JAPANESE MILLET: Studies on its yield, chemical composition and nutritive value.

A thesis presented in part fulfilment of the requirements for the degree of Master of Agricultural Science in Animal Science at Massey University, New Zealand.

Daniel H. Faggi

1971

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACKNOWLEDGEMENTS

I would like to express my gratitude to those who in anyway helped with the preparation of this thesis.

I extend my gratitude to Mr. A.W.F. Davey and Dr. G.F. Wilson, my supervisors, from whom I received extensive co-operation. At the same time I would like to thank Mr. W.C. Currie for helpful discussion and criticism throughout this project.

I would also like to make special mention to those people who have given me valuable assistance in various ways:

Mr. N.A. Thomson for his contribution in the laboratory work.

All field personnel of No. 2 Dairy Unit for their collaboration with the milking and handling of animals.

Mr. W.B. Currie for his collaboration with statistical analyses and gas chromatographic determinations.

Dr. R.D. Reeves for his collaboration with the analytical determinations with the Atomic Absorption Spectrophotometer.

Prof. R.E. Munford for his collaboration with the milk analyses and computer work.

Also my appreciation to Miss. M.G. Campbell and library staff, who made possible the compilation of all reference material.

Also I would like to extend my thanks to my wife, Milka for her work in typing this thesis.

I would like finally to thank the F.A.O. for granting the scholarship and Prof. I.L. Campbell and Prof. D.S. Flux for making facilities available for my post graduate studies at Massey University.

INTRODUCTION

Under pastoral conditions, such as in New Zealand, there are 2 periods of the year when feed demands by livestock are frequently greater than that normally produced by pastures, i.e. during the summer - early autumn and winter.

The roughage problem for summer feeding is just as important as for winter, but it is more commonly neglected. Most cows invariably decrease in production during the dry season and this can be attributed to a number of factors. Cows are approaching the end of their lactation periods and can be expected to drop in milk flow, but the chief cause for the drop in production is the feed shortage which accompanies dried pastures.

During the last three summer seasons (1969 - 1970 - 1971) in the Manawatu area, serious limitations to efficient milk production were due principally to the lack of summer pasture. In these drought seasons, most of the typical species of permanent pasture became semi-dormant and thus under these conditions, farmers were forced either to feed hay, silage and/or concentrates or to use a regular system of growing supplementary pasture crops in order to provide additional grazing during the season of short permanent pasture. Summer annual grasses like Millet and sudangrass are very useful as supplementary feed crops because their period of maximum growth occurs during the mid-summer months when many perennial pasture species are in production slumps.

Still under normal summer conditions, the average production of a common mixed pasture during the summer time is about 3,000 lb of dry matter per acre which is less than $\frac{1}{4}$ of the total annual production. Mitchell (1963) suggested that there are some tropical plants which could be expected to give under New Zealand conditions a ceiling potential for growth of over 40,000 lb of dry matter per acre per year.

If drought periods occur frequently enough, it would seem that the inclusion of summer annual grasses in the pasture programme could be considered a standard practice on many farms. However, if the season resulted in good pasture growth planning to preserve surpluses of summer crops offers the ideal solution. In some years this silage may be very useful in helping to overcome a pasture shortage later in the season. Summer crops are considered to be more valuable as a mid-summer pasture crop than hay because they tend to be succulent and consequently there is difficulty in proper drying.

Under these conditions, in the present experiment, an evaluation of a summer annual crop (Japanese Millet) was undertaken to provide information on whether this forage could supply the adequate foodstuffs for dairy cattle production.

CHAPTER ONE

REVIEW OF LITERATURE

Under the name Millet is included a number of species which are used as summer growing grain and grazing crops. Although they belong to different species they have some similarity in field behaviour (Hart, 1958). Each of the species is identified under several different names in different parts of the world. Table 1.1 presents some of the principal Millets with their botanical and common names; they can be classified according to use into grazing, grain and dual purpose types (Hart, 1958). Most of them have been used according to tradition, particularly in those countries (Africa and India) which are centres of diversification.

1.1. Species of Millet

The most commonly used Millet species will be described taking into account plant characteristics which are more related with grazing conditions.

Echinochloa crusgalli, var. edulis.

Among grazing type Millets Hart (1958) described White Panicum as one of the best, while being less hardy than Japanese Millet. In low density stands White Panicum has a semi-prostrate growth habit which distinguishes it from other Millets, which have an upright habit. Although a coarse stemmed plant, it is well accepted by stock (Humphreys, 1965). Seed maturity is a slow process and generally takes 2 to 3 weeks longer than Japanese Millet.

Echinochloa crusgalli, var. frumentacea.

Although Japanese Millet has finer leaves and stems than White Panicum, it is not necessarily more palatable. Ahlrich *et al.*, (1957) indicated that the leaf blades are wider and the stems are coarser than the average of the species. It is a vigorous grower and will tolerate temporary flooding (Humphreys, 1965). The plant can reach a height of up to 5 - 6 feet (Ahlrich et al., 1957) and can mature in about 100 - 120 days (Hart, 1958). It is ready for grazing very quickly, sometimes as soon as 3 weeks after sowing (Humphreys, 1965), however it is usually ready for grazing 4 - 6 weeks after planting (Douglas, 1959). Grazing is recommended to start (Douglas, 1959) when the height of the crop is 12 - 15 in., using the strip grazing method which enables fullest utilization of the crop. Under conditions of adequate soil fertility and weather, growth of Japanese Millet is particularly rapid. During the whole season, under Queensland conditions about 7 cuttings were recorded (Hart, 1958); at Massey University Japanese Millet was grazed 4 - 5 times. Table 1.2 illustrates the composition of the aerial parts of Japanese Millet according to Crampton and Harris (1969).

Japanese Millet is capable of a yield in excess of 5 tons of dry matter per acre, depending on soil fertility and water availability (Ahlrich et al., 1967), and when used for silage the yield was reported to be as high as 10 tons per acre, at the time the seeds began to fill (Squire, 1958).

Several varieties of Japanese Millet were collected in India and among them two types (25 and 46) were reported as the most promising varieties (Singh, 1957). Both types take about 70 days from sowing to maturity, and are used for grain purposes. Type 25 yielded 600 lb of grain and type 46, 1000 lb. Also Ahlrich et al., (1967) reported that Japanese Millet can produce up to 800 lb of grain per acre; however if the crop is fertilized and irrigated seed production can yield in excess of one ton of grain per acre. Under dry years, seed production is drastically reduced, sometimes as little as 100 lb per acre. It was found that under Indian conditions the most suitable time to sow Japanese Millet was the third week of June; when seeding was made 2 weeks earlier or later, the crop yield was reduced (Singh, 1957).

Japanese Millet was reported as a weed in several cultives: in cotton (Rea, 1953; Swezey and Fisher, 1955); in rice (Kasahara and Kinoshita, 1954; Lucero, 1953; Foury, 1954; Dirven and Poerink 1955); in sugar beet (Ririe, 1954; Warren, 1954) and in corn (Vengris, 1955).

TABLE 1.1

Species of Millets

BOTANICAL NAME	USE	COMMON NAME	OTHER COMMON NAMES	REFERENCE
Echinochloa crusgalli var. edulis	grazing	White Panicum		Hart (1958), Douglas (1959), Humphreys (1965).
Echinochloa crusgalli var. frumentacea	grazing and grain	Japanese Millet	Barnyard Millet, Chiwapa	Hart (1958), Masefield (1955), Ahlrich et al.,(1957), Douglas (1959), Crampton and Harris (1969), Singh (1957), Squire (1958), Humphreys (1965).
Echinochloa colona	grain			Masefield (1955).
Eleusine coracana	grain	Finger Millet	African Millet, Indian Millet, Rupoko, Rukweza, Njena, Rviyo, Ragi	Hart (1958), Masefield (1955), Ward (1968), Johnson (1968).
Eragrostis abyssinica	grain	Teff		Masefield (1955).
Panicum miliaceum	grain	French Millet	Millet Panic, Proso, Hog, Broom, Corn Millet, Italian, Foxtail, Hungarian, Siberian Millet, Panicum, Common Millet, White French	Hart (1958).
Panicum miliare	grain	Little Millet		Nanda et al.,(1957, a, b).

TABLE 1.1 - Species of Millets, continued

BOTANICAL NAME	USE	COMMON NAME	OTHER COMMON NAMES	REFERENCE
Panicum crusgalli	grain			Masefield (1955).
Paspalum scrobiculatum	grain			Masefield (1955).
Pennisetum glaucum	grazing	Pearl Millet		King (1947), Rusoff et al., (1961), Padmanabha Reddy Peta (1966), Reddy et al., (1965), Roark et al., (1952), Shankar et al., (1963), Crampton & Harris (1969), Mays & Washko (1961), Burton (1951), Clark et al., (1965), Hemken et al., (1962), Marshall et al.,(1953), Miller et al.,(1963, 1965).
Pennisetum glaucum hybrid	grazing	Stan Millet		Miller et al.,(1958), Burton & De Vane (1951), Miller et al., (1958), Hawkins et al.,(1958).
Pennisetum glaucum var. Gahi-1	grazing	Pearl Millet Gahi-1		Beaty et al.,(1965), Broyles & Fribourg (1959), Rusoff et al., (1961).
Pennisetum spicatum	grain	Bulrush Millet		Masefield (1955).
Pennisetum typhoides	grazing	Bulrush Millet	Pearl Millet, Indian Millet, Horse Millet	Hart (1958), Norman (1962, 1963, 1965), Norman & Stewart (1964), Norman & Phillips (1968), Phillips & Norman (1966), Burton et al.,(1969), Burton & Forston (1966), Burton et al.,(1969), Lahiri et al.,(1965,1966),Murray & Romyn (1937), Pokhriyal et al., (1967), Ward (1968), Johnson (1969), Humphreys (1965).

TABLE 1.1. - *Species of Millets*, continued

BOTANICAL NAME	USE	COMMON NAME	OTHER COMMON NAMES	REFERENCE
Setaria sphacelata		Nandi Setaria		Humphreys (1965).
Setaria italica - var. Stramineofructa Bailey	grazing	German Millet		Broyles & Fribourg (1959), Kildee *et al.*,(1925).
Setaria italica	grazing and grain	Nunbank Setaria		Hart (1958).
Setaria italica var. purpurea	grain	Korean Setaria		Hart (1958).
Setaria italica - dwarf	grain	Dwarf Setaria		Hart (1958).
Setaria italica - giant	grazing and grain	Giant Setaria	Italian, Foxtail, Hungarian, Siberian Millet, Panicum	Hart (1958), Kildee *et al.*, (1925), Crampton & Harris (1969).

Eleusine coracana.

Finger Millet is grown extensively in Central Africa, Southern India, Malaysia and China (Johnson, 1968; Masefield, 1955). It is an annual plant with a high variation in height (from 10 in. to more than 4 feet). It is called Finger Millet because the inflorescence appears not unlike a human hand, with the palm upwards and the fingers partially contracted (Johnson, 1968). Generally it is seeded at the rate of 6 - 8 lb. per acre, taking a period of 4 - 5 months to mature and producing about 1,200 lb. of grain per acre (Masefield, 1955). However under dry conditions the crop could mature more rapidly, taking about 4 months. Although the crop is fairly drought resistant, it needs as little as 15 in. well distributed rainfall. Johnson (1968) reported several insects and diseases which can produce serious damage to the crop.

Panicum miliaceum.

The stems and leaves are hardy and fibrous, which make the crop virtually useless as a grazing or hay plant (Hart, 1958).

Setaria italica - giant.

Although Giant Setaria is a dual purpose Millet, it provides relatively inferior grazing compared to the grazing types of Millet. The crop takes about 105 days to mature, which provides a sufficient time to produce a green material; heavy and quick grazing was suggested (Hart, 1958). It was reported as having a quick growth, either with very early or very late seeding; under some conditions it can be harvested 40 - 50 days after seeding (Kildee et al., 1925) which is a shorter time than that reported by Hart (1958). When used for grazing purposes it can yield from 10 to 14 tons of green material (Kildee et al., 1925), which can be obtained with a thicker seeding. Aerial part composition of Giant Setaria is presented on Table 1.2.

Among Setaria Italica varieties are found Common, German and Hungarian which seem to be the most important. Common Millet yields the best quality of feed, while the German variety is coarse and not so palatable (Kildee et al., 1925).

Setaria italica - dwarf.

It is the quickest maturing Millet, and thus produces small amounts of aerial parts available as foodstuff (Hart, 1958).

Setaria italica, var. purpurea.

Similar characteristics to those presented for Dwarf setaria led Hart (1958) to suggest that Korean Setaria be not used as grazing type Millet.

Setaria sphacelata.

Nandi setaria is a native plant from Nandi district of Kenya with an average height of 5 feet (Humphreys, 1965). It is a very variable species and a number of different types have been recognised; from short and dense plants to tall, erect and coarse growing types. It has a long growing season, being more cold tolerant than general summer crops. It stays green and succulent well into the winter and comes away early in the spring (under Australian conditions). Under irrigated conditions Humphreys (1965) reported that yields of up to 11 tons of dry matter per hectare per year have been recorded.

Pennisetum glaucum.

Pearl Millet is a common Millet crop used under U.S.A. conditions. Pearl Millet has upright habit growth and will normally attain a height of 6 to 10 feet at maturity. Leaves are normally about one inch wide and two to three feet long (Russoff et al., 1961). Aerial part composition is presented on Table 1.2.

Pearl Millet is described by Mays and Washko (1961) as the type of millet most desirable for pasture in that it is higher

TABLE 1.2

Chemical composition and nutritive value of

some important Millets

(Adapted from Crampton and Harris, 1969)

CHEMICAL COMPOSITION (on dry matter basis)	Japanese Millet	Pearl Millet	Giant Setaria
Dry matter (%)	22.7 (13)*	20.7 (9)	27.1 (18)
Ash (%)	8.4 (16)	9.1 (12)	9.1 (25)
Crude fiber (%)	29.9 (7)	31.2 (8)	31.0 (7)
Ether extract (%)	2.7 (10)	2.8 (22)	2.7 (15)
N.F.E. (%)	50.0	46.9	47.0
Crude Protein (%)	9.0 (35)	10.0 (19)	10.2 (14)
DIGESTIBILITY COEFFICIENTS			
Dig. C.protein (%) (cattle)	61.11	62.00	64.71
Dig. C.protein (%) (sheep)	50.00	63.00	60.78
Dig. Energy kcal/kg (cattle)	2822	2734	2822
Dig. Energy kcal/kg (sheep)	2690	2866	2734
Met. Energy kcal/kg (cattle)	2314	2242	2314
Met. Energy kcal/kg (sheep)	2206	2350	2242
TOTAL DIGESTIBLE NUTRIENTS (%)			
Cattle	64	62	64
Sheep	61	65	62

* Coefficient of variation (%)

yielding and produces more aftermath than other millets. If allowed to mature, it is a tall growing, coarse stemmed plant but is relatively fine-stemmed and succulent if pastured early.

Pennisetum glaucum, hybrid.

Starr Millet is an improved variety of Pearl Millet which is leafier, has shorter internodes and matures later than Pearl Millet (Burton and De Vane, 1951).

Pennisetum glaucum, var. Gahi-1.

Gahi-1 Pearl Millet is another Pennisetum glaucum hybrid; 4 inbred lines were involved in the production of this hybrid. It is characterized by abundant leaves production and by good seedling vigour; it is later maturing and more productive than common Pearl Millet. Gahi-1 Pearl Millet is quick to establish and drought resistant, it recovers rapidly after grazing or clipping and produces highly palatable, nutritious forage (Russoff et al., 1961; Hart and Burton, 1965). Gahi-1 Pearl Millet yielded nearly 3 times (21.457 lb D.M./acre) than the stabilized synthetic variety, Starr Pearl Millet which produced 7.194 lb D.M./acre (Burton, 1959).

Pennisetum typhoideum.

Bulrush Millet is commonly planted in Africa, India and particularly in the south-eastern states of U.S.A. where it is the highest yielding summer annual forage crop. In Africa and India it is cultivated on over 35 million acres and is primarily used for human food (Begg, 1965; Burton and Forston, 1966; Hart and Burton, 1965). Under dry conditions grain yield is as low as 300 - 600 kg grain/Ha, however under irrigation yields are relatively higher, 1100 to 1700 kg grain/Ha (Begg, 1965). Straw production is also reported to be extremely low (1100 - 2200 kg straw/Ha) under drought season, however they produce nearly double (3300 - 4500 kg straw/Ha.) under irrigated conditions. According to Begg (1965) Bulrush Millet can produce a yield of 62.700 kg of silage per hectare which is considered a very good yield.

Bulrush Millet is described as a tall, succulent, annual fodder crop with a very high potential for dry matter production and for the uptake of available nitrogen (Norman and Stewart, 1964). It is a relatively coarse plant with a higher water requirement compared with other Millets (Johnson, 1969). It usually reaches a height of 6 to 10 feet when mature which take about 3 and a half to 5 months (Masefield, 1955). However the species is variable with respect to height, tiller number, pubescence of leaf-blade and sheath, and length of inflorescence.

The maximum leaf area index is reached in about 7 weeks from emergence (Norman and Begg, 1968) and the highest growth potential falls in the 7 to 14 week period. Anthesis occurs from 8 to 10 weeks after planting; hot, dry weather is needed for flowering and seed-set. The optimum temperature for net photosynthesis is 86°F to 95°F.

A variety selected under Australian conditions (Katherine region) has given an average annual dry matter yield of nearly 12.000 lb/acre. Crude protein yield varies in accordance with the nitrogen status of the soil and when grown after a legume but without N fertilizer the average is approximately 600 lb/acre, though figures of over 1000 lb/acre have been recorded.

Quality of Bulrush Millet, as it can be described by its chemical composition and digestible coefficients has been improved by introducing dwarf gene into his genetical material (Burton and Forston, 1966). The dwarf gene produced an increase in leaf % by shortening internode length, the content of crude protein, ether extract and nitrogen free extract in the forage (Burton et al., 1969). Also the introduction of dwarf gene reduced rate of growth, plant height and dry matter yields without otherwise affecting the appearance of the plant. Apart from these reductions, the response of animals fed with dwarf plants was greater than the response of animals fed with tall Millet plants when both plants were cut at 74 days after planting. Dairy heifers ate 21 % more dwarf forage, gained 49 % faster and produced as much gain per hectare as heifers similarly fed with tall forage.

Several diseases were reported to attack Bulrush Millet and among them Claviceps fusiformis was indicated as the more important (Johnson, 1969).

1.2. <u>Productivity of Millets</u>

Among plant characteristics, dry matter and crude protein yield are commonly taken as indices of herbage value in relation to livestock. Some authors prefer to express crop yield as total digestible nutrients (TDN). From the findings of Faires <u>et al</u>., (1941), Pearl Millet produced an average of 1420 lb of TDN per acre, ranging from 959 to 1950 lb TDN/acre/year; expressing the result on D.M. yield, 3.394 lb/acre was obtained. The grazing period extended over 109 days, suppling the bulk of material in mid and late summer which permitted 4 grazings. The crop was uniformly distributed throughout the grazing season which produced enough material to maintain an average 78 cows - day per acre for the whole season. Chemical composition at the time of grazing for the 4 cuttings, indicated an average level for crude protein content of 10.14% and for crude fibre content of 31.24%. On the evidence of Faries <u>et al</u>., (1941) plants were more nutritious in the early periods of seasonal growth which agreed with other results reported on section 1.4.

In Minnesota, several Millets species were tested during the dry season (Arny <u>et al</u>., 1946). Hay yields of Millet had a higher production than those for Sudan, Soybean or oats. Among Millet species, several varieties within 3 groups (foxtail, proso Millet and Japanese Millet) were recorded (Table 1.3).

In general hay yields of all prosos millet were somewhat lower than the foxtail varieties; Japanese Millet was among the lowest yields.

TABLE 1.3

Hay Millet Yields

(Adapted from Arny *et al.*, 1946)

Variety	Group	$\bar{x}$ hay yield	$\bar{x}$ height (in)
German	foxtail	3.1 tons/acre	37
Empire	foxtail	3.5	38
Golden	foxtail	2.9	36
Red Siberian	foxtail	3.0	35
Hungarian	foxtail	2.6	33
Red Turghai	Proso millet	2.7	35
Crown	Proso millet	2.7	36
Yellow Manitoba	Proso millet	2.7	38
Black Voronezh	Proso millet	2.5	42
Japanese Millet	Proso millet	2.6	42

Roark *et al.*, (1952), Arnold (1956) and Blout (1956) indicated that Starr Pearl Millet produced more green forage than Tift Sudangrass; however Miles *et al.*, (1956) found that the latter produced 15% more green matter and 53% more dry matter than Starr Pearl Millet. Roark *et al.*, (1952) pointed out that Pearl Millet produced 1660 lb TDN/acre while Tift sudangrass supplied 490 lb TDN/acre. In grazing studies Miles *et al.*, (1956) obtained 56% more TDN/acre and a lower cost per pound of TDN from the sudangrass than the Millet; also sudangrass had a higher quality grazing crop than Millet for dairy cows. The differences between this experiment and those of Roark *et al.*, Arnold and Blout were attributed principally to differences in the stage at which the two species were harvested, being the earlier stage of growth more favourable for sudangrass than for Millet. On the other hand, Ronningen et al., (1955) comparing Pearl Millet and Tift Sudangrass during the first experimental year found that the former produced nearly 100% more than the sudangrass, however in the second year, the Millet was the lowest producer.

Gahi-1 Pearl Millet planted in wide rows (24 in - or 36 in) yield more than Millet planted in 7 inch rows, particularly in those rainy years (Hart and Burton, 1965). During dry years, there were only small differences. However, contrary to the above results Craigmiles et al., (1958) reported that Starr Millet produced higher yields in 7 inch drill rows than in 36 inch rows, but rainfall was adequate or excessive in all experimental years so the superiority of wide rows in drought periods was not apparent. Decreasing the row spacing and increasing the seeding rate, Hart and Burton (1965) indicated that plants produced more leafy forage because stems were smaller in diameter as the plants became more crowded. There was no effect of row spacing on dry matter digestibility; all treatments having the same value (61%). Craigmiles et al. suggested that row seeding has some advantages because it is possible to obtain better weed control, less seed is required per acre, and there is less waste forage from trampling since animals tend to walk between the rows while grazing.

In Connecticut, Brown (1924) (cited by Jung and Reid, 1966) compared yields obtained from Japanese Millet, soybeans, sudangrass or mixtures over a 3 year experiment; Japanese Millet yielded more than any of the other species or mixtures. Odland et al., (1942) studied the adaptation of Japanese Millet as a supplementary pasture. It was planted at 5 dates (from 20th of May to 15th of June) and harvested when reached a reasonable grazing stage. Japanese Millet planted during June provided the highest grazing period and yield of dry matter.

Only three experiments under New Zealand conditions on Japanese Millet productivity have been reported. The Millet was compared with other summer crops, particularly with sudangrass and maize, and indicated a variable response. During the first experiment (Lynch, 1966) Japanese Millet was seeded on 20/11/65 at the rate of 20 lb/acre. At the first cut (10/1/66) produced a yield of 3430 lb D.M./acre, however it had a poor response after grazing and no information after the 2nd cutting was obtained. When Japanese Millet was fertilized with 2 cwt. of sulphate of ammonia, yield was increased until 4320 lb D.M./acre. In the same report, Lynch (1966) presented a new approach with Japanese Millet where it was seeded at the same time and rate as previously reported. Although in this case the crop was cut twice (10/11/66 and 11/2/66) produced less amount than previously was indicated (2300 and 2500 lb D.M./acre respectively for 1st and 2nd cut). Japanese Millet produced a higher yield than maize but it was overyield by sudan hybrid which obtained near 6000 lb D.M./acre under 3 cuttings during the whole season.

A second report (Lynch, 1968) from Ruakura was presented with a new information on Japanese Millet. Here again the crop was compared with sudangrass hybrid and maize, planted on different areas of New Zealand. Dry matter yield of Japanese Millet varied from 2860 lb/acre which was the lowest yield until 8360 lb, depending on the type of soil and climate conditions under the area tested. Always first growth produced a higher yield than regrowth, which sometimes was higher than sudangrass; however there was not a uniform response. From the findings of Lynch (1968) it appears that Japanese Millet produces less than sudangrass, however the differences between crops were not bigger than 1000 lb dry matter per acre for the whole season. In a new research report from New Zealand Department of Agriculture (Honore, 1967) Japanese Millet, 5 sudangrasses and maize were compared. All crops were seeded on 2/12/66 and first and second cut were reported to be made on 28/2/67 and 19/4/67 respectively. At the first cutting Japanese Millet produced the highest yield (6230 lb D.M./acre), however the recovery was lower, being outyielded for the other sudangrass at the second cutting. Japanese Millet response during regrowth had a similar pattern than that previously reported by Lynch (1968). Sudangrass produced the highest yield of dry matter (8930 lb D.M./acre) being for Japanese Millet 700 lb less.

Bulrush Millet has been proved the most productive and versatile annual forage of those tested at Katherine (Norman, 1966).

The average dry matter yield over 11 years was 11.540 lb/acre and had a mean deviation from the mean of 23%. It was found a correlation of $\hat{r}$ = 0.76 between dry matter yield and total annual rainfall (Norman and Begg, 1968). The first full scale growth and development study of Bulrush Millet was made by Begg (1965) using Katherine Pearl Millet. The growth and recovery from defoliation was measured under a first harvest series of treatments similar to that present in the experiment of Phillips and Norman (1967). Begg (1965) recorded a maximum dry matter yield 16 weeks from emergence of 21.735 kg/ha. During weeks 12 and 13, the crop increased in dry matter yield at a rate of 480 lb/acre/day. On the evidence of Phillips and Norman (1967), maximum rate of growth was reached in weeks 9 and 10, but did not exceed 242 lb/acre/day. According to Begg (1965) full light interception was obtained at the 5th week, after that there was a marked increase in dry matter production, internode length and leaf area index (maximum value was 9 reached at the 7th week). In the same experiment, regrowth yields were higher when the harvest of first cut was made at an early stage (3 - 4 weeks after emergence) when the apical meristem was below the cutting height, rather than later. The same pattern during regrowth was reported by Phillips and Norman (1967). From the findings of Begg (1965) at all maturity stages the leaves, both green and dry, contained a higher percentage of nitrogen than the stems. The nitrogen % in the green leaves and stems increased during the 4th and 5th weeks, then decreased during the following harvests. A peak yield for the whole plant of 215 kg nitrogen/ha. was recorded 9 weeks after emergence and the yield remained about this level for the remainder of the harvesting period.

Phillips and Norman (1962) reported the effect of 3 different preceding crops (peanuts, cotton and sorghum) on Bulrush Millet production. The preceding crop did not effect the dry matter yield of Bulrush Millet but the nitrogen yield of Millet following peanuts was half as high again as that following cotton or sorghum. A similar experiment was made the following year (Phillips and Norman, 1962); dry matter, nitrogen content and nitrogen yield of Millet were highest after peanuts and lowest after sorghum, with values cotton intermediate. The results from these two experiments tend to show that sequence effects on Bulrush Millet are largely attributable to differences in residual available nitrogen.

The mean growing period of Pennisetum typhoides was reported to be 21 weeks (Phillips and Norman, 1966). Dry matter yield was associated with differences in soil water storage and presumably the results are depending on ploughing treatments. When a primary land preparation was made during the dry season (June) it was found a very small effect on dry matter yield, however when the preparation was made early in the wet season, a significant effect was observed and also more water was stored in the soil. With inter-row cultivation dry matter yield was also increased. As in general high nitrogen content was associated with low dry matter yield, the above treatments no increased forage nitrogen content. This experiment (Phillips and Norman, 1966) showed that variation in the depth and time of chisel ploughing appears to influence crop growth, and that, in the cultivation of Bulrush Millet there was little to be gained by shallow ploughing in the dry season or by more than one inter-row cultivation.

The effect of time of sowing on Millet growth was reported by Nanda et al., (1957 a,b). In the first experiment two millet species were considered (Setaria italica and Panicum miliaceum) which were sown at 4 and 3 different dates respectively, at intervals of 35 days one to the other. During the second experiment the latest two species were again used plus Japanese Millet and two other Millets grains; all species were sown at five different dates using the same intervals as in experiment one. The same responses were observed on both experiments: the vegetative period of the main shoot was progressively reduced with the time of sowing. This reduction on the vegetative period was also accompanied with a progressive reduction in the vegetative growth as measured by dry weight of plant. From the findings of Nanda et al. it appears that environmental conditions govern these changes in the growth of the plant. Thus changes in the light and temperature conditions might change some plant characteristics such as the growth rate, steam to leaf ratio, leaf shape, size and number. It appears that the complex of environmental conditions available to plants sown on later dateis more favourable for the completion of development at a faster rate. Also it was observed that stem elongation was determinated by the length of the vegetative period. With late sowing, stem elongation started earlier and was faster, while delaying the onset of flowering by earlier sowing stem elongation was retarded. Apparently Nanda *et al*. suggested that no stem growth takes place in these Millets as long as the growing points remain in vegetative conditions. The stem growth appears to be initiated after the growing points have changed from the vegetative to the reproductive conditions.

Two varieties of *Pennisetum typhoides* (early and late maturity) were studied by Ramond (1968) in relation to tillering, heading, flowering, stem height and ear area. In all cases, tillering began 13 days after sowing and ended between the 35th and the 40th day. Total tiller number was high, 25 - 30 for the early and 30 - 40 for the late type, but only about 25% of the tillers produced ears. With later sowing dates, the interval from sowing to flowering was reduced, flowering occurred earlier and stem height and straw to grain ratios were reduced.

1.3. Effect of Climate on Millet Growth.

Although Millet was reported as a drought and heat resistant plant (Lahiri and Kumar, 1966; Hart and Burton, 1965; Mays and Washko, 1961; Burton and Fortson, 1966), several experiments have reported that water shortage affects its yield. During the summer of 1970 and 1971 it was observed that Japanese Millet seeded at Massey University, grown relatively more fast when abundant water was supplied. Hart (1958) indicated that at least two times, water must be supplied in order to obtain a reasonable plant development: one after germination to encourage secondary root development and the other at heading stage of maturity. Among Millet, Pennisetum typhoides was reported as a crop which needs less total rainfall than sorghum, but although it can withstand drought, it is less drought-resistant than sorghum because it lacks the ability to arrest growth when the soil is dry and to resume growth later (Johnson, 1969).

Arny et al., (1946) working during the dry season at Minnesota found that Millet produced reasonably well (3.6 tons of hay/acre) in those years when rainfall was average or above average for the season. However when Millet was planted during years when rainfall was below the average for the season, plant yield decreased about 50% compared with the normal years. An experiment made under Pensylvanian conditions, Mays and Washko (1961) reported that D.M. of Common Pearl Millet and Gahi-l Pearl Millet were also reduced more than 50% as a result of a dry season. Faires et al., (1941) indicated that periods of drought during the growing season greatly reduced the yields of Pearl Millet, which seemed to be very susceptible to changes in moisture conditions. Sudangrass, another summer crop, was also reported to be affected by drought conditions, since the dry matter yield was reduced on 50% (Jung and Reid, 1966).

Studies made on plant resistance under acid and semi acid conditions (Henkel, 1961), suggest that tolerance to drought changes with the physiological age of the plant and it was observed that maximum effects are produced at the time of generative organs formation (critical stage). The magnitude of the effect may be relatively less in other stages in comparison with the critical stage; nevertheless it indicates that moisture stress induces some changes in the cell which cannot be fully rectified by the establishment of an optimum moisture regime at the later stages of crop's growth.

The effects of soil moisture deficit at different development stages (2, 3, 4, 5 and 6 weeks) on Bulrush Millet have been studied by Lahiri and Kharabanda (1965) and Lahiri and Kuman (1966). Although it is commonly accepted that Bulrush Millet is a drought resistant species, it was found that plant mortality can be fairly high, particularly at the critical stage: 5th and 6th week stage. During the early stage (two weeks) drought did not produce any significant effect on the height of plants; however during more advanced stages, moisture deficit had an adverse effect, being greatest at the 5 week stage. When the drought was applied during the 6th week, as the plants were approaching maturity, the growth was affected relatively less in proportion. With respect to the effect of drought on leaf number of the main shoot, Lahiri and Kharabanda (1965) and Lahiri and Kuman (1966) reported similar trends as in the case of height growth of plants; the maximum effect being produced at the 5th week while intermediary effects were produced at the 3rd and 4th week stage. Also during the 5th and 6th week have been produced the maximum effect of drought with regard to the time taken for ear-emergence. These results are according to Henckel (1961); in general susceptibility to drought increase with the age of the plant. It seems that climax of sensitivity for vegetative growth occurs little just before to maturity and that for yield at the initiation of the reproductive phase. Lahiri and Kuman (1966) indicated a parallelism of drought sensitivity at different developmental stages in two other Millet varieties, and it was suggested that the mechanism of drought action, in general, was similar to that indicated above and then a common mode of action may also be operating in all other Millet varieties.

1.4. Effect of Cutting Height and Frequency on Millet Production.

The effects of cutting height and frequency on perennial grasses have been reviewed by numerous workers (Humphreys, 1966). Generally as the frequency of clipping of perennial grasses increases, there is a reduction in growth rate and forage yield. On the other hand, the effect of differential clipping heights on growth and forage production of perennial grasses indicated that in almost every case reducing the stubble height resulted in slower recovery rates, lower total forage yields and reduced root and rhizome growth. It appears that the same pattern would occur in Millet (Norman, 1966).

The effects of row spacing, height of plants before cutting and height of stubble remaining after cutting on the growth of Pearl Millet were studied by Hoveland and McCloud (1957). It was found that rows spaced 18 to 20 in. apart produced the highest yields. Although the highest total yield was produced when the plants were allowed to grow to the height of 54 in. and were cut down to 4 in., this treatment resulted in the lowest protein content. They also indicated that the lowest yields were obtained when the plants were allowed to grow to a height of 12 in. and were cut down to a 4 in. stubble. The latter cutting treatment resulted in the highest protein content. Hoveland and McCloud concluded that the best combination of production and quality was obtained when 30 in. plants were clipped to an 18 in. stubble.

Broyles and Fribourg (1959) studied the response of two Millets (German Millet and Gahi-1 Pearl Millet) and two sudangrasses, to the following cutting treatments: (a) cut when 20 in. in height to a 6 in. stubble, (b) cut at 30 in. to a 6 in. stubble, (c) cut at 30 in. to a 10 in. stubble and (d) cut at early bloom to a 4 in. stubble. Taking an average for all treatment together, Gahi-1 Pearl Millet produced the highest dry matter yield (4363 lb/acre) and the highest crude protein yield (397 lb/acre), while German Millet produced the lowest values for both characteristics (1313 lb D.M./acre and 174 lb crude protein/acre). Gahi-1 under treatment (c) produced the highest level for either dry matter (5190 lb) or crude protein yield (494 lb) per acre, followed by treatments (d), (b) and (a) with respect to dry matter yield. Crude protein values followed a reverse order to that presented above for dry matter. It was found that the relationships between dry matter and nitrogen % of the forage followed a straight line when the logarithm of both variables were used. These relationships indicated that as cutting intensities decreased and the height of the grasses increased, there was a general decrease in the nitrogen % of the harvested forage.

Mays (1961) and Mays and Washko (1961) presented some information particularly related to the stubble height remaining after cutting on two Millet varieties (Gahi-1 Pearl Millet and Common Pearl Millet) and two sudangrass varieties. Each time the forage reached a height of 18 to 20 inches, it was cut back to 2, 4, 6 or 8 in. above the soil surface. With these treatments it could be possible to know the stubble heights at which maximum recovery of plant growth is obtained and also which stubble heights allow for maximum production of harvestable forage. Under grazing management it is very important to know whether Millet should be moderately or severely defoliated at each time to obtain the maximum production of high quality forage per season. Because of the drought season during the second year, all treatments averaged two cuts less than during the previous year which was under normal conditions. The number of harvests per season was greatly influenced by the different cutting heights. During normal years as the height of cutting was decreased from 8 to 2 in., for both Millets the number of cuttings decreased from 6 to 3. It seems that Common Pearl Millet was little more affected than Gahi-1 Pearl by the drought since the former produced one cut less at 6 in. heights. Among the 4 species, Mays (1961) and Mays and Washko (1961) showed evidence that Common Pearl Millet was the highest yielding variety and Gahi-1 Pearl Millet produced slightly more than the two varieties of sudangrass. In all varieties, as the number of cuttings increased dry matter yield significantly decreased; there was a negative relationship between number of cuttings per season and dry matter yield. The highest dry matter yield was obtained from those plants harvested at 2 in. height (1.45 tons D.M./acre for Common and 1.18 tons D.M./acre for Gahi-1 Pearl Millet); the lowest was obtained at 8 in. cut. Amount of stem and leaf on herbage harvested varied considerably on the height at which it had been cut; those cut at 2 in. contained the highest proportion of stem tissue while those cut at 6 and 8 in. were almost entirely leaves. Tiller counts indicated that the number of tillers increased more after Millet was cut at 2 in. height than after cutting at 4, 6 and 8 in. heights. It appears that differences in vigour and recovery rate after cutting were related to differences in the amount of photosynthetic tissue remaining on plants cut at different heights.

With respect to chemical composition, Mays (1961) and Mays and Washko (1961) reported that lowering the cutting height of forage from 8 to 2 in., increased its crude fibre content and decreased its content of crude protein and TDN. Protein and TDN values were higher at first cutting than at latter cuttings. The higher value of protein at first cutting indicates a decrease in nitrogen availability as the season progressed. As a general conclusion the highest dry matter yields were obtained when any Millet varieties were cut at the lowest height (2 in.) The nutritive value, measured by its crude protein, crude fibre and TDN indicated that the highest values were obtained at the highest height (8 in.), however the nutritive value of forage removed was not high enough to offset the yield disadvantage of these treatments. Although Millet produced smaller amounts of dry matter when it was cut at high heights, forage yield was distributed more uniformly and pasturage was available more often than when the plants were cut at lower heights.

Two experiments related to the effects of frequent defoliation on Millet production were presented by Norman (1962). In the first trial, Japanese Millet and 7 other Millet varieties were compared under 3 different systems of cutting: (A) Cut at 4, 8, 12 and 16 weeks after sowing; (B) Cut at 6, 12 and 18 weeks after sowing and (C) Cut at 12 and 18 weeks after sowing. From this trial, 2 varieties were selected (Katherine bulrush Millet and Gahi-1 bulrush Millet) and examined in greater detail in experiment two. Cutting treatments on experiment two were as follows: (A) cut at 4, 8 and 12 weeks after sowing; (B) cut at 8 and 12 weeks after sowing; (C) cut at 4 and 12 weeks after sowing and (D) cut 12 weeks after sowing. In experiment one the results for Japanese Millet and White french Millet were so

TABLE 1.4

Dry matter yield and nitrogen yield of Millets under three cutting treatments.

(Adapted from Norman, 1962)

Cutting treatments	White Panicum	Katherine Bulrush M.	Gahi-1 Bulrush M.	Starr Bulrush M.	S. J. Bulrush M.	Selection 7 Bulrush M.
Dry matter yield (lb/acre)						
4, 8 and 12 weeks	3540	4590	5600	4510	4500	4020
6 and 12 weeks	3340	6700	8340	6430	4260	4960
12 weeks	4190	12940	5780	4300	2940	3780
average	3690	8080	6750	5080	3900	4250
Nitrogen yield (lb/acre)						
4, 8 and 12 weeks	62.4	80.6	89.5	78.0	78.3	75.2
6 and 12 weeks	48.7	91.8	88.7	76.8	55.3	64.6
12 weeks	41.1	88.0	62.4	39.6	44.4	51.8
average	50.7	86.8	80.2	64.8	59.3	63.9

poor that no information was reported. Results for the other 6 Millet varieties on Dry matter yield and Nitrogen yield are presented on Table 1.4.

Table 1.4 indicates a marker interaction in dry matter yield between varieties and cutting treatments. According to the previous experiments, under most frequent cuttings, yields were the lowest; however there were some irregular responses. Nitrogen yield showed a general increase with increasing frequency of cutting. The different responses among Millet varieties were related to their developmental vegetative and reproductive stages. Katherine Bulrush Millet completed its developmental phases by 12 - 13 weeks, but the other 4 Millets only needed 8 - 9 weeks. Results from the second experiment, Norman (1962) indicated a similar pattern as was shown for the first experiment: there was an interaction between varieties and cutting treatments. However, nitrogen yield showed an increase with decreased frequency of cutting. It was indicated that dry matter yields were relatively low because the experiments were carried out in years of below-average rainfall.

Among a group of 6 summer pasture species, Bulrush Millet gave the highest average dry matter and crude protein yield over three seasons (12.100 and 791 lb/acre respectively) (Norman and Wetselaar, 1960). During the first experiment (A) the herbages were sampled for yield at 4, 8, 12, and 16 weeks after sowing. During the following experiment (B) plants were subjected under two treatments: cut at 8 and 12 weeks and cut again at 16 weeks. A third experiment (C) took into account 3 treatments: cut at 6, 12 and 18 weeks; cut at 9 and 18 weeks and the last, cut at 12 and 18 weeks. Millet made rapid growth between 4 and 12 weeks with a reduction in growth rate between 12 and 16 weeks, however it showed a steady growth up to 16 weeks (11.890 lb D.M./acre). A high crude protein content (24%) was obtained at 4 weeks after sowing and then fell steadily to 6.5% at 16 weeks. However crude protein content showed a decreased pattern as the plant matured, the crude protein yield of bulrush Millet continued to increase up to 6 week reading a maximum of 769 lb/acre. According to Norman and Wetselaar (1960) Bulrush Millet produced the highest dry matter yields when left uncut, however if the crop was cut twice in the season the crop produced the highest yield when the cut was made later (12 and 16 weeks) rather than earlier in the season (8 and 16 weeks). The same pattern was observed during experiment (C), and also the treatment with the highest cut frequency produced the lowest yield. With respect to crude protein content, Norman and Wetselaar suggested that it decreased as the date of cutting was delayed. Cutting more frequently (6, 12 and 18 weeks) gave forage of a high c. protein content than cutting at 9 and 18 weeks, which in turn gave higher quality material than those at 12 and 18 weeks. Total crude protein yield followed a similar but contrary pattern than that shown for dry matter yield, producing a level as high as 1000 lb crude protein/acre. From the findings of Norman and Wetselaar it appears that the best management for the late-maturing bulrush Millet is to be cut for silage at 12 weeks. From this response under frequent cutting, indicates that the crop has a big potential as a grazing plant.

In order to test the comportament of two Millets, Katherine Pearl and Ingrid Pearl, they were compared in two cutting experiments where different cutting regimes were included in each (Phillips and Norman, 1967). During the first experiment the three treatments were described as follows: (A) plants were cut 3 times (at 4, 8 and 12 weeks) plus recovery at 18 weeks; (B) plants were cut twice (at 6 and 12 weeks) plus recovery at 18 weeks and (C) plants were cut once at 12 weeks plus recovery at 18 weeks. On the second experiment, each variety was cut at 4, 6, 8, 10, 12, 14, 16 and 18 weeks after sowing. Total dry matter yield of both varieties was markedly reduced by repeated cutting, being the highest yield 18.310 lb/acre. In view of soil water deficiencies Phillip and Norman indicated that it was unlikely that any further dry matter increase would have occurred beyond 18 weeks. Regrowth was higher when it was made earlier during first growth but recovery yields fell rapidly from the earliest cut, reaching zero at 14 weeks. Similar trend was reported by Begg (1965) who indicated that this response was due by the fact that apical meristem of Katherine Pearl remained low until the end of week 5, then rises steadily at approximately 4 cm/day. Thus with a later date of first harvest a progressively greater number of apices are raised above cutting height and the tiller density and yield of the recovery growth falls. Nitrogen content followed a contrary pattern to that presented for dry matter yield in Phillips and Norman's experiment. During the first growth nitrogen content decreased from earlier cut to maturity stages. But during regrowth nitrogen content rose for the earliest cut until the latest cut. Ingrid Pearl Millet was reported by Phillips and Norman reached maximum dry matter yield a fortnight before Katherine Pearl and also the former reached the highest nitrogen yield. Maximum nitrogen yield was reached at 14 - 16 weeks with the highest yield of 114 lb/acre which had an equivalent of 714 lb of crude protein/ acre. In Begg's experiment (1965) nitrogen yield of Katherine Pearl reached a maximum at the 11th week and showed only a slight decline for the next 6 weeks.

More recently, Beaty et al., (1965) reported a new approach about effect of cutting on Millet productivity. Pennisetum typhoides and 2 sudangrass varieties were harvested at frequencies of 2, 3, 4 and 5 week intervals and also treatments were removals of 1/3, 1/2, 3/4 and 7/8 of existing heights. In Table 1.5 is presented Millet results for dry matter yields; forage production tended to increase as harvest frequency was extended for 2 to 5 weeks. The highest yield reduction resulted when a 2 week frequency was combined with removal of 7/8 of the plant. Height at which the crop was clipped had less effect on production than did harvest frequency. Millet produced a highest dry matter yield than both sudangrass varieties. Also Millet was more resistant to drought than the other two species. Gahi-1 Millet continued to produce well late into the season and then still supplied forage in the Autumn, while sudangrass practically stopped growth late in the Summer. The optimum frequency of clipping would depend on whether quality or quantity was the primary objective. If a high quality forage is desired then a 2 or 3 week clipping frequency combined with 1/3 removal would be more advantageous. While 5 weeks frequency combined with a 3/4 or 7/8 removal would give the highest yields.

TABLE 1.5

Effect of cutting height and frequency on Gahi-1 Millet

(Adapted from Beaty *et al*., 1965)

Height of forage removed \ Frequency of cutting	2	3	4	5
1/3	6040*	5468	5938	5473
1/2	5698	6011	6974	6654
3/4	5205	5820	8164	8966
7/8	4400	5233	6995	8376

* lb dry matter/acre

The effect of maturity of Pearl Millet on forage yield and quality was reported by Burton *et al*., (1968). Early and late bulrush Millet were cut at 2, 4, 6 and 8 week intervals for 24 weeks. As the cutting interval increased from 2 to 8 weeks, total forage yields increased in the same direction. On average cutting every 8 weeks produced 95% more D.M. (7366 kg D.M./Ha) than those plants cut every 2 weeks (4338 kg D.M./Ha); late variety produced more than early variety on the 4 cutting treatments. Although an 8 week cut interval produced the highest D.M. yield, it was observed that the seasonal distribution yield was better for 2 weeks cut. Also increasing the cutting from 2 to 8 weeks increased the plant height and D.M. %, and decreased the % and yield of leaves. The largest differences between early and late varieties were among leaves % and leaves yield. Under all treatments, late variety had a higher leaves % and produced more leaves/acre being the highest differences when they were cut at 6 week intervals. Crude protein content of leaves, stem and heads decreased and crude fibre % increased as the cutting interval increased. Crude protein content and crude fibre content on leaves are higher and lower respectively than in stems. Dry matter digestibility also showed a change according with cutting intervals, it dropped as the cutting intervals increased from 2 to 8 weeks. The digestible dry matter in late Pearl Millet stems dropped much faster than in leaves.

1.5. Effect of Stage of Maturity on Nutritive Value of Millet.

It is commonly accepted that the primary objective in any study of the chemical composition of forage is to obtain an indication of its nutritive value. Although the information gained is of the less value than that obtained from feeding trials, it is a practical method of herbage evaluation. The chemical composition of pasture herbage and, correspondingly, its nutritive value depends primarily on the degree of maturity attained by the plant at the time of cutting or grazing. Beaty et al., (1965) studying Gahi-1 Millet cut at different stages of growth indicated that certain features of plant such as succulence, leafiness and younger growth are associated with higher quality, while older stemmy and harder material are considered to be of lower quality.

It is a well known fact that certain progressive changes in plant composition are incident to advancement of maturity. This is characterized by rapid elongation of the stem during the period immediately preceding bloom, and the resulting changes in the leaf to stem ratio. As the plant matures, the moisture content decreases and the dry matter content increases correspondingly. Of the dry matter content, the per cent of crude protein decrease (Phillip et al., 1954; French, 1957; Cooper, 1956; Featherstone et al., 1951; Norman, 1939); the per cent of lignin and crude fibre increase (Phillips et al., 1954; French, 1957; Crampton and Forshaw, 1940; Heinrichs and Carson, 1956; Kamstra et al., 1958; Sullivan et al., 1956); the per cent of nitrogen free extract generally increase (Heinrichs and Carson, 1956; Phillips et al., 1954) and the per cent of ash and ether extract remain about the same level, although they may be variable (Heinrichs and Carson, 1956), as the plant matures. Tropical grasses have a higher crude protein % than temperate species; French (1957) indicated that this fraction is also more digestible in tropical grasses than in temperate pasture.

In the production of a high quality forage, it is very important to know the relative plant changes during growth. The upward trends of lignin, crude fibre and cellulose, and the downward trends of crude protein, ether extract and ash, point the probability of close relationship among these constituents. Results from Sullivan et al.,

(1956) have shown highly significant positive correlation among constituents within each group and a significant negative correlation between any two constituents of the different above groups. Some values obtained by several investigations are summarized in Table 1.6.

TABLE 1.6

Relationships between chemical components

Components	Coefficient of correlation	Reference
Protein - Crude Fibre	-0.781	Phillips *et al.*, (1954)
	-0.665	Rusoff *et al.*, (1961)
Protein - Ether Extract	0.789	Phillips *et al.*, (1954)
Protein - Dry Matter	-0.741	Rusoff *et al.*, (1961)
Protein - Ash	0.852	Phillips *et al.*, (1954)
Protein - Lignin	0.840	Watkins and Kearns (1956)
Crude Fibre - Ether Extract	-0.707	Phillips *et al.*, (1954)
Crude Fibre - Ash	-0.645	Phillips *et al.*, (1954)
Crude Fibre - Dry Matter	0.581	Rusoff *et al.*, (1961)

Information about Millet on chemical composition changes as the plant matures was reported by Rusoff *et al.*, (1961). Gahi-1 Pearl Millet and Common Pearl Millet were cut at 5 successive times indicating a similar pattern to those reported previously. Table 1.7 shows the chemical composition for both Millets. It is evident that the greatest relative changes with aging of plant tissues occurred in the protein and crude fibre contents. However in Common Millet crude fibre % did not increase continuously up to the seed stage; this change was suggested apparently due to the formation of the grains,

TABLE 1.7

Chemical composition of two Millet varieties

(Adapted from Rusof et al., 1961).

GAHI-1 PEARL MILLET Cuttings	Height	Crude Protein	Crude Fibre	Dry Matter	NFE	Ether Extract	Ash
1 - at 30	37.7	11.7	27.6	14.7	43.9	1.9	14.9
2 - 10 days later	39.7	8.3	32.5	15.6	45.6	2.0	11.4
3 - 10 days later	61.0	5.7	34.2	16.9	47.2	1.9	11.0
4 - 10 days later	69.7	6.0	33.0	23.1	48.8	1.7	10.5
5 - 10 days later	73.5	5.4	37.7	25.6	44.9	1.9	10.1
COMMON PEARL MILLET							
1 - at 30	31.5	10.7	27.1	11.6	46.3	2.1	13.8
2 - 10 days later	45.5	8.5	35.6	17.0	41.3	1.4	13.2
3 - 10 days later	53.5	6.4	33.3	18.7	48.0	1.6	10.7
4 - 10 days later	64.7	4.3	30.4	23.1	53.8	1.7	9.8
5 - 10 days later	63.7	4.9	29.6	27.6	54.5	2.0	9.0

which resulted in an increase in the percentage of nitrogen free extract.

Two other varieties of Millet, Bulrush Millet and a Millet grain were described on their chemical composition by French (1946). Both species were cut when they were 4 to 6 feet high. Chemical composition was similar to that reported previously by Rusoff et al., (1961) during the third cutting. A higher crude protein % and lower crude fibre % were obtained by Bulrush Miller due to a younger stage of maturity than grain Millet. Due to the same effect, digestibility analyses and S.E. for Bulrush Millet were also higher than grain Millet.

Under African conditions it is a normal practice to graze Millet stubble left standing after the grains have been harvested (principally dried stalks and leaves) (French, 1943). The relative feeding value was reported, expressed by their chemical composition and digestibility analyses results, since this crop represents an important source of foodstuffs for livestock. Chemical composition indicated that Bulrush Millet was more fibrous than grain Millet. Digestibility analyses showed that a bigger selection was made in the case of Bulrush Millet than grain Millet since a bigger proportion of material offered was remained uneaten.

Young Gahi-1 Pearl Millet leaves from the top of the plant and old leaves from the bottom of the same plant were compared, and it was observed that young leaves contained more crude protein % and less lignin % than older leaves (Burton et al., 1964). The amount of cellulose did not differ between both types of leaves, however young leaves were more palatable to cattle than old leaves. Also young leaves had a higher dry matter digestibility (75.3 %) than old leaves (61.4 %). When 18 successive leaves from top to bottom were collected in the same plant, it was observed that dry matter digestibility decreased from 73.9 % to 58.2 %.

It is essential to know whether the changes in chemical composition of grass at the various stages of growth are reflected in the rate of consumption of milk by the dairy cow. Blaser (1962) and Burton et al., (1963) indicated that the reduction in feeding value with advances in growth stage are attributed to: decreased consumption and decreased digestibility energy and then, this reduction in digestible energy is associated with: (a) increases in structural carbohydrates and lignification, (b) reduction in soluble carbohydrate in some forages and (c) a reduction in digestible crude protein when it is used for energy.

For many years digestion data have been used extensively in evaluating quality of forage. However Crampton (1957), Crampton et al., (1961), Blaxter (1961) and Reid (1961) have showed that neither TDN nor the digestibility of calories are as an accurate or complete measure of forage nutritive value as might be desired and that voluntary intake of the forage should be taken into consideration.

1.6. Grazing Experiments

Experiments with dairy and beef cattle in particular have been published using different varieties of Millets as a grazing crop. In the next section the effect of Millet will be reviewed particularly in relation to milk production and live weight gains.

Millet Affecting Milk Production

The following experiments with dairy cattle have been done principally under U.S.A. conditions where Millet and sorghum are the main summer crops. Under this situation most of them were made with the aim of finding which is the best summer crop to supply animal requirement principally under grazing condition.

