donker 1966 a,b). It has been suggested (Norman and Green 1958, McLusky 1960, Tayler and Large 1955) that the "rejection" of this herbage is responsible for a decrease in the utilisation of a pasture. Results of experiments conducted in this thesis throw some doubt on these claims.

At the beginning of the behavioural experiment, the herbage around the dung patch was 1.6 inches higher ($p < 0.01$) than the herbage in the "unaffected" areas. At the end of the study the herbage around the patch was still 1.5 inches higher ($p < 0.01$). This is shown diagrammatically in Fig 7.1 c, d and e. Assuming that the height is a reasonable indication of the amount of herbage on offer - that the 30% increase in height agrees with the 30% increase in yield obtained in the "patch" experiments suggests it is, - then the amount of herbage grazed from each area would be similar.

The results from the "patch" experiments indicate that, provided moisture conditions are sufficient for growth, a response in the regrowth herbage may still be evident after 5 months, i.e. seven grazings at 3-weekly intervals. These grazings are represented by fig 7.1 f and g. However, in the field study (Chap 2) it was noted that the herbage around the patch ceased to be "rejected" after 3-4 grazings. The situation is then represented by fig 7.1 h and i. This situation remains while the "dung patch herbage" continues to show a response and the result is an increase in the dry matter available to the animal. The major loss which is incurred is from the area

FIG. 7.1 DIAGRAMMATIC REPRESENTATION OF HERBAGE AROUND A DUNG PATCH AT SUCCESSIVE GRAZINGS.



covered by the dung patches, and its subsequent depressed regrowth (Chap 3).

In the mathematical model below, an effort is made to present this hypothesis on an empirical basis. The formula derived assumes that, as explained above, the stocking rate is of sufficient intensity that the animals graze the same amount from the "dung patch herbage" as from the "unaffected" area. Consequently, the only loss in utilisation is from the area beneath the dung patch both while it is present and, following its disappearance, during the subsequent regrowth from the area. Any increase in utilisation accrues between when the herbage around the patch ceases to be "rejected" and when the herbage ceases to respond to the dung. It also assumes a "steady state" situation, when for every dung patch that is deposited thereby creating an "affected" area, an equivalent area is returning to the "unaffected" state. The stocking rate assumed is equivalent to 1.1 cows per acre (average of the 2 farms in the field study Chap 2) grazing a 24 hour rotation at 3-weekly intervals.

Then the potential dry matter available to the animal, (T)

$$T = \left[(100 - pm) + p \;\; (m-1) \;\; R\right] U \; + \; \left[(c-r) \;\; px\right] (D-Y)$$

Where p = % paddock covered by dung patches/grazing

l = No. of grazings dung patch takes to disappear

c = " " dung patch is effective

r = " " dung patch herbage is "rejected"

m = " " the regrowth in the patch area remains "depressed" after dung disappears

x = average "effective" area of dung patch (times p)

y = yield "unaffected" herbage (before grazing)

D = yield "dung patch" herbage

R = av. yield of regrowth in the patch area

U = % herbage utilised by the animal at each grazing.

Table 7.1 contains the values used for the evaluation of T in three different situations which, from the limited information available, would appear likely to occur during a grazing season. The value for p is estimated from the data in Chap 2 for the stocking rate stipulated in the assumptions. Values for l and r are taken from Table 1 and Table 4 from Weeda (1967) who, over a 2 year period, studied the rate of disappearance of dung patches and the "rejection" of herbage around them. The values for the remaining factors were taken from the two ecological studies Chap 3 and Chap 5 and from Table 4 of Norman and Green (1958). A somewhat arbitrary value of 50% for U was adopted for all calculations. This value has little effect on the relative T values between paddocks with or without dung patches.

TABLE 7.1

Effect of Dung Patch on Utilisation of Herbage in a paddock

(grazing period = 3 weeks)

Calculation		I	II	III
Factor	p%	0.4	0.4	0.4
	l (no.graz.)	7	4	2
	c (")	4	7	10
	r (")	2	3	2
	m (")	11	8	3
	x (times p)	2.5	3	3
	y lbs/ac	2000	2700	3000
	D "	2300	3300	4000
	R "	600	600	1500
	U %	50	50	50
Td (lbs/ac)		967	1316	1581
Tu (lbs/ac)		1000	1350	1500
(Td-Tu) Difference %		- 3%	-2.5%	+ 6%

$$T = \left[(100 - pm) + p\ (m-1)\ R\right]\ U + \left[(c-r)\ px\right]\ (D-Y)$$

Td = potential dry matter available in "dung patch paddock".

Tu = U.Y = potential dry matter available in "unaffected" paddock.

The first calculation (I) represents the situation which probably occurs in the summer when, because of lack of moisture and high temperatures all yields are relatively low, the response around the patch is limited and the patch remains on the paddock for a relatively long time (5 months). When the patch finally disintegrates the average yield from the area is depressed for a further 3 months. The conditions then are similar to those which occurred during the dry period of the second ecological study and yield values are taken from this period. The result is a small (3%) depression in the potential dry matter available in the dung patch paddock. If moisture limitations are removed, the response to the dung patch (D-Y), is likely to be considerably greater (2nd Ecolog. Study - last harvest). Furthermore, under summer conditions the herbage is likely to be short and the animals intake restricted, in which case additional response will be fully utilised, increasing Td values accordingly and reducing the differential between Td and Tu.

The second calculation (II) illustrates an intermediate, and probably the most common situation which occurs. The values for yields are from the first 3 week growth in both ecological studies. "Rejection" is longer because of the longer herbage and larger response (D-Y).

The result is that there is a small depression in utilisation owing to the presence of the dung patch.

The third calculation (III) is representative of the situation which may occur e.g. in the Autumn, where the response to the dung is both long term and extensive although the dung patch disappears relatively rapidly and losses in utilisation from the patch area itself are small. The result is an increase of 6% in the potentially available herbage in the "dung patch" paddock. It is possible that the gains made in this situation may balance the losses in the other two.

It may be estimated that at the "steady state" the proportion of the paddock which would appear affected by the dung patches after grazing in the three situations are 6.4%, 8.0% and 10.8% respectively. Actual measurements of this proportion recorded by research workers are 22% (Tayler and Rudman 1966), 15% (McLusky 1960) and 26% (Arnold and Holmes 1958). The variation between the results are no doubt a reflection of the grazing intensity employed in the respective experiments. This effect of grazing intensity on rejection of "dung patch herbage" was shown in the behavioural study (Chap 4) where the animals grazed the "unaffected" areas 24 hours before they attempted grazing the "dung patch" herbage. Probably the most important assumption in the model above is that the grazing intensity is such that the cows are forced to graze the "dung patch" herbage. Any management which allows this herbage to become rank will reduce the value of T accordingly.

The author recognises that calculations I, II and III have obvious limitations, one of which is the reduction of a number of dynamic processes, geometric in nature, into an arithmetic function by use of the "steady state concept" and "average percentage" values. However, the function enables an estimate to be made of the relative importance of dung patches deposited throughout the year in a grazed pasture. The extent to which they influence the utilisation of the pasture at subsequent grazings depends on the values accorded the variables in the function. These values are, in turn, dependent on

a) the magnitude, extend and duration of the response of the herbage around the dung patch.

b) the areas covered by the dung patch, its rate of decay and the subsequent regrowth in the area.

c) the period and the extent of "rejection" of the herbage around the dung patch.

The factors which influence these values are numerous and complex, and are dependant upon physical and biological processes each with their inherent variability. Some of these processes have been evaluated within the confines of the experiments related and discussed in this thesis. Others, however, have yet to be evaluated before an adequate appreciation of the whole situation can be obtained. It would, for example, appear desirable to repeat the ecological experiments over longer periods, on different soils, under different climatic conditions and in the presence of applied inorganic fertilisers.

CONCLUSION

It is apparent from the results and the discussion in this thesis that while cattle continue to graze pasture, particularly at high stocking rates and all the year round as is the practice in New Zealand, the dung patch will remain as an inherent and ecologically significant component of the fertility cycle; not necessarily hindering pasture utilisation but rather acting as a source of nutrients whose availability to the plant depends on the many biological processes controlling their release and subsequent uptake.

SUMMARY

Results from a field investigation indicated that dairy cows defaecate on average 13.4 times per day. Each defaecation covered on average 113 sq.ins. of pasture. There was little difference between estimates of this area made in the Winter, Spring and Summer. The percentage area of paddock covered by dung patches after a 24-hour grazing ranged between 0.31% and 0.52%, depending principally on the stocking rate. Distribution patterns, consistency and the rate of disappearance of dung patches in the pasture were recorded.

The results of an experiment conducted in the late Spring, showed there was a significant increase in the grass species, in particular ryegrass, growing around a dung patch. This response was greatest in the first 6 inch ring around the patch and was still evident in the regrowth from this area. However, indications were that the response initially extended up to 18 inches from the edge of the dung patch.

Chemical analyses of soil samples taken from under and around the dung patch suggested the grass response was primarily due to K and N compounds mobilised from the dung. The weight and fibre content of the dung patch as well as the decay of herbage beneath it and the subsequent regrowth from the patch area were followed throughout the experiment.

A second experiment conducted during the Summer which had included two defoliation treatments to more closely simulate the grazing situation, also established a significant increase in the growth of grass species around the dung patch. The response was confined to the first 6 inch ring and was greater in the defoliated treatments.

Measurements of the loss of NH_3 from a dung patch in the pasture indicated that during hot, dry weather up to 5.2% of the N in dung may be lost from this source.

The grazing pattern of a pasture in which dung patches were deposited were followed. Using cows which were blinkered to eliminate sight as an aid to their selection of herbage, the results suggested that the odour of the dung patch was the primary cause for the rejection of herbage around it.

In a general discussion, the results of the above experiments were used in a mathematical model to estimate the effect dung patches may have on the utilisation of pasture in a grazed paddock.

BIBLIOGRAPHY

Arnold G.W. and Holmes W. (1958) J. Agric Sci. 51:248 Studies in Grazing Management. VII The Influence of Strip Grazing Versus Controlled Free Grazing on Milk Yields, Milk Composition and Pasture Utilisation

Ball R. (pers. comm) Scientist DSIR, Grasslands Divn. Palmerston North

Barley K.P. (1964) 5th Proc. Aust. Soc. Anim. Prod. = 241 Earthworms and the Decay of Plant Litter and Dung.

Barley K.P. (1959) Aust. J. Agric Res 10:171. The Influence of Earthworms on Soil Fertility. I. Earthworms Populations found in the Agricultural Land near Adelaide.

Barrow M.J. and Lambourne L.J. (1962) Aust. J.Agric Res 13:461 Partition of Excreted Nitrogen, Sulphur and Phosphorous between Faeces and Urine of Sheep being fed Pasture.

Bromfield S.M. (1961) Aust. J. Agric Res. 12:111 Sheep Faeces in Relation to the Phosphorous Cycle Under Pastures.

Brougham R.W. (1959) N.Z. Jl. Agric Res. 2:1232 The Effects of Frequency and Intensity of Grazing on the Productivity of a Pasture of Short-Rotation ryegrass and Red and White Clover.

Bower C.A., Reitemeier R.F. and Fireman M. (1952) Soil Sci. 73:251 Exchangeable Cation analysis of Saline and Alkali Soils.

Beruldsen E.T. and Morgan A. (1938) J. Dep. Ag. Vic. 36:60 Irrigated Pastures - Influence of Grazing.

Brown J. (1963) Personal Communication to Dale W.

Bornemissza G.F. (1960) J. Aust. Inst. Agric. Sci. 26:54 Could Dung Eating Insects Improve our Pasture?

Castle (1968) Hannah. Dairy Res. Inst. Rep. 1968 :22

Castle M.E., Foot A.S. and Halley R.J. (1950) J. Dairy Res. 17:215 Some Observations on the Behaviour of Dairy Cows with Particular Reference to Grazing

Castle M.E. and Drysdale A.D. (1966) J. Agric. Sci.67:397 Liquid Manure as a Grassland Fertilizer. V The response to Mixtures of Liquid Manures (Urine) and Dung.

Dale W.R. (1961) 23rd Proc. N.Z. Grassld. Ass : 118 Some Effects of Sheep Urine on Pasture.

Dale W.R. (1963) Dip. Ag. Sci. Thesis Lincoln College, N.Z. Page 74. Nutrient Cycles under Grazing.

Davies E.B., Hogg D.E. and Hopewell H.G. (1962) Int. Soc. Soil Sci. Trans. IV and V : 715 Extent of Return of Nutrient Elements By Dairy Cattle. Possible Leaching Losses.

Doak B.W. (1952) J. Agric. Sci. 42:162
Some Chemical Changes in the Nitrogenous Constituents of Urine when voided on Pasture.

Doak B.W. (1954) J. Agric. Sci. 44:133
The Presence of Root Inhibiting Substances in Cow Urine and the Cause of Urine Burn.

During C. and McNaught K.J. (1961) N.Z. Jl. Agric. Res. 4:591
The Effect of Cow Urine on Growth of Pasture and Uptake of Nutrients.

