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.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

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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. Productivity of Millets

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 et al., (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 et al., (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 et al., 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-1 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.