Among the first reports of Pearl Millet (*Pennisetum glaucum*) with dairy cattle, King (1947) stated that this plant proved to be the best temporary grazing pasture tested at the Georgia Research Station. Pearl Millet grown on good land, fertilized liberally and grazed rotationally, required only 0.3 of an acre to provide all the forage a dairy cow would consume during the summer time. In trials at the Mississippi station Pearl Millet was superior to Tift sudan or grain sorghum as a summer grazing pasture. Roark, *et al*., (1952) reported that lactating cows grazed 1.261 and 2.056 lb TDN per acre from millet pasture while grain sorghum provided 830 lb and 1.480 lb respectively for the first and second year. Pearl Millet was reported by Marshall *et al*., (1953) as the most commonly used summer temporary pasture under Florida conditions. A 3 year experiment was made in order to know the nutritive value of Pearl Millet to produce milk. Grazing was initiated with lactating cows when the millet was 14 to 22 inches tall and approximately 14 days were required after the last grazing for the new shoots to obtain grazing height. In the 3 years, Millet planting was made at different times (March 28, April 20, May 16) and it was observed that the interval from planting until the initiation of the first grazing became shorter with the later plantings; the intervals ranged from 25 to 47 days. The length of grazing seasons was also affected by the time of planting, being 123 days for the early sowing and 100 days for the latest. Marshall et al., indicated that for the whole season during the first two years there was an average of 5 lb liveweight gain per animal, however in the third year there was a loss of 26 lb per animal; no reasons were suggested to explain these differences. Pearl Millet produced an average of 26.6 lb of milk yield which contained 4.9 % of butterfat; the yield on FCM was 30.3 lb. This level of milk production was obtained as result Millet was supplemented with concentrates at the rate of 1 lb per 3.5 lb of FCM produced. Estimations of TDN grazed per acre from Millet was 2.113 lb as average for the 3 years, which agreed with the results reported by Roark et al., (1952). Miller et al., (1958) reported as two year experiments with Starr Millet and Tift sudangrass which were compared under Georgia conditions to determine their relative values for dairy cows. A 4 week interval between 2 consecutive grazings in the same paddock was adopted as grazing management for both species. A concentrate mixture was fed at approximately the rate of one pound to each 4 pounds of FCM produced. The same amount of milk (26.6 lb) was obtained for both Millet and sudangrass herbage, however as the former had a lower fat test (3.84%) than the latter (4.20%), the FCM for sudangrass was bigger (27.1 lb) than that for the Millet (25.6 lb). No explanation for butterfat % differences was reported. Although the primary reason to grow summer crops is usually to maintain milk production when permanent pasture forage is of low quality, this experiment showed a low level of FCM persistency for both crops. There were no statistically significant differences in the liveweight gains of the cows grazing the two species; 0.52 lb/cow/day was gain per animals on Millet while 0.74 lb/cow/day for those on sudangrass. Digestibility data indicated that both forage had same values (59.8 and 60.4 % respectively for Millet and sudangrass). With respect to intake, cows grazing Millet consumed an average of 6 % less TDN per unit body weight than those grazing sudangrass. It was pointed that considerable quantities of material were left after grazing, however a more intensive grazing system apparently would have seriously reduced milk production. TDN yield determinated by the cage clipping method indicated that 1.860 and 1.892 lb TDN respectively for Millet and sudangrass were produced per acre and per year.

Three summer annual pasture (Gahi-1 Pearl Millet and two sudangrass) varieties were compared by Clark et al., (1965) in a three year experiment; two levels of grain were also tested. The first two years experiments were also reported by Hemken et al., (1962). At the same time, a small plot experiment with the 3 pastures was conducted; plants were approximately 24 in. in height when cut, and averaged 3 harvests per season for each species tested. Gahi-1 Pearl Millet produced 1.4 tons of dry matter per acre which was an intermediate value between the other 2 species, but produced the lowest (2.5 tons dry matter/acre) under green chop conditions. Trampling and selective grazing were reported as responsible for the highest values under green chop conditions. Millet was the highest (2.3 cows/acre/day) on carrying capacity and then the highest values of milk yield per acre, because values for milk yield were the same for the 3 species (44 lb). However Millet showed a marked depression on butterfat % which agreed with the findings of Miller et al., (1958). The three summer crops produced a reduction on live weight, being the lowest (-0.33 lb/cow/day) for Millet and the other 2 species near the same (-0.47 and -0.48 lb/cow/day). Chemical analysis indicated that Millet had the highest crude protein content. Analysis of rumen sampling showed that cows on Millet had a lower molar per cent of rumen acetic acid (62.4 vs. 64.4 %) and a higher molar per cent of propionic acid (24.5 vs. 21.7 %) than those for sudangrass.

Starr Millet was compared with sudangrass and Johnsongrass by means of grazing dairy cows, and also they were tested under fed-lot conditions, being consumed by dairy cattle (Hawkins et al., 1958). In addition to the green forages, cows ate enough concentrate to meet nutrient needs. Millet from the grazing experiment was used when it was at the stage of pre-bloom and half-bloom, while that for green chop was early bloom. TDN for Millet was 63% and digestible crude protein 59%, however sudangrass obtained a lower (58%) and higher values (65%) respectively. FCM yield from Millet grazed cows decreased from 25 lb to 19 lb during a test of 4 weeks long, however when Millet was cut and dropped it produced the same level (24 lb) during 15 days experiment. These changes on milk production were found to be according to Millet quality. It was suggested that the stage of maturity at which Millet or sudangrass was grazed was more important than temperate grasses species.

As previously was mentioned, Miller et al., (1958), Clark et al., (1965), Hemken et al., (1962) reported that milk obtained from Pearl Millet pasture had a particularly low butterfat content. A new experiment was made in order to find possible causes of milk fat test depression (Miller et al., 1965). Some details from the same experiment were previously presented by Miller et al., (1963). The problem was related to the feeding of concentrate mixture and also to grass tetany (hypomagnesemia), both of which can depress milk fat test. Under this situation, if milk fat depression of animals grazing Pearl Millet was similar to that when cows fed a high concentrate - low roughage ration; it was proposed to feed a buffer supplement ($KHCO_3$). At the same time if milk fat depression was related to hypomagnesemia, it was suggested to give $MgCO_3$ also as a supplement. Both supplements were given to cows grazing either on Pearl Millet or sudangrass. The supplements were added to the grain which was fed at an average level of 17.1 lb per day. The results indicated that milk yield, solid not fat and protein in the milk were not significantly different between herbages and among supplement treatments. The only significant difference was presented on milk fat test; cows on Pearl Millet produced a milk with a fat test of the 2.83 % while those on sudangrass had a value of 3.59 %. There was a bigger difference between fat test of Millet and sudangrass than in earlier work of Hemken et al., and Clark et al.; no reasons were found to explain these differences. The feeding of $KHCO_3$ and $MgCO_3$ did not prevent the depression associated with Pearl Millet; it was suggested that as the cows in Millet had no decrease in saliva flow, the supplement of a buffer substance did not prevent the depression of milk fat test. Blood analysis indicated no differences among mineral contents, which eliminated the possibility of depression milk fat test associated with a mineral deficiency. Analysis of total urine alkalinity showed that it was increased by both $KHCO_3$ and $MgCO_3$ as compared to the control groups. Rumen VFA data was reported; there was no difference in total VFA concentration on both pastures (8.15 and 8.10 meq./100 ml rumen liquor for Millet and sudangrass. However acetic and butyric acid concentration on Pearl Millet was significantly lower (4.50 and 0.66 meq./100 ml rumen liquor respectively) than that on sudangrass (5.24 and 1.01 meq./100 ml). At the same time propionic acid concentration on Pearl Millet (2.64 meq./100 ml rumen liquor) was significantly higher than that on sudangrass (1.68meq./100 ml). Changes on rumen VFA were similar to the results reported by Clark et al., (1965) and Hemken et al., (1962). It was suggested that the mechanism by which Pearl Millet had a lower milk fat test was due to changes in the ratio of acetic and propionic acids. It was indicated that any of the two suggested mechanisms to explain milk fat test changes, were responsible for fat test depression.

Padmanabha (1965) conducted three new experiments trying to find the association between depression on milk fat test and grazing of Pearl Millet by dairy cattle. The same experiment was summarized and reported by Reddy et al., (1965). During the first experiment both Pearl Millet and sudangrass were supplemented with soybean oil meal (SOM), alfalfa hay or urea. Once again, it was observed that cows grazing Pearl Millet showed lower ruminal acetic and butyric acid proportion, higher ruminal propionic acid proportion and lower milk fat level, than the animal grazing sudangrass. Those cows on Millet and supplemented with alfalfa hay showed a higher acetate and propionate proportions and higher milk fat test than the control cows. Neither SOM nor urea corrected milk fat depression. During the second experiment cows were fed with Pearl Millet and sudangrass in the form of hay or silage. Cows on Millet hay showed a lower milk fat test, a lower acetate and a higher propionate proportion than those cows fed on sudangrass. Pearl Millet silage produced the same changes on rumen UFA as was mentioned for Millet hay. These results were in the same direction as those for the first experiment. In the third experiment, Millet and sudangrass were supplied in the form of pasture or green chop; two supplements were also administered: sodium acetate or alfalfa hay. Similar results were again found: cows grazing Millet showed a lower fat test, a lower acetate (52.7 vs. 57.1 %) and butyrate (7.0 vs. 9.7 %) proportions and higher propionate (36.9 vs. 30.0 %) proportions than those cows grazing sudangrass. When alfalfa hay was supplemented to Millet, a very small increase on fat test was observed, and higher acetate and propionate rumen proportions. Neither supplementations with sodium acetate nor alfalfa hay, nor green chop feeding prevented fat depression. Analysis of milk fat showed that saturated fatty acid decreased in the same direction as milk fat test decreased; either sodium acetate or alfalfa hay seemed to prevent the decrease in saturated fatty acids. Blood glucose levels followed a negative relationship with respect to milk fat %; supplements of sodium acetate showed no affect on glucose levels. Padmanabha concluded that milk fat depression observed in cows grazing Pearl Millet seems to be associated with lower acetate and butyrate levels, a higher propionate level, an increase in blood glucose level and a decrease in non-esterified fatty acids.

Morgan and Ellzey (1961) reported the effect of Millet silage harvested at two stages of maturity on dairy cattle performance. Ground corn was added as a preservative and compared with that Millet silage alone. Immature stage (seed heads had not emerged) and mature stage (seed heads were fully emerged and were in the soft dought stage) were chosen as the time to harvest the crop. Immature Millet and immature Millet plus corn additive were the treatments which had the highest intake, with the latter bigger than the former. The highest level of milk production (28.7 lb) was provided by the immature Millet plus corn, while the lowest was mature Millet (24.5 lb); values for immature Millet (25.7 lb) and mature Millet plus corn (27.0 lb) were intermediate. There were no differences on body weight.

Live Weight Gains Produced by Millet

Norman (1963) produced some evidence supporting the best comportaiment of beef cattle grazing Bulrush Millet rather than lucerne. The average gains for cattle grazing Millet was 224 lb while those on lucerne was 201 lb per head. Similar results were reported by Norman and Stewart (1964) when beef cattle grazing Bulrush Millet was compared with those grazing native pasture and lucerne. The highest liveweight gain per acre was because the stocking rate was increased from one animal per 10 acres to 1 animal per acre.

Bulrush Millet also has the potential of a standing forage to be grazed throughout the summer season. Standing, mature Millet planted during the summer was maintained in situ until the winter (dry season). Beef cattle were stocked at 4 animals per acre during a period of 19 weeks (Norman, 1965; Norman and Steward, 1964). There was an average gain of 115 lb/animal during the first 12 weeks and the animals held their weight for a further 7 weeks. On the other hand, beef cattle grazing native pasture were reported to have lost 132 lb per head in the same time. It was observed that during the first weeks animals consumed the leaf blades and heads of Millet which contains about 25% of total dry matter and 11 - 12% of crude protein. During the rest of the period animals consumed the stem and leaf sheaths which contains the rest of dry matter (75%) and lower crude protein contains (5.5%). From the findings of Norman and Steward (1965) it appears that during the growing period (summer) of Bulrush Millet liveweight gains were lower than during the dry season where the plants were matured.

On a new approach, Norman and Phillips (1968) reported that earlier grazing of Bulrush Millet during the late wet season (March) produced higher liveweight gains than later in the season (April and May). The rate of liveweight gain over the period while the animals were gaining weight, declines significantly as the date of starting to graze Millet became later. These results are in accordance with those reported above by Norman (1963), as the earlier grazing started, the higher were the liveweight gains. From all the evidence reported for the previous authors the liveweight gain on Bulrush Millet appears to be governed by quantity and quality of herbage grazed.

From the findings of Burton and DeVane (1951) it was found that Starr Pearl Millet produced more pounds of steer gain per acre than Cattail Pearl Millet variety. Most of this increase was accounted for by the better daily gains made by steer grazing Starr Millet. It was suggested that the superior performances of Starr Millet could be due by the fact that it matures about one month later, and is more leafy and supplies more days of grazing than Cattail Millet.

According to Marshall et al., (1953) dairy heifers between the age of 7 to 10 months gained 1.0 lb pf body weight per day as a result of a grazing experiment with Pearl Millet. The length of the grazing season ranged from 80 to 105 days and each Millet paddock was rotated about 4 - 5 times per season. The evidence of this trial indicated that the yield of TDN per year was 1.660 lb TDN/acre which may not have been a good production since it was gained from a poor soil. However among summer crops, Pearl Millet can supply a reasonably high yield of herbage where dairy heifers were able to make satisfactory growth.

1.7. Animal Response to Millet Grain

Millet grain is used for animal rations and generally as a maize grain replacement. Murray and Romyn (1937) and Ward (1968) indicated that Millet grain (Pennisetum typhoides) was fully equal to maize in either partial or complete replacement when mature steers were finished. Where maize or Millet provided the entire grain portion of the respective rations, carcass weights and payout were about equal. The main differences in feeding value from the maize ration reflected lower carbohydrate and higher protein content where Millet is included. The use of Millet could well affect some saving in additional protein concentrate; a 3/4 replacement of maize by Millet in Ward's experiment could be expected to reduce the quantity of protein supplement by approximately 1/10. A similar response was observed when the same grain Millet replaced the maize in broiler rations (Lloyd, 1964) and in pig rations (Calder, 1955).

Tommervik and Waldern (1969) reported a comparative feeding value of Millet grain and other grains (wheat, corn, barley and oats) for lactating cows. The Millet and other grains were compared in digestion, lactation and acceptability trials. Millet was not significantly different from the other grains in yield of daily milk, fat correct milk, solid no fat or milk/protein. Differences in digestible dry matter, digestible crude protein and TDN consumption did not result in differences in milk production. Millet intake and acceptability indicated that it was the most acceptable of the pelleted grains ration, however these differences were not sufficiently high to affect milk production.

CHAPTER TWO

MATERIALS AND METHODS

2.1. Experimental Plan

The experimental work was organised to provide information on two aspects of the use of Japanese Millet :

A. A study of the productivity of Japanese Millet first growth and regrowth, following grazing.

B. An assessment of the nutritive value of Japanese Millet for lactating cattle.

Table 2.1 indicates the timing of the two parts of the study.

2.1.1. Productivity of Japanese Millet

Productivity was assessed by measuring the following parameters in both the first growth and regrowth after grazing :

Dry matter yield / hectare
Protein yield / hectare
Dry matter yield / day
Protein yield / day

In addition, changes in chemical composition were measured throughout the growing period. The parameters (dry matter, organic matter, crude protein, crude fibre, ether extract, soluble carbohydrate) were selected to yield information for the indirect estimation of nutritive value.

2.1.2. Animal Studies

The nutritive value of the Japanese Millet was investigated with lactating dairy cows using the following parameters :

Milk yield and composition
Body-weight changes
Voluntary intake in the grazing situation

More intensive studies on digestive characteristics of the feed were made using pen-fed sheep. The following parameters were measured at the same time as the grazing experiment with cattle :

TABLE 2.1 GENERAL OUTLINE OF THE EXPERIMENT

A - JAPANESE MILLET PRODUCTIVITY

FIRST GROWTH	REGROWTH		
20 - 11 - 69 (sowing)			
20 - 12 - 69			
26 - 12 - 69			
1 - 1 - 70			
8 - 1 - 70	8 - 1 - 70		
15 - 1 - 70	15 - 1 - 70		
22 - 1 - 70	22 - 1 - 70		
29 - 1 - 70	29 - 1 - 70	ANIMAL EXPERIMENT	PERIOD II
5 - 2 - 70	5 - 1 - 70		PERIOD III
12 - 2 - 70	12 - 1 - 70		PERIOD IV

Date of sampling

B - ANIMAL EXPERIMENT

TRAINING PERIOD	Cows and sheep	6 - 16.1.70
PERIOD I	Preliminary Period	17 - 23.1.70
PERIOD II	First Experimental Period	24 - 30.1.70
PERIOD III	Second Experimental Period	31 - 6. 2.70
PERIOD IV	Third Experimental Period	7 - 13.2.70
PERIOD V	Post Experimental Period	14 - 20.2.70

Apparent digestibility of dry matter of the feed
Apparent digestibility of organic matter of the feed
Apparent digestibility of crude protein of the feed
Apparent digestibility of crude fibre of the feed
Total and individual volatile fatty acids (VFA) concentration in rumen liquor
Volatile fatty acids proportions in rumen liquor
Rumen ammonia concentration in rumen liquor

There was an introductory period of 10 days as suggested by Lindahl (1960) before the experiment started, where both sheep and cattle were selected and trained under the experimental conditions (see Table 2.1).

A 7 day Preliminary Period (Period I) preceeded the first Experimental Period (Period II). The 6 sheep and members of 3 pairs of monozigous twin cows were randomly divided into 2 groups of 3 animals and allotted to one of two treatments : JAPANESE MILLET or PASTURE. The Experimental Periods (Periods II, III, IV) were each of 7 days which corresponded to the interval used to assess the changing state of maturation of the Japanese Millet crop. A 7 days Post-Experimental Period (Period V) was used in an attempt to characterise any possible carry-over effect of the Japanese Millet treatment, especially in the lactating cattle.

During Periods I and V sheep and cows were fed pasture.

Animal distribution during experimental periods is illustrated on Table 2.2.

TABLE 2.2 <u>DETAILED LAYOUT OF EXPERIMENT</u>

PERIOD	PASTURE		JAPANESE MILLET	
	SHEEP	COWS	SHEEP	COWS
I	1 3 7* 4 6 8	37 76 112** 38 75 111		
II	1 3 7	38 75 111	4 6 8	37 76 112
III	1 3 7	38 75 111	4 6 8	37 76 112
IV	1 3 7	38 75 111	4 6 8	37 76 112
V	1 3 7	37 76 112 38 75 111		

* Number of sheep

** Number of cow

2.2. Food Supply and Feeding

2.2.1. Climate

The weekly rainfall and mean temperature data (D.S.I.R. Division of Plant Physiology - Palmerston North) for the period covered by the experiment and the average for the last 30 years are presented in Table 2.3.

A fairly early spring was followed by dry conditions starting in December and continuing until autumn. The drought produced a considerable decrease in pasture production; under these conditions it was necessary to irrigate to provide sufficient pasture for use in the experiment.

2.2.2. Japanese Millet

2.2.2.1. Management

A 0.526 hectare paddock (2.45 acres = 1 hectare), with a previous history of permanent pasture treated each autumn with 250 kg superphosphate per hectare, was prepared (ploughed) for the Millet. The crop was drilled at the rate of 17.9 kg / hectare with a dressing of 250 kg superphosphate per hectare on 20.11.69. To control the rate of maturation of the crop in order to have material of adequate quality and quantity at the planned time of the experiment (see Table 2.1), the crop was grazed with 72 cows in 2 half day periods approximately 6 weeks after sowing. An area of 50 m^2 chosen at random, was protected from grazing at 6 weeks in order to record the maturation changes of the first growth.

Following the pre-experimental grazing, the crop was topped to 5 - 7 cm with no attempt being made to harvest the small amount of cuttings. This litter in the regrowth crop lead to some bias in chemical determinations made on material harvested at later dates.

Approximately 76.2 mm of water was spray-irrigated onto the Japanese Millet on 5.1.70 (i.e. approximately 3 weeks before the first experimental grazing = Period II).

The crop was attacked by a heavy infestation of Armyworm (Pseudaletia separata) in late January (10th. week first growth, 4th. week regrowth). No chemical control was attempted since this occurred during the experimental period (Period II) and animals could not be removed from the crop (see Section 4.2. for comments on the effect of the attack on crop yields).

TABLE 2.3 RAINFALL AND MEAN TEMPERATURE DURING NOV. – DEC. 1969 , JAN. – FEB. 1970 AND AVERAGE FOR THE LAST 30 YEARS

WEEKLY PERIOD	PRECIPITATIONS (mm)		TEMPERATURE (°C)	
	1969 – 70	$\bar{x}$ 30 YEARS	1969 – 70	$\bar{x}$ 30 YEARS
1 – 14 NOVEMBER	0		15° 5	
15 – 21	0		16° 5	
22 – 28	32		14° 5	
$\bar{x}$ NOVEMBER	33	81	15° 5	14°
29 – 5 DECEMBER	27		17° 5	
6 – 12	25		17° 5	
13 – 19	17		19°	
20 – 26	0		18° 5	
$\bar{x}$ DECEMBER	93	105	18°	16°
27 – 2 JANUARY	0		19°	
3 – 9	16		19°	
10 – 16	3		19°	
17 – 23 PERIOD I*	8		19° 5	
24 – 30 PERIOD II	0		20° 5	
$\bar{x}$ JANUARY	27	85	19° 5	17°
31 – 6 FEBRUARY III	2		17°	
7 – 13 PERIOD IV	3		17°	
14 – 20 PERIOD V	0		17° 5	
20 – 28	5		19°	
$\bar{x}$ FEBRUARY	9	65	18°	17° 5

* Experimental period

2.2.2.2. Experiment and grazing

The timing of experimental activities with the Japanese Millet crop are outlined above (see Section 2.1).

First growth and regrowth material was sampled once weekly. Fifteen sub-samples (30 cm x 30 cm) selected at random were cut with hand shears to a stubble length of about 2.5 cm and the green weight obtained. The crop mean height was estimated from the height of each sub-sample and a subjective assessment of flowering was made. The 15 samples were then bulked, mixed and 2 composite samples of 200 g. were taken (Lynch, 1966). One sample was immediately frozen, freeze dried and ground through a Wiley Mill using a 1 mm sieve. The second sample was dried at 100° C in a forced draught oven to obtain an estimate of the dry matter content.

2.2.3. Mixed Pasture

2.2.3.1. Management

Paddocks A, B, C, D, of mixed pasture of approximately 0.48, 0.48 0.53 and 0.57 hectares respectively were used. The main pasture species present were Perennial ryegrass (Lolium perenne L.), Cocksfoot (Dactylis glomerata L.) and White clover (Trifolium repens L.) ; however there was a considerable variation in pasture maturity and composition among the 4 paddocks. The seed mixture used was the same for each paddock (5 lb Ariki Ryegrass, 7 lb Manawa Ryegrass, 4 lb Apannui Cocksfoot and 3 lb Hina White Clover), however as a result of grazing and pasture management, some other species were introduced. All areas received a topdressing of 250 kg superphosphate per hectare during March 1969. As conditions were dry, three of the four paddocks (B, C, D) received 76.2 mm of water during one irrigation cycle between late January and mid-February.

2.2.3.2. Experiment and grazing

Because of poor growing conditions, the four paddocks were grazed only once during the experiment. Pasture was sampled only during the 5 periods (Periods I, II, III, IV, V) using the technique described below (see Section 2.2.4.2).

2.2.4. Utilization of Feeds

2.2.4.1. Cows

Both Japanese Millet and Pasture were break-grazed each day using an electric fence. The size of the break was adjusted each day according to the amount of material left on the previous break and the amount available in the new break. The break of Japanese Millet was approximately 250 m^2 (0.06 acre) per day, but in pasture the size of the breaks were quite variable.

Although the grazing area was restricted, the herbage available was more than sufficient to allow for selective grazing at the expense of incomplete utilization of both types of feed. Under this type of grazing management, 0.53 hectare of Japanese Millet regrowth provided ample feed for 3 cows over 21 days.

The mixed pasture grazed during the Preliminary Period (Period I) was typical of the pasture conditions prevailing on the rest of the farm at that time. However the mixed pasture offered, particularly during Periods III, IV and V, was of higher quality than average as a result of the use of irrigation.

Drinking water was supplied in every break of grass and Millet with portable water troughs coupled to the main water supply.

2.2.4.2. Sheep

Japanese Millet and Pasture were cut daily at 8.30 a.m. using a power driven mower classified as 'SICKLE - TYPE' (Lynch, 1966) from the break due to be grazed by the cows. (The cut material was transported rapidly to the animal house to minimize wilting changes).

Material for each of two feeds was weighed in tared plastic buckets and offered to the animals at 9.30 a.m. and 5.30 p.m. in approximately equal amounts. The afternoon ration was stored in plastic buckets in a cool room at 5° C in order to minimize changes in the water content and to avoid heating of the material. Two samples, each of 200 g were taken daily from the food offered; one of them was dried at 100° C for 24 hrs. to provide an estimate of dry matter content. The other was frozen and bulked over the 7 day faecal collection period. Once each period was finished a composite sample of each food was formed and dried in a freeze drier, ground (1 mm sieve) and stored at -5° C.

The level of feeding was adjusted, on the basis of the previous day's refusals, to provide for about 110 % of <u>ad libitum</u> intake. Because of considerable variation in the quality, especially pasture quality, the level of feeding was such that it allowed animals a certain degree of selection of the material offered.

2.3. Animals

2.3.1. Cows

Three sets of lactating monozygous twins (Table 2.4) were selected on the basis of minimal within set differences in milk yield, composition and calving date. Individuals within sets were randomly assigned to one of two treatment groups and fitted with leg tags prior to commencing the experiment.

Ten days before the Preliminary Period (Period I), a period of training was commenced during which the cows were managed separately from the herd, grazing blocks of pasture restricted with an electric fence. Cr_2O_3 administration was also commenced in this period (see Section 2.5.1.1). This period was used to familiarize the animals to the experimental routine before collecting preliminary data to be used in statistical analyses.

2.3.2 Sheep

Six adult Romney wethers prepared with large rumen fistulas 12 months prior to use were selected from 8 such animals; 2 having been discarded on the basis of low feed intakes. Animals were kept in metabolism crates with free access to water in a climate chamber with controlled temperature (13° C). Ten days before digestion studies commenced, faecal collection harnesses and bags were fitted to the animals.

All sheep were treated with the anthelmintic Thiabenzole (Merck Sharpe and Dohme) during the first feeding period (Period II).

TABLE 2.4 **CHARACTERISTICS OF THE ANIMALS USED**

COWS	PAIR I		PAIR II		PAIR III	
	37	38	75	76	111	112
BREED	JERSEY		JERSEY x FRIESIAN		JERSEY x FRIESIAN	
AGE (years)	5		2		7	
LACTATION NUMBER	4 th		1 st		6 th	
BODY WEIGHTS (kg)	365	349	269	269	413	402
CALVING DATES	8.8.69	16.7.69	27.7.69	1.8.69	30.7.69	27.7.69
DIFFERENCE (days)	23		5		7	
MILK YIELD (kg)	11.31	11.09	7.53	8.19	12.08	11.25
DIFFERENCES	0.22		0.66		0.83	
FAT %	5.50	5.37	4.78	4.86	4.57	4.78
DIFFERENCES	0.13		0.08		0.21	
PROTEIN %	3.93	3.82	3.52	3.53	3.93	4.00
DIFFERENCES	0.11		0.01		0.07	
LACTOSE %	5.18	5.02	5.32	5.33	5.22	5.12
DIFFERENCES	0.16		0.01		0.10	

2.4. Animal Production

2.4.1 Milk Sampling and Analyses

Cows were milked twice daily at 6.00 a.m. and 4 p.m. with a herringbone low line 'double up' plant. During the preliminary and experimental periods, milk yields were recorded and samples taken at each milking using either bucket collection or milk meters. Samples were stored under refrigeration for no more than 3 days before being analysed for butterfat, protein and lactose contents using a Grubb Parsons MK 1 Infra Red Milk Analyser (Munford, 1968). A computer programme (Munford, 1970) was used to calculate yields of components for each milking interval and yields and weighted compositions of each 24 hours' production.

2.4.2 Body Weights

Under grazing conditions the estimation of true body weight is made difficult by variations in 'gut fill'. To minimise this source of error each animal was weighed 3 times during each period and the mean weight was taken as the body weight for that period.

Body weights were measured immediately after morning milkings between 7.30 - 8.00 a.m., before the cows were given the new break of feed. Morning weighings were made because they have been shown to be more accurate than those taken at other times during the day (Harris et al., 1959). The weighings were considered accurate to the nearest 1 lb.

2.5. Voluntary Intake of Herbage

Food intakes were estimated by an indirect technique employing chromium sesquioxide (Cr_2O_3) as a reference marker for faecal output and using sheep fed representative herbage samples to determine organic matter digestibility.

$$\text{INTAKE (kg/day)} = \text{weight faeces voided (kg/day)} \times \frac{100}{100 - \text{DIG. FORAGE \%}}$$

(The estimation of organic matter digestibility is described in Section 2.6).

2.5.1. Faecal Output

The concentration of marker (Cr_2O_3) in a faecal sample from animals given repeated constant dosings of the marker provides an estimate of total faecal output (Lambourne, 1957 (a), Lancaster, et al., 1953).

$$\text{FAECAL OUTPUT (kg/day)} = \frac{Cr_2O_3 \text{ administered per period}}{Cr_2O_3 \text{ concentration on faeces over the period}}$$

2.5.1.1. Administration of marker

The marker was administered (by means of a balling gun at milking time) in two 10 g doses of powder in gelatin capsules. The 10 to 14 hours interval was chosen in an attempt to control the reported diurnal pattern of Cr_2O_3 excretion (Hardison and Reid, 1953; Lancaster et al, 1953; Smith and Reid, 1955). 'Steady state' conditions were approximated by a preparatory dosing regimen commencing 10 days before the preliminary period (Period I) (see Section 2.1.2.).

2.5.1.2. Faecal collection

In order to compare two alternative means of obtaining representative samples, both 'grab' samples of rectal contents and 'sward' samples of paddock dung patches were used.

'GRAB' SAMPLES

'Grab' samples of faeces were obtained from the rectum of each animal by either natural defaecation or by manual removal (Lancaster, Coup and Percival, 1953). The samples were taken after milking at the time of marker administration.

In some cases, as a consequence of the animal defaecating in the paddock or on entering the holding yard, the rectum was empty. In those cases the animal was separated from the group and left in the yard (no more than half an hour) and some time later it was sampled .

'Grab' samples of about 300 g wet material were stored in polythene bags until bulking to obtain 24 hour composite samples (see Section 2.5.1.3).

'SWARD' SAMPLES

As the blocks of pasture and Japanese Millet offered each day to the cows were separated from the rest of the paddock (by means of electric fences), the total faecal output (less any defaecation in the race or yard) for each cow during the day was distributed in the break. A sample of approximately 50 g of each 'pat' distributed in the block for each treatment was collected, mixed together and a bulk sample of 300 - 400 g was drawn at random and placed in polythene bags.

2.5.1.3. Bulking, drying and grinding faecal samples

'GRAB' SAMPLES

Afternoon samples were retained in polythene bags until the next morning, when the second sample for the same day was obtained. The samples were bulked on an equal weight basis and the dry matter of composite day samples for each individual cow was determined by drying in an oven at 100° C for 24 hours. These samples were bulked for 7 day periods (Lambourne, 1957), ground (1 mm sieve), sub-sampled and stored for future analyses. Precautions were taken to prevent losses of Cr_2O_3 through the escape of fine faecal dust.

A total of 30 bulked samples were prepared during the whole experiment and were analysed for Cr_2O_3 content (see Section 2.5.1.4).

'SWARD' SAMPLES

Each bulk sample representing the total faeces voided for the group of cows for each day (56 bulked samples) was kept separately and dried and ground in the same way as 'grab' samples.

2.5.1.4. Chromic sesquioxide measurement

Cr_2O_3 was assayed in the cows' faeces using the method described by Williams, David and Iismaa (1962), using an Atomic Absorption Spectrophotometer (A.A.S.) with a chromium hollow cathode tube (Ransley Glass Instrument Ltd., Melbourne, Australia). Readings were made on the chromium resonance line at 3578.7 A^o. The hollow cathode current was 35 mA and the modulation frequency 50 cyc. / sec. . The acetylene pressure used was 25 cm head of water, and the air pressure 30 lb / in^2.

Samples were prepared using the procedure of Christian and Coup (1954) as modified for use with the A.A.S. by Williams et al., (1962). Samples were read in the A.A.S. against a blank solution and compared with a set of standard chromium solutions. Calcium, magnesium and silicate ions were added to standard solutions to overcome interferences from these ions in the determination of chromium in the unknown samples (Williams et al, 1962).

2.6. Measurement of Nutritive Value

2.6.1. Measurement of Apparent Digestibility

All digestion trials were conducted at the Animal Physiology Unit, Massey University, with the six sheep described earlier (see Section 2.3.2.). Although it was fully realized that differences do exist in the respective digestive abilities of different species of ruminants, especially with regard to less digestible roughages (Lancaster, 1950; Cipolloni, et al., 1951), sheep were employed in the trials mainly for practical reasons. The experiment was designed to have the dairy cows under grazing conditions and the sheep were used simply to provide additional information on the feeds used.

The foodstuff samples fed to the sheep in the digestibility trial were collected so as to be as nearly representative as possible of what the cattle actually consumed during each day through the 5 experimental periods (see Section 2.2.4.2.).

Table 2.5. illustrates the eight digestibility trials made during the experimental work.

Each morning, feed offered to and refused by all sheep was carefully weighed and sampled for dry matter and chemical analyses as described in Section 2.2.4.2. As the refusals of all sheep consisted mainly of stems, the refusals from the 3 sheep on each treatment were mixed and 2 composite samples of 200 - 400 g. were taken each day. One was dried at 100° C for 24 hrs to provide a measurement of the dry matter content. The other was stored at -5° C, and subsequently bulked with others during the collection period, mixed, sampled, freeze dried and ground (1 mm. sieve).

TABLE 2.5.

DIGESTIBILITY TRIALS

DIGESTIBILITY TRIAL	STAGE OF EXPERIMENT	PERIOD	TYPE OF FEED	NUMBER OF SHEEP USED
1	PRELIMINARY	I	PASTURE	6
2	EXPERIMENTAL	II	PASTURE	3
3	EXPERIMENTAL	II	J. MILLET	3
4	EXPERIMENTAL	III	PASTURE	3
5	EXPERIMENTAL	III	J. MILLET	3
6	EXPERIMENTAL	IV	PASTURE	3
7	EXPERIMENTAL	IV	J. MILLET	3
8	EXPERIMENTAL	V	PASTURE	3

The total faecal output of 7 day collection periods for sheep was stored in covered plastic buckets at -5^{0} C. At the end of the collection period the bulked faeces were thawed, weighed, mixed and sampled. Two bulk samples of 200 g. were taken, one was dried at 100^{0} C for 48 hrs for the determination of dry matter content. The other was freeze dried, ground (1 mm. sieve) and stored at -5^{0} C for future analyses.

Digestibility estimates for dry matter, organic matter, crude protein and crude fibre were obtained for each of the feeds in each period during the experiment (Table 2.5.).

Apparent digestion coefficients were determined as follows :

$$\text{DIGESTION COEFFICIENT (\%)} = 100 \times \frac{\text{Nutrient in feed consumed} - \text{Nutrient in faeces}}{\text{Nutrient in feed consumed}}$$

2.6.2. Rumen Sampling

Samples of rumen contents of sheep were taken to determine the ammonia concentration, total concentration of volatile fatty acids (VFA) and individual VFA concentrations and proportions.

Sheep were sampled three times daily at 9.30 a.m. (prior to first feeding), 11.30 a.m. and 1.30 p.m. . The samples were obtained during the last 2 days of each experimental period.

Rumen liquor was aspirated from a mid-rumen location. The samples were centrifuged at 2000 x g for 20 min. and the supernatants used to determine ammonia and VFA concentration (see Section 2.7.2).

2.7. Analytical Methods

2.7.1. Herbage and Faecal Material

2.7.1.1. Proximate analysis

Moisture in air dry samples, ash, crude protein, crude fibre, ether extracts and nitrogen free extracts were determined by A.O.A.C. (1965) methods.

2.7.1.2. Soluble carbohydrate analyses

Soluble carbohydrates of feed samples were extracted using a modified method based on that of Bailey (1962), in which the sugars are liberated by the acid hydrolysis of the ethanol - soluble, water - insoluble fraction of the plant tissues. Two grams of dried material was used and refluxed with 400 ml 80 % ethanol for 10 min. The material was filtered and made up to 100 ml with water. A 10 ml aliquot was evaporated to dryness in an evaporating basin over a water bath, water was added to the contents of the basin and filtered into a 100 ml volumetric flask. Total water - soluble sugar from the latter solution was measured using the sulphuric acid method of Bath (1958). Optical densities were read on a S.P. 500 Spectrophotometer (Unicam Instrument Ltd., Cambridge, England) at 332 mu against a water blank and compared with a set of standard glucose solutions treated with sulphuric acid. In order to avoid interference with the readings on the Spectrophotometer, great care was taken during sample preparation - bubbling was avoided during mixing of samples and chilled sulphuric acid; filters (glass fibre paper - Whatman GF/B) were used instead of tissue paper to dry the top of silica cuvettes ; silica cuvettes were not rinsed between different samples but simply drained by inversion on glass filters.

2.7.2. Rumen Liquor

2.7.2.1. Total VFA concentration and proportions

TOTAL VFA CONCENTRATION

A 5 ml sample of centrifuged rumen liquor (see Section 2.6.2) was steam distilled in a Markham (1942) apparatus and acids in the distillate titrated with standardised NaOH to a phenolpthalein end point. Distillates were cleared of bicarbonate by bubbling with CO_2- free air prior to titration. Distillations were duplicated and where titration differences of greater than 1 % were observed, the distillations were repeated. A further 1 ml. 0.1 M NaOH was added to the neutralized distillates, the duplicates bulked and evaporated to dryness at 90° C. Dried samples were stored frozen until analyzed for VFA proportions.

VFA PROPORTIONS

The proportions of individual VFA were determined using a Varian Aerograph Series 1200 gas chromatograph. Recordings were made using a Leeds and Northrup Speedomax H model 207 S recorder with a strip chart integrator (Disc Instruments, California, U.S.A.) (see Fig 2.1). The column used was of 6' x 1/8" stainless steel packed with 20% FFAP on 60/80 mesh Chromosob W (Hammarstrand, 1966). Neutralized VFA (Na salts) were reconstituted with distilled water and injected into a carrier gas stream of dry nitrogen saturated with formic acid by passage through a gas-tight tower bubbler fitted to the gas sampling ports of the accessory panel of the chromatograph. Standard solutions of Na acetate, Na propionate and Na butyrate were used to devise correction factors for the hydrogen flame ionization detector (Packett and McCure, 1967).

Correction Factor : (relative to Na butyrate)

$$\text{ACETATE} = \frac{209.7702}{\text{acetate area relative to butyrate } 100\ \%}$$

$$\text{PROPIONATE} = \frac{119.6865}{\text{propionate area relative to butyrate } 100\ \%}$$

Isovalerate and valerate, called C_5 , were assigned respective factors equal to 100 % for butyrate.

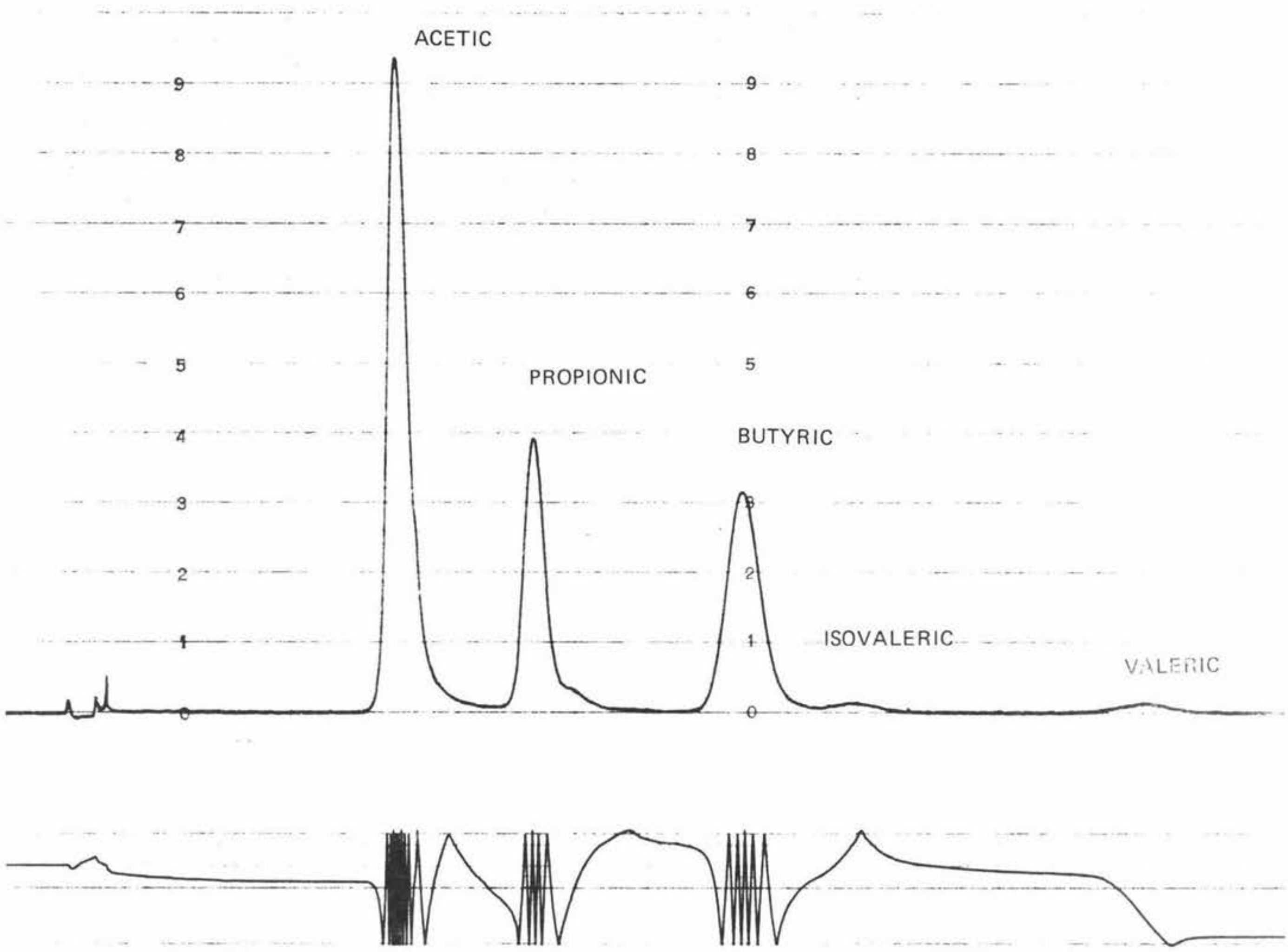


Fig. 2.1 Chromatogram of short chain fatty acids obtained from rumen liquor (Sample sheep 3, Period 3, 11 p.m.) separated on FFAP at 145° C.

Chromatograph conditions were as follows :

OVEN	temp.	145° C	(conditioned at 160° C overnight between runs)
INJECTOR	temp.	170° C	
DETECTOR	temp.	170° C	
HYDROGEN	flow rate	25 ml. / min.	
NITROGEN	flow rate	25 ml. / min.	

Samples were analysed in duplicate and if differences of greater than 1 percentage unit in any of the major components were observed, further replication was made.

2.7.2.2. Rumen ammonia concentration

The ammonia content of 1 ml. of centrifuged rumen liquor was determined using the diffusion apparatus of Conway and O'Malley (1956).

2.8. Statistical Methods

2.8.1. Analysis of Variance

2.8.1.1. One way analysis

Analysis of variance as outlined by Snedecor and Cochran (1968) was used to partition and test sources of variation. It was used to examine: a) differences in body weight between the treatment groups during the preliminary period, b) differences in VFA proportions between the treatement groups during the preliminary period and c) differences in milk yield and composition between the treatment groups during the preliminary period.

The model used was the following :

$$Y_{il} = \mu_{il} + T_i + e_{il}$$

$$i = 1,2$$

$$l = 1,2,\ldots,n$$

The components of variance are given in Table 2.6.

TABLE 2.6.

One way analysis of variance

SOURCE	d.f.	Components of mean squares
Total (S)	N-1	
Treatments (T)	1	$G^2 + nG_T^2$
Residual	2(n-1)	G^2

2.8.1.2. Two ways analysis

This model was used to test differences in the following cases: a) differences in ammonia concentrations between treatments and periods, b) differences in VFA concentration, proportions and individual concentration between treatments and periods.

The model used was the following :

$$Y_{ijl} = \mu_{ijl} + T_i + P_j + (TP)_{ij} + e_{ijl}$$

$i = 1,2$
$j = 1,2,\ldots,p$
$l = 1,2,\ldots,n$

The components of variance are given in Table 2.7 (variables assumed completely fixed).

TABLE 2.7.

Two ways analysis of variance

SOURCE	d.f.	Components of mean squares
Total (S)	N - 1	
Treatments (T)	1	$G^2 + pn\,G^2_T$
Periods (P)	(p - 1)	$G^2 + 2n\,G^2_P$
T x P (TP)	(p - 1)	$G^2 + n\,G^2_{TP}$
Residual	N - 2p	G^2

The statistical procedure outlined above enables the testing of overall differences between treatments and between periods. In the case where the interaction was significant, a Duncan's new multiple range test (Steel and Torrie, 1960) between treatments within periods was used for comparing pairs of means.

2.8.1.3. Three ways analysis.

This model was used to test differences in the following cases :
a) differences in ammonia concentrations between treatments, periods and times,
b) differences in VFA concentrations, proportions and individual concentrations between treatments, periods and times.

The model used was the following :

$$Y_{ijkl} = \mu_{ijkl} + T_i + P_j + H_k + (TP)_{ij} + (TH)_{ik} + (PH)_{jk} + (TPH)_{ijk} + e_{ijkl}$$

$i = 1,2$ $\qquad$ $k = 1,2,\ldots,h$

$j = 1,2,\ldots,p$ $\qquad$ $l = 1,2,\ldots,n$

The classification of the components of variance is given in Table 2.8.

TABLE 2.8.

Three ways analysis of variance

Source	d.f.	Components of mean squares
Total (S)	N - 1	
Treatments (T)	1	$G^2 + pnh\, G^2_T$
Periods (P)	(p - 1)	$G^2 + 2nh\, G^2_P$
Times (H)	(h - 1)	$G^2 + 2pn\, G^2_H$
T x P (TP)	(p - 1)	$G^2 + nh\, G^2_{TP}$
T x H (TH)	(h - 1)	$G^2 + pn\, G^2_{TH}$
P x H (PH)	(p - 1) (h - 1)	$G^2 + 2n\, G^2_{PH}$
T x P x H (TPH)	(p - 1) (h - 1)	$G^2 + n\, G^2_{TPH}$
Residual	N - 2ph	G^2

2.8.1.4. Three ways analysis - Hierarchal model

This model was used to test differences in body weight between treatments, between periods nested within treatment groups and cows nested within periods x treatments.

The model used was the following :

$$Y_{ijkl} = \mu_{ijkl} + T_{i} + P_{ij} + C_{ijk} + e_{ijkl}$$

$i = 1,2,$ $\quad$ $k = 1,2,....,c$

$j = 1,2,....,p$ $\quad$ $l = 1,2,....,n$

The analysis of variance and components of means squares are presented in Table 2.9.

TABLE 2.9.

Analysis of variance - Hierarchal model

SOURCES	d.f.	Components of mean square
Total	N - 1	
Treatments (T)	1	$G^2 + n\,G^2_{C:\,TP} + cn\,G^2_{P:\,T} + pcn\,G^2_{T}$
Periods (P:T)	(p - 1)	$G^2 + n\,G^2_{C:\,TP} + cn\,G^2_{P:\,T}$
Cows (C: PT)	2p (c- 1)	$G^2 + n\,G^2_{C:\,TP}$
Residual	difference	G^2

2.8.2. Analysis of Covariance

2.8.2.1. One way analysis

This analysis was used to test differences in the following cases : a) differences on body weight between treatments and b) differences on milk yield and composition between treatments.

The model used was the following :

$$Y_{il} = \mu_{il} + T_i + b_{YX} (x_{il} - \bar{x}_{..}) + e_{il}$$

The analysis was performed as outlined by Snedecor and Cochran (1968).

2.8.2.2. Two way analysis

Milk data were analysed for variations arising from differences between treatments and periods using an I B M 1620 computor and a programme (Munford, 1970) enabling simultaneous analyses of the 7 milk variables to be performed.

2.8.3. Standard Analytical Procedures.

Comparison among pairs of means were made using the T - test (Snedecor and Cochran, 1968) where only a single comparison was made, and the Duncan new multiple range test (Steele and Torrie, 1960) where multiple comparisons were made. Sample statistics mainly standard errors and coefficients of variation were computed by usual procedures.

2.8.4. Linear Regression.

Relationships between two variables were evaluated with simple correlation and regression estimates. The extent of covariation was indicated by the squared estimated of the correlation coefficient.

Comparisons of pair of linear regression coefficients were made by analysis of deviations from regression as in the analysis of covariance (Snedecor and Cochran, 1968).

2.8.5. Multiple Regression.

Multiple regression techniques (Snedecor and Cochran, 1968) were used to examine relationships between more than two variables. The extent of such relationships were assessed by the multiple correlation coefficient analogous to the squared correlation coefficient above. Because all analyses showed interdependence amongst the three variables, standarised partial regression coefficients and partial correlation coefficients were computed to determine the relative importance of the variable. This procedure also indicated the 'paths' of casual relationships among the variables.

Comparisons of pair of multiple regression coefficients were made by analyses of deviations from regression as in the analysis of covariance (Snedecor and Cochran, 1968) (see Appendix 22).

CHAPTER THREE

RESULTS

3.1. Result Methods

Japanese Millet growth was sampled according to the technique described in Section 2.2.2.2. Appendix 1 presents information about cut sampling variation which indicates that during first growth as the plant matured there was a small change in the coefficient of variation, however during regrowth at early stage there was a high coefficient which decreased as the plant matured.

Milk sampling and analyses as described in Section 2.4.1., are presented in Tables 3.10.; 3.12.; 3.14. and 3.15. where standard error of means are given.

The technique used in order to minimise errors in body weight measuring due to variation in "gut fill" (see Section 2.4.2.) was successful, since the standard error of mean for each cow was relatively low (Table 3.7.). However as there was a big variation in body weight between cows, standard error of mean for treatment was higher than those previously mentioned.

Recovery of Cr_2O_3 on cow faeces by atomic absorption method (Section 2.5.1.4.) was tested by mean of 3 standard concentrations (Appendix 33.). Recovery average for all standard was 99.84 % $\pm$ which indicated the method was suitable for experimental requirements.

Voluntary intake was measured by means of two techniques (Section 2.5.1.2.) which were compared in order to observe any important differences. Results are presented on Table 3.8. where it is indicated that in both pasture and Japanese Millet, voluntary intake measured by "sward" faecal samples gave a higher value than those estimated by "grab" faecal samples, however in 8 Periods comparisons only 4 were significantly ($P < 0.01$) different.

Taking into account the whole indirect method of measuring voluntary intake of herbage (Section 2.5.), it appears that an overestimation occurred. Section 4.2. discusses possible causes of this observation.

Results from digestion analysis are reported in Table 3.1. where the animal variation within group treatment is indicated by mean of standard error.

Rumen sampling results (VFA and ammonia) are both described in Table 3.2. and 3.5. where the variability between animals is expressed by the standard error of mean.

Results from chemical analysis of herbage are illustrated on Appendix 2 and 3 with their corresponding standard error and coefficient of variation.

3.2. Japanese Millet Production

The productivity of Japanese Millet was assessed from samples taken as described in Section 2.2.2.2. and analysed for the content of dry matter, ash, crude protein, crude fibre, ether extract and soluble sugar as in Section 2.7.1. Classification of the crop on the basis of a maturity index (Harris et al., 1969) and on height was made to assist in describing the changes observed in chemical analyses (see Plates A, B and C).

The yield of dry matter in kg / hectare (lb / acre = = 0.8926 x kg / hectare) for the first growth and for the regrowth following cutting is shown in Fig. 3.1. and Appendix 1. To aid interpretation the estimated height and maturity index of the crop is also indicated. Changes in chemical composition at each of the samplings is shown in Fig. 3.2. and Appendix 2. to aid interpretation of maturation changes.

The production of dry matter in the first growth was closely related ($r = 0.9987$; $n = 6$) to increases in crop height from the time measurements were first taken until nine weeks after sowing. During this time an increase of 428.6 kg / hectare of dry matter accompanied each one cm increase in crop height (see Fig. 3.3.). From 10 weeks after sowing, when the crop was in early bloom further increases in dry matter yield were not accompanied by increased crop height.

The chemical nature of the crop changed throughout the growing period. A steady increase in dry matter content was in part responsible for increased dry matter yields even when crop height was not increasing. Other chemical changes - namely a fall in the content of crude protein and ether extract, and increasing content of crude fibre support the change in maturation index illustrated in Fig. 3.1.

The yield of crude protein in kg / hectare for the first growth and regrowth are presented in Fig. 3.4. The changes in crude protein yields showed a different pattern to those of dry matter yield. Crude protein yields for the first growth increased until the 10th week after sowing and the yields from the regrowth did until the 4th week after cutting. However dry matter yields

FIRST GROWTH JAPANESE MILLET

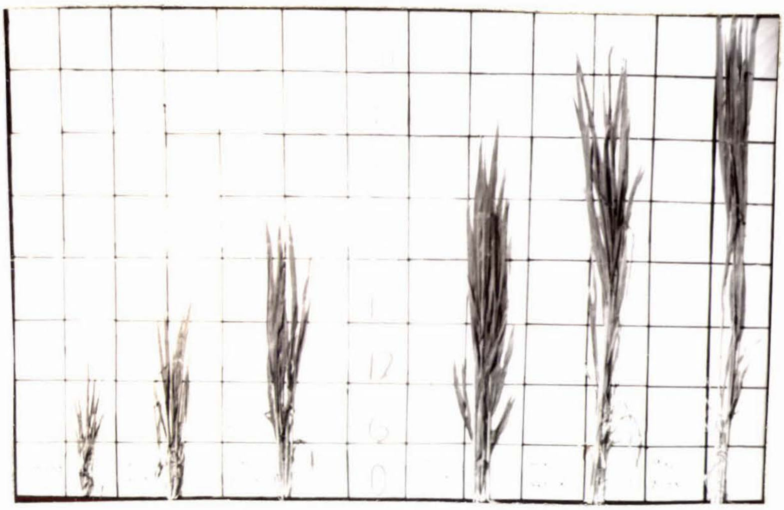


PLATE A. Samples from 4th. to 9th. week after sowing.