Drysdale A.D. and Strachan M.A. (1966) J. Agric. Sci. 67:337
Liquid Manure as a Grassland Fertilizer. IV The Effect of Liquid Manure on the Mineral Content of Grass and Clover.

Drysdale (1965) J. Agric. Sci 65:333
Liquid Manure as a Grassland Fertilizer. III The Effects of Liquid Manure on the Yield and Botanical Composition of Pasture and its Interaction with Nitrogen, Phosphate and Potash Fertilizers.

Edmond D.B. (1965) 27th Proc. N.Z. Grassld. Ass. : 112.
Pasture Growth at Moderate Stocking Rates.

Elliott R.C., Fokkenia K. and Fresch C.H. (1961) Rhod. Agric.J. 58:124
Herbage Consumption Studies on Beef Cattle.

Goodall V.C. (1951) 13th Proc. N.Z. Grassld Ass : 86
The Day and Night Grazing System.

Guild W.J. McL. (1955) Soil Zoology. Ed. Kevan D.K. McE. Published Butterworths.

Garner F.H. (1963) J. Br. Grassld. Soc. 18:79
The Palatibility of Pasture Plants.

Gunary D. (1968) J. Agric. Sci. 70:33
The Availability of Phosphate in Sheep Dung.

Green J.O. and Cowling D.W. (1960) Proc. VIII Int. Grassld Congr. : 126
The Nitrogen Nutrition of Grassland.

Hancock J.R. (1953) Anim. Breed. Abstr. 21:1
Grazing Behaviour of Cattle

Hancock J. and McArthur A.T.G. (1951) Proc. Ruakura Fmrs'. Conf. Week : 32
Tips on Cow Management arising from Grazing Behaviour Studies.

Hilder E.J. (1964) 5th Proc. Aust. Soc. Anim. Prod. : 241
The Distribution of Plant Nutrients By Sheep at Pasture.

Hiller A, Plazin J. and van Slyke D.D. (1948) J. biol. Chem. 176:1401
A study of the Conditions for Kjeldahl determinations of Nitrogen. (Hg^{++} as catalyst).

Henderson C.R. (1963) Monograph by Am. Soc. Anim. Sci. Techniques and Procedures in Animal Production Research. Chapter I.

Hignett P.G. (1956) J.Br. Grassld. Soc. 11:194
Some Diseases Associated particularly with the grazing animal.

Herriott J.B.D. and Wells D.A. (1963) J.Agric. Sci. 61:89
The Grazing Animal and Sward Productivity.

Jackson M.L. (1958) Prentice-Hall, Inc.
Soil Chemical Analysis.

Johnstone-Wallace D.B. and Kennedy K. (1944) J. Agric. Sci. 34:190
Grazing Management Practices and Their Relationships to the Behaviour and Grazing Habits of Cattle.

Kydd D.D. (1964) J. Ecol. 52:139
The Effect of Different Systems of Cattle Grazing on the Botanical Composition of Permanent Downland Pasture.

Keeney D.R. and Bremner J.M. (1966) Nature 211:892
A Chemical Index of Soil Nitrogen availability.

Keeney D.R. and Bremner J.M. (1966) Agron. J. 58:498
Comparison and Evaluation of Laboratory Methods of Obtaining an Index of Soil Nitrogen Availability.

Lancaster R.J. (1950) 10th Proc. N.Z. Soc. Anim. Prod. :45
The Estimation of Digestibility.

Laurence B.R. (1954) J. Anim. Ecol 23:234
The Larval Inhabitants of Cow Pats.

Laurence B.R. (1955) J. Anim. Ecol. 24:187
The Ecology of some British Sphaeroceridae (Borboridae, Diptera).

Lotero J., Woodhouse W.W. Jr, and R.G. Petersen (1966)
Local Effect on Fertility of Urine Voided by Grazing Cattle.

Lotero J., Woodhouse W.W. Jr and Petersen R.G. (1965)
Proc. IXth Int. Grassld. Congr :1687
Distribution and Loss Rate of N and K Applied To the Soil by Grazing Animals.

McLusky D.S. (1960) J.Br. Grassld. Soc 15:181
Some Estimates of the Areas of Pasture Fouled by the Excreta of Dairy Cows.

Metson A.J. and Hurst Frances B. (1953) N.Z. Jl. Sci. Technol. 35A:327
Effects of Sheep Dung and Urine on a Soil Under Pasture at Lincoln, Canterbury, with Particular reference to Potassium and Nitrogen Equlibria.

Melville J. and Sears P.D. (1953 II) N.Z. Jl.Sci. Technol. 35A:30
II The Influence of Red and White Clovers, Super phosphate, Lime and Dung and Urine on the Chemical Composition of Pasture.

Marten G.C. and Donker J.D. (1966) Proc Xth Int. Grassld. Congr. :359
Animal Excrement as a Factor Influencing Acceptability of Grazed Forage.

Marten G.C. and Donker J.D. (1964a) J. Dairy Sci. 47:773
Selective Grazing Induced by Animal Excreta I. Evidence of Occurance and Superficial Remedy.

Marten G.C. and Donker J.D. (1964b) J.Dairy Sci. 47:871
Selective Grazing Induced by Animal Excreta II Investigation of a Causal Theory.

McQueen I.P.M. (1963) :149 Massey Dairyfarming Annual :149
Avoiding Pasture Damage under Wet Soil Conditions.

Minson D.J. (1963) Proc. N.Z. Soc. Anim Prod. 23:63
Methods of Assessing Herbage Feeding Value.

Nielson R.L. (1951) Proc. 13th Conf. N.Z. Grassld. Ass. :158
Earthworms and Soil Fertility.

Needham A.E. (1957) J.Exptl. Biol. 34:425
Components of Nitrogenous Excreta in the Earthworms *Lumbricus terrestris*, L. and *Eisenia foetida* (sav.)

Norman M.J.T. and Green J.O. (1958) J. Br. Grassld. Soc. 13:39
The Local Influence of Cattle Dung and Urine upon the Yield and Botanical Composition of Permanent Pasture.

Plice M.J. (1951) Agron. J. 43:341
Sugar versus the Intuitive Choice of Foods by Livestock.

Petersen R.G., Lucas H.L., and Woodhouse W.W.Jnr. (1956I)
Agron. J. 48:440
The Distribution of Excreta by Freely Grazing Cattle and its Effect on Pasture Fertility.

Petersen R.G., Lucas H.L., and Woodhouse W.W.Jnr. (1956II)
Agron. J. 48:444
II Effect of Returned Excreta on the Residual Concentration of some Fertilizer Elements.

Satchell J.E. (1955) Soil Zoology - Ed. Kevan D.K.McE.
Published Butterworths.

Satchell J.E. (1958) Soils Fertil. 21:209
Earthworm Biology and Soil Fertility.

Snedecor G.W. (1959) Iowa State College Press.
Statistical Methods.

Sears P.D. and Newbold R.P. (1942) N.Z. Jl. Sci. Technol. 24A:36
The Effect of Sheep Droppings on Yield, Botanical Composition and Chemical Composition of Pasture. I.

Sears P.D. and Goodall V.C. (1948) N.Z. Jl. Sci. Technol. 30:231
Part II.

Sears P.D. and Thurston W.G. (1952) N.Z. Jl. Sci. Technol 34A :445
Part III.

Sears P.D. (1953I) N.Z. Jl. Sci. Technol 35A. Suppl. 1:1
Pasture Growth and Soil Fertility.
I. The Influence of Red and White Clovers, Super phosphate, Lime and Sheep Grazing on Pasture Yields and Botanical Composition.

Sears P.D. and Evans L.T. (1953 III) N.Z. Jl. Sci. Technol. 35A :42
III The Influence .... on the Soil Composition and on Earthworm and Grass Grub Populations.

Sears P.D. (1953 IV) N.Z. Jl. Sci. Technol. 35A :53
IV The Influence on Soil Fertility of Clovers, Superphosphate, Lime, Dung and Urine Applied to Pastures as measured by the Growth of Subsequent Forage Crops.

Sears P.D. (1953 V) N.Z. Jl. Sci. Technol. 35A:68
V The Effects of Nitrogenous Fertilizers, and of "Day" and "Night" Grazing.

Sears P.D. (1953 VII) N.Z. Jl. Sci. Technol. 35A:221
VII General Discussion of the Experimental Results and of their Application to Farming Practice in New Zealand.

Sears P.D. (1960) Proc. VIIIth Int. Grassld. Congr. :130
Grass/Clover Relationships in New Zealand.

Sears P.D. (1950) J. Br. Grassld. Soc. 5:267
Soil Fertility and Pasture Growth.

Sears P.D. (1951) N.Z. Jl. Sci. Technol. 33A:1
The Technique of Pasture Measurement.

Suckling F.E.T. (1951) 13th Proc. N.Z. Grassld. Ass. :119
Results of Recent Experiments on Surface Sowing.

Stapledon and Davies (1908) "Ley Farming".

Stockdill S.M.J. (1968) Private Communication. N.Z. Soil News May :53
Some Effects of Earthworms on Soils Under Pasture.

Tayler J.C. and Large R.V. (1955) J. Br. Grassld. Soc. 10:341
The Comparative Output of Two Seed Mixtures.

Tayler J.C. and Rindman J.E. (1966) J. Agric. Sci. 66:29
The Distribution of Herbage at Different Heights in "Grazed" and "Dung Patch" Areas of a Sward under Two Methods of Grazing Management.

Thomas (1960) N.Z.J. Sci. 3:8
Notes on a preliminary investigation into the habits of the l.fc cycle of Copris incertus Say: (Coprini:coleoptera).

Truog E. (1930) J. Am. Soc. Agron. 22:874
The Determination of the readily-available Phosphorous of Soils.

Troughton A. (1957) C.A.B. Bulletin No.44
The Underground Organs of Herbage Grasses.

Tribe D.E. (1949) J. Agric. Sci. 39:309
The Importance of Sense of Smell to the Grazing Sheep.

Tribe D.E. (1950) J. Br. Grassld. Soc. 5:209
The Behaviour of the Grazing Animal: A Critical Review of Present Knowledge.

Volk G.M. (1959) Agron. Jnl. 51:746
Volatile Loss of Ammonia Following Surface Appl. of Urea to Turf or Bare Soils.

Goedewaagen and Schuurman (1950 a) From Troughton (1957)

Linkola and Tiirikka (1936) From Troughton (1957)

Waite R, MacDonald W.B. and Holmes W. (1951) J.Agric.Sci. 41:163
Studies in Grazing Management.
III The Behaviour of dairy cows grazed under the Close-folding and Rotational Systems of Management.

Waksman (1932) Prin ciples of Soil Microbiology.

Wardrop J.C. (1963) Br. J.Anim.Behav. 1:23
Studies in the Behaviour of Dairy Cows at Pasture.

Washko J.B. and Marriott L.F. Proc. VIIIth Int. Grassld Congr. :137
Yield and Nutritive Value of Grass Herbage as Influenced by Nitrogen Fertilisation in the Northeastern United States.

Watanabe F.S. and Olsen S.R. (1965) Proc. Soil Sci. Soc. Am. 29:677
Test of an Ascorbic Acid Method for Determining Phosphorous in water and $NaHCO_3$ Extracts from Soil.

Waters R.S. (1955) N.Z. Jl. Sci.Technol. 36A:516
Numbers and Weights of Earthworms under a Highly Productive Pasture.

Watkin B.R. and Wheeler J.L. (1966) J Br. Grassld. Soc. 21:14
Some Factor affecting Earthworm Populations under Pasture.

Watkin B.R. (1954) J.Br. Grassld.Soc. 9:35
The Animal Factor and Levels of Nitrogen.

Watkin B.R. (1957) J.Br.Grassld.Soc. 12:264
The Effect of Dung and Urine and its Interactions with applied Nitrogen. Phosphorous and Potassium on the Chemical Composition of Pasture.

Weeda W.C. (1967) N.Z. Jl. Agric.Res. 10:150
The Effect of Cattle Dung Patches on Pasture Growth, Botanical Composition and Pasture Utilisation.

Weeda (1963) Personal Communication.

Wheeler J.L. (1958) J.Br.Grassld.Soc. 13:196
The Effect of Sheep Excreta and Nitrogenous Fertilizer on the Botanical Composition and Production of hay.

Wolton Margaret K. (1955) J.Br.Grassld.Soc. 10:240
The Effect of Sheep Excreta and Fertilizer Treatments on the Nutrient Status of Pasture Soil.

Worden, Sellers and Tribe (1963) "Animal Health, Production and Pasture."

