PHYSIOLOGICAL STUDIES ON THE INTER-RELATIONSHIP OF TILLERS, PLANT DENSITY AND PRODUCTIVITY OF MILLET
(Pennisetum typhoides (Burm) S. and H.)

BY

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for higher degree.



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CERTIFICATION

This thesis titled "PHYSIOLOGICAL STUDIES ON THE INTER- RELATIONSHIP OF TILLERS, PLANTS DENSITY AND PRODUCTIVITY OF MILLET *(Pennisetum typhoides* (Burm) S. and H." by Dora Nguemo Iortsuun meets the regulations governing the award of the degree of DOCTOR OF PHILOSOPHY of Ahmadu Bello University, and it is approved for it's contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to the loving memory of my parents.

Mr. Timothy Akaahar Yuwa (M.O.N.)
Mrs. Ruth Ityiar Yuwa
Madam Anna Faalye Kuhe (Aya)
who each had a "Ph. D minus opportunity".

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ABSTRACT

The physiological implications of tiller number, intra - row spacing and their interactions were studied at Institute of Agricultural Research, Ahmadu Bello University, Zaria using Dauro, Maiwa and SAMMIL-7 varieties of millet as the test crop.

The physiological observations and measurements made included time to 50% flowering, number of tillers developed, number of tillers that produced useable heads, nodal tillers produced, leaf number, leaf area, leaf area index, plant height, head length and diameter, harvest index, and grain yield from mainstem and from tillers.

The varieties varied significantly in some of these characters studied.

All the varieties responded to increased spacing by developing more tillers, and up to an average of 14.4 tillers per plant were developed in Maiwa.

The three varieties varied significantly (P = 0.01) in the time they took to reach 50% flowering, with Dauro taking the longest time (102 days) and SAMMIL-7 the shortest (56 days). Reduction in tiller number and the closer spacing significantly reduced (he time taken by Dauro to flower, increased the percentage of seeded heads, grain yield and tiller contribution to grain yield over the control.

Analysis of the tillers showed thai Dauro had the highest percentage of ear bearing tillers (73.1 %). followed by Maiwa (69.8%), while SAMMIL-7 had the least (53.1 %). But Maiwa had the highest percentage of heads that seeded well (86.1%) followed by SAMMIL-7 (75.6%), while Dauro had the least (67.6%).

Tiller contribution to yield was high, ranging from 66.9% in SAMMIL-7 to 73.4% in Maiwa. Reducing the tiller number to two in Dauro and two and four in Maiwa increased grain

yield above the control, but was of no added advantage in SAMMIL-7. A closer spacing and decreased tiller number significantly reduced the percentage seeded heads in SAMMIL-7, a dwarf variety.

Nodal tiller production was closely associated with time of repening when the weather was still wet. thus it was highest in the early variety SAMMIL-7 and least in the late variety Dauro.

SAMMIL-7 had the highest harvest index under different spacings and tiller numbers compared with Maiwa and Dauro, and there was little variation within each variety.

In Dauro there was a significant ($P = 0.05$) positive correlation between grain yield and plant height ($r = +0.586$) as well as percentage headed tillers ($r = +0.523$) and leaf area index ($r = +0.659$). However, significant negative correlation ($r = -0.552$) was observed between nodal tillers and yield. There was no consistency in the yield contributing factors among the varieties and years.

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CHAPTER 1

1. INTRODUCTION

Pearl millet is the second most important cereal crop of Nigeria next to sorghum. In Nigeria and other parts of Africa, millet is mainly grown for grains, unlike in some other parts of the World such as the United States of America and Australia, where it is grown mainly for fodder. It is also grown in some parts of Europe, USSR, India, Sri Lanka and in many parts of East and Central Africa for animal and human consumption. In Nigeria, the grains of millet are used in different ways as source of food. The dried grain which have a nutritional composition of 11.0% protein and 69% carbohydrates are mashed, cooked and eaten with stew ("Burabusko") or are turned into flour and used in making different types of porridges ("Kunu" and Akamu") or pastes ('Tuwo', 'Kafa,' 'Fura', 'Waina', 'Dambu', 'Danwake', 'Masa') or mixed with wheat to make bread and biscuits (Olatunji *et al.*, 1982). The sprouted seeds are used for making local malt or alcoholic drinks ("burukutu"). Millet therefore, has great potential for providing variable local food delicacies.

Millet comprise of five general, namely *Pennisetum. Paspalum, Panicum, Setaria and Echinochloa*. The most commonly found genera here in Nigeria is the *Pennisetum* and it has two main species *P. typhoides* and *P. Purpureum*. There are two main cultivars grown here in Northern Nigeria - the early non-photosentive type known as "Gero" and the photosensitive tall and late maturing type called "Maiwa" (Bhardwaj and Webster, 1971). "Dauro" is also a

photosensitive millet grown principally around parts of Southern Zaria and the Plateau in Nigeria (Labe, 1983). The World millet production stands at about 40 million metric tons produced on about 60 million hectares annually. Africa and Asia produce about 98% of the World's millet while Nigeria in 1992 produced about 3.2 million tons from about 3.3 million hectares with an estimated yield of 970 kg/ha (FAO, 1993). Pearl millet is grown on an estimated 27 million hectares in Africa and India with 56% of the production in Africa (FAO, 1985a). Of the 14 million hectares grown in West Africa, Nigeria (28%) is the largest producer followed by Niger (22%) and Mali (10%). World demand for coarse grains is projected to rise by 2.5% a year from the year 1970 - 2000. This is far in excess of millet production in the 1960s and 1970s (0.86%). On a World wide basis there may be an imbalance in millet demand and supply particularly in the non semi - arid and tropical countries where millet production has been declining by more than 2% per year. The demand for coarse grains may likely be for their use as animal feed and for human food.

Yield of millet in Nigeria is low compared to other countries such as India and United States of America due to low plant population (because it is intercropped with other crops such as *Sorghum bicolor* and cowpea - *Vigna unguiculata*), untimely planting and bird damage (Kassam *et at.*, 1975). Egharevba (1976b), Nwasike *et al.* (1982) and Njoku and Mijindadi (1985) proposed a number of limiting factors of millet yield in Nigeria with the principal ones being: Inherent low soil fertility, limited and untimely cultural practices and frequent droughts. With high inputs millet can yield about 1000 - 1500 kg/ha; with low input its yields are low.

At Samaru, grain yield increased up to the level of 60,000 plants per hectare while in India, plant population of up to 160,000 plants per hectare still gave high yields (Egharevba (1979). The main effect of spacing on yield it largely due to a change in the radiant energy distribution. With closer and more uniform spacing giving a higher population, it could be that more radiant energy would be intercepted by the plants and that less would fall on the soil surface to cause evaporation, therefore resulting in higher yields. Highest yields are, however, obtained not only when the sunlight is best utilized but also when the maximum amount of photosynthate produced in green parts translocates into the grain. When there are too few plants per unit area, insufficient photosynthate may be produced for large grain yields and with too many plants, per unit area much of the photosythate may be retained in the sower at the expenses of the grain (Scarsbrook and Doss, 1973). There is therefore a need to find the balance between photosynthate production, plant population and optimum grain yield.

Millet has morphologically similar interconnected units called tillers which are produced quite early in the life of the plant with their number varying from plant to plant and from cultivar to cultivar. Nigerian varieties have 5 - 15 tillers. This could change with spacing of the plants as increased spacing has been found to increase tillering (Azam - Ali et al., 1984). Tillering habit may be of some advantage when the plants are grown as fodder but when grown for grain, this quality is undesirable since not all the tillers would product heads and the tillers appear at different times, some of which head late (Ramond, 1968). Reducing tiller number to 3 and 5 per stand has been found to increase yield (Egharevba, 1977). The non head forming tillers are parasitic on the main shoot, especially under high population when not all tillers can

receive enough sunlight.

Studies by other workers have shown that the millet plant in the vegetative stages has a highly organised system and is not just a collection of individual tillers (Khan and Kassam, 1984). There is a need to extend such a study to the reproductive stage. This study was therefore undertaken on three millet varieties viz: Maiwa, Dauro and SAMMIL-7 (Gero) with the following objectives:

1. To study the effect of spacing on growth and yield
2. To study the effect of tiller removal on growth and yield attributes.
3. To study the interaction between tiller number and plant spacing on grain yield and other attributes;
4. To compare the above in the three millet varieties. viz: Dauro, Maiwa and SAMMIL-7

CHAPTER 2

2. LITERATURE REVIEW

2.1 Millet Taxonomy and origin

The taxonomy of bulrush or pearl millet has long been in a state of flux due to wide variation found in the species. Chase (1921) studied the synonymy especially with respect to Linnaeus work and concluded that, *Panicum glaucum* applied clearly to pearl millet which should thus be *Pennisetum Glaucum*. One of the earlier attempts at organising the nomenclature of the species was made by Thieselton-Dyer (1934). After reviewing literature and specimens, he placed the genus in the section *Penicillaria*. He also listed several synonyms which included *Pennisetum typhoides* (Burm) and *Pennisetum americanum* (L.). The use of *Pennisetum typhoides* (Burm) Stapf and Hubb was recommended. However, he concluded that *Pennisetum americanum* (L.) K. Schum was the proper name of *Pennisetum spicatum* (L.) Koern and that *P. spicatum* and *P. typhoides* were not distinct species. In his opinion and that of others, the differences were only varietal, therefore *P. americanum* (L.) K. Schum was also the correct name for pearl millet.

Common names given to the crop are as numerous as the taxonomic synonyms. Robbins (1917) lists Pearl, Cattail, African, Egyptian, India, Horse and Japan millet. Ayyangar *et al.*, (1933) adds bulrush millet which is common in Africa while Candle and Dark millet are former European names. Bajra, Bajri, Cumbu and Sajja are frequently used by Pakistani and Indian workers. Bambala or Mbambala, Souna, Sanic, Gero and Maiwa are names in common use in

various parts of Africa. Gero (*Pennisetum typhoides S.* and H), Maiwa (*Pennisetum Maiwa S.* and H.) and Dauro (*Pennisetum dauro*) are typical of such names in Nigeria.

Dauro, a variety of Pearl millet is the only known millet produced principally by transplanting. It is not well known beyond Southern Zaria in Kaduna State and Parts of the middle belt and Plateau in Nigeria where it has been in production for centuries. Direct seeding at Samaru in Kaduna State gave good results (Labe, 1983). The fact that millet variety produced principally by transplanting has not been reported anywhere else in the world and the supposed origin of the name being southern Zaria in Kaduna State brings the origin of the this type of millet closer to Nigeria (Labe, 1983). Considering its line of evolution, it cannot be stated with certainty as to whether it descended from gero (P. typhoides S. and H.) or Maiwa (P. Maiwa S. and H.) though Bhardwaj *et at.* (1969) and Bhardwaj and Webster (1971) considered it to be a specialized type of Maiwa as it is similar to Maiwa in being photosensitive, late maturing and grown in a limited area. It is however different from Maiwa in being mainly transplant millet and generally shorter in height. Even when the possibility of descending from either gero or Maiwa is ruled out, it cannot be stated with certainty that it descended from a wild species since there is no wild species which has a close resemblance to it so as to associate them. Purseglove (1968) contends that even the well known *P. typhoides* S. and H. is not well known in a wild state and the wild species from which it originated is not known with certainty. He therefore concluded that subsequent evolution of millet races in West Africa is due primarily to natural hybridization aided by environmental conditions and natural selection.

Many authors consider central tropical Africa to be the place of origin of pearl millet. Cobley (1965) and Krishnaswamy (1951) pointed out that despite its long use in India, it was considered to have been introduced from Africa. In his review, the origin and distribution of the millets was considered on the basis of taxonomic and cytological evidence. He quoted Stapf as saying that the home of the Pearl millet is Africa and that these have been derived from two sources, one being the tall widely distributed mesophytic *P. purpureum* and the other, the Xerophytic group of smaller species ranging across the African Continent from Sene-Gambia to the Red Sea. The parent stock was largely perennial, but as perennially is often not absolute in tropical grasses, annual types may frequently have arisen being utilised by cultivators for grain. Due to the african origin, Janhar (1981), proposed that the name *P. americanum* is misleading because it advently implies the American origin for pearl millet. He further asserted that the specific epithet '*typhoides*' (typha-cattail) describes more precisely the botanical identity of pearl millet which is also known as 'Cattail millet'.

2.2 Tillering and grain yield

Pennisetum typhoides is a short season annual (Cobley, 1965), although Curson (1940) pointed out that in South Africa after overwintering, the stubble shoots grow/regenerate again in the spring too give a second crop. It completes its life cycle in less than 100 days and reaches physiological maturity at the 76th day after seeding as there is no significant reduction in fodder yield after this (Rao and Roa, 1982). Generally, it is an erect robust bunch of grain which at maturity may be 2.0-3.3 metres tall (Burton, 1951), or as high as 5 meters though dwarf varieties may only reach a height of 1 metre. It is highly tillering and the main shoot consists

of number of these morphologically similar interconnected units. The tiller number varies between plants and between varieties. Ramond (1968) reported up to 40 tillers in some cultivars while Bhardwaj and Webster (1971) reported 8 - 14 tillers in some other. In some locally grown varieties 5-15 tillers have been recorded (Baker; unpublished quoted by Egharevba, 1977). Tiller contribution to grain yield varies as several studies in other crops have revealed.

Ramond (1968) noticed that only 25% of the tillers ever produced viable seeds. Khan and Kassam (1984) quoted Baker (unpublished) who observed that although tillers made up to 60% of the total plant dry weight, their contribution to the total grain yield was only 15% Kassam *et el.*, (1975) working with some Indian millet varieties reported that tillers may contribute between 3 - 72.3% to grain yield. At Samaru it was found that percentage contribution of tillers to grain yield ranged from 43.7% - 56.8% in Gero varieties tested which were dwarf composite, SE 13 and Ex-Borno (Anon 1988). Egharevba *et el.*, (1983) found tiller contribution to grain yield to range from 14-35% and contribution generally increased with decrease in plant population. They also observed that while the number of total tillers was 6 - 10, that of effective tillers was only 2-4. This high ratio of dry weight to grain yield was due to a large number of tillers which did not produce seeds. Egharevba *et el.*(1981) quoted a millet breeder Nwaike (unpublished) as noting that tiller productivity and final contribution to grain yield was more in the less tillering than the profuse tillering varieties. Varietal difference have also been observed (Anon, 1988). The total grain yields and the grain yield contributed by the mainstems and tillers respectively for both Ex-Bornu and SE13 were much higher than those for dwarf composite. However, Dwarf composite had the highest percentage of the grain yield contributed by tillers.

Reduction in tiller number has been found to substantially increase grain yield in millet. Egharevba (1977) found that maintaining three and five tillers per stand increased yield by about 20% above the control but retaining more than five tillers caused a significant decrease in yield. The reduction in tiller number had no advantage on the biological yield of the plant. He assumed that the non-head forming tillers were parasitic on the main shoot for nutrients and water and that there was intra-plant competition for nutrients as more heads were formed per stand and this was detrimental to grain yield. This assumption has not been tested to ascertain the extent of the effect of this intra-plant competition in millet during grain formation. But it has been found that the grain yield contributed by tillers in millet variety Ex Bornu increased, with the increased in number of tillers per plant and was highest in the control in which no tiller was removed. In the Dwarf composite variety however, grain yield contributed by tillers increased with tiller number up to 3 tillers per plant and decreased thereafter (Anon, 1988). Khan and Kassam (1984) limited their studies to the vegetative phase of two millet cultivars, ex-Bornu and KG3 in which they found varietal differences in the proportion of photosynthates exported from the source leaf to other parts of the plant in the early stages of plant growth, with Ex-Bornu exporting more. The tillers did not receive absolute independence even at late vegetative stage and the plant at this stage appeared to be a highly organised system rather than a collection of individual tillers. The daughter tillers were supported more by the main shoot at the early stages of their growth (45 days) which declined later at 72 days. The support of the main shoot by the tillers also declined at this stage. The pattern of distribution signified close vascular connections between the parent plant and the daughter tillers but rather poor connections between sister tillers as sister tillers were not dependent on each other in both cultivars.

In varieties Ex-Bornu and Dwarf composite, using 1-5 tillers showed that the grain yields for the mainstems were increased as the number of tillers was increased. This indicated that at the plant spacing of 75cm x 25cm used, depriving the plants of an adequate number of tillers could have adverse effects on the grain yield of the mainstems. The authors suggested that there may be some physiological relationship between mainstem and tillers which governs optimum grain yield of the mainstem in these varieties (Anon, 1988). Several workers have shown that in grasses and cereals the young tillers were supplied with assimilates by the mainstem but as they develop and enlarge, the degree of support declined and the tillers became autotrophic (Quilan and Sagar, 1962 and Lupton, 1966 in *Triticum aestivun*; Williams, 1964 in perennial grasses, Ryle, 1970 in *Lolium* species and Nyahoza *et el.*, 1973 and 1974 in *Pea pratensis)*. Marshall and Sagar (1968) and Clifford *et al.* (1973) studied the interdependence of tillers in *Lolium multiflorum* and showed that the main shoot exported radiocarbon to the tillers in equal proportion s but the leaves of the tillers exported more to the parent plant than to the sister tillers. Rawson and Hofstra (1969) showed that wheat plants with 6-8 tillers did not show complete independence of the main shoot and the tillers even during the last stages of grain filling. In barley however, there was a sharp decline in the percentage of ^{14}C translocated to all tillers when the main stem began rapid growth (Lauer and Simmons, 1985). These workers concluded that the shift in main shoot photoassimilates translocated away from tillers to the main shoot stem contributed to the premature abortion of tillers in barley. Earlier in the life of the plant, most of the ^{14}C fixed by the first developing leaves on the main shoot was translocated to newly emerging main shoot leaves or to young tillers.