PLATE B. Samples from 10th. to 12th. week after sowing.

REGROWTH JAPANESE MILLET

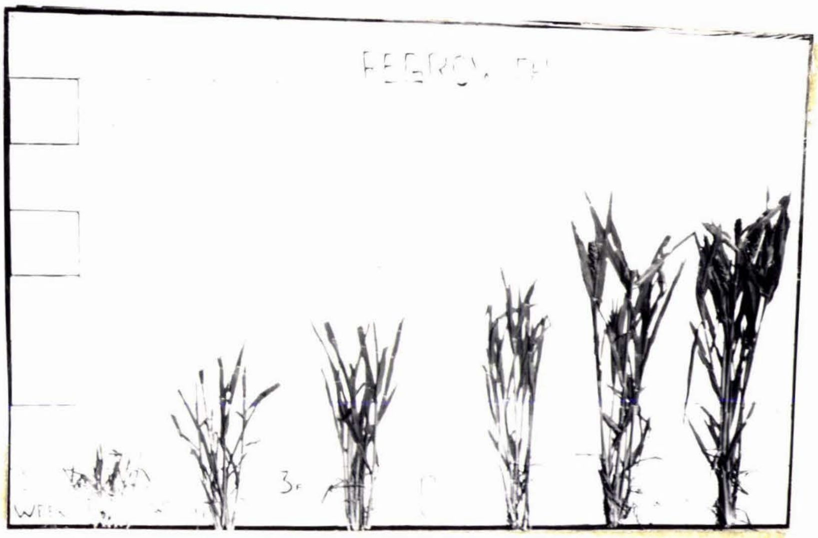


PLATE C. Samples from 1st. to 6th. week after cutting.

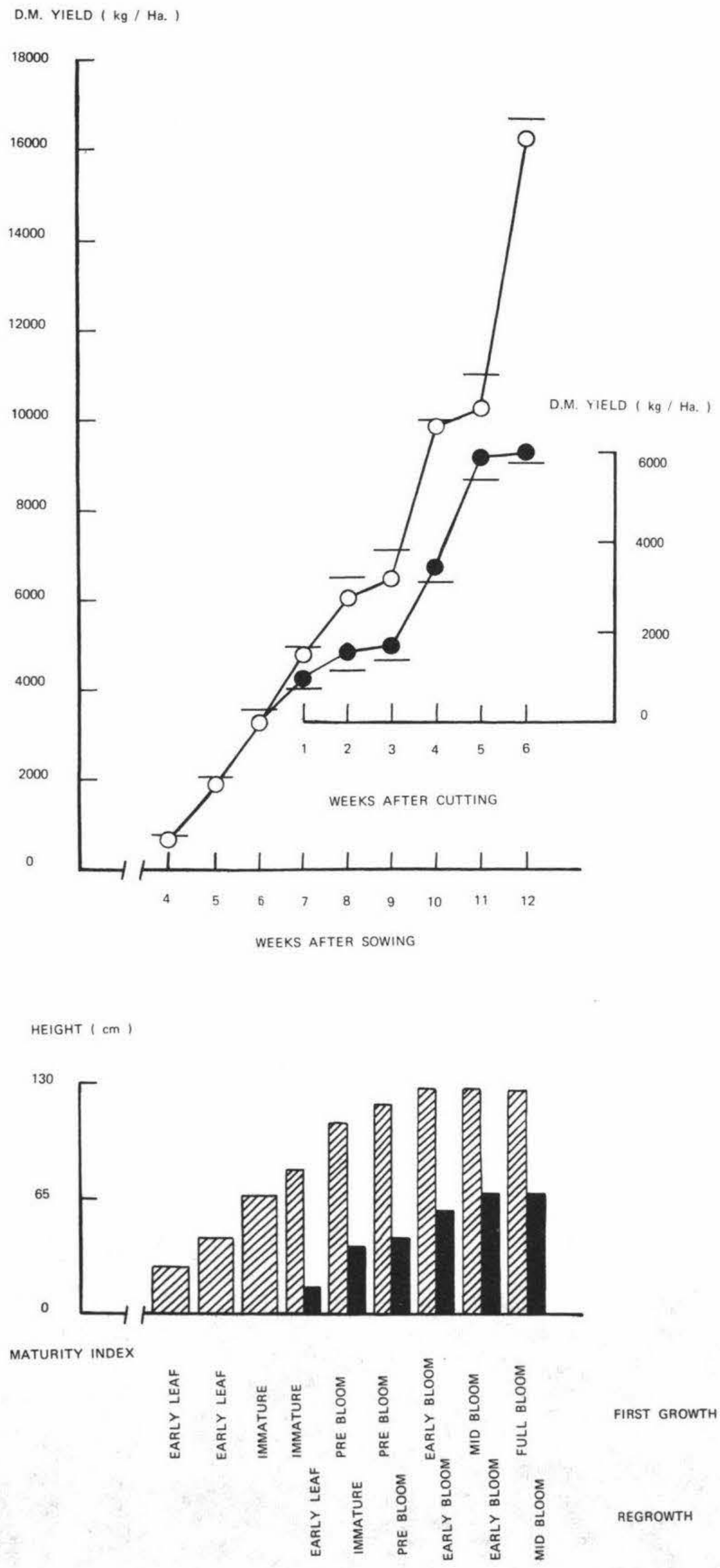


Fig. 3.1 Changes in dry matter (D.M.) yields (± S.E.), heights and maturity index of Japanese Millet after sowing.

(○First growth, ● Regrowth)

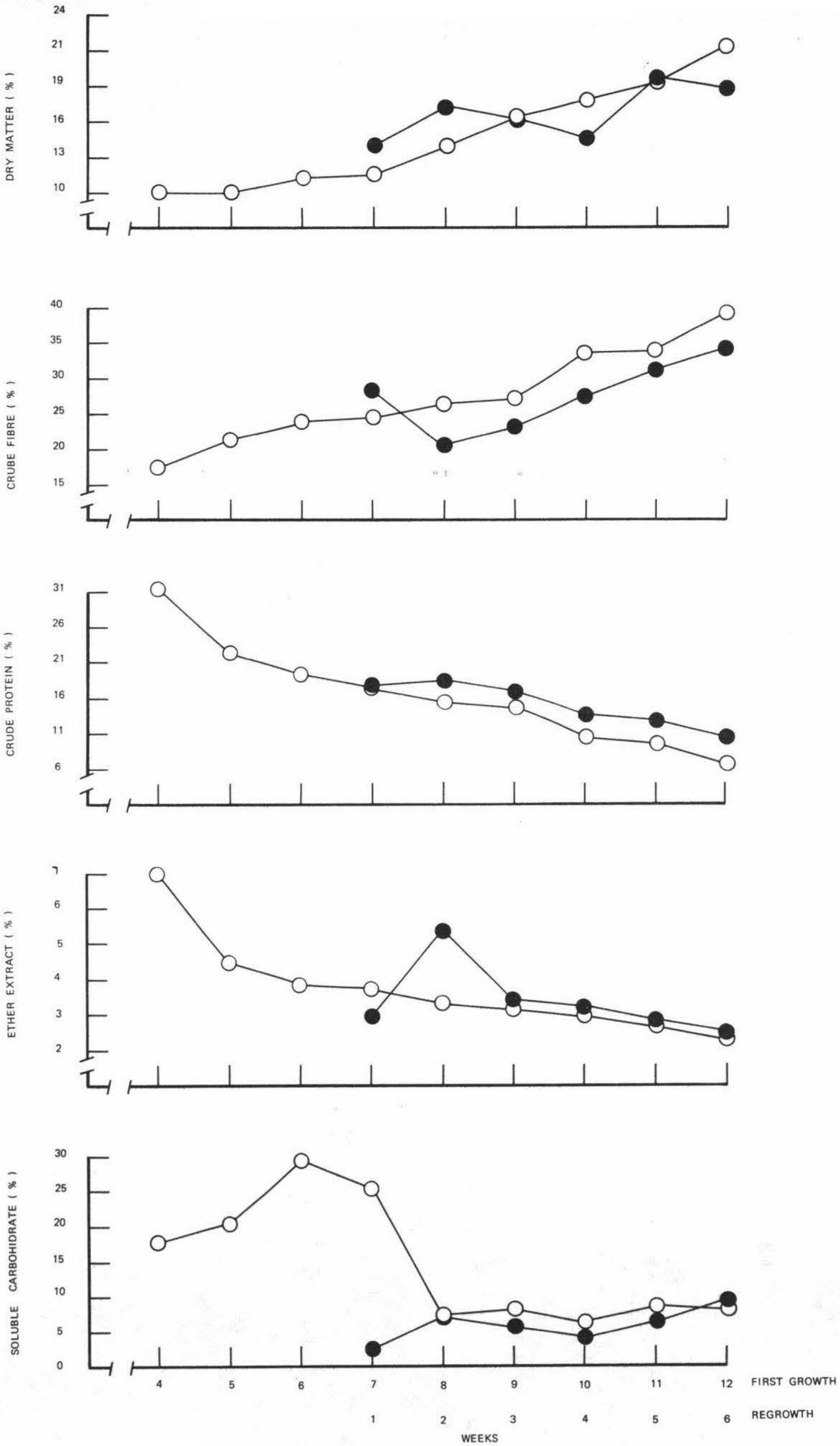


Fig. 3.2 Changes in the composition of Japanese Millet during growth.

(Chemical components on a dry matter basis)

(○ First growth, ● Regrowth)

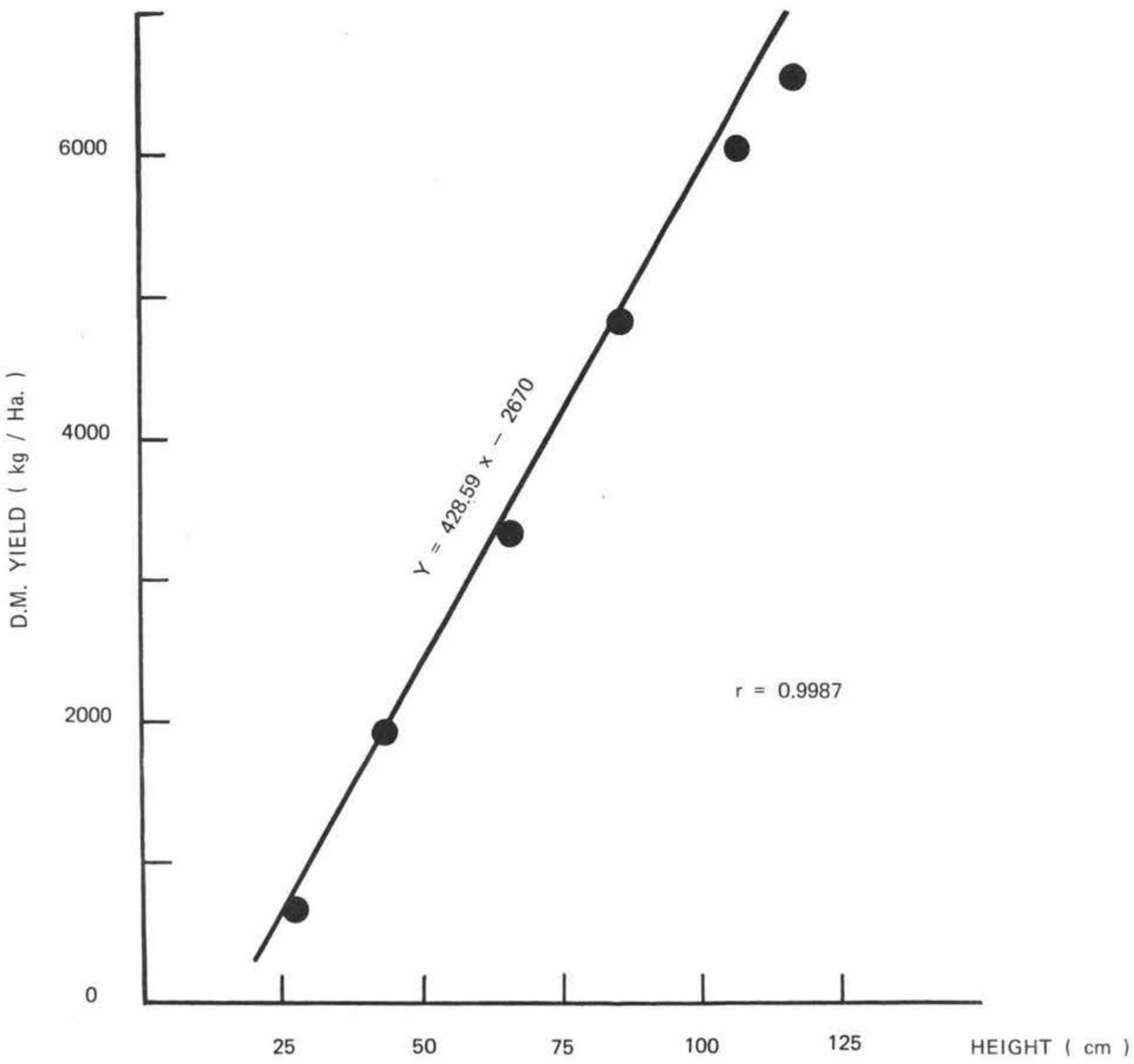


Fig. 3.3 Relationship between dry matter (D.M.) yield and height of Japanese Millet during the first six cuttings.

for first growth and regrowth increased until the 12th and 5th week respectively.

Gains of dry matter yield and protein yield per day in kg / hectare are presented in Fig. 3.5. The maturity index at each cutting date is included to aid interpretation of changes in gains. At the same stages of development determined by the maturity index, the first growth and regrowth follow the same pattern of changes.

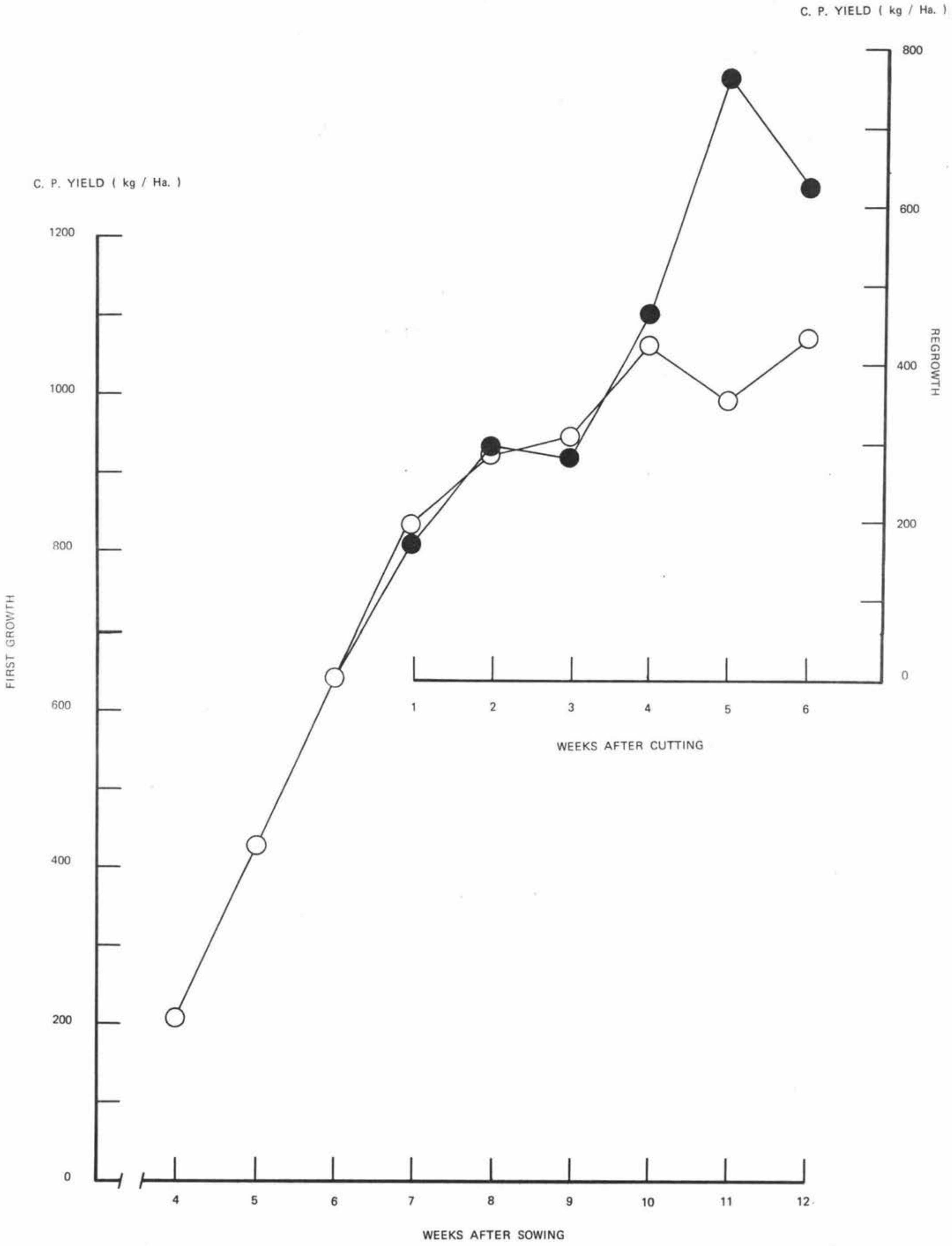


Fig. 3.4 Changes in crude protein (C.P.) yields of Japanese Millet after sowing.

(○ First growth, ● Regrowth)

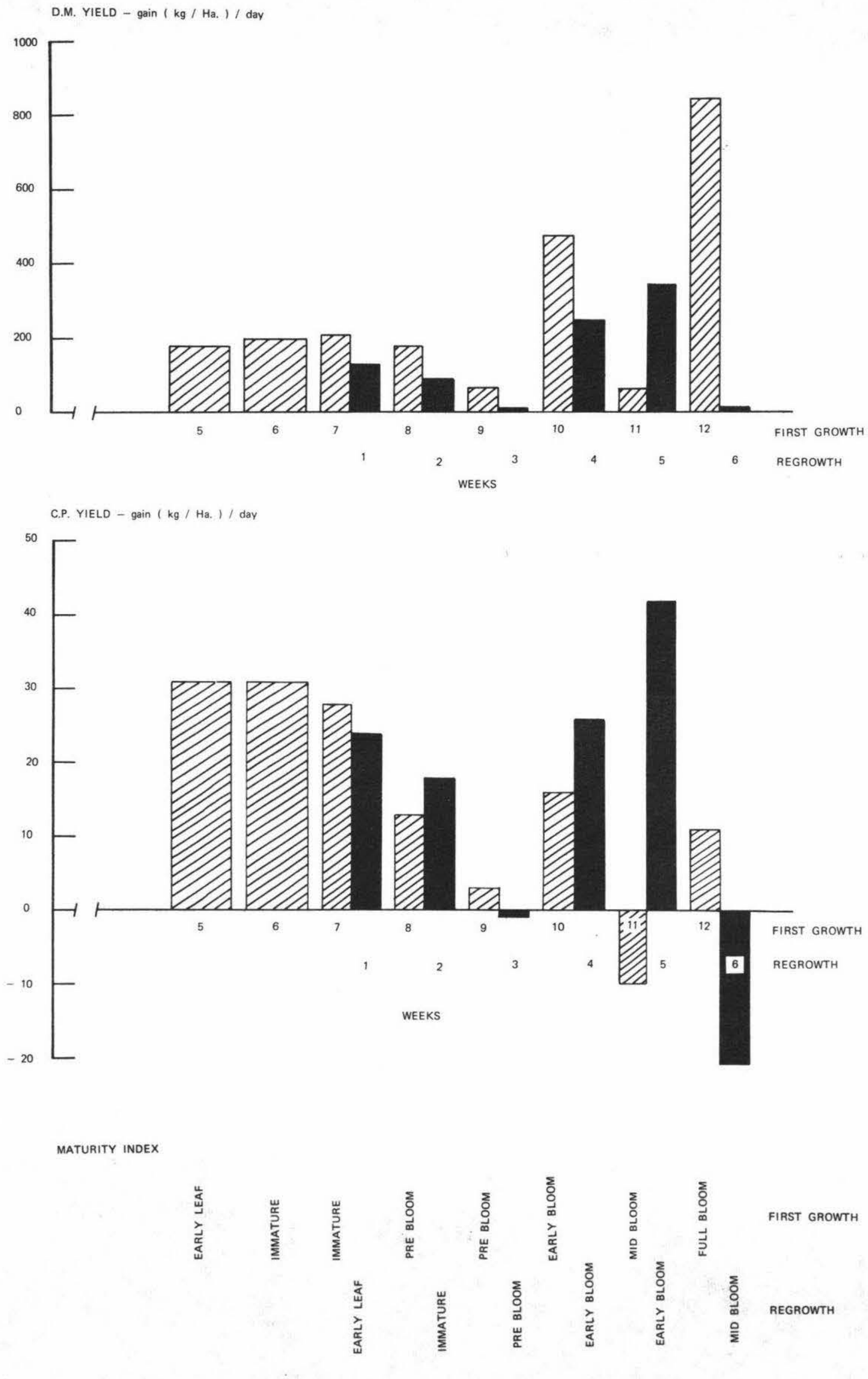


Fig. 3.5 Changes in gain of dry matter (D.M.) and crude protein (C.P.) yield per day for Japanese Millet after sowing. (First growth, Regrowth)

3.3. Measurement of Nutritive Value of Japanese Millet

3.3.1. Chemical Composition

The chemical composition of the mixed pasture and Japanese Millet used as feedstuffs are presented as Treatment x Period means in Fig. 3.6. and Appendix 3. There were no distinct patterns of changes in pasture components as a result of using different paddocks of mixed pasture during the experiment (see Section 2.2.3.). With the Japanese Millet the percentage of dry matter, crude fibre, soluble carbohydrates and nitrogen - free extract increased, whilst the percentage of crude protein, ether extract and ash decreased. These changes have been related to maturation of the crop in Section 3.2. and will be related in Section 4.2.

3.3.2. Sheep Experiments

3.3.2.1. Measurement of apparent digestibility

Throughout this thesis 'digestibility' refers to apparent digestibility.

Digestibility

Digestibility of feedstuffs determined in feeding experiments with sheep are presented as Treatment x Period means in Fig. 3.7. Comparison of digestibility coefficients (means of 3 sheep $\pm$ S.E.) between treatments for dry matter, organic matter, crude protein and crude fibre during Periods II, III and IV are shown in Fig. 3.7.

Digestibility of Dry Matter (D.D.M. %)

Pasture D.D.M. % was significantly ($P < 0.05$) less than Millet D.D.M. % in Period II, not different ($P > 0.10$) in Period III and significantly ($P < 0.05$) greater than Millet D.D.M. % in

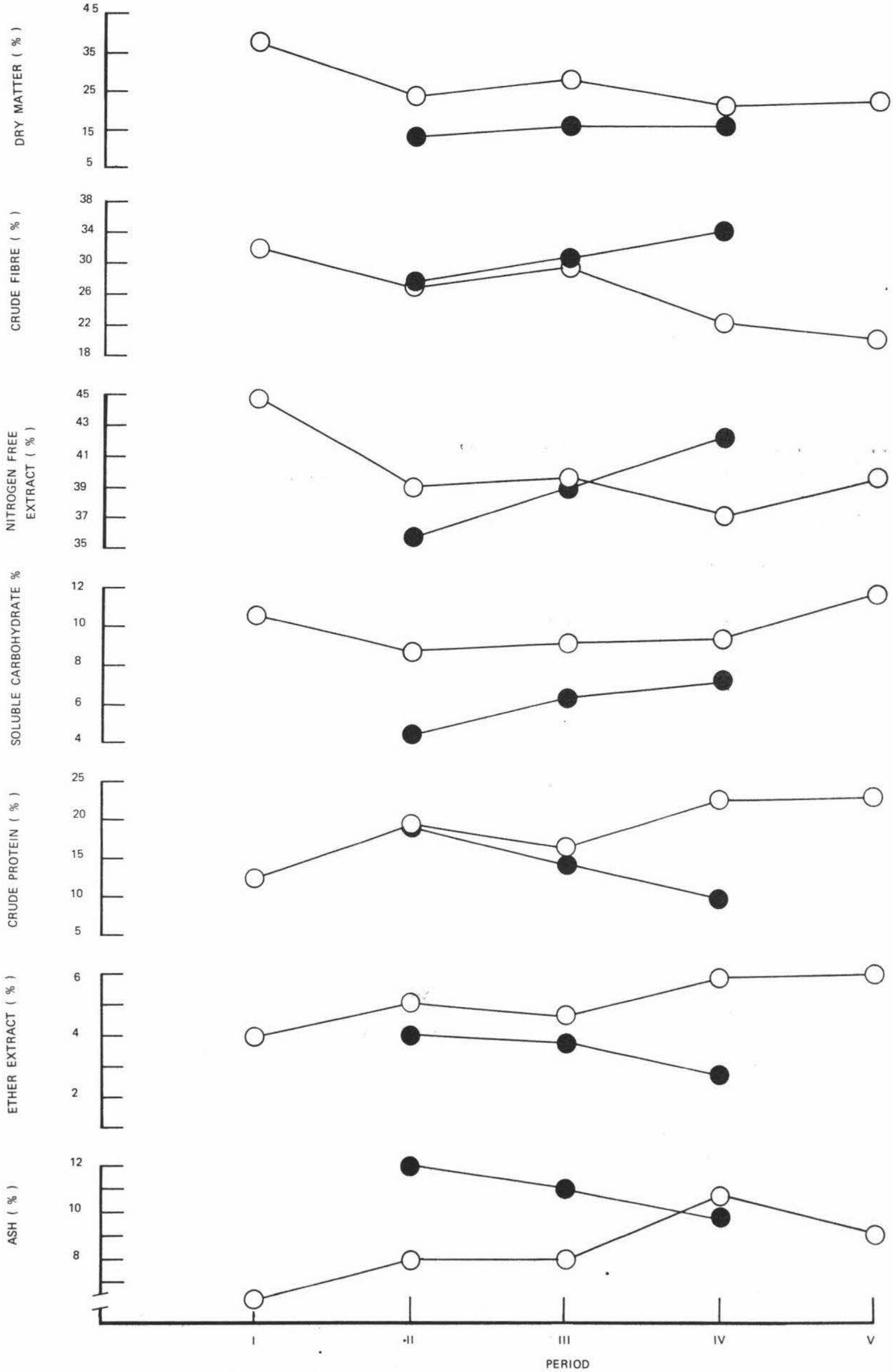


Fig. 3.6 Chemical composition of Pasture and Japanese Millet on dry matter basis during experimental periods.

(○ Pasture, ● Japanese Millet)

Period IV (Fig. 3.7.). Pasture D.D.M. % increased from Period II until the post experimental period (Period V) with all period means being significantly ($P < 0.05$) different (Table 3.1.). Millet D.D.M. % fell during the 3 experimental periods (Periods II, III and IV) with the last period (Period IV) being significantly ($P < 0.05$) less than Periods II and III (Table 3.1.).

Digestibility of Organic Matter (D.O.M. %)

Differences on D.O.M. % between Pasture and Japanese Millet during Period II, III and IV were the same as was described for D.D.M. % (Fig. 3.7.). Table 3.1. indicates that pasture D.O.M. % increased from Period II until Period V, the 4 periods means being significantly ($P < 0.05$) different; however there was no difference ($P > 0.05$) between Period I and Period IV. Millet D.O.M. % fell from Period II to Period IV, the last period (Period IV) being significantly ($P < 0.05$) lower than Periods II and III (Table 3.1.).

Digestibility of Crude Protein (D.C.P. %)

Pasture and Millet D.C.P. % was not significantly ($P > 0.10$) different in Period II and III but pasture D.C.P. % was significantly ($P < 0.05$) higher than that for Millet in Period IV (Fig. 3.7.). Pasture D.C.P. % increased from Period II to Period V (Post-experimental period) with all periods means being significantly ($P < 0.05$) different (Table 3.1.); the coefficient for Periods I and III were not significantly ($P > 0.05$) different. Millet D.C.P. % decreased from Period II to Period IV, with all period means being significantly ($P < 0.05$) different (Table 3.1.).

Digestibility of Crude Fibre (D.C.F. %)

Pasture D.C.F. % was significantly ($P < 0.05$) less than Millet D.C.F. % in Period II,and not significantly ($P > 0.10$) different in Periods III and IV (Fig. 3.7.). Pasture D.C.F. % increased from Period II to Period IV, all pairs of means except

TABLE 3.1 APPARENT DIGESTIBILITY

(Comparison of Periods within Treatments)

DIGESTIBILITY OF PASTURE

PERIOD	DRY MATTER	ORGANIC MATTER	CRUDE PROTEIN	CRUDE FIBRE
I	71.3 (±0.75) a*	72.4 (±0.70) a	70.0 (±1.52) a	61.3 (±0.73) ab
II	60.8 (±1.80) a	62.2 (±1.94) ab	75.8 (±1.81) ab	28.0 (±4.77) ab
III	65.5 (±1.25) a	67.2 (±1.09) ab	70.6 (±1.34) b	52.0 (±1.09) a
IV	69.5 (±1.21) a	71.3 (±1.05) b	80.2 (±1.17) ab	52.7 (±1.44) b
V	78.0 (±0.81) a	80.0 (±0.76) ab	83.4 (±0.77) ab	69.5 (±0.48) ab

DIGESTIBILITY OF JAPANESE MILLET

PERIOD	DRY MATTER	ORGANIC MATTER	CRUDE PROTEIN	CRUDE FIBRE
II	68.7 (±1.64) a*	70.7 (±1.88) a	77.4 (±1.13) a	58.1 (±1.95)
III	65.4 (±1.70) b	67.5 (±1.41) b	71.1 (±0.29) a	57.7 (±3.76)
IV	60.0 (±2.67) ab	62.4 (±2.08) ab	58.8 (±2.93) a	50.4 (±4.94)

* Means denoted by common letters are significantly ($P < 0.05$) different .

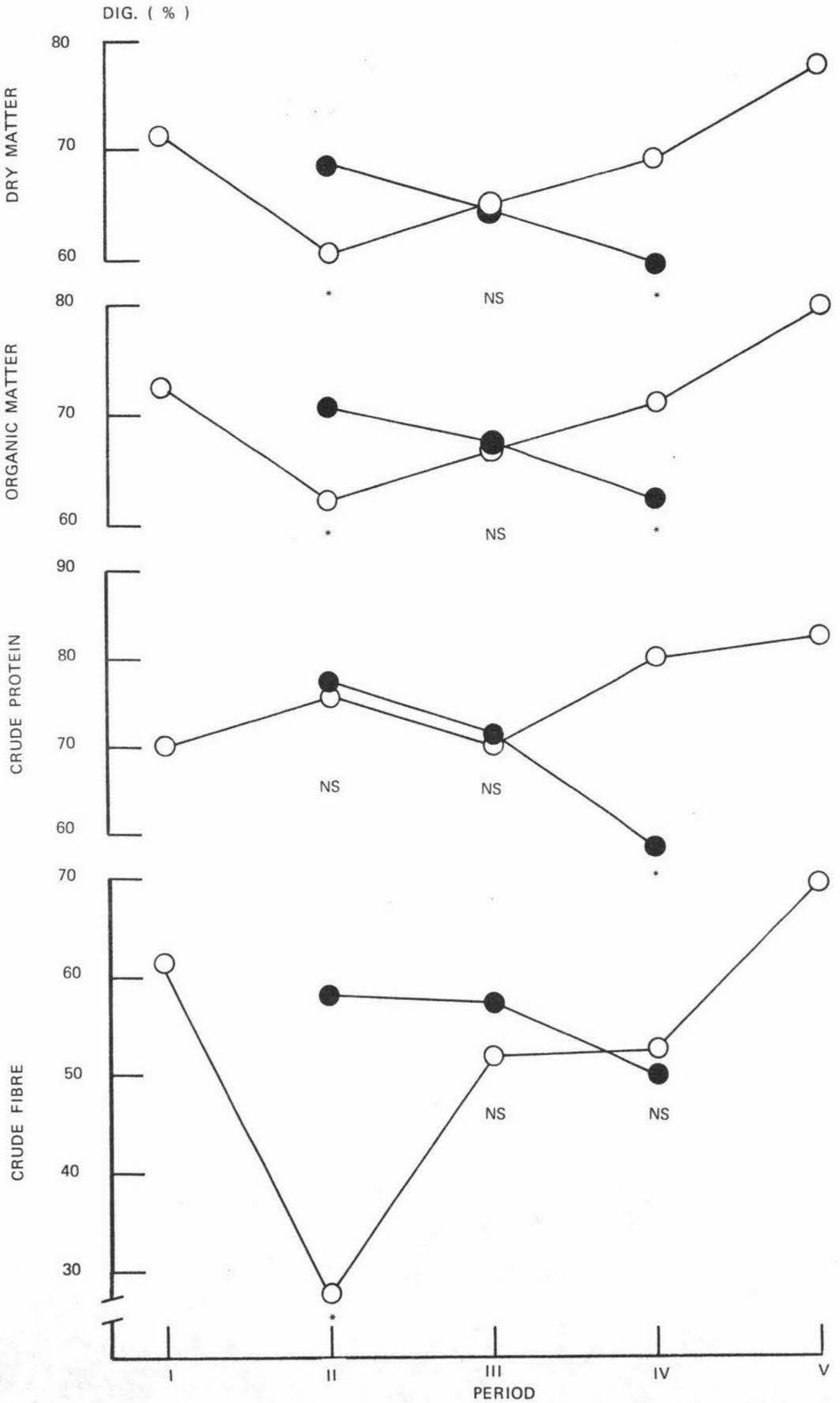


Fig. 3.7 **Apparent digestibilities (DIG. %) and standard errors.**

(○ Pasture, ● Japanese Millet)

Probability of differences between treatments within periods:

NS = $P > 0.10$ * = $P < 0.05$

Periods III and IV being significantly ($P < 0.05$) different. There were no significant ($P > 0.05$) differences among period means for Millet D.C.F. %.

3.3.2.2. Rumen volatile fatty acids (VFA)

A - Total Rumen VFA Concentration (mM / 100 ml L.R.)

Total rumen VFA concentration means of pasture and Japanese Millet during Periods I, II, III and IV for 3 times ($\pm$ S.E.), 6 sheep and 2 days sampling are presented on Table 3.2.

Changes in the concentration of VFA in rumen fluid from animals fed mixed pasture and Japanese Millet were compare by analyses of variance corresponding to the three way model described in Section 2.8.1.3. for rumen characteristics. The analysis of variance (Appendix 5) showed significant ($P < 0.05$ and $P < 0.001$) variation due to differences between treatments, experimental periods, sampling times and all interactions.

Differences between pasture and Millet means (each from 3 sampling times on 2 days for 3 sheep) were analysed on a within-period basis using the 2 way model for rumen characteristics described in Section 2.8.1.2. Results of analysis within periods (Fig. 3.8. and Appendix 5) indicated that VFA concentrations in rumen liquor of sheep fed pasture were significantly ($P < 0.001$) higher than in sheep fed Millet in Periods II, III and IV. VFA concentrations in pasture fed sheep were significantly ($P < 0.05$) higher in Period IV than in Periods I, II and III. Sheep fed Millet showed no significant ($P > 0.05$) differences in VFA concentrations during Periods II, III and IV. The absence of a (T x H) interaction in Period II, suggested in Fig. 3.9. is confirmed by the analysis of variance ($P > 0.10$) on Appendix 5. During Period III and IV the (T x H) interactions were highly significant ($P < 0.001$) as a consequence of different patterns of changes with time in the two treatment groups (Fig. 3.9.). These (T x H) interactions for changes in VFA concentrations make difficult any interpretation of the differences between sampling times.

TABLE 3.2

TOTAL RUMEN VFA CONCENTRATIONS

(mM VFA / 100 ml)

PERIOD	TIMES	PASTURE	JAPANESE MILLET
I	9 a.m.	7.56 (0.43)*	
	11 a.m.	10.28 (0.45)	
	1 p.m.	9.66 (0.51)	
	MEANS	9.17 (0.27)	
II	9 a.m.	7.65 (0.95)	6.82 (0.66)
	11 a.m.	9.75 (0.81)	7.76 (0.48)
	1 p.m.	10.74 (0.59)	8.43 (0.45)
	MEANS	9.38 (0.46)	7.67 (0.31)
III	9 a.m.	7.13 (0.48)	7.50 (0.33)
	11 a.m.	9.27 (0.41)	6.97 (0.40)
	1 p.m.	10.78 (0.36)	7.31 (0.40)
	MEANS	9.06 (0.24)	7.26 (0.22)
	9 a.m.	6.85 (0.50)	7.02 (0.28)
	11 a.m.	10.91 (0.42)	7.30 (0.24)
	1 p.m.	13.75 (0.90)	8.13 (0.51)
	MEANS	10.50 (0.37)	7.48 (0.21)

* Standard errors of means.

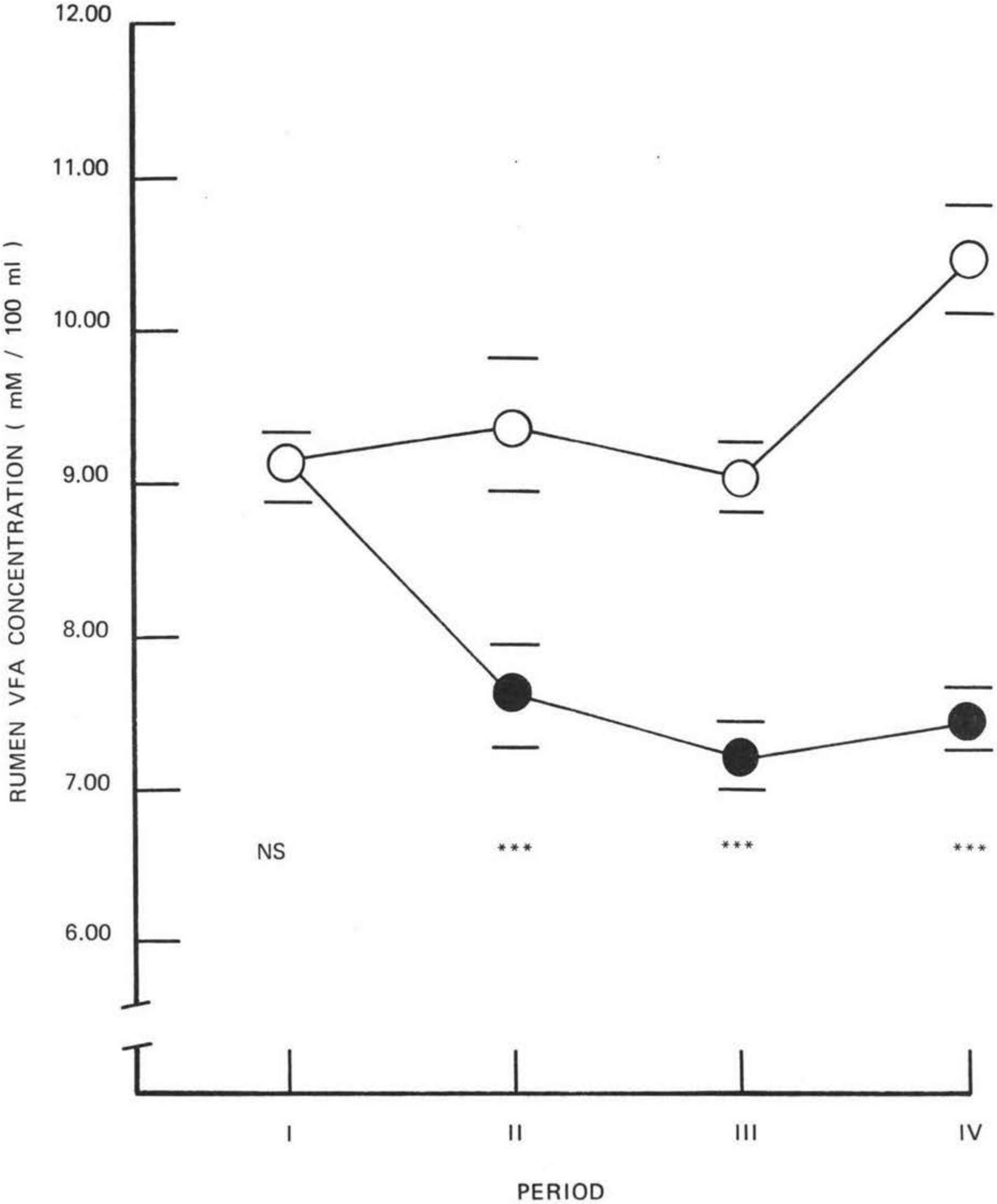


Fig. 3.8 Rumen volatile fatty acids (VFA) concentrations and standard errors.

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods:

NS = $P > 0.10$ *** = $P < 0.001$

Changes in VFA concentrations at times of sampling are presented as Treatments x Periods x Times subclass means in Fig.3.9. In nearly all periods, the pattern of changes in VFA concentrations did not vary between treatments. VFA concentrations increased with time after feeding, being highest 4 hours after feeding for all Treatment x Period groups except for Millet fed animals in Period III and for pasture fed group in Period I (Fig. 3.9.).

Relationships between changes in VFA concentrations and changes in : A - digestible organic matter intake on sheep, B - soluble carbohydrates percentage of feed, C - crude fibre percentage of feed, D - digestible crude fibre percentage of feed, E - crude fibre percentage of feed, F - digestible crude protein percentage of feed, were exmined by linear regression analyses (see Section 2.8.4.) and presented in Table 3.3. All relationships were weak - e.g. only 17.92 % of the variation in VFA concentration was related to variation in crude fibre percentage, this being the highest $\hat{r}^2$ obtained.

B - Individual VFA Proportions and Concentrations

VFA PROPORTIONS (%)

Changes in rumen fluid VFA proportions from animals fed mixed pasture and Japanese Millet are presented in Fig. 3.10. Differences in the proportions of acetic, propionic and butyric acids between day 1 and day 2 in the preliminary period were examined by simple analysis of variance. Since there were no significant ($P > 0.10$) differences between days, further analyses were performed on samples obtained during one sampling day.

Variation in the proportions of each acid were examined by analyses of variance using the model described for analyses of total VFA concentrations (see Section 3.3.2.2. - A above) and are presented in Fig. 3.10. There were significant Treatment x Period x Time interactions which make the results difficult to interpretate. Relationships between changes in VFA proportions and changes in digestibility coefficients (dry matter and crude fibre) and changes in chemical composition of feed (% crude fibre and % soluble

TABLE 3.3

Relationships between rumen VFA concentrations and chemical components and digestibility of feed .

VFA CONCENTRATION ON :	TREATMENT	REGRESSION COEFFICIENT	CORRELATION COEFFICIENT	$\hat{r}^2$
D.O.M. INTAKE (sheep)	PASTURE	- 0.0005 (±0.0018)	- 0.0732	0.54 %
	J. MILLET	+ 0.0024 (±0.0000)	+ 0.3544	12.56 %
SOLUBLE CARBOHYDRATES %	PASTURE	- 0.1511 (±0.4733)	- 0.0882	0.78 %
	J. MILLET	- 0.0793 (±0.1840)	- 0.1607	2.58 %
CRUDE FIBRE %	PASTURE	- 0.1389 (±0.0830)	- 0.4211	17.73 %
	J. MILLET	- 0.0192 (±0.0887)	- 0.0817	0.67 %
DIGESTIBLE CRUDE FIBRE	PASTURE	- 0.0145 (±0.0254)	- 0.1564	2.44 %
	J. MILLET	+ 0.0820 (±0.0363)	+ 0.0851	0.72 %
CRUDE PROTEIN %	PASTURE	+ 0.1014 (±0.0731)	+ 0.3589	12.88 %
	J. MILLET	+ 0.0223 (±0.0592)	+ 0.1411	1.99 %
DIGESTIBLE CRUDE PROTEIN %	PASTURE	+ 0.1018 (±0.0604)	+ 0.4233	17.92 %
	J MILLET	+ 0.0014 (±0.0012)	+ 0.0185	0.o3 %

(All regression coefficients are no significantly ($P > 0.10$) differents)

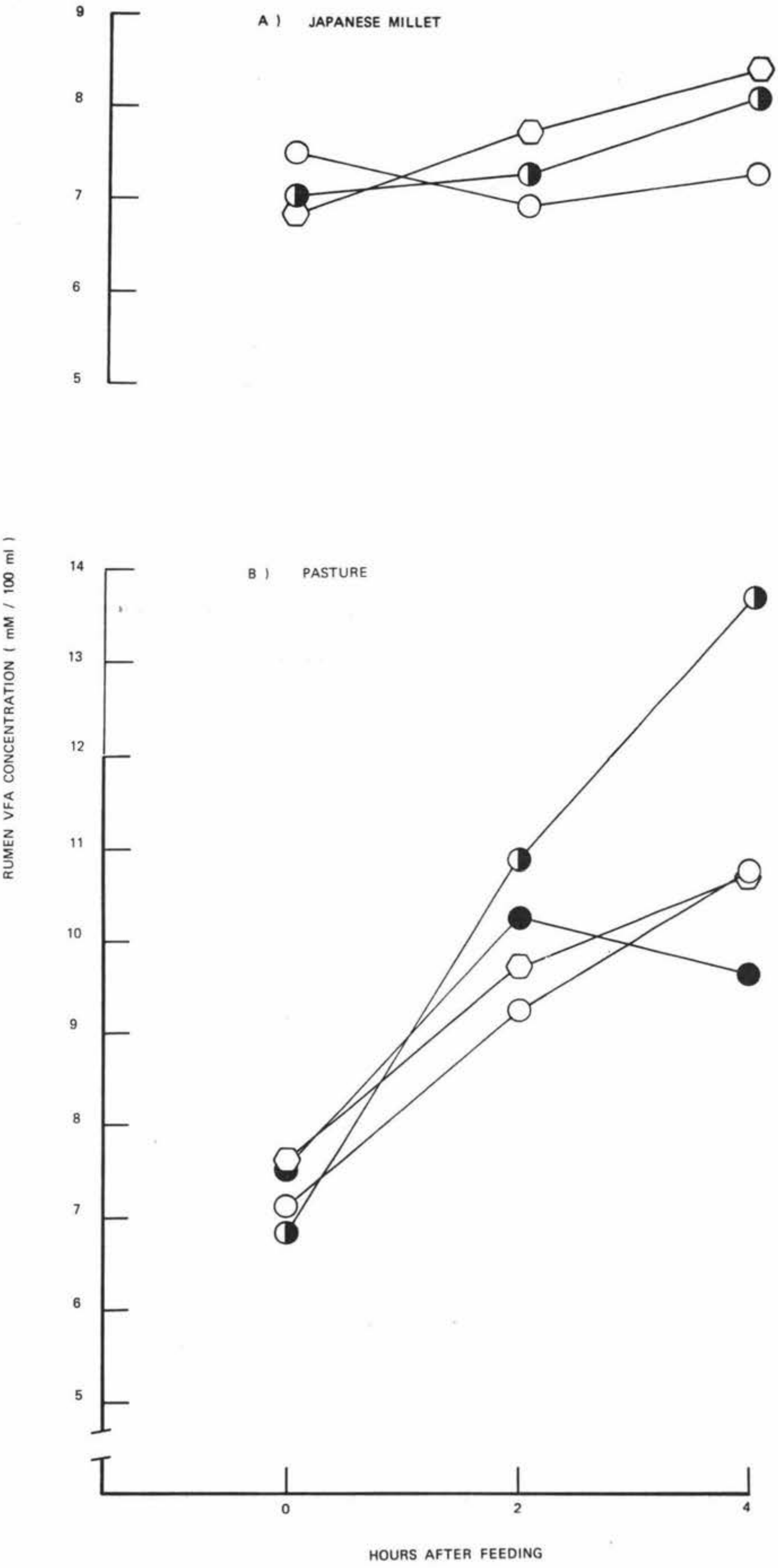


Fig. 3.9 Rumen changes in volatile fatty acids (VFA) concentration after feeding.
(● Period I, ⬡ Period II, ○ Period III, ◑ Period IV).

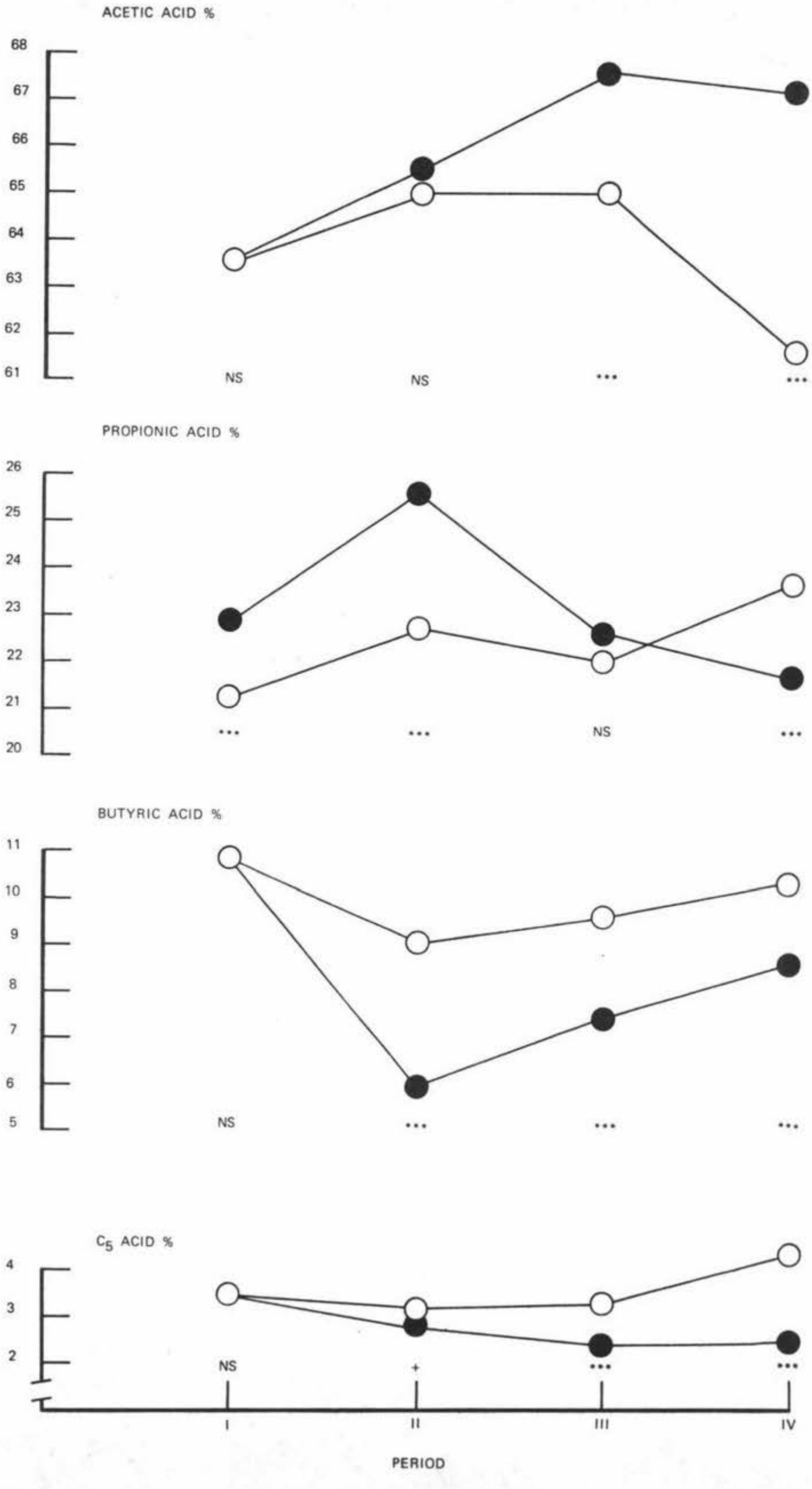


Fig. 3.10 Rumen volatile fatty acids (VFA) proportions

(○ Pasture, ● Japanese Millet)

Probability of differences between treatments within periods :

NS = $P > 0.10$ + = $P < 0.10$ *** = $P < 0.001$

carbohydrates) were examined by linear regression analysis (see Section 2.8.4.); but no meaningful relationships were found (Table 3.4.).

VFA CONCENTRATIONS (mM / 100 ml L.R.)

Changes in individual VFA concentrations in rumen fluid from animals fed mixed pasture and Japanese Millet are illustrated in Fig. 3.11. (Analyses of variance were made in the same form as described for total VFA concentrations see Section 3.3.2.2.). Hyghly significant ($P < 0.001$) Period x Treatment x Time interactions complicates their interpretation and there were no obvious relationships with other parameters such as digestibility of the components.

3.3.2.3. Rumen ammonia concentration

Rumen ammonia concentrations means (pasture and Japanese Millet during Period I, II, III and IV for 3 times (± S.E.), 6 sheep and 2 days sampling) are presented on Table 3.5.

Changes in the concentration of ammonia in rumen fluid of sheep fed Japanese Millet and mixed pasture were examined by analysis of variance corresponding to the 3 way model for rumen characteristics described in Section 2.8.1.3. The analysis of variance (Appendix 6) indicated that variation due to differences between treatments, experimental periods, sampling times and all interactions except (T x P x H) were very highly significant ($P < 0.001$).