APPENDIX

N.B. Probability levels in Analyses of Variance are;

+ p 0.10

* p 0.05

** p 0.01

Appendix - Chapter Two

2.1 Measurements made on Dung Patches Chosen at Random

(Each patch was labelled with numbered, plastic disc) Type (T) = D = discrete S = scattered. Area (A) in sq. inches. Consistency (c) on 1-5 scale. 1 = liquid. 5 = firm

Mitchell's Farm - Winter

Paddock	I			II			III			IV		
Number of Patch	A	C	T	A	C	T	A	C	T	A	C	T
1	71	3	D	180	2	S	75	3	D	111	4	D
2	72	4	D	83	4	D	107	4	D	232	3	S
3	79	4	D	152	2	D	86	4	D	204	3	S
4	56	3	S	88	3	D	84	3	D	164	4	D
5	143	4	D	80	3	S	82	3	D	328	2	D
6	92	4	D	160	4	D	101	2	S	80	4	D
7	68	3	S	110	3	D	116	4	D	140	3	S
8	100	3	D	200	3	S	116	4	D	54	4	D
9	212	3	S	108	3	D	240	2	S	124	3	D
10	104	4	D	118	2	D	187	3	D	44	3	D
11	156	3	D	96	4	D	176	3	S	74	4	D
12	148	3	S	84	5	D	51	3	D	102	3	S
13	172	2	D	64	3	S	192	3	S	110	4	D
14	308	2	D	100	3	D	188	3	S	42	3	D
15	68			196	3	S	128	1	S	104	3	D
16	84	4	D	82	4	D	128	3	D	136	3	S
17	124	3	S	100	4	D	74	4	D	152	3	D
18	72	3	D	72	5	D	100	3	S	92	3	D
19	78	3	D	87	4	D	166	3	D	74	3	D
20		3	D	62	3	D	64	3	D	128	2	S
21		3	S	114	3	D	106	3	S		2	S
22	68	3	S	84	2	S	70	5	D	132	3	D
23	58	4	D	84	3	S	236	3	S	92	3	S
24		2	S	128	3	S	100	3	S	103	4	D
25	96	3	D	72	3	D	104	2	D	280	1	S
26	60	4	D	96	4	D	104	2	S	104	3	D
27	82	4	D	63	3	D	96	3	D	128	3	D
28	86	3	D	80	3	D	244	3	S	99	4	S
29	88	3	D	36	4	D	136	3	S	188	3	D
30	112	2	S	86	3	S	114	3	D	132	3	D
31	111	3	D	54	3	D	64	2	S	68	4	S
32	82	4	D	51	4	D	160	2	S	73	3	D
33	67	3	D	58	3	D	58	3	D	176	2	D
34	128	3	S	128	3	S	140	4	D	102	3	D
35	97	3	D	72	3	D	68	3	D	98	3	D
36	23	2	S	100	2	D	95	3	D	152	3	D
37	52	4	D	288	2	S	40	4	D	58	4	D
38	100	3	D	64	4	D	142	4	D	152	3	S
39	216	3		220	4	D	130	4	D	144	3	D
40	68	5	D	114	3	S	122	4	D	118	4	S
41	54	4	D	55	3	S	88	4	D	102	4	D
42	52	4	D	174	3	S	79	3	D	128	3	D
43	104	3	D	54	3	S	84	3	D	122	3	S
44	108	3	D	60	3	D	52	4	D	76	4	D
45	76	5	D	84	4	S	172	3	D	102	2	D
46	132	2	D	72	3	D	96	3	D	164	2	D
47	136	4	S	98	4	D	90	4	D	114	4	D
48	151	4	D	92	3	S	96	2	D	160	3	D
49	68	2	D	32	4	D	100	3	D	105	4	D
50	100	4	S	114	2	D	74	3	S	96	4	D
Mean	99.6			100.9			114.6			123.7		
SE	7.5			7.1			6.8			7.8		

No. 3 Dairy Unit - Massey University

	Spring									Summer					
Paddock	I			II			III			I			II		
Number of Patch	A	C	T	A	C	T	A	C	T	A	C	T	A	C	T
1	176	3	D	132	2	S	276	2	S	100	3	D	168	3	D
2	104	2	D	124	3	D	128	2	S	48	3	D	132	3	D
3	76	2	S	124	3	D	88	3	D	208	4	D	92	3	D
4	140	2	D	110	2	S	92	3	D	128	3	D	70	3	D
5	60	2	S	108	3	S	120	2	S	112	4	D	84	4	S
6	100	2	D	100	2	D	80	2	D	90	3	D	112	4	D
7	152	2	S	180	2	D	152	1	D	60	4	D	228	2	D
8	126	2	D	105	3	D	86	3	D	48	4	D	164	3	D
9	96	2	S	80	2	S	54	3	D	120	4	D	104	3	D
10		2	S	112	2	D	76	2	S	92	3	D	156	4	S
11	92	3	D	86	2	D	244	1	D	120	2	S	72	3	D
12	166	2	S	227	1	D	96	2	D	176	2	D	72	3	D
13	76	2	D	135	2	D	116	2	S	192	2	D	100	4	D
14	110	2	S	100	3	D	178	2	S	64	4	D	76	4	D
15	76	3	D	112	2	S	116	2	D	106	3	D	92	3	D
16	44	2	D	100	2	D	138	3	D	48	3	D	132	3	D
17	108	2	D	80	3	D	228	2	S	248	3	D	116	2	D
18	154	1	D	100	2	S	188	1	D	116	3	D	152	3	D
19	100	2	S	156	2	D	80	3	S	50	3	D	124	5	D
20	92	3	D	196	2	S	108	2	D	56	4	D	92	2	S
21	201	2	D	104	2	S	124	2	D	104	3	D	172	2	D
22	116	3	D	72	2	S	92	3	D	112	3	D	160	4	D
23	128	3	D	248	2	D	88	2	S	102	3	D	84	3	D
24	80	3	D	48	3	D		2	D	76	3	D	180	3	D
25	230	2	D	156	2	S	120	2	D	70	4	D	48	3	D
26	125	2	D	60	2	D	72	2	S	132	3	D	68	3	D
27	72	3	D	70	3	S	100	2	S	220	2	S	76	3	D
28	96	2	D	140	2	S	170	1	D	128	4	D	68	4	S
29	60	2	S	200	2	D	88	2	D	124	3	D	188	3	D
30	88	3	D	76	3	S	120	1	S	44	4	D	212	3	D
31	88	2	D	112	2	D	128	3	D	92	3	D	120	3	D
32	130	1	S	90	2	S	128	1	D	132	3	S	76	3	D
33	62	2	D	145	2	D	128	3	D	104	3	D	138	2	D
34	42	4	D	204	2	D	92	2	S	240	2	S	84	3	D
35	152	2	D	100	2	S	142	2	D	168	3	D	104	3	D
36	196	2	D	56	3	S	116	3	D	88	3	D	108	4	D
37	90	2	D	74	3	D	84	3	D	68	4	D	88	4	D
38	108	2	D	120	1	S	104	2	D	112	4	D	100	2	D
39	160	2	D	72	2	D	276	2	D	104	2	D	160	3	D
40	170	1	S	130	2	D	200	2	S	96	3	D	216	3	D
Mean	113.7			118.6			121.6			112.4			117.4		
SE	7.1			7.5			8.8			8.3			7.9		

Appendix - Chapter Three

3.1

Approximate Degrees of Freedom

Calculation of approximate degrees of freedom used for seeking the required F-value for the Treatment source of variation in the general analysis of the herbage data (Table 3.1).

$$n_1 = \frac{(T + BTR)^2}{\frac{T^2}{f_T} + \frac{BTR}{f_{BTR}}} \qquad n_2 = \frac{(BT + TR)^2}{\frac{BT^2}{f_{BT}} + \frac{TR^2}{f_{TR}}}$$

n = estimated degrees of freedom (df).
T, Tr, Bt and BTR = appropriate mean square values. (Table 3.2)
f = df of respective mean squares.

The F-test becomes $T + BTR > BT + TR$ for $n1/n_2$ df.

3.2

Least Significant Difference (LSD)

The LSD between means was calculated according to the equation

$$LSD\begin{pmatrix}0.05\\0.01\end{pmatrix} = t\begin{pmatrix}0.05\\0.01\end{pmatrix} \text{df EMS} \left(\frac{2 \cdot EMS}{n}\right)^{\frac{1}{2}}$$

Where t = the appropriate t-value for the df in the Error Mean Square (EMS) at the 5% (0.05) and 1% (0.01) level of probability.

EMS in each case was the denominator of the F-ratio.

n = no. of items per mean.

Unless otherwise stated, all LSD's on graphs are those for 5% level of probability.

3.3

Coefficient of variation: (CV):

The CV for the whole experiment was obtained from the analysis of variance of the transformed data (App 3.)

If $s^2 (\log_e x)$ is the mean square of the estimate of individual values

Then

$s^2 (\log_e \bar{x}) = 0.07413$

$s (\log_c \bar{x}) = 0.2725$

Antilog of 0.2725 = 1.31

Interpreting this, one standard deviation in the logarithms of the herbage weights corresponds to a percentage standard deviation of 1.31 in the original harvest, i.e. the coefficient of variation is 31%.

Analysis of Variance of Total Dry Weight of Herbage (TDM) for the Whole Experiment I

Transformation of Data $X = \log_c X$

Where X = individual herbage weight. (lbs/ac)

Blocks 4 Harvests 9 Treatments 3 Rings 3

Source of Variation	df	Mean Square	F-ratio	Result
Blocks	3	0.35768	13.41	* *
Harvest	8	7.16369	268	* *
Error 1	24	0.02667		
Treatment	2	0.09937	9.60	* *
T x H	16	0.04455	4.30	*
Error 2	54	0.01035		
Rings	2	0.00331		
R x H	26	0.01262		
R x T	4	0.00629		
R x T x H	32	0.00840		
Error 3	162	0.04650		

Mean total Dry Weight of Herbage (TDM) lbs/ac (mean of 4 blocks) and Results of Analysis of Variance at each Harvest

Harvest	1	2	3	4	5	6	7	8	9	10
Ring 4A	2592	2392	2417	1931	2671	3114	3759	4300	5550	7483
B		2406	2372	1925	2664	3434	3943	4309	5289	7766
C		2089	2154	1967	2655	3454	4439	4713	6391	8298
3 A	2654	2380	2417	1933	2671	3114	3759	4300	5550	7491
B		2402	2072	2114	2891	2411	4134	4357	5196	6778
C		2093	2147	2073	3013	3497	4606	4666	6171	7346
2 A	2821	2355	2418	1939	2670	3114	3759	4302	5552	7489
B		2319	1939	2276	2701	3340	3985	4276	5491	7390
C		2201	2259	2320	3336	3571	4947	4500	5578	7294
LSD (0.05)		NS	175	151	223	NS	590	NS	835	NS
A mean		2376	2418	1935	2671	3115	3759	4301	5551	7448
B mean		23 76	2128	2105	2752	3396	4021	4314	5326	7312
C mean		2128	2187	2120	3002	2508	4664	4627	6047	2646
LSD (0.05)			101	89	130		342		485	

Analysis of Variance (TDM)

Source of Variation	df	2 MS	3 MS	4 MS	5 MS	6 MS	7 MS	8 MS	9 MS	10 MS
Block	3	12826	5307	111430	478633*	903591	2987914**	1181234*	2246680**	2471841**
Treatment	2	245876	281220	127477	355595	492677	2602398**	407580	1634472 **	335768
B x T	6	68263	28126	42964	49466	225181	199982	228199	102165	217947
Ring	2	71	44857	170811*	193844**	219	103751	26468	123972	1318871
B x R	6	45458	25425	6422	26831	94652	98969	52239	538529	541176
T x R	4	13690	83762**	42024**	164269**	11740	102406	15093	337047	478245
B x T x R	12	15678	13112	9727	21199	64324	40401	23018	169581	272225

3.6

Yield of Ryegrass Species (lbs/ac)
(Mean % 4 Blocks)

Harvest		1	3	5	7	9
Ring 4	A	501	522	741	1093	1280
	B		573	791	865	1662
	C		554	601	1561	1955
3	A	614	521	742	1129	1283
	B		464	848	999	1337
	C		620	643	1575	2487
2	A	646	523	738	1128	1284
	B		487	721	781	1363
	C		542	780	1862	1918
LSD (0.05)			NS	NS	630	370
A Mean			522	740	1117	1282
B Mean			508	786	882	1454
C Mean			572	675	1646	2120
LSD (0.05)					550	213

Analysis of Variance

Source of Variance	df	MS_3	MS_5	MS_7	MS_9
Block	3	116853	310544	2517363*	2411585
Treatment	2	13669	37639	1837016*	2351000
BT	6	44967	182144	365530	726432
Ring	2	3202	4666	15743	99605
B x R	6	21284	14708	70500	91433
T x R	4	8586	23347	53759	218211 *
B x T x R	12	13003	14592	37553	58236

3.7

Yield of Clover (Ac) Species (lbs/ac)

Mean of 4 Blocks

Harvest		1	3	5	7	9
Ring 4	A	504	501	804	1045	889
	B		665	596	909	731
	C		517	480	847	1068
3	A	633	502	803	1044	891
	B		512	651	922	1421
	C		486	807	902	855
2	A	556	499	799	1044	892
	B		550	679	1083	461
	C		448	668	924	731
LSD (0.05)			NS	NS	NS	NS
A	Mean		500	802	1045	890
B	Mean		576	642	972	871
C	Mean		484	652	891	885