These studies show that the interdependence of tillers and main shoot vary from one plant specie and variety to another and changes with age and physiological state of the plant. This confers on the plant varying physiological responses.

2.3 Climate and Millet Growth

While the bulk of cereal production in tropical countries is represented by maize, the production in the areas with less than 600mm of seasonal rainfall is mainly represented by sorghum and millet, totalling about one quarter of the maize production. In comparison with maize and sorghum, millet has stronger and deeper rooting system, requires less water over the growth period (300 - 350mm) and together with sorghum can withstand high maximum temperature even though they have similar temperature requirements as maize (Frere, 1986).

In areas with short growing seasons, there is a progressive shifting from maize to millet which shows greater tolerance for shorter lengths of growing season. Limitations are however imposed by the existence of a possible humid period at the end of the growing cycle inducing disease problems and the possibility of seed germination on the plant itself as well as problems of drying and post harvest conservation. The morphological and ecological characteristics of millet therefore make it suited to a wide range of environments and the rational exploitation of those characteristics would normally allow higher yields to be obtained from the crop (Anon, 1987).

2.3.1 Water Availability

Since millet is a major crop in arid and semi-arid regions, the effect of climate on its growth is of major importance. Millet is grown in areas with rainfall of 125mm to 900mm (Jain and Mathur, 1961). A rainfall of 1300mm during the growth of a crop of *Katherine in new* Guinea has been recorded. Where dry matter for fodder is required, 500mm rainfall has been estimated as its requirement. However in areas where it is grown for grain, rainfall may be as low as 800mm (Krishnaswamy, 1951). Bulrush millet is perhaps more widely grown than any other crop in the tropical areas of low rainfall (Frere 1986). Unlike 'gero' (SAMMIL-7 or SE 2124) and Maiwa which are mainly grown north of latitude 11° East, Dauro's location is restricted to the highlands with relative high rainfall which are south of Kaduna State and parts of Plateau State in Nigeria. It is also grown in parts of Bauchi, Benue and Niger States. The major producing areas fall within the Guinea Savanna with an annual rainfall range of 1270mm to 1016mm. Millet crop is grown in those area where maize and sorghum fail because of low *rainfall and adverse soil conditions* (Burton, 1951).

Millet grain crops grow better than sorghum in dry conditions (Catterinet *et al.*, 1963), since they are mainly of short duration of one hundred days or less. According to Cocheme and Franquin (1967). The growing season for millet crops ranges from 60 to 200 days. FAO (1976b) however states the most suitable growing period for millet at 90-240 days. For short growing seasons, millet crop gives the highest relative yield but with longer growing season, sorghum and maize give higher yields.

Since millet seedlings are drought tolerant, early plantings could be carried out during the preparatory period in order to extend the effective moist period. Thus, the minimum water-availability period for a millet crop has been determined to be about 50 days (Cocheme and Franquine, 1967). These workers also found from data collected over 11 years at Bombey in Senegal that even in the semi-arid zones, too much water or excessively long wet period can reduce production even in an adapted variety. Therefore, millet crop yields in the area are not necessarily more than average even if annual rainfall is above normal. Poor rain distribution can however affect the performance of millet causing the yields to vary from year to year depending to a large extent on rainfall distribution among other factors (Anon 1989b). Preliminary results by ICRISAT (International Crops Research Institute for Semi-Arid and Tropical Areas) workers show that cultivated pearl millet is particularly sensitive to water stress before flowering. They found that, contrary to some results in the literature, there was no compensation by tillers for the reduction in seed production by the main shoots. They assumed that a spacial reaction to water stress could be due only to the morphology of the plant and may not indicate drought resistance of a physiological nature (Anon, 1994).

2.3.2. Light and Temperature

Temperature is the main factor determining the growing period of annual crops and the light intensity during the growing season determines the limit of the amount of dry matter that the crop can accumulate when water is abundant (Ong and Menteith, 1985). The geographic distribution of the areas where millet is grown point to its high temperature requirement for growth. Burton (1965) described it as a warm season annual, grown where summer temperatures are reasonably high. Begg (1965) stated that it was well adapted to the dry monsoonal tropics

and warm temperature regions. Low temperatures have however been shown to retard germination. During the developmental stage of growth, Ong and Monteith, (1986) found that the rate of tillering depended on the number of leaves on the main culm which is governed by temperature and daylength. The duration of tillering is mainly influenced by the supply of assimilates which is determined by plant population or timing of reproductive growth.

In millet it appears that adverse weather conditions during the grain filling stage can be compensated for by the translocation to grain of material previously stored in stem tissue. In ideal conditions grains are found to continue to grow until they reach a maximum size which is genetically determined but growth can be curtailed by the premature death of all green tissue and or the exhaustion of stored material (Ong and Montheith, 1985). Increase in total plant dry weight during the grain filling phase is largely in the grain, but as tillers in many varieties elongate and flower after the main shoot, there is also some increase in non-grain components, mainly tiller stems (Maiti and Bidinger, 1981). Senescence of the lower leaves continues and by the end of the grain-filling phase, normally only the upper two to four leaves remain green. Some varieties develop small tillers on the upper nodes of the stem, particularly towards the end of the grain filling phase. These tillers have a shorter developmental cycle than the basal tillers, producing a few leaves and a small panicle.

Leaves from tillers can account for 60-70% of the total leaf area in a healthy millet crop (Gregory and Squire, 1979). Although the photosynthetic efficiency of leaves on tillers may be less than on the main culm (since they are usually shaded) they sometimes make major

contribution to final yield (Egharevba, 1977). There is much evidence that tillering in cereals is sensitive to both temperature and light. In general, basal tillers start to emerge after the production of specific number of leaves. Subsequent tillers are produced at a rate further associated with the number of leaves on the main culm and varietal differences regarding this have been reported. Cultivar Katherine Pearl tillered after 4 or 5 leaves were produced (Begg, 1965), while cv, Ingrid Pearl tillered after eight or nine leaves (Pearson, 1975). Egharevba (1977) found tiller formation to be observable as from two weeks after seedling emergence in cv. Ex-Bornu.

2.3.3. Spacing, Light and Temperature

The dominance of the main stem is modified by photoperiod and the light regime within the canopy is also modified by temperature or plant spacing. These bring about small differences in tillering within the canopy as shown by studies on vegetative and reproductive plants. In long days for instance, longer duration of growth and developmental stage increased the number of tillers produced mainly because tillering continued for a longer period (Ong, 1983a). When light competition is reduced or delayed by decreasing plant population or low temperatures, tillering increased dramatically. For millet (Bk 560) grown in Niger, a stand with 2.9 plants/m^2 had 2.8 times more tillers than a stand with 11.5 plants/m^2 (Azam-Ali *et al.*, 1984). Fussel *et al.* (1980) reported even more prolific tillering for the same species, that is 7.8 time more at 21°C than at 30°C. Egharevba (1977) also found population density to affect tiller formation. The lowest population density of 30,000 plants per hectare which he tested resulted in more tillering of up to 12 tillers by the eight week while the highest density of 50,000 plants per hectare produced

6 tillers in the same period. Puckridge (1962) observed similar results with wheat when he planted 57,000 plants per hectare, he recorded a total of 33 shoot per stand whereas at 708,000 plants per hectare he recorded only 3 shoots per stand. High tillering ability on the other hand continues to be an important objective in most of the pearl millet seed parents breeding programm in India (Anon, 1992). The two highest tillering male-sterite lines 5054A and 3383A developed at the Indian Agricultural Research Institute, New Delhi, which have been extensively used for hybrid breeding have low grain yield seed size and are susceptible to downy mildew.

The agronomic significance of tillers is most evidence in millet/legume intercrops when most of the increase in yield is usually derived from the additional tillers produced (Roa and Willey, 1980). This is due to the necessity to space the millet wider for the intercrop and since wider spacing causes more tillers to be formed. In pure stand however, high tillering ability may be disadvantageous in those areas where millet is sown for grain. Hence it is important that the plant spacing/population should be correctly determined to give the desired effect of adequate number of tillers for maximum yield. Egharevba (1977) concluded that in Nigeria reducing tillers from 10 to 3 or 5 consistently increased grain yield of millet (cv. Ex Bornu) by 15 to 30%. On the other hand, uniculm plants yielded about 20% less than the high tillering control. Since plant spacing/population, tiller number and yield are known to interact, it is important to establish the degree of this interaction for each variety of pearl millet.

2.4. Effects of plant spacing on yield:

Dungan *et al.*, (1958) summarised many of the row spacing investigations and found that

the results were inconclusive with rather great variation encountered from year to year and from location to location, depending upon environmental and climatic conditions. The main effect of spacing on yield according to them is believed to be largely due to a change in the radiant energy distribution. With closer and more uniform spacing of plants it could be assumed that more radiant energy would be intercepted by the plants and that less would fall on the soil surface to cause evaporation. Higher plant population could have a similar effect.

One of the recommended practices in all systems of "Dry Farming" is the low seed rate and wide spacing. This recommendation is presumably based on the thinking that the smaller the plant density the greater the moisture at the disposal of each plant. Evapotranspiration rate is mainly dependent on the quantity of moisture present in the soil. Shallow rooted crops grown extensively in an area, with different morphological and physiological characteristics, have similar evaportranspiration rates under the same soil and climatic conditions. The evaportranspiration rate under different plant densities of sorghum and groundnut grown under identical conditions have been shown to be almost the same (Lakshminarayana and Reddi, 1969). in a study of the effect of plant populations and row widths, light penetration and yield of irrigated corn, Scarsbrook and Doss (1973) found grain yields to be maximum where 85-95% of the sunlight was intercepted by the plant canopy. For highest yields sufficient light must penetrate the plant canopy to permit leaves to produce the maximum amount of useable photosynthate/unit area. Little light should be allowed to reach the ground in the canopy because this is lost to the plants food making process. Using plant populations of 8,000, 16,000, 32,000 and 48,000 (in 20" and 40" row), these workers found that as the population increased, amount

of light measured at ground level decreased sharply. The denser canopy produced with added Nitrogen resulted in more light being absorbed or refelected. Less light reached the ground in 20" than 40" rows which may partially account for higher grain yields.

In India, Pearl millet (HB-3) with a row spacing of 60cm gave the highest grain yield of 12.53kg/ha. Grian yield was the lowest 10.22kg/ha) when the row spacing was the maximum (90cm) and this yield was statistically at par with the grain yield obtained under row spacing of 30cm (Parmar *et al.*, 1982). Dhankar *et al.*, (1982) however found grain production of BJ 104 and PHB 14 not to be much altered by plant densities. Similarly, Balyan *et al.*, (1982) found that yield and yield attributing characters were not much affected by planting density in hybrid pearl millet. Using planting densities of 53,000 plants/ha (optimum population) and 26,500 plants/ha (suboptimum population) at Samaru, it was observed that the optimum plant density generally gave higher grain yield than the sub-optimum density in a local variety (ExBomo) and improved variety (SAMMIL-1) (Anon 1988). It would appear therefore that planting densities affect the various varieties differently.

Langer and Lambert (1963) found that cutting of tillers in grasses led to reduction in plant density which resulted in higher tiller production per plant due to less competition for light. They therefore postulated that in a sward, competition between and within plants is severe and may restrict many tillers from contributing to seed yield. Their experiment also indicated that seed yield can be increased by reducing population density and therefore the pressure of competition, but some varieties respond to this better than others and hence the need to study

the physiological implications of variation in plant density. This variation is further shown by studies under dry land conditions which have revealed non-significant differences in grain yield of pearl millet due to various plant densities but fodder yield showed significant differences due to various plant densities (Umrani *et al.*, 1982). These workers showed that higher plant densities of 225,000 plants/ha gave a significantly more yield. In their experiments on row spacing, they observed no significant differences in grain yields as well as fodder yield of pearl millet.

Working with four populations viz: 50,000; 75,000; 100,000 and 125,000 plants per hectare, it was observed that the grain yield of SE 13 increased up to 100,000 plants/ha while in ExBornu it was up to 125,000 plants/ha and then declined thereafter (Anon 1988). In Dwarf Composite it was found that the grain yield was higher at 50,000 plants/ha than the next higher three densities. The same pattern was followed by yield contributed by tillers and mainstems. In all the three varieties, the mean grain yield from the mainstems and the total means showed increase with increase in plant density. The mean grain yield for the tillers was however not affected by the plant density although its percentage contribution to the total yield declined steadily with the increase in plant density (Anon 1988).

2.5 Translocation of photosynthates in millet and related crops:

Egharevba (1981) using shading techniques and radiocative labelling, showed that the flag leaf contributed 32% of the total dry matter in the grain while the top, middle and bottom zones of leaves contributed 42, 16 and 6% respectively to the grain. This gave an efficiency index of 6.4, 1.2, 0.5 and 0.3 producing grain yield from flag leaf, top, middle and bottom zones, respectively. He attributed the high efficiency of the flag leaf to its younger age, proximity to sink and position to intercept a good proportion of the incoming radiation. Rao and Singh (1987) in their defoliation and shading experiments with Bajra (*Pennisetum typhoides)* found that a reduction in the photosythetic surface area either by shading or defoliation at the time of anthesis cause reduction in grain number per ear, grain size, rate of grain development and the final grain yield. These reductions were almost in proportion to the cut in leaf area.

Several workers have shown that in grasses and cereals the young tillers were supplied with assimilates by the mainstem but as they develop and enlarge, the degree of support declined and the tillers became autotrophic (Quinlan and Sagar, 1962 and Lupton 1966 in *Triticum aestium*, Williams, 1964 in perennial grasses, Ryle, 1970 in *Loluim Spp.* and Nyahoza, *et al.*, 1974 in *Poa pratensis*). Mayer and Porter (1960) in their experiments with rye found large amounts of labelled ^{14}C in the roots but little activity in the adjacent tillers. Studies with wheat revealed that the movement of ^{14}C within the wheat plant was extensive in the early stages of growth but gradually became more localized until after ear emergence when there was little movement of ^{14}C between tillers in 24 hours (Quinlan and Sagar, 1962). They showed that meristematic regions and tillers became dependent on their own leaves which also supplied

assimilates to associated tillers. The only detailed study of photosynthate movement in millet is that of Khan and Kassam (1984) who showed varietal differences in percentage export of assimilates in the vegetative phase of two varieties of millet, Ex Bornu and KG3, with the former exporting a higher percentage. Their work showed that with the emergence of tillers, roots were the main sinks from the main shoot and tillers, particularly the lower leaves. All the source leaves on the main shoot supplied considerable proportion of photosynthates to each tiller in both cultivars. As the plant reached the end of its vegetative phase, the radiocarbon translocated to the daughter tillers from the main shoot had considerably declined and sister tillers were also unimportant sinks, but the root was still a dominant sink at this stage. This pattern implies very close vascular connections between the parent plant and the daughter tillers but rather poor vascular connections between the sister tillers. There is little information concerning the pathway from one tiller to another. Marshall and Sagar (1968) and Clifford *et al.*, (1973) studied the interdependence of tillers in *Lolium multiflorum* and showed that the main shoot exported radiocarbon to the tillers in equal proportions but the leaves of the tillers exported more to the parent plant than to the sister tillers. Rawson and Hofstra (1969), showed that wheat plants with 6-8 tillers did not show complete independence of the main shoot and the tillers even during the last stages of grain filling. In millet the tiller did not receive absolute independence even at a late vegetative stage (Khan and Kassam, 1983). The question is what happens during the reproductive phase?

2.6 Photoassimilate Movement during reproductive Phase:

The influence of reproductive structures on the pattern of assimilate distribution varies. In wheat Doodson *et al.*, (1964) and in young plants of *Lolium multiflorum*, Marshall and Sagar (1968) found that up to half of labelled carbon which left the source leaf was present in roots but in flowering cereals the proportion was less (Wardlaw and Porter, 1967). In the flag leaf of wheat, 15-20 days after anthesis, movement of assimilates upwards was twice as fast as downwards but removal of the grains reduced upward movement in favour of downwards (Wardlaw, 1965). He concluded that storage organs have a polarizing effect on demand for assimilates caused by presence of reproductive structure which made expanded leaves on reproductive shoots to increase their export compared to similar leaves on vegetative shoots (Ryle and Powell, 1972).

Larger sinks dominate import of assimilates over smaller ones even when the larger sink is more distant away from the source leaf (Cook and Evans, 1978). These workers trimmed wheat plants to two tillers with one completely defoliated and the other with either the flag permiltinate or 3rd highest leaf left as the source. Ears were left with either 6 or 24 grains giving combinations of distance to large and small sinks. They showed that there was discontinuity in the relative distance versus activity curve suggesting that there may have been significant resistance to the transfer of assimilates between the tillers.