Differences between treatment means were tested on a within-period basis and are presented in Fig. 3.12. Rumen ammonia concentration, means of 18 determinations (3 sampling times on 2 days for 3 sheep) were significantly ($P < 0.05$) and highly significantly ($P < 0.001$) greater in sheep fed mixed pasture than in sheep fed Japanese Millet in Period II and Periods III and IV respectively. Rumen ammonia concentrations in pasture fed sheep

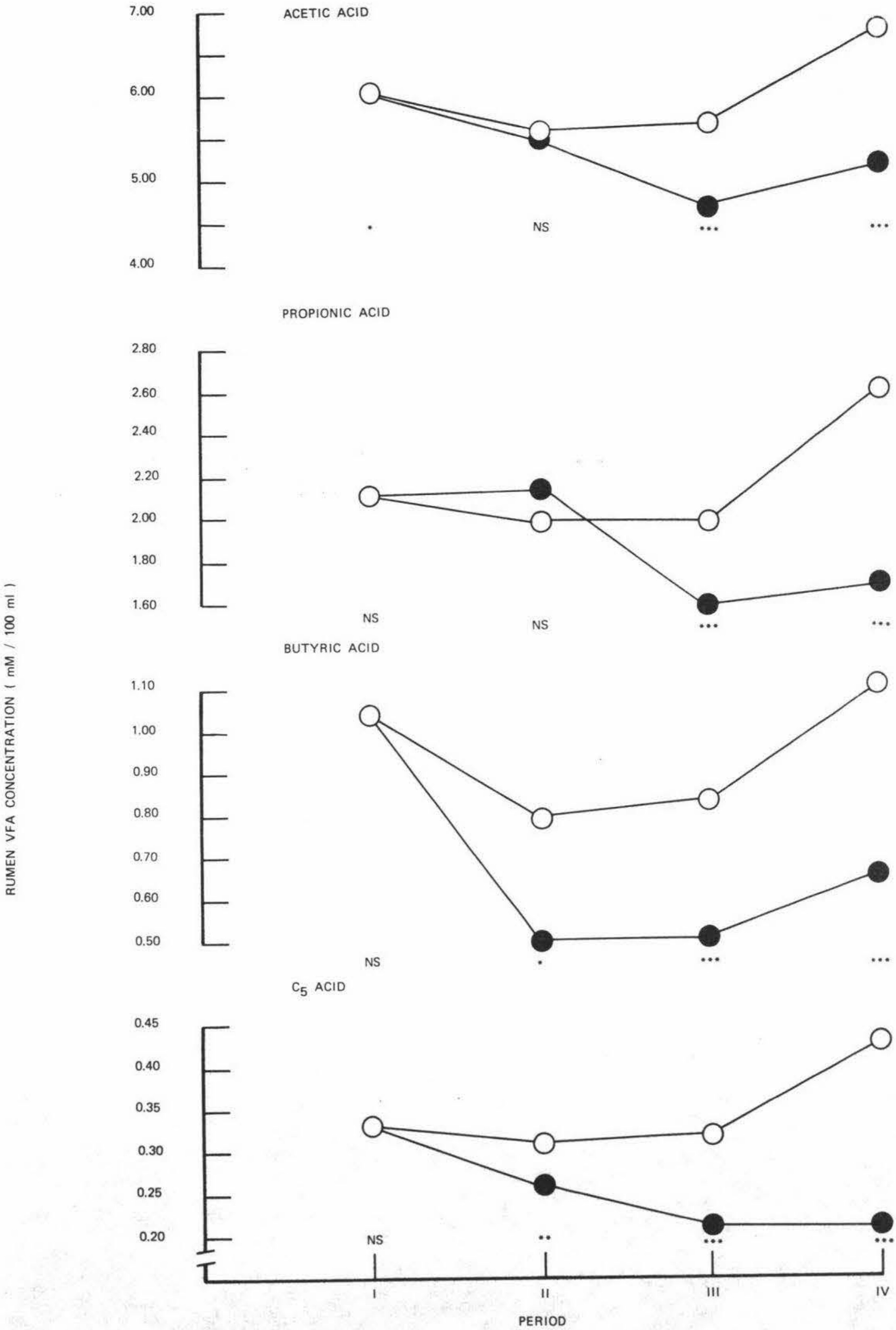


Fig 3.11 **Individual concentrations of rumen volatile fatty acids (VFA).**

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods :

NS = P > 0.10   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

TABLE 3.4

Relationships between rumen VFA proportions and chemical components and digestibility of feed

	TREATMENT	REGRESSION COEFFICIENT	CORRELATION COEFFICIENT	$\hat{r}^2$
ACETIC ACID % on	PASTURE	−0.2070 (±0.0957) *	−0.5143	0.26 %
DIGESTIBLE O.M. %	J. MILLET	−0.2086 (±0.1187) NS	−0.5533	0.31 %
ACETIC ACID % on	PASTURE	−0.0429 (±0.0365) NS	−0.3102	0.10 %
DIGESTIBLE C.F. %	J. MILLET	−0.0904 (±0.0886) NS	−0.3598	0.13 %
ACETIC ACID % on	PASTURE	+0.1971 (±0.1253) NS	+0.4000	0.16 %
CRUDE FIBRE %	J. MILLET	+0.2732 (±0.2079) NS	+0.4447	0.28 %
ACETIC ACID % on	PASTURE	−0.6745 (±0.6846) NS	−0.2636	0.07 %
S. CARBOHYDRATES %	J. MILLET	+0.6351 (±0.4233) NS	+0.4933	0.24 %
PROPIONIC ACID % on	PASTURE	+0.0328 (±0.0633) NS	+0.1424	0.02 %
DIGESTIBLE O.M. %	J. MILLET	+0.3059 (±0.1499) +	+0.6108	0.37 %
PROPIONIC ACID % on	PASTURE	−0.2634 (±0.3998) NS	−0.1797	0.03 %
S. CARBOHYDRATES %	J. MILLET	−1.3464 (±0.3987) *	−0.7872	0.62 %
BUTYRIC ACID % on	PASTURE	+0.1601 (±0.0538) **	+0.6340	0.40 %
DIGESTIBLE O.M. %	J. MILLET	−0.1435 (±0.0889) NS	−0.5206	0.27 %
BUTYRIC ACID % on	PASTURE	+1.0570 (±0.3352) *	+0.6583	0.43 %
S. CARBOHYDRATES %	J. MILLET	+0.8596 (±0.1450) ***	0.9131	0.83 %

NS = $P > 0.10$ + = $P < 0.10$ ** = $P < 0.01$

* = $P < 0.05$ *** = $P < 0.001$

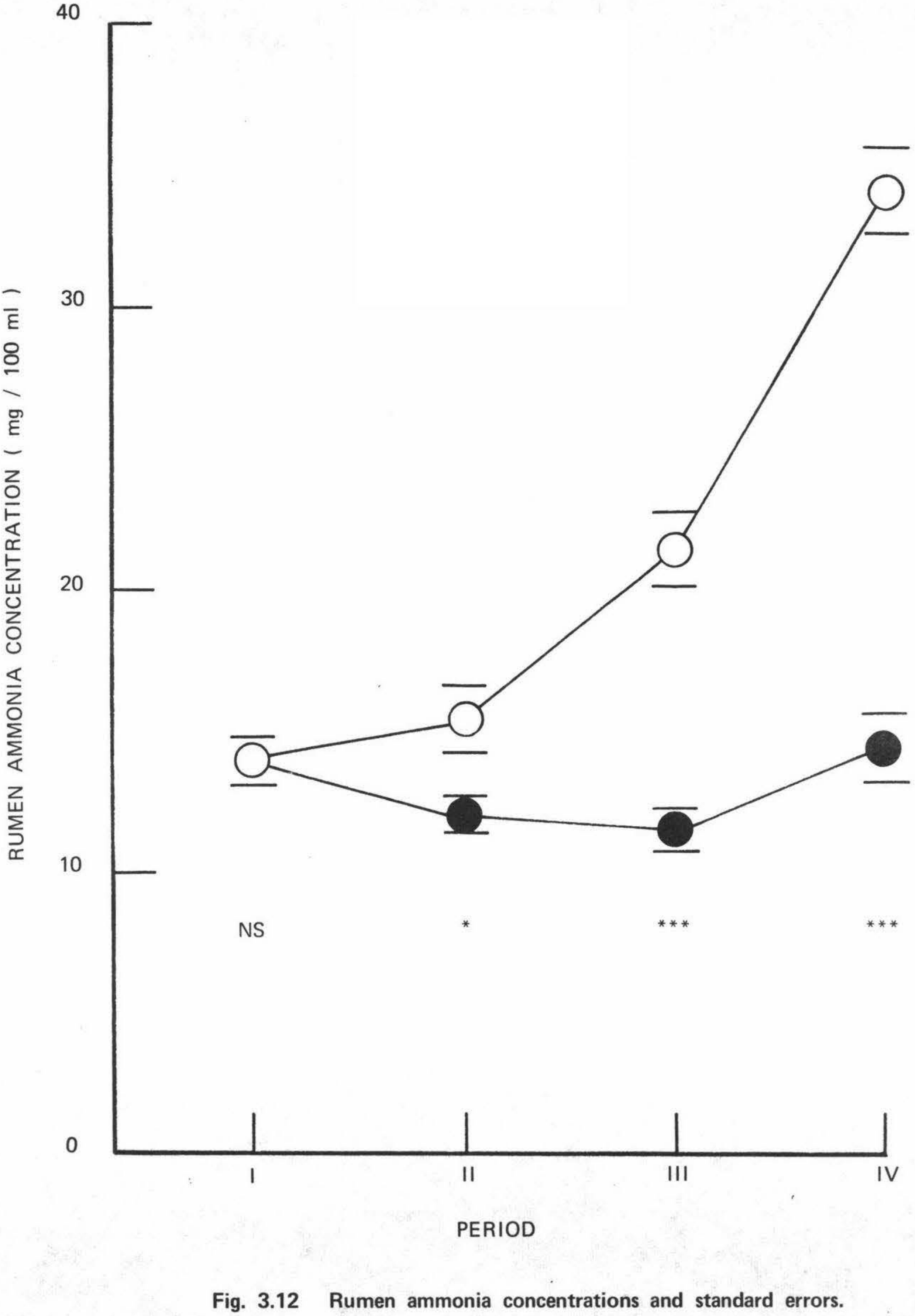


Fig. 3.12 Rumen ammonia concentrations and standard errors.

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment with periods :

NS = P>0.10 * = P<0.05 *** = P < 0.001

were significantly ($P<0.05$) higher in Period III and IV than in Period I or II. The only significant ($P<0.05$) period difference in rumen ammonia concentration in Millet fed sheep was between Period III and IV (see Fig. 3.12.).

Changes in rumen ammonia concentrations at times of sampling are presented as Treatment x Period x Time subclass means in Fig. 3.13. The pattern of changes in ammonia concentrations with time of sampling varied between treatments, Treatment x Time interaction and, especially in pasture fed animals, between periods (period x time interaction). In the latter animals in Period I and II, highest concentrations were measured 2 hours after feeding but in Period III and IV, highest concentrations were measured 4 hours after feeding (Fig. 3.13. B). The concentration of ammonia in the rumen liquor of animals fed Japanese Millet had risen slightly by 2 h after feeding and was at a similar level 4 hours after feeding for each of the experimental periods (Fig. 3.13. - A).

Examination of sources of variation on a within-period basis were done using the 2 way model described in Section 2.8.1.2. The analyses (Appendix 6) indicated that treatment differences were increasingly responsible for observed variance as the experiment progressed. The absence of a (T x H) interaction in Period II, suggested in Fig. 3.13. , is confirmed by the analysis ($P>0.10$) (Appendix 6). The interaction became increasingly significant in Period III ($P<0.10$) and Period IV ($P<0.01$). These (T x H) interactions make difficult any interpretation of significant differences between sampling times.

The relationship between changes in rumen ammonia concentration and changes in crude protein content of feedstuffs was examined by regression analyses (Table 3.6. - A, Fig. 3.14. and Appendix 7.). A highly significant ($P<0.001$) positive regression ($\hat{b} = 1.4623 \pm 0.3603$) in the pasture fed animals explained 55.9 % of the variation in rumen ammonia concentrations. In animals fed Millet, the relationship between the two variables was weak and negative ($\hat{r} = -0.38$) (only 14.7 % of the variation in rumen ammonia concentrations was related to variation in crude protein content in Millet); the regression coefficient ($\hat{b} = -0.2437 \pm 0.2223$) was not significantly ($P>0.10$)

TABLE 3.5

Changes in rumen ammonia concentrations after feeding

(mg $NH_3.N$ / 100 ml)

PERIOD	TIMES	PASTURE	JAPANESE MILLET
I	9 a.m.	11.53 (1.56)*	
	11 a.m.	15.92 (1.40)	
	1 p.m.	14.51 (1.35)	
	MEANS	13.99 (0.83)	
II	9 a.m.	13.38 (2.56)	8.83 (1.32)
	11 a.m.	19.70 (2.01)	13.72 (0.96)
	1 p.m.	13.44 (1.13)	13.78 (1.10)
	MEANS	15.51 (1.14)	12.11 (0.66)
III	9 a.m.	14.24 (1.70)	10.83 (1.53)
	11 a.m.	23.97 (0.52)	12.59 (1.57)
	1 p.m.	26.36 (3.91)	11.61 (1.58)
	MEANS	21.52 (1.43)	11.68 (0.90)
IV	9 a.m.	18.96 (1.56)	10.36 (0.37)
	11 a.m.	36.38 (1.81)	16.74 (2.29)
	1 p.m.	46.97 (3.89)	16.57 (2.80)
	MEANS	34.11 (1.52)	14.56 (1.21)

* Standard errors of means

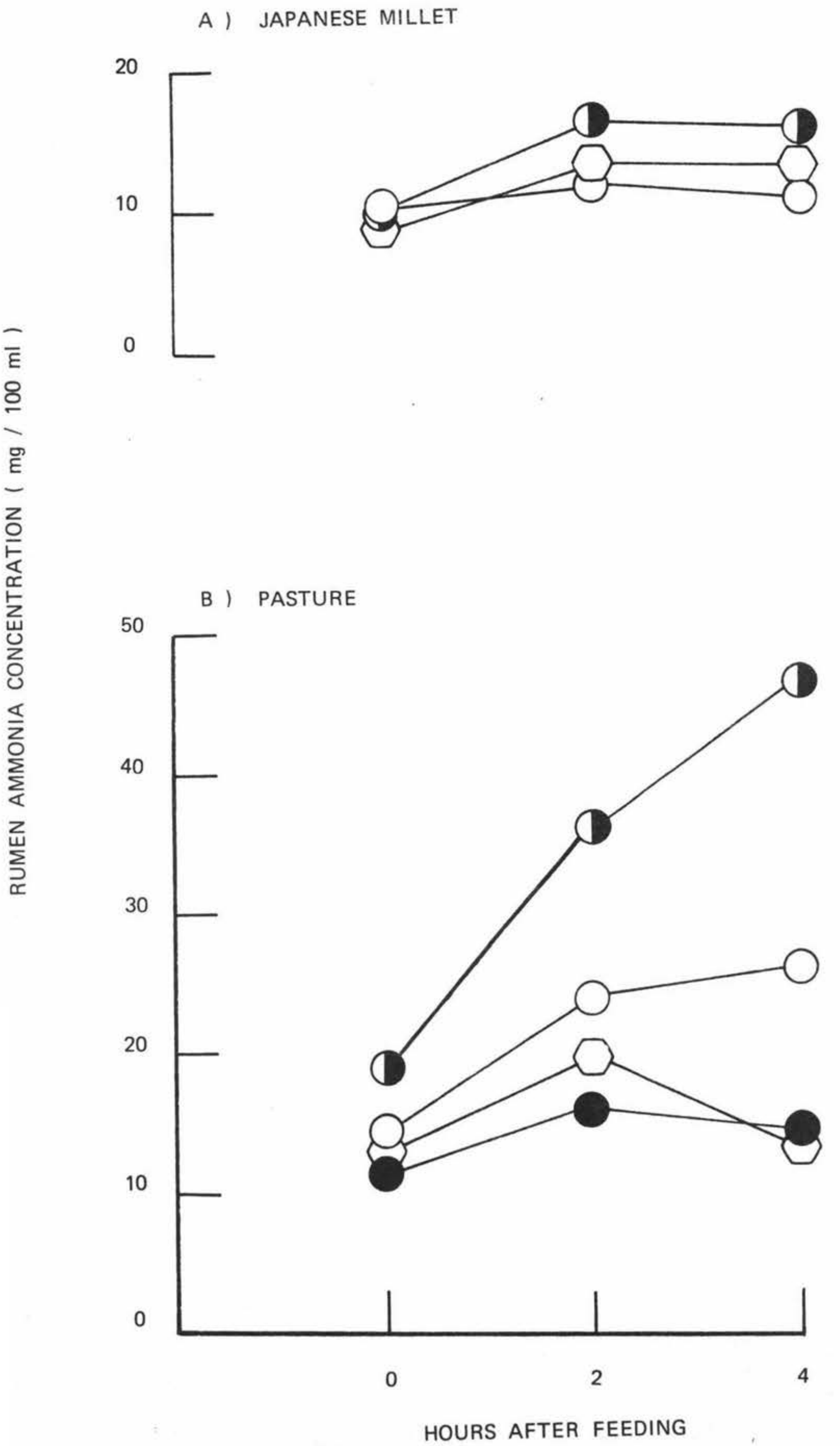


Fig. 3.13 Changes in rumen ammonia concentration after feeding.

(● Period I, ⬡ Period II, ○ Period III, ◑ Period IV) different from zero.

When variations in rumen ammonia concentrations were related to digestible crude protein contents in the feeds (Table 3.6. B, Fig 3.14. and Appendix 7.) the correlation for pasture fed animals was weaker ($\hat{r}$ = 0.6429) and the correlation for Millet fed animals was stronger ($\hat{r}$ = - 6416) than the relationship between ammonia concentrations and crude protein contents of feeds. These correlations are of similar magnitude but of different sign, thus in pasture fed animals, rumen ammonia concentration increased as digestible crude protein content of the feed increased whereas in Millet fed animals, rumen ammonia concentrations fell as the content of digestible crude protein in Millet increased.

Relationships between rumen ammonia concentration and the intake of crude protein (g / day) by the sheep were computed (Table 3.6. C, Fig 3.14. and Appendix 7.). A highly significant ($P < 0.001$) positive regression ($\hat{b}$ = 0.1632 $\pm$ 0.0412) was found with the pasture fed animals and accounted for 55.1 % of the variation in rumen ammonia concentrations to variation in crude protein intake. However, Millet fed sheep showed a weakly significant ($P < 0.10$) negative regression ($\hat{b}$ = - 0.0484 $\pm$ 0.0223) and only 38.1 % of the variation in rumen ammonia concentrations was associated with variations on intake of crude protein. Since the significance of these relationships (positive for pasture and negative for Millet) was not chqnged by these analyses, they cannot be explained by differences in selection of herbage eaten by sheep during these studies.

3.3.3. Dairy Cow Experiments

3.3.3.1. Live weights

In an attempt to reduce short term variation in estimates of live weight, cows were weighted three times each week (see Section 2.4.2.) and the mean weight was taken as the period weight (the average coefficient of variation of 30 of these means were 0.7 % ; individuals means $\pm$ S.E. and coefficient of variation are

TABLE 3.6

Relationships between rumen ammonia concentration, crude protein %, crude protein digestible % and crude protein intake

A) AMMONIA CONCENTRATION on CRUDE PROTEIN %

TREATMENT	REGRESSION COEFFICIENT	CORRELATION COEFFICIENT	$\hat{r}^2$
PASTURE	+1.4623 (0.3603)***	+0.7476	55.9 %
J. MILLET	-0.2437 (0.2223) NS	-0.3829	14.7 %

B) AMMONIA CONCENTRATION on CRUDE PROTEIN DIGESTIBLE

TREATMENT	REGRESSION COEFFICIENT	CORRELATION COEFFICIENT	$\hat{r}^2$
PASTURE	+1.0709 (0.3539) **	+0.6429	41.3 %
J. MILLET	-0.1953 (0.0882) +	-0.6416	41.2 %

C) AMMONIA CONCENTRATION on CRUDE PROTEIN INTAKE

TREATMENT	REGRESSION COEFFICIENT	CORRELATION COEFFICIENT	$\hat{r}^2$
PASTURE	+0.1632 (0.0412)***	+0.7423	55.1 %
J. MILLET	-0.0484 (0.0223) +	-0.6172	38.1 %

NS = $P > 0.10$ ** = $P < 0.01$

+ = $P < 0.10$ *** = $P < 0.001$

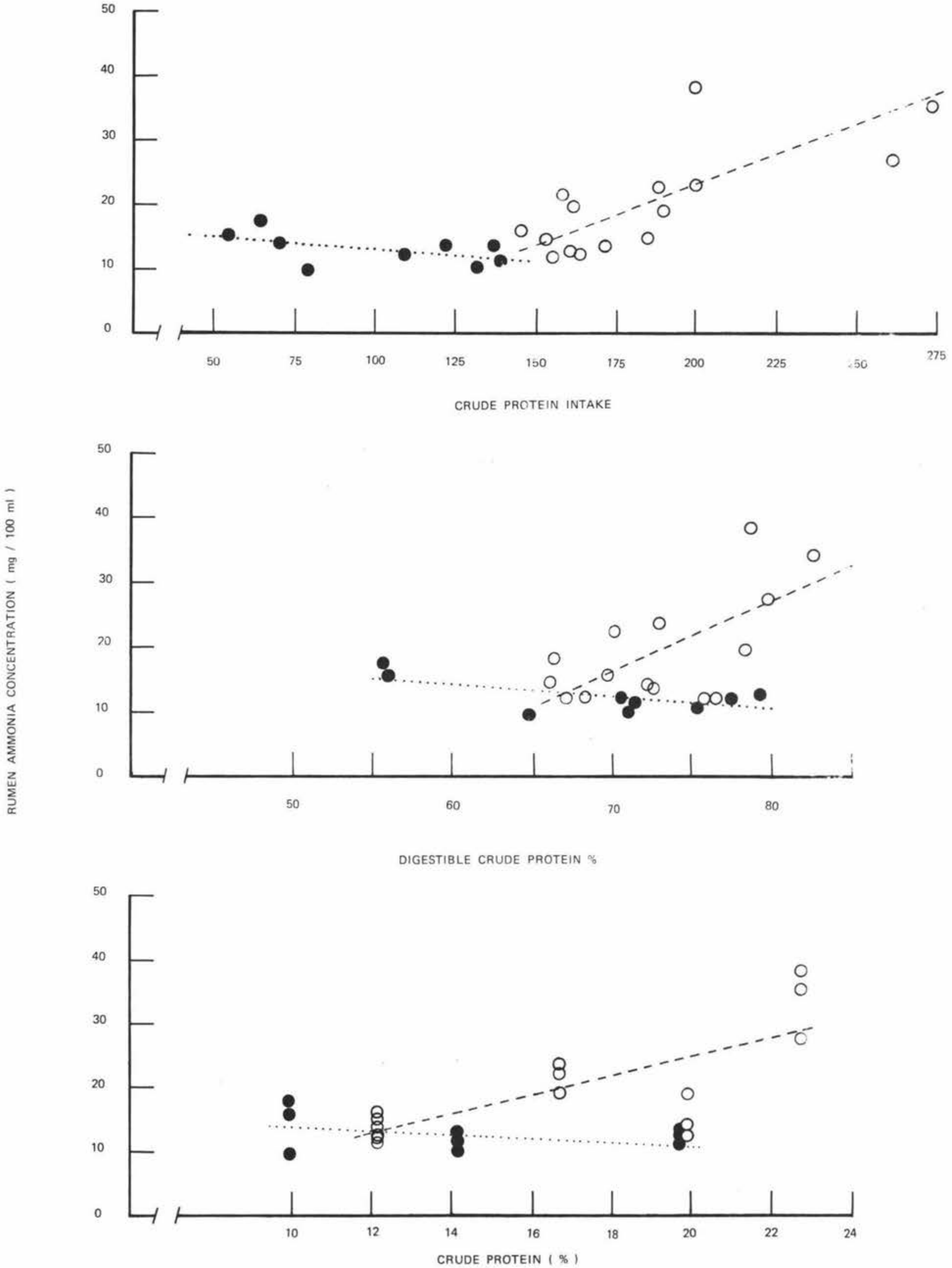


Fig. 3.14 Relationships between rumen ammonia concentration and crude protein %, digestible crude protein % and crude protein intake.

(○ Pasture, ● Japanese Millet)

given in Table 3.7.). Cow period means obtained in this way for Period II, III and IV are presented in Fig. 3.15.

Differences in live weight (during 3 experimental Periods = II, III and IV) were examined by analysis of variance using a hierarchial model (see Section 2.8.1.4.) to partition variation into that associated with treatments, periods within treatments and cows within periods and treatments (Appendix 8.). There was no significant variation due to differences between breatment means (unadjusted) or periods within treatments means (Fig. 3.15.). Highly significant ($P<0.001$) variations due to differences between cows within periods and treatments were observed and resulted from selecting twin sets to have different body weights for use in regression studies with milk production (see Section 3.3.3.3.).

Since 'cow' variation represented the bulk (99.62 %) of total observed variation (see Appendix 8.), further analyses of covariance were made using mean live weight in Period I (Preliminary period) as the concomitant variable. To conserve degrees of freedom, an abbreviated model of analyses of covariance was used (see Section 2.8.2.1.). Before preliminary data were used as the concomitant variable, a simple analysis of variance of live weight (see Section 2.8.1.1.) in Period I was made which indicated no significant ($P>0.10$) differences between the two treatment groups. Analyses of covariance showed that the use of the regression term reduced within-treatment variation (99.35 %) when the three experimental periods were analysed together (Appendix 9.). Despite this adjustment, there was no significant ($P>0.10$) difference between treatment means detected by analyses of covariance. To demonstrate a significant ($P<0.05$) treatment differences in live weight, a difference between adjusted means of 8.74 kg would have been required.

Analyses of covariance in each experimental period (Periods II, III and IV) using Period I as the concomitant variable were made, using the same model as previously described. The use of the regression term reduced within treatment variation by 99.4 % , 78.8 % , and 98.8 % for Periods II, III and IV respectively (Appendix 10, 11 and 12.) Despite these adjustments, there were no

TABLE 3.7

CHANGES IN MEAN LIVE WEIGHTS OF COWS (kg)

PASTURE				
PERIOD	COW 38	COW 75	COW 111	MEANS
I	349 (2.26)*	269 (1.64)	413 (1.44)	344 (41.65)
II	343 (8.27)	268 (4.03)	401 (3.43)	337 (38.50)
III	343 (4.39)	272 (1.71)	414 (3.25)	343 (40.99)
IV	334 (1.89)	269 (0.94)	402 (1.09)	335 (38.40)
V	342 (1.46)	270 (0.99)	407 (0.30)	340 (39.57 (
JAPANESE MILLET				
PERIOD	COW 37	COW 76	COW 112	MEANS
I	365 (2.74)	269 (2.65)	402 (2.78)	345 (39.62)
II	351 (2.28)	269 (1.64)	397 (1.53)	339 (37.43)
III	348 (2.28)	264 (0.40)	392 (2.92)	335 (37.55)
IV	348 (0.40)	267 (1.14)	396 (2.23)	337 (37.64)
V	352 (3.41)	263 (2.98)	392 (3.64)	336 (38.12)

* Standard error of means

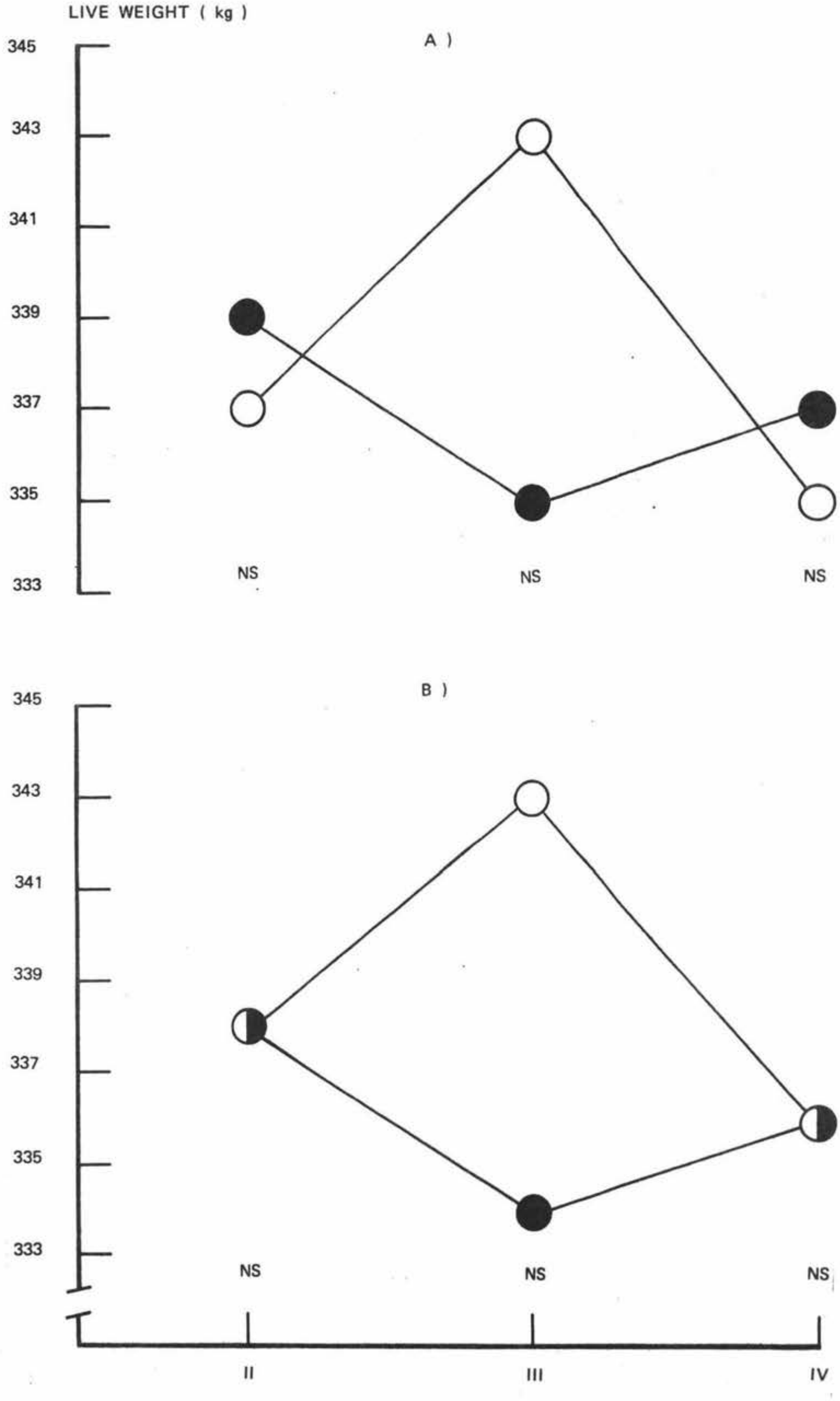


Fig. 3.15 Changes in mean live weights of cows during Periods II, III and IV.
A) unadjusted means ; B) means adjusted for preliminary period differences

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods :

NS = P > 0.10

significant ($P > 0.10$) differences between treatment means adjusted (Fig. 3.15.) in any of the analyses.

3.3.3.2. Voluntary intake of herbage

As a considerable amount of feed was left in each break in both treatments after grazing, it was assumed that the amount of feed available did not limit the voluntary intake of animals. The average intake of digestible organic matter (D.O.M.) in kg / cow / day as determined by the 'grab' sample and 'sward' sample techniques (see Section 2.5.1.2.) are presented as Treatment x Period means in Fig. 3.16. A, 3.16. B and Table 3.8. The D.O.M. intake determined from 'grab' samples did not differ ($P > 0.10$) between treatments during the 5 experimental periods (Fig. 3.16. A.). There were, however, significant ($P < 0.05$) differences between periods in the pasture group but no significant ($P > 0.10$) differences in the Millet fed group (Table 3.8.). Intakes measured using 'sward' samples during Periods II, III and IV (see Section 2.5.1.2.) showed no significant ($P > 0.10$) differences between treatments (Fig. 3.16. B.). There were no significant ($P > 0.10$) differences between periods in the Millet group but significant ($P < 0.05$) differences were observed between periods in the pasture fed group (Table 3.8.).

When D.O.M. intakes were determined using 'grab' samples (Table 3.8.), Millet fed cows decreased their intake in Period II (78.16 %), in Period III (69.52 %) and in Period IV (68.47 %) relative to the intake of mixed pasture in Period I (100 %). The decrease in D.O.M. intakes occurred as the Millet regrowth matured progressively (see Fig. 3.1.).

The coefficients of variation for estimates of pasture D.O.M. intakes using 'grab' sampling (7.27 % to 17.43 %) are a consequence of vaŕiation between cows within periods. Estimates of Millet intake were less variable (6.08 % to 15.66 %). When 'sward' sampling was used to estimates intakes, differences between cows were removed by bulking (see Section 2.5.1.2.) so the reduced variation in the pasture fed group (2.13 % to 10.79 %) and the Millet fed group (7.85 % to 9.42 %) principally reflects

TABLE 3.8

Comparison between Digestible Organic Matter Intake of herbage estimated by 'grab' and 'sward' sampling

	PERIOD	'GRAB'	'SWARD'	Difference between techniques		
				DIF.	% of GRAB	PROB.
PASTURE	I	14.24 (0.28) de+	16.04 (0.59) a	1.79	9.67	$P<0.01$
	II	10.41 (1.03) ce	10.58 (1.14) a	0.17	1.59	$P>0.10$
	III	11.92 (1.38) b	11.32 (0.39) a	0.60	-5.02	$P>0.10$
	IV	11.54 (1.38) ad	13.40 (1.45) a	1.86	13.86	$P>0.10$
	V	15.81 (0.44) abc	17.41 (0.37) a	1.61	9.24	$P<0.001$
J. MILLET	II	11.13 (1.74)	12.48 (1.18)	1.34	10.76	$P>0.10$
	III	9.91 (1.23)	12.47 (1.04)	2.56	20.54	$P<0.10$
	IV	9.75 (0.76)	12.05 (0.95)	2.29	19.05	$P<0.10$

+ Means denoted by the same letter are significantly ($P<0.05$) differents.

Means are in kg/day.

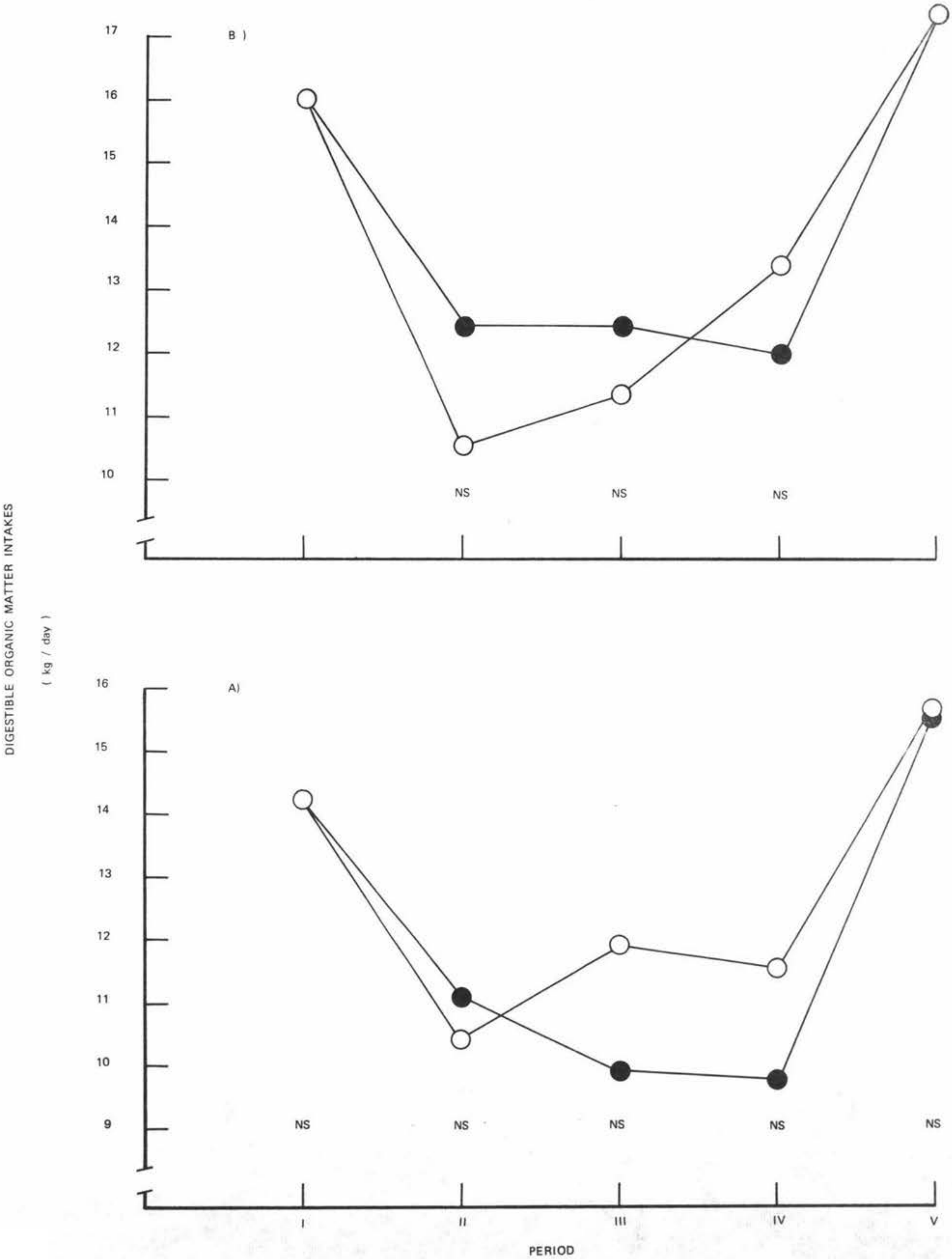


Fig. 3.16 Digestible organic matter intake (D.O.M.I.)

A) Estimated from 'grab' samples of faeces.

B) Estimated from 'sward' samples of faeces

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods :

NS = P > 0.10

variation between days within periods.

The relationships between intakes determined by the two sampling techniques ('grab' and 'sward' sampling) are shown in Fig. 3.17. and Appendix 13. Estimates of pasture intake obtained from the two methods were highly correlated ($\hat{r}$ = 0.9481 ; n = 5) but estimates of Japanese Millet intakes by the two methods were less related ($\hat{r}$ = 0.5993 ; n = 3). Analyses of regression slopes (Appendix 14.) showed non - significant departure from parallelism (P 0.10) so the common regression ($\hat{r}$ = 0.8899 ; n = 8) (see Fig. 3.17. and Appendix 13.) describes the relationships between estimates using the two techniques.

When intakes (measured by means of 'grab' sample)were expressed in term of metabolic size (D.O.M. intake g / kg $L.W.^{0.75}$) (Table 3.9. and Fig. 3.18.),cows fed pasture had a significantly ($P < 0.05$) higher intake than cows fed Millet in Periods III and IV. There were significant ($P < 0.05$) differences among periods in both the pasture and Millet treatments (Table 3.9.).

When intakes were expressed on the basis of metabolic body size, the variance of means was reduced (coefficient of variation from pooled estimate of variance = pasture 4.62 % and Millet 5.55 %) compared with those expressed on D.O.M. intake (kg / day) (pasture 6.39 % and Millet 6.79 %). Since D.O.M. intake was related to $L.W.^{0.75}$ both directly ($\hat{r}_{(D.O.M.\ intake\ -\ L.W.^{0.75})}$ = 0.3602) and indirectly through fat-corrected milk yield (see milk production results 3.3.3.3.), expressing intakes in this way reduced variation arising from differences between animals as a consequence of different live weights. The reduction in the variance of the means, gave rise to significant ($P < 0.05$) treatment differences in Period III and IV (Fig. 3.18.).

The relationship between D.O.M. intake (g / kg $L.W.^{0.75}$) and the chemical composition of feedstuffs was examined graphically, along with the relationship to the digestibility of various constituents of the feeds. D.O.M. intake (g / kg $L.W.^{0.75}$) was closely related to the content of soluble carbohydrates in pasture ($\hat{r}$ = 0.9788) and in Japanese Millet ($\hat{r}$ = - 0.9683). The regressions are shown in Fig. 3.19. and

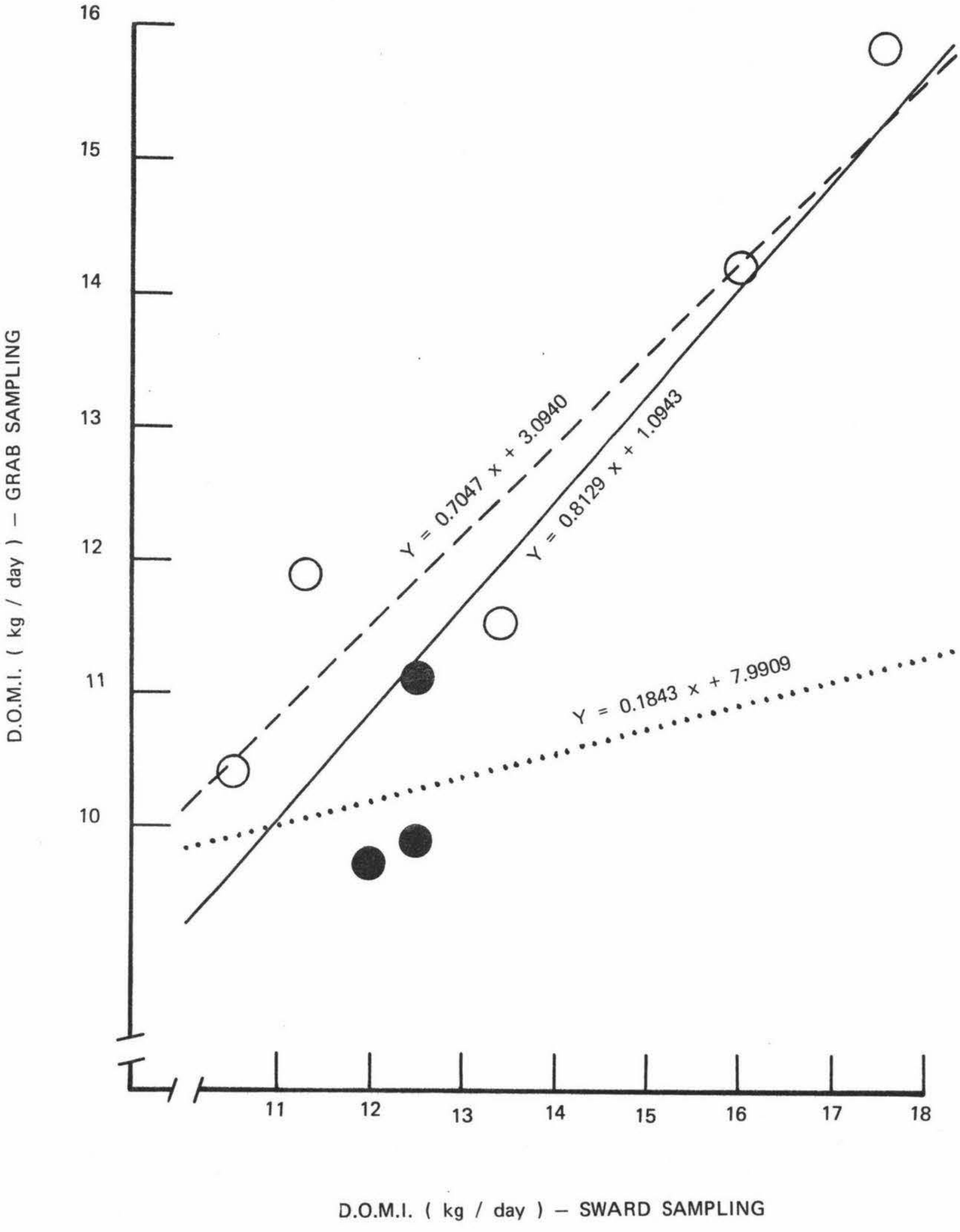


Fig. 3.17 Relationships between digestible organic matter intake (D.O.M.I.) of herbage estimated by 'grab' and 'sward' sampling.

(--- ○ Pasture, ···· ● Japanese Millet, —— Total)

TABLE 3.9

COMPARISON OF DIGESTIBLE ORGANIC MATTER

INTAKE ('grab' sample) - g / kg L.W.$^{0.75}$

PERIOD	PASTURE D.O.M.I.(±S.E.)	C.V.%	JAPANESE MILLET D.O.M.I.(±S.E.)	C.V.%	Sig. of diff. between Treatments
I	181(8.57) ab[+]	4.73	180(5.29) cde	2.94	NS
II	133(1.76) ab	1.33	140(11.35) ch	8.11	NS
III	150(4.51) a	3.01	127(5.36) dg	4.22	*
IV	148(5.04) b	3.41	125(3.84) ef	3.08	*
V	199(19.34)ab	9.72	201(7.55) fgh	3.76	NS

+ Means denoted by the same letter are significantly ($P < 0.05$) different.

NS = $P > 0.10$

* = $P < 0.05$

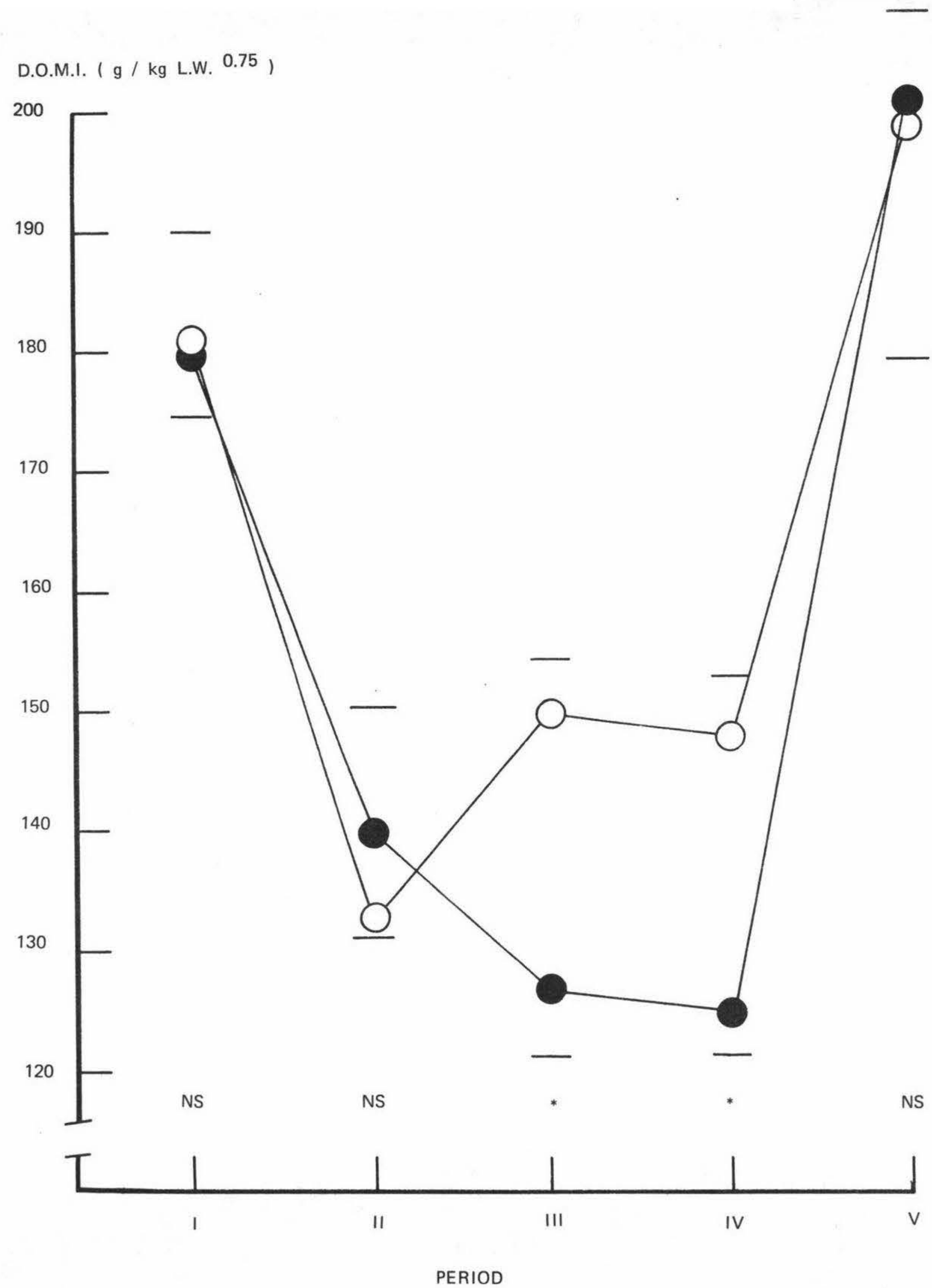


Fig. 3.18 Digestible organic matter intake (D.O.M.I.) in g / kg L.W. $^{0.75}$ estimated from 'grab' sample of faeces.

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods.

NS = $P > 0.10$ * = $P < 0.05$

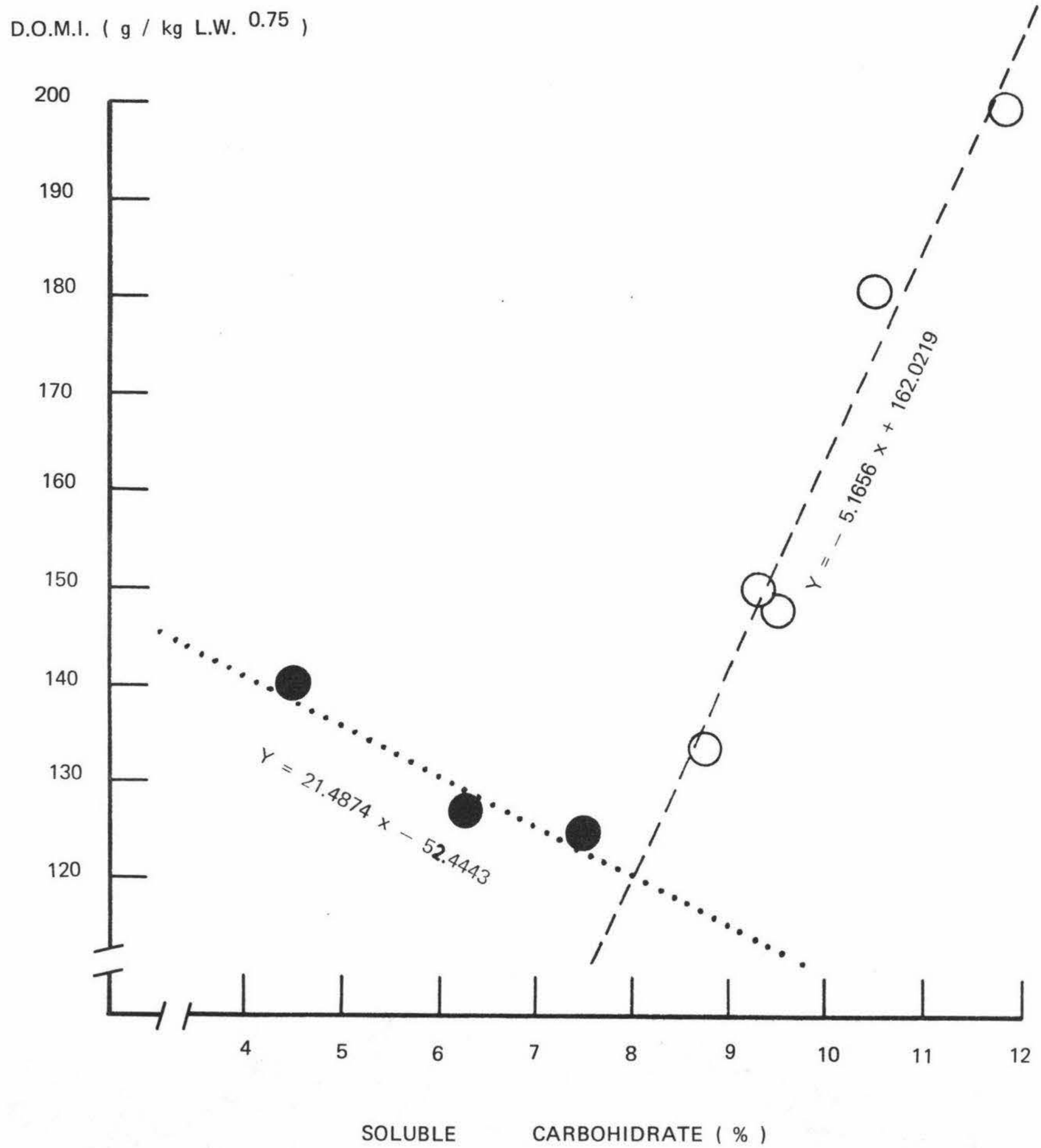


Fig. 3.19 Relationships between digestible organic matter intake (D.O.M.I.) in g / kg L.W. $^{0.75}$ and the soluble carbohydrate content of herbage. (Intakes estimated by grab samples of faeces).

(○ Pasture, ● Japanese Millet)

Appendix 15., and since the slopes clearly differed, no common regression was computed. There were no obvious relationships between intake and any of the other feed constituents. Examination of intakes and the digestibility of feed constituents indicated useful relationships between D.O.M. intake (g / kg L.W.$^{0.75}$) and the digestibility of dry matter and crude fibre. In the first case (Fig. 3.20. and Appendix 16.) correlations of $\hat{r}$ = 0.9333 for pasture and $\hat{r}$ = 0.8561 for Japanese Millet were computed. A non- significant ($P > 0.10$) departure from parallelism (Appendix 17.) allowed the data to be combined as shown ($\hat{r}$ = 0.9201). D.O.M. intake (g / kg L.W.$^{0.75}$) and the digestibility of crude fibre were related for pasture ($\hat{r}$ = 0.8994) and Japanese Millet ($\hat{r}$ = 0.6307). A non - significant ($P > 0.10$) departure from parallelism (Appendix 17.) again allowed the data to be combined as in Fig. 3.20 and Appendix 16. ($\hat{r}$ = 0.7126).

3.3.3.3. Milk yield and composition

A - MILK YIELD

Changes in unadjusted mean milk yields (cow x treatment x period) from cows fed mixed pasture and Japanese Millet are presented in Table 3.10. Treatment x period adjusted means with standard errors are illustrated in Fig. 3.21.

Differences in milk yield during Periods II, III and IV taken together were examined by analysis of variance using the 2 way model for milk production described in 2.8.1.2. There were no significant ($P > 0.10$) effects of treatment, period or the Treatment x Period interaction on milk yield (Appendix 18. - A.).