Analysis of Variance

Source of Variation	df	MS_3	MS_5	MS_7	MS_9
B	3	8615	660551	777334	911020
T	2	28807	96480	71285	1194
BT	6	23430	395613	555940	473936
R	2	15131	51260	22329	393507
BR	6	9380	54324	22434	214032
RT	4	7523	31971	10769	351507
BTR	12	41656	35508	14894	216674

3.8

Yield of "Other Grass" Species (OG) (lbs/ac)
(Mean of 4 Blocks)

Harvest		1	3	5	7	9
Ring 4	A	486	540	573	509	611
	B		632	767	514	828
	C		510	925	588	496
3	A	538	539	572	506	611
	B		527	875	716	719
	C		528	1084	675	602
2	A	455	539	568	509	612
	B		469	787	732	920
	C		604	1110	709	495
LSD (0.05)			NS	NS	NS	NS
A Mean			539	571	508	612
B Mean			543	813	654	822
C Mean			547	1040	657	531

Analysis of Variance

Source of Variation	df	MS_3	MS_5	MS_7	MS_9
B	3	66112	268599	107263	973071
T	2	202	659322	86988	* 271239
BT	6	60481	162012	14573	395918
R	2	2843	26351	44192	3947
BR	6	28598	15798	22065	36471
RT	4	17299	13030	15179	26039
BTR	12	26781	16551	31635	28493

3.9

Yield of Total Grass Species (TGG) lbs/ac
(Mean of 4 Blocks)

Harvest		1	3	5	7	9
Ring 4	A	1018	1079	1477	2288	3930
	B		1264	1704	2657	3988
	C		1154	1653	3355	4413
3	A	1507	1079	1629	2287	3927
	B		1045	1847	2844	3774
	C		1245	1828	3418	4655
2	A	1238	1081	1475	2291	3928
	B		1051	1601	2529	4454
	C		1224	2318	3797	3910
LSD (0.05)			NS	284	320	538 (0.10)
A Mean			1081	1526	2289	3928
B Mean			1120	1717	2689	4072
C Mean			1208	1932	3524	4326

Analysis of Variance

Source of Variation	df	MS_3	MS_5	MS_7	MS_9
B	3	86832	241808	2684288 **	1105119
T	2	51012	495216	4770873 **	487393
BT	6	45801	340418	64409	231473
R	2	8227	120050*	32943	1375
BR	6	35478	25061	55926	330685
RT	4	31556	223801**	147322 *	529739 +
BTR	12	14058	34825	43627	182071

Yields from Regrowth Treatment (D) lbs/ac.

3.10 Duration of Patch at Time of Removal and Cutting of Plots = Duration (days). Ring = Diam. (ft.) of sampling ring

Duration - 3 days Harvest 2 for Treatment C

	Block	I	II	III	IV	Mean
Ring	4	3072	3301	3852	3333	3389
	3	3465	3382	3796	4088	3684
	2	2593	2979	4295	3314	3296
	1	2605	2140	2446	2568	2439

LSD (0.05) = 569

Duration - 6 days Harvest 3

	Block	I	II	III	IV	Mean
Ring	4	3292	3088	4485	4198	3766
	3	3578	3367	5320	4026	4073
	2	2409	3724	4997	4427	3889
	1	2018	3032	2947	2812	2703

LSD (0.05) = 795

Duration - 15 days Harvest 5

	Block	I	II	III	IV	Mean
Ring	4	3407	2831	3260	3950	3362
	3	4029	2740	3811	3859	3601
	2	5663	3351	5121	4620	4689
	1	2076	1076	1394	1969	1379

LSD (0.05) = 747

Duration - 25 days Harvest 7

	Block	I	II	III	IV	Mean
Ring	4	3329	2815	2615	3468	3057
	3	3799	2735	3095	4151	3446
	2	5732	3227	4179	4569	4427
	1	342	369	220	391	305

LSD (0.05) = 764

Analysis of Variance of Treatment D for the 4 Harvests

Source of Variation	df.	3 MS	6 MS	15 MS	25 MS
Block	3	409787	1938707**	1057020*	977920*
Ring	3	1141568**	1520480*	7617540**	12467339**
Residual	9	127108	247347	218466	228379

Total Dry Weight of Herbage (TDM) beneath
Artificial (B) and Dung Patch (C)

3.11 TDM (gms) Treatment B

Block	I	II	III	IV	Mean
Harvest 1	32.70	31.80	33.90	30.80	32.10
2	35.10	29.20	31.80	27.50	31.10
3	10.10	9.40	8.50	9.20	9.30
4	5.45	7.95	5.01	8.26	6.67
5	6.31	7.58	7.35	5.11	6.59
6	2.56	3.69	4.70	3.30	3.56
7	2.73	3.64	3.71	2.94	3.25
8	1.94	3.12	2.45	2.43	2.48
9	3.38	3.31	2.40	4.96	3.51

Treatment C

	I	II	III	IV	Mean
1	32.70	31.80	33.90	30.80	32.10
2	23.20	17.20	16.90	22.60	19.90
3	8.30	3.60	7.00	9.20	7.00
4	6.62	5.19	7.37	6.87	6.51
5	1.87	4.04	3.62	7.54	4.24
6	1.92	1.84	3.54	3.30	2.6
7	1.12	0.82	2.2	3.16	1.90
8	0.40	0.62	2.27		0.82
9	1.59	1.28	2.37	2.19	1.86

The samples were hand-separated into clover petiole, grass leaf, grass stem and dead matter and were recorded similar to the two tables above. The results, mean of 4 Blocks i.e. shown in fig.3.7

3.12 Determination of Fibre Content of Dung
Using Acid Detergent

Reagents: Acid Detergent solution made adding 20 gm. cetyl trimethylammonium bromide (CTAB) to 1 litre $1NH_2SO_4$

Decalin - reagent grade decahydronapthalene

Acetone

Apparatus: Filters which were used were 100 ml sintered glass Pyrex funnels used for straining rumen liquor samples.

Method: Weigh 2gms of air dry sample into a 300 ml round or flat-bottomed flask. Add 100 ml acid detergent solution (room temperature) and 2 ml of Decalin. Fit flask to conventional reflux apparatus and heat to boiling in 5 - 10 minutes. Reflux gently for a further 60 mins. Remove flask, add approximately 5 gms of filter-aid. Filter hot, using light suction. Wash with acetone until filtrate is clear. Dry at 100°C for 8 hrs. and weigh. Ignite funnel in muffle furnace at 800°C for 2 hrs, cool in dessicator and weigh again.

Calculation:

$$\% \text{ Fibre content in Sample} = \frac{Wd - Wi}{s} \times 100$$

Wd = oven dry wt. of funnel

Wi = wt. ignited funnel

s = sample weight.

3.13

Level of "Water Available Nitrogen" (ppm) in Soil Samples taken Beneath and Around Dung Patch at 3",9",12" and 18" radii from Centre at Harvest 2,4,6,8,10

0.1" Depth

Harvest 2

Block	I	II	III	Mean
Radius 3"	411.6	516.6	443.8	
	460.1	497.0	441.0	461.6

Harvest 4

	I	II	III	Mean
3"	581.0	474.6	534.8	530.1
9"	520.8	457.8	498.4	492.3
12"	471.8	434.0	442.4	449.4
18"	382.2	380.8	400.4	387.8

LSD ($p<0.05$) = 46.3

Analysis of Variance

Source of Variation	df	MS	F-ratio
Block	2	2769	5.2 *
Radius	3	11192	20.8 **
Residual	6	537	

Harvest 6

3"	459.2	462.0	478.8	466.7
9"	449.4	452.2	455.0	452.2
12"	366.8	435.4	390.6	397.7
18"	379.4	401.8	392.0	391.1

LSD (0.05) = 33.8

Bl.	2	598	
Rad.	3	4364	15.2 **
Res.	6	287	

Harvest 8

3"	477.4	469.0	478.8	475.1
9"	420.0	436.8	429.8	428.9
12"	389.2	406.0	378.0	391.1
18"	417.2	413.0	417.2	415.8

LSD (0.05) = 18.8

Bl.	2	37	
Rad.	3	3729	41.9 **
Res.	6	89	

Harvest 10

3"	460.0	420.0	386.4	422.3
9"	379.4	361.2	344.4	361.7
12"	364.0	385.0	369.6	372.9
18"	378.0	379.4	364.0	373.8

LSD (0.05) = 36.0

Bl.	2	906	
Rad.	3	2189	6.76
Res.	6	324	

"Water Available Nitrogen" (ppm)

3.14

1 - 3" Depth

Analysis of Variance was only attempted where warranted

Harvest 2 Block	I	II	III	Mean
Radius 3"	257.6	380.9	315.0	
	288.4	369.6	322.0	322.2

Harvest 4	I	II	III	IV	Mean
3"	327.6	351.4	357.0	389.2	356.3
9"	336.0	354.2	397.6	351.4	359.8
12"	320.6	289.8	386.4	400.4	349.3
18"	322.0	308.0	350.0	362.6	335.6

Harvest 6					
3"	329.0	408.8	424.2	333.2	373.8
9"	334.6	337.4	326.2	329.0	331.8
12"	407.4	323.4	358.4	319.2	352.1
18"	271.6	329.0	294.0	291.2	296.1

Source of Variation	df	MS	F-ratio
Block	3	927	
Radius	3	4325	3.4 (3.63)
Residual	9	1270	

Harvest 8					
3"	329.0	271.6	362.6	259.0	296.5
9"	357.0	317.8	330.4	309.4	328.7
12"	315.0	332.2	305.2	308.0	315.4
18"	312.2	316.4	314.8	319.2	316.4

Harvest 10					
3"	266.0	277.2	280.0	254.8	269.5
9"	296.8	275.8	271.6	245.0	272.4
12"	280.0	247.8	238.0	252.0	254.5
18"	288.4	257.6	268.8	239.4	263.3

3.15

Levels of "Available Phosphorus" (ppm) in Soil Samples
Taken Beneath and Around Dung Patch at 3",9",12", and 18"
radii from Centre at Harvest 2, 4, 6, 8, 10

0 - 1" Depth

Pre-experimental Level = 82.5 ± 9.8 ppm

Harvest 2

Block	I	II	III	IV	Mean
Radius 3"	115	97	61	74	87

Harvest 4

	I	II	III	IV	Mean
3"	85	129	118	134	116
9"	79	75	120	103	94
12"	61	82	97	72	78
18"	63	64	62	87	69

LSD ($p<0.05$) = 23

Analysis of Variance

Source of Variation	df	MS	F-ratio
Block	3	661	
Radius	3	1405	6.47 *
Residual	9	217	

Harvest 6

	I	II	III	IV	Mean
3"	88	78	137	113	104
9"	113	74	134	79	100
12"	58	77	117	89	85
18"	65	68	142	78	88

Source of Variation	df	MS	F-ratio
Bl.	3	2745	11.8 *
Rad.	3	327	1.4 NS
Res.	9	232	

Harvest 8

	I	II	III	IV	Mean
3"	139	94	74	63	93
9"	55	71	59	59	61
12"	74	69	43	57	61
18"	65	57	46	56	56

LSD (0.05) = 25

Source of Variation	df	MS	F-ratio
Bl.	3	662	
Rad.	3	1127	4.41 *
Res.	9	255	

Harvest 10

	I	II	III	IV	Mean
3"	108	77	191	106	121
9"	74	65	159	123	105
12"	52	71	115	129	92
18"	46	63	117	199	106

Source of Variation	df	MS	F-ratio
Bl.	3	7108	6.48 *
Rad.	3	552	0.5 NS
Res.	9	1096	

3.16

Levels of "Exchangeable Potassium" (ppm) in Soil Samples at 3", 9", 12" 18" radii, from Centre of Dung Patch outwards

0 - 1" Depth

Pre-experimental Level = 229 ± 4 ppm

Harvest 2 - Level 3" radius (beneath patch) = 433 ± 6 ppm

Harvest 4

Block		I	II	III	IV	Mean
Radius	3"	436	550	760	900	8.661
	9"	160	120	270	244	199
	12"	116	192	288	296	223
	18"	136	134	249	240	187

LSD ($p<0.05$) = 112

Analysis of Variance

Source of Variation	df	MS	F-ratio
Block	3	42017	7.3 **
Radius	3	211101	36 **
Residual	9	5738	

Harvest 6

	I	II	III	IV	Mean
3"	396	426	356	448	406
9"	244	196	222	168	207
12"	148	154	212	180	173
18"	140	128	260	216	186

LSD (0.05) = 76

Source of Variation	df	MS	F-ratio
Bl.	3	1186	
Rad.	3	48095	23 **
Res.	9	2094	

Harvest 8

	I	II	III	IV	Mean
3"	900	424	224	536	521
9"	100	214	194	216	181
12"	102	236	144	302	196
18"	104	240	148	328	205

LSD (0.05) = 265

Source of Variation	df	MS	F-ratio
Bl.	3	20250	
Rad.	3	107321	3.96 *
Res.	9	27106	

Harvest 10

	I	II	III	IV	Mean
3"	532	572	1040	488	658
9"	176	184	732	340	358
12"	120	204	396	362	270
18"	114	168	200	272	203