The demand for assimilates may not be for that produced by photosynthesis alone but also for reserves being transferred from the leaf blades and the stem. Ong (1983) showed this at late

booting in millet *Setaria italica* or Jingu where photosynthesis contributed 91.8% and the amount transferred to the ear from storage was 1.48%/plant with the highest rate of transfer being from the blade and the 2nd highest being from the stem.

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Location and Crops

This study was carried out for four years (1987-1989 and 1992) at the Institute for Agricultural Research (IAR) farm Samaru, Zaria, (11° 10'N and 7° 30'E). Millet was chosen as test crop and the variety selected were Dauro, Maiwa and SAMMIL-7 obtained from I.A.R.

Dauro is an open pollinated variety widely grown in the Northern Guinea and Sudan Savannah zones of Nigeria. It is photosensitive and can be grown by transplanting or by direct seeding.

Maiwa is an open pollinated photosensitive variety, more extensively grown in Savanna regions. It differs from other cultivated pearl millet varieties in having more densely hairy awns, and lemmas. It is resistant to downy mildew (Bhardwaj and Welster, 1971).]

SAMMIL-7 (old variety code SE 2124) is an improved variety developed at IAR, Samaru through recurrent selection from Ex-Borno and released in 1986. Its morphological identifiers include cylindrical ear head (length ranging from 30 - 40cm) and plant height ranging from 210-230cm. It is early maturity (65 - 86 days) and resistant to major millet diseases. It is adapted for cultivation in all Savanna zones (Anon, 1989a).

3.2 Cropping History of the Experimental Site

The crop grown on the fields used in this trial for the last three years preceeding the experiments in a given year are indicated as follows

Experimental Year	Previous Cropping
1987	Fallow - Maize - Maize
1988	Cowpea - Maize - Fallow
1989	Millet - Millet - Millet
1992	Maize - Maize - Maize/Sorghum/Rice

3.3 Experimental Treatments

The spacing treatments consisted of 30, 25, 20 and 15cm intra-row spacing with a common inter-row spacing of 75cm. This gave a plant population of 50,000, 65,000, 80,000 and 95,000 plants per hectare.

The experimental treatments were made up of three millet varieties, five tiller removal and four spacings. The three millet varieties as earlier mentioned were Dauro, Maiwa and SAMMIL-7. The five tiller removals consisted of maintaining all tillers formed i.e. Control (TN), maintaining one, two, three and four tillers per stand in 1987-1989 and in 1992; two, three, four and five tillers per stand (T^1, T^2, T^3, T^4, and T^5) in addition to the control in which no tillers were removed. The tillers were removed leaving the required number in each plot by cutting them from the base using a sharp knife. Since tillers of millet appear in a regular sequence on either side of the main-stem, the youngest tillers that appeared were the ones removed, leaving the oldest in that sequence, of the required number in addition to the main stem. This was done 6-7 weeks after sowing during the period of active tiller formation. It was repeated as necessary to maintain the desired tiller numbers as stated above.

3.4 Experimental Design and Layout

The trial was laid out in a Randomised Complete Block Design (RCBD) with three replications with a total of 180 plots. Each plot measured 6 metres long by 4.5metres wide for an effective plot size of $27m^2$. There was one metre boarder between plots and 1.5m between blocks. Each gross plot had 8 rows while the net plot had 6 rows.

3.5 Land Preparation and Planting

The land was ploughed, harrowed and ridged at 75cm apart and seeds were sown as soon as rains were established. Sowing was done in each of the four years as indicated below:

1987 1st and 2nd July

1988 14th and 15th June

1989 21st June

1992 20th June

Each year, plants were thinned to one per stand 4 weeks after sowing and supplying was done where necessary.

3.6 Fertilizer Application

After harrowing, nitrogen fertilizer (NPK 20:20:20) at the rate of 100kg/ha and single super phosphate at the rate of 50kg/ha was applied as basal dressing. Calcium ammonium nitrate (CAN) at the rate of 100kg/ha was applied as side dressing immediately after thinning at 4 weeks after sowing as the second dose of fertilization.

3.7 Crop Protection Practices

Before planting, the millet seeds were dressed with Fernisan-D powder. Pre-emergence herbicide cesaprim (EW 500) was applied a day after seeding at the rate of 38ml to 10 litres of water per hectare to control weeds. As a supplement to this, two hoe weedings at 5 and 9 weeks after planting were also carried out for effective weed control. Vetox 85 at the rate of 1.12kg a.i/ha in 255 litres of water was applied at 6 weeks after planting to protect plants against stem borers, grasshoppers and other worms.

Birds were scared by employment of young children and women as bird scarers between 6.00am to 6.00pm from the time of plant heading to harvest.

3.8 Data Collection and Observations

Data were collected from five plants of desired tiller number randomly selected from the two central rows in each plot and these were summed and averaged. The destructive harvest of the plants was however carried out from the 2nd and 5th rows of each plot. Meteorological data were obtained from the meteorological section of the Institute for Agricultural Research, Samaru. Data were collected on the following parameters measured.

(a) Plant Height: This was at the time of full heading using a centimetre graduated pole. The height of each plant was taken as distance from the soil level to the tip of the ear of the mainstem.

(b) Tillers Developed: The number of tillers developed by each plant in the control plots were counted, as well as the number of branches on the main tillers were also counted and hereafter referred to as nodal tillers.

(c) Days to 50% Flowering: The number of days taken from sowing to when half of the plants in a plot had their heads emerged from the flag leaf, was counted.

(d) Number of Headed Tillers Per Plant: Number of tillers on each plant in a plot, and the number of tillers which developed heads were counted, and the percentage of ear bearing tillers was calculated.

(e) Seeded Heads: After harvest, the total number of heads formed and the heads that set seed were counted and the percentage seed bearing tillers calculated.

(f) Number of Leaves Per Plant

This was determined during grain filling when no more new leaves were being produced. All the green leaves on a plant were counted.

(g) Leaf Area Per Plant and Leaf Area Index (LAI)

This was determined non-destructively during grain filling by multiplying length and maximum width of the leaves and a constant factor of 0.761 derived by Egharevba, (1977). Joshi and Yadav (1982) also considered this method reliable and accurate. The LAI was calculated as a ratio of leaf area over the land area occupied by the plant in a plot.

(h) Head Size: The length and diameter of the heads were determined after harvest by measuring the length with a metre rule and the diameter with a vernier calliper.

(i) Grain Yield: The heads of the plants in the two central rows were harvested, threshed and weighed. The weight was converted to kilogram per hectare (kg/ha).

(j) Harvest Index: The complete shoot of each plant was removed from ground level at maturity and dried in an oven at 70°C for 48 hours and the temperature was raised to

105°C for 6 hours after which they were weighed. The heads of each of these were threshed and weighed. The harvest index (H.I) was calculated as a ratio of the seed weight to the shoot (stover) weight and expressed as percentage.

(k) Disease Score and Bird Damage: This was scored 0-5 ranging from no damage (0) to most severe damage (5).

3.9 Harvesting:

The plants were harvested as soon as the grains reached physiological maturity which was determined by the development of the black layer according to Rao and Rao (1982). Since the varieties matured at different times, their harvest dates are as shown below:

		Dauro and Maiwa
1987	4th October	10th November
1988	29th September	28th October
1989	25th September	30th October
1992	21st September	2nd November

The head of the mainstem of each plant was harvested into paper bags while those of the tillers were harvested separately into other bags. These were sun-dried, threshed and weighed. These weights wee expressed as mainstem and tillers grain yield.

3.10 Yield Estimation Using Head Measurements

An attempt was made to estimate yield using linear measurements of the head i.e. length and diameter as well as weights of the heads, seed and chaff. Using randomly selected 123 fully

seeded heads, data were collected for each head. The seeds were then carefully removed, counted and weighed. Correlation and computer pictorial graphs were drawn in an attempt to relate the seed weight to the other measurements which could then be used to estimate, yield when heads are damaged.

3.11 Data Analysis: The data collected were analysed using Analysis of variance (ANOVA). Treatments were compared using the technique of least significance difference (LSD) at 5% level of probability. Combined analysis of the three years 1987-1989 and 1992 data were carried out for each variety. Simple correlation and step-wise correlations were carried out to assess the contributions of factors to yield in each variety.

CHAPTER 4

4. RESULTS

4.1 Number of days to 50% flowering.

The three varieties varied significantly (p=0.01) in the time taken to reach 50% flowering. Dauro took the longest time (102 days) and SAMMIL-7 the shortest (55.9 days) while Maiwa was intermediate (90.4 days) (Table 1a).

Varying the tiller number significantly reduced the number of days Dauro took to flower (P=0.01). When only one tiller was retained it took the shortest time (98.3 days) compared to the control (102.3 days). In Maiwa and SAMMIL-7 however, the difference in days to 50% flowering was not significant.

Spacing significantly affected the number of days the three varieties took to reach 50% flowering. A spacing of 15cm resulted in the longest time taken for all varieties while increasing spacing generally decreased the period.

The interaction between tiller number and spacing was significant (P=0.01, Table 1b). This was most noticeable especially in Dauro where a combination of 20cm spacing and one tiller resulted in significantly shortest time to flowering compared to control.

Table 1a. Effect of year of planting, tiller number and spacing on number of days to 50% flowering of millet.

Treatment	Millet varieties		
Year	Dauro	Maiwa	SAMMIL-7
1987	95.6	83.3	64.9
1988	104.3	97.0	53.9
1989	106.2	90.9	48.8
Mean	102.0	90.4	55.9
	LSD 0.91**		
Tiller No.			
1	98.3	90.7	56.2
2	103.3	90.8	54.9
3	103.4	90.2	56.8
4.	102.8	90.1	56.0
Control	102.3	90.3	55.9
	LSD 2.00**		
Spacing (cm)			
30	102.8	89.3	56.0
25	102.7	90.0	54.7
20	99.5	90.4	55.6
15	103.1	91.9	57.1
	LSD 1.82**		

** Significant at 1% level of Significance.

Table 1b: Interaction: spacing x tiller number x variety in days to 50% flowering (1987 - 1989)

		Varieties		
Spacing (cm)	*Tiller*	*Dauro*	*Maiwa*	SAMMIL-7
30	1	101.2	90.3	57.7
	2	104.9	88.3	55.6
	3	103.2	88.8	55.7
	4	102.3	88.3	56.2
	Control	101.0	89.8	55.1
25	1	103.9	90.4	55.2
	2	101.8	90.0	54.8
	3	102.4	89.6	54.7
	4	103.7	89.4	53.9
	Control	101.7	89.7	55.0
20	1	83.7	89.7	56.3
	2	102.9	91.1	53.9
	3	103.9	89.9	57.0
	4	104.1	90.3	56.2
	Control	102.8	91.0	54.6
15	1	103.8	92.3	55.7
	2	103.4	92.7	55.4
	3	104.1	92.7	59.8
	4	101.2	91.1	57.8
	Control	102.8	90.6	57.0
	LSD = 4.11**			

** Significant at 1% level of significance.

4.2 Plant height

The effect of variety, Tiller number and spacing on the height of the plants is presented in Table 2 (1987) - 1989) and Table 3a and 3b (1992). Dauro plants grew significantly taller (320.8cm) than Maiwa (273.7cm) which in turn was much taller than SAMMIL-7 (203.5cm).

Varying the tiller number and spacing of the plants as well as their interaction had no significant effect on the height of the plants. Similar results were obtained in the 1992 trial (Table 3a) during which Dauro's height was 363.7cm, Maiwa 370.8cm and SAMMIL-7 , 188.8cm. The interaction between variety, tiller number and spacing was however significant ($P = 0.01$, Table 3b). In Dauro, as the tiller number was increased and spacing decreased, there was an increase in plant height. A similar pattern was observed in Maiwa although in this case it reached a maximum at 5 tillers while the control was shorter at closer spacing.

Table 2: **Effect of year of planting, tiller number and spacing on plant height (cm) in millet (1987 - 1989).**

Treatment	Millet Varieties		
Year	Dauro	Maiwa	SAMMIL-7
1987	291.4	228.2	196.6
1988	287.2	285.4	207.2
1989	383.7	307.6	206.6
Mean	320.8	273.7	203.5
	LSD 5.52**		
Tiller No.			
1	314.6	273.5	203.6
2	328.6	275.8	201.2
3	317.8	273.0	204.7
4	319.4	266.8	203.3
Control	323.3	279.6	204.3
	NS		
Spacing (cm)			
30	319.1	267.6	199.7
25	315.2	271.9	206.4
20	325.0	271.3	205.3
15	323.8	284.1	202.6
	NS		

** significant at 1% level of significance

NS Not significant

Table 3a: Effect of variety, tiller number and spacing on plant height of the millet (1992)

Variety	Plant height (cm)
Dauro	363.7
Maiwa	270.8
SAMMIL-7	188.8
	LSD = 7.82 **

Treatment	**Millet Varieties**		
Tiller number	Dauro	Maiwa	SAMMIL-7
2	362.9	276.4	184.8
3	366.3	275.5	193.1
4	368.6	256.7	189.7
5	358.9	281.3	190.1
Control	361.8	264.0	186.1
Spacing (cm)			
30	363.0	266.4	188.5
25	365.8	273.4	191.0
20	361.8	275.5	186.5
15	364.1	267.8	189.1
	NS		

** Significant at 1% level of significance.

NS Not significant

Table 3b: Interaction: spacing x tiller number x variety in plant height (cm) of the millet (1992).

		Millet Varieties		
		Dauro	Maiwa	SAMMIL-7
spacing (cm)	Tillers			
30	2	368.0	250.0	183.5
	3	352.5	237.0	204.5
	4	367.0	261.5	188.5
	5	366.0	291.5	182.5
	Control	361.5	292.0	183.5
25	2	370.0	259.0	196.5
	3	374.0	339.0	190.5
	4	375.0	263.0	184.5
	5	352.5	265.5	190.0
	Control	357.5	240.5	193.5
20	2	352.5	312.5	180.5
	3	361.5	264.0	181.0
	4	362.0	257.0	198.5
	5	367.5	287.0	191.5
	Control	365.5	257.0	181.0
15	2	361.0	284.0	178.5
	3	377.0	262.0	196.5
	4	370.5	245.5	187.5
	5	349.5	281.0	196.5
	Control	362.5	266.5	186.5
	LSD 34.98**			

** Significant at 1% level of significance.

4.3 Tiller Number, Headed Tillers and Percentage Seeded Heads.

The maximum number of tillers developed by the varieties in the different spacings is shown in Table 4. All the varieties responded to increased spacing by increase in tiller number. Maiwa and SAMMIL-7 responded more than Dauro. Maiwa developed the highest number of tillers (14.4) at 30cm spacing and the lowest (5 tillers) at 15cm spacing.

The percentage headed tillers of the three varieties is presented in Tables 5. The varieties varied significantly (P=0.01) in the percentage of tillers that produced heads. Dauro had the highest. (73.1%) followed by Maiwa (69.8%) while SAMMIL-7 had the least (53.1%). Varying the number of tillers and spacing as well as their interactions had no pronounced or significant effect on the percentage number of tillers that developed heads.

Table 4: **Maxmum number of tillers developed by the millet varieties at the different plant spacing. (Pooled data of 4 years).**

	Millet Varieties		
	Dauro	Maiwa	SAMMIL-7
Spacing (cm)			
15	7.8	**5.0**	7.4
20	7.6	**6.0**	6.2
25	8.4	**12.4**	11.4
30	8.6	14.4	12.0
Mean	8.1	**9.5**	9.3

Table 5: **Effect of year of planting, tiller number and spacing on the percentage of *headed tillers of millet***

Treatment	Millet Varieties		
Year	Dauro	Maiwa	SAMMIL-7
1987	44.3	49.4	50.4
1988	76.4	80.6	62.4
1989	98.7	79.3	46.4
Mean	73.1	69.8	53.1
	LSD = 3.82**		
Tiller No.			
1	74.9	62.2	50.8
2	75.7	67.8	52.2
3	71.9	72.1	51.2
4	71.8	67.5	52.2
Control	71.4	79.4	58.9
	NS		
Spacing (cm			
30	74.0	72.5	55.1
25	69.9	66.1	52.6
20	73.0	69.3	52.6
15	75.5	71.2	51.9
	NS		

** Significant at the 1% level of significance

NS not significant.

The percentage of heads that set seed is shown in Table 6a. Maiwa had the highest percentage of heads that set seed (86.1%) followed by SAMMIL-7 (75.6%) while Dauro had the least (67.6%). Varying the tiller number significantly affected the percentage seeded heads (P=0.01). In Dauro, reducing tiller number increased the percentage seeded heads. In Maiwa a similar pattern was observed but this effect was even more striking as each reduction in tiller number correspondingly increased the percentage heads that seeded. In SAMMIL-7 the effect was not so pronounced though maintaining 3 tillers gave the highest percentage seeded heads.

A change in spacing of the plants had no effect on the percentage seeded heads but the interaction between variety, spacing and tiller number was highly significant (P=0.01 Table 6b). In SAMMIL-7, a closer spacing reduced the percentage seeded heads as tiller number was decreased. In Maiwa and Dauro as the spacing and tiller number were reduced, the percentage of heads that seeded increased.