Since the 'residual' term accounted for all observed variation (see Appendix 3.18. - A.), analysis of covariance was performed using mean milk yield in Period I (Preliminary Period) as the concomitant variable. The model used (2 way with covariance) was described in Section 2.8.2.2. Before preliminary data was used as the concomtant variable, a one way analysis of variance

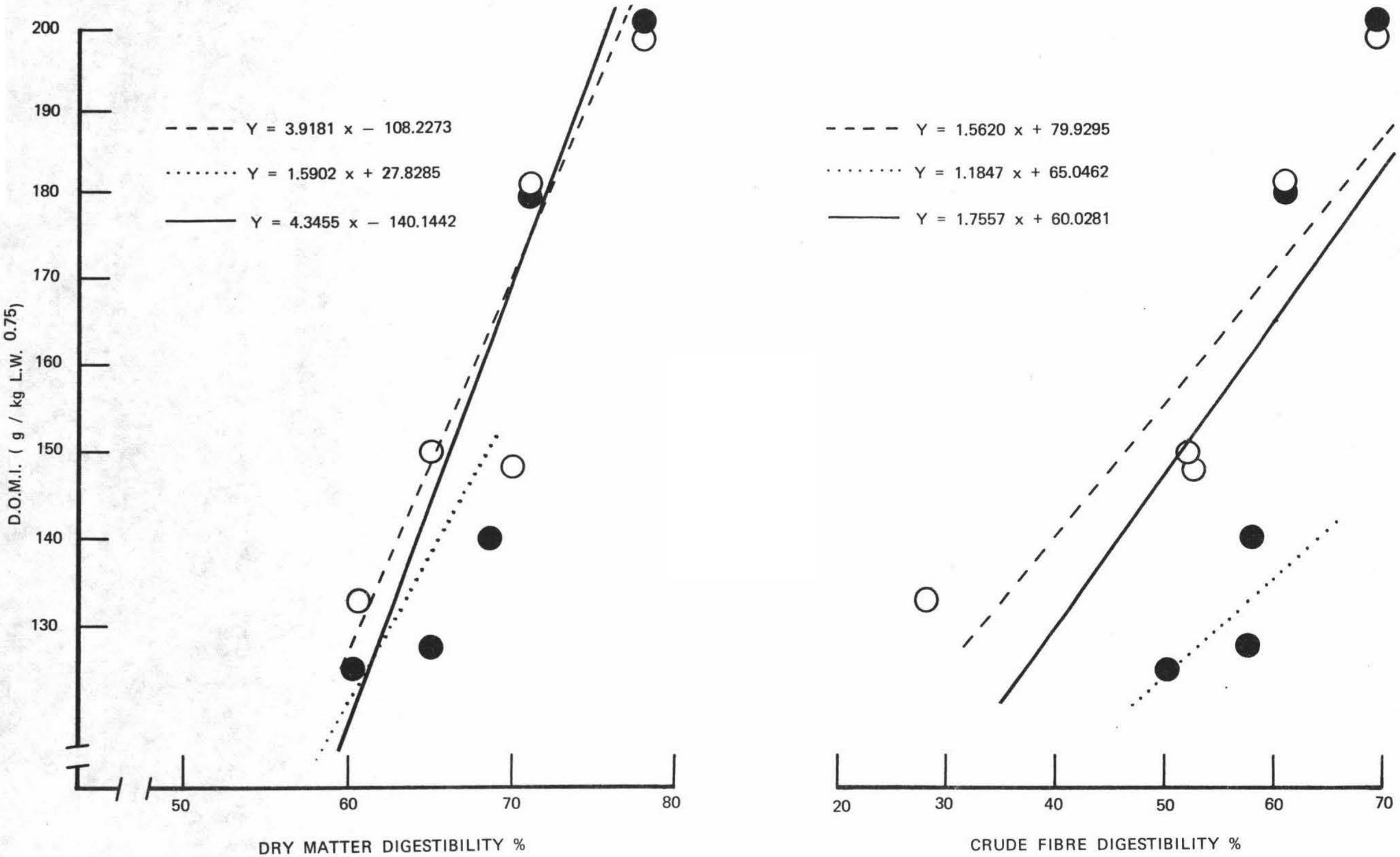


Fig. 3.20 **Relationships between digestible organic matter intake (D.O.M.I.) in g / kg L.W. $^{0.75}$ and dry matter digestibility and crude fibre digestibility.** (Intakes estimated by 'grab' samples of faeces).

(---○ Pasture, ·····● Japanese Millet, —— Total).

TABLE 3.10

MEAN MILK YIELD (kg / day)

PERIOD	PASTURE	JAPANESE MILLET
I	10.67 (1.46)*	10.81 (1.18)
II	10.11 (1.44)	10.33 (0.95)
III	9.44 (1.28)	9.02 (1.04)
IV	10.35 (1.17)	8.34 (1.00)
V	10.88 (1.52)	8.91 (0.90)

* Standard error of means

TABLE 3.11

Comparison of adjusted milk yield (kg / day)

PERIOD	PASTURE	JAPANESE MILLET	SIGNIFICANCE
II	10.16 (0.15)* a+	10.28 (0.15) cd	NS ($P > 0.10$)
III	9.50 (0.15) ab	8.97 (0.15) c	S ($P < 0.01$)
IV	10.40 (0.15) b	8.29 (0.15) d	S ($P < 0.001$)

* Standard error of means

\+ Means denoted by the same letter are significantly ($P < 0.05$) differents.

(see Section 2.8.1.1.) of milk yield in Period I was made (Appendix 18. - B.), indicating no significant ($P > 0.10$) variation due to differences between the treatment groups.

Analysis of covariance (Appendix 18. - C.) showed that the use of the regression term reduced residual variation by 98.30 %. The residual variance was reduced from 19.5852 to 0.3333 and treatment variance increased from 11.6434 to 15.5953 (see Appendix 18. - A. and C.). After accounting for differences in the preliminary period, there was significant ($P < 0.01$) variation associated with treatments, periods and the Treatment x Period interaction. As the interaction had a significant influence, a 2 way comparison of adjusted means was made (Table 3.11.). During Period II there was no significant ($P > 0.10$) difference between treatments, but during Period III and IV, pasture fed cattle produced significantly ($P < 0.01$ and $P < 0.001$) more milk than Millet fed cows. Differences between Periods in each treatment group were tested by Duncan's multiple range test (see Section 2.8.3.). There were significant ($P < 0.05$) differences between Period II and Period III, and between Period III and IV in pasture fed cattle. There were significant ($P < 0.05$) differences between Period II and III and between Periods II and IV for Millet fed cattle (see Fig. 3.21.).

Differences in milk yield considered on a within-Period basis were examined first by analyses of variance and then by analyses of covariance using preliminary data as the concomitant variable. The model used (one way with covariance) is described in Section 2.8.2.1. Analyses of variance for data in each of four periods indicated no significant ($P > 0.10$) differences between the treatments (Appendix 19.). The use of covariance reduced within treatment variation by 97.75 %, 98.82 %, 98.11 % and 96.60 % respectively in Period II, III, IV and V. Despite this adjustment, there was no significant ($P > 0.10$) difference between treatment means in Period II (Appendix 19.). However during Period III, IV and V differences between treatments were significant ($P < 0.10$, $P < 0.001$, and $P < 0.01$) for Periods III, IV and V). The results of these analyses confirmed the results found by analysis of covariance

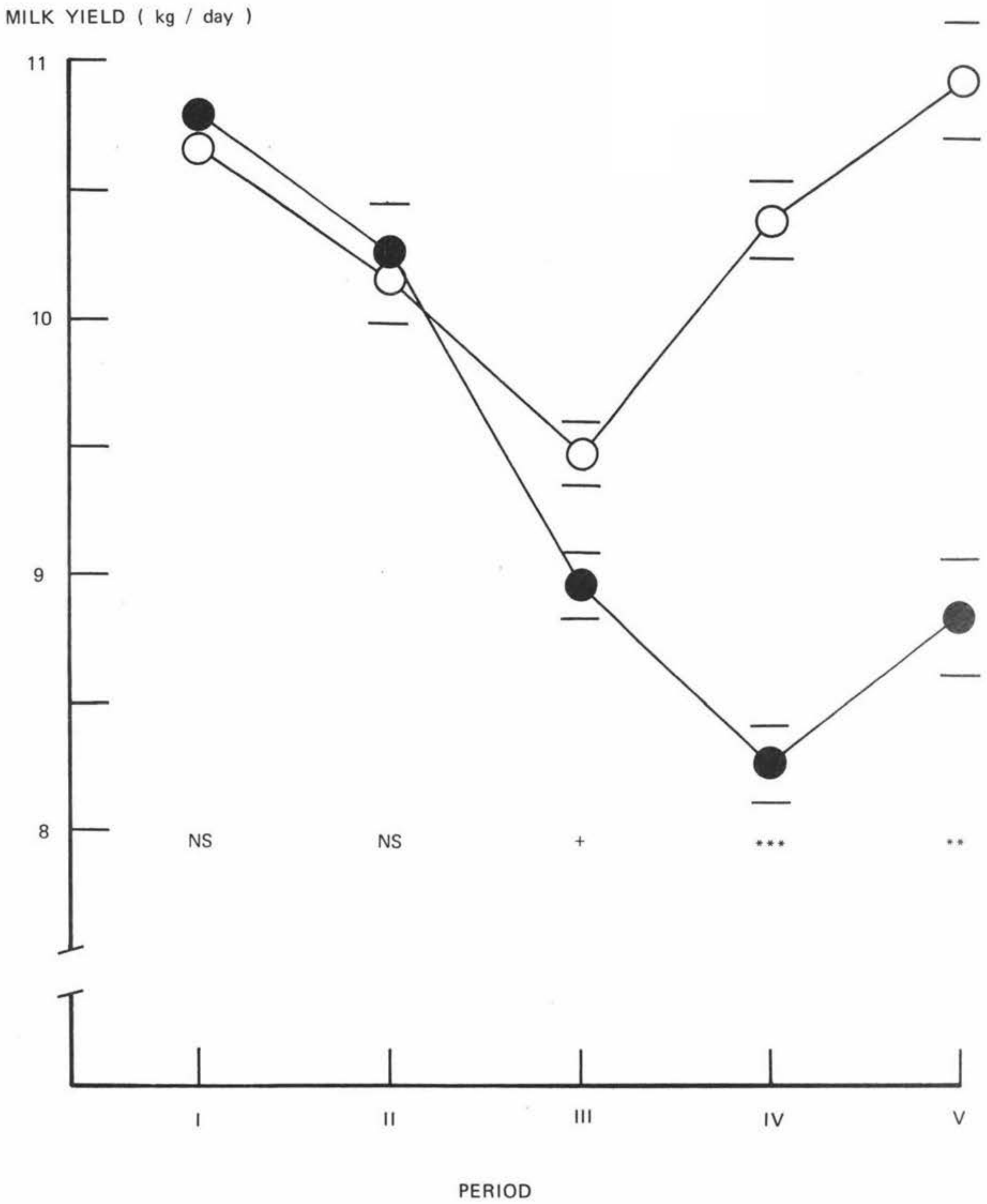


Fig. 3.21 MILK YIELD (Means adjusted for preliminary period differences).

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods :

NS = P > 0.10 + = P < 0.10 ** = P < 0.01 *** = P < 0.001

taking the three experimental periods together.

B - FAT CORRECTED MILK (FCM)

As milk fat percentage differed between pairs of twins, the use of FCM yield rather than the actual milk yield increases the differences between treatments within periods. Changes in FCM yield means (unadjusted) (Cow x treatment x period) from cows fed pasture and Millet are presented in Table 3.12. The treatment x period adjusted means and standard errors are illustrated in Fig. 3.22.

Changes in FCM yield in Periods II, III and IV taken together were examined by analysis of variance using the model described earlier. There were no significant ($P > 0.10$) effects of treatment, period and Treatment x Period interaction on variation in FCM yield (Appendix 20. - A.). Since the 'residual' term accounted for all the observed variation, analysis of covariance was performed using mean FCM yield in Period I as the concomitant variable. The model used (2 way with covariance) was described in Section 2.8.2.2. There were no significant ($P > 0.10$) treatment differences in FCM yield in Period I (Appendix 20. - B.).

Analysis of covariance (Appendix 20. - C.) showed that the use of the regression term reduced residual variation by 98.34 %. After accounting for differences in the preliminary period, there were highly significant ($P < 0.01$) and ($P < 0.001$) differences among treatment, periods and the (treatment x period) interaction (Appendix 20. - C.). Comparison of adjusted means (Table 3.13.) showed no significant ($P > 0.05$) differences between treatments in Period II but in Period III and IV, pasture fed cows produced significantly ($P < 0.05$) and ($P < 0.001$) respectively more FCM than Millet fed cows. The only significant ($P < 0.05$) difference between Periods for pasture fed cows was between Period III and IV (Table 3.13.). For Millet fed cows, differences in FCM yield for all periods were significantly ($P < 0.05$) different; FCM production fell progressively during the experiment (Table 3.13. and Fig. 3.22.).

FCM yields were examined on a within-period basis by analyses of variance and then by analyses of covariance using preliminary data as the concomitant variable. The models used were the same as described for milk yield (Section 3.3.3.3. - A.). Analyses of variance for data in each of the four experimental periods (II, III, IV and V) indicated no significant ($P > 0.10$) treatment differences (Appendix 21.). The use of analysis of covariance reduced within treatment variation by 96.64 %, 99.56 %, 97.81 % and 98.59 % respectively in Periods II, III, IV and V. There was no significant ($P > 0.10$) difference between treatments in Period II but in the other Periods, significant ($P < 0.05$, $P < 0.001$ and $P < 0.01$ for Periods III, IV and V) treatment differences were found.

C - RELATIONSHIP BETWEEN FCM - D.O.M.I. - $L.W.^{0.75}$

Fat corrected milk yield (kg / day), digestibe organic matter intake (kg / day) and live weight (kg $L.W.^{0.75}$) were related using multiple regression analysis (see Section 2.8.5.). Separate multiple regressions were fitted for each of the two treatments (pasture and Millet). Analysis of residuals after fitting the multiple regression (Appendix 22 - Table A.) indicated that the regression relationships were not significantly ($P>0.10$) different. Therefore new relationships were fitted to the total data (pasture and Millet together) (Appendix 23.) giving the following results :

$$F.C.M. = - 58.8421 + 0.1714 \ L.W.^{0.75} + 0.3651 \ D.O.M.I.$$

		REDUCTION in VARIATION	C.M.D.*
Multiple regression	-	$P < 0.001$	92.30 %
On $L.W.^{0.75}$ alone	-	$P < 0.001$	73.25 %
On D.O.M.I. alone	-	$P < 0.001$	51.20 %

* Coefficient of multiple determination

The coefficient of multiple determination (C.M.D.) (92.30 %) indicated that most of the variance in FCM was associated

TABLE 3.12

MEAN FCM YIELS (kg / day)

PERIOD	PASTURE	JAPANESE MILLET
I	12.84 (1.83)*	12.79 (1.56)
II	11.97 (1.74)	12.00 (1.16)
III	11.46 (1.60)	10.74 (1.44)
IV	12.67 (1.62)	9.83 (1.26)
V	13.17 (1.82)	11.09 (1.29)

* Standard error of means

TABLE 3.13

Comparison of adjusted mean FCM yield (kg / day)

PERIOD	PASTURE	JAPANESE MILLET	SIGNIFICANCE
II	11.95 (0.19)*	12.02 (0.19) b	NS ($P > 0.10$)
III	11.44 (0.19) a+	10.76 (0.19) b	S ($P < 0.05$)
IV	12.65 (0.19) a	9.85 (0.19) b	S ($P < 0.001$)

* Standard error of means

\+ Means denoted by the same letter are significantly ($P < 0.05$) differents.

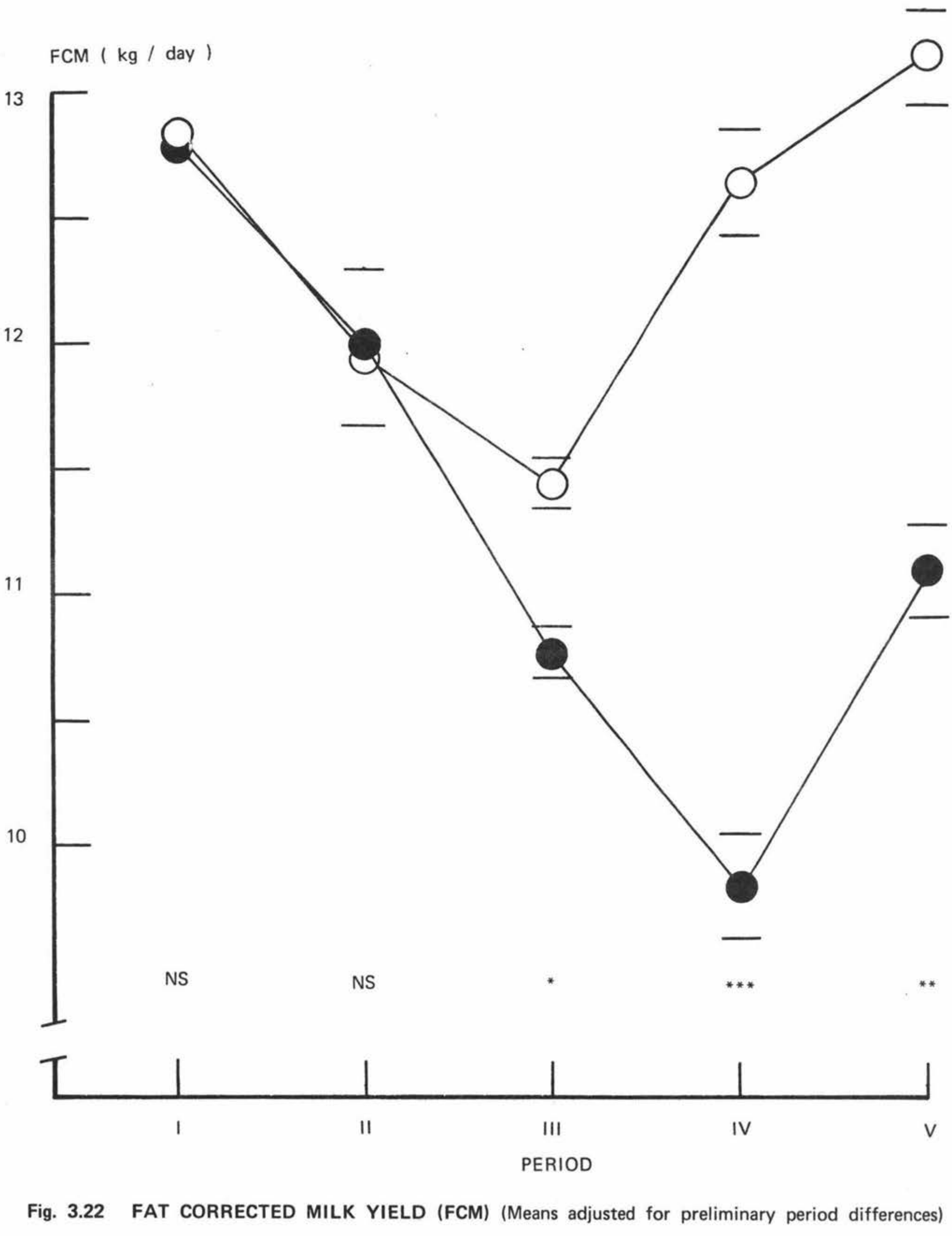


Fig. 3.22 FAT CORRECTED MILK YIELD (FCM) (Means adjusted for preliminary period differences)

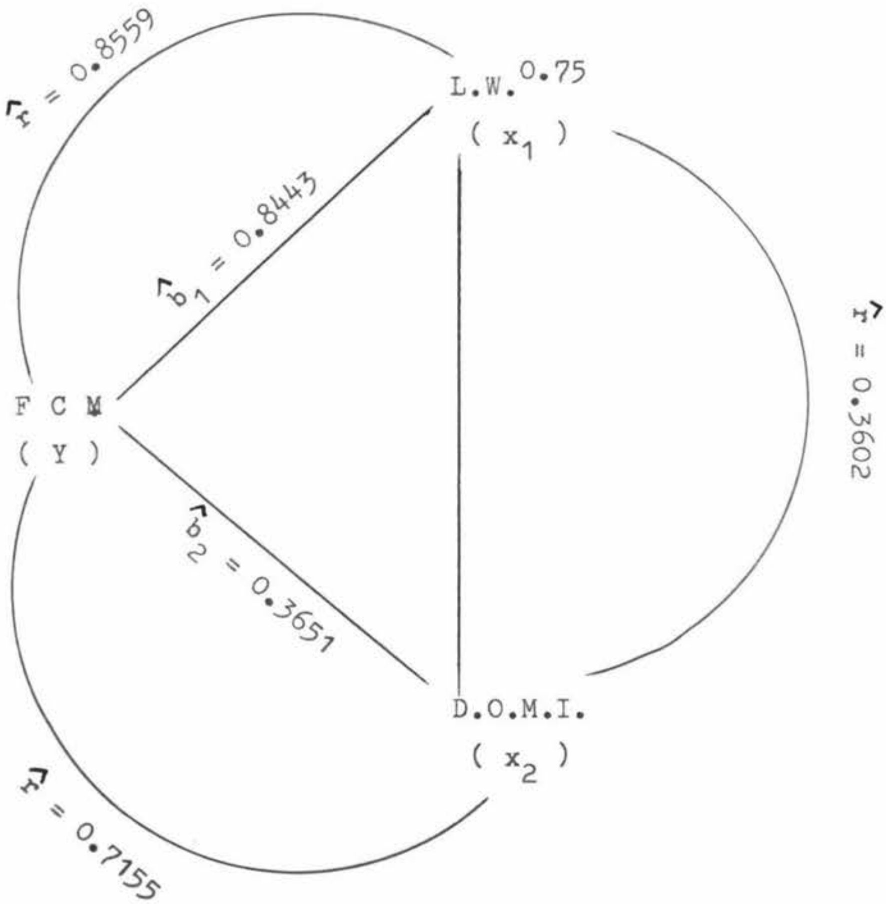
(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods:

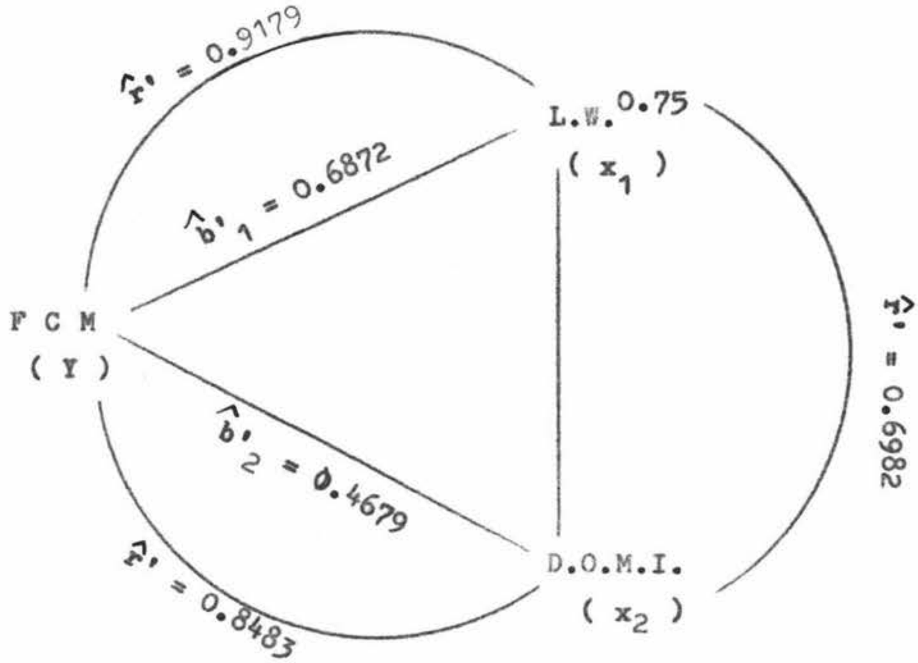
NS = P > 0.10 * = P < 0.05 ** = P < 0.01 *** = P < 0.001

with variation in live weight and D.O.M.I. ; and of these, body weight made the biggest contribution.

Partial regression coefficients and raw correlation coefficients were computed :



The standardized partial regression and partial correlation coefficients were estimated :



The standardized partial regression coefficients indicate that variation in live weight was approximately 50 % more important in determining FCM yield than was variation in D.O.M. intake.

D - RELATIONSHIP BETWEEN FCM - O.M.I. - D.O.M.

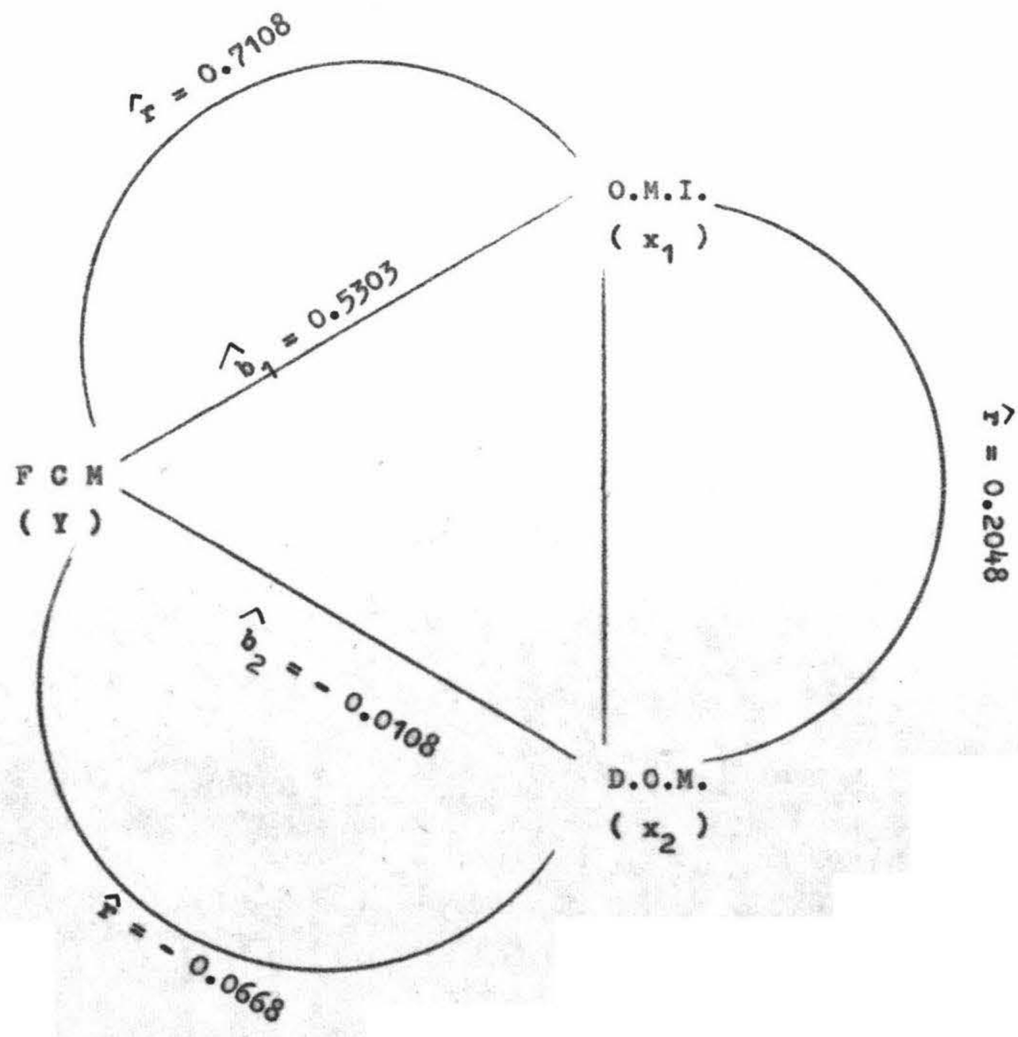
Following the same pattern as in the latter relationship, a new multiple regression analysis was made. Fat corrected milk (kg / day), organic matter intake (kg / day) and digestible organic matter (%) were related. Separate multiple regressions were fitted for each of the two treatments (pasture and Japanese Millet); and both were computed into an analysis of residuals after fitting the multiple regression. It was found that the regression relationships were not significant ($P > 0.10$) different (Appendix 22.- Table B.). Taking into account the information for both herbage (pasture and Millet) together (Appendix 24.) it was decided to fit a common multiple regression. The following multiple regression equation was fitted :

$$FCM = 5.6122 + 0.5303 \ O.M.I. - 0.0108 \ D.O.M.$$

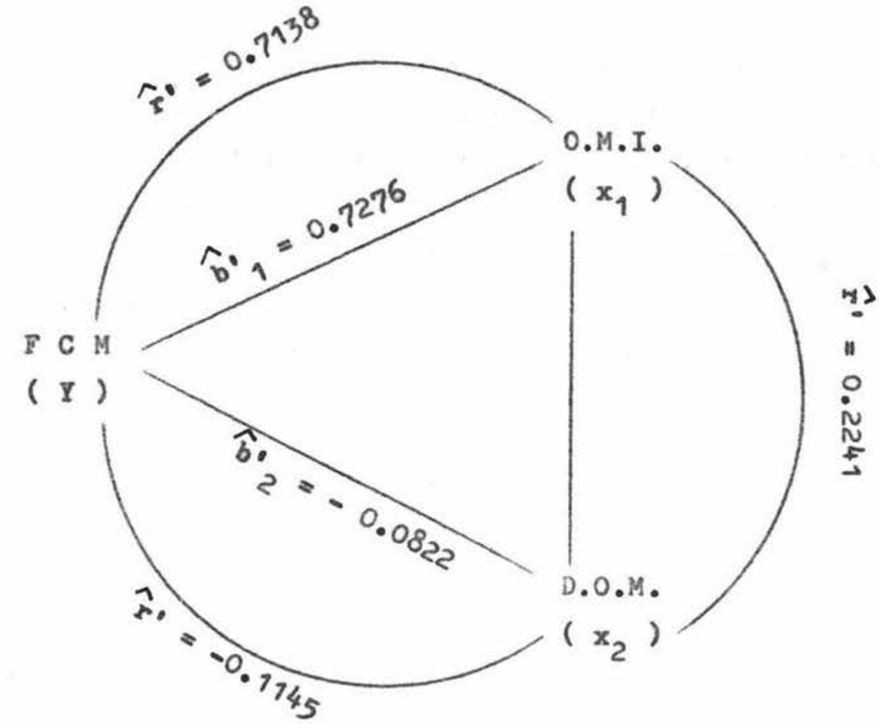
		REDUCTION in VARIATION	C.M.D.*
Multiple regression	-	$P < 0.001$	51.17 %
On O.M.I. alone	-	$P > 0.10$	50.52 %
On D.O.M. alone	-	$P < 0.001$	0.45 %

Only 51.17 % of FCM yield variation was associated with variation in digestible organic matter and organic matter intake; and nearly all this relationship was associated with intake. Partial regression coefficients and raw correlation coefficients confirm the latter suggestion, showing a particular weak relationship ($\hat{r}$ = 0.0668) between FCM and D.O.M.

Partial regression coefficient and raw correlation coefficients :



These correlation coefficients were not much improved by calculation of standardized partial regression and partial correlation coefficients, Standardized partial regression coefficients and partial correlation coefficients :



The standardized partial regression coefficient indicates that almost the whole variation in FCM for this relationships is associated with organic matter intake and practically none with D.O.M.

E - FAT - PROTEIN - LACTOSE YIELD

Changes in yields of butterfat, protein and lactose (cows x treatments x periods) as unadjusted means, are presented in Table 3.14. Fig. 3.23. illustrates treatment x period adjusted means and standard errors during the five experimental periods. Yields of the three components were examined by analyses of variance, during Period II, III and IV together, according to the model used in the same circumstances for milk yield (see Section 3.3.3.3. - A.). None of the 3 analyses showed significant ($P > 0.10$) differences (Appendix 25.) and in each analyses, the residual term accounted for all of the observed variation. Analyses of covariance were performed,

TABLE 3.14

Daily yields of milk components (kg / day)

PERIOD	MILK COMPONENTS	PASTURE	JAPANESE MILLET
I	FAT	0.571 (0.086)*	0.565 (0.074)
	PROTEIN	0.397 (0.065)	0.395 (0.054)
	LACTOSE	0.541 (0.070)	0.552 (0.055)
II	FAT	0.528 (0.079)	0.524 (0.053)
	PROTEIN	0.369 (0.065)	0.371 (0.046)
	LACTOSE	0.513 (0.070)	0.520 (0.045 (
III	FAT	0.512 (0.076)	0.475 (0.069)
	PROTEIN	0.345 (0.059)	0.324 (0.046)
	LACTOSE	0.478 (0.061)	0.451 (0.045)
IV	FAT	0.568 (0.078)	0.433 (0.059)
	PROTEIN	0.397 (0.057)	0.308 (0.047)
	LACTOSE	0.519 (0.053)	0.416 (0.045)
V	FAT	0.587 (0.085)	0.502 (0.063)
	PROTEIN	0.435 (0.075)	0.356 (0.052)
	LACTOSE	0.551 (0.075)	0.445 (0.039)

* Standard errors of means

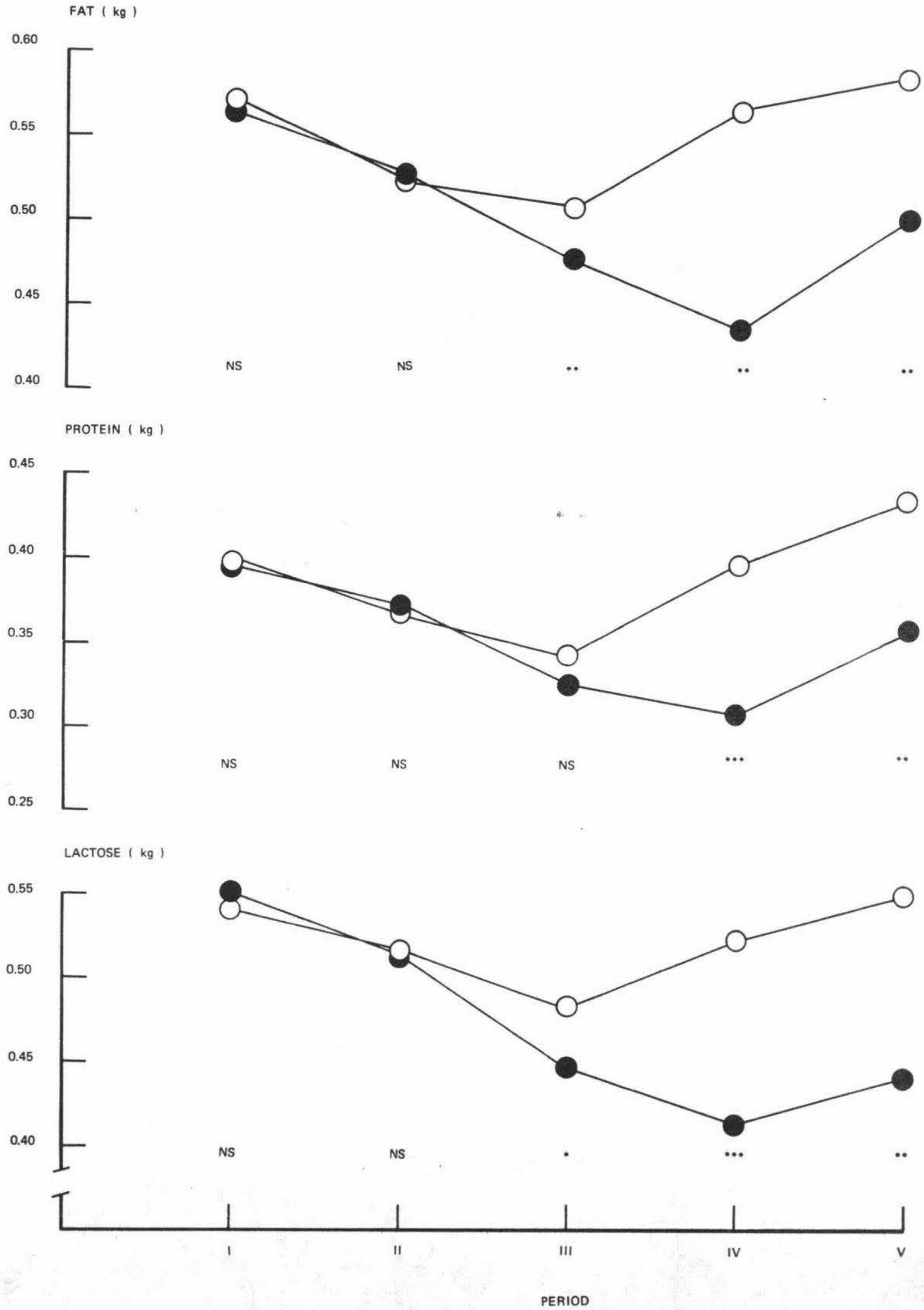


Fig. 3.23 DAILY YIELDS OF MILK COMPONENTS (Means adjusted for preliminary period differences)

(○ Pasture, ● Japanese Millet)

Probability of differences between treatment within periods :

NS = $P > 0.10$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

using the means for Period I as concomitant variable; models used were described in Section 3.3.3.3. - A. Previous analyses of variance (1 way model) during Period I for the three component yields (Appendix 26.) showed no significant ($P > 0.10$) variation due to differences between the treatment groups. Analysis of covariance showed that the use of the regression term in reduced residual variation by 97.98 %, 97.98 % and 97.64 % for fat, protein and lactose yield. On the three components, the effect of treatments, periods and (treatment x period) interaction were significant ($P < 0.01$, $P < 0.05$, and $P < 0.001$ respectively) different (Appendix 27.). A 2 way comparison of adjusted means between treatments and within treatments are presented for each of the three yield components in Appendix 27. During Period II, none of the three yield components showed significant ($P > 0.10$) differences between pasture and Millet fed cows. But during Periods III and IV, the fed pasture group had a higher significant ($P < 0.01$) and ($P < 0.001$) yield than Millet fed cows.

Fat, protein and lactose yields were computed on a within-Period basis (II, III, IV and V) being first analysed by analyses of variance and then by analyses of covariance, using the same model described for milk yield on Section 3.3.3.3. - A. Analysis of variance showed that there were no significant ($P > 0.10$) differences within periods for any of the three components of yield (Appendix 28.). However when analysis of covariance was employed, the variation within treatment was considerably reduced and in milk component yield, a significant ($P < 0.05$, $P < 0.01$, $P < 0.001$) difference was observed (Appendix 28.). Results of these analyses are illustrated on Fig. 3.23.

F - FAT - PROTEIN - LACTOSE PERCENTAGES

Changes in the percentage of fat, protein and lactose (cows x treatment x periods means) as unadjusted means for pasture and Japanese Millet fed cows are presented on Table 3.15. Variation in the adjusted treatment x period means and standard errors are illustrated on Fig. 3.24.

TABLE 3.15

CHANGES IN MILK COMPOSITION (%)

PERIOD	MILK COMPONENTS	PASTURE	JAPANESE MILLET
I	FAT	5.34 (0.35)*	5.21 (0.25)
	PROTEIN	3.69 (0.13)	3.63 (0.12)
	LACTOSE	5.09 (0.06)	5.12 (0.05)
II	FAT	5.22 (0.27)	5.07 (0.23)
	PROTEIN	3.61 (0.14)	3.57 (0.13)
	LACTOSE	5.09 (0.03)	5.04 (0.05)
III	FAT	5.43 (0.39)	5.23 (0.25)
	PROTEIN	3.62 (0.15)	3.57 (0.11)
	LACTOSE	5.08 (.0.05)	5.03 (0.09)
IV	FAT	5.47 (0.25)	5.17 (0.27)
	PROTEIN	3.81 (0.15)	3.65 (0.14)
	LACTOSE	5.04 (0.06)	5.01 (.0.07)
V	FAT	5.41 (0.39)	5.61 (0.28)
	PROTEIN	3.96 (0.17)	3.96 (0.20)
	LACTOSE	5.08 (0.04)	5.02 (0.08)

* Standard error of means

Changes in the percentages of the milk components during the experimental periods (Periods II, III and IV) were examined by analysis of variance using the model described in Section 3.3.3.3- A. None of milk components (fat, protein and lactose percentages) showed significant differences among treatments, periods and Treatment x Period interaction between cows fed pasture and Millet (Appendix 29.) As in the three analyses, residual terms accounted for all observed variation (see Appendix 29.), further analysis of covariance were made using mean milk components in Period I (Preliminary Period) as the concomitant variable. The model used was the same as described in Section 3.3.3.3. - A. Previous analyses of variance (1 way model) during Period I for the three milk components (fat, protein and lactose percentages) showed no significant ($P > 0.10$) differences for the three analyses (Appendix 30.) due to the differences between the treatment groups. Analyses of covariance (Appendix 31.) showed that only significant ($P < 0.05$) difference between treatment accounted only with lactose %. A significant ($P < 0.10$) difference between periods was observed with butterfat % and none of the three components showed a significant Treatment x Period interaction.

The use of the regression term reduced within treatment variation by 92.70 %, 93.80 % and 73.07 % for fat, protein and lactose percentages. Although the Treatment x Period interactions were not significant, a 2 way comparison of adjusted means were made in the three milk components (Appendix 31.). Only Protein % in the pasture treatment showed differences between periods means; Period IV was higher significant ($P < 0.05$) than Period III and II.

Analyses of the percentages of the milk components within Periods (II, III, IV and V) were first analysed by analyses of variance (the model used was the same as described for milk yield - Section 3.3.3.3. - A.). It was found that fat, protein and lactose percentage, during the 4 periods, were not significantly ($P > 0.10$) different (Appendix 32.). As in all cases the residual term accounted for all the observed variation, an analysis of covariance was computed for each milk component (model used was described in Section 3.3.3.3. - A.). Results from analyses of covariances are

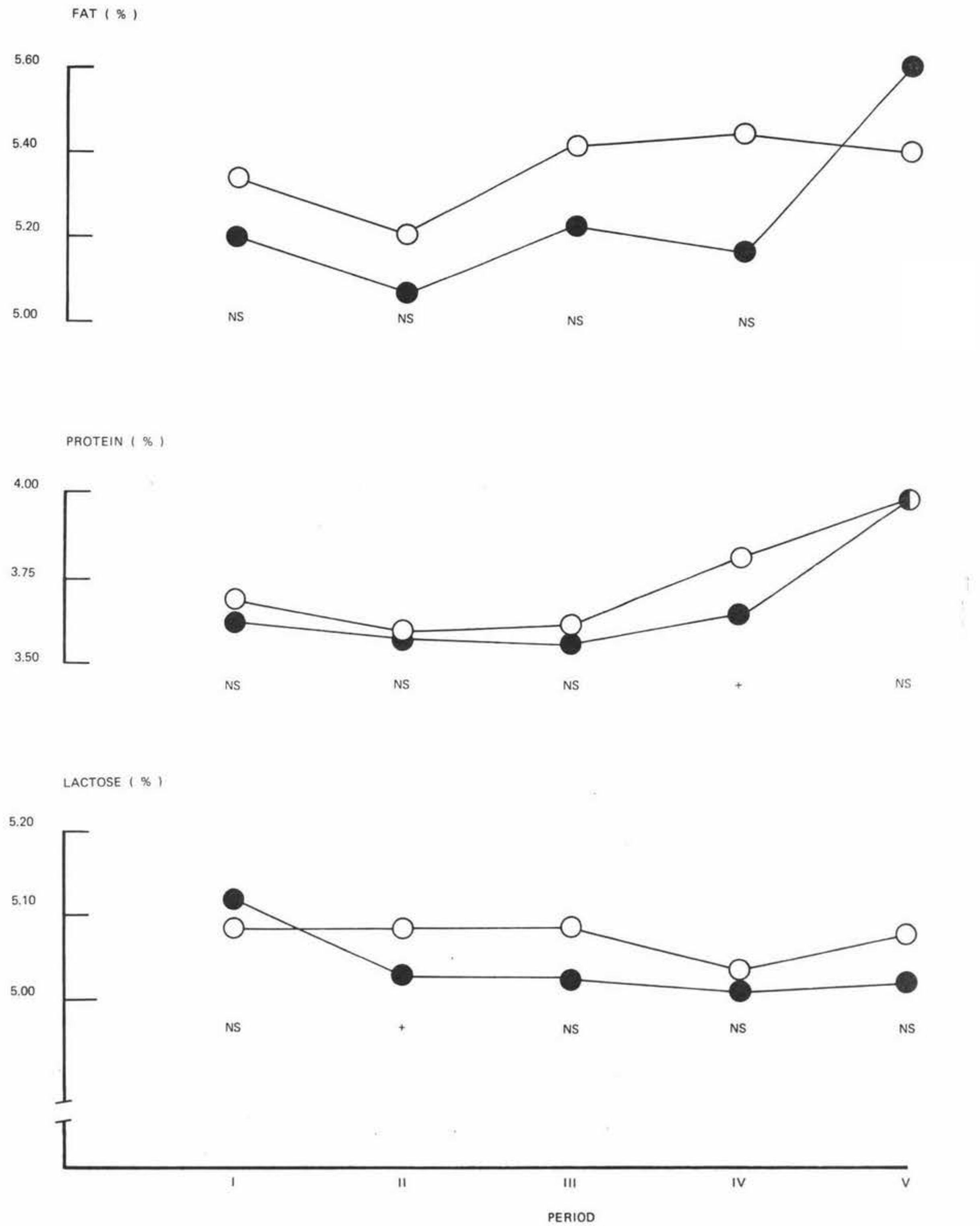


Fig. 3.24 CHANGES IN MILK COMPOSITION. (Means adjusted for preliminary period differences)

(○Pasture, ●Japanese Millet)

Probability of differences between treatment within periods:

NS = P > 0.10 + = P < 0.10 * = P < 0.05

presented in Appendix 32. and are summarized on Fig. 3.24. The butterfat % in the Millet group during Period IV was significantly ($P < 0.05$) greater than that in the pasture fed group. Protein % in the group fed pasture during Period III was the only case where it was significantly ($P < 0.10$) different from Millet fed group and the lactose % in the pasture group was significantly ($P < 0.10$) greater than the Millet only during Period II.

CHAPTER FOUR

DISCUSSION

4.1. Discussion of Methods Used.

4.1.1. Experimental Design.

Indoor experiments with dairy cows can be made with changeover designs (Holmes et al., 1960; Castle et al., 1960); however under grazing conditions such designs are less satisfactory, particularly because pasture composition and nutritive value are changing as the experimental progresses and there may be period x treatment interactions. Under this situation, if changeover designs are used these interactions can be confused with the effect of other variables (Greenhalgh, 1966). Under grazing conditions, analysis of covariance provides a satisfactory technique in that variation associated with differences between animals before the experiment started can be eliminated. Data from the Preliminary Period which are covariates in the analysis of experimental periods, are used as correction factors. In the present experiment, observations of live weight, milk yield and composition were used as covariables; in this form variance residual to the treatment effect was reduced by an average of 95%.

When results are analyzed by covariance, the main limitation of the design is the difficulty of eliminating carry-over effects, but if individual periods are analyzed separately and the previous adjusted mean period data used as the covariables, individual period effects can be detected. However, since as in the present experiment, herbage effects were of interest throughout the whole experiment, carry-over effects are considered as real factors which are occurring under practical conditions and so were analyzed within treatment effects as a whole.

In the present experiment, although covariance analysis was used and then differences before experimental periods started were eliminated, the effect of stage of lactation can be suggested as interfering with the results, particularly on those of milk production. As the latter effect appears to be particularly highly related with the treatment effect, in most cases differences between treatments were non significant.

4.1.2. Voluntary Intake Measurement.

Voluntary intakes of grazing cows were measured by means of an indirect method (see Section 2.5) which employs an indigestible marker (Cr_2O_3) to measure faecal output. Cr_2O_3 was used since it has all the requirements for a tracer to be used satisfactorily as described by Raymond and Minson (1955) in their review.

As the irregular excretion pattern associated with Cr_2O_3 administration precludes the sampling of faeces to be truly representative of the mean Cr_2O_3 concentration over the period, two techniques were used to collect faeces from grazing cattle: 'grab' and 'sward' samples, and their values compared. As indicated in Section 3.1. and 3.3.3.2., voluntary intake measured by means of 'sward' sampling gave a higher value than that from 'grab' sampling (Table 3.8.). Raymond and Minson (1955) comparing 'sward' sampling with total faecal collection found that the total faecal output estimated from 'sward' samples gave on average an estimation 4.6% higher than that obtained by 'bag' collection. Greenhalgh (1966) comparing the total faecal output measured by 'grab' and 'sward' sampling found that the latter gave a value 6.0% higher than those from 'grab' sampling. In Greenhalgh's experiment as in the present study, 'sward' sampling corresponded to the total group of cows since no 'pats' identification from each cow was made. In the present experiment 'sward' samplings were 9.96% higher than the former, which indicated a value a little higher than that reported by Greenhalgh (1966). However Lambourne (1957 b) working with sheep, pointed out that up to 10% differences were present when faeces samples from a group of sheep were bulked together. In Fig. 3.17 and Appendix 13., two single regressions for pasture and Japanese Millet between D.O.M. Intakes measured by 'grab' and 'sward' sampling were computed and a common regression for both herbages was also presented. As the analysis of regression slopes (Appendix 14.) showed non-significant departure from parallelism ($P > 0.10$), the common regression (see Fig. 17) with a coefficient of correlation of

$\hat{r}$ = 0.8899 (n = 8) describes the relationship between estimates using the two techniques. It is observed (Appendix 13.) that in the case of cows fed on pasture, there was a higher ($\hat{r}$ = 0.9481) correlation between 'grab' and 'sward' techniques than those cows fed on Japanese Millet ($\hat{r}$ = 0.5993). The later value appears not to be representative since only 3 points were used to compute the correlation coefficient. However when all values, either from pasture or Japanese Millet, were computed together a higher correlation was obtained as indicated above.

When intake is measured by means of 'grab' sampling, it includes within and between day variation, since the individual period - cow mean intake is expressed by the average of two faecal samples per day along the experimental period. However when intake is measured by means of 'sward' sampling not only daily variation but also cow variation is included since faeces for all the experimental group are bulked together. Lambourne (1957 b) indicated that a sheep may show variations of at least 30 - 50 % in faecal output between successive 2 or 3 day periods, thus a similar variation can be assumed between a group of sheep. In order to minimise that source of error, animal faeces samples may be collected and analysed separately. However with 'sward' sampling within day variation is controlled by the fact that all the 'pats' excreted during the day are sampled (Langland et al., 1963; Raymond and Minson, 1955; Minson et al., 1960). If a cow has a bigger or smaller Cr_2O_3 excretion, this variation would affect all the cows from the groups, since 'sward' sampling technique used in this experiment did not differentiate between individual cow's 'pats'. On the other hand, when 'grab' samples are used, this irregular Cr_2O_3 excretion would only affect that particular cow, and hence there is less variability. Using coloured polystyrene particles (Raymond and Minson, 1955; Minson et al., 1960; Corbett, 1960; Moule, 1965) 'pats' for each cow could be identified and then cow variation could be controlled. Because of practical circumstances, in this experiment these colour markers were not used. Also using a large number of animals over a sufficiently long time period, it seems that fluctuations in the excretion of Cr_2O_3 could be reduced (Linkous et al., 1954).

Although it is evident that the 'sward' technique gave a higher value of voluntary intake than 'grab' sampling, it appears that the former is a simpler method for the collection of faeces. Under the present experimental conditions, 'sward' sampling was a quicker and less troublesome technique than 'grab' sampling, however this finding does not agree with previous reports (Moule, 1965; Corbett et al., 1960; Langlands et al., 1963 b) which indicated that 'sward' sampling is not as practical a method as 'grab' sampling. The present experiment was made during a time of the year where climatic conditions and insects had very small effect on a 'pat's' condition, and also 'pat' identification was not carried out; all these factors seem to be the reason why 'sward' sampling would appear to be a simpler technique to use.

In the following discussion, only results obtained by 'grab' sampling will be used, since they appear to be more reliable.

Values of cow's voluntary intakes reported in Fig. 3.16 and Fig. 3.18 seem to be higher than those generally reported (e.g. Corbett, 1969; Greenhalgh, 1970); several reasons could be suggested to explain this. Cows in the experiment were at a stage of lactation where intake was presumably at the highest value (Hutton, 1963). However it appears that errors introduced in the indirect method used to estimate intake were among the principal factors affecting this high intake value.

The accuracy of faecal output estimates will depend principally on two factors: per cent Cr_2O_3 recovery in faeces and the need for the faecal sample to be representative of the total faecal output. One of the major problems with the Cr_2O_3 marker is that it does not mix uniformly with the feed eaten and is thus not mixed uniformly in the excreted faeces. Using powder Cr_2O_3 it was found that faecal output of an individual sheep may be estimated with a coefficient of variation of 12% (Lambourne and Reardon, 1963 a). A value of 10% was reported using cattle (Lancaster et al., 1953). Other investigations revealed similar coefficients of variation (Raymond and Minson, 1955; Smith and Reid, 1955; Wallace, 1956; Moule, 1965; Pigden and Brisson, 1957; Coop and Hill, 1962). However Corbett (1960) suggested that the coefficient of variation can be reduced to 5% if paper Cr_2O_3 is used rather than powder Cr_2O_3.

Several authors have reported a diurnal variation in Cr_2O_3 excretion in the faeces (Coup, 1950; Kane et al., 1952; Hardison and Reid, 1953; Lancaster et al., 1953; Mahaffey et al., 1954; Corbett et al., 1958, 1959, 1960; Smith and Reid, 1955). Then when faeces samples are taken it could therefore lead to an under- or over-estimation of the Cr_2O_3 concentration of the total faecal output. Lambourne (1957 a) pointed out that the major factor relating to the irregularity in the excretion pattern is the rate of passage of the digesta and hence marker concentration through the digestive system. Corbett et al., (1959) pointed out that this variable marker excretion arises mainly from uneven clearance from the stomach, particularly the reticulo-rumen. Of the principal factors affecting diurnal variation of Cr_2O_3 excretion, the followings can be indicated:

(a) Frequency of feeding (Mahaffey et al., 1954; Moore, 1959; Bloom et al., 1957).

(b) The level of feed intake (Raymond and Minson, 1955; Lambourne, 1957 a; Raymond et al., 1953; Lambourne and Reardon, 1963 a; Stevenson, 1962).

(c) Time of feeding (Kane et al., 1950; Linkous et al., 1954; Hardison and Reid, 1953).

(d) Time of marker administration (Raymond and Minson, 1955).

(e) Frequency of administration (Kane, et al., 1952; Hardison and Reid, 1953; Lambourne and Reardon, 1963 a; Bloom et al., 1957; Brisson et al., 1957; Lambourne 1957 b; Corbett, 1958, 1960; Pigden and Brisson, 1957).