LSD (0.05) = 205

Source of Variation	df	MS	F-ratio
Bl.	3	109331	6.9 *
Rad.	3	160914	10.2 **
Res.	9	15784	

3.17 Levels of Exchangeable Potassium

1 - 3" Depth

Harvest 2

Block	I	II	III	IV	Mean
Radius 3"	155	127	112	141	134

Harvest 4

3"	90	120	220	185	154
9"	100	90	165	130	121

Harvest 6

3"	115	105	135	110	116
9"	135	95	115	115	115

Harvest 8

3"	105	125	80	185	124
9"	105	110	80	126	105

Harvest 10

3"	80	140	345	110	169
9"	70	95	315	100	145

Analysis of Variance

Source of Variation	df	MS	F-ratio
Block	3	4194	
Radius	1	2111	4.5 NS
Res.	3	471	

3.18

Number of Tillers Counted in Cores (2in) taken from beneath Patches (B,C) and in Control Plots (A)

Harvest 1 - Pretreatment. (5 cores/plot)

Block	Treatment A					B					C				
I	18	8	19	14	15	20	2	16	18	10	10	11	15	8	21
II	10	9	13	9	15	8	15	15	8	11	3	16	28	15	9
III	8	8	21	5	4	14	37	23	0	11	60	24	8	6	12
IV	23	11	11	27	11	8	7	33	17	13	7	14	8	10	9
Mean	12.9					13.9					19.7				

Harvest 2 - 3 cores/patch (plot)

	A			B			C		
I	14	27	15	29	16	11	13	18	20
II	7	16	12	26	8	14	46	33	20
III	7	8	10	7	10	14	42	24	5
IV	18	31	16	14	10	12	19	20	11
Mean	15.1			14.2			22.6		

Harvest 3

	A			B			C		
I	14	6	7	16	6	18	17	23	12
II	38	13	26	10	2	13	26	28	11
III	17	16	32	20	16	4	19	21	21
IV	13	2	28	20	5	14	6	3	10
Mean	17.7			12.0			16.5		

Harvest 4

	A			B			C		
I	26	42	17	10	17	22	21	6	11
II	23	27	5	11	11	16	14	11	9
III	7	20	14	4	6	13	9	17	0
IV	26	26	37	23	21	11	0	28	35
Mean	22.6			13.8			13.4		

Harvest 5

	A			B			C		
I	16	19	19	9	14	30	12	6	23
II	16	10	15	7	9	7	7	4	6
III	22	32	52	11	21	11	6	8	7
IV	9	8	29	7	15	18	4	1	7
Mean	20.6			13.3			7.6		

Harvest 6

	A			B			C		
I	15	19	24	17	9	6	6	8	16
II	17	12	13	13	11	15	9	9	3
III	7	11	21	5	5	6	13	13	9
IV	10	8	7	5	4	4	10	16	20
Mean	13.7			8.3			11.0		

Harvest 7

	A			B			C		
I	9	13	23	6	10	6	5	5	6
II	12	15	5	8	5	4	3	0	6
III	14	16	9	4	4	15	8	7	4
IV	21	9	6	16	4	6	5	6	13
Mean	12.7			5.8			2.3		

Number of Rooted Nodes on Stolons from Cores taken beneath Patches (B,C) and in Control Plots (A)

Harvest 1 - Pretreatment (5 cores/plot)

	A					B					C				
I	18	16	24	11	22	5	21	24	55	52	33	6	12	13	30
II	15	6	8	0	0	4	5	11	12	5	11	10	21	16	30
III	36	31	45	10	25	5	2	23	0	4	0	0	19	31	11
IV	15	2	9	8	0	26	21	13	5	4	8	8	25	18	13
Mean	15.0					15.3					15.7				

Harvest 2 - (3/patch (plot))

	A			B			C		
I	6	3	20	8	34	12	9	5	14
II	16	12	14	13	8	35	13	26	6
III	13	11	27	20	16	12	23	15	7
IV	7	21	7	39	19	17	17	18	2
Mean	13.1			19.4			13.0		

Harvest 3

	A			B			C		
I	27	33	24	18	6	21	9	11	12
II	3	26	0	15	9	16	35	15	14
III	14	22	6	27	12	29	19	5	19
IV	21	15	17	18	2	20	8	8	3
Mean	17.4			16.1			13.2		

Harvest 4

	A			B			C		
I	2	4	17	9	11	0	0	0	0
II	10	16	36	8	9	6	13	14	9
III	40	12	22	22	33	18	0	0	2
IV	12	12	0	12	23	30	0	6	3
Mean	15.2			15.1			3.9		

Harvest 5

	A			B			C		
I	23	28	12	8	14	0	0	4	13
II	7	31	12	0	14	0	0	4	13
III	13	22	5	3	4	9	0	12	0
IV	26	19	15	3	6	19	0	0	0
Mean	17.7			6.7			6.1		

Harvest 6

	A			B			C		
I	19	21	29	3	5	12	0	0	0
II	32	33	16	4	7	15	2	0	0
III	18	20	15	0	0	0	15	12	13
IV	60	40	12	0	2	0	5	14	4
Mean	26.2			4.0			5.4		

Harvest 7

	A			B			C		
I	7	16	6	0	8	0	0	0	0
II	25	21	4	5	9	2	0	0	0
III	22	11	34	2	0	7	4	7	0
IV	15	14	24	0	0	4	3	4	3
Mean	17.4			1.7			0.3		

Raw Data for the Herbage in Ecological Experiment No. I (Chap 3)

Key to Identification: (e.g.)

Harvest	Total Dry Matter	Ring Sample	Treatment	Block Yields (lbs/ac) I	II	III	IV	Mean
2	TDM	4	A	2369	2298	2665	2236	2392

Harvest : 1 - 10

Component: TDM = Total Dry Matter
RYE = Ryegrass Species
CF = Cocksfoot
FOG = Yorkshire Fog
OG = Other Grass Species
TGG = Total of the above 4 Grass Components (Total Grasses)
WDS = Weed Species
AC = Clover Species
DM = Dead Matter

Ring: 4 = 4ft. Diameter Ring
3 = 3ft. " "
2 = 2ft. " "

Treatment: A = Control
B = Artificial Patch
C = Dung Patch

Total Dry Matter

1TDM A	2237	2495	2751	2886	2592
1TDM B	2360	2494	2874	2886	2654
1TDM C	2335	2776	3399	2874	2821
2TDM4A	2369	2298	2665	2236	2392
2TDM4B	2514	2404	2475	2234	2406
2TDM4C	2255	1943	1926	2234	2089
2TDM3A	2373	2299	2636	2212	2380
2TDM3B	2510	2400	2469	2230	2402
2TDM3C	2251	1941	1950	2230	2093
2TDM2A	2372	2298	2514	2238	2355
2TDM2B	2215	2693	2027	2339	2319
2TDM2C	2068	2514	2027	2197	2201
3TDM4A	2493	2397	2456	2323	2417
3TDM4B	2371	2521	2236	2360	2372
3TDM4C	2193	2326	2039	2057	2154
3TDM3A	2492	2397	2457	2322	2417
3TDM3B	2102	2012	2015	2158	2072
3TDM3C	2057	2072	2072	2385	2147
3TDM2A	2496	2395	2459	2321	2418
3TDM2B	1797	2018	1884	2059	1939
3TDM2C	2041	2018	2450	2528	2259
4TDM4A	1748	1993	2174	1809	1931
4TDM4B	1858	1761	2023	2057	1925
4TDM4C	1826	1943	2222	1878	1967
4TDM3A	1747	1991	2176	1816	1933
4TDM3B	1926	1935	2224	2370	2114
4TDM3C	2081	2108	2057	2045	2073
4TDM2A	1746	2018	2178	1815	1939
4TDM2B	2036	2280	2454	2335	2276
4TDM2C	2312	2390	2220	2358	2320
5TDM4A	2275	2592	2787	3032	2671
5TDM4B	2390	2757	2667	2842	2664
5TDM4C	2610	2748	2463	2800	2655
5TDM3A	2275	2591	2788	3032	2671
5TDM3B	2445	2990	2916	3211	2891
5TDM3C	2716	2901	2999	3435	3013
5TDM2A	2275	2592	2785	3029	2670
5TDM2B	2730	2657	2509	2909	2701
5TDM2C	3112	3691	2965	3576	3336
6TDM4A	2908	2812	3154	3583	3114
6TDM4B	2844	3450	3927	3516	3434
6TDM4C	2913	3856	3445	3601	3454
6TDM3A	2910	2812	3154	3581	3114
6TDM3B	2382	3474	4234	3554	3411
6TDM3C	2639	3772	3682	3897	3497
6TDM2A	2909	2813	3153	3581	3114
6TDM2B	2859	3548	3539	3415	3340
6TDM2C	3709	3355	3847	3374	3571

7TDM4A	2764	3704	4303	4266	3759
7TDM4B	3131	3810	4156	4675	3943
7TDM4C	3381	4592	4856	4927	4439
7TDM3A	2764	3703	4303	4267	3759
7TDM3B	3533	3706	4642	4654	4134
7TDM3C	3685	4789	4997	4953	4606
7TDM2A	2762	3705	4302	4266	3759
7TDM2B	3755	3337	3990	4859	3985
7TDM2C	4615	5171	4721	5281	4947
8TDM4A	3716	4255	4828	4402	4300
8TDM4B	3927	4191	4237	4881	4309
8TDM4C	4179	4725	4452	5494	4713
8TDM3A	3715	4255	4827	4401	4300
8TDM3B	4001	4085	4297	5045	4357
8TDM3C	4386	4932	4207	5140	4666
8TDM2A	3718	4256	4831	4403	4302
8TDM2B	3760	4114	4652	4578	4276
8TDM2C	3976	4652	4606	4767	4500
9TDM4A	5000	5647	5501	6051	5550
9TDM4B	3748	5335	5739	6333	5289
9TDM4C	5039	6524	6528	7473	6391
9TDM3A	5000	5647	5501	6050	5550
9TDM3B	4291	5841	5406	5248	5196
9TDM3C	5000	6497	6122	7064	6171
9TDM2A	5001	5649	5502	6054	5552
9TDM2B	5360	5994	5488	5121	5491
9TDM2C	5948	5668	5364	5332	5578
0TDM4A	7200	7352	7689	7689	7483
0TDM4B	6620	8001	7889	8556	7766
0TDM4C	7753	8056	8735	8648	8298
0TDM3A	7201	7383	7690	7690	7491
0TDM3B	6107	7449	7541	6014	6778
0TDM3C	6083	7460	8937	6903	7346
0TDM2A	7203	7373	7690	7690	7489
0TDM2B	6228	6546	8205	8582	7390
0TDM2C	6615	6992	7313	8256	7294

Ryegrass Species

1RYE C	452	599	465	489	501
1RYE B	208	403	1039	807	614
1RYE C	587	1064	1052	489	798
3RYE4A	472	238	541	837	522
3RYE4B	734	403	447	708	573
3RYE4C	548	605	509	555	554
3RYE3A	474	238	539	834	521
3RYE3B	336	542	542	432	463
3RYE3C	596	620	477	787	620
3RYE2A	473	239	542	836	522
3RYE2B	340	344	772	491	487
3RYE2C	386	464	712	606	542

5RYE4A	431	880	835	818	741
5RYE4B	573	1296	612	681	790
5RYE4C	364	633	369	1036	601
5RYE3A	432	879	834	820	741
5RYE3B	563	1437	554	834	847
5RYE3C	489	492	632	960	643
5RYE2A	432	864	836	818	737
5RYE2B	602	1066	399	813	720
5RYE2C	593	404	979	1144	780
7RYE4A	497	711	1032	2133	1093
7RYE4B	658	571	830	1401	865
7RYE4C	642	1977	1603	2021	1561
7RYE3A	497	852	1031	2135	1129
7RYE3B	635	667	1300	1395	999
7RYE3C	775	1294	2349	1881	1575
7RYE2A	496	850	1034	2133	1128
7RYE2B	376	367	1314	1066	781
7RYE2C	735	1811	2546	2114	1802
9RYE4A	688	1016	2144	1270	1280
9RYE4B	862	1975	1722	2089	1662
9RYE4C	1208	1826	2023	2764	1955
9RYE3A	700	1016	2144	1270	1283
9RYE3B	814	1344	1297	1890	1336
9RYE3C	1300	1950	2388	4308	2486
9RYE2A	698	1015	2146	1273	1283
9RYE2B	1015	1319	1480	1636	1363
9RYE2C	1484	1645	1608	2932	1918