Table 6a: Effect of variety, tiller number and spacing on the percentage seeded head in 1992.

Variety	% Seeded Heads
Dauro	67.6
Maiwa	86.1
SAMMIL-7	75.6
	LSD = 7.18**

Treatments	Millet Varieties		
Tiller number	Dauro	Maiwa	SAMMIL-7
2	77.0	93.0	74.6
3	70.0	90.1	86.8
4	69.9	93.1	63.9
5	54.5	88.5	73.6
Control	66.9	65.8	79.1
	LSD = 16.00**		
Spacing (cm)			
30	69.0	87.4	84.0
25	64.0	79.6	81.5
20	71.3	84.4	62.9
15	63.3	93.0	74.0
	NS		

** Significant at 1% level of significance

NS not significant.

Table 6b: **Interaction of variety, spacing and tillers on percentage seeded heads (1992).**

		Millet Varieties		
		Dauro	Maiwa	SAMMIL-7
Spacing (cm)	Tillers			
30	2	82.0	87.5	84.5
	3	85.5	86.5	90.5
	4	55.0	95.0	78.5
	5	61.0	88.5	91.5
	Control	61.5	79.5	75.0
25	2	66.5	98.0	95.0
	3	65.0	94.0	91.0
	4	69.0	87.0	63.5
	5	49.5	96.0	66.5
	Control	70.0	23.0	92.5
20	2	87.5	92.0	58.5
	3	60.0	83.5	77.5
	4	82.5	90.3	58.5
	5	44.0	75.5	57.0
	Control	82.5	80.5	63.0
15	2	72.0	94.5	60.5
	3	69.5	69.5	88.0
	4	73.0	100.0	56.0
	5	63.5	94.0	79.5
	Control	53.5	80.0	86.0
LSD = 31.91**				

** Significant at 1% level of significance

4.4 Nodal Tillers

These results are presented in Table 7 (1987 - 1989) and Tables 8a and 8b (1992). The tested varieties produced significantly different number of nodal tillers in all trials. SAMMIL-7 consistently produced the highest number ranging from 3.0 -3.24 followed by Maiwa (1.6 - 2.6) while Dauro produce the least (0.27 - 1.6) showing varietal difference in this character. Varying the number of tillers had no effect on the number of nodal tillers produce while varying the spacing of the plants only affected Maiwa which gave the highest number of nodal tillers at a wider spacing of 30cm (P0.05, Table 7). In the 1992 experiment, though the same trend was observed it was not significant. The interaction between variety, spacing and number of tillers retained was significant only in 1992 (P=0.01, Table 8b).

Table 7: **Effect of year of planting, tiller number and spacing on the production of nodal tillers in the three varieties of millet.**

Treatment	Millet Varieties		
Year	Dauro	Maiwa	SAMMIL-7
1987	3.1	5.3	4.0
1988	1.6	1.4	2.5
1989	0.0	1.1	2.4
Mean	1.6	2.6	3.0
	LSD 0.32 **		
Tiller No.			
1	1.5	2.4	3.0
2	1.5	2.8	2.8
3	1.7	2.4	3.2
4	1.7	3.1	3.4
Control	1.5	2.1	2.5
	NS		
Spacing (cm)			
30	1.6	3.5	2.9
25	1.6	2.8	3.1
20	1.6	2.2	3.1
15	1.5	1.8	2.8
	LSD 0.64*		

* Significant at 5% level of significance

** Significant at 1% level significance

Table 8a: Effective of variety, tiller number and spacing on nodal tiller production in 1992

Variety	Number of nodal tillers
Dauro	0.27
Maiwa	1.60
SAMMIL-7	3.24
	LSD = 0.559**

	Variety		
Tiller Number	Dauro	Maiwa	SAMMIL-7
2	0.31	2.10	3.20
3	0.21	1.06	3.05
4	0.46	1.65	2.64
5	0.15	1.98	3.96
Control	0.23	1.22	3.36
Spacing (cm)			
30	0.28	2.17	2.87
25	0.27	1.74	3.37
20	0.36	0.98	3.29
15	0.18	1.52	3.44
	NS		

** Significant at 1% level of significance

NS Not significant

Table 8b: **Interaction of variety, spacing and tiller number on nodal tiller production 1992**

		Millet Varieties		
		Dauro	Maiwa	SAMMIL-7
Spacing (cm)	Tillers			
30	2	0.50	3.30	2.80
	3	0.15	1.15	4.80
	4	0.30	0.00	1.10
	5	0.15	5.65	4.45
	Control	0.30	0.75	1.20
25	2	0.30	1.00	6.30
	3	0.25	1.30	1.15
	4	0.65	4.65	3.30
	5	0.00	1.60	3.80
	Control	0.15	0.15	2.30
20	2	0.30	0.30	2.40
	3	0.30	0.65	3.95
	4	0.45	0.30	2.65
	5	0.45	0.65	3.80
	Control	0.30	3.00	3.65
15	2	0.15	3.80	1.30
	3	0.15	1.15	2.30
	4	0.45	1.65	3.50
	5	0.00	0.00	3.80
	Control	0.15	1.00	6.30
LSD = 2.54**				

** Significant at 1% level of significance.

4.5 Leaf Number Per Plant Stand

The varieties varied significantly (P=0.01) in number of leaves they produced with Dauro and Maiwa being at par (45.9 and 43.9 respectively Table 9a), while SAMMIL-7 had the least (29.2). Varying tiller number and spacing did not significantly alter the number of leaves produced by the varieties. Nonetheless, reducing the number of tillers generally reduced the number of leaves per plant in all the varieties. The Interactions between variety, number of tillers and spacing were also not significant (Table 9b).

Table 9a: **Effect of year of planting, tiller number and spacing on the number of leaves per plant produced by the three varieties of millet (1987 - 1989)**

Treatment	*Millet varieties*		
Year	Dauro	Maiwa	SAMMIL-7
1987	43.7	43.4	30.9
1988	48.9	45.5	28.0
1989	45.2	42.9	28.4
Mean	45.9	43.9	29.2
	LSD 2.82**		
Tiller No.			
1	36.7	30.8	20.7
2	43.2	41.0	24.5
3	53.3	46.6	30.0
4	50.9	53.0	33.8
Control	45.5	48.3	36.9
	NS		
Spacing (cm)			
30	46.6	44.4	25.8
25	46.5	45.3	27.9
20	45.1	44.0	30.8
15	45.3	42.0	32.3
	NS		

** Significant at 1% level of significance

NS Not Significant

Table 9b: **Interaction of tillers, spacing and varieties on the number of leaves per plant produced (1987 - 1989).**

		Varieties		
Spacing (cm)	Tiller No	Dauro	Maiwa	SAMMIL-7
30	1	34.9	29.1	18.1
	2	43.7	42.3	20.9
	3	52.3	44.2	27.4
	4	51.1	55.5	32.3
	Control	51.2	51.2	29.9
25	1	35.2	33.4	18.4
	2	42.2	40.5	21.9
	3	55.5	49.2	32.2
	4	56.1	54.8	31.8
	Control	43.5	48.4	35.3
20	1	40.2	31.0	18.4
	2	46.1	43.1	28.6
	3	53.6	45.6	25.7
	4	45.4	54.0	34.5
	Control	40.1	46.4	46.5
15	1	36.2	29.6	27.9
	2	40.8	38.0	26.7
	3	51.6	47.2	34.8
	4	50.9	47.6	36.3
	Control	47.2	47.4	35.9
	LSD 12.72*			

* Significant at 5% level of significance.

4.6. Leaf Area Per Plant

The effect of varieties, tiller number and spacing on the leaf area produced is presented in Table 10 (1987 - 89) and Table 11a (1992) while the interactions (1992) are presented in Table 11b. The varieties varied significantly (P=0.01) in the leaf area produced with Dauro having the highest (138.1dm^2) followed by maiwa (111.3 dam^2) and then SAMMIL-7 (60.9dm^2) (1987 - 89), Dauro (132.7dm^2) Maiwa (106.0dm^2) and SAMMIL-7 (42.3dm^2) (1992). In the 1987 - 1989 trials, varying tiller number did not significantly affect the leaf area but in the 1992 trial it did (P=0.05, Table 11a). In all the trials however reducing the tiller number consequently reduced the leaf area. The highest leaf area was attained at 5 tillers while the control had less. This was significant in Maiwa and SAMMIL-7 (Table 11a). The interaction between 5 tillers and 15 - 25cm spacing gave a significantly higher leaf area than the control in Maiwa while in SAMMIL-7 it was 5 tillers and 25cm spacing (P=0.01, Table 11b).

In all the trials, varying the spacing resulted in a marked change in leaf area of all the varieties (P=0.01). Increased spacing generally increased the leaf area especially in Dauro and Maiwa. This was not in terms of leaf number as such but as a result of an increase in leaf size which consequently led to an increase in leaf area.

Table 10: **Effect of year of planting, tiller number and spacing on the leaf area per plant (dm^2) of the three varieties of millet (1987 - 1989).**

Treatment	Millet Varieties		
Year	Dauro	Maiwa	SAMMIL-7
1987	134.4	110.6	70.9
1988	139.3	111.1	55.0
1989	140.6	112.1	56.9
Mean	138.1	111.3	60.9
	LSD 11.95 **		
Tiller No.			
1	102.5	77.5	52.3
2	125.7	103.9	47.6
3	170.2	122.6	62.5
4	153.4	126.5	71.9
Control	138.7	125.8	70.4
	NS		
Spacing (cm)			
30	159.0	110.8	50.9
25	134.2	106.0	53.9
20	125.0	129.1	62.5
15	134.1	99.2	76.4
	LSD 23.90**		

** Signifcicant at 1% level of significance.

NS Not significant

Tabele 11a: Effect of variety, tiller number and spacing on leaf area per plant (dm^2) in 1992.

Variety	Leaf area (dm^2)
Dauro	132.7
Maiwa	106.0
SAMMIL-7	42.3
	LSD = 12.37**

	Millet Varieties			
Treatment	Tiller Number	Dauro	Maiwa	SAMMIL-7
	2	108.1	67.3	36.0
	3	150.4	95.5	40.3
	4	125.2	111.4	36.8
	5	163.2	166.6	65.3
	Control	138.9	89.1	33.1
		LSD = 27.66 *		
	Spacing (cm)			
	30	119.3	123.4	42.3
	25	143.7	86.1	58.8
	20	139.8	84.9	29.1
	15	128.2	129.5	39.0
		LSD = 24.74**		

** Significant at 1% Level of significance

* Significant at 5% level of significance

Table 11b: **Interaction of variety, tiller numbers and spacing on the leaf area per plant (dm^2) in 1992**

Spacing (cm)	Tillers	Varieties		
		Dauro	Maiwa	SAMMIL-7
30	2	99.2	106.5	34.4
	3	130.7	127.1	52.2
	4	110.5	157.3	31.1
	5	141.5	130.8	42.8
	Control	114.5	95.6	51.0
25	2	121.4	66.9	54.7
	3	130.5	61.5	49.2
	4	115.9	89.4	36.9
	5	198. 3	160.4	125.9
	Control	152.5	52.4	27.1
20	2	132.9	43.0	33.4
	3	149.2	116.8	21.3
	4	146.2	88.4	29.5
	5	124.9	134.2	22.1
	Control	145.9	42.3	19.3
15	2	78.8	52.9	21.7
	3	111.1	76.6	38.6
	4	120.3	110.7	49.6
	5	188.0	241.1	50.2
	Control	142.6	166.3	35.0
		LSD = 55.15 **		

** Significant at 1% level of significance.

4.7 Length and Diameter of Heads

The results of the main effects are presented in Tables 12a (1987 - 89) and Table 13a (1992). The varieties differed markedly in head length in all trials. Maiwa always produced the longest heads (41.9cm) followed by Dauro (36.4cm) and least by SAMMIL-7 (34.6cm) (P=0.01). It appears that varying the tiller number did not affect the length of heads produced in all trials. Similarly, varying the spacing did not affect the lengtrh of heads produced markedly in all trials except for SAMMIL-7 in the 1987 - 89 trial (Table 12a, P=0.05). In this variety, a spacing of 20cm produced the longest heads which was, however, at par with the spacing of 30cm. In all the trials, the interactions between variety, spacing and number of tillers retained was significant (P=0.01, Tables 12b and 13b). As the spacing was increased and number of tillers decreased, the length of the heads tended to increase especially in Maiwa and SAMMIL-7.

The head diameters are presented in Table 14a (1987 - 89) and Table 15a (1992). The varieties varied significantly in head diameter in all the trials (P=0.01) with Maiwa having the fattest heads (2.14 - 2.75cm). SAMMIL-7 consistently had fatter heads than Dauro in the three year study but in the 1992 trial it was slightly less than that of Dauro. Varying the tiller number and spacing of the plants had no effect on the diameter of the heads produced in all the trials. The interactions between varieties, spacing and number of tillers was significant in all the trials (P=0.03, Tables 14b and 15b).

Table 12a: Effect of year of planting, tiller number and spacing on the length of heads (cm) of the millet varieties (1987 - 89)

Treatmetnt	Millet Variesties		
Year	Dauro	Maiwa	SAMMIL-7
1987	38.2	42.3	36.6
1988	38.5	42.7	34.2
1989	32.6	41.9	33.0
Mean	36.4	41.9	34.6
	LSD 0.79 **		
Tiller No.			
1	36.6	42.5	34.6
2	36.7	42.0	33.4
3	36.4	42.9	35.4
4.	35.5	41.0	35.2
Control	36.7	42.4	34.5
	NS		
Spacing (cm)			
30	36.7	42.4	34.8
25	36.2	42.3	34.1
20	36.3	41.3	36.3
15	36.6	41.7	33.3
	LSD 1.59*		

* Significant at 5% level of significance

** Significant 1% level of significance

NS Not significant.

Table 12b: Interaction of varieties, spacing and tiller number on head length (cm) (1987 - 89)

		Varieties		
spacing (cm)	Tiller No.	Dauro	Maiwa	SAMMIL-7
30	1	36.7	41.6	34.8
	2	38.2	44.4	32.8
	3	39.3	41.2	33.9
	4	32.7	41.7	37.6
	Control	36.6	43.1	34.7
25	1	36.5	43.2	33.7
	2	35.3	41.1	34.0
	3	35.9	42.9	33.3
	4	35.9	41.3	34.8
	Control	37.1	43.1	34.9
20	1	36.0	41.7	35.3
	2	35.4	40.4	36.7
	3	36.0	41.7	39.8
	4	37.1	39.2	34.2
	Control	37.0	43.4	35.3
15	1	37.1	43.4	34.5
	2	37.9	41.9	30.2
	3	34.5	41.8	34.7
	4	36.2	41.8	34.3
	Control	37.0	39.7	33.0
		LSD = 3.60**		

** Significant at 1% level of significance

Table 13a: **Effect of variety, tiller number and spacing on length of heads (cm) in 1992**

Variety	Length of heads (cm)
Dauro	35.3
Maiwa	34.2
SAMMIL-7	30.5
	LSD = 2.26**

	Varieties		
	Dauro	Maiwa	SAMMIL-7
Tiller number			
2	38.4	53.7	30.1
3	34.2	49.0	29.9
4	35.3	54.4	31.4
5	34.2	59.2	30.4
Control	34.4	54.8	30.7
	NS		
Spacing (cm)			
30	35.0	53.1	29.6
25	36.2	53.0	31.3
20	35.8	56.1	30.6
15	34.1	54.7	30.5
	NS		

** significant at 1% level of significance

NS *Not Significant.*

Table 13b: Interaction of varieties, spacing and tiller number on head length in 1992

Spacing (cm)	Tiller No.	Varieties		
		Maiwa	Dauro	SAMMIL-7
30	2	36.4	50.1	29.8
	3	34.2	49.2	28.5
	4	36.5	51.5	29.9
	5	31.5	55.7	31.5
	Control	36.6	59.0	28.5
25	2	36.7	55.7	32.0
	3	37.6	52.9	30.6
	4	37.6	53.0	26.2
	5	33.6	56.6	32.9
	Control	35.8	46.7	34.7
20	2	46.4	48.9	28.9
	3	32.3	46.5	31.4
	4	34.6	56.2	35.1
	5	33.8	66.1	28.0
	Control	32.1	62.9	29.5
15	2	34.2	60.1	29.8
	3	32.7	47.4	29.3
	4	32.5	56.8	34.5
	5	38.1	58.4	29.3
	Control	33.1	50.7	30.0
	LSD = 10.07**			

** Significant at 1% level of significant.

Table 14a: **Effect of year of planting, tiller number and spacing on the diameter of heads (cm) of millet varieties (1987 - 89).**

Treatment	Millet Varieties		
Year	Dauro	Maiwa	SAMMIL-7
1987	1.83	2.09	1.99
1988	1.98	2.22	2.06
1989	1.55	2.11	1.84
Mean	1.79	2.14	1.96
	LSD 0.040**		
Tiller number			
1	1.82	2.15	1.95
2	1.77	2.16	1.90
3	1.79	2.14	1.97
4	1.77	2.15	2.01
Control	1.79	2.00	1.97
Mean	1.79	2.10	1.96
	NS		
Spacing (cm)			
30	1.79	2.13	1.97
25	1.77	2.16	1.95
20	1.81	2.14	2.03
15	1.77	2.12	1.90
Mean	1.79	2.13	1.96
	NS		