(f) Method of marker administration (Corbett et al., 1958, 1959, 1960; Mahaffey et al., 1954; Raymond and Minson, 1955; Corbett and Greenhalgh, 1958; Langlands et al., 1963 a, b).

(g) Time of faeces sampling (Hardison and Reid, 1953; Lancaster et al., 1953; Smith and Reid, 1955; Brisson, 1960; Corbett, 1960).

(h) The quality and physical state of the feed (Lambourne, 1957a).

(i) Whether the animals are grazing or stall fed (Hardison and Reid, 1953; Raymond and Minson, 1955).

Under grazing situations, such as in the present experiment only some of these factors were controlled and then it appears that Cr_2O_3 recoveries in the faeces were less than 100%.

Generally, powder Cr_2O_3 is used in the form of an oil suspension. However a slow and more regular release of Cr_2O_3 was obtained by incorporating the Cr_2O_3 as sheets encased in gelatin capsules, shredded paper or as pellets (Corbett and Greenhalgh, 1958; Corbett et al., 1960; Langlands et al., 1963; Pigden and Brisson, 1957). Dosing Cr_2O_3 gelatine capsules in oil suspension causes an uneven mixing of the Cr_2O_3 in the digesta due to the sudden release of large doses into the alimentary tract. However using the slow release carriers, such as the above mentioned, the variability of diurnal excretion is reduced and so lowers the level of errors occurring when an oil suspension is administered by gelatin capsule. In the present experiment the powder Cr_2O_3 was administered in the commerical form (no oil suspension) and then it is presumed that bigger errors than those produced using oil suspension have been made.

Other possible causes could be mentioned which produce a low recovery of Cr_2O_3 in the faeces such as regurgitation of gelatine capsules (Corbett et al., 1960), absorbtion or retention of the marker in the digestive tract (Deinum et al., 1963; Moore, 1959), or failure to obtain representative faecal sampling. A significant loss of 2.6% due to the grinding of faeces has been shown by Stevenson (1962) and recognised as a cause of bias (Wallace, 1961; Coop and Hill, 1962). Bulking faecal samples can introduce a bias of as much as 5 to 10 % in marker concentration (Lambourne, 1957 b, Lancaster et al., 1953) and ashing of faeces (Stevenson, 1962) are suggested as further causes of a low recovery of Cr_2O_3.

Small errors in digestibility analyses can affect, in a bigger manner, the calculation of intake. Lancaster (1950) suggested that the error introduced into calculations of intake by using digestibility data obtained on the basis of 2 or 3 stall fed animals, can be of the order of $\pm$5 %. Corbett (1969) indicated that an error of 5 units in estimated digestibility would give a bias of 20% or more in the estimated intake.

Taking into account all the above factors it appears that the relatively high voluntary intakes found in the present experiment could be explained. Since these high values occurred for both types of herbage, it seems likely that the sources of error were common to both so that comparisons between the feeds for nutritive evaluation, is probably still valid.

4.1.3. Apparent Digestibility Method.

Digestibility trials were made with the aim of characterizing herbage values and also as a requirement for estimate voluntary intake of the grazing cows. Digestibility analyses associated with parallel grazing experiments in the field, as in the present study involve day to day variation in the composition and digestibility of the freshly cut material which can be accounted for by the methods used here (Greenhalgh et al., 1960; Anon, 1961). However since digestibility studies were made with sheep, it appears that digestibility data obtained in this way might be used with some reservations: (1) the effect of animal selectivity; (2) differences in level of intake between lactating cows and sheep; (3) differences in animal species affecting digestibility. For a long time the selectivity exercised by grazing animals has been recognized. This selectivity leads to the consumption of more leaves than stem materials which produces a higher digestibility of the feed eaten along with a higher content of nitrogen, ether extract, and sugar and lower fibre, than for the pasture herbage as a whole (Fontenot and Blaser, 1965; Hardison et al., 1954). Probably the greatest opportunity forselection occurs when plant growth is most rapid. Norman and Phillips (1968) indicated that beef cattle grazing Bulrush Millet in the mature or semi-mature stage showed a preference for those plant fractions with a high content of digestible carbohydrate. Because grazing animals selected the herbage, a fall in the digestibility of grazed herbage as a consequence of plants maturing occurs more slowly under grazing than under stall fed conditions. When the pasture included a large proportion of new growth, differences in digestibility between grazing and stall fed animals could be only slightly higher for the former (Fels et al., 1959). This complication could have occurred in the present study when cows were grazing the pasture during Period IV and V. However when the opportunity for selection is large, such as in the case of Japanese Millet, Taylor and Deriaz (1963) pointed out that differences in digestibility can be as high as 15 units or more. Information from the present experiment indicated that even stall fed sheep showed an appreciable selectivity of the feed offered. During those Periods where either pasture (e.g. Period II) or Japanese Millet (e.g. Period III and IV) had a relative low quality (as indicated by their chemical composition) the highest selectivity was observed (Appendix 4.). For example during Period II where pasture had the highest maturity among pastures used, sheep selected material which was 5.2% lower in crude fibre and 3.15% higher in crude protein compared with the total material offered. Differences of 4.0% in crude fibre content between Japanese Millet offered and consumed were found in Periods III and IV.

Following from the above results, it seems that the chemical composition and digestibility data from clipped herbage is not an adequate index of the herbage selected by grazing animals. In order to overcome this problem, techniques other than clipping might be used to avoid pasture selection. Oesophageal sampling techniques and in vitro digestibility appear as reasonable methods by which pastures consumed by grazing animals can be evaluated.

Some studies indicated differences in level of intake between grazing and stall fed animals as affecting digestibility (Blaxter, 1961; Blaxter et al., 1956; Raymond et al., 1959; Ivins, 1960). However Hutton (1962) working with cows receiving pasture ad. lib. and 60% of ad. lib. reported no differences in digestibility between the two groups of animals. In the present study as both sheep and dairy cows received the herbage ad. lib., it appears that no differences can originate in this way.

Watson et al., (1948) summarized numerous digestibility trials made with different animal species and they concluded that steers can digest herbage to a greater extent than sheep, however the differences were not statistically significant. However Cipolloni et al., (1951) indicated that digestibility values vary between sheep and cattle.

4.2. Discussion of Experimental Results

4.2.1. Japanese Millet Production.

4.2.1.2. Japanese Millet yields.

Japanese Millet could be an important herbage crop in the future, particularly for dairy cattle because it produces forage of reasonably high nutritive value in a relatively short time. The present work has shown that Japanese Millet can provide a high yield of forage as a summer crop during December, January and February when permanent pastures tend to be less productive, particularly in those years when droughts are prevalent.

The yield of dry matter increased with maturity. The highest yield for first growth was obtained at the 12th week (16,344 kg/Ha.) while regrowth at the 6th week yielded 6,001 kg/Ha. Although the latest stage of first growth and regrowth produced the highest yield, they were not suitable for grazing purposes because of poor herbage quality and poor crop utilization. Begg (1965) working with Bulrush Millet (Pennisetum typhoides) found that the highest crop yield (21,735 kg/Ha.) was at the 16th week after emergence. This high value was obtained at a time of active internode elongation following full light interception and floral initiation. Also Broyles and Fribourg (1959) and Mays and Washko (1961) found that Pearl Millet (Pennisetum glaucum) produced the highest yield when the plants were allowed to reach maturity. During first growth it required 56 days after sowing to reach the pre bloom stage. However during regrowth this stage was reached only 21 days after the crop was cut. During the first growth, each stage of growth had a length of 2 weeks while regrowth the length was only one week (see Fig. 3.1). Also at the same stage of maturity, regrowth plants were shorter than the first growth. A similar pattern was observed by Begg (1965) and Nanda et al., (1957 a, b) working with Millet; vegetative stage of regrowth was shorter than that of first growth. The latter authors, working with 6 types of Millet, found a progressive shortening of the vegetative period with a delay from the time of sowing.

A presumption can then be made with regard to the above observations. The faster maturity of regrowth appears to be a consequence of climatic effects on the crop. This presumption is based on the fact that climatic conditions during first growth were not optimal for plant maturation, consequently the crop exhibited its full potential for leafy growth for a longer time than for regrowth. Information from Bulrush Millet (Begg, 1966) indicated that flowering occurred in response to photoperiodicity and not to time of sowing. Plants sown between December to the first week of February showed that all became floral in the last week of February. From the observations made on Japanese Millet in this study, first growth and regrowth flowered at the same time (i.e. mid-February) which are highly suggestive of climatic conditions prevalent during this time of the season having an effect on flowering. Begg's (1966) investigation with the phytotron indicated that Bulrush Millet flowered at less than 12.5 hrs. of photoperiodicity; and he found that plants exposed to 16 hours of light were still vegetative 55 weeks after sowing. These results showed that the Millet investigated by Begg (1966) was in fact a short-day plant, and that under Australian conditions, sowing at the end of September, the subsequent plants would remain vegetative until the following February after which all plants flowered at the same time. Floral initation occurred rapidly when sowings were made after February depending on temperature conditions. This variety took 23 to 44 days to flower. Although all this information is about Bulrush Millet, there is no evidence regarding factors affecting flowering on Japanese Millet.

Plant response to cutting as noted by Begg (1965) depends upon the height of the apical meristem in the plant. When cutting was made below this meristem height, all shoots grew again. However when cutting was made during the period when apical meristem increased due to internode elongation this resulted in poor plant recovery by the fact that some proportion of shoot apices were removed by defoliation. Begg (1965) indicated that Bulrush Millet is very susceptible to defoliation once active internode elongation has commenced in the primary shoot and tillers. It must be pointed out that in the present experiment, Japanese Millet regrowth was satisfactory simply because the apical meristem was below the cutting height at the time of cutting.

Fig. 3.3 shows a positive correlation ($\hat{r}$ = 0.9987) between height and dry matter yields of Japanese Millet. This could be of practical significance from the farmer's point of view because he could evaluate the crop production by the height of the plant. This would aid in deciding the time of cutting. Care however should be exercised in the use of this generalization for the following reasons: height is related to stage of growth and there are differences in dry matter yield at the same stage of growth. Genetical studies of Burton (1951), Shankar et al., (1963) and Pokhriyal et al., (1967) with Pennisetum typhoides have shown that high yielding plants tend to have more stems which are wider and larger, wider leaves, taller plants and heavier straw weight than less productive plants. A significant positive correlation (+0.34) was observed between yield and plant height.

During first growth of Japanese Millet, height increased until the 10th week after sowing and then remained static until the 12th week. Burton et al., (1969) working with two varieties of Pennisetum typhoides found the same relationship existed; but observed a decrease in height during the following 2 weeks after the 12th week. Results contrary to the above were obtained by Begg (1965). This showed that the same Millet species exibited a continuous height increase from the time of emergence until the 16th week. However Japanese Millet results are in accord with those of Begg (1965) in that the plant height at the 10th week was approximately the same (130 cm).

Daily gains in terms of dry matter yield of Japanese Millet seemed to depend on several factors: increase in height, dry matter content, internode length, width and length and number of stems and leaves (Begg, 1965; Burton, 1951; Shankar et al., 1963; Pokhriyal et al., 1967). During the first growth, the highest gain of 853 kg dry matter per hectare per day was obtained during the last week (12th week). This value can be considered as being high since perennial pastures under temperate conditions have been shown to approach 200 kg increases in dry matter per hectare and per day (Corbett, 1969). Begg (1965) working with Pennisetum typhoides obtained a yield of 440 kg dry matter per hectare per day with a standard error of ±40 at the peak growth rate which was at the 9th week after emergence. This gain was only 48% of the potential yield of 920 kg dry matter per hectare per day that the crop could have yielded under the climatic conditions studied. When comparing Begg's results with those in the present experiment an important difference seems to arise. Whereas Begg found the highest growth rate occurred during the vegetative stage, in the present study with Japanese Millet, maximum growth rate was obtained at an advanced stage of maturity. It appears as if this difference arises from species differences not ruling out that differences could have existed in other factors such as soil type and environmental conditions.

Although tiller counts were not made, visual observations of regrowth and first growth of Japanese Millet suggested that the stand thickened following the first harvest as a result of increases in tiller number.

A comparison of production was made between first growth and regrowth of Japanese Millet at the same stage of growth and also on the same day. Results showed that first growth produced nearly double (479 kg dry matter/Ha/day) the dry matter produced by the regrowth (250 kg dry matter/Ha/day). The conditions (stage of growth and environmental) under which this comparison was made are the same. Consequently it may be reasonable to state that this comparison is valid.

In sampling Japanese Millet precautions were taken to keep all variables constant (see section 2.2.2.). In Appendix 1. are presented the coefficients of variation of sampling. The smaller coefficient obviously shows that little variation was found in the first growth and therefore crop uniformity. In contrast, the picture was different for the regrowth stage. During the early regrowth there was less uniformity in plant growth as evidenced by the larger coefficient of variation which subsequently decreased as the plants matured and attained uniformity. Non uniform plant growth at the early stage of regrowth cannot be adequately explained, however it appears as if drought conditions had a greater effect on the early sprouts than at the later stage of maturity.

Yields of crude protein expressed as kg per hectare showed similar values at the 10th week (1063 kg) and 12th week (1072 kg) with a slight decline in between (Fig. 3.6.). The highest yield of crude protein (761 kg) for regrowth was however obtained in the 5th week after cutting. But on the basis of the maturity index, the highest yield of crude protein was obtained at the same stage of growth (early bloom) both on first growth and regrowth. Therefore it can be suggested that this index is a satisfactory practical guide in assessing the yield of crude protein of Japanese Millet.

The curve of protein yield for first growth and regrowth (Fig. 3.4.) followed a different pattern to that of dry matter yield shown in Fig. 3.1. Since dry matter content and crude protein content have a negative relationship with plant maturity, it is not possible to obtain high yields of both at the same stage of growth. The decision of time of cutting will depend on whether one decides a high yield of dry matter or crude protein is desirable. Where crude protein is concerned the maturity index could be suitably applied as indicated above. Japanese Millet does not deviate from other herbage in protein quality in early growth. The average yield of crude protein of Bulrush Millet from 16 trials was shown to be 769 kg/Ha. with the maximum value of 1337 kg/Ha. (Norman and Begg, 1968). The same authors obtained the lowest yield during February when the rainfall was low and when nitrogen uptake by the plant was at its maximum. It appears as if the low rainfall prevalent during their trial had in fact affected nitrogen uptake by the plant, despite the ability of the plant root to penetrate deep into the soil as shown by Norman (1966). Begg (1965) had recorded peak yields of 1398 kg crude protein per hectare from the 9th week after emergence and continuing for 7 more weeks at the same level.

Fig. 3.5. shows crude protein gain per day per hectare. Negative values during pre-and mid-bloom in the first growth and mid-bloom in the regrowth in fact showed no gains in crude protein. It might be suggested that a high utilization or translocation of crude protein by or to other parts of the plant such as the root system particularly in the mid-bloom stage might be a contributory cause. This effect was found to be bigger in the regrowth than in the first growth stage and may be as a consequence of a lower aerial to root ratio in the regrowth stage which had a bigger crude protein requirement.

Among factors which controlled growth of Japanese Millet in the present study, two can be suggested as being important: water supply and insect attack.

Experimental evidence obtained by Faires et al., (1941); Arny et al., (1946); Mays and Washko (1961); Jung and Reid (1966); Henkel (1961); Lahiri and Kharabanda (1965) and Lahiri and Kuman (1966) (see section 1.3) show conclusively that, on average, dry matter yield of Millet was reduced by 50% as a result of drought conditions. Obviously low rainfall and high ambient temperatures seem to have been contributory causes. The crop of Millet in the present experiment received most of the rainfall in its first growth (during the end of November and December). Subsequent high temperature conditions and low rainfall, particularly during the month of January and February, resulted in a poor rate of growth. Table 2.3 indicates that the precipitation during January and February were 58 mm (2.26 in) and 54 mm (2.22 in) below the averages obtained during the last 30 years respectively. The temperature during this period was also above the average (see Table 2.3). Since the experiment was carried out during a period of drought, its effect on dry matter yield could not have been assessed simply because a comparison could not be made with yields under optimal rainfall conditions. Fig. 3.1. and Fig. 3.5. do however suggest substantially poor yields between 8th and 9th week of first growth and also in the 2nd and 3rd week of regrowth. In all probability this must have been due to a reduction in the gain in dry matter during these periods. Table 2.3. indicates a low rainfall during this period. These results are in accord with those of the above authors and particularly with those of Henkel (1961) who reported that the maximum effect of drought was during the formation of generative organs. A salient feature of first growth and regrowth of Japanese Millet was a reduction in dry matter yield at the flowering stage as reported by Henkel (loc. cit.).

Plants of both first growth and regrowth of Japanese Millet were attacked by army-worm (*Pseudaletia separata*) as mentioned in section 2.2.2.2. Although evidence presented by Broyles and Fribourg (1959), Hart (1958), Ahlrich et al., (1967), Johnson (1968), Hawkins et al., (1958) that different Millet species were resistant to insect attack, it appears that in the present experiment a decrease in crop yield occurred as a result of army-worm attack. It must be pointed out that effective worm control would result in higher crop yield. However under the present circumstances chemicals could not be used as a result of dairy cattle grazing the crop.

4.2.1.2. Japanese Millet chemical composition

Burns and Wedin (1964), Rusoff <u>et al</u>., (1961) and Sullivan (1961) showed that the nutritive value of summer pasture, measured by its chemical composition declined with age of the plant. Japanese Millet does not deviate from other perennial grass species in this property and Fig. 3.2. illustrates the latest statement. Curves of crude protein, ether extract and soluble carbohydrate content showed a decrease in trend while crude fibre and dry matter an increase. These are in agreement with results of most authors mentioned above in the review (Section 1.5.).

From chemical analysis it could be seen that chemical composition of pre bloom stage of the first growth and early bloom of regrowth is the same, although the dry matter yield was higher during the first growth as mentioned earlier. It is apparent that the biggest yield of green matter of the same nutritive value could therefore be obtained in the first growth rather than during regrowth.

Whereas the first growth showed a steady increase in the dry matter content during the whole sampling period (4th to 12th week), regrowth showed variations as evidenced by the relatively high decrease in dry matter content at the 4th week after cutting (see Fig. 3.2.). A reasonable suggestion to make regarding this variation in regrowth could be on the basis of the water condensation on the plant surface, since samplings were made earlier in the morning. Regrowth plants being less dense in foliage (as shown by lower dry matter yields) compared with the first growth, the condensation of water on the whole plant would have been greater. There is a possibility that the greater water content might have had an effect on dry matter determinations.

There are significant variations in the crude protein content of pasture herbage. For example Johns (1955 a) gave values in excess of 30% of crude protein on dry matter basis for temperate pastures, while Harvey (1952) and Milford (1960 a) found values as low as 3% in tropical pastures. The low value observed in the early leaf stage of Japanese Millet regrowth (see Fig. 3.2.) can be accounted for by the amount of dead material accumulated at the base of the plant. This coincides with the apparently high crude fibre content at the same stage of growth. The crude protein content did not seem to vary during immature stages of either first growth and regrowth. However variation occurred during the pre bloom, early bloom and mid bloom stages, the highest values being recorded in the regrowth stage. It appears as if an increase in utilization of available nitrogen with plant maturity particularly in the regrowth stage gave rise to this variation. Phillips et al., (1954) comparing early and late maturing species at the same stage of maturity found a higher crude protein content in the early maturing ones. On this basis of comparison, the crude protein content of the regrowth was higher than in the first growth simply because regrowth matures faster. Marshall et al., (1953) working with Pearl Millet found that the crude protein content 33 days after planting was 23.4%, while Japanese Millet in the present experiment at the same time was 22.3% and so agreed with that of Marshall et al. (loc. cit.). However crude protein content during the second week of regrowth of Japanese Millet was lower than that obtained by Marshall et al., (loc. cit.). Dawson et al., (1940) however were of the opinion that the day of growth was indeed not a good measure of stage of maturity, at least from the point of view of crude protein content. The total crude protein yield for regrowth was higher than for first growth (see Fig. 3.3.) despite a low dry matter yield but a higher crude protein content. Begg (1965) and Mays and Washko (1961) working with Bulrush Millet and Pearl Millet respectively have shown that the crude protein content of the leaf was higher than in the stem, while Cragmiles et al., (1958) showed a decline in the crude protein content in Millet plant as the leaf to stem ratio decreased. Although in the present study, no measurement of leaf to stem ratio and separate chemical analyses on leaves and stems were made, it was presumed that the decline in crude protein content with maturity was due to a lower leaf to stem ratio and therefore a decline in the total crude protein content. This presumption was made on the evidence of the above authors and it could be reasonable to state that it did occur in the present experiment.

The status of crude fibre content with regard to plant maturity was mentioned in the section where crude protein content was discussed and also in section 1.5. Suffice it to say that as the plant matures there is an increase in the crude fibre content. A reciprocal relationship has been shown to exist between crude protein and crude fibre content in that a decline in crude protein was associated with an increase in crude fibre. Mays and Washko (1961) showed this relationship with Millet and demonstrated that this increase in crude fibre was in fact due to a greater crude fibre content in the stem and to a lower leaf to stem ratio. It is reasonable to assume that Japanese Millet does not differ from other species in this respect. The crude fibre content in the first growth during early leaf, immature, pre bloom and early bloom stages was higher than regrowth, while the crude protein content followed an opposite trend. This reciprocal relationship which was found in other species of Millet, is also true for Japanese Millet. Phillips et al., (1954) observations on crude protein content and plant maturity relationships with temperate pastures applies to Japanese Millet when we consider maturity rate. Since in the present study regrowth matured faster than the first growth the crude fibre content was low and crude protein content higher than first growth. Consequently observations made on Japanese Millet can be explained in the light of those of Phillips et al., (1954) and then it was necessary to take the differential maturity rate of regrowth and first growth of Japanese Millet into consideration.

The soluble carbohydrate content of Japanese Millet throughout the experimental period is shown in Fig. 3.2. There was an increase in soluble carbohydrate content (29.7%) up to about the 6th week of first growth, decline to 7.58% at the 8th week and thereafter a diphasic pattern was followed until the last experimental week (12th). Soluble carbohydrate content of regrowth was lower than first growth and showed a diphasic pattern throughout the whole period. Waite and Boyd (1953) have indicated that the proportion of soluble carbohydrate in herbage rises to a peak during early growth and then falls as the flower develops at the growing point and as reserve carbohydrates form in the seed. Weinmann (1952) showed that the seasonal variation of soluble carbohydrates is essentially the same for all perennial grasses. It could however be changed by climatic conditions and by growth behaviour of species. Referring back to Fig. 3.2., the increase in soluble carbohydrate content in the first growth could be attributed to a concentration in the leaves in the same direction as the amount of leaves increase. The decrease in the pre bloom stage of first growth might have been due to a translocation of this accumulated carbohydrate to other parts of the plant presumably to the root system as found by Weinmann (1948) in the case of alfalfa. This accumulation in the root of alfalfa was associated with maturation of aerial part of the plant. The slight increase observed in both growths of Japanese Millet at the highest stage of maturity was presumably due to mobilization of nutrients for seed formation (Weinmann, 1952). Organic reserves, particularly carbohydrate, are described as being essential for plant life and for plant regeneration. Where regeneration is concerned Weinmann (1952) has shown the importance of stored reserves. The carbohydrate content of the aerial part of grasses decreased with stem formation, consequent to an increase in growth rate and concurrent with synthesis of more complex polysacharides from photosynthetic material. Present observations with Japanese Millet tend to show the possibility of stored reserves during first growth governing the regrowth stage as evidenced by regrowth characteristics.

Ether extract content decreased linearly as the plants matured in both first growth and regrowth stages (Fig. 3.2.). These results conform with the findings of other investigations (see Section 1.5.).

The present experiment is an attempt to obtain a reasonable body of data that could be usefully applied to assessing the nutritive value of Japanese Millet without the use of animal trials. Parameters such as dry matter and crude protein yield, growth rate and chemical composition give a good index with regard to the nutritive value of Japanese Millet as the crop matured. Burton <u>et al</u>., (1969) working with Bulrush Millet have also suggested the applicability of these parameters to obtain a reasonable assessment of herbage quality. This suggestion has been made on the basis of excellent relationships between animal performance (voluntary intake, liveweight gain) and the parameter mentioned above.

In connection with Japanese Millet production, since the crop is produced to be consumed by livestock, herbage utilization arises as an important factor. Hardison <u>et al</u>., (1954) and Weston (1959) found a better utilization of pasture when grazed at an early stage than at late stage of maturity. Similar trends were observed in the present experiment with Japanese Millet. Apparently such a situation could arise consequent to the selective grazing habit of animals as mentioned before.

4.2.2. Feed Characteristics.

4.2.2.1. Chemical composition.

The conduct of animal trials to establish the feeding value of forages is time consuming and expensive. Many workers have attempted to derive relationships for the prediction of nutritive criteria from chemical composition of the forage. In the present study it was decided to measure chemical composition in order to describe nutritive value of herbage and to attempt some type of extrapolation of the plant characteristics described with animal experiments to the stage where only chemical information was required.

Changes in chemical composition of Japanese Millet during the animal experiments are described in Fig. 3.6. and Appendix 3. where values are very similar to those reported in Fig. 3.2. and Appendix 2., during the same stage of growth. However some small differences are obvious since first growth and regrowth of Japanese Millet was sampled once a week and data obtained during the animal experiment are the result of a composite sample bulked for each day of the week. It can be appreciated that the latter is a better estimation since it took into account day to day variation. Changes in chemical composition of Japanese Millet as the plant matured were discussed in section 4.2.1.

Changes in chemical composition of pasture are described in Fig. 3.6. and Appendix 3. Considering the chemical composition of each pasture paddock separately, it is observed that these changes followed the normal pattern as discussed in section 1.5. Pasture at early stages of growth such as those used during Period IV and V contain the highest contents of crude protein and the lowest content of crude fibre. Pasture during Period II had a relatively high crude protein content due to a larger proportion of clover, however the graminaes were nearly all at the seed stage. This high proportion of clover resulted in a content of crude fibre which was lower than Period I and III despite visual observations indicating a lower pasture quality in Period II. Data from Hutton (1961) and Davey (1964) on the chemical composition of mixed pasture during summer could be used for comparative purposes. It appears that the data from Hutton are more useful since chemical composition was obtained during periods of equivalent length of those used in the present study. Pasture during Period I had a lower crude protein and nitrogen-free extract and higher crude fibre, ether extract and ash content than those reported by Hutton (1961) and Davey (1964). Period II, with a high clover content as noted above, had a higher content of crude protein, ether extract and ash, and lower content of crude fibre and nitrogen-free extract than that reported by Hutton (1961). During the following three Periods (III, IV and V) pasture in the present experiment had a higher nutritive value (measured by chemical composition) than that reported by Hutton (1961). In the later case it can be suggested that the use of irrigation was the cause of this improvement.

From the later comparison, it appears that the pasture had a lower nutritive value than those reported by Hutton (1961) and Davey (1964) during Period I but was of higher quality during the other four Periods. Any comparison between Japanese Millet was dependent on the quality of pasture available and the result obtained here might not be typical of comparisons based on non-irrigated pasture.

4.2.2.2. Apparent digestibility.

Some aspects of digestibility studies have been discussed in section 4.1.3. Digestibility coefficients as in Table 3.1. and Fig. 3.7. seem valuable in estimating the general effect of maturity on the nutritive value of the herbage, particularly Japanese Millet since it was sampled at different stages of growth. As mentioned before, pasture maturity changes are not so evident, since different stands of pasture at different stage of maturity were used. Since digestibility of herbage determines its potential feeding value for the ruminant (Armstrong, 1964; Wilson and McCarrick, 1966) it is important to know the changes occurring with advancing herbage maturity. Among single factors, Armstrong (1964) and Waite (1963) pointed out that digestibility is the most important determinant of herbage nutritive value.

Organic matter digestibility of Japanese Millet decreased from

70.7% (Period II) to 62.4% (Period IV), falling at the rate of 0.87 percentage units per day. Similar changes in the digestibility of dry matter, crude protein and crude fibre were 0.89, 0.89 and 0.37 percentage units per day respectively. These rapid decreases in digestibility are typical of tropical herbages as they are adapted to a short growing season (Corbett 1969); e.g. early vegetative growth from tropical grasses can have a relatively high digestibility (e.g. 75%) and contain from 15 to 20% of crude protein, but as soon as flowering started there is a rapid decline in quality. This observation can be applied to the Japanese Millet since the crop was starting to flower when it was used for the animal experiments.

Studying temperate pasture, Wilson and McCarrick (1967) indicated that the dry matter digestibility decreased by a range of 0.39 to 0.46 percentage units per day, the highest rate occurring at an advanced stage of maturity. Milford and Minson (1966) in their review reported that the digestibility of temperate pastures declines with maturity at the rate of 0.5 digestibility unit per day; but tropical pastures decline at approximately half this rate. These authors attributed the difference to the higher digestibility of temperate pasture than tropical pastures at early stage of growth. A steady fall in the digestibility with increasing maturity of forage has also been reported by Minson et al., (1960, 1964); Pritchard et al., (1963).

Variation in leaf to stem ratios and in the crude fibre and lignin distribution between these parts of Japanese Millet plant could cause variation in digestibility (French 1957; Milford and Minson, 1966). The latter authors indicated that this effect is more obvious in tropical fodders where, despite the high crude fibre content, this fraction is more digestible than in temperate pasture. It was also found that stems of immature grasses tend to be more digestible than leaves, but the digestibility declines with advancing maturity more rapidly than for leaves (Lambourne and Reardon, 1962; Pritchard et al., 1963; Terry and Tilley, 1964). Butterworth (1967) working with tropical grasses indicated that digestibility can fall with advancing maturity to values so low that the animals are unable to maintain their body weight though abundant feed may be available. French (1946) has indicated that lignification of the fibre in summer crop occurs at a more rapid rate about the time of flowering or emergence of the flower bud, and it was considered important to cut and feed the crop before any marked lignification of the fibre had made it less digestible. The negative association of digestibility with lignin or fibre content is well established and easy to rationalize, since the problem involves the nutritive availability of different chemical fractions of forages and factors such as lignification affecting this availability (Van Soest, 1965). Crampton (1957) had also indicated that the rate of digestion of forages could be inhibited by any factor that depresses micro-flora activity in the rumen. This can include excessive lignification of the forage as a result of maturation, and partial starvation of flora from nitrogen and/or specific mineral deficiency. As mentioned in section 4.2.1. it was presumed that the stem to leaf ratio of Japanese Millet changed with advanced maturity and it appears that as the plant had a higher proportion of stems, there was an expected decrease in the digestibility. Although the digestibility of soluble carbohydrate was not determined in the present study, evidence produced by Ely et al., (1953) supported that this parameter declines with advancing stages of growth based on digestibility data of orchard grass. Japanese Millet during Period II, which was the youngest of the stages compared, had the highest nutritive value.

Table 3.1. contains the digestibility means for pasture and Japanese Millet with their standard errors. The highest coefficient of variation for Japanese Millet was obtained in crude fibre digestibility during Period IV (9.80%) and that for pasture was also on crude fibre digestibility but during Period II (17.04%). The latter high value was also accompanied by high coefficients of variation for dry matter, organic matter and crude protein digestibility. It seems that these highest values were a consequence of graminaes during Period II being at the most mature stage of growth compared with other periods. Taking into account the average coefficient of variation for the 5 Periods for each digestibility coefficient, it is observed that all indices other than crude fibre had a similar variation (1.94%, 1.62% and 1.77% for dry matter, organic matter and crude protein respectively). Forbes et al., (1946) reported a coefficient of variation of 1.9% resulting from animal variation in digestibility; a higher value (3.0%) was indicated by Minson et al., (1964). However Minson and Milford (1963) noted that for those pastures low in protein it is possible to obtain a coefficient of variation as high as 30%.

The latter report could be applied to try to explain the high coefficient for Japanese Millet during Period IV which had a relatively low content of crude protein (9.81%); however it does not explain the high coefficient found on pasture fed sheep during Period II, since that pasture was relatively high in crude protein (19.65%).

In general, variation between sheep (standard error of means) in the digestibility of Japanese Millet was higher than for pasture. This variation could have resulted from differences among sheep in selectivity; e.g. sheep 8 from Japanese Millet fed group consumed nearly all the forage offered while sheep 2 and 4 for the same group made a high selection. The effect of selection during digestibility trials was discussed in section 4.1.3. Variability between the 3 sheep fed Japanese Millet (Table 3.1.) increased as the experiment progressed; particularly in the case of dry matter and crude fibre digestibility. Dry matter digestibility of Japanese Millet had a coefficient of variation of 2.39% in Period II and increased until 4.45% in Period IV. Crude fibre digestibility showed a higher variation, it had a value of 3.35% at period II and increased until 9.80% in period IV. Organic matter and crude protein digestibility showed a small drop in the coefficient of variation during Period III, however the highest value was obtained on Period IV. Wilson and McCarrick (1967) working with temperate pasture at different stages of growth reported similar results; they found that the determination of a mean digestibility, with the same standard error of grasses which were 70, 60 and 50 percent digested would require 2, 7 and 20 wether sheep respectively. As the plant matured the sheep lost sensitivity in detecting digestibility differences.

With respect to pasture digestibility data in the present experiment it was found that they were highly related to the pasture paddock used (see section 2.2.3.1.). During period I, reasonably high quality pasture was available as indicated by its dry matter digestibility (71.3%). In the following Period (II), as the cows were grazing a new pasture paddock containing mature graminae and a high proportion of clover, dry matter, organic matter and crude fibre digestibilities decreased but crude fibre digestibility increased; the latter could be explained as effect of the high proportion of clover. During Period III, IV and V, pasture quantity was much improved since irrigation had been used. The values for dry matter, organic matter, crude protein and crude fibre digestibilities (Table 3.1 and Fig. 3.7.) show that during the last Period (V) the pasture attained the highest quality, after steadily increasing from Period III. This assumption is supported by the fact that variation in digestibility between sheep within the pasture group decreased from Period III to Period V. This is in accord with the result found for Japanese Millet but in a reverse way, since as the quality of pasture increased there was less variability among sheep.

4.2.2.3. Volatile fatty acids.

Quantitatively, the most important end products of rumen digestion are the steam-volatile fatty acids - acetic, propionic and butyric. Warner (1964) has suggested that some 70 to 80% of the energy supply of the ruminant on normal feeds is provided by VFA. The efficiency with which the energy of VFA is utilized by the animal appears to vary with the molar proportion of the acids in the mixture and the purpose for which they are used (Blaxter 1962). The decrease in efficiency of use of metabolizable energy as feeds become less digestible might be due, at least in part to the associated shift in rumen fermentation products from propionate plus butyrate in highly digestible feeds to predominantly acetate in feeds of low digestibility. For example, the efficiency of milk synthesis increased as the proportion of acetic acid fell unless the fall is very large, and, if the propionic acid levels are high, milk fat production then decreases markedly due to a change in the supply of acetate and β- hydroxybutyrate precursors (Rook 1961 a).

V.F.A. proportions change between herbage species, and they show somewhat smaller changes with increasing maturity of pasture than those changes reported for digestibilities values (Bath and Rook, 1965). Changes from lower to higher proportions of acetic acid, and a corresponding reduction in the proportion of propionic plus butyric acids, have been reported to accompany increasing maturity and fibre content and decreasing digestibility of the feed (Bath and Rook 1965). Generally, tropical pastures yield higher proportions of acetic acid than temperate feeds (Topps <u>et al.</u>, 1965) as a result of higher contents of crude fibre in the former herbages.

The V.F.A. concentrations are a reflection of microbial activity and of absorption or passage out of the rumen. Following the ingestion of readily fermentable feed, microbial activity increases rapidly, resulting in an increase in V.F.A. concentrations. In Fig. 3.8. changes in total V.F.A. concentration are not very marked during the first three experimental Periods (I, II and III) for pasture fed sheep; however there was a sudden increase during Period IV. This increase could be related to pasture quality since it improved, particularly during Period IV compared with the previous periods. However other factors such as changes in the pattern of feeding could affect this result. Values of total V.F.A. concentrations reported by Davey (1964) and Johns (1955 b) for mixed summer pasture had a higher value than those found in the present experiment during Period I, II and III, however values for Period IV, where quality of pasture was improved had similar values to those previously reported. Here again is observed the effect of the drought conditions on Pasture nutritive value. Also in Fig. 3.8. are shown changes in total V.F.A. concentration in Japanese Millet fed sheep; during the three Periods (II, III and IV) there were no marked changes. It seems that the marked difference in Japanese Millet quality during these periods did not affect the total V.F.A. concentration. It could be suggested that as an effect of sheep selection, the ration consumed was maintained at the same quality, however as described above, there were marked differences in Japanese Millet in digestibility during the 3 experimental periods and even after sheep selection was accounted for (Appendix 4.), there were differences between Periods in chemical composition of Japanese Millet. Miller et al., (1963, 1965) indicated that total V.F.A. concentration in Millet fed sheep had a level of 8.15 mm/100 ml of rumen liquor which is a higher level than observed here. It could be suggested that the highest level reported by Miller et al., (loc. cit) was due to the fact that younger Millet of a higher quality was employed.

There was a consistent effect of time of sampling on the total V.F.A. concentration (Fig. 3.9.), these changes being greater for pasture fed sheep than those on Japanese Millet. This variation between times of sampling can indicate that the intake of feed throughout the sampling period was also variable. As noted in section 3.3.2.2. there was a highly significant interaction between periods and sampling times which makes difficult any interpretation of the differences between sampling times.

Changes in V.F.A. proportions are illustrated in Fig. 3.10. Proportions of acetic acid were higher and proportions of propionic and butyric acid were lower than those reported by Johns (1955 b) using sheep fed summer pasture; then it might appear that the pastures used in the present experiment had a higher content of fibre (Balch, 1960) than those reported by Johns (1955 b). However the V.F.A. proportions reported by Davey (1964) using summer pasture, showed higher acetate and butyrate proportions and lower propionate proportions than those in the present experiment. V.F.A. proportions for sheep fed Japanese Millet, a more fibrous material (Table 3.10) than the Pasture, differed from the pasture values, since a higher acetate proportion was found in Period II, III and IV. There was a high variation in propionate concentration between both herbages, but nutyrate concentration was always higher for Pasture than for Japanese Millet. In accord with the results presented in section 3.3.2.2. there was also a highly significant Treatment x Period x Time interaction for V.F.A. concentration which makes the results difficult to interpret. Proportions of acetic acid reported by Clark et al., (1965) and by Henken et al., (1962) using Gahi-1 Pearl Millet and those of Padmanabha (1965) studying Pearl Millet, were higher than those for Japanese Millet in the present experiment, which indicated that the material used in the present experiment was younger and so of higher quality than those used in the above studies. At the same time propionate concentrations found by Clark et al., (loc. cit.) and Henken et al., (loc. cit.) were lower than those presented in Table 3.10.

Individual concentrations of the V.F.A.s are shown in Fig. 3.11. and again there was highly significant interaction between treatment and period which complicates their interpretation. The values of acetic and butyric concentrations for pasture fed sheep were lower and propionic concentration higher than those reported by Davey (1964). This is in agreement with the previous comparison for total concentration and the V.F.A. proportions. Data from Miller et al., (1963, 1965) indicated that acetic and propionic acid concentrations from animals fed Pearl Millet were lower and butyric acid concentration was higher than those for Japanese Millet here.

Rook (1964), Bath and Rook (1965) have reported that the proportion of acetic acid was inversely related to the content of soluble carbohydrate which promotes the formation of propionic acid and so there was a positive correlation between the proportion of the latter and sugar (Terry and Tilley, 1962). Relationships between the composition or digestibility of the feed and the proportions of the propionic or butyric acids have generally not been so precise as those with acetic acid. In the present study, relationships between V.F.A. concentrations and chemical components and digestibility of feed, and also between V.F.A. proportions and chemical components and digestibility of the feeds were examined. For the first relationships, Table 3.3 shows that none of these were highly correlated, none of the regression coefficients being significantly ($P > 0.10$) different from zero. In pasture fed sheep, the correlation between acetic acid proportion and carbohydrate was negative and weak which does not agree with the results of Rook (1964) and Bath and Rook (1965). In the case of Japanese Millet there was also a weak but positive relationship based on only 3 pairs of data. All relationships between the proportions of propionic and butyric with chemical components and digestibility were weak (Table 3.4) except butyric proportions and the content of soluble carbohydrates. Both relationships (pastures and Japanese Millet) were positive and that for Japanese Millet had a particularly high correlation coefficient ($\hat{r}$ = 0.9131). However as forages with the same digestibility can have different contents of soluble carbohydrates, the latter correlation can be used for feed evaluation only with questionable validity (Raymond, 1969).

Annison (1954) has shown some correlation between the C_5 fraction of the V.F.A. and the quantity of protein feed. In the present study no attempt was made to examine relationships between the C_5 acid fraction and plant characteristics.

During the last decade many authors have attempted to use V.F.A. concentrations and proportions to explain animal production variations; however these explanations contain several anomalies and are difficult to generalize from (Raymond, 1969). This idea is confirmed in the present experiment, where no useful relationships were found. Raymond (1969) concluded that the level of feed digestibility instead of rumen acid pattern is better emphasised in determining the efficiency with which the digestible and metabolizable energy in feeds are utilized by the ruminant. This does not mean that rumen acid patterns are not important, but since the latter can not be readily used in the interpretation of animal production results, they must be used only with some reservations.

4.2.2.4. Ammonia.

Most of the nitrogenous constituents of the feed consumed by the ruminant are digested and transformed by the rumen microbial population such that there is little relationship between the form of these constituents and those nitrogenous constituents absorbed from the digestive tract. Ammonia produced in the rumen is one of the main nitrogen substrates, which can be utilized by the rumen microbial population or it can be absorbed from the rumen. The microbial proteins are then subjected to proteolytic attack in the abomasum and the aminoacids are absorbed and used as the main source of amino acids to the ruminant. (McDonald, 1968). Rumen metabolism of nitrogenous compounds has been reviewed by Blackburn (1965), Waldo (1968) and Smith (1969) who give an exhaustive literature on this subject.

Ammonia concentration in the rumen increased after feeding as a consequence of degradation of nitrogenous compounds. As the rumen microbial population can not use all the ammonia released, there is some absorption into the blood (McDonald, 1968). Protein utilization by the ruminant will depend on these two mechanisms: rate of ammonia release from nitrogenous feed constituents and ammonia assimilation into bacterial protein. When ingested food produces an excess of free ammonia in the rumen there is a relative waste of nitrogen to the animal. When the material consumed had a high level of protein, such as high quality pasture, there is an excess over animal protein requirement; however with food of low protein content it could be that the amount of protein ingested would not be sufficient and then this loss of ammonia becomes of greater importance.

Annison et al., (1954) described several factors which affect the level of ammonia in the rumen, such as the solubility of the protein, the amount of protein in the ration the level of dry matter intake and other unknown variables. As noted before, with low levels of protein intake, it could be possible that rate of ammonia production could be low and so could limit the growth of the microbial population leading to a decrease in food digestibility and voluntary intake. However Graham (1967) indicated that the assessment of a protein deficiency could be difficult owing to the fact that a low protein content in pasture is usually, though not invariably, accompanied by a low content of digestible organic matter as well as other nutrients. In the present study the high protein levels in pasture herbage are reflected by the highest ammonia levels in rumen contents (Fig. 3.12. and Fig. 3.13.), and particularly so during Period IV where the highest crude protein contents were found. However the level of crude protein in herbage did not always coincide with ammonia concentrations in the rumen. This is clear in the case of Japanese Millet, where ammonia was found to have a higher concentration during Period IV than in Period II or III the latter having a higher level of crude protein than the former. This relationship between ammonia concentration and crude protein content of both herbages is illustrated in Fig. 3.14. It is observed that rumen NH_3 and feed crude protein contents for pasture and Japanese Millet were related in an opposite manner; as crude protein content of pasture increased there was a higher ammonia level, however the reverse was observed for Japanese Millet. No explanation is offered for this difference. Johns (1955 b) working with summer pasture found a higher ammonia level than those in this study, however he also reported that highest levels of ammonia did not coincide with those of protein suggesting that selectivity of pasture consumed could be the reason for these differences.

Two other relationships are presented on Fig. 3.14. Ammonia concentration was related with digestible crude protein % and crude protein intake of sheep. Both relationships differed between pasture and Japanese Millet, in the same way as in the case of relationships between ammonia and crude protein content. In the case of Japanese Millet fed sheep there was no consistent effect of time of sampling on the concentration of rumen ammonia. In each period, ammonia concentration was near the same 2 hours or 4 hours after feeding. This could suggest that intake of feed throughout this time was also the same. However this explanation is not in accord with that given for total V.F.A. concentration, since the latter parameter increased with time after feeding. The significant treatment x time interactions found in analyses of NH_3 and V.F.A. data complicates interpretation of differences between herbages and times of sampling so the inconsistency of rumen changes noted above are to be expected.

4.2.3. Dairy cattle.

4.2.3.1. Voluntary intake.

Under conditions of incomplete pasture utilization, such as in the grazing of tropical pastures, it is very important to distinguish between that material offered to the animal and that forage selectively consumed by animals. Moir (1960) and Arnold (1960) reported that for animals under these conditions, forage consumed when grazing was substantially superior to the average value of the total feed offered. In the present experiment, as mentioned before, Japanese Millet was grazed under conditions allowing selectivity, so it is possible to suggest that herbage consumed by grazing dairy cows had a higher nutritive value than that assessed by chemical analysis of the material consumed by stall fed sheep. It could be assumed that if the dairy cows consumed forage with the nutritive value as determined with the sheep, milk production would have been inferior to that reported.

Feed intake has been used as an excellent index for evaluating feeding value of forages (Crampton 1957). Differences between the feeding values of tropical grasses were due principally to differences in intake (Milford, 1960 b).

The effect of maturity of Japanese Millet on the intake of digestible organic matter by dairy cows is illustrated in Fig. 3.16. and Fig. 3.18. Wilson and McCarrick (1967) found that either digestibility or intake of herbage from mixed pasture diminished with advancing herbage maturity. Minson and Milford (1966) and Milford and Minson (1967) showed that the feeding value, defined by intake of digestible dry matter, varied widely and that the most important factor determining the intake of digestible energy from a tropical forage was its stage of maturity.

In the present experiment animals fed with Japanese Millet at an early stage of maturity (Period II) showed a decrease in intake compared with the consumption of pasture during Period I, however there was no difference from the intake of cows fed on pasture at the same time (Period II). The pasture during Period II, as described in section 4.2.2. could be classified as atypical of summer pasture, having a nutritive value higher than an average mixed pasture at this time of the year (Hutton, 1961). Although Japanese Millet during Period II started to flower and nutritive value was decreasing, voluntary intake was comparable to that of pasture. Then it appears that Japanese Millet at the early bloom stage might have had a higher quality than average summer pasture. During Period III and IV the level of intake of Japanese Millet continued to decrease paralleling the decrease in nutritive value of the crop. At the same time, intake of pasture increased along with the increase in pasture quality. The pasture used during Period V was of the highest quality, and the voluntary intakes of both groups increased to such a level where treatment differences disappeared. During Period IV cows grazing pasture had an intake 1.79 kg higher than those on Japanese Millet, but during Period V, the former was only 0.02 kg higher than the latter. This pattern shows that, although cows on Japanese Millet decreased herbage consumption, when they were returned to better quality pasture they had the potential to restore intake to the level of cows grazing pasture throughout. Then it could be suggested that if it is necessary to use a summer crop during a short period (as in the present experiment: 3 weeks), there is no carry over effect of such herbage on the intake when animals are returned to pasture.

It was previously shown (section 4.2.1.) that as Japanese Millet matured, its quality (assessed by chemical composition) decreased. It is not then surprising to note that cows grazing this crop decreased their daily intake as they were shifted from the youngest to the most mature stage of growth. Also it is not surprising to note the increase in their intake when they were shifted from the mature Japanese Millet to a high quality mixed pasture. Changes in intake of pasture fed cows can also be related to changing chemical composition. It is reasonable to think that for voluntary intake of cows grazing either pasture or Japanese Millet, some type of relationship with digestibility data or with the chemical components could have existed. In both herbages, digestibility and intake diminished as the plant advanced in maturity, the effect for pasture being more obvious than that for Japanese Millet.

When voluntary intake is compared with chemical composition, expected relationships are more difficult to rationalize than the relationships between digestibility and chemical component. There could be factors that affect intake but have no direct or reliable effect on digestibility; e.g. toxic or inhibitory materials or substances that impart undesirable tastes or those that alter the metabolism of the animal (Van Soest, 1965). Milford and Minson (1966) have pointed out that the main factor which determines the level of animal production is the amount of digestible nutrients consumed per day, and then, the latter is dependant upon the digestibility of that pasture and its voluntary intake. Working with tropical pastures, Milford and Minson (1966) found that the intake of digestible nutrients was more related with intake than with dry matter digestibility - separate correlation coefficients were reported to be $\hat{r} = +0.916$ and $\hat{r} = +0.546$ respectively. However Minson et al., (1964) have shown that the digestibility is more important in temperate pasture than intake in determining the intake of digestible nutrients. Milford (1967) working with tropical legumes and Lucerne, found a general relationship between voluntary intake and dry matter digestibility ($\hat{r} = +0.696$); however the prediction error associated with the regression equation was high and voluntary intake could not be estimated accurately from dry matter digestibility data. For tropical forages Milford (1960 a) also concluded that intake was not closely related to digestibility. However Jung and Reid (1966) determining the nutritive value of sudangrass found a positive correlation ($\hat{r} = +0.811$) between ad. lib. intake (g/kg L.W. $^{0.75}$) and dry matter digestibility. Also Milford and Minson (1968) found a positive relationship ($\hat{r} = 0.73$) for tropical pasture (chloris gayana). Several authors working with temperate pasture (Crampton et al., 1960 b; Blaxter et al., 1961; Campling et al., 1963; Balch and Campling, 1962; Campling, 1964; Wilson and McCarrick, 1966, 1967; Minson et al., 1964; Blaxter and Wilson, 1963, 1962; Van Soest, 1965) have shown that the voluntary intake of a feed by ruminants is very dependent on food digestibility. This would imply that the level of voluntary consumption of forages might be consistently predicted from a knowledge of the dry matter digestibility. However Hutton (1962) found no relationship between the two variables when he was working with good quality pasture having over 70% apparent organic matter digestibility. On the other hand, Conrad (1966) reported a negative relationship when a feed of high digestibility was used. If this relationship exists, it has been suggested that this association occurs because foods of high digestibility are cleared from the digestive tract by absorption and by expulsion of indigested residues, at a faster rate than are foods of low digestibility (Blaxter et al., 1961). Then this material of lower digestibility can affect further intake since the volume occupied by this lower digesting fraction becomes large in relation to the volume of the digestive tract thereby limiting further intake. A process like this could have been occurring with the Japanese Millet; as the plant matured, crude fibre content increased, digestibility decreased and then intake decreased. This relationship has been demonstrated in coarse forages of high fibre content (Balch and Campling, 1962; Campling, 1964). Foods which differ from one another in digestibility also differ in such other respects as chemical composition and physical structure, and the association between intake and digestibility (or rate of digestion) may not be entirely a causative one. In particular, differences in chemical physical composition may affect the taste and texture of the food and thus its palatability (Greenhalgh and Reid, 1967). In the present experiment regressions of the estimates of digestible organic matter intake (g/kg L.W.$^{0.75}$) on soluble carbohydrates content, dry matter digestibility and crude fibre digestibility were studied and the results are plotted in Fig. 3.19. and Fig. 3.20. The regressions between intake and soluble carbohydrates content were different for pasture and Japanese Millet; however it appears that the relationship in the case of pasture would be more realistic than for Japanese Millet since the latter regression was computed using only 3 pairs of data. Relationships between intake and dry matter digestibility for Japanese Millet and pasture were found to be relatively high ($\hat{r}$ = 0.8561 and $\hat{r}$ = 0.9333 respectively). When both sources of data were taken together (as a comparison of regression slopes for pasture and Japanese Millet were not significantly different (Appendix 17.); a correlation of $\hat{r}$ = 0.9201 was found (Appendix 16). This strong correlation is in accord with the above mentioned authors. Under these conditions voluntary intake of cows grazing either pasture or Japanese Millet could be predicted from dry matter digestibility. Wilson and McCarrick (1966) found that the relationship between intake and crude fibre content was stronger than that between intake and dry matter digestibility and then crude fibre was suggested as a better indicator of voluntary intake than dry matter digestibility. From these results, it appears that crude fibre content plays an important role in governing both digestibility and intake, and then the indigestible fraction of herbage consumed would be an important factor in determining its nutritive value. In the present study it was found that intake of Japanese Millet was related to crude fibre digestibility having a correlation of 0.6307, however pasture had a higher value ($\hat{r}$ = 0.8999). The latter relationship could be more reliable since more data were available for the computations (Appendix 16.). Since the comparison between both regression slopes (pasture and Japanese Millet, Appendix 17.) indicated no significant differences between slopes a common relationship was computed which had a correlation of 0.7126. In the case of Japanese Millet the digestibility of crude fibre decreased as the content of crude fibre increased with maturation, however there was not the same pattern in the case of pasture. Thus for Japanese Millet a similar relationship to that reported by Wilson and McCarrick (1966) was demonstrated.

Minson and Milford (1967) found that voluntary intake of mature Pangola grass was low, but it was increased when a legume was included in the diet. They suggested that this increase was due to an elimination of a crude protein deficiency, since Pangola grass had a relatively low (4%) protein content. Similar results were reported by Milford and Minson (1965); intake of two tropical grasses fell rapidly when the crude protein content fell below 7%. Intake of temperate pastures was limited when herbage had less than 8.5% content of crude protein (Blaxter and Wilson, 1963). Feeding area or increasing the crude protein content of the grass by applying a nitrogenous fertilizer has resulted in increased voluntary intake (Campling, 1964). In the present study it was found that pasture crude protein content and intake were highly correlated ($\hat{r}$ = 0.9434) however a negative and weak relationship was found in the case of Japanese Millet ($\hat{r}$ = -0.0532). In accord with the above information, the crude protein content of Japanese Millet during period IV which was the lowest level during the whole experiment (9.81%) appears not to have limited intake - it might have had the crop been tested at a more advanced stage of maturity when crude protein had decreased to a lower level. For example Japanese Millet during the first growth at the 12th week after sowing decreased in crude protein content to

6.56%; at this level it is presumed that voluntary intake would have been limited. At early stages of growth it appears that the level of protein is adequate (Milford and Minson, 1966). However at an advanced stage of maturity animal production is generally poor as a consequence of the low level of crude protein. This response can be due to a low level of dry matter intake caused by the factors discussed and/or insufficient dietary protein for maintenance and production. On the other hand, the intake of tropical pastures grown with high nitrogen applications may be adversely affected; when Chloris gayana was heavily fertilized the content of crude protein was increased from 8 to 13% and intake was depressed by 33% (Milford and Minson, 1966). The same authors reported similar effects in other tropical grasses; Milford and Minson (1966) working with 7 tropical grasses and 3 legumes, found that intake and crude protein were not correlated for most species studied. They suggested that the crude protein contents of those herbages were probably adequate to satisfy the nitrogen requirement of an active rumen flora. Those herbages where high positive correlations were found had much lower levels of crude protein in the plant.