Clover Species

1 AC A	355	770	318	575	504
1 AC B	428	526	746	831	633
1 AC C	403	24	1052	746	556
3 AC4A	548	383	516	557	501
3 AC4B	734	353	1007	566	665
3 AC4C	394	837	509	328	517
3 AC3A	548	384	515	557	501
3 AC3B	587	584	444	432	512
3 AC3C	453	372	497	620	486
3 AC2A	547	381	514	556	499
3 AC2B	593	707	303	597	550
3 AC2C	285	422	758	326	448
5 AC4A	364	527	835	1486	803
5 AC4B	309	302	747	1023	595
5 AC4C	470	851	321	277	480
5 AC3A	363	527	834	1485	802
5 AC3B	342	268	933	1058	650
5 AC3C	298	987	1532	411	807
5 AC2A	363	514	836	1484	799
5 AC2B	409	317	1002	988	679
5 AC2C	652	588	1186	248	668

7 AC4A	525	481	2064	1110	1045
7 AC4B	658	724	1039	1215	909
7 AC4C	506	926	1117	837	847
7 AC3A	524	480	2066	1109	1045
7 AC3B	990	703	927	1070	922
7 AC3C	772	1195	948	691	902
7 AC2A	524	482	2064	1107	1044
7 AC2B	1052	666	1158	1457	1083
7 AC2C	969	1190	850	684	923
9 AC4A	389	509	1869	786	888
9 AC4B	337	266	802	1520	731
9 AC4C	403	1238	913	1718	1068
9 AC3A	399	506	1869	787	890
9 AC3B	685	2916	1189	891	1420
9 AC3C	650	715	855	1201	855
9 AC2A	399	510	1870	786	891
9 AC2B	376	298	657	510	460
9 AC2C	533	680	965	744	730

Cocksfoot

1 CF A	0	49	85	0	31
1 CF B	0	92	109	146	88
1 CF C	35	24	36	232	83
3 CF4A	68	121	45	45	70
3 CF4B	0	100	66	94	65
3 CF4C	87	45	121	144	99
3 CF3A	74	119	47	47	72
3 CF3B	0	59	220	65	86
3 CF3C	101	62	62	214	110
3 CF2A	78	119	50	45	73
3 CF2B	0	179	170	0	87
3 CF2C	101	119	96	91	102
5 CF4A	45	151	194	272	166
5 CF4B	0	247	185	199	158
5 CF4C	130	82	172	139	131
5 CF3A	44	152	193	271	165
5 CF3B	0	268	202	0	117
5 CF3C	0	146	268	241	164
5 CF2A	41	147	193	271	163
5 CF2B	0	0	174	147	80
5 CF2C	124	1218	147	395	471
7 CF4A	27	222	256	169	169
7 CF4B	32	190	250	467	235
7 CF4C	169	321	825	541	464
7 CF3A	26	220	259	169	169
7 CF3B	0	149	602	372	281
7 CF3C	184	623	399	247	363
7 CF2A	27	220	257	170	168
7 CF2B	73	202	556	340	293
7 CF2C	229	827	330	684	518

9 CF4A	45	621	495	786	487
9 CF4B	0	640	344	633	404
9 CF4C	100	392	653	224	342
9 CF3A	50	620	495	787	488
9 CF3B	0	584	432	524	385
9 CF3C	250	650	122	495	379
9 CF2A	50	625	496	786	489
9 CF2B	4	119	657	717	374
9 CF2C	239	0	537	266	260
			Other Grasses		
1 OG A	514	697	501	232	486
1 OG B	452	403	721	572	538
1 OG C	379	489	403	550	455
3 OG4A	548	743	541	325	539
3 OG4B	497	1082	403	543	631
3 OG4C	745	534	162	596	509
3 OG3A	548	742	539	325	538
3 OG3B	483	402	444	778	527
3 OG3C	512	456	641	500	527
3 OG2A	547	740	542	326	538
3 OG2B	537	524	340	473	468
3 OG2C	671	542	294	910	604
5 OG4A	887	679	724	0	572
5 OG4B	963	523	986	596	767
5 OG4C	991	961	910	839	925
5 OG3A	885	679	724	0	572
5 OG3B	831	837	963	867	875
5 OG3C	1276	1130	867	1064	1084
5 OG2A	887	666	721	0	568
5 OG2B	873	878	855	583	797
5 OG2C	1429	1071	652	1287	1110
7 OG4A	470	408	688	470	509
7 OG4B	344	610	541	559	513
7 OG4C	575	412	922	442	588
7 OG3A	468	399	688	468	506
7 OG3B	530	518	1115	697	715
7 OG3C	480	527	650	1040	674
7 OG2A	468	409	689	468	509
7 OG2B	638	602	717	969	732
7 OG2C	923	570	657	684	709
9 OG4A	1250	564	330	302	611
9 OG4B	1874	318	802	316	828
9 OG4C	454	456	325	747	496
9 OG3A	1249	563	331	301	611
9 OG3B	1243	348	811	471	718
9 OG3C	450	1168	366	423	602
9 OG2A	1250	565	330	303	612
9 OG2B	1875	478	767	560	920
9 OG2C	597	795	160	427	495

Dead Matter

3 DM4A	623	529	564	557	568
3 DM4B	346	403	291	376	354
3 DM4C	350	279	633	348	403
3 DM3A	623	527	563	557	568
3 DM3B	336	322	381	453	373
3 DM3C	390	560	414	214	395
3 DM2A	625	528	565	556	568
3 DM2B	124	220	317	349	252
3 DM2C	386	422	418	556	445
5 DM4A	229	137	0	181	137
5 DM4B	263	137	160	0	140
5 DM4C	240	165	344	447	299
5 DM3A	226	140	0	178	136
5 DM3B	342	89	86	223	185
5 DM3C	0	146	0	754	225
5 DM2A	225	128	0	179	133
5 DM2B	436	372	45	0	213
5 DM2C	0	220	0	395	153
7 DM4A	220	149	0	169	134
7 DM4B	155	190	250	233	207
7 DM4C	201	45	0	295	135
7 DM3A	220	149	0	169	134
7 DM3B	35	149	140	0	81
7 DM3C	146	143	348	196	208
7 DM2A	225	147	0	170	135
7 DM2B	151	202	0	0	88
7 DM2C	0	101	188	50	85
9 DM4A	449	1016	20	605	523
9 DM4B	300	318	516	316	363
9 DM4C	353	456	325	1344	619
9 DM3A	450	1016	110	605	545
9 DM3B	41	700	378	578	424
9 DM3C	301	584	489	438	453
9 DM2A	450	1015	110	606	545
9 DM2B	376	1351	220	358	576
9 DM2C	418	960	859	321	640

Weed Species

1WDS A	122	219	85	0	107
1WDS B	378	0	0	85	116
1WDS C	354	451	36	110	238
3WDS4A	224	479	369	0	268
3WDS4B	403	201	0	94	174
3WDS4C	87	45	121	61	79
3WDS3A	223	480	369	0	268
3WDS3B	378	59	0	128	141
3WDS3C	41	0	41	0	20
3WDS2A	225	478	367	0	267
3WDS2B	197	0	0	142	85
3WDS2C	243	0	197	124	141

5WDS4A	318	151	194	272	234
5WDS4B	309	220	0	369	224
5WDS4C	392	110	344	513	340
5WDS3A	325	152	193	271	235
5WDS3B	342	89	175	223	207
5WDS3C	298	0	0	68	91
5WDS2A	317	147	193	271	232
5WDS2B	409	0	45	376	208
5WDS2C	372	220	45	142	195
7WDS4A	525	555	0	84	291
7WDS4B	217	0	291	94	150
7WDS4C	305	0	0	146	112
7WDS3A	524	554	0	86	291
7WDS3B	423	369	0	325	279
7WDS3C	256	0	0	50	76
7WDS2A	524	556	0	87	291
7WDS2B	675	0	0	340	253
7WDS2C	459	0	0	105	141
9WDS4A	449	112	0	181	185
9WDS4B	412	160	0	252	206
9WDS4C	805	130	194	298	357
9WDS3A	450	113	0	181	186
9WDS3B	169	408	0	0	144
9WDS3C	500	193	429	0	281
9WDS2A	450	114	0	179	186
9WDS2B	160	59	55	50	81
9WDS2C	772	0	266	427	366

Yorkshire Fog

7FOG4A	497	1036	215	84	458
7FOG4B	1002	1257	1039	607	976
7FOG4C	979	825	387	688	720
7FOG3A	497	1037	214	86	459
7FOG3B	918	1222	557	837	884
7FOG3C	1067	1052	301	840	815
7FOG2A	496	1038	216	87	459
7FOG2B	790	1098	160	680	682
7FOG2C	1342	671	96	951	765
9FOG4A	1651	1750	566	2117	1521
9FOG4B	1011	1706	1550	1266	1383
9FOG4C	1713	2023	2023	224	1496
9FOG3A	1649	1750	548	2117	1516
9FOG3B	1329	1693	1350	840	1303
9FOG3C	1499	1300	1482	495	1194
9FOG2A	1650	1751	551	2119	1518
9FOG2B	1553	2698	1645	1176	1768
9FOG2C	1903	1870	965	211	1237

Total Grass Species

1TGG A	929	1369	1039	734	1018
1TGG B	990	2311	1492	1235	1507
1TGG C	685	868	1834	1565	1258
3TGG4A	1096	1007	1007	1208	1079
3TGG4B	1234	1562	938	1323	1264
3TGG4C	1360	1163	775	1319	1154
3TGG3A	1097	1004	1007	1207	1079
3TGG3B	799	1046	1189	1145	1045
3TGG3C	1171	1139	1118	1550	1244
3TGG2A	1098	1006	1011	1209	1081
3TGG2B	882	1089	1264	969	1051
3TGG2C	1126	1172	1075	1521	1223
5TGG4A	1362	1697	1757	1091	1477
5TGG4B	1511	2096	1759	1449	1704
5TGG4C	1514	1621	1454	2021	1652
5TGG3A	1962	1693	1759	1100	1628
5TGG3B	1416	2543	1720	1705	1846
5TGG3C	1875	1768	1467	2200	1827
5TGG2A	1369	1677	1756	1094	1474
5TGG2B	1475	1967	1415	1544	1600
5TGG2C	2087	2661	1733	2790	2318
7TGG4A	1493	2518	2238	2901	2288
7TGG4B	2099	2895	2576	3131	2675
7TGG4C	2367	3665	3739	3647	3354
7TGG3A	1493	2519	2236	2901	2287
7TGG3B	2084	2484	3548	3259	2844
7TGG3C	2510	3450	3700	4013	3418
7TGG2A	1489	2537	2238	2900	2291
7TGG2B	1875	2468	2712	3061	2529
7TGG2C	3185	3879	3682	4440	3797
9TGG4A	3711	4009	3521	4477	3930
9TGG4B	2697	4590	4420	4243	3988
9TGG4C	3477	4698	5094	4381	4413
9TGG3A	3700	4010	3521	4475	3927
9TGG3B	3393	4088	3837	3778	3774
9TGG3C	3548	5003	4347	5722	4655
9TGG2A	3700	4008	3521	4482	3928
9TGG2B	4445	4615	4555	4201	4454
9TGG2C	4224	4307	3273	3838	3910

Appendix - Chapter Four

Height of Herbage (Inches) recorded at Random fixed sites in each Paddock (Line Transect) - "Unaffected" Herbage

I Paddock - Blinkered Herd

Site	Initial	24	34	58
	Grazing Period (Hrs)			
1	1	1	1	1
2	5	1	1	1
3	5	4	2	2
4	4	1	1	1
5	10	10	6	1
6	5	1	1	1
7	5	2	2	1
8	7	5	1	1
9	6	1	1	1
10	4	4	3	1
11	4	1	1	1
12	8	8	5	4
13	3	1	1	1
14	10	1	1	1
15	4	1	1	1
16	7	6	1	1
17	6	3	2	2
18	6	4	4	3
19	2	1	1	1
20	2	1	1	1
21	9	1	1	1
22	6	1	1	1
23	6	2	1	1
24	4	3	3	2
25	1	1	1	1
26	6	1	1	1
27	4	1	1	1
28	8	1	1	1
29	7	1	1	1
30	8	1	1	1
31	5	5	5	2
32	6	1	1	1
33	7	1	1	1
34	7	7	2	1
35	5	2	1	1
36	7	1	1	1
37	3	1	1	1
38	7	7	4	1
Total	210	95	65	47
Mean	5.5	2.50	1.71	1.24
SE ±	0.36	0.39	0.22	0.10

II Control Herd

Site	Initial	24	34	58
	Grazing Period (Hrs)			
1	8	3	4	1
2	3	3	1	1
3	7	1	1	1
4	6	6	2	1
5	3	1	1	1
6	8	1	1	1
7	3	1	1	1
8	7	3	1	1
9	8	1	1	1
10	2	1	2	1
11	2	1	1	1
12	5	4	1	1
13	4	1	1	1
14	6	1	1	1
15	3	1	1	1
16	7	4	2	1
17	5	1	1	1
18	9	1	1	1
19	5	4	2	1
20	5	1	1	1
21	3	2	2	2
22	4	2	1	1
23	4	4	3	3
24	1	1	1	1
25	7	6	3	2
26	6	1	1	1
27	5	1	1	1
28	8	4	1	1
29	8	1	1	1
30	4	1	1	1
31	5	1	1	1
32	3	3	1	1
33	3	1	1	1
34	4	1	1	1
35	2	1	1	1
36	6	6	1	1
37	4	1	1	1
38	3	1	1	1
Total	186	78	50	42
Mean	4.9	2.00	1.31	1.11
SE ±	0.34	0.26	0.11	0.06