** Significant at 1% level of Significance

NS Not significant

Table 14b: **Interaction of varieties, spacing and tiller number on head diameter (cm) (1987 - 89).**

Spacing (cm)	Tiller No.	Millet vaieties		
		Dauro	Maiwa	SAMMIL-7
30	1	1.89	2.03	1.95
	2	1.79	2.20	1.99
	3	1.94	2.15	1.93
	4	1.62	2.19	2.03
	Control	1.74	2.06	1.93
25	1	1.87	2.28	1.92
	2	1.78	2.14	1.86
	3	1.63	2.16	1.88
	4	1.77	2.15	1.99
	Control	1.81	2.09	2.09
20	1	1.85	2.14	1.99
	2	1.82	2.20	1.93
	3	1.84	2.16	2.13
	4	1.83	2.09	2.04
	Control	1.72	2.09	2.05
15	1	1.69	2.16	1.91
	2	1.66	2.16	1.91
	3	1.74	2.08	1.93
	4	1.87	2.15	1.99
	Control	1.87	2.14	1.85
LSD = 0.183**				

** Significant at 1% level Significance

Table 15a: **Effect of variety, tiller number and spacing on diameter of heads (cm) 1992**

Variety	Width of heads (cm)
Dauro	2.19
Maiwa	2.75
SAMMIL-7	1.76
	LSD = 0.150**

Tiller number	Varieties		
	Dauro	Maiwa	SAMMIL-7
2	2.07	2.62	1.80
3	2.07	2.61	1.75
4	2.33	2.57	1.60
5	2.38	3.10	1.88
Control	2.07	2.86	1.86
	NS		
Spacing (cm)			
30	2.29	2.65	1.75
25	2.21	2.78	1.82
20	2.10	2.84	1.72
15	2.16	2.75	1.83
	NS		

** Significant at 1% level of significance

NS Not significant

Table 15b: **Interaction of variety, tiller number and spacing on head diameter (cm) 1992**

		Varieties		
spacing (cm)	Tiller No.	Dauro	Maiwa	SAMMIL-7
30	2	1.65	2.55	1.90
	3	2.80	2.85	1.90
	4	2.45	2.40	1.70
	5	2.65	2.85	1.70
	Control	1.90	2.65	1.75
25	2	2.05	2.80	1.85
	3	1.60	2.30	1.55
	4	2.05	2.95	1.70
	5	2.75	3.10	2.00
	Control	2.40	2.85	2.00
20	2	2.80	2.70	1.75
	3	1.70	2.85	1.95
	4	2.15	2.50	1.45
	5	1.95	3.30	1.75
	Control	1.90	2.85	1.70
15	2	1.80	2.45	1.70
	3	2.00	2.45	1.60
	4	2.70	2.55	1.55
	5	2.20	3.15	2.10
	Control	2.10	3.15	2.20
	LSD 0.671*			

* Signifcicant at 5% level of significance

4.8 Grain Yield

The results of grain yield per hectare are presetnted in Table 16 (1987 - 89 trials) and Table 17a and 17b for (1992) trial. In all the trials, the varieties differed signifcicantly in grain yield (P=0.01) in the 1987 - 89 trials. It was observed that SAMMIL-7 had the highest mean yield of 433kg/ha which was significantly higher (P=0.01) that Maiwa which yieldedd 398kg/ha. Dauro had the lowest yields of 192kg/ha which was significantly lower (P=0.01) than the other two varieties (Table 16). Low yields were generally recorded for the 1987 - 89 trial especially for 1987 and 1988. In the 1992 trail (Table 17a) yield obtained was much higher. Maiwa gave the highest yield of 3660kg/ha followed by SAMMIL-7 which yielded 2002kg/ha while Dauro's yield was significantly lower at 992kg/ha (P=0.01).

In all the trials, varying the tiller number did not significantly affect the grain yield. Nonetheless, reducing the number of tillers increased grain yield in Dauro and Maiwa compared to the control. In the 1992 trial, retention of two tillers gave the best yield of 1199kg/ha in Dauro while 2 and 4 tillers retention gave the best yield of 3995 and 3961kg/ha, respectively in Maiwa. In SAMMIL-7 however, reducing the tiller number did not improve the yield when compared to the control.

In all the varieties, closer spacing gave higher yield in the 1992 trial and this effect was significant (P=0.05, Table 17a). In the earlier trials, the reactions of the varieteies to spacing was slightly different and is highly significant (P=0.01, Table 16). Dauro produced its highest yield at a spacing of 30cm while Maiwa's was at 25cm, but both had their lowest yield at the

close spacing of 15cm. SAMMIL-7 on the other hand, produced highest yield at the spacing of 20cm and lowest at 30cm.

The interaction between variety, spacing and tiller number in 1992 was not significant but it was observed that in Dauro the best yield of 1480 - 1349kg/ha was obtained at the combination of 20cm spacing and 2 -3 tillers retained. In Maiwa the best yield was obtained at a spacing of 15cm and 2 tillers per plant while in SAMMIL-7 the combination of 15cm spacing, 2 and 5 tillers gave the best yield though the control in this variety had the highest yield.

Table 16: **Effect of year of planting, tiller number and spacing on grain yield (kg/ha) of millet (1987 - 89)**

Treatment	Milelet Varieties		
Year	Dauro	Maiwa	SAMMIL-7
1987	59	74	45
1988	72	177	198
1989	444	942	1057
Mean	192	398	433
	LSD 62.4**		
Tiller number			
1	189	396	285
2	189	398	495
3	197	427	450
4	203	385	402
Control	181	385	434
	NS		
Spacing (cm)			
30	244	409	275
25	184	432	414
20	163	369	565
15	175	383	478
	LSD 125.1 **		

** Significant at 1% level.

Table 17a: **Effec of variety, tiller number and spacing on grain yield (kg/ha) in 1992**

Variety	Grain Weight (kg/ha)
Dauro	992
Maiwa	3660
SAMMIL-7	2002
	LSD 409.0**

Tiller number	Millet Varieties		
	Dauro	Maiwa	SAMMIL-7
2	1199	3995	1765
3	1146	3529	1963
4	939	3961	1786
5	786	3289	1837
Control	891	3525	2659
	NS		
Spacing (cm)			
30	395	3036	1823
25	560	2823	1728
20	1252	2590	1843
15	1264	5190	2614
	LSD 818.1*		

* Significant at 5% level of probability

** Significant at 1% level of probability

Table 17b: **Interaction of variety, tiller number and spacing on grain yield (kg/ha) in 1992**

Spacing (cm)	Tiller No.	Varieties		
		Dauro	Maiwa	SAMMIL-7
30	2	791	3342	1555
	3	688	2730	1965
	4	483	3843	2355
	5	476	2667	1660
	Control	524	2596	1597
25	2	1183	2877	934
	3	1005	2370	1879
	4	711	2375	1976
	5	766	2772	1227
	Control	634	2822	2625
20	2	1549	3690	1725
	3	1480	3792	2052
	4	1084	3151	1145
	5	1174	2995	1618
	Control	971	4321	2675
15	2	1272	6070	2868
	3	1411	5222	1955
	4	1477	5576	1668
	5	727	4722	2842
	Control	1434	4359	3738
	N.S			

NS Not significant.

4.9. Tiller contribution to yield

The contribution to yield of the tillers as compared to the main stem was investigated and the results are presented in Figure 1. The contribution of the tillers to yield as affected by varying tiller numbers and spacing are shown in figures 2 and 3 respectively.

In Dauro the main stem had a yield of 5.6g representing 30% of the total yield (18.6g) of the plant while the tillers contributed 13.0g representing 69.8% of the total yield. In Maiwa the main stem yield was 18.9g which represented 27% of the total yield while the tillers contributed 51.4g which was 73.4% out of a total of 70.0g from the plant. In SAMMIL-7 the main stem had a yield of 11.6g and the tillers 23.5g representing 33% and 66.9% respectively out of the total plant yield of 35.1g.

Varying tiller number significantly affected the contribution of the tillers to the plants yield (Fig. 2). Maintaining 4 and 5 tillers in Dauro, and 5 tillers in Maiwa significantly increased tiller contribution to yield above the control while maintaining 2 tillers in Dauro, 2 and 3 tillers in Maiwa gave a significantly lower contribution of tillers to grain yield. In SAMMIL-7 maintaining 5 tillers increased the yield contribution of tillers significantly above the control.

A plant spacing of 20cm and 15cm gave the highest tiller contribution to yield in Dauro and Maiwa, respectively. In SAMMIL-7 though 20cm spacing gave the least contribution there were no differences from the other spacings (fig. 3).

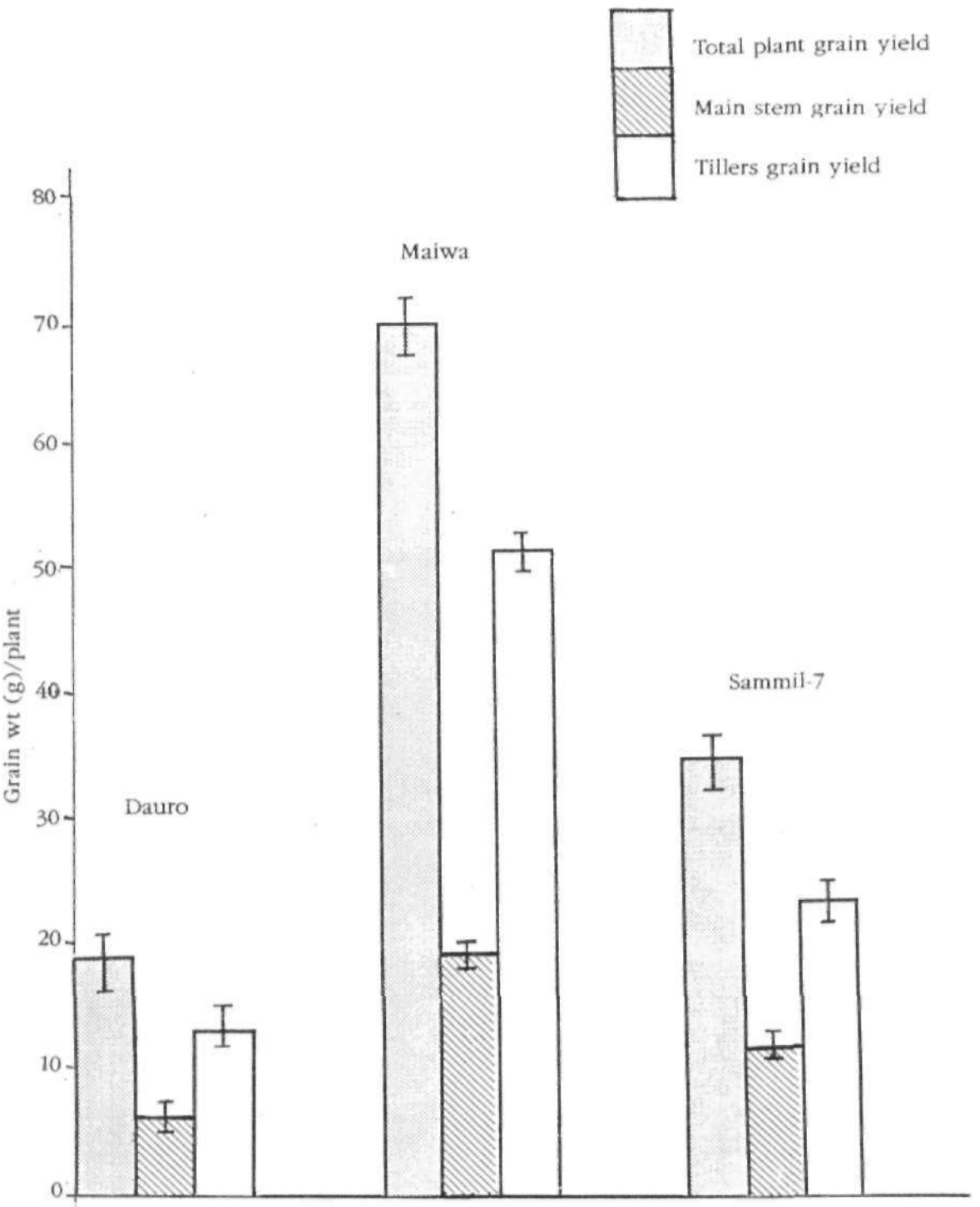


FIGURE: 1 A comparison of the total grain yield (g/plant) of the plant with the contributions of the main stem and tillers in 1992.

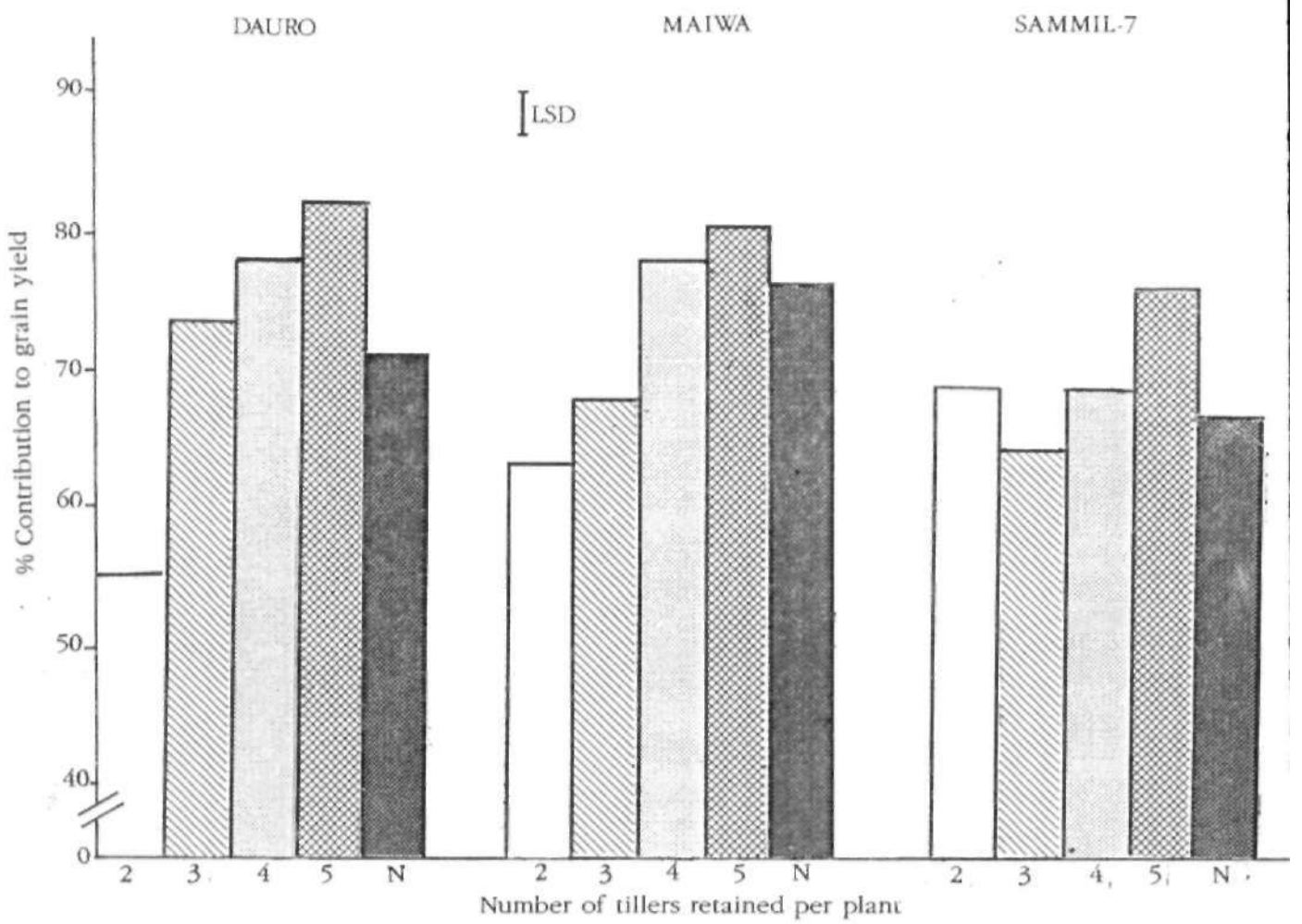


FIGURE 2: The contribution of Tillers to plant grain yield as affected by varying tiller number in 1992