Voluntary intake from a group of animals can be measured with a coefficient of variation ranging from 7 to 14% (Corbett, 1969). Heaney et al., (1968) noted that a larger number of animals could be used to reduce this variation. In the present study intakes of pasture fed cows were estimated with a coefficient of variation of 6.39% and 6.79% for Japanese Millet fed animals which are similar to variations reported by Corbett et al., (1963). In the case of Japanese Millet fed cows, the coefficient of variation decreased from Period II to Period IV so variation between cows in intake decreased as the crop became more mature. Among pasture fed cows there was a small variation and coefficients of variation changed without any obvious pattern among experimental periods, Period I and V had the lowest variation and Period II, III and IV the highest. In the case of Japanese Millet differences in intake appeared to be due to differences in body weight and this effect diminished as intake decreased as a consequence of a drop in herbage quality. As expected there was considerable between animal variability which was reduced when intake was expressed as g/kg L.W. $^{0.75}$ instead of kg/day (Corbett, 1969). As a consequence, the coefficient of variation was reduced (pasture was reduced from 6.39 to 4.62% and Japanese Millet from

6.79 to 5.55%) and then during two periods (III and IV) differences in voluntary intake between pasture and Japanese Millet appeared as significantly different. Then as a result of higher between cow variability, the intake data expressed in kg. D.O.M./day illustrated in Fig. 3.16. were not significantly different between treatments.

4.2.3.2. Live weight changes.

Changes in milk yield and composition can result from several factors, among which food intake, foodstuff quality and changes in body weight can be described as the most important. From this statement changes in body weight were studied in an attempt to explain some of the changes in milk production.

In general, cows' body weights decrease early in lactation particularly in high producing animals. As the amount of food consumed is not sufficient to supply production requirements, any difference is met by transformation of body weight (Hutton, 1963). Later in the lactation (about 5 - 6 months after calving), cows increase body weight as intake is higher than requirements for milk production after which body weight remains more or less constant until the end of lactation.

Cows employed in the present experiment were at about the fifth or sixth month of lactation, and had passed the peak of milk production. It is assumed that cows were at the stage of maximum voluntary intake and, as there was an excess of nutrient intake, body weight could have reached the highest lactation value. The latter suggestion is supported since there were no significant differences in body weight between periods or between treatment groups. Although tropical pastures have been described as having a lower nutritive value than the temperate pastures, the former have been attributed with producing high body weight gains (Norman and Begg, 1968). However in none of the experimental periods were there significant differences in body weights of cows on the two treatments. It appears that food intake was sufficient to maintain body weight, but not milk yield as the results indicated a decrease from Period I to III and from I to IV for pasture and Japanese Millet respectively. Multiple regression relationships among milk yield, body weight and intake are discussed in section 4.2.3.3.

4.2.3.3. Milk yield.

Although plant characteristics can give a good indication of nutritive value of the herbage concerned, a more useful measure would seem to be the final production such as milk, meat and wool. The aim of pasture production in relation to animal production lies in the fact that the pasture produced must essentially be utilized with the maximum efficiency through the production of products ultimately desired. Humphreys (1966) contended that the maximum output of animal products was governed by a number of factors such as adequacy of the amount of pasture presented, the continuity of pasture presentation, the nutritive value of the pasture which influences its intake and its digestibility and its efficient consumption and conversion.

Huber and Boman (1966) pointed out that as the plane of energy nutrition rises, the yield of milk increases, although at an ever diminishing rate due to an association with an increase in live weight gains. The increase in milk yield that occurs with increase in plane of nutrition is probably associated with increases in the amounts of precursors for milk synthesis reaching the mammary gland (Rook and Line, 1961). On the other hand under conditions of constant levels of energy, increases in the level of protein fed above normal levels have little effect on milk yield or composition (Kirchgessner et al., 1967, cited by Armstrong, 1968); levels of dietary protein considerably below requirement lead to a decline in milk yield and protein content (Rook and Line, 1962).

Tropical pasture species are characterised by their low feeding value for milk production (Holder, 1967; Dale and Holder, 1968; Hamilton et al., 1970). These authors have shown that the low intake of digestible energy by cows grazing tropical pastures resulted in a low level of milk production, a contributory cause being their low digestibility. The figures of Dale and Holder (1968) for FCM yield showed a marked decline from 11.6/kg/day to 6.3 kg/day as the plants advanced in age. Cows grazing kikuyu grass (Pennisetum clandestinum) at stocking rates of 1.65 to 3.29 cows/Ha. produced 336 kg of butterfat/Ha (Colman and Holder, 1968), however butterfat production per cow was relatively low ranging from 99 kg to 118 kg. With dry matter digestibility at

60.8%, the daily milk yield decreased by 0.4 - 0.5 kg/week (Hamilton et al., 1970). The above data clearly indicated that tropical herbages do not generally meet the demand for digestible energy required to sustain an adequate level of milk production. When tropical grasses were supplemented with protein the response in milk production was still lower than when supplemented with energy. The maximum response however was obtained with the supplement of both protein and energy (Hamilton et al., 1970) concluded that energy was significantly more important than protein as a supplement to tropical pasture feed. Armstrong (1964) studying the effect of maturity on several grasses found that as plants advanced in maturity there was a highly significant increase in the losses of energy in the faeces. High faecal energy loss, consequent to a decrease in digestibility, has been attributed to low efficiency of energy utilization by lactating cows (Rook and Balch, 1961). The effect of changes in herbage quality on responses in milk production have been reviewed by Burt (1957) and Rook (1961 a).

The variation in response between treatment groups and between periods within treatment groups in the present experiment using pasture and Japanese Millet are shown in Fig. 3.21. The variation between cows grazing the same pasture in the initial period of the experiment (Period I) was very small as shown by the differences in their means indicated in Table 3.10, which confirmed that there was variation in intake and body weight during the same period.

The responses in intake, milk yield and body weight changes during Period II between treatment groups, were not significant, however Japanese Millet fed cows showed a slightly higher value for milk yield and body weight when compared with those grazing pasture. Wilson (1969) working with 3 ryegrass varieties on the performance of dairy cows under indoor conditions only found small differences in digestibilities but no differences in total concentration and proportions of VFAs. On these findings he concluded that differences in milk yield could be explained by differences in intake. Since the chemical composition of both herbages during Period II in the present experiment were not different (Appendix 3.), the higher production by the group grazing Japanese Millet could be explained by the slightly higher intakes (Fig. 3.16.). In conclusion, it might be stated that the response in milk yield of cows grazing Japanese Millet was the same as for those grazing pasture, showing that there was no variation between herbages in nutritive value during Period II.

During Period III significant differences in milk yield were observed between the two groups of cows; a higher milk yield was produced by cows grazing pasture. Nutritive value assessed by chemical composition, of pasture was comparatively higher than Millet, while the dry matter, organic matter and crude protein digestibilities of both herbages were the same. The intake of digestible organic matter for pasture fed cows was higher than for Millet fed cows, then as a consequence the intake of energy by the cows grazing pasture was greater. This greater energy intake was however more efficiently utilized for gains in body weight rather than for an increase in milk production (see Table 3.7 and Fig. 3.21.) probably as a result of advancing lactation as shown by Hutton (1963). This is apparent from the fact that milk yield continued to decline despite an increase in their intake whereas body weight gains occurred. In contrast, cows grazing Japanese Millet showed a continued decline in milk yield and body weight, consequent to a decrease in both intake and the nutritive value of the crop. At this stage of growth, Japanese Millet is less useful to sustain milk production especially when cows are at an advanced stage of lactation when compared with pasture.

Highly significant differences in milk yield were observed during Period IV; cows grazing pasture produced significantly more milk than those grazing Millet. The nutritive value of pasture increased during this period but intake decreased slightly compared with Period III. The increasing milk yield of pasture fed cows despite a decrease in intake appeared to be possibly due to a compensatory increase in its nutritive value. Cows grazing Millet declined in their milk yield possibly as a result of both a decrease in intake and to a decrease in nutritive value. The improvement in pasture quality was obviously due to irrigation as mentioned earlier. If a comparison was to be made between unirrigated pasture and Millet, such a difference might not be expected which would then imply, that differences between Millet and pasture might not be significant.

During the last Period (post experimental period) both groups of cows grazed the same pasture which was the one with highest nutritive value (measured by its chemical composition). This appears to be the reason why both groups of cows showed an increase in milk yield. The response in milk yield of cows which grazed Japanese Millet appears to be the same as those cows grazing pasture during the whole experiment, since the former increased by 0.57 kg of milk/day and the latter by 0.53 kg of milk/day between Period IV and V. Whereas the response to milk production remained the same for both groups of cows when they were grazing together during Period V, their actual milk yield continued to differ simply because cows that grazed Japanese Millet produced less probably as a result of a carry-over affect from Period IV. Apparently this carry-over effect is a consequence of quality differences between the two herbages rather than to differences in intake, since intakes were similar during Period V (see section 4.2.3.1.). From the point of view of recovery of milk yield it appears that cows grazing more mature Millet do not respond with a subsequent increase in production when changed over to high quality pasture. It does not however mean that such a refractory response would be obtained with Millet at an earlier stage of growth.

Results obtained in this experiment for the response in milk yield of lactating cows changed from pasture to Millet are in accordance with the findings of Hamilton et al., 1970 and Dale and Holder, 1968, where milk yield decreased due to the effect of grazing tropical pastures. Body weight changes do not however conform to the findings of the above authors. Previous reports (section 1.6) have shown that beef cattle grazing Millet respond by significantly increasing body weight.

FCM yield (Fig. 3.22.) followed the same pattern as milk yield due to only slight differences in the fat content. In Period V the fat content of milk from cows that grazed Japanese Millet was significantly greater than those on pasture. This difference in fat content was not reflected in the FCM yield in Period V probably due to the large difference in milk yield.

In light of the present experimental results it can be stated that the cows grazing Japanese Millet were unable to utilize the crop fully at the accelerated stage of growth which means that a part of the crop was allowed to mature; also it can be said that with maturity there was a decline in intake probably resulting from changes in palatability. Wilson and McDowall (1966) stated that differences in palatability could explain those differences found in milk and butterfat yield of cows grazing Ruanui and Ariki ryegrass. It appears that in the present study the decline in intake therefore, resulted in a decline in milk yield. A more meaningfull relationship between these factors and body weight changes are dealt with the analyses of multiple regressions.

Values for FCM yield in the present experiment were lower than those reported by Marshall, Sanchez, Somers and Arnold (1953) using Pearl Millet, however the latter reported a lower value for butterfat %. It appears that these differences arise simply because Marshall et al. supplemented with concentrates and the crop was used at an early stage of growth than that used in the present study. Miller, Beaty and Underwood (1958) also obtained a higher level of milk production and a lower butterfat % compared with those reported here; a similar explanation to that offered for Marshall et al.'s results appears to hold true in the latter study. Near twice the milk yield obtained with Japanese Millet was reported by Clark, Hemken and Vandersall (1965) and Hemken, Vandersall and Clark (1962) grazing Gahi-l Pearl Millet supplemented with concentrates. As in the previously discussed experiments, butterfat % showed a marked depression. The differences in butterfat % between the present experiment and those reported by Clark et al. and Hemken et al. might be due to the higher proportions of rumen acetic acid obtained here with Japanese Millet. Hawkins, Smith and Kelley (1958) reported that cows grazing Star Millet decreased their FCM yield from 25 lb to 19 lb during a test period of 4 weeks. Similar results were obtained in the present experiment since FCM yield decreased from 26.4 lb to 21.7 lb during the 3 weeks.

As indicated in section 1.6., there is a generally reported decrease in fat % associated with the grazing of Millet; however in the present experiment this feature was not observed. Several hypotheses were offered to explain this response, however as discussed earlier, none of them were entirely satisfactory.

Wallace (1956, 1961), Hutton (1962), Corbett (1960), present information in the form of a multiple regression where intake was related to metabolic body weight, FCM and gains in body weight; however it was noted that there was not agreement in the coefficients of these variables among the authors mentioned above. On the other hand Ingalls <u>et al</u>., 1965, indicated that 70% of the variation in production potential between forages can be accounted for in terms of differences in voluntary intake, compared with 30% by differences in digestibility. Wilson (1966) concluded that differences in intake largely accounted for differences in milk production.

The multiple regression analysis where variation of FCM yields were related with variations on D.O.M. intake and metabolic body weight are presented on section 3.3.3.3. A highly significant multiple regression was fitted which indicated that 92.30% of FCM yield variation was associated with variations of D.O.M. intake together with metabolic body weights. When the two variables were analysed separately with FCM yield, it was found that the association between FCM yield and metabolic body weight was greater (C.M.D. = 73.25%) than between FCM yield and D.O.M. intake (C.M.D. = 51.20%). The latter results indicated that the use of multiple regression analysis improved the relationship among these three variables and there is evidence of a D.O.M. intake x metabolic body weight interaction affecting changes in FCM yield. When standardized partial regression and partial correlation coefficients were used, it was found that 3/5 of the variation on FCM was associated with body weight and about 2/5 with intake.

Changes on FCM yield were also related with changes in organic matter intake and organic matter digestibility %; a highly significant multiple regression was found. In accord with the previous results, it was observed that 51.30% of changes on FCM yield were associated with changes on organic matter intake and organic matter digestibility together. When analysed separately, however it was observed that nearly all the variation previously explained was due to changes in organic matter intake (98.73%) and only a small proportion due to changes in organic matter digestibility (1.27%). This result is in accord with those reported by Ivins (1960) who indicated that there was no apparent association between digestibility and level of milk production. Other reports (Hamilton <u>et al</u>., 1970) also indicated that milk production was highly related to dry matter intake ($\hat{r} = 0.89$). However Brundage (1960) explained that changes in daily milk production of grazing cows were due to variation in herbage intake, digestibility or some combination of these two variables. The present study shows that as there was no association between FCM yield and organic matter digestibility, the use of the multiple regression did not improve the existent relationship between FCM yield and organic matter intake. When standardized partial regression and partial correlation coefficients were estimated, they confirmed the previous results.

Taking into account both multiple regressions fitted, it is observed that among those variables associated with changes in FCM yield, body weight appears to be the main factor, followed by changes in digestible organic matter intake, organic matter intake and organic matter digestibility in that order of importance. Since the three sets of twins were selected to have widely differing liveweights, the conclusions drawn from the multivariate analyses were to be expected.

4.2.3.4. Milk composition.

It is generally established that the level and type of feeding affect milk composition. Changes encountered in milk composition have been related particularly to the levels of energy and protein intake and also associated with changes in the amounts and relative proportions of VFA in the rumen. Evidence from experiments where infusion of VFA have been employed, provide further information on the relationships between VFA and milk production (Rook and Balch, 1961; Rook, Balch and Johnson, 1965; Storry and Rook, 1965, 1966; Wilson, Davey and Dolby, 1967; Balch and Rowland, 1959; Balch, 1955; Rook, 1961 a; Ørskov, Flatt, Moe, Munson, Hemken and Katz, 1969).

The synthesis and secretion of milk fat has been reviewed recently by Jones (1969) and Storry (1970) and it is now accepted that short chain fatty acid (4 - 10 carbons atoms) are synthesized by the mammary gland using acetic and β-hydroxybutyric acid; the long chain fatty acid (18 carbons atoms) are derived from plasma triglycerides and intermediate chain fatty acids (12 - 16 carbons atoms) are derived from both of these forms. Generally a low milk fat % can be associated with a high level of energy intake, with a high molar proportion of propionic acid and a low proportion of acetic acid in the rumen (Balch and Rowland

1957; Balch, 1960; Rook and Line, 1961; Bath and Rook, 1963). Using a ration containing roughages, this depression in rumen acetate was related to a decrease in the crude fibre content of the diet.

Changes in SNF content are related to stage of lactation, they are relatively high in the first month after calving, drops to a low level in the second month and then rise as lactation progresses (Legates, 1962). The same pattern of change with stage of lactation was indicated for protein content (Slack, Mather and Pfau, 1962). At the beginning of lactation the lactose content is comparatively low; within a few days however, values are attained which remained remarkably constant for the greater part of lactation (Rook and Campling, 1965). At the point where the decrease in the milk yield is accelerated due to advanced pregnancy, there was a progressive decrease in the lactose content of milk.

Rook and Line (1961), Burt (1957) and Rook (1961 a) showed that increases in the plane of energy increased the yield of milk, decreased the fat %, increased SNF content and yield, and increased the yields of both protein and lactose. Changes in SNF content were almost entirely accounted for by changes in the concentrations of all three of the major milk proteins, casein, α-lactalbumin and β-lactoglobulin (Rook and Line, 1961). Experimental evidence has shown an increase in propionic acid in the rumen, as a result of either dietary factors or intra ruminal infusions, have resulted in an increase in the content of the SNF fraction. Rook (1961 a) has indicated that severe underfeeding of protein has produced a reduction of SNF content while moderate underfeeding apparently has little effect on SNF. Rook and Line (1962) presented evidence that feeding protein at levels above feeding standards does not increase SNF content; however levels below those recommended decreased SNF.

It has been shown that milk protein content was increased by an increase in the level of energy intake, and this effect was known to be dependent on an increase in the uptake of propionic acid from the rumen (Rook and Balch, 1961) or by infusions of propionic acid into the rumen (Wilson et al., 1967). These rises in protein content could be due to an increase in microbial protein synthesis in the rumen resulting in an increase in the relative amounts of amino acid nitrogen absorbed from the small intestine, and therefore an increase in the protein content of the milk secreted (Rook and Line, 1961).

Lactose content is little affected under conditions of a low level of energy intake, however it is more affected when the energy level is considerably restricted (Rook and Line, 1961). When the level of feeding was changed from low-energy ration to a high-energy ration lactose was only slightly increased (Rook and Line, 1961).

Changes in the yields of milk components in the present study are shown in Fig. 3.23. It can be observed that changes between treatment and within treatments groups are closely related to changes on milk yield (Fig. 3.21.). These responses arose from the fact that the contents in milk of fat, protein and lactose showed very small changes during the whole experiment (see Fig. 3.24.).

Changes in butterfat % are illustrated in Fig. 3.24. where a significantly higher content was only observed in pasture fed cows during Period V. During the previous Periods (I, II, III and IV) however pasture fed cows showed higher contents of butterfat than those fed Japanese Millet although these differences were not significant. The cows grazing pasture during Period V showed a decrease in butterfat % while those grazing Japanese Millet an increase. The latter decrease in butterfat % in pasture fed cows was probably a result of an increase in the nutritive value of pasture, an increase in voluntary intake and to an overall increase in the intake of energy (Rook and Line, 1961). Tilley, Deriaz and Terry (1960) obtained a positive correlation between the soluble carbohydrate content of pasture and the proportion of propionic acid in the rumen. Storry and Sutton (1969) and Storry and Rook (1966) have shown that the feeding of milk fat depressing diets is associated with changes in rumen VFA, characterized by a decrease in acetate and sometimes of butyrate and an increase in the proportion of propionate and valerate. In Period V the soluble carbohydrate content of the pasture increased when compared with pasture in earlier periods. In view of the findings of Tilley et al., (1960); Storry and Sutton (1969) and Storry and Rook (1966), the decrease in fat % observed in Period V could therefore be attributed to an increase in the intake of soluble carbohydrate and associated changes in the rumen fermentation pattern. Rumen characteristics of sheep fed pasture showed an increase in the proportion of propionic acid and a decrease in acetic acid in Period IV. Although VFA measurements were not taken in Period V, the quality of pasture was higher in Period V, and so it might be reasonable to suppose that these changes in rumen fermentation were also present in Period V. In conclusion, a declining fat test of pasture fed cows could be explained by an increase in the intake of energy and an increase in the intake of soluble carbohydrates with concurrent changes in rumen fermentations. A similar pattern was reported by Wilson (1969) working with 3 different ryegrass varieties. Data obtained from experiments where VFA infusions were made, support this view.

The content of butterfat in milk from Japanese Millet fed cows during Period V shows a surprising increase, which is not in accord with the above mentioned factors affecting fat % changes. It could be possible that this level of butterfat is a consequence of confounded treatment and stage of lactation effects. This increase might be explained by the fact that a continued low level of nutrition had a cumulative effect on lactation persistency and subsequently these cows manifested drying-off effects earlier than pasture grazed cows.

An earlier discussion showed that an increase in the level of energy can increase the yield and content of protein and lactose (Rook and Line, 1961). Underfeeding experiments by Flux and Patchell (1954) and Patchell (1956) showed a decline in the percentage of SNF in cows fed at a level below their requirements after calving. In the present experiment a significant treatment difference in protein % of milk was only observed in Period IV (Fig. 3.24.). A period effect in the protein % of pasture fed cows was also observed in Period IV where it was greater than Period II and III (Appendix 31.). Such variation was not apparent in Japanese Millet fed cows.

The increase in protein % of pasture fed cows in Period IV appears to have resulted from an increase in energy intake and protein intake and the utilization of that energy for protein synthesis. The results of Rook and Line (1961) and Gordon and Forbes (1970) suggested an interaction between protein and energy in the subsequent utilization of nutrients for the synthesis of milk constituents. Potter, Purser and Cline (1968) demonstrated a positive relationship between glucose infusion and a change in the amino acid composition of sheep muscle. This implied that with specific metabolic energy sources there is some variation in the utilization of protein precursors. In Period V protein % of both groups of cows was the same. It could be suggested that Japanese Millet fed cows showed a greater response than pasture fed cows, possibly as a result of greater microbial protein synthesis in the rumen when compared with those cows fed on pasture throughout. The increase in protein % of pasture fed cows appears to result from an increase in the nutritive value of pasture and an increase in the overall intake of both protein and energy.

Lactose content did not vary markedly in cows grazing pasture (Fig. 3.24.). A slight decline was however observed in cows grazing Japanese Millet. From the other observations it appears that the differences in lactose % were due to stage of lactation effects, as discussed earlier for fat contents, rather than treatment effects, which were in accord with the previous results of Rook and Line (1961).

4.3. Summary and Conclusions.

Japanese Millet, a summer crop, was examined to obtain primary information on its value for dairy purposes, since no such information was available under New Zealand conditions. The value of herbage depends on its capacity to support milk production which is a function of both quality and quantity of forage grown; hence aspects of plant growth as well as animal production were studied.

From the results reported in the present study it appears that Japanese Millet at an early stage of maturity had a marked superiority over the more mature stages. The criterion used to reach this conclusion was principally milk yield, since animal production provides the ultimate evaluation of herbage quality. However other criteria have been used such as dry matter and crude protein yield, gains per day and per hectare of dry matter and crude protein, chemical composition, digestibility analyses, rumen fermentation characteristics, voluntary intake and body weight, since these are probably the main attributes necessary to determine the nutritive value of a feedstuff.

The experiment indicated that both first growth and regrowth of Japanese Millet produced the highest yield of dry matter at the last stage of growth examined (see Section 4.2.1.). Although the highest crude protein content of the crop was obtained at an early stage of maturity, the highest crude protein yield was obtained once the plant started to flower. The first growth produced the highest gain of dry matter per day and per hectare while regrowth provided the highest crude protein yield per day and per hectare. As the regrowth matured, an increase was observed in dry matter %, crude fibre %, and a decrease in crude protein %, ether extract % and soluble carbohydrates %. All digestibility coefficients (dry matter, organic matter, crude protein and crude fibre) decreased (see Section 4.2.2.) and changes in rumen characteristics (VFA and ammonia) indicated that there was a progressive loss in nutritive value as the crop matured. The effect of feeding Japanese Millet on milk yield was greater than on milk composition; as the crop advanced in maturity, milk yield decreased principally as a result of a decreased voluntary intake resulting from continued decreases in herbage quality (see Section 4.2.3.). Quantitative estimates of intake obtained here appear unreliable (see Section 4.1.2.) but the data appears suitable for comparative purposes especially when the expected decline with crop maturation was observed.

It may be pointed out that, in terms of both the supply of digestible nutrients and milk production, there is a marked advantage in the early harvesting of Japanese Millet; however if dry matter yield is the criteria of harvesting, late cutting is the more promising management. Thus if the primary objective of producing a summer crop such as Japanese Millet is to maintain a number of animals over an extended period of time, it might be advantageous to harvest late and to compensate for the reduced unit nutritive value of the forage by the increase in yield obtained. On the other hand, if the primary purpose is to maintain a high level of milk production during a relative short time it would appear useful to cut earlier and more frequently in order to exploit herbage with a high nutritive value. Supporting the latest conclusion it could be added that better crop utilization is also obtained at an earlier stage of growth rather than later. In grazing at an advanced stage of growth, a relatively high proportion of plant growth will be wasted.

It can be concluded that under the drought summer conditions that were encountered here, Japanese Millet proved to be a satisfactory summer crop for milk production, particularly when perennial pastures tend to decrease in their nutritive value. Results of the present experiment also indicated the need for further studies to ascertain the effects of using Japanese Millet at different stages of growth for milk production, since the present study covered a period of only 3 weeks when the crop was at relatively advanced stage of maturity.

REFERENCES

AHLRICH, V.E., YOUNG, W.C. and BYRD, M. (1967). Miss. Farm Res. 30 (4) : 1.

ANNISON, E.F. (1954). Biochem. J. 57 : 400.

ANNISON, E.F., CHALMERS, M.I., MARSHALL, S.B.M. and SYNGE, R.L.M. (1954). J. Agric. Sci. 44 : 270.

ANON. (1961). Grassl.Res. Inst. Bull. 45, Com. Bur. Past. Crops, Farnham Royal, C.A.B.

A.O.A.C. (1965). Official Methods of Analysis of the Association of Official Agricultural Chemists. 10th ed., Washington.

ARMSBY, H.P. (1917). The nutrition of Farm Animals. London, McMillan.

ARMSTRONG, D.G. (1964). J. Agric. Sci. 62 : 399.

ARNOLD, B.L. (1956). Miss. Farm Res. 19 (4) : 6.

ARNOLD, G.W. (1960). Aust. J. Agric. Res. 11 : 1026.

ARNY, A.C., BRIDGFORD, R.O. and CRIM, R. (1946). Univ. of Minnesota, Agric. Exp. Stat. Bull. 390.

BAILEY, R.W. (1962). Analyt. Biochem. 3 : 178-185.

BAILEY, R.W. (1964). N.Z.J. Agric. Res. 7 : 416.

BALCH, C.C. (1955). J. Dairy Res. 22 : 220.

BALCH, C.C. (1960). Proc. 8th Int. Grassl. Congr., p. 528.

BALCH, C.C., BALCH, D.A., BARTLETT, S., JOHNSON, V.W., ROWLAND, S.J. and TURNER, J. (1954). J. Dairy Res. 21 : 305.

BALCH, C.C., REID, J.T. and STROUD, J.W. (1957). Brit. J. Nut. 11 : 184.

BALCH, C.C. and ROWLAND, S.J. (1957). Brit. J. Nutr. 11 : 288.

BALCH, C.C. and ROWLAND, S.J. (1959). J. Dairy Res. 26 : 162.

BALCH, C.C. and CAMPLING, R.C. (1962). Nut. Abst. Rev. 32 : 669.

BATH, I.H. (1958). Analyst 83 : 451.

BATH, I.H. and ROOK, J.A.F. (1963). J. Agric. Sci. 61 : 341.

BATH, I.H. and ROOK, J.A.F. (1965). J. Agric. Sci. 64 : 67.

BEATY, E.R., SMITH, Y.C., McCREERY, R.A., ETHREDGE, W.J. and BEASLEY, K. (1965). Agron. J. 57 : 277.

BEGG, J.E. (1965). J. Agric. Sci. 65 : 341.

BEGG, J.E. (1966). Scientific Liaison Conf., Darwin. Melbourne, 1966.

BIGGS, D.A. (1967). J. Dairy Sci. 50 : 799.

BLACKBURN, T.H. (1965). In Physiology of Digestion in the Ruminant. Butterworths, London.

BLASER, R.E. (1962). Ann. Meeting Ass. South. Agric. Workers, Florida.

BLAXTER, K.L. (1961). Symp. Energy Metab., Wageningen European Ass. Anim. Prod. p. 211.

BLAXTER, K.L. (1962). In The Energy Metabolism of Ruminants. Hutchinson, London.

BLAXTER, K.L., N. McC. GRAHAM and F.W. WAINMAN. (1956). Brit. J. Nut. 10 : 69.

BLAXTER, K.L., WAINMAN, F.W. and WILSON, R.S. (1961). Anim. Prod. 3 : 51.

BLAXTER, K.L. and WILSON, R.S. (1963). Anim. Prod. 5 : 27.

BLAXTER, K.L. and WILSON, R.S. (1962). J. Brit. Soc. Anim. Prod. 4 : 351.

BLOOM, S., JACOBSON, N.L., ALLEN, R.S., McGILLIARD, L.D. and HOMEYER, P.G. (1957). J. Dairy Sci. 40 : 240.

BLOUT, C.L. (1956). Miss. Farm.Res. 19 (4) : 6.

BRATZLER, J.N. (1951). J. Anim. Sci. 10 : 592.

BRISSON, W.F. (1960). Proc. 8th Int. Grassl. Cong. p. 435.

BRISSON, W.F., PIGDEN, W.J. and SYLVESTRE, P.E. (1957). Can. J. Anim. Sci. 37 : 90.

BROYLES, K.R. and FRIBOURG, H.A. (1959). Agron. J. 51 : 277.

BRUNDAGE, A.L. (1960). Proc. 8th Int. Grassl. Cong. p. 450.

BRYANT, A.M. (1964). N.Z.J. Agric. Res. 7 : 694.

BURNS, J.C. and WEDIN, W.F. (1964). Agron. J. 56 : 457.

BURT, A.W.A. (1957). Dairy Sci. Abstr. 19 : 435.

BURTON, G.W. (1951). Agron. J. 43 : 409.

BURTON, G.W. (1959). Agron. J. 51 : 479.

BURTON, G.W. and DE VANE, E.H. (1951). Southern Seedsman, March issue.

BURTON, G.W., JACKSON, J.E. and HART, R.H. (1963). Agron. J. 55 : 500.

BURTON, G.W., KNOX, F.E. and BEARDSLEY, D.W. (1964). Agron. J. 56 : 160.

BURTON, G.W. and FORSTON, J.C. (1966). Crop Sci. 6 : 69.

BURTON, G.W., GUNNELLS, J.B. and LOWREY, R.S. (1968). Crop Sci. 8 : 431.

BURTON, G.W., MONSON, W.G., JOHNSON, J.C., LOWREY, R.S., CHAPMAN, H.D. and MARCHANT, W.H. (1969). Agron. J. 61 : 607.

BUTTERWORTH, M.H. (1967). Nut. Abstr. Rev. 37 : 349.

CALDER, A. (1955). Rhodesia Agric. J. 52 : 161.
CANAWAY, R.J., TERRY, R.A. and TILLEY, J.M.A. (1965). Res. Vet. Sci. 6 : 416.
CAMPLING, R.C. (1964). Proc. Nutr. Soc. 23 : 80.
CAMPLING, R.C., FREER, M. and BALCH, C.C. (1963). Brit. J. Nut. 17 : 263.
CASTLE, M.E., DRYSDALE, A.D. and WATSON, J.N. (1960). J. Dairy Res. 27 : 419.
CIPOLLONI, M.R., SCHNEIDER, B.H., LUCAS, A.L. and PAVLECH, H.M. (1951). J. Anim. Sci. 10 : 337.
CLARK, N.A., HEMKEN, R.W. and VANDERSALL, J.H. (1965). Agron. J. 57 : 266.
COLMAN, R.L. and HOLDER, J.M. (1968). Proc. Aust. Soc. Anim. Prod. 7 : 129.
CONRAD, H.R. (1966). J. Anim. Sci. 25 : 227.
CONWAY, E.J. and O'MALLEY, E. (1956). Brit. J. Nutr. 10 : 115.
COOK, C.W. and HARRIS, L.E. (1950). Utah Sta. Agric. Exp. Sta. Bull. 342.
COOK, C.W., STODDART, L.A. and HARRIS, L.E. (1952). J. Anim. Sci. 11 : 578.
COOK, C.W., STODDART, L.A. and HARRIS, L.E. (1954). Utah Sta. Agric. Exp. Sta. Bull. 372.
COOP, I.E. and HILL, M.K. (1962). J. Agric. Sci. 58 : 187.
COOPER, C.S. (1956). Agron. J. 48 : 257.
COUP, M.R. (1950). Proc. N.Z. J. Sci. Tech. 34A : 347.
CORBETT, J.L. (1958). Proc. Brit. Soc. Anim. Prod. p.3.
CORBETT, J.L. (1960). Proc. 8th Int. Grassl. Congr. p. 438.
CORBETT, J.L. (1969). International Encyclopaedia of food and nutrition. Pergamon Press, Oxford and New York.
CORBETT, J.L., GREENHALGH, J.F.D., GWYNN, P.E. and WALKER, D. (1958). Brit. J. Nut. 12 : 266.
CORBETT, J.L. and GREENHALGH, J.F.D. (1958). Nature, London. 182 : 1014.
CORBETT, J.L., GREENHALGH, J.F.D. and FLORENCE, E. (1959). Brit. J. Nut. 13 : 337.
CORBETT, J.L., GREENHALGH, J.F.D., McDONALD, I. and FLORENCE, E. (1960). Brit. J. Nut. 14 : 289.

CORBETT, J.L., LANGLANDS, J.P. and REID, G.W. (1963). Anim. Prod. 5 : 119.

CRAGMILES, J.P., BAIRD, D.M. and McCULLOUGH, H.E. (1958). Georgia Agric. Expt. Sta. Mimeo. Ser. N.S. 47.

CRAMPTON, E.W. (1957). J. Anim. Sci. 16 : 546.

CRAMPTON, E.W. and FORSHAW, R.P. (1940). J. Nut. 19 : 161.

CRAMPTON, E.W., DONEFER, E. and LLOYD, L.E. (1960a). J. Anim. Sci. 19 : 538.

CRAMPTON, E.W., DONEFER, E. and LLOYD, L.E. (1960b). Proc. 8th Int. Grassl. Conf. p. 462.

CRAMPTON, E.W. and HARRIS, L.E. (1969). In Applied Animal Nutrition. Freeman, San Francisco, W.N.

CURRAN, M.K., LEAVER, J.D. and WESTON, E.W. (1967). Anim. Prod. 9 : 561.

DALE, A.B. and HOLDER, J.M. (1968). Proc. Aust. Soc. Anim. Prod. 7 : 86.

DAVEY, A.W.F. (1964). M. Agric. Sci. Thesis, Massey University.

DAVEY, A.W.F. (1965a). Proc. N.Z. Soc. Anim. Prod. 25 : 106.

DAVEY, A.W.F. (1965b). N.Z. J. Agric. Res. 8 : 409.

DAVISON, M.E. (1965). Diss. Abstr. 26 : 4925.

DAWSON, J.R., KOPLAND, D.W. and GRAVES, R.R. (1940). U.S.D.A. Tech. Bull. No. 739.

DECAEN, C. and ADDA, J. (1966). 17th Int. Dairy Congr., Munich, A, 161.

DEINUM, B., IMMINK, H.J. and DEIJS, W.B. (1963). Nut. Abstr. Rev. 33 : 848.

DIRVEN, J.G.P. and JONGE POERINK, H.J. (1955). Trop. Agric. Trin. 32 : 115-23.

DOUGLAS, N.J. (1959). Queensland Agric. J. 85 (10) : 632.

ELY, R.E., KANE, E.A., JACOBSON, W.C. and MOORE, L.A. (1953). J. Dairy Sci. 36 : 334.

FAIRES, E.W., DAWSON, J.R., LAMASTER, J.P. and WISE, G.K. (1941). U.S.D.A. Tech. Bull No. 805.

FEATHERSTONE, J., RICHABY, C.D. and CAVELL, A.J. (1951). J. Brit. Grassl. Soc. 6 : 161.

FELS, H.E., MOIR, R.J., ROSSITER, R.C. (1959). Aust. J. Agric. Res. 10 : 237.

FLUX, D.S. and PATCHELL, M.R. (1954). J. Agric. Sci. 45 : 248.

FONTENOT, J.P. and BLASER, R.E. (1965). J. Anim. Sci. 24 : 1202.
FORBES, E.B., ELLIOT, R.F., SWIFT, R.W., JAMES, W.H. and SMITH, V.F. (1946). J. Anim. Sci. 5 : 298.
FOURY, A. (1954). Terre Maroc. 28 : 447.
FRENCH, M.H. (1943). East African Agric. J. 9 : 88.
FRENCH, M.H. (1946). East African Agric. J. 11 : 159.
FRENCH, M.H. (1957). Herbage abstracts 27 : 1.
GARRIGUS, N.P. and RUSK, H.P. (1939). Ill. Agric. Exp. Sta. Bull. 454.
GAUSSERES, B. (1965). Ann. Biol. Anim. Biochem., Biophys. 5 : 407.
GORDON, F.G. and FORBES, T.G. (1970). J. Dairy Res. 37 : 481.
GRAHAM, N.M. (1967). Aust. J. Agric. Res. 18 : 137.
GRAY, F.V., WELLER, R.A. and JONES, G.B. (1965). Aust. J. Agric. Res. 16 : 145.
GRAY, F.V., WELLER, R.A., PILGRIM, A.F. and JONES, G.B. (1967). Aust. J. Agric. Res. 18 : 625.
GREENHALGH, J.F.D. (1966). Proc. X Int. Grassl. Cong., p. 351.
GREENHALGH, J.F.D. (1970). Proc. XI Int. Grassl. Cong., p. 856.
GREENHALGH, J.F.D., CORBETT, J.L. and McDONALD, I. (1960). J. Agric. Sci. 55 : 377.
GREENHALGH, J.F.D. and REID, G.W. (1967). Nature. London, 214 : 744.
HAMILTON, R.I., LAMBOURNE, L.J., ROE, R. and MINSON, D.J. (1970). Proc. XI Int. Grassl. Cong. p. 860.
HAMMARSTRAND, K. (1966). Gas Chromatographic Analysis of Fatty Acids. Varian Aerograph. California, U.S.A.
HARDISON, W.A. and REID, J.T. (1953). J. Nut. 51 : 35.
HARDISON, W.A., REID, J.T., MARTIN, C.M. and WOOLFOLK, P.G. (1954). J. Dairy Sci. 37 : 89.
HARRIS, L.E., COOK, C.W. and BUTCHER, J.E. (1959). Agron. J. 51 : 226.
HARRIS, L.E., CRAMPTON, E.W. and ASPLUND, J.M. (1969). In Techniques and Procedures in Animal Science Research, p. 157. Published by Am. Soc. An. Sci.
HART, J. (1958). Queensland Agric. J. 84 (12) 703.
HART, R.H. and BURTON, G.W. (1965). Agron. J. 57 : 376.
HARVEY, J.M. (1952). Queensland J. Agric. Sci., 9 : 169.
HAWKINS, G.E., SMITH, L.A. and KELLEY, W.B. (1958). Agr. Exp. Sta. of the Alabama Polytech. Inst. Leaflet 60.

HEANEY, D.P., PRITCHARD, G.I. and PIEDEN, W.J. (1968). *J. Anim. Sci.* 27 : 159.

HEINRICHS, D.L. and CARSON, R.B. (1956). *Can. J. Agric. Sci.* 36 : 95.

HEMKEN, R.W., VANDERSALL, J.H. and CLARK, N.A. (1962). *J. Dairy Sci.* 45 : 685.

HENKEL, P.A. (1961). *Proc. Madrid Symp.* UNESCO Pub., p. 67.

HILLER, A., PLAZIN, J. and VAN SLTKE, D.D. (1948). *J. Biol. Chem.* 176 : 1401.

HOLDER, I.H. (1967). *Trop. Grassls.* 1 : 135.

HOLMES, W., ARNOLD, G.W. and PROOVAN, A.L. (1960). *J. Dairy Res.* 27 : 191.

HONDRE, E.N. (1967). Res. Div. - Dept. of Agric. N.Z. Res. Rep. No. 25.

HOVELAND, G.S. and McCLOUD, D.E. (1957). *Sunshine State Agric. Res. Rep.* 2 : 14.

HUBER, J.T. and BOMAN, R.L. (1966). *J. Dairy Sci.* 49 : 816.

HUMPHREYS, L.R. (1965). 'A Guide to Better Pastures for the Tropics and Subtropics'. Wright Stephenson & Co., Ltd., Melbourne.

HUMPHREYS, L.R. (1966). 'Pasture defoliation practice: A review.' *J. Aust. Inst. Agric. Sci.* 32 : 93.

HUTTON, J.B. (1961). *N.Z. J. Agric. Res.* 4 : 583.

HUTTON, J.B. (1962). *Proc. N.Z. Soc. Anim. Prod.* 22 : 12.

HUTTON, J.B. (1963). *Proc. N.Z. Soc. Anim. Prod.* 23 : 39.

HYDEN, S. (1961). *Annals. Roy. Agric. Coll.* Sweden. 27 : 51.

INGALLS, J.R., THOMAS, J.W., BENNE, E.J. and TESAR, H. (1965). *J. Anim. Sci.* 24 : 1159.

IVINS, J.D. (1960). *Proc. 8th Int. Grassl. Cong.* p. 459.

JOHNS, A.T. (1955 a) *N.Z. J. Sci Techn.* [A] 37 : 301.

JOHNS, A.T. (1955 b) *N.Z. J. Sci. Tech.* [A] 37 : 323.

JOHNSON, D.T. (1968). *Rhodesia Agric. J.* 65 : 87.

JOHNSON, D.T. (1969). *Rhodesia Agric. J.* 66 : 19.

JONES, E.A. (1969). *J. Dairy Res.* 36 : 145.

JONES, A.S., LIVINGSTONE, R.M. and CADENHEAD, A. (1965). *An. Prod.* 7 : 279.

JUNG, G.A. and REID, R.L. (1966). *West Virgin. Univ. Agric. Exp. St. Bull.* 524 T.

KAMSTRA, L.D., MOXON, A.L. and BENTLEY, O.G. (1958). J. Anim. Sci. 17 : 199.

KANE, E.A., JACOBSON, W.C. and MOORE, L.A. (1950). J. Nut. 41 : 583.

KANE, E.A., JACOBSON, W.C. and MOORE, L.A. (1952). J. Nut. 47 : 263.

KASAHARA, Y. and KINOSHITA, O. (1954). Proc. Crop Sci. Soc. Japan. 22 : 7.

KILDEE, H.H., WEAVER, E., SHAW, J.M. and ELY, F. (1925). Agric. Exp. Sta. Iowa State Col. of Agric. and Mech. Arts, Bull. No. 231.

KING, G.H. (1947). 27th Ann. Rep - Georgia Coastal Plain Exp. Sta. Bull. 44 : 36.

KINGSBURY, L.R. (1965). Proc. N.Z. Soc. Anim. Prod. 25 : 119.

KIRCHGESSNER, M., FRIESECKE, H. and KOCH, G. (1967). Cited by ARMSTRONG, D.G. (1968). Proc. Nut. Soc. 27 : 57.

LABEN, R.C. (1963). J. Dairy Sci. 43 : 1293.

LAHIRI, A.N. and KHARABANDA, B.C. (1965). Proc. Nat. Inst. Sci. India 31 B (1 and 2) : 14.

LAHIRI, A.N. and KUMAR, V. (1966). Proc. Nat. Inst. Sci. India 32 B (3 and 4) : 116.

LAMBOURNE, L.J. (1957 a) J. Agric. Sci. 48 : 275.

LAMBOURNE, L.J. (1957 b) J. Agric. Sci. 48 : 415.

LAMBOURNE, L.J. and REARDON, T.F. (1962). Nature. 196 : 961.

LAMBOURNE, L.J. and REARDON, T.F. (1963 a). Aust. J. Agric. Res. 14 : 239.

LAMBOURNE, L.J. and REARDON, T.F. (1963 b). Aust. J. Agric. Res. 14 : 257.

LANCASTER, R.J., COUP, M.R., PERCIVAL, J.P. (1953). N.Z. J. Sci. Tech. A 35 : 117.

LANCASTER, R.J. (1950). Proc. 10th N.Z. Soc. Anim. Prod. p. 45.

LANE, G.T., CUMMINGS, K.R., NOLLER, C.H. and COLENBRANDER, V.F. (1966). J. Anim. Sci. 25 : 1256.

LANE, G.T., NOLLER, C.H., COLENBRANDER, V.F. and CUMMINGS, K.R. (1968). J. Dairy Sci. 51 : 114.

LANGLANDS, J.P., CORBETT, J.L., McDONALD, I. and REID, G.W. (1963 a). Brit. J. Nut. 17 : 211.

LANGLANDS, J.P., CORBETT, J.L., McDONALD, I. and REID, G.W. (1963 b). Brit. J. Nut. 17 : 219.

LEGATES, J.E. (1962). J. Dairy Sci. 45 : 990.

LYNDAHL, I.L. (1960) In Techniques and Proc. in An.Prod.Res. Am.Soc.An.Sci.

LINKOUS, W.N., HARDISON, W.A., GRAF, G.C. and ENGEL, R.W. (1954). J. Anim. Sci. 13 : 1009.

LLOYD, G.L. (1964). Rhodesia Agric. J. 61 : 50.

LUCERO, C.F. (1953). Phillipp. Agric. 37 : 99.

LYNCH, P.B. (1966). 'Conduct of Field Experiments'. N.Z. Dept. Agric. Bull. 399.

LYNCH, P.B. (1966). Ruakura Agric. Res. Centre - Circular Memo. SFR 15.

LYNCH, P.B. (1968). Ruakura Agric. Res. Centre - Circular Memo. DFR 52.

MAHAFFEY, M.J., MILLER, W.J., DONKER, J.D. and DALTON, H.L. (1954). J. Dairy Sci. 37 : 672.

MARSHALL, S.P., SANCHEZ, A.B., SOMERS, H.L. and DIX ARNOLD, P.T. (1953). Univ. of Florida, Agric. Exp. Sta. Bull. No. 527.

MASEFIELD, G.B. (1955). A Handbook of Tropical Agriculture. Ed. Oxford Univ. Press.

MAYS, D.A. (1961). Diss. Abst. B 22 (1) : 17.

MAYS, D.A. and WASHKO, J.B. (1961) Pennsylvania State Univ. Bull. 682.

McANNALLY, R.A. and PHILLIPSON, A.T. (1942). J. Physiol. 101 : 13.

McDONALD, I.W. (1968). Nut. Abstr. and Rev. 38 : 381.

MEEKER, E.W. and WAGNER, E.C. (1933). J. Ind. Engineering Chem. (Anal. Edin.) 5 : 396.

MILES, J.T., COWSERT, W.C., LUSK, J.W. and OWEN, J.R. (1956). Miss. Farm Res. 19 (4) 6.

MILFORD, R. (1960 a). Aust. J. Agric. Res. 11 : 138.

MILFORD, R. (1960 b). Aust. J. Agric. Res. 11 : 121.

MILFORD, R. (1967). Aust. J. Exp. Agric. 7 : 540.

MILFORD, R. and MINSON, D.J. (1965). Proc. IX Inter. Grassl. Cong. p. 815.

MILFORD, R. and MINSON, D.J. (1966). Proc. Aust. Soc. Anim. Prod. 6 : 319.

MILFORD, R. and MINSON, D.J. (1967). Aust. J. Exp. Agric. 7 : 546.

MILFORD, R. and MINSON, D.J. (1968). Aust. J. Exp. Agric. 8 : 413.

MILLER, T.B. (1961). Herbage Abstr. 31 : 81.

MILLER, W.J., BEATY, E.R. and UNDERWOOD, L.M. (1958). Georgia Agri. Exp. Sta. - Univ. of Georgia Tech. Bull. N.S. 16.

MILLER, R.W., WALDO, D.R., OKAMOTO, M., HEMKEN, R.W., VANDERSALL, J.H. and CLARK, N.A. (1963). J. Dairy Sci. 46 : 621.

MILLER, R.W., HEMKEN, R.W., VANDERSALL, J.H., WALDO, D.R., OKAMOTO, M. and MOORE, L.A. (1965). J. Dairy Sci. 48 : 1319.

MINSON, D.J. (1960). J. Brit. Grassl. Soc. 15 : 86.

MINSON, D.J. (1963). Proc. N.Z. Soc. Anim. Prod. 23 : 63.

MINSON, D.J. and MILFORD, R. (1963). J. Brit. Grassl. Soc. 22 : 170.

MINSON, D.J. and MILFORD, R. (1966). Aust. J. Agric. Res. 17 : 411.

MINSON, D.J. and MILFORD, R. (1967). Aust. J. Exp. Agri. Anim. Husb. 7 : 546.

MINSON, D.J., RAYMOND, W.F. and HARRIS, C.E. (1960). J. Brit. Grassl. Soc. 15 : 174.

MINSON, D.J., HARRIS, C.E., RAYMOND, W.F. and MILFORD, R. (1964). J. Brit. Grassl. Soc. 19 : 298.

MITCHELL, K.J. (1963). Proc. N.Z. Inst. of Agric. Sci. 9 : 80.

MOIR, K.W. (1960). Qd. J. Agric. Sci. 17 : 391.

MOORE, J.A. (1959). Agric. Prog. 34 : 48.

MORGAN, E.B. and ELLEZ, D.H. (1961). J. Dairy Sci. 44 : 974.

MOULE, C.R. (1965). Manual Techniques, C.S.I.R.O., Melbourne, Australia.

MUNFORD, R.E. (1968). Dairy farming Annual 1968 : 35.

MUNFORD, R.E. (1970). Statistic Programme (mimeographed).

MURRAY, C.A. and ROMYN, A.E. (1937). Rhodesia Agric. J. 34 : 309.

NANDA, K.K., GROVER, R. and CHINOY, J.J. (1957). Phyton 8 (2) : 97.

NANDA, K.K., GROVER, R. and CHINOY, J.J. (1957). Phyton 9 (1) : 15.

NORMAN, A.G. (1939). Biochem. J. 33 : 1201.

NORMAN, M.J.T. (1962). Aust. Div. Land Res. Reg. Surv. Tech. Pap. No. 19. C.S.I.R.O.

NORMAN, M.J.T. (1963). Aust. Div. Land Res. Reg. Surv. Tech. Pap. No. 22. C.S.I.R.O.

NORMAN, M.J.T. (1965). Aust. J. Exp. Agric. Anim. Husb. 5 : 227.

NORMAN, M.J.T. (1966). Aust. Div. Land Res. Reg. Surv. Tech. Pap. No. 28. C.S.I.R.O.

NORMAN, M.J.T. and WETSELAAR, R. (1960). Aust. Div. Land Res. Reg. Surv. Tech. Pap. No. 9. C.S.I.R.O.

NORMAN, M.J.T. and STEWART, G.A. (1964). J. Aust. Inst. Agric. Sci. 30 : 39.

NORMAN, M.J.T. and BEGG, J.E. (1968). J. Aust. Int. Agric. Sci. 34 : 59.

NORMAN, M.J.T. and PHILLIPS, L.J. (1968). Aust. J. Exp. Agric. Anim. Husb. 8 : 288.

ODLAND, T.E., COX, T.R. and MORAN, C.H. (1942). J. American Soc. Agron. 34 : 229.

OLMSTED, W.H., WITAKER, W.M. and DUDEN, C.W. (1929). J. Biol. Chem. 85 : 109.

ØRSKOV, E.R., FLATT, W.F., MOE, P.W., MUNSON, A.W., HEMKEN, R.W. and KATZ, I. (1969). Brit. J. Nutr. 23 : 443.

PADMANABHA REDDY PETA. (1966). Diss. Abst. Sect. B, 27 (9) : 2934.

PATCHELL, M.R. (1956). N.Z. J. Sci. Tech. 38 A : 682.

PHILLIPS, T.G., SULLIVAN, J.T., LOUGHLIN, M.E. and SPRAGUE, V.G. (1954). Agron. J. 46 : 361.

PHILLIPS, L.J. and NORMAN, M.J.T. (1962). Aust. Div. Land Res. Surv. Tech. Pap. No. 20. C.S.I.R.O.

PHILLIPS, L.J. and NORMAN, M.J.T. (1966). Aust. J. Exp. Agric. Anim. Husb. 6 : 78.

PHILLIPS, L.J. and NORMAN, M.J.T. (1967). Aust. Div. Land Res. Tech. Memo. 67118. C.S.I.R.O. Canberra.

PIGDEN, W.J. and BRISSON, G.J. (1957). Can. J. Anim. Sci. 37 : 185.

POKHRIYAL, S.C., MANGATH, K.S. and GANGAL, L.K. (1967). Indian J. Agri. Sci. 37 (2) : 178.

POTTER, E.L., PURSER, D.B. and CLINE, J.H. (1968). J. Nut. 95 : 655.

PRITCHARD, G.I., FOLKINS, L.P. and PIGDEN, W.J. (1963). Can. J. Plant Sci. 43 : 79.

RAMOND, C. (1968). Agron. Trop. Paris 23 (8) : 844.

RAYMOND, W.F. (1964). J. Brit. Grassl. Soc. 19 : 81.

RAYMOND, W.F. (1969). Advances in Agron. 21 : 1.

RAYMOND, W.F. and MINSON, D.J. (1955). J. Brit. Grassl. Soc. 10 : 282.

RAYMOND, W.F., HARRIS, C.E. and HARKER, V.G. (1953). J. Brit. Grassl. Soc. 8 : 301.

RAYMOND, W.F., MINSON, D.J. and HARRIS, C.E. (1959). J. Brit. Grassl. Soc. 14 : 75.

REA, H.E. (1953). Proc. 6th South. Weed Conf., p. 88. Texas Agric. Exp. Sta. College Sta.