Analysis for Heights Mmts. of "Unaffected" Herbage

Source of Variation	df	ss	MS	F-ratio	
Blinkered V Control	1	12	12	4.7	*
Between Grazing Periods	3	770	257	67	**
Interaction	3	2	0.7		
Error	296	757	2.6		

4.2

Height of Herbage (Inches) surrounding Dung Patches in each Paddock - "Dung Patch" Herbage

Patch No.	I - Blinkered Herd, Grazing Period (hrs): Initial	24	34	58	II - Control Herd, Grazing Period (hrs): Initial	24	34	58
1	6	4P	3G	2G	5	5P	3G	3G
2	7	6N	4P	3P	7	5P	2G	2G
3	7	7	5G	3P	7	4P	4P	3G
4	7	5P	3G	2G	7	5P	5P	3G
5	7	7	5G	4G	5	5	4P	1G
6	8	4P	2G	2G	7	5P	3G	2G
7	7	6N	4G	4G	9	5P	3G	2G
8	8	2G	2G	2G	7	4P	5P	3P
9	7	6N	6P	6P	8	7N	7N	4G
10	7	5P	4P	2G	5	4N	3G	2G
11	7	7N	3P	2G	8	6P	3G	3G
12	7	7N	4P	3G	7	4P	4P	4P
13	6	5N	4P	2G	7	5P	5P	2G
14	8	8N	4P	3G	5	4P	3G	2G
15	6	5P	4P	3G	8	5P	4G	3G
16	6	4P	2G	2G	7	5P	2G	2G
17	6	5P	4P	4P	7	7	4P	3G
18	7	6N	4P	4P	7	4P	2G	2G
19	7	6N	4P	3G	7	4P	2G	2G
20	7	5P	5P	2G	9	6P	4P	4P
21	6	5N	3G	3G	8	6N	4P	3G
22	7	7	6P	4G	8	5P	3G	3G
23	5	2G	1G	1G	6	5N	5P	5P
24	7	6N	4P	2G	7	5P	4P	2G
25	7	6P	5P	5P	6	4P	1G	1G
26	8	4P	3G	4P	7	4P	3P	3G
27	3	2G	1G	1G	8	5P	4P	4P
28	8	8	5P	4P	6	3G	2G	2G
29	6	4P	1G	1G	5	3P	2G	1G
Total	193	154	105	83	202	137	100	76
Mean	6.65	5.3	3.62	2.86	6.96	4.72	3.44	2.62
SE ±	0.18	0.30	0.26	0.23	0.19	0.19	0.24	0.18
% U		14				7		
% N		38				13	3	
% P		38	55	27		76	42	17
% G		10	45	73		4	55	83

U = Ungrazed N = Nibbled P = Partially Grazed G = Grazed around patch

Analysis for Height Mmts of "Dung Patch" Herbage

Source of Variation	df	ss	MS	F-ratio
Blinkered V Control	1	2	2	
Between Grazing Periods	3	558	186	124 **
Interaction	3	6	2	
Error	225	336	1.5	

Appendix - Chapter Five

5.1 Total Dry Weight of Herbage (TDM) from Treatments A and B

Mean of 4 Blocks

Harvest		1	2	3	4
Treatment	A4	2634	3898	3572	3826
Ring	3	2683	4203	3646	4123
	2	2570	3808	3743	4041
	B4	2625	3641	3673	4166
	3	2730	4109	3834	4041
	2	3134	4550	5392	5137
LSD (0.05)			213	357	607

Analysis of Variance

Source of Variation	df	MS 1	MS 2	MS 3	MS 4
Block	3	52763	876853	86639	694300
Treatment	1	247260	102960	2501960	1222280
Error 1	3	311890	298280	350346	323800
Ring	2	107195	422930	2121345 **	818850 *
R x T	2	207515+	1050330 *	1514370 **	712760 *
Error 2	12	58635	19275	54392	155630

5.2 Analysis of Variance for Total Grass Species for R_2 of A and B Treatments - all Harvests.

Source of Variation	df	MS	F-ratio	Result
Block	3	6590		
Treatment	1	3910200	26.3	**
Harvests	3	1565223	10.5	**
T x H	3	48890		
Error	21	148590		

5.3 Analysis of Variance for Ryegrass Species for R_2 of A and B Treatments - all Harvests.

Source of Variation	df	MS	F-ratio	Result
Block	3	364126	4.94	**
Treatment	1	1986523	26.9	**
Harvests	3	444598	6.0	**
T x H	3	16062		
Error	21	73647		

5.4 Cumulative Growth Data for Ring 2 of Treatments C,D,E and F using the formula outlined in Chap 5, analysis of data section

dW is the calculated growth between harvests.

Harvest		1	dW_1	2	dW_2	3	dW_3	4
I	C	2390	271	2661	1366	4027	45	4022
	D	3071	611	3682	368	4050	2262	6312
	E	2390	92	2482	2000	4482	-4	4478
	F	3071	759	3830	896	4726	593	5319
II	C	2533	45	2578	317	2895	902	3797
	D	2970	726	3696	-91	3605	2386	5991
	E	2533	143	2676	1420	4096	717	4813
	F	2970	855	3825	138	3963	1430	5393
III	C	2827	239	3066	253	3319	-92	3227
	D	3668	464	4132	198	4330	896	5225
	E	2827	289	3116	685	3801	68	3689
	F	3668	989	4657	-55	4602	312	4914
IV	C	2533	-152	2381	1292	3673	202	3875
	D	2868	1687	4555	511	5066	2096	7162
	E	2533	1159	3692	446	4138	165	4303
	F	2868	1823	4691	-188	4503	145	4648
Mean Yield	C	2570		2672		3477		3731
	D			4017		4263		6173
	E	3143		2992		4129		4321
	F			4251		4448		5264
LSD (0.05)				492		558		708

Analysis of Variance/Harvest

Source of Variance	df	MS_2	MS_3	MS_4
Block	3	497720	435646	557080
Cutting	1	307400	699640	263640
Dung	1	6780800	1210040	10176040
C x D	1	7095346	233960	2871360
Error	9	95159	121992	184121

MS_1 as for A and B

5.5 Analysis of Total Grass Species (TGG) in Ring 2 for Treatments C, D, E and F at each Harvest

Source of Variation	df	MS_2	MS_3	MS_4
Block	3	180832	572982 *	152385
Cutting	1	2800598 **	2878955	850537 *
Dung	1	2479048 **	527435	4898467 **
C x D	1	50852	62635	405463
Error	9	70418	113646	149271

MS_1 as for A and B

5.6 Analysis of Ryegrass Species (Rye) in Ring 2 for Treatments C, D, E and F at each Harvest

Source of Variation	df	MS_2	MS_3	MS_4
Block	3	13707	73554	140646
Cutting	1	359700 *	322624	10050
Dung	1	341348 *	39601	766062
C x D	1	248751 *	119370	59903
Error	9	50826	91243	127291

MS_1 as for A and B

5.7 Analysis of Variance for Yield of Yorkshire Fog (Fog) Ring 2 for Cutting Treatments C,D,E, and F at Harvest 4

Source of Variation	df	MS	F-ratio	Result
Block	3	51387		
Cutting	1	660652	5.9	*
Dung	1	1320772	11.7	*
C x D	1	88064		
Error	9	112782		

LSD 0.05 = (538)

5.8 % Dead Matter in Ring 2 for all Treatments at Harvest 4

Transformed by Angle = Arcsin $(\text{Percentage})^{\frac{1}{2}}$

Block		I	II	III	IV	Mean	%
Treatment	A	36.9	36.3	51.3	41.0	41.3	
	B	39.2	41.0	50.2	35.1	41.3	44
	C	17.5	0	16.4	0	8.5	
	D	0	0	17.5	16.4	8.5	2
	E	31.3	30.0	25.8	31.9	29.7	
	F	22.3	33.8	22.0	28.0	27.7	23

Analysis of Variance

Source of Variation	df	MS	F-ratio	Result
Block	3	54		
Cutting	2	2204	42.9	**
Dung	1	2		
C x D	2	3		
Error	15	51		

Analysis of the remaining botanical components at various harvests was not warranted as no consistent differences between treatments was noticeable (see raw data).

Botanical Composition of the Sward throughout the experiments in the uncut plots (A and B)

Treatment A

	Harvest	1	2	3	4
	TDM	2570	3870	3743	4041
Component	Total Grasses	1385	1803	896	1252
	Ryegrasses	612	571	349	474
	Clovers	660	910	554	732
	Dead Matter	463	747	2279	1722
	Green Matter	2108	3060	1469	2319

Treatment B

	TDM	3144	4551	5392	5137
Component	Total Grasses	1982	2704	1453	1994
	Ryegrasses	960	1476	620	972
	Clovers	614	870	869	829
	Dead Matter	298	750	2937	2292
	Green Matter	2847	3801	2455	2845

5.9 Raw Data for The Herbage in Ecological Experiment No. II

(For Key to Identification see heading page for Raw Data, E.E. I)

Note: Harvest 3 is omitted. Only 4 harvests were taken and botanicals for Ring 2 only on 3rd (4) Harvest.

Total Dry Matter

1TDM4A	2445	2484	2807	2803	2635
1TDM4B	3188	2291	2355	2663	2624
1TDM3A	2531	3005	2665	2531	2683
1TDM3B	3047	2275	2463	3131	2729
1TDM2A	2390	2532	2827	2532	2570
1TDM2B	3070	2969	3668	2868	3144
2TDM4A	4358	3450	4099	3684	3898
2TDM4B	3975	3941	3041	3608	3641
2TDM4C	1229	1516	1975	1153	1468
2TDM4D	1238	1410	1922	1527	1524
2TDM3A	5063	3605	4264	3879	4203
2TDM3B	4678	3733	3599	4425	4109
2TDM3C	1395	1485	2364	1332	1644
2TDM3D	1657	1774	2510	1681	1906
2TDM2A	4716	3484	3705	3323	3807
2TDM2B	4849	4757	4597	3999	4551
2TDM2C	1420	1475	1939	1149	1496
2TDM2D	2344	2289	2882	2721	2559
2TDM2E	2073	2206	2624	3116	2505
2TDM2F	3392	3263	3990	3916	3640
4TDM4A	4262	3684	3576	2766	3572
4TDM4B	4287	3436	3571	3395	3672
4TDM4C	2335	1394	1484	1504	1679
4TDM4D	1569	1628	1624	1617	1609
4TDM3A	4019	4061	3867	2639	3646
4TDM3B	3995	3903	3843	3596	3834
4TDM3C	2421	1309	1595	1532	1714
4TDM3D	2179	1774	2331	1977	2065
4TDM2A	4486	3935	3438	3112	3743
4TDM2B	5548	5153	5337	5530	5392
4TDM2C	2188	1351	1884	2073	1874
4TDM2D	1903	1098	2500	2441	1985
4TDM2E	3613	3273	3038	3296	3305
4TDM2F	4036	3231	3686	3461	3604
5TDM4A	4179	3867	3392	3867	3826
5TDM4B	4023	4558	4232	3851	4166
5TDM4C	1690	1413	1091	1442	1409
5TDM4D	1628	1243	1027	1761	1415
5TDM3A	4234	4395	4195	3670	4124
5TDM3B	4076	4359	4365	3366	4042
5TDM3C	1807	1717	1383	1622	1632
5TDM3D	1923	1461	1312	1887	1646
5TDM2A	5102	4206	3498	3355	4040
5TDM2B	5594	4771	5833	4348	5137
5TDM2C	1636	1806	1369	1843	1664
5TDM2D	3558	2601	2749	3627	3134
5TDM2E	3516	3889	3020	3374	3450
5TDM2F	4472	4486	3898	4491	4337

1RYE4A	1124	770	309	279	621
1RYE4B	1339	734	447	584	776
1RYE3A	1162	933	292	253	660
1RYE3B	1583	954	468	781	946
1RYE2A	1098	786	312	252	612
1RYE2B	1627	625	735	855	960
2RYE4A	610	484	412	846	588
2RYE4B	1112	1300	426	612	863
2RYE4C	614	364	355	185	380
2RYE4D	174	438	325	412	337
2RYE3A	709	503	417	891	630
2RYE3B	1824	858	289	885	964
2RYE3C	697	354	781	211	511
2RYE3D	98	408	477	336	330
2RYE2A	661	487	372	763	571
2RYE2B	1985	1572	873	1521	1488
2RYE2C	707	353	349	183	398
2RYE2D	142	505	547	570	441
2RYE2E	372	353	418	652	449
2RYE2F	744	1241	919	1057	990
4RYE2A	312	156	275	652	349
4RYE2B	776	721	266	717	620
4RYE2C	657	216	285	422	395
4RYE2D	170	174	501	441	321
4RYE2E	721	229	547	528	506
4RYE2F	1209	1034	698	174	779
5RYE4A	502	387	236	231	339
5RYE4B	564	502	380	385	458
5RYE4C	607	451	110	548	429
5RYE4D	603	360	307	263	383
5RYE3A	506	438	292	220	364
5RYE3B	569	521	393	268	438
5RYE3C	650	548	137	617	488
5RYE3D	808	262	131	283	371
5RYE2A	597	418	243	202	365
5RYE2B	896	1287	758	390	833
5RYE2C	588	579	137	698	501
5RYE2D	2064	832	767	579	1060
5RYE2E	666	505	482	638	573
5RYE2F	804	717	1089	942	888