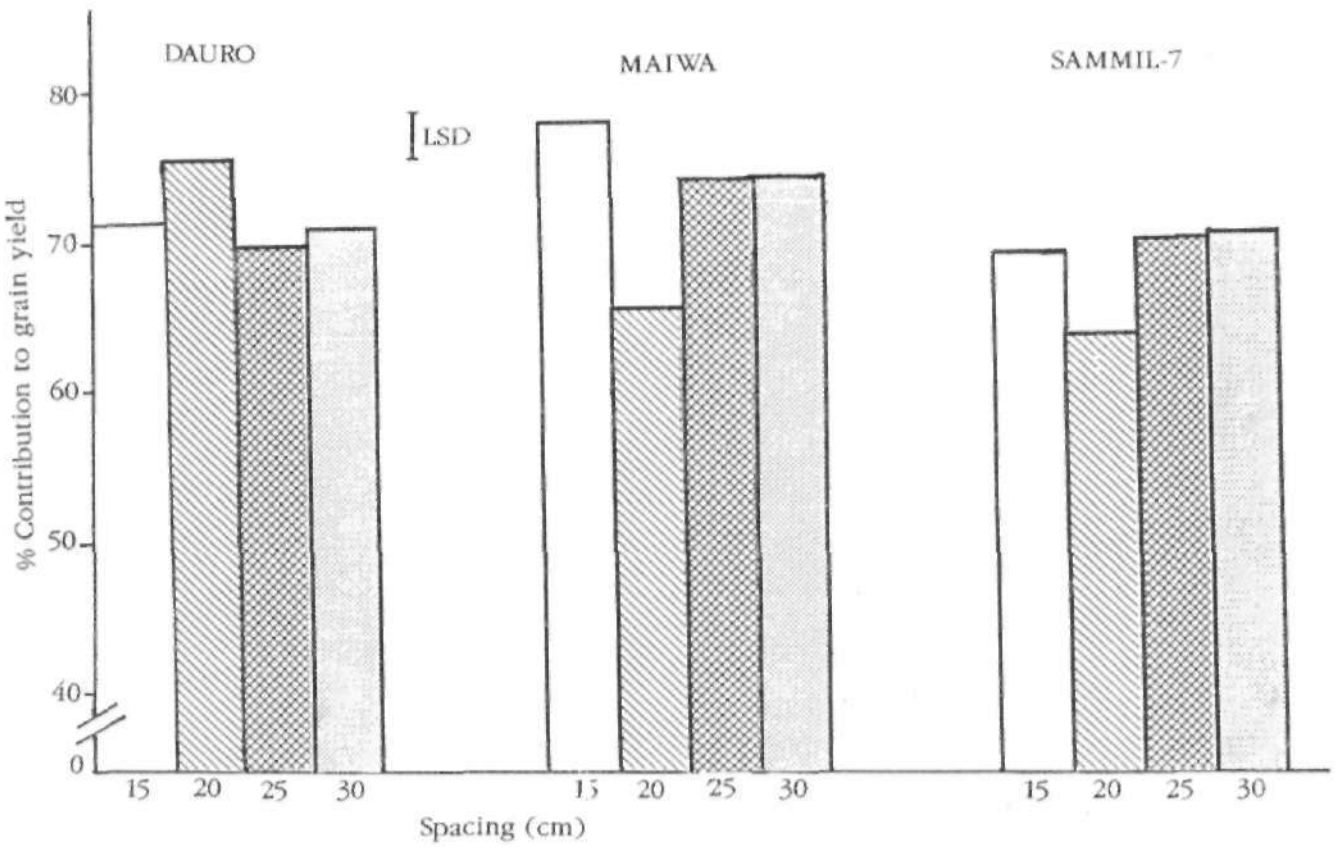


FIGURE 3: The contribution of tillers to plant grain yield as affected by plant spacing

4.10. The Harvest Index (H.I.)

This is the ratio of total dry weight to grain weight taken at maturity. SAMMIL-7 had the highest harvest index compared to the other two varieties, both under different spacings or number of tillers maintained (Figures 4 and 5). It was highest at 20cm spacing (35.9%) and decreased under wider or closer spacings. When no tillers were removed (control) the harvest index of SAMMIL-7 was highest (30.9×10^{-2}).

The harvest index of Maiwa and Dauro remained almost constant within the variety despite changes in plant spacing and tiller number. That of Dauro was much lower, ranging from 1.1×10^{-2} to 1.9×10^{-2} under different tiller numbers. Maiwa had a harvest index of 4.8×10^{-2} to 6.9×10^{-2} under different plant spacings and 4.8×10^{-2} to 8.4×10^{-2} under different tiller numbers.

4.11. Leaf Area Index (LAI)

These results are presented in Table 18. The LAI was highest in Dauro (8.41) which was at par with Maiwa (8.10) and these were significantly higher than that of SAMMIL-7 (2.61), ($P=0.01$).

Reduction in tiller number caused a decrease in LAI in all the varieties. The LAI of the control was nonetheless lower than when 5 tillers were retained. In all the varieties a spacing of 15cm gave the highest LAI while 30cm spacing gave the lowest in Dauro and SAMMIL-7 but in Maiwa it was achieved at 25cm spacing. Therefore increasing the spacing decreased LAI, generally. Varying the tiller number and spacing, as well as the interaction did not, however, affect the LAI, significantly.

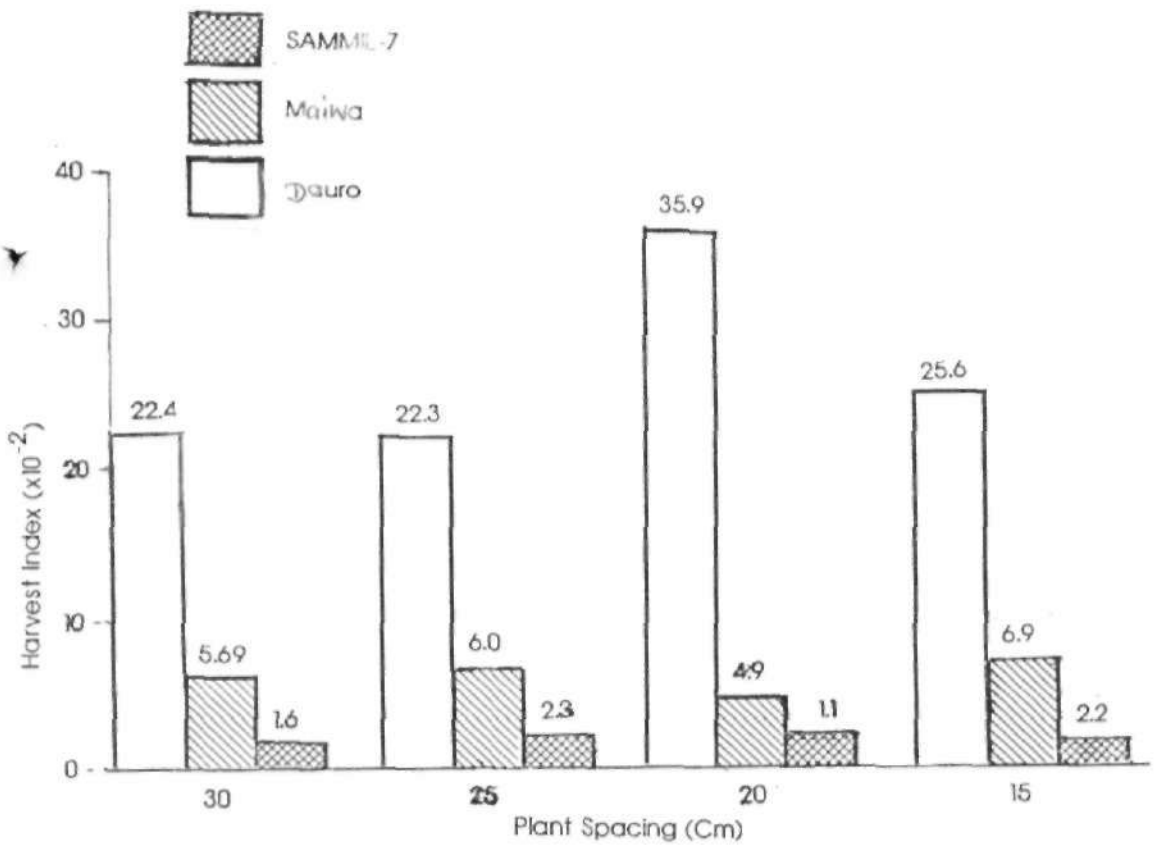


Fig. 4 Harvest Index of SAMMIL - 7, Maiwa and Dauro Millet at the different plant spacings

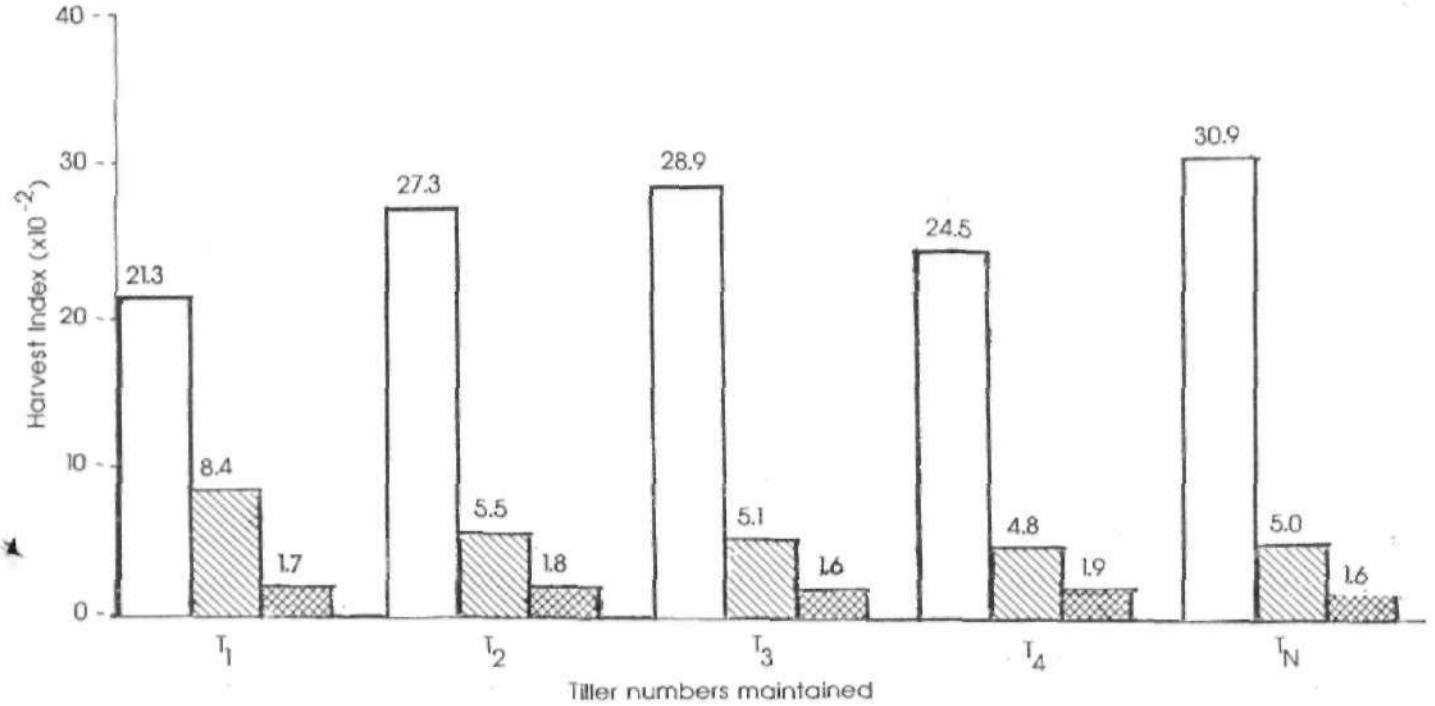


Fig. 5 Harvest Index of Sammil - 7, Maiwa and Dauro Millet when different tiller numbers were maintained

Table 18a: **Effect of variety, tiller number, and spacing on the leaf area index (LAI) in 1992.**

Variety	LAI
Dauro	8.41
Maiwa	8.10
SAMMIL-7	2.61
	LSD 2.25**

	Millet varieties		
Tiller number	Dauro	Maiwa	SAMMIL-7
2	6.65	3.97	2.15
3	8.15	12.16	2.45
4	7.88	6.85	2.44
5	10.47	11.19	3.97
Control	8.90	6.36	2.03
	NS		
Spacing (cm)			
30	5.30	10.46	1.88
25	7.64	4.59	3.13
20	9.32	5.69	1.94
15	11.39	11.67	3.47
	NS		

** Significant at 1% level of significance

NS Not significant.

Table 18b: **Interaction of variety, tiller number and spacing on leaf area index (LAI) in 1992**

		Varieties		
Spacing(cm)	Tiller No.	Dauro	Maiwa	SAMMIL-7
30	2	4.41	4.74	1.53
	3	5.81	3.76	2.32
	4	4.92	6.74	1.40
	5	6.29	5.82	1.90
	Control	5.09	4.25	2.26
25	2	6.34	3.57	2.92
	3	6.96	3.28	2.63
	4	6.19	4.77	1.97
	5	10.58	8.56	6.71
	Control	8.58	8.56	1.45
20	2	8.86	2.87	2.23
	3	9.94	7.79	1.42
	4	9.74	6.05	1.96
	5	8.32	8.95	2.81
	Control	9.73	2.82	1.29
15	2	7.00	4.71	1.93
	3	9.88	6.81	3.43
	4	10.69	9.84	4.40
	5	16.70	21.45	4.47
	Control	12.67	15.58	3.12
		N.S		

NS Not significant.

4.12. Correlation Analysis

In Dauro (Table 19, 1987 - 1989) there was a significant positive correlation between grain yield and plant height (r = + 0.586) and percentage headed tillers (r = + 0.523) while it was negative with nodal tillers (r= - 0.552). The low negative correlations between yield and headed tillers (=-0.134), number of leaves (r=-036), head length (r=-0.371) and head diameter (r=-0.477) were all non significant as well as the positive low correlations between yield with leaf area and days to 50% flowering. In 1992 Dauro showed a significant positive correlation between yield and leaf area index (r= + 0.659 Table 22). Stepwise regression of yield showed that plant height, percentage headed tillers and head diameter were the most contributing factors to yield. These contributed 34.3%, 39.4% and 41.8% in step 1, 2 and 3 respectively in 1987 - 1989. In 1992 the leaf area index and the leaf area were the most contributing factors to yield and they contributed 50.9 and 61.2% at step 2 and 3, respectively.

In all the trials Maiwa showed no significant correlation between yield and other attributes (Table 20 and 23). Stepwise regression showed that number of days to 50% flowering and percentage headed tillers were the most contributing factors to yield in 1987 - 1989. These contributed 24.2% and 26.9% at step 2 and 3, respectively. In 1992 no factor was of more importance than the other in the ranking.

In SAMMIL-7, there were non-significant correlations between yield and other characters (Tables 21 and 24). The correlations between yield and plant height, number of leaves leaf area and head length were positive in 1987 - 1989 while in 1992 it was those with days to 50% flowering, head diameter and percentage seeded heads. Stepwise regression showed that number

of days to 50% flowering, number of leaves and headed tillers were the most contributing factors to yield in 1987 - 1989. These contributed 24.4%, 32.6% and 45.9% at step 2 and 3, respectively. In 1992 it was the head diameter which contributed 42.6% at step 3.

Table 19: Correlation between yield and various characters in Dauro (1987 -89)

		I.	II.	III.	IV.	V.	VI	VII	VIII	IX	X.
		Grain yield kg/ha	Plant height(cm)	Nodal tillers	Headed tillers	Number of leaves/plant	Leaf area (dm^2)	Head length	Head diameter	Days to 50% flowering	% Headed tillers
I.	Grain yield kg/ha	1.00									
II.	Plant height(cm)	0.586*	1.00								
III.	Nodal tillers	-0.552*	-0.673*	1.00							
IV.	Headed tillers	-0.134	-0.214	0.423	1.00						
V.	Number of leaves/plant	-0.036	0.155	0.278	0.755*	1.00					
VI.	Leaf area (dm2)	0.081	-0.098	0.117	0.497	-0.741*	1.00				
VII.	Head length	-0.371	-0.458	0.542*	0.115	-0.063	0.192	1.00			
VIII.	Head diameter	-0.477	-0.530	0.631*	0.258	0.150	-0.005	0.707*	1.00		
IX.	Days to 50% flowering	0.059	0.104	0.115	0.006	0.010	0.138	-0.108	-0.087	1.00	
X.	% Headed tillers	0.523	0.579*	0.718*	0.005	-0.164	-0.048	-0.388	-0.438	0.045	1.00

* Significant at 5% level of probability

Table 20: Correlation between yield and various characters in Maiwa (1987-1989)

		Grain yield kg/ha	Plant height(cm)	Nodal tillers	Headed tillers	Number of leaves/plant	Leaf area (dm^2)	Head length	Head diameter	Days to 50% flowering	% Headed tillers
		I.	II.	III.	IV.	V.	VI	VII	VIII	IX	X.
I.	Grain yield kg/ha	1.00									
II.	Plant height(cm)	0.176	1.00								
III.	Nodal tillers	-0.116	-0.057	1.00							
IV.	Headed tillers	0.040	0.046	-0.002	1.00						
V.	Number of leaves/plant	-0.082	0.084	0.145	0.766*	1.00					
VI	Leaf area (dm2)	0.009	0.040	0.153	0.588*	0.745*	1.00				
VII	Head length	-0.151	0.185	-0.018	-0.023	0.001	-0.132	1.00			
VIII	Head diameter	-0.076	-0.082	0.032	0.006	0.077	0.008	0.266	1.00		
IX	Days to 50% flowering	-0.492	-0 111	-0.044	-0.082	0.046	0.117	0.049	0.325	1.00	
X.	% Headed tillers	0.097	0.064	-0.649*	0.262	0.029	0.027	0.073	0.071	0.131	1.00

* Significant at 5% level of probability.