REDDY, P.P., VANDERSALL, J.H., HEMKEN, R.W. and CLARK, N.A. (1965). J. Dairy Sci. 48 : 810.

REID, J.T. (1961). J. Dairy Sci. 44 : 2122.
REIS, P.J. and SCHINCKEL, P.G. (1961). Aust. J. Agric. Res. 12 : 335.
RIRIE, D. (1954). Proc. 6th Ann. Calif. Weed Conf. p. 30-2. Agron. Dept., Univ. Calif., Davis.
ROARK, D.B., MILES, J.T., LUSK, J.W. and COWSERT, W.C. (1952). Proc. Assoc. South. Agric. Workers 49th Ann. Conv. 76-77.
RONNINGEN, T.S., DECKER, A.M., JONES, R.L., and FOSTER, J.E. (1955). Maryland Agric. Exp. Sta. Bull. 455.
ROOK, J.A.F. (1961a). Dairy Sci. Abst. 23 : 251.
ROOK, J.A.F. (1961b). Dairy Sci. Abst. 23 : 303.
ROOK, J.A.F. (1964). Proc. Nutr. Soc. 23 : 71.
ROOK, J.A.F. and CAMPLING, R.C. (1965). J. Dairy Res. 32 : 45.
ROOK, J.A.F. and BALCH, C.C. (1961). Brit. J. Nut. 15 : 361.
ROOK, J.A.F. and LINE, C. (1961). Brit. J. Nut. 15 : 109.
ROOK, J.A.F. and CAMPLING, R.C. (1965). J. Dairy Res. 32 : 45.
ROOK, J.A.F., LINE, C. and ROWLAND, S.J. (1960). J. Dairy Res. 27 : 427.
ROOK, J.A.F., BALCH, C.C. and JOHNSON, V.W. (1965). Brit. J. Nut. 19 : 93.
RUSOFF, L.L., ACHACOSO, A.S., MONDART, C.L.(Jr.), and BONNER, F.L. (1961). La. Agric. Expt. Sta. Bull. 542.
SHANKAR, K., AHLUWALIA, M. and JAIN, S.K. (1963). Indian J. Genet. 17 : 318.
SLACK, N.H., MATHER, R.E. and PFAU, K.O. (1962). J. Dairy Sci. 45 : 144.
SMITH, R.H. (1969). J. Dairy Res. 36 : 313.
SMITH, A.M. and REID, J.T. (1955). J. Dairy Sci. 38 : 515.
SNEDECOR, G.W. and COCHRAN, W.G. (1968). Statistical Methods. 6th ed. Iowa State College Press, Ames, Iowa, U.S.A.
SQUIRE, M.J.E. (1958). Agric. Gazette of N.S.W. 69 (10) : 505.
STEEL, R.G.D. and TORRIE, J.H. (1960). Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., U.S.A.
STEVENSON, A.E. (1962). N.Z. J. Agric. Res. 5 : 339.
STORRY, J.E. (1970). J. Dairy Res. 37 : 139.
STORRY, J.E. and ROOK, J.A.F. (1965). Biochem.J. 96 : 210.
STORRY, J.E. and ROOK, J.A.F. (1966). Brit. J. Nut. 20 : 217.

STORRY, J.E. and SUTTON, J.D. (1969). Brit. J. Nut. 23 : 511.
SULLIVAN, E.F. (1961). Agron. J. 53 : 357.
SULLIVAN, J.T. (1964). Agric. Res. Serv. U.S.D.A. 34 - 62.
SULLIVAN, J.T., PHILLIPS, R.H., LOUGHLIN, M.E. and SPRAGUE, V.G. (1956). Agron. J. 46 : 11.
SWEZEY, A.W. and FISHER, J.R. (1955). Down to Earth 11 : 2-5.
TAYLOR, J.C. and DERIAZ, R.E. (1963). J. Brit. Grassl. Soc. 18 : 29.
TERRY, R.A. and TILLEY, J.M.A. (1962). Expt. Grassl. Res. Inst. Hurley 14 : 58.
TERRY, R.A. and TILLEY, J.M.A. (1964). J. Brit. Grassl. Soc. 19 : 363.
TILLEY, J.M.A., DERIAZ, R.E. and TERRY, R.A. (1960). Proc. 8th Int. Grassl. Cong. p. 533.
TOMMERVIK, R.S. and WALDERN, D.E. (1969). J. Dairy Sci. 52 : 68.
TOPPS, J.H., REED, W.D.C. and ELLIOT, R.C. (1965). J. Agric. Sci. 64 : 387.
ULYATT, M.J. and HENDERSON, B.S. (1968). N.Z. J. Agric. Res. 11 : 939.
VAN SOEST, P.J. (1963). J. Dairy Sci. 46 : 204.
VAN SOEST, P.J. (1965). J. Anim. Sci. 24 : 834.
VENGRIS, J. (1955). Agron. J. 47 : 213.
WAITE, R. (1963). Agric. Prog. XXXVIII : 1.
WAITE, R. and BOYD, J. (1953). J. Sci. Fd. Agric. 4 : 197.
WALDO, D.R. (1968). J. Dairy Sci. 51 : 265.
WALLACE, L.R. (1956). Proc. 7th Int. Grassl Cong. p. 134.
WALLACE, L.R. (1961). N.Z. Soc. Anim. Prod. p. 64.
WARD, H.K. (1968). Rhodesia Agric. J. 65 : 139.
WARNER, A.C.I. (1964). Nut Abst. Rev. 34 : 339.
WARREN, L.E. (1954). Proc. Amer. Soc. Sug. Beet Technol. 8 : 124-9.
WATKINS, W.E. and KEARNS, J.V. (1956). J. Anim. Sci. 15 : 153.
WATSON, C.J., DAVIDSON, W.M., KENNEDY, J.W., ROBINSON, C.H. and MUIR, G.W. (1948). Sci. Agric. 28 : 357.
WEINMANN, H. (1948). J. Brit. Grassl. Soc. 3 : 115.
WEINMANN, H. (1952). Proc. 6th Int. Grassl. Cong. 1 : 655.
WELLER, R.A., GRAY, F.V., PILGRIM, A.F. and JONES, G.B. (1967). Aust. J. Agric. Res. 18 : 107.

WESTON, R.H. (1959). Aust. J. Agric. Res. 10 : 865.

WILLIAMS, C.H., DAVID, D.J. and JISMAA, U. (1962). J. Agric. Sci. 59 : 381.

WILSON, G.F. (1966). N.Z. J. Agric. Res. 9 : 1053.

WILSON, G.F. (1969). Ph.D. Thesis, Massey University.

WILSON, G.F. and McDOWALL, F.H. (1966). N.Z. J. Agric. Res. 9 : 1042.

WILSON, G.F., DAVEY, A.W.F. and DOLBY, R.M. (1967). N.Z. J. Agric. Res. 10 : 215.

WILSON, R.K. and McCARRICK, R.B. (1966). Proc. X Int. Grassl. Cong. p. 371.

WILSON, R.K. and McCARRICK, R.B. (1967). Irish J. Agric. Res. 6 : 267.

APPENDIX 1.

Changes in dry matter yields and heights of Japanese Millet at various stages of growth

STAGE OF MATURITY	DRY MATTER YIELD kg / HECTARE	C.V %+	HEIGHT (cm) AVERAGE	RANGE
FIRST GROWTH				
EARLY LEAF	664 (49.17)	7.39	27.5	25 - 30
EARLY LEAF	1920 (101.11)	5.30	43.0	40 - 46
IMMATURE	3344 (245.28)	7.33	66.0	60 - 72
IMMATURE	4822 (134.72)	2.79	86.0	81 - 91
PRE BLOOM	6081 (407.50)	6.70	107.0	102 - 112
PRE BLOOM	6561 (623.89)	9.51	117.0	112 - 122
EARLY BLOOM	9917 (72.22)	0.73	127.0	122 - 132
MID BLOOM	10372 (770.56)	7.43	127.0	122 - 132
FULL BLOOM	16344 (403.06)	2.47	127.0	122 - 132
REGROWTH				
EARLY LEAF	947 (105.83)	11.57	15.0	10 - 20
IMMATURE	1581 (151.94)	9.61	38.0	36 - 40
PRE BLOOM	1667 (176.94)	10.61	43.5	41 - 46
EARLY BLOOM	3420 (313.61)	9.17	58.5	56 - 61
EARLY BLOOM	5889 (391.94)	6.66	68.5	66 - 71
MID BLOOM	6001 (255.28)	4.25	68.5	66 - 71

+ Coefficient of variation

APPENDIX 2.

CHEMICAL COMPOSITION OF JAPANESE MILLET

FIRST GROWTH

WEEK AFTER SOWING	DRY MATTER %	ORGANIC MATTER %	C. PROTEIN (N x 6.25) %	C.V.%	CRUDE FIBRE %	C.V.%	ETHER EXTRACTS %	C.V.%	SOLUBLE CARBOHID. %	C.V.%
4	10.14	82.66	31.34 (0.07)*	0.22	17.66 (0.13)	0.74	7.04 (0.11)	1.63	17.82 (0.19)	1.07
5	10.06	84.38	22.28 (0.08)	0.36	21.46 (0.43)	2.00	4.54 (0.14)	3.19	20.39 (0.43)	2.11
6	11.61	85.04	19.19 (0.12)	0.63	23.97 (0.22)	0.92	3.85 (0.09)	2.46	29.69 (0.50)	1.67
7	11.74	85.59	17.33 (0.04)	0.26	24.65 (0.17)	0.71	3.76 (0.13)	3.46	25.43 (0.71)	2.79
8	14.81	86.72	15.30 (0.09)	0.59	26.65 (0.27)	1.01	3.35 (0.10)	2.99	7.58 (0.24)	3.23
9	16.77	87.31	14.45 (0.05)	0.38	27.15 (0.05)	0.20	3.16 (0.08)	2.53	8.22 (0.25)	3.10
10	17.52	87.89	10.72 (0.30)	2.80	33.96 (0.20)	0.60	2.95 (0.08)	2.88	6.50 (0.22)	3.46
11	19.46	89.26	9.60 (0.12)	1.30	34.08 (0.27)	0.81	2.65 (0.06)	2.45	8.80 (0.32)	3.64
12	21.40	89.43	6.56 (0.08)	1.22	39.70 (0.15)	0.39	2.28 (0.07)	2.43	8.02 (0.11)	1.37
REGROWTH WEEK AFTER CUTTING										
1	13.98	83.56	17.89 (0.10)	0.59	28.70 (0.34)	1.20	2.90 (0.07)	2.58	2.56 (0.18)	7.22
2	17.02	86.80	18.44 (0.12)	0.65	20.70 (0.15)	0.72	5.33 (0.13)	2.53	7.47 (0.12)	1.61
3	16.53	87.55	16.90 (0.14)	0.86	23.30 (0.31)	1.33	3.43 (0.09)	2.62	5.89 (0.10)	1.70
4	14.68	88.17	13.57 (0.12)	0.88	27.62 (0.25	0.91	3.21 (0.06)	1.87	4.23 (0.12)	2.95
5	19.73	88.33	12.93 (0.18)	1.43	31.19 (0.14)	0.45	2.81 (0.09)	3.37	6.59 (0.39)	5.92
6	18.90	88.58	10.39 (0.17)	1.68	34.31 (0.15)	0.44	2.46 (0.04)	1.63	9.44 (0.38)	4.03

* Standard error of means.

APPENDIX 3.

Chemical composition of pasture and Japanese Millet during the animal trial

FEED	PERIOD	D.M. %	ASH %	C.PROTEIN %	C.V.%	CRUDE FIBRE %	C.V.%	E. EXTRACTS %	C.V.%	S. CARBOHYD. %	C.V.%	NITR.-FREE-EXT. %	C.V.%
PASTURE	I	37.52	7.25	12.15 (0.05)*	0.41	31.92 (0.02)	0.08	3.97 (0.11)	2.77	10.40 (0.35)	3.34	44.71 (0.13)	0.29
	II	23.63	8.98	19.65 (0.01)	0.07	27.21 (0.60)	2.21	5.12 (0.13)	2.54	8.74 (0.17)	1.95	39.40 (0.48)	1.24
	III	28.14	8.99	16.62 (0.01)	0.03	30.03 (0.15)	0.52	4.68 (0.04)	0.85	9.27 (0.15)	1.62	39.68 (0.19)	0.48
	IV	21.15	11.63	22.71 (0.03)	0.15	22.50 (0.32)	1.42	5.89 (0.22)	3.74	9.56 (0.08)	0.84	37.27 (0.50)	1.35
	V	22.41	10.06	22.95 (0.07)	0.31	21.22 (0.08)	0.40	5.94 (0.23)	3.87	11.87 (0.22)	1.89	39.83 (0.24)	0.61
J. MILLET	II	13.01	13.00	19.32 (0.03)	0.16	27.85 (0.18)	0.65	3.94 (0.03)	0.88	4.43 (0.05)	1.13	35.89 (0.20)	0.57
	III	16.06	12.05	14.05 (0.07)	0.50	31.03 (0.08)	0.27	3.79 (0.15)	3.96	6.33 (0.12)	1.90	39.08 (0.16)	0.42
	IV	16.33	10.84	9.81 (0.07)	0.71	34.25 (0.73)	2.13	2.78 (0.06)	2.16	7.45 (0.24)	3.22	42.32 (0.72)	1.70

* Standard error of mean .

APPENDIX 4.

Chemical composition of material offered and consumed by sheep.

		ORGANIC MATTER %		CRUDE PROTEIN %		CRUDE FIBRE %	
		OFFERED	CONSUMED	OFFERED	CONSUMED	OFFERED	CONSUMED
PASTURE	I+	92.8	92.8	12.2	12.2	31.9	31.9
	II	91.0	90.3	19.7	22.8	27.2	22.0
	III	91.0	92.0	16.6	17.6	30.0	28.6
	IV	88.4	88.5	22.7	23.2	22.5	22.1
	V	89.9	89.9	23.0	23.3	21.2	20.7
J. MILLET	II	87.0	87.3	19.3	19.9	27.9	27.2
	III	88.0	88.1	14.1	16.5	31.0	28.6
	IV	89.2	89.4	9.8	10.9	34.2	30.5

\+ Experimental Periods.

APPENDIX 5.

Analysis of variance of rumen VFA concentrations

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCE ESTIMATES	% of TOTAL
Periods (P)	3	7.4931	P < 0.05	1.3728	1.56
Treatments (T)	1	107.1570	P < 0.001	52.5775	59.56
Time (H)	2	82.3453	P < 0.001	26.7811	30.34
P x T	3	10.4302	P < 0.01	1.0535	1.19
P x H	6	5.4684	P < 0.05	0.2889	0.33
T x H	2	26.5564	P < 0.001	4.0924	4.64
P x T x H	6	4.5517	P < 0.05	0.1062	0.12
Residual	121	2.0021		2.0021	2.27
Total	143	4.7629			

Analyses of variance of rumen VFA concentrations within periods

(MEAN SQUARES)

SOURCES	d.f.	PERIOD I		PERIOD II		PERIOD III		PERIOD IV	
Treatment(T)	1	1.3225	NS	26.1462	***	29.0165	***	81.9628	***
Time(H)	2	24.4204	***	17.0542	**	9.0025	***	48.2735	***
T x H	2	1.5555	NS	1.8310	NS	11.6107	***	28.9740	***
Residual	30	2.6582		2.7785		0.9630		1.4246	
Total	35	3.8006		4.2078		2.8324		7.9770	

NS = P > 0.10

** = P < 0.01

*** = P < 0.001

APPENDIX 6.

Analysis of variance of rumen ammonia concentrations

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCE ESTIMATES	% of TOTAL
Periods(P)	3	876.6548	P < 0.001	23.64	16.7
Treatments(T)	1	2536.7172	P < 0.001	34.88	24.7
Times(H)	2	804.4254	P < 0.001	16.23	11.5
P x T	3	628.0614	P < 0.001	16.74	11.8
P x H	6	200.0836	P < 0.001	14.56	10.3
T x H	2	180.6417	P < 0.001	6.47	4.6
P x T x H	6	45.5529	P > 0.10	3.36	2.4
Residual	121	25.4114		25.41	18.0
Total	143	94.8923			

Analyses of Variance of rumen ammonia concentrations within Periods

(MEAN SQUARES)

SOURCES	d.f.	PERIOD I		PERIOD II		PERIOD III		PERIOD IV	
Treatments(T)	1	5.5775	NS	103.8700	*	872.2178	***	3439.2360	***
Time (H)	2	60.1287	NS	94.6912	*	150.2471	*	922.7967	***
T x H	2	2.7411	NS	32.9413	NS	101.8717	+	356.5587	**
Residual	30	26.9451		15.7561		25.6939		34.0977	
Total	35	26.8477		23.7663		61.3506		200.5965	

NS = P > 0.10
\+ = P < 0.10
* = P < 0.05
** = P < 0.01
*** = P < 0.001

APPENDIX 7.

Analysis of regression of rumen liquor ammonia concentration on crude protein content, digestible crude protein content and intake of crude protein on sheep.

PASTURE

Independent variable	SOURCE	d.f.	M.S.	F_{ratio}	PROBAB.	$\hat{r}$	$\hat{b} \pm S.E.$
CRUDE PROTEIN CONTENT	Linear regression	1	553.1277	16.4758	P < 0.001	0.7476	1.4623
	Residual	13	33.5722				(±0.3603)
	Total	14	70.6833				
DIGESTIBLE CRUDE PROTEIN	Linear regression	1	409.0018	9.1584	P < 0.01	0.6429	1.0709
	Residual	13	44.6588				(±0.3539)
	Total	14	70.6833				
INTAKE CRUDE PROTEIN	Linear regression	1	660.6033	26.1057	P < 0.001	0.8170	0.1797
	Residual	13	25.3049				(±0.1268)
	Total	14	70.6833				

JAPANESE MILLET

Independent variable	SOURCE	d.f.	M.S.	F_{ratio}	PROBAB.	$\hat{r}$	$\hat{b} \pm S.E.$
CRUDE PROTEIN CONTENT	Linear regression	1	8.0911	1.2023	P > 0.10	- 0.3829	-0.2437
	Residual	7	6.7295				(±0.2223)
	Total	8	6.8997				
DIGESTIBLE CRUDE PROTEIN	Linear regression	1	22.7254	4.8998	P > 0.10	- 0.6416	-0.1953
	Residual	7	4.6389				(±0.0882)
	Total	8	6.8997				
INTAKE CRUDE PROTEIN	Linear regression	1	18.3841	3.4957	P > 0.10	- 0.5771	-0.0454
	Residual	7	5.2590				(±0.0640)
	Total	8	6.8997				

APPENDIX 8.

ANALYSIS OF VARIANCE OF COW LIVE WEIGHTS

SOURCE	D.F.	M. S.	PROBABILITY	VARIANCES	
				ESTIMATE	% OF TOTAL
TOTAL+	53	14821.4231			
TREATMENTS	1	115.5740	P > 0.10	1.2988	0.006
PERIODS	4	64.7269	P > 0.10	0.	0.
COWS	12	64786.7800	P < 0.001	21568.7580	99.62
RESIDUAL	36	80.5060		80.5060	0.37

\+ Analysis was made using individual weighings in lb .

APPENDIX 9.

Analysis of Covariance of body weights adjusted for differences during the Preliminary Period - Total experimental period.

SOURCE	d.f.	Σy^2	$\hat{b}$	DEVIATIONS FROM REGRESSION d.f.	S.S.	M.S.
Treatments	1	12.8480				
Error	4	86410.6879	0.9417	3	422.4084	140.8028
TOTAL+	5	86423.5359	0.9413	4	489.2194	122.3049
Differences between residuals				1	66.8110	66.8110
Between treatments $F_{1,3} = 0.47$ $P > 0.10$						

Adjusted means (kg) after analysis of covariance

Japanese Millet	336 (± 4.37)	99.35 % reduction of variance
Pasture	339 (± 4.37)	

Analysis of error of variance

(Regression of body weight during 3 experimental period on body weight during Preliminary Period)

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
Due to regression	1	85988.2795	85988.2795	611.3353	$P < 0.001$
Residual	3	422.4084	140.8028		
Total+	4	86410.6879			

+ Data used for covariance analysis were cow means (during 3 periods) expressed in lbs.

APPENDIX 10.

Analysis of Covariance of body weight during Period II adjusted for differences during Preliminary Period

SOURCE	d.f.	$\sum y^2$	$\hat{b}$	DEVIATIONS FROM REGRESSION d.f.	S.S.	M.S.
Treatments	1	29.6148				
Error	4	84042.1059	0.9289	3	376.5415	125.5138
TOTAL+	5	84071.7207	0.9289	4	380.0298	95.0075
Differences between residuals				1	3.4883	3.4883
Between treatments $F_{1,3} = 0.0278$ $P > 0.10$						

Adjusted means (kg) after analysis of covariance

Japanese Millet	338 (± 4.13)	99.40 % reduction of variance
Pasture	338 (± 4.13)	

Analysis of error of variance

(Regression of body weight during Period II on body weight during Preliminary Period)

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
Due to regression	1	83665.5644	83665.5644	665.5262	$P < 0.001$
Residual	3	376.5415	125.5138		
Total+	4	84042.1059			

+ Data used for covariance analysis were cow means expressed in lbs.

APPENDIX 11.

Analysis of Covariance of body weight during Period III adjusted for differences during Preliminary Period

SOURCE	d.f.	$\sum y^2$	$\hat{b}$	DEVIATIONS FROM REGRESSION		
				d.f.	S.S.	M.S.
Treatments	1	474.1926				
Error	4	90766.6630	0.8873	3	14429.5696	4809.8565
TOTAL+	5	91240.8556	0.8859	4	15123.9142	3780.9786
Differences between residuals				1	694.3446	694.3446
Between treatments				$F_{1,3}$ = 0.14		$P > 0.10$

Adjusted means (kg) after analysis of covariance

Japanese Millet	334 (±25.62)	78.80 % reduction of variance
Pasture	343 (±25.62)	

Analysis of error of variance

(Regression of body weight during Period III on body weight during Preliminary Period)

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
Due to regression	1	76337.0934	76337.0934	15.8670	$P < 0.05$
Residual	3	14429.5696	4809.8565		
Total+	4	90766.6630			

+ Data used for covariance analysis were cow means expressed in lbs.

APPENDIX 12.

Analysis of Covariance of body weight during Period IV adjusted for differences during Preliminary Period

SOURCE	d.f.	$\sum y^2$	$\hat{b}$	DEVIATIONS FROM REGRESSION		
				d.f.	S.S.	M.S.
Treatments	1	31.1448				
Error	4	84769.7185	0.9309	3	739.8355	246.6118
Total+	5	84800.8633	0.9310	4	735.1001	183.7750
Differences between residuals				1	4.7354	4.7354
Between treatments $F_{1,3} = 0.02$ $P > 0.10$						

Adjusted means (kg) after analysis of covariance

Japanese Millet	336 ($\pm$ 5.79)	98.84 % reduction of variance
Pasture	336 ($\pm$ 5.79)	

Analysis of error of variance

(Regression of body weight during Period IV on body weight during Preliminary Period)

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
Due to regression	1	84029.8830	84029.8830	342.1624	$P < 0.001$
Residual	3	739.8355	246.6118		
Total+	4	84769.7185			

+ Data used for covariance analysis were cow means expressed in lbs.

APPENDIX 13.

Comparison of D.O.M. Intake as determined by the two faecal sampling methods

PASTURE

$\hat{r} = 0.9481$ $\hat{b} = 0.7047 \pm 0.1098$ $Y = 0.7047\,x + 3.0940$

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBAB.
Linear regression	1	17.2528	17.2528	26.6494	$P < 0.05$
Residual	3	1.9423	0.6474		
Total	4	19.1951			

JAPANESE MILLET

$\hat{r} = 0.5993$ $\hat{b} = 0.1843 \pm 2.4629$ $Y = 0.1843\,x + 7.9909$

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBAB.
Linear regression	1	0.4107	0.4107	1.7872	$P > 0.10$
Residual	1	0.7340	0.7340		
Total	2	1.1447			

TOTAL

$\hat{r} = 0.8899$ $\hat{b} = 0.8129 \pm 0.2603$ $Y = 0.8129\,x + 1.0943$

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBAB.
Linear regression	1	25.5367	25.5367	11.6863	$P < 0.05$
Residual	6	13.1090	2.1848		
Total	7	38.6457			

APPENDIX 14.

Regressions of 'grab' sampling on 'sward' sampling

Comparison of regressions for pasture and Japanese Millet.

SOURCE	$\sum x^2$	$\sum xy$	$\sum y^2$	$\hat{b}$	RSS	d.f.	RMS
Japanese Millet	0.1210	0.2230	1.4447	1.8430	1.0340	1	1.0340
Pasture	34.7451	24.4837	19.1951	0.7047	1.9423	3	0.6474
			POOLED RESIDUALS		2.9763	4	0.7441
Pooled within	34.8661	24.7067	20.6398	0.7086	3.1322	5	
			BETWEEN SLOPES		0.1559	1	0.1559
					$F_{1,4} = 0.2095$	$P > 0.10$	

APPENDIX 15.

Regressions of D.O.M. Intake (g / kg L.W.$^{0.75}$) on soluble carbohydrates.

PASTURE

$\hat{r} = 0.9788$ $\hat{b} = 21.4874 \pm 2.5951$ $Y = 21.4874\ x - 52.4443$

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
Linear regression	1	2788.7627	2788.7627	68.5552	$P < 0.01$
Residual	3	122.0373	40.6791		
Total	4	2910.8000			

JAPANESE MILLET

$\hat{r} = -0.9683$ $\hat{b} = -5.1656 \pm 1.3326$ $Y = 162.0219 - 5.1656\ x$

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
Linear regression	1	124.3878	124.3878	15.0247	$P > 0.10$
Residual	1	8.2789	8.2789		
Total	2	132.6667			

APPENDIX 16.

Relationships between D.O.M. Intake (g / kg $L.W.^{0.75}$) and digestibilities.

PASTURE

DIGESTIBLE DRY MATTER %

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Linear regression	1	2535.6554	20.2774	P< 0.05
Residual	3	125.0482		
Total	4	730.2000		

$\hat{r} = 0.9333$ $\hat{b} = 3.9181 \pm 0.8700$

DIGESTIBLE CRUDE FIBRE %

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Linear regression	1	2357.1945	12.7737	P< 0.01
Residual	3	184.5352		
Total	4	730.2000		

$\hat{r} = 0.8999$ $\hat{b} = 1.5620 \pm 0.4370$

JAPANESE MILLET

DIGESTIBLE DRY MATTER %

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Linear regression	1	97.2228	2.7430	P> 0.10
Residual	1	35.4439		
Total	2	66.3333		

$\hat{r} = 0.8561$ $\hat{b} = 1.5902 \pm 0.9601$

DIGESTIBLE CRUDE FIBRE %

SOURCE	d.f.	M.S.	F_{ratio}	Probability
Linear regression	1	52.7714	0.6605	P >0.10
Residual	1	79.8953		
Total	2	66.3333		

$\hat{r} = 0.6307$ $\hat{b} = 1.1847 \pm 1.4577$

APPENDIX 16.
(continuation)

TOTAL

	SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
DIGESTIBLE	Linear regression	1	6521.9224	44.1238	$P < 0.001$
DRY MATTER %	Residual	8	147.8097		
	Total	9	856.0400		

$\hat{r} = 0.9201$ $\hat{b} = 4.3455 \pm 0.6542$

	SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
DIGESTIBLE	Linear regression	1	3912.4248	8.2541	$P < 0.05$
CRUDE FIBRE %	Residual	8	473.9969		
	Total	9	856.0400		

$\hat{r} = 0.7126$ $\hat{b} = 1.7557 \pm 0.6111$

APPENDIX 17.

Regressions of D.O.M. intake on digestible D.M. % and D.O.M. intake on digestible crude fibre % . Comparison of regressions of pasture and Japanese Millet.

A - D.O.M.I. (g/kgL.W.$^{0.75}$) on Dig.D.M.% .

SOURCE	Σx^2	Σxy	Σy^2	$\hat{b}$	RSS	d.f.	RMS
Japanese Millet	38.4488	61.1400	132.6667	1.5902	35.4439	1	35.4439
Pasture	165.1789	647.1760	2910.8000	3.9180	375.1446	3	125.0482
			POOLED RESIDUAL		410.5885	4	102.6471
Pooled Within	203.6271	708.3160	3043.4667	3.4785	579.5998	5	115.9200
			BETWEEN SLOPES		169.0113	1	169.0113
					$F_{1,4}$ = 1.6568		$P > 0.10$

B - D.O.M.I. (g/kg L.W.$^{0.75}$) on Dig.Crude Fibre % .

SOURCE	Σx^2	Σxy	Σy^2	$\hat{b}$	RSS	d.f.	RMS
Japanese Millet	37.5981	44.5433	132.6667	1.1847	79.8953	1	79.8953
Pasture	966.1223	1509.0860	2910.8000	1.5620	553.6030	3	184.5343
			POOLED RESIDUAL		633.4983	4	158.3746
Pooled Within	1003.7204	1553.6293	3043.4667	1.5479	638.6496	5	127.7299
			BETWEEN SLOPES		5.1513	1	5.1513
					$F_{1,4}$ = 0.0325		$P > 0.10$

APPENDIX 18.

A) Analysis of Variance of Milk Yield* during Periods II, III, and IV.

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCES ESTIMATE	% OF TOTAL
Treatment (T)	1	11.6434	NS	0	0
Period (P)	2	8.5468	NS	0	0
T x P (TP)	2	9.5800	NS	0	0
Residual	12	19.5852		19.5852	100
Total	17	16.6423			

B) Analysis of Variance for Milk Yield* during Period I (Preliminary Period).

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCES ESTIMATE	% OF TOTAL
Treatments (T)	1	0.1293	NS	0	0
Residual	4	25.7258		25.7258	100
Total	5	20.6065			

C) Analysis of Residuals of Y (Periods II, III and IV) after fitting Regression on Preliminary Period.

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Treatment (T)	1	15.5953	46.783	$P < 0.001$
Period (P)	2	8.5469	25.639	$P < 0.001$
P x T	2	9.5803	28.739	$P < 0.001$
Residual	11	0.3333		
Total	16	3.4698	(Reduction in Variance) 98.30 %	

* Analysis was made using mean (cow x period x treatment) milk yields in lb.

NS = $P > 0.10$

APPENDIX 19.

Analyses of milk yield within periods

ANALYSIS OF VARIANCE

SOURCES	PERIOD II			PERIOD III			PERIOD IV			PERIOD V		
	d.f.	MS	% tot.Var.	d.f.	MS	% tot.Var.	d.f.	MS	%tot.Var.	d.f.	MS	% tot.Var.
Treatments	1	0.3711 NS	0	1	1.2476 NS	0	1	29.1853 NS	25.96	1	28.4186 NS	11.16
Residuals	4	21.6996	100	4	19.8989	100	4	17.1570	74.04	4	22.7116	88.84
Total	5	17.4339		5	16.1687		5	19.5627		5	23.8530	

NS = $P > 0.10$

ANALYSIS OF RESIDUALS AFTER COVARIANCE

SOURCES	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.
Treatments	1	0.0792	$P > 0.10$	1	2.0478	$P < 0.10$	1	32.3807	$P < 0.001$	1	32.0463	$P < 0.01$
Residual	3	0.4876		3	0.2342		3	0.3248		3	0.7724	
Total	4	0.3855		4	0.6876		4	8.3387		4	8.5909	

APPENDIX 20.

A) Analysis of Variance of FCM Yields* during Periods II, III and IV.

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCE ESTIMATE	% OF TOTAL
Treatment(T)	1	30.2170	NS	0	0
Period(P)	2	6.4990	NS	0	0
T x P (TP)	2	16.0775	NS	0	0
Residual	12	32.0183		32.0183	100
Total	17	27.0346			

B) Analysis of Variance for FCM* during Period I (Preliminary Period).

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCE ESTIMATE	% OF TOTAL
Treatment (T)	1	0.0157	NS	0	0
Residual	4	42.2675		42.2675	100
Total	5	33.8171			

C) Analysis of Residual of Y (Periods II, III, and IV) after fitting regression on Preliminary Period.

SOURCE	d.f.	M.S.	F_{ratio}	Probability
Treatment (T)	1	28.1894	52.964	$P < 0.001$
Period (P)	2	6.4990	12.210	$P < 0.01$
T x P (TP)	2	16.0771	30.206	$P < 0.001$
Residual	11	0.5322	(Reduction in Variance) 98.34 %	
Total	16	4.9498		

* Analysis was made using mean (cow x treatment x period) FCM yields in lb.
NS = $P > 0.10$

APPENDIX 21.

ANALYSIS OF FCM YIELD WITHIN PERIODS

ANALYSIS OF VARIANCE

SOURCES	PERIOD II			PERIOD III			PERIOD IV			PERIOD V		
	d.f.	M.S.	% Tot.Var.	d.f.	M.S.	% Tot.Var.	d.f.	M.S.	% Tot.Var.	d.f.	M.S.	%Tot.Var.
Treatment	1	0.0071 NS	-	1	3.8161 NS	-	1	58.5499 NS	-	1	31.5197 NS	-
Residual	4	31.6083	100	4	33.7584	100	4	30.6880	100	4	36.2021	100
Total	5	25.2881		5	27.7699		5	36.2604		5	35.2656	

ANALYSIS OF REGRESSION Y AFTER FITTING REGRESSION ON X

SOURCES	PERIOD II			PERIOD III			PERIOD IV			PERIOD V		
	D.f.	M.S.	PROB.	d.f.	M.S.	PROB.	d.f.	M.S.	PROB.	d.f.	M.S.	PROB.
Treatments	1	0.0365	NS	1	3.3915	*	1	56.9348	***	1	30.2348	**
Residual	3	1.0611		3	0.1482		3	0.6716		3	0.5112	
Total	4	0.8049		4	0.9590		4	14.7374		4	7.9421	

NS = P > 0.1o   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

APPENDIX 22.

Comparison of multiple regression relationships for pasture and Japanese Millet fed animals.

To test if there were significant differences in the relationships between the dependant and independant variables for the two sets of data (one from each treatment), a comparison of variances residual to that explained by the regressions, was performed. The procedure is analogous to comparisons of two o more linear regressions as used earlier (intake, digestibility, chemical components; see Section 3.3.3.2) and as part of an analysis of covariance (Currie, *pers. comm.*).

For each treatment group, total variance (n - 1 d.f.) was partitioned into that associated with regression on x_1 and x_2 (2 d.f.) and the residual (n - 3 d.f.). Residual sums of squares and their corresponding d.f. were added (Pooled Residuals). Sums of squares and products ($\sum y^2, \sum x_1^2, \sum x_2^2, \sum yx_1, \sum yx_2, \sum x_1x_2$) and total d.f. were added for the 2 treatment groups giving statistics for computing the Pooled within regression. Deviation sums of squares after fitting this multiple regression were compared with the Pooled Residuals above. Differences between regressions were tested using the F ratio of $\frac{\text{Pooled within Residual MS}}{\text{Pooled Residual MS}}$. These analyses are shown in the following Table A and B .

TABLE A.

Comparison of multiple regressions for pasture and Japanese Millet

(Y = FCM , x_1 = L.W.$^{0.75}$, x_2 = D.O.M.I.)

SOURCE	$\sum y^2$	$\sum x_1^2$	$\sum x_2^2$	$\sum x_1y$	$\sum x_2y$	$\sum x_1x_2$	Reg.SS	Dev.SS	d.f.	Dev.MS
Pasture	94.83	1450.52	140.60	338.57	90.25	312.59	83.10	11.72	12	0.97
Japanese Millet	37.11	788.27	34.20	142.13	27.86	143.32	26.13	10.99	6	1.83
					POOLED RESIDUALS			22.71	18	1.26
Pooled within	131.95	2238.80	174.80	480.70	118.12	455.92	103.16	28.79	20	1.44
					BETWEEN SLOPES			6.08	2	3.04
							F = 2.4097	P > 0.10		

TABLE B.

Comparison of multiple regressions for pasture and Japanese Millet

(Y = FCM , x_1 = O.M.I. , x_2 = D.O.M.%)

Pasture	94.83	152.06	520.22	92.95	45.09	163.02	65.43	29.40	12	2.45
Japanese Millet	37.11	33.68	103.96	28.49	26.44	15.44	25.94	11.17	6	1.86
					POOLED RESIDUALS			40.57	18	7.81
Pooled within	131.95	185.74	624.18	121.43	71.53	178.46	83.89	48.05	20	2.40
					BETWEEN SLOPES			7.48	2	3.74
							F = 0.4792	P > 0.10		

APPENDIX 23.

MULTIPLE REGRESSION ANALYSIS

F C M – L.W.$^{0.75}$ – D.O.M.I.

Total data from Pasture and Japanese Millet.

$\hat{b}_1 = 0.1714$ $\hat{b}_2 = 0.3651$

ANALYSIS OF VARIANCE

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBAB.	C.M.D.+
Total	29	174.6751				
x_1 and x_2	2	161.2202	80.6101	161.7702	$P < 0.001$	92.30 %
Residual	27	13.4549	0.4983			

TEST OF EACH x AFTER THE EFFECT OF THE OTHER HAS BEEN REMOVED

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
x_1 and x_2	2	161.2202			
x_1 alone	1	127.9511			
x_2 after x_1	1	33.2691	33.2691	66.7652	$P < 0.001$
x_1 and x_2	2	161.2202			
x_2 alone	1	89.4309			
x_1 after x_2	1	71.7893	71.7893	144.0684	$P < 0.001$
DEVIATION	27	13.4549	0.4983		

+ Coefficient of multiple determination

APPENDIX 24.

MULTIPLE REGRESSION ANALYSIS

F C M - O.M.I. - D.O.M.

Total data from Pasture and Japanese Millet.

$\hat{b}_1 = 0.5303$ $\hat{b}_2 = -0.0108$

ANALISIS OF VARIANCE

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBAB.	C.M.D.+
Total	29	174.6751				
x_1 and x_2	2	89.3855	44.6828	14.1482	P<0.01	51.17 %
Residual	27	85.2896	3.1589			

TEST OF EACH x AFTER THE EFFECT OF THE OTHER HAS BEEN REMOVED

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
x_1 and x_2	2	89.3855			
x_1 alone	1	88.2479			
x_2 after x_1	1	1.1376	1.1376	0.3601	P > 0.10
x_1 and x_2	2	89.3855			
x_2 alone	1	0.7792			
x_1 after x_2	1	88.6063	88.6063	28.0497	P < 0.001
DEVIATION	27	85.2896			

+ Coefficient multiple determination.

APPENDIX 25.

Analysis of Variance of fat, protein and lactose yields* during Periods II, III and IV.

FAT YIELD

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCES ESTIMATE	VARIANCES % OF TOTAL
Treatment (T)	1	7.5869	$P > 0.10$	0.2634	3.60
Period (P)	2	0.8502	$P > 0.10$	0	0
T x P (TP)	2	3.4159	$P > 0.10$	0	0
Residual	12	7.0602		7.0602	96.40
Total	17	5.9318			

PROTEIN YIELD

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCES ESTIMATE	VARIANCES % OF TOTAL
Treatment (T)	1	2.8968	$P > 0.10$	0	0
Period (P)	2	0.9314	$P > 0.10$	0	0
T x P (TP)	2	1.6822	$P > 0.10$	0	0
Residual	12	4.2358		4.2358	100
Total	17	3.4679			

LACTOSE YIELD

SOURCE	d.f.	M.S.	PROBABILITY	VARIANCES ESTIMATE	VARIANCES % OF TOTAL
Treatment (T)	1	3.6622	$P > 0.10$	0	0
Period (P)	2	2.4475	$P > 0.10$	0	0
T x P (TP)	2	2.2967	$P > 0.1o$	0	0
Residual	12	4.2678		4.2678	100
Total	17	3.7861			

* Analysis was made using mean(cow x period x treatment) yields in lb.

APPENDIX 26.

Analysis of Variance of Fat, Protein and Lactose Yields* during Preliminary Period.

FAT YIELDS

SOURCE	d.f.	S.S.	M.S.	F_{ratio}	PROBABILITY
Total	5	37.5935	7.5187		
Treatment	1	0.0321	0.0321	0.0034	P > 0.10
Residual	4	37.5614	9.3904		

PROTEIN YIELDS

Total	5	20.8255	4.1651		
Treatment	1	0.0034	0.0034	0.0006	P > 0.10
Residual	4	20.8221	5.2055		

LACTOSE YIELDS

Total	5	23.4915	4.6983		
Treatment	1	0.0852	0.0852	0.0146	P >0.10
Residual	4	23.4063	5.8516		

* Mean (cow x period x treatment) yields were in lb.

APPENDIX 27.

Analysis of Residual of Y (fat,protein and lactose yield) after fitting regression on x. Analysis of periods II, III and IV corrected using Preliminary Period as covariable.

FAT YIELD

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Total[+]	16	1.017588		
Treatment	1	6.183678	43.450	$P < 0.001$
Period	2	0.850186	5.973	$P < 0.05$
T x P	2	3.415950	24.002	$P < 0.001$
Residual	11	0.142314		

Comparison of adjusted means (kg fat/ day)

PERIOD	PASTURE	JAPANESE MILLET	PROBABILITY
II	0.530 (0.099)[@] [*]	0.527 (0.099) bc	$P > 0.10$
III	0.509 (0.099) a	0.478 (0.099) b	$P < 0.05$
IV	0.566 (0.099) a	0.436 (0.099) c	$P < 0.001$

PROTEIN YIELD

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Total[+]	16	0.547970		
Treatment	1	2.598991	30.367	$P < 0.001$
Period	2	0.931529	10.884	$P < 0.01$
T x P	2	1.682021	19.653	$P < 0.01$
Residual	11	0.085585		

Comparison of adjusted means (kg protein/ day)

PERIOD	PASTURE	JAPANESE MILLET	PROBABILITY
II	0.368 (0.077)[@] [*]	0.372 (0.077) bc	$P > 0.05$
III	0.344 (0.077) a	0.325 (0.077) b	$P < 0.05$
IV	0.397 (0.077) a	0.308 (0.077) c	$P < 0.001$

APPENDIX 27.

(Continuation)

LACTOSE YIELD

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Total+	16	1.003557		
Treatment	1	5.459329	54.135	$P < 0.001$
Period	2	2.447400	24.268	$P < 0.001$
T x P	2	2.296749	22.775	$P < 0.001$
Residual	11	0.100845		

Comparison of adjusted means (kg lactose/ day)

PERIOD	PASTURE	JAPANESE MILLET	PROBABILITY
II	0.518 (0.083)@	0.515 (0.083) bc	$P > 0.10$
III	0.483 (0.083) a *	0.447 (0.083) b	$P < 0.01$
IV	0.524 (0.083) a	0.412 (0.083) c	$P < 0.001$

+ Analyses were made using means (cows x treatment x period) yiels in lb.

* Means denoted by common letters are significantly ($P < 0.05$) differents.

@ Standard error of adjusted mean.

APPENDIX 28.

Analyses of variance and analyses of residuals of Y after regression on within period basis fat, protein and lactose yield.

FAT YIELD

ANALYSIS OF VARIANCE

SOURCE	PERIOD II			PERIOD III			PERIOD IV			PERIOD V		
	d.f.	MS	% tot.Var.	d.f.	MS	% tot.Var.	d.f.	MS	% tot.Var.	d.f.	MS	% tot.Var.
Treatments	1	0.0071 NS	0	1	1.0094 NS	0	1	13.3982 NS	31.85	1	5.3865 NS	0
Residual	4	31.6083	100	4	7.6341	100	4	6.9247	68.15	4	8.1352	100
Total	5	25.2881		5	6.3092		5	8.2194		5	7.5855	

NS = P > 0.10

ANALYSIS OF RESIDUAL AFTER COVARIANCE

SOURCE	d.f.	MS	PROBAB	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.
Treatments	1	0.0018	P>0.10	1	0.7105	P<0.01	1	12.2982	P <0.01	1	4.6392	P < 0.01
Residual	3	0.2411		3	0.0176		3	0.2280		3	0.0924	
Total	4	0.1812		4	0.1908		4	3.2455		4	1.2291	

PROTEIN YIELD

ANALYSIS OF VARIANCE

SOURCE	d.f.	MS	% tot.Var.	d.f.	MS	% tot.Var.	d.f.	MS	% tot.Var.	d.f.	MS	% tot.Var.
Treatments	1	0.0112 NS	0	1	0.3385 NS	0	1	5.9183 NS	18.90	1	4.5973 NS	0
Residual	4	6.6217	100	4	4.0402	100	4	4.0370	81.10	4	6.0595	100
Total	5	5.2996		5	3.2999		5	4.4133		5	5.7671	

NS = P > 0.10

ANALYSIS OF RESIDUAL AFTER COVARIANCE

SOURCE	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.
Treatments	1	0.0145	P > 0.10	1	0.2819	P > 0.10	1	5.6737	P < 0.001	1	4.3338	P < 0.01
Residual	3	0.1511		3	0.0536		3	0.0942		3	0.0954	
Total	4	0.1169		4	0.1106		4	1.4891		4	1.1550	

APPENDIX 28.

(Continuation)

LACTOSE YIELD

ANALYSIS OF VARIANCE

SOURCE	PERIOD II d.f.	MS	% tot.Var.	PERIOD III d.f.	MS	% tot.Var.	PERIOD IV d.f.	MS	% tot.Var.	PERIOD V d.f.	MS	% tot.Var.
Treatments	1	0.0044 NS	0	1	0.5087 NS	0	1	7.7157 NS	36.95	1	8.1457 NS	22.14
Residual	4	4.6303	100	4	4.1825	100	4	3.5525	63.05	4	5.1928	77.86
Total	5	3.7051		5	3.4477		5	4.3853		5	5.7834	

NS = P >0.10

ANALYSIS OF RESIDUAL AFTER COVARIANCE

SOURCE	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.	d.f.	MS	PROBAB.
Treatments	1	0.0085	$P > 0.10$	1	0.9159	$P < 0.05$	1	8.9849	$P < 0.001$	1	9.7223	$P < 0.01$
Residual	3	0.1321		3	0.0570		3	0.0927		3	0.2645	
Total	4	0.1012		4	0.2717		4	2.3157		4	2.6290	

APPENDIX 29.

Analysis of variance and test of significance of treatment for fat, protein and lactose % means during II, III and IV Periods together

	SOURCE	d.f.	M. S.	PROBABILITY	VARIANCE ESTIMATE	VARIANCE % OF TOTAL
FAT %	TREATMENT (T)	1	0.20182	$P > 0.10$	0	0
	PERIODS (P)	2	0.06431	$P > 0.10$	0	0
	T x P (TP)	2	0.00841	$P > 0.10$	0	0
	RESIDUAL	12	0.23916		0.23916	100
	TOTAL+	17	0.18924			
PROTEIN %	TREATMENT (T)	1	0.03362	$P > 0.10$	0	0
	PERIODS (P)	2	0.03887	$P > 0.10$	0	0
	T x P (TP)	2	0.00636	$P > 0.10$	0	0
	RESIDUAL	12	0.05617		0.05617	100
	TOTAL+	17	0.04695			
LACTOSE %	TREATMENT (T)	1	0.00852	$P > 0.10$	0	0
	PERIODS (P)	2	0.00259	$P > 0.10$	0	0
	T x P (TP)	2	0.00038	$P > 0.10$	0	0
	RESIDUAL	12	0.01097		0.01097	100
	TOTAL+	17	0.00859			

APPENDIX 30.

Analysis of variance and test of significance of treatment for fat, protein, lactose % means during Preliminary Period.

	SOURCE	d.f.	M.S.	PROBABILITY	VARIANCE ESTIMATE	VARIANCE % OF TOTAL
FAT %	TOTAL	5	0.22208			
	TREATMENT	1	0.02842	P > 0.10	0	0
	RESIDUAL	4	0.27050		0.27050	100
PROTEIN %	TOTAL	5	0.03813			
	TREATMENT	1	0.00551	P > 0.10	0	0
	RESIDUAL	4	0.04629		0.04629	100
LACTOSE %	TOTAL	5	0.00842			
	TREATMENT	1	0.00187	P > 0.10	0	0
	RESIDUAL	4	0.01006		0.01006	100

APPENDIX 31.

Analysis of Residual of Y (fat, protein and lactose %) after fitting regression on x . Analysis of periods II, III and IV corrected using Preliminary Period as covariable.

FAT %

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Total	16	0.023158		
Treatment	1	0.032974	1.888	P > 0.10
Period	2	0.064299	3.681	P < 0.10
T x P	2	0.008420	0.482	P > 0.10
Residual	11	0.017465		

Comparison of adjusted means (%)

PERIOD	PASTURE	JAPANESE MILLET	PROBABILITY
II	5.15 (0.08)[@]	5.13 (0.08)	P > 0.10
III	5.36 (0.08)	5.29 (0.08)	P < 0.10
IV	5.40 (0.08)	5.34 (0.08)	P < 0.10

PROTEIN %

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Total	16	0.008176		
Treatment	1	0.002036	0.584	P > 0.10
Period	2	0.038870	11.155	P < 0.01
T x P	2	0.006360	1.825	P > 0.10
Residual	11	0.003484		

Comparison of adjusted means (%)

PERIOD	PASTURE	JAPANESE MILLET	PROBABILITY
II	3.58 (0.03)[@] a[*]	3.61 (0.03)	P > 0.10
III	3.59 (0.03) b	3.60 (0.03)	P > 0.10
IV	3.78 (0.03) ab	3.69 (0.03)	P < 0.05

APPENDIX 31.

(Continuation)

LACTOSE %

SOURCE	d.f.	M.S.	F_{ratio}	PROBABILITY
Total	16	0.003938		
Treatment	1	0.024539	8.300	$P < 0.05$
Period	2	0.002590	0.876	$P > 0.10$
T x P	2	0.000384	0.129	$P > 0.10$
Residual	11	0.002956		

Comparison of adjusted means (%)

PERIOD	PASTURE	JAPANESE MILLET	PROBABILITY
II	5.10 (0.03)@	5.02 (0.03)	$P < 0.05$
III	5.10 (0.03)	5.01 (0.03)	$P < 0.05$
IV	5.05 (0.03)	4.99 (0.03)	$P < 0.10$

@ Standard error of adjusted mean.

* Means denoted by common letters are significantly ($P < 0.05$) different.

APPENDIX 32.

Analyses of variance and analyses of residuals of Y after regression on within period basis, fat, protein and lactose percentages.

FAT %

ANALYSIS OF VARIANCE

SOURCE	d.f.	PERIOD II MS		% tot.Var.	PERIOD III MS		% tot.Var.	PERIOD IV MS		% tot.Var.	PERIOD V MS		% tot.Var.
Treatments	1	0.0320	NS	0	0.0576	NS	0	0.1291	NS	0	0.0602	NS	0
Residual	4	0.1915		100	0.3247		100	0.2013		100	0.3463		100
Total	5	0.1596			0.2713			0.1868			0.2891		

NS = P > 0.10

ANALYSIS OF RESIDUAL AFTER COVARIANCE

SOURCE	d.f.	MS	PROBAB.	MS	PROBAB.	MS	PROBAB.	MS	PROBAB.
Treatments	1	0.0015	P > 0.10	0.0031	P > 0.10	0.0487	P > 0.10	0.1840	P < 0.05
Residual	3	0.0058		0.0039		0.0348		0.0075	
Total	4	0.0058		0.0037		0.0383		0.0516	

PROTEIN %

ANALYSIS OF VARIANCE

SOURCE	d.f.	PERIOD II MS		% tot.Var.	PERIOD III MS		% tot.Var.	PERIOD IV MS		% tot.Var.	PERIOD V MS		% tot.Var.
Treatments	1	0.0025	NS	0	0.0050	NS	0	0.0389	NS	0	0.00001	NS	0
Residual	4	0.0547		100	0.0512		100	0.0627		100	0.1027		100
Total	5	0.0443			0.0420			0.0578			0.0822		

NS = P > 0.10

APPENDIX 32.

(Continuation)

PROTEIN %

ANALYSIS OF RESIDUAL AFTER COVARIANCE

SOURCE	d.f.	PERIOD II MS	PERIOD II PROBAB.	PERIOD III MS	PERIOD III PROBAB.	PERIOD IV MS	PERIOD IV PROBAB.	PERIOD V MS	PERIOD V PROBAB.
Treatments	1	0.0008	P > 0.10	0.00002	P > 0.10	0.0122	P < 0.10	0.0107	P > 0.10
Residual	3	0.0049		0.0052		0.0021		0.0029	
Total	4	0.0039		0.0039		0.0046		0.0048	

LACTOSE %

ANALYSIS OF VARIANCE

SOURCE	d.f.	MS		% tot.Var.	MS		% tot.Var.	MS		% tot.Var.	MS		% tot.Var.
Treatments	1	0.0038	NS	0	0.0045	NS	0	0.0010	NS	0	0.0047	NS	0
Residual	4	0.0050		100	0.0154		100	0.0126		100	0.0112		100
Total	5	0.0047			0.0132			0.0103			0.0099		

NS = P > 0.10

ANALYSIS OF RESIDUAL AFTER COVARIANCE

SOURCE	d.f.	MS	PROBAB.	MS	PROBAB.	MS	PROBAB.	MS	PROBAB.
Treatment	1	0.0075	P < 0.10	0.0125	P > 0.10	0.0053	P < 0.10	0.0117	P > 0.10
Residual	3	0.0012		0.0046		0.0035		0.0023	
Total	4	0.0028		0.0066		0.0040		0.0466	

APPENDIX 33.

Recovery of Chromic determined by Atomic Absorption Spectrophotometer Method.

I STANDARD

N° Sample	Amount Applied	Amount Found	Recovery %
1	3.95 mg Cr / g ash	3.94 mg Cr / g ash	99.87
2	3.95	3.92	99.25
3	3.95	3.97	100.42
4	3.95	3.94	99.88
$\bar{x}$			99.86 ± 0.24

II STANDARD

N° Sample	Amount Applied	Amount Found	Recovery %
1	19.70 mg Cr / g ash	19.91 mg Cr / g ash	101.05
2	19.70	19.48	98.91
3	19.70	19.65	99.75
4	19.70	19.51	99.05
$\bar{x}$			99.69 ± 0.49

III STANDARD

N° Sample	Amount Applied	Amount Found	Recovery %
1	30.46 mg Cr / g ash	29.67 mg Cr / g ash	97.42
2	30.46	30.87	101.35
3	30.46	30.70	100.80
4	30.46	30.57	100.36
$\bar{x}$			99.98 ± 0.88