Clover Species

1 AC4A	392	646	841	841	680
1 AC4B	828	825	718	330	675
1 AC3A	405	787	799	760	688
1 AC3B	578	545	614	781	629
1 AC2A	381	657	845	758	660
1 AC2B	519	859	588	487	613

2 AC4A	784	862	656	1472	943
2 AC4B	954	1103	516	974	887
2 AC4C	110	454	295	197	264
2 AC4D	298	394	346	321	340
2 AC3A	912	900	685	1550	1012
2 AC3B	1264	894	575	1195	982
2 AC3C	125	444	354	226	287
2 AC3D	298	319	676	405	424
2 AC2A	850	868	593	1328	910
2 AC2B	969	1190	597	721	869
2 AC2C	128	441	289	183	260
2 AC2D	142	505	459	763	467
2 AC2E	271	969	496	372	527
2 AC2F	170	684	519	156	382
4 AC2A	583	707	583	340	553
4 AC2B	1163	413	960	937	868
4 AC2C	570	487	395	579	507
4 AC2D	855	229	473	124	420
4 AC2E	289	556	850	330	506
4 AC2F	280	257	330	174	260
5 AC4A	878	929	270	851	732
5 AC4B	1206	456	506	885	763
5 AC4C	523	747	229	332	458
5 AC4D	389	334	298	424	361
5 AC3A	888	1055	333	808	771
5 AC3B	1222	480	524	942	792
5 AC3C	560	909	289	372	533
5 AC3D	462	539	143	283	357
5 AC2A	1071	1011	280	740	775
5 AC2B	1733	427	464	694	829
5 AC2C	505	956	289	422	543
5 AC2D	464	675	386	689	553
5 AC2E	1126	583	514	505	682
5 AC2F	671	491	1011	942	779

Yorkshire Fog

1FOG4A	73	222	617	841	438
1FOG4B	158	252	518	532	365
1FOG3A	74	268	587	760	422
1FOG3B	59	274	295	468	274
1FOG2A	73	225	620	758	419
1FOG2B	0	298	698	547	386
2FOG4A	1481	724	1559	442	1052
2FOG4B	1112	472	851	612	762
2FOG4C	48	75	158	289	142
2FOG4D	98	139	325	153	179
2FOG3A	1720	757	1610	465	1138
2FOG3B	656	411	1583	799	862
2FOG3C	56	74	187	333	163
2FOG3D	381	161	402	238	295
2FOG2A	1604	730	1383	399	1029
2FOG2B	776	712	1471	758	929
2FOG2C	55	73	156	285	142
2FOG2D	1052	298	721	514	647
2FOG2E	413	220	657	933	556
2FOG2F	1015	128	556	1291	748

4FOG2A	583	312	445	496	459
4FOG2B	220	878	694	1218	752
4FOG2C	239	160	358	289	262
4FOG2D	211	330	524	1149	553
4FOG2E	1048	556	487	1448	884
4FOG2C	887	225	1144	1802	1014
5FOG4A	711	773	575	929	747
5FOG4B	401	1048	1142	461	763
5FOG4C	337	183	185	504	302
5FOG4D	357	261	277	617	378
5FOG3A	718	879	712	879	797
5FOG3B	408	784	960	605	689
5FOG3C	360	223	235	566	346
5FOG3D	402	497	366	605	468
5FOG2A	841	841	593	804	769
5FOG2B	445	717	1107	1480	937
5FOG2C	326	234	234	643	359
5FOG2D	822	910	1181	1415	1082
5FOG2E	349	969	1360	979	914
5FOG2F	1788	1300	1015	1259	1341

Other Grasses

1 OG4A	412	272	449	307	360
1 OG4B	383	412	282	318	349
1 OG3A	417	328	426	277	362
1 OG3B	304	638	468	345	439
1 OG2A	404	280	450	280	353
1 OG2B	216	859	1061	399	634
2 OG4A	174	344	82	220	205
2 OG4B	0	314	121	541	244
2 OG4C	11	121	77	34	61
2 OG4D	50	84	96	137	92
2 OG3A	202	360	86	232	220
2 OG3B	0	784	107	500	348
2 OG3C	14	119	95	38	67
2 OG3D	131	89	125	101	111
2 OG2A	188	349	73	197	202
2 OG2B	193	712	183	239	332
2 OG2C	13	119	78	32	60
2 OG2D	142	298	174	137	188
2 OG2E	478	156	211	436	320
2 OG2F	542	455	878	78	488
4 OG2A	87	0	170	91	87
4 OG2B	0	0	321	0	80
4 OG2C	174	55	73	105	102
4 OG2D	151	41	124	170	121
4 OG2E	142	32	87	101	90
4 OG2F	160	193	147	206	176

5	OG4A	126	77	100	116	105
5	OG4B	121	272	126	192	178
5	OG4C	50	41	20	71	45
5	OG4D	114	160	50	139	116
5	OG3A	128	86	125	110	112
5	OG3B	122	172	175	134	151
5	OG3C	53	50	26	83	53
5	OG3D	134	161	38	131	116
5	OG2A	151	82	105	101	110
5	OG2B	170	570	59	262	265
5	OG2C	50	55	27	91	56
5	OG2D	105	50	165	473	198
5	OG2E	280	390	59	101	208
5	OG2F	266	404	78	271	255
			Dead Matter			
1	DM4A	440	447	504	504	474
1	DM4B	350	344	635	426	439
1	DM3A	447	539	480	456	480
1	DM3B	304	274	614	626	454
1	DM2A	432	455	510	455	463
1	DM2B	0	326	404	459	297
2	DM4A	653	828	901	699	770
2	DM4B	596	708	1002	722	757
2	DM4C	442	500	1046	417	601
2	DM4D	557	353	807	504	555
2	DM3A	760	864	939	736	825
2	DM3B	796	492	972	1064	831
2	DM3C	500	489	1252	480	680
2	DM3D	730	799	828	605	741
2	DM2A	707	836	813	629	747
2	DM2B	583	478	1379	560	750
2	DM2C	510	487	1029	413	610
2	DM2D	845	661	891	707	776
2	DM2E	537	487	813	684	630
2	DM2F	744	620	919	1291	894
4	DM2A	2873	2753	1995	1494	2278
4	DM2B	3273	2886	2937	2652	2937
4	DM2C	547	432	753	661	598
4	DM2D	473	317	850	537	544
4	DM2E	1374	1471	1061	923	1207
4	DM2F	1452	1517	1402	1038	1352
5	DM4A	1504	1353	2069	1663	1647
5	DM4B	1729	2188	1904	1848	1917
5	DM4C	151	0	545	474	293
5	DM4D	194	87	82	139	126
5	DM3A	1523	1538	1130	1210	1350
5	DM3B	1753	2179	1529	1007	1617
5	DM3C	161	0	399	1267	456
5	DM3D	116	0	536	1019	418
5	DM2A	1838	1471	2133	1443	1721
5	DM2B	2238	2050	3443	1434	2291
5	DM2C	147	0	684	606	359
5	DM2D	0	0	248	289	134
5	DM2E	951	969	574	946	860
5	DM2F	937	1392	547	988	966

Total Grasses

1TGG4A	1610	1266	1376	1429	1420
1TGG4B	1881	1399	1247	1436	1491
1TGG3A	1655	1529	1306	1291	1445
1TGG3B	1947	1434	1231	1595	1552
1TGG2A	1576	1291	1383	1291	1385
1TGG2B	1843	1783	2496	1806	1982
2TGG4A	2266	1553	2055	1509	1846
2TGG4B	2225	2087	1399	1766	1869
2TGG4C	674	562	591	504	583
2TGG4D	323	662	747	704	609
2TGG3A	2633	1622	2114	1589	1989
2TGG3B	2481	2054	1980	2173	2172
2TGG3C	769	548	1064	584	741
2TGG3D	611	659	1004	676	738
2TGG2A	2454	1567	1829	1360	1803
2TGG2B	2955	2905	2528	2427	2704
2TGG2C	776	547	583	501	602
2TGG2D	1337	1103	1443	1222	1276
2TGG2E	1264	730	1287	2022	1326
2TGG2F	2303	1825	2349	2427	2226
4TGG2A	983	468	891	1241	896
4TGG2B	997	1599	1282	1935	1453
4TGG2C	1071	432	717	818	759
4TGG2D	533	547	1149	1760	997
4TGG2E	1912	818	1121	2077	1482
4TGG2F	2257	1452	1990	2183	1970
5TGG4A	1339	1238	913	1277	1192
5TGG4B	1087	1823	1649	1039	1399
5TGG4C	995	676	316	1124	778
5TGG4D	1075	782	635	1020	878
5TGG3A	1353	1404	1130	1210	1274
5TGG3B	1100	1479	1529	1007	1279
5TGG3C	1064	823	399	1267	888
5TGG3D	1344	921	536	1019	955
5TGG2A	1618	1342	942	1107	1252
5TGG2B	1342	2574	1926	2133	1993
5TGG2C	965	868	399	1434	917
5TGG2D	2992	1792	2114	2468	2342
5TGG2E	1296	1866	1903	1719	1696
5TGG2F	2859	2422	2183	2473	2484

Appendix - Chapter Six

Chemical Analysis of Glass Wool Pads for Ammonia Content (Castle - priv. comm.).

The laboratory process was as follows;

The flasks were shaken vigorously 3 or 4 times at intervals over about 3 hours. This ensured that the acid and the ammonia held in the pads came into equilibrium with the water. A 100 ml aliquot was then decanted into a 100 ml volumetric flask. This was then transferred to a 30 ml Kjeldahl flask. The flask was attached to a condenser via a splash head. An excess (15 ml) of 40% NaOH was added to the flask with the aid of a glass drop-funnel attached to each flask. The contents of the flask were mixed and 50 ml distilled across into 25 ml of 4% Boric acid to which 4 drops of 'Kjeldahl' indicator had been added. The distillate from the Control Treatment was then titrated with N/100 H_2SO_4: for the other treatments with N/10 acid.

Calculation: From weighing a few pads, it was estimated that about 10 ml of water had been absorbed along with the ammonia. This gave 30 ml of acid and ammonia per pad.

Then 30 ml added to 200 ml water = 230 ml

If 1 ml N/10 $H_2SO_4 = 17 \cdot 10^{-4}$ g NH_3

And if x = titration figure and 0.0979 N acid used

Then NH_3 in 230 ml solution $= \frac{230}{100} \cdot \frac{17}{1} x \cdot \frac{0.0979}{0.1} \cdot 10^{-4}$

$$= 38.28\, x \cdot 10^{-4}$$

$$= 3.83\, x \text{ mgm } NH_3$$

Results were expressed in mgm. NH_3 / 24 hours.

Ammonia (mgm/24 hrs) collected from Dung Patches

Treatment 1-5 - varying times patch exposed before cage applied

I and II are duplicates of treatment

a - h = Sampling days (1, 2, 3, 4, 5, 7, 9, 13)

Treatment		Control	1	2	3	4	5
a	I	0.651	40.19	25.46			
	II	.459	33.88	21.39			
b	I	.574	28.71	20.67	14.62	13.02	10.95
	II	.574	19.91	21.44	18.21	12.25	15.84
c	I	.727	35.25	31.00	19.14	21.90	15.31
	II	.383	24.12	26.41	30.05	28.14	20.10
d	I	.459	46.32	40.96	26.99	31.16	18.95
	II	.383	41.42	38.28	42.87	35.60	24.85
e	I	.344	41.42	39.43	26.49	31.01	22.39
	II	.421	27.94	26.57	40.19	42.11	26.03
f	I	.325	16.14	10.87	7.08	11.29	7.08
	II	.268	10.03	8.27	18.85	17.66	9.67
g	I	.287	7.08	5.42	3.69	5.57	5.36
	II	.249	3.45	8.13	10.39	10.01	4.97
h	I	.067	2.34	5.27	2.96	1.50	3.78
	II	.115	3.35	3.83	3.70	1.74	2.87
Total Prodn.	I		247.7	196.8	127.8	137.8	104.9
(mgm/13 days)	II		188.2	176.9	213.6	184.3	120.3
Mean			217.9	186.8	171.2	161.1	112.6

Analysis of Variance of total production means

Source of Variation	df	MS	F-ratio	Result
Block	1	466		
Treatment	4	11917	1.9	NS
Error	4	6383		

Treatments 1 - 5 were analysed within each day (where possible differences seemed apparent). Only significant result was on day b - LSD 10.07 mgm/24hrs gave 1, 2, 3 > 4, 5.