Table 21: **Correlation between yield and other characters in SAMMIL-7 (1987 - 89).**

		I. Grain yield kg/ha	II Plant height(cm)	III. Nodal tillers	IV. Headed tillers	V Number of leaves/plant	VI Leaf area (dm^2)	VII Head length	VIII Head diameter	IX Days to 50% flowering	X. % Headed tillers
I.	Grain yield kg/ha	1.00									
II.	Plant height(cm)	0.050	1.00								
III.	Nodal tillers	-0.060	-0.040	1.00							
IV.	Headed tillers	0.408	0.001	0.160	1.00						
V.	Number of leaves/plant	0.361	0.054	0.198	0.202	1.00					
VI	Leaf area (dm2)	0.051	-0.024	0.127	0.140	0.305	1.00				
VII	Head length	0.025	0.001	-0.088	0.044	0.056	0.022	1.00			
VIII	Head diameter	-0.136	-0.079	-0.065	0.113	0.008	-0.023	0.311	1.00		
IX	Days to 50% flowering	-0.493	-0.133	0.002	0.289	-0.157	-0.045	-0.106	0.147	1.00	
X.	% Headed tillers	-0.384	0.033	-0.604*	0.468	-0.196	-0.129	0.098	0.143	0.290	1.00

* Significant at 5% level of probability

Table 22: **Correlation between yield and other characters in Dauro (1992)**

		I	II	III	IV	V	VI	VII	VIII	IX	X
		Days to 50% flowering	Plant height	Nodal tillers	Headed tillers	Leaf area	Grain yield	Head length	Head diameter	Leaf area index	% Seeded heads
I	Days to 50% flowering	1.00									
II	Plant height	-0.138	1.00								
III	Nodal tillers	0.223	-0.103	1.00							
IV	Headed tillers	-0.212	0.924*	-0.151	1.00						
V	Leaf area	-0.335	0.417	-0.132	0.372	1.00					
VI	Grain yield	0.149	-0.337	-0.055	-0.266	-0.102	1.00				
VII	Head length	-0.370	-0.283	0.043	-0.161	0.074	0.187	1.00			
VIII	Head diameter	-0.392	0.296	-0.284	0.331	0.238	-0.155	0.168	1.00		
IX	Leaf area Index	-0.134	0.239	-0.121	0.239	0.659*	0.287	-0.072	0.064	1.00	
X	% Seeded heads	-0.096	-0.322	0.112	-0.269	-0.283	0.232	0.278	0.090	-0.159	1.00

* Significant at 5% level of probability

Table 23: Correlation between yield and other characters in Maiwa (1992)

		I	II	III	IV	V	VI	VII	VIII	IX	X
		Days to 50% flowering	*Plant height*	Nodal tillers	Headed tillers	*Leaf area*	Grain yield	Head length	*Head diameter*	Leaf area index	% Seeded heads
I	Days to 50% flowering	1.00									
II	Plant height	0.022	1.00								
III	Nodal tillers	0.301	-0.129	1.00							
IV	Headed tillers	0.231	0.767*	-0.022	1.00						
V	Leaf area	0.049	0.617*	-0.152	0.529*	1.00					
VI	Grain yield	-0.035	-0.034	0.130	0.063	0.079	1.00				
VII	Head length	0.347	0.188	0.032	0.249	0.102	0.047	1.00			
VIII	Head diameter	0.156	0.345	-0.029	0.383	0.291	0.052	0.245	1.00		
IX	Leaf area index	0.030	0.603*	-0.201	0.529*	0.901*	0.303	0.131	0.270	1.00	
X	% Seeded heads	0.066	0.009	0.125	-0.138	0.156	0.203	0.253	-0.269	0.157	1.00

* Significant at 5% level of probability

Table 24: **Correlation between yield and other characters in SAMMIL-7 (1992).**

		I Days to 50% flowering	II Plant Height	III Nodal tillers	IV Headed tillers	V Leaf area	VI Grain yield	VII Head length	VIII Head diameter	IX Leaf area index	X % Seeded heads
I	Days to 50% flowering	1.00									
II	Plant Height	0.271	1.00								
III	Nodal tillers	0.183	-0.212	1.00							
IV	Headed tillers	0.051	0.503*	-0.154	1.00						
V	Leaf area	0.176	0.505*	0.149	0.258	1.00					
VI	Grain yield	0.048	-0.212	-0.020	-0.261	-0.210	1.00				
VII	Head length	0.176	0.028	0.110	-0.079	0.124	-0.048	1.00			
VIII	Head diameter	0.287	-0.172	0.220	-0.236	0.138	0.458	-0.251	1.00		
IX	Leaf area index	0.170	0.402	0.192	0.287	0.863*	-0.029	0.136	0.146	1.00	
X	% Seeded heads	0.278	0.058	0.142	-0.073	0.044	0.370	0.125	0.374	-0.055	1.00

* Significant at 5% level of probability.

4.13. Yield estimation using head measurements.

These measurements are presented in Appendix 2 while a pictorial view of the pearson correlation of the grain weight and head length, diameter as well as the chaff weight is presented in Figure 6. Grain weight of the head correlated positively with all the three parameters measured, however, head length showed a much more clearer picture of the relationship and highest positive correlation ($r = + 0.7304$) with the grain weight. This close association is shown by the close clustering of points when grain weight (x-axis) was plotted against head length (y-axis).

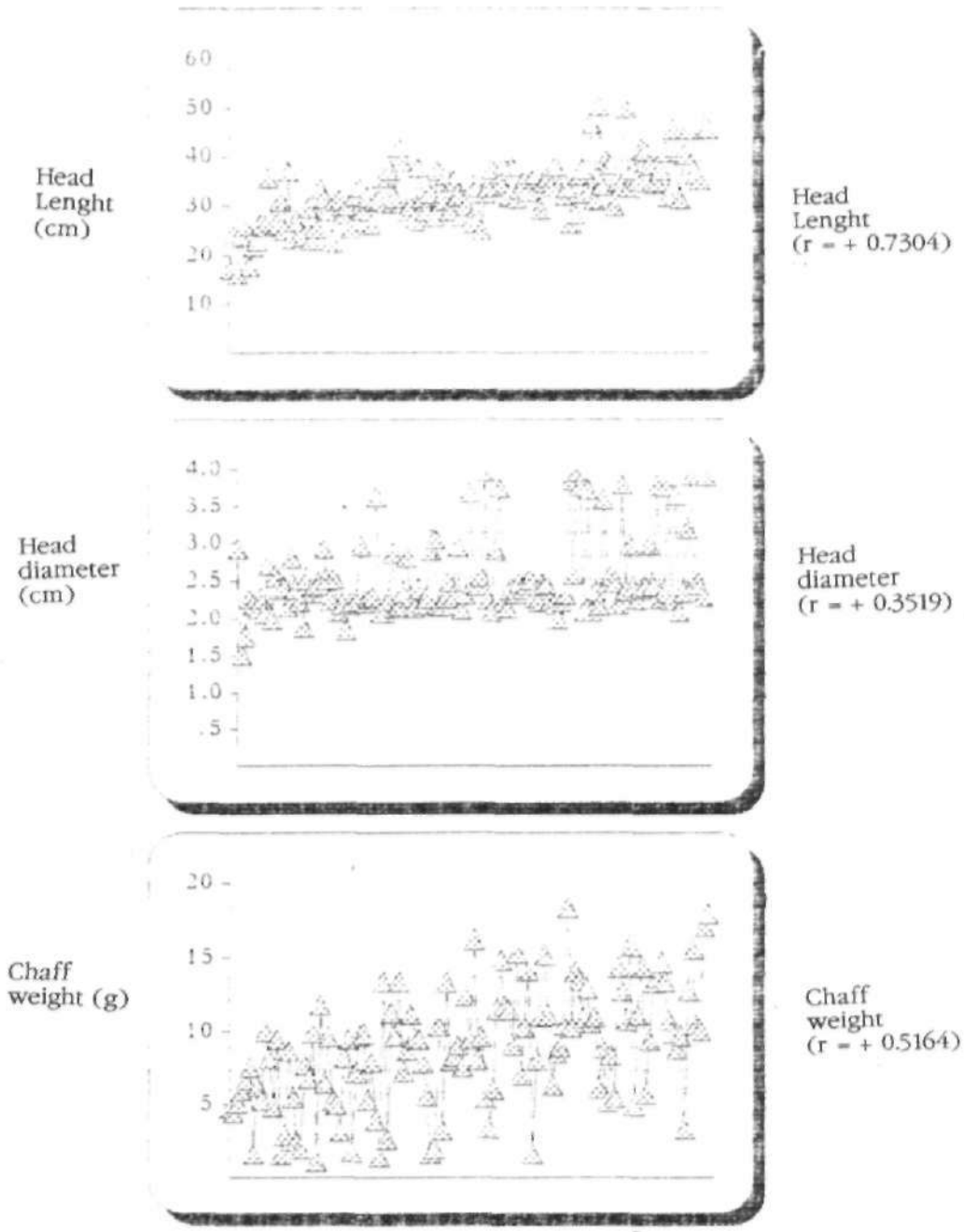


FIGURE 7: Pictorial Correlation between Grain weight and Head Length, diameter and Chaff weight

CHAPTER 5

5. DISCUSSION

(Individual Traits)

5.1 Days to 50% Flowering

The three varieties of millet used in the trial varied significantly in time taken to achieve 50% flowering (Table 1.a and 1b) due to the fact that Dauro and Maiwa are photosensitive millets and therefore head late while SAMMIL-7 which belongs to the 'gero' millets is non-photosensitive and early maturing (Bhardwaj and Webster, 1971, Labe, 1983). Though Dauro is mainly transplanted in the areas it is mainly grown in Jos Plateau and Southern part of Kaduna State in Nigeria, it can be grown by direct seeding without disadvantage in yield (Labe, 1983). It therefore appears that, the major problem of the photosensitive millets when grown in areas proceeding northwards in Nigeria is the reduced soil moisture content and relative humidity by the time the plants experience the photoinduction and start flowering. This would imposed other growth constraints on the plant. This is so because as one moves northwards in Nigeria, the number of rainfall months becomes reduced progressively while that of dry months increase. Maiwa though photosensitive had an advantage over Dauro by perceiving the change in day length earlier (90.4 days against Dauro's 102 days) and thereby having a longer wet period for grain filling and maturity. Reduction in tiller numbers did not significantly affect the number of days the varieties Maiwa and SAMMIL-7 took to reach 50% flowering because the inherent photosensitivity and non-photosensitivity characteristic of the varieties was more important

in determining the flowering date than the reduction in competition between the tillers for photosynthates due to their interdependence as found by Khan and Kassam (1984). However, with one tiller maintained in Dauro there were less sinks and all available photosynthates were mobilised for maximum growth and early perception of the photoperiod and thereby leading to earlier flowering and maturity. Therefore there was a significant reduction in number of days to 50% flowering down to 98 days. This is in conformity with the work of Clifford *et al.*, (1973) who showed in *Lolium multiflorum* that the main shoot exported radio-carbon to the tillers in equal proportions.

Although population stress is known to forced plants to flower earlier, increasing plant spacing generally decreased the days taken to reach 50% flowering in all the varieties. This was because a reduction in plant density by increased spacing resulted in higher and faster growth due to less competition for light and nutrients and therefore a quicker attainment of plant maturity. This agrees with the observation of Nelson (1977) in proso millet that plants decreased slightly in time to heading under wider row spacing. In this study, 20 cm in Dauro and 25cm in SAMMIL-7 appeared to be the most appropriate spacing to achieve this since they gave significantly shorter times.

5.2. Plant Height

Dauro consistently had a greater height which is contrary to observations by other workers that it is shorter than Maiwa (Bhardwaj and Webster, 1971). This may be due to great stem elongation so as to flower as the right photoperiod set in earlier than in the traditionally growing areas South of Zaria in Nigeria. Increase in tiller number and decrease in spacing led to development of taller plants. This means that at closer spacing there was

increased competition for light as the number of tillers increased and there was increased mutual shading thereby leading to taller plants. Kasperbauer (1971) showed that in dense plantings of tobacco, partly shaded plants in a row grew much taller than plants on the outside of the community, and these inside plants had longer internodes. Light has for long been shown to depress stem elongation, a function controlled by red light (Parker *et al;* 1949). However, with unrestricted tiller numbers in Maiwa (as observed in the control), competition between tillers for nutrients probably overcame that for light leading to an overall shorter plants. This is contrary to the observation of Nelson (1977) in Proso millet that plants responded to wider row spacing by increase in height. It shows that the higher tillering due to wider spacing observed by several workers and in the study may not necessarily be accompanied by increase in height due to other factors as shown in this study. SAMMIL-7 variety was not affected, however.

Plant height is reduced by short day induction (Ong and Everard, 1979). Govil *et al.*, (1981), observed that productive genotypes of millet exhibit accelerated growth of internodes at the end of vegetative period while dwarf genotypes that show retarded growth have their productivity restricted. Row spacing alone has been found to show no significant difference in fodder yield of pearl millet (Umrani *et al.*, 1982), but in combination with other factors they found it to show a remarkable difference just as is observed in plant spacing interaction with tiller numbers of Dauro and Maiwa in this study, which was manifested by increased height.

5.3. Tiller number

The increase in tiller number following an increase in plant spacing (Table 4) agrees with the results of other workers. This has been attributed to a reduction or delay in light competition by decrease in plant population which leads to a dramatic increase in tillering. Studies with other grasses such as Cocksfoot, Timothy and Meadow fescus have also shown that a reduction in plant density resulted in higher tiller production per plant due to less competition for light (Langer and Lambert, 1963). Similarly in wheat a population of 57,000 plants/ha recorded 33 shoots per stand whereas 708,000 plants/ha had only 3 shoots per stand (Puckridge, 1968). Egharevba (1977) found population density to affect tiller formation in millet var. Ex-Bornu in a similar manner. Low population of 50,000 plants/ha produced 12 tillers in comparison with a population of 80,000 plants/ha which produced 6 tillers at Zaria. In Niger Republic, studies on millet (BK 560) have shown that a stand with 2.9 plants/m^2 had 2.8 times more tillers than a stand with 11.5 plants/m^2 (Azam-ali *et al.*, 1984).

5.4. Headed Tillers and Seeded Heads

The percentage headed tillers was quite high in all the varieties ranging from 53.1 - 73.1%. This is at variance with Egharevba *et al.*, (1983) who observed only 2 - 4 effective tillers out of 6 - 10 tillers that were produced in pearl millet (i.e. 33 - 40%). A head may be produced but may not necessarily set seed so that there would be a marked difference between head formed and heads that set seed which actually contributes to the grain yield. This was investigated and found to be true. Though the percentage of heads that set seed was high ranging from 67.60 - 86.1% (Table 5a), the remaining 13.9 -33.4% heads that did not set seed could affect final grain yield to a large extent. The low seed set by Dauro could be attributed to the fact that it headed very late in the season by which time the soil moisture

content and the atmospheric humidity were fast depleting. This resulted in premature drying of the plants and inflorescence thereby preventing pollination and causing poor seed set. This is in agreement with Ong and Monteith (1985) who also observed that growth of millet grain could be curtailed by the premature death of all green tissue and the exhaustion of stored material. Thus, eventhough Dauro had a high percentage heading, this did not correspond with the percentage heads that set seed due to shorter grain filling duration imposed by environmental factors. Egharevba *et al.*, (1983) also found that tall millet plants are not more efficient in grain yield but the length of grain filling duration most significantly correlated with grain yield. In the Zaria environment, the grain filling duration of Dauro is shortened by lack of moisture after its photoinduction for flowering. This explains why the crop perform better in the mild humid zones of Southern Kaduna and parts of Plateau in Nigeria, leading to its cultivation being restricted to these areas with continued light rains after the onset of the appropriate photoperiod.

A reduction in tiller number led to an increase in percentage of heads that seeded in all the varieties (Table 6a). This is in agreement with the work of Egharevba (1977) who stated that the non-head forming tillers were parasitic on the main shoot for nutrients and water causing intra-plant completion for nutrients as more heads were formed per stand which was detrimental to yield. Results of this study show that even though more heads may be formed in a plant thereby increasing intra-plant competition for nutrients, water and photosynthates, the reduction in yield is additionally caused by failure of many heads to set seed as a consequence of this competition. Therefore, reducing the number of potential head forming tillers increased seed set as a consequence of reduction in this intra-plant competition. The inter-dependence of tillers in cereals and grasses has been established by

several workers (Ryle, 1970 in *Lolium* spp. Nyahoza *et al*,. 1973 and 1974 in *Poa pratensis)*. Marshall and Sagar (1968) and Clifford *et al.* (1973) studied the interdependence of tillers in *Lolium multiflorum* and showed that the main shoot exported radiocarbon to the tillers in equal proportions but the leaves of the tillers exported more to the parent plant than to the sister tillers. Dependence of tillers on the main shoot until late in life of the plant (72 days) and increased independence of sister tillers from each other as the plant approached the end of vegetative growth has also been established in millet by Khan and Kassam (1983). This further agrees with the finding in this study that reduction in tiller number would conserve food produced in the main stem that would have been shared among many tillers and thereby this would be used in grain formation leading to a higher percentage seeded heads as inter and intra plant competition is reduced.

The significant increase in percentage seeded heads as a result of interaction between reduced spacing and tiller number (Table 6b) indicates that as the plants became closer, the interplant shading of leaves that could have caused them to become photosynthetic parasites and thereby reduce movement of photosynthates to the developing seeds, was reduced by tiller removal. This agrees with Scarsbrook and Doss (1973) who also observed in corn that grain yields were maximum where 85 - 95% of the sunlight was intercepted by the plant canopy and highest yields were obtained when sufficient light penetrated the plant canopy to permit leaves to produce the maximum amount of useable photosynthates per unit area.

5.5. Nodal Tillers

The observed presence of nodal tillers in this study is consistent with the work of Maiti and Bidinger (1981) who also noticed these small tillers in the upper nodes of the stem

in millet towards the end of the grain filling phase in some varieties. These had a shorter developmental cycle than the basal tillers producing a few leaves only. In this study it was observed that the panicles of the nodal tillers were at different stages of development and had not set seed at harvest time of the main stem and basal tillers. The high production of these nodal tillers by SAMMIL-7 may be associated with its earlier maturity during which time the weather was still moist and conducive for growth. Though water availability is a limiting factor in millet production, too much water or excessively long wet periods can reduce production even in an adapted variety (Cocheme and Franquine, 1967). One of the ways that grain production is reduced could be by increased production of nodal tillers with partialy developed panicles which do not contribute to the final grain yield but drain nurients that could have otherwise gone into grain production of the main culm and basal tillers. They could also contribute to the higher ratio of straw dry weight to grain yield as also observed by Egharevba *et al.*, (1983).

5.6. Number of Leaves, Leaf Area and Leaf Area Index

The early variety SAMMIL-7 had fewer leaves than the photosensitive varieties Dauro and Maiwa (Table 9a). It would appear that the number of leaves produced by each variety on each stem is genetically fixed though Ong and Monteith (1985) found this to be governed by temperature and daylength in pearl millet. The transition from vegetative to reproductive phase is principally a function of daylength especially in photosensitive varieties. This will also be influenced by crop duration and may explain why Dauro and Maiwa with a longer crop duration had more leaves than SAMMIL-7.

When tillers were reduced to 3 and 4 (1987-89) and 5 (1992) the leaf area increased above the control. This indicates that with the non-reduction of tiller as is the case in the

control, too many leaves might have been developed leading to higher death rate of the lower leaves as a result of overshading or with reducing in tillers and consequently leaves, the remaining ones became wider thereby giving a higher leaf area due to more availability of light as light is known to enhance leaf growth (Parker *et al.*, 1949). This was found to be so as the number of leaves was similary less though not significant in the control (Table 9a). A negative effect of high leaf area on yield has been shown in rice where var. IR64 which had lower leaf area, produced the highest grain yield and agronomic efficiency (Dingkuhn *et al.*, 1991). This negative effect of high leaf area on yield could explain why there was an increase in yield when the number of tillers were reduced as has also been observed in millet by Egharevba (1977) who only attributed the increase in yield to less competition for nutrients. Gregory and Squire (1979) found among the head forming and non-heading tillers that leaves from tillers can account for 60 - 70% of the total leaf area in a healthy millet crop. It would appear that not all this is useful to the plant in its grain forming process because a high plant biomass at flowering may offer a good basis for high yield potential but poses a serious constrain to growth during repening according to Dingkuhn *et al.*, (1991). This, they explained was due to a very productive growth phase and subsequent dilution of foliar nitrogen, especially in medium to long duration plants.

Increased spacing led to an increase in leaf area especially in Dauro and Maiwa (Table 10 and 11a) because of more availability of light and less competition for nutrients which led to an increase in leaf size and consequently leaf area.

The leaf area index (LAI) is a ratio of the leaf area per unit area of land and is an effective measure of the functional size of the crop standing on a specific land area (Brown

and Blaser 1968). The concept of the LAI is fast changing. Formerly, higher yields were associated with higher LAI, but with better understanding of the physiology of dry matter production and storage in the plant, it has been observed that a lower LAI may give higher yield. Many studies have sought to link leaf size and yield. Vega *et al.* (1972) showed that a reduction in photosynthetic system caused a reduction in yield. This may however, depend on the growth habit of the plant as earlier recorded by Watson (1952), who found that the net assimilation rate (NAR) of Kale decreased linearly with increase in LAI but the NAR of Sugarbeet was less affected by change in LAI. He further asserted that defoliation in plants where NAR is in excess of the optimum can increase the dry matter as could be the case in Kale. This was further supported by the work of Khan and Sagar (1969) who were able to increase export of photosynthates from a source leaf by 30 - 50% by reducing the number of sources of photosynthates through defoliation. In this study a reduction in tiller number caused a decrease in LAI (Table 18) and yet yield was increased (Tables 16 & 17a). This therefore indicates that the overall efficiency of the remaining leaves and tillers was increased when tillers were reduced. This may have been achieved through less shading of the leaves left which then exposed a larger surface area to light for higher photosynthetic rate and increased export of photosynthates and net assimilation rate (NAR).

Studies by other workers have shown that as LAI increase, light interception increase and so also does NAR up to a point (optimum LAI) when shading of lower leaves start and the NAR reduces, thus total dry matter yield is not proportional to LAI at this point. As LAI increases beyond optimum value, the lower leaves have a deficit of photosynthesis over respiration since the foliage is below the light compensation point thus they are partially parasitic and depend for their respiration on their own dry matter or on the transfer of

metabolites from the upper to lower leaves resulting in decreased growth rate. Davidson and Donald (1958) interpreted the results of decrease in relative growth rate as LAI increase in terms of competition for light leading to this changing relationship of photosynthesis and respiration. The higher LAI of 5 tillers than the control (Table 18a) was achieved principally through the development of wider and longer leaves as younger and therefore parasitic tillers on the older tillers were removed.

Closer spacing gave a higher LAI (Table 18) though this was not significant but it did give a higher yield (Table 16 and 17a). A decrease in LAI can only lead to an increase in NAR only where the NAR is in excess of optimum (Watson 1952). For this reason, it would appear that the reduction in tiller number led to a decreased LAI but higher NAR and yield because NAR was in excess, while closer spacing increased LAI and yield because it led to an increase in NAR which was below the optimum. Optimum LAI has been suggested for different crops. In rice an optimum LAI of 7 has been postulated by Tanaka *et al.* (1966), and Murty and Murty (1981) found a positive correlation between LAI and yield for an LAI range of 2-6 in rice.

5.7. Head Length and Diameter

Varietal differences were observed in the head length and diameter with Maiwa having the longest and widest heads (Tables 12a and 13a). This agrees with Ong and Everard (1979) who similarly showed varietal differences in millet head lengths ranging from 21.7cm - 28.8cm in the varieties they tested. Although these parameters may be genetically determined for each variety, there is an indication that they can be modified by change in certain environmental factors and varieties react differently. Thus, Ong and Everard (1979)

showed that in millet var. BK560 and KH105, the head length was reduced by about 4cm by short day induction while varieties MN104 and MBH110 were unaffected. Though not much attention has been paid to the measurement of these parameters, Langer and Lambert (1963) quoted Engledor as having used the product of the number of ears/plant and the number of grains/ear as some of the parameters for determining yield in cereals. An increase in grain yield has also been found to be dependent on panicle mass which is the ratio of panicle yield and the number of panicles (Anon. 1994). Spacing and tiller number did not change the head length and diameter significantly (Tables 12a and 13a) but their interaction did (Tables 12b and 13b). An increase in spacing and decrease in tiller number led to an increase in head length and diameter especially in Maiwa and SAMMIL-7 where 25 - 30cm and 20cm spacing gave the longest heads respectively. Dauro showed no response. This means that as spacing is increased and tiller number is reduced in these varieties, there is less competition for light and nutrients and this causes more food to be available for the overall growth of the plant including the head even before grain formation. The increase in head length and diameter would subsequently lead to an increase in panicle size, number and yield.

Numerous workers have reported a higher vegetative growth in millet as a result of increased spacing. Some have shown that light regimes in the canopy are modified by temperature and plant spacing and that a reduction in light competition by decreasing plant population increases vegetative growth in millet. They have however, emphasised the importance of light in relation to tillering and looked at the vegetative growth interms of increase in tillering (Egharevba, 1977; Fussel *et al.*, 1980, Azam-Ali *et al.*, 1984, Ong 1983). Similar results have also been observed in wheat (Puckridge, 1968). Results obtained in this study clearly show that the increase in vegetative growth in form of increased tillering

when spacing is increased could also include formation of larger heads and therefore, higher yields when this is combined with a reduction in tillers.

5.8. Grain Yield and Tiller contribution to Yield

The results in Tables 16 and 17a show that SAMMIL-7 and Maiwa were superior to Dauro in yield (P=0.01). This is closely linked with their high percentage seeded heads which was 75.6% and 86.% respectively against Dauro's 67.6%, (Table 6a). This is probably associated with the earlier heading and grain filling in these two varieties which occurred when the weather was still favourable for growth. This gave them the advantage of a longer grain filling duration which Egharevba *et al.* (1983) found to be highly correlated with grain yield in millet. Due to late heading in Dauro, the grain filling duration was shortened by cessation of rains and rapid depletion of soil moisture which caused seed not to be properly filled but remained small and also it caused the failure of many heads (32.4%) to set seed (Table 6a) as the foliage rapidly dried up.

Differences in grain yield were non-significant due to varying tiller numbers. However, reducing the tiller numbers led to an increase in yield above that of the control in Maiwa (10-13%) and Dauro (12 - 34%). There was no response in SAMMIL-7, (Table 17a). This result is in conformity with the work of Egharevba (1977) who found that reduction in tiller number increased grain yield in millet. His results indicated that maintaining 3 or 5 tillers per stand increased yield by 20% above the control. In this study the results indicate that there are varietal differences in the tiller number that would give each variety a high yield and some varieties respond better than others. While in Dauro it was 2, 3 and 4 tillers in Maiwa it was 2 and 4 tillers which gave yields much higher than the control.

In the 1992 trial it was clear that a closer spacing gave a significantly higher grain yield (Table 17a, P=0.05) but in the earlier trials, the varieties reacted in different ways to spacing (Table 16, P=0.01). In the 1987 - 89 trial, Dauro and Maiwa both had their lowest yield at 15cm spacing and their highest at 30cm and 25cm spacing respectively while SAMMIL-7 gave it's highest yield at 20cm and lowest at 30cm. In India it was found that pearl millet (Pb - 3) at a row spacing of 60cm gave the highest grain yield and the lowest at the maximum row spacing of 90cm although this yield was statistically at par with the grain yield obtained under the row spacing of 30cm (Parmer *et al.*, 1982). It has however been observed in many studies that yield is not much affected or altered by plant densities in pearl millet (Balyan *et al.*, 1982, Umrani *et al., 1982)*. Similar non-significant findings have been reported in other millet varieties such as BJ104 and PHB14 (Dhankhar *et al.*, 1982). The observation in this study that a closer spacing gave a significantly better yield in the 1992 trial (Table 17a) is supported by the work of Nelson (1977) who tested several varieties of proso millet in several environments at 18, 36, 53 and 71cm row spacing and found yield to be highest with the closest row spacing of 18cm and lowest with the widest row spacing of 71cm. According to this result, each additional 18cm row width reduced yield by 220kg/ha. This shows that there is variability in results obtained by different workers. The effect of plant spacing on yield could be explained by several factors which include; light penetration in the canopy, water use efficiency and evapotranspiration rates. High yields may be obtained when sufficient light penetrates the plant canopy to permit leaves to produce the maximum amount of useable photosynthate per unit area. By using an adequate plant spacing, little light would be allowed to reach the ground in the canopy because such light energy is lost to the plants food making process and also causes higher evapotranspiration (Lakschminarayana and Reddi 1969; Scarsbrook and Doss, 1973). This explanation is also supported by Egharevba

(1978) who found that there are optimum plant populations of millet for different localities which he associated with the water regime of the locality. According to his observation, in Nigeria 60, 000 plants/ha gave the best yield of 2,645kg/ha at Samaru while Bama and Kano which are in the drier areas gave best yield of 2118kg/ha and 1805kg/ha with only 40,000 plants/ha. He also found that 75cm row spacing and 25cm plant spacing respectively gave the best yield at Samaru for variety Ex-Bornu.

A right combination of reduced tillers and spacing as shown by the interactions gave the best yield by the varieties under study (Table 17b). These results show that a closer plant spacing could produce high yield if the tillers are reduced to a number that is specific to each variety. Thus for Maiwa and SAMMIL-7 it was a spacing of 15cm and 2, 4 or 5 tillers while for Dauro it was a combination of 20cm spacing and 2-3 tillers that gave the best grain yield. The results in Table 16 show that low yields were obtained in the 1987 - 89 trial, especially in 1987 for all the varieties. This was probably due to several factors including the long dry spell in June - July which led to late planting and poor plant establishment, high disease score and bird damage. In the 1992 trial (Table 17a) yield was much higher due to early planting, good field location and generally better weather conditions. The variability in grain yield from one year to the other in millet has also been observed by other workers (Anon, 1994).

Grain yield per plant was highest in Maiwa (70g) and least in Dauro (18.6g) while SAMMIL-7 had 35.1g. Tiller contribution to yield did not however vary greatly and was considerably high from all the varieties ranging from 66.9 - 73.0% though it was highest in Maiwa 73% and least in SAMMIL-7 (66.9%) (Fig.1). This shows the importance of tillers as contributors to grain yield irrespective of the total yield of the plant. This is contrary to

the work of Rao and Willey (1980) who observed that although tillers made up 60% of the total dry matter in millet, they represented only 15% of the grain yield since many fail to produce grains. Egharevba (1977) found that uniculm plants of millet yield 20% less than the high tillering control. These workers, however, did not show the contribution of the tillers to the total plant yield as shown in this study.

Although in Dauro the highest yield was recorded at 30cm spacing, the tiller contribution to yield was highest at 20cm which implies that within the plant, tiller contribution to yield may be high but the total yield may not necessarily be affected. The tiller contribution to yield is governed by the interplant competition which is different from the intraplant competition that determines the total yield of the plant. This also indicates that at 20cm spacing in Dauro and 15cm in Maiwa, the interplant competition for light, minerals and water was just right to allow for the tillers in each plant to quickly reach maturity and cease depending on the main stem and thereby are able to set their grain and make a large contribution to the overall yield of the plant. This is in conformity with other studies which have shown that the time at which competition becomes severe may govern the number of inflorescence per plant and the number of seeds per inflorescence (Langer and Lambert, 1963). This stage appears to occur at the time the head starts to form on the main stem and the intensity of the competition depends on the number and stage of development of the younger tillers.

In all the varieties reduction in number of tillers increased the remaining tiller contribution to yield. This agrees with studies by other workers who have shown that a wider spacing reduces plant density in millet resulting in higher tiller production per plant but less

number of effective tillers. This is because the none head forming and young tillers become parasitic on the main stem for nutrients and water as more heads are formed leading to less contribution of tillers to yield (Langer and Lambert, 1963; Egharevba, 1977; Khan and Kassam, 1984).

5.9. The Harvest Index (H.I)

The Harvest Index is a stable character that is used for comparison. The higher H.I. observed in SAMMIL-7 which is a dwarf variety conforms with the finding of Rawson (1971) in wheat that dwart varieties had the highest harvest index. It appears that high plant height has a negative effect on H.I. since the major part of the plant metabolite is retained in the vegetative structure in tall genomes while a large proportion is partitioned for grain development in dwarf genomes. This may explain why Maiwa and Dauro which produced tall plants had lower H.I. and also why there was little change in the two varieties under different spacings and tiller number (Figs 4 and 5). Partitioning ability of metabolites in these tall varieties is poor. Peries *et al.* (1990) suggested that tillering may have a negative effect on the H.I. in sorghum. Maiwa's H.I. improved to 8.4 x 10^{-2} when one tiller was maintained as the ineffective (non productive) tillers were removed. Biological yield of Maiwa and Dauro varieties is rather too high compared to its grain yield, and it appears that this imbalance could be augmanted by reduction in plant height more effectively, rather than changes in plant spacing or tiller number, especially in Dauro.

5.10. Correlations

Nodal tillers showed a significant negative correlation with yield ($r=-0.552$, Table 19). This indicates that yield increased as nodal tillers decreased in Dauro. This agrees with

Maiti and Bidinger (1981) who also made the observation that nodal tillers formed towards the end of grain filling period do not contribute to yield but constitute a drain on assimilates. This is because they head late producing small panicles that don't set seed. This would particularly be so in Dauro because the plant itself heads late in the season and therefore the nodal tillers would cause additional drain on the food that would otherwise have been used for grain development.

An increase in plant height resulted in a significant increase in yield ($r = +0.586$). This agrees with the work of Govil *et al.* (1981) who found that most of the highly productive genotypes of pearl millet exhibited accelerated growth of the internodes at the end of the vegetative period while dwarf genotypes manifested predominance of retarded growth which perhaps restricts their productivity. On the contrary, Egharevba *et al.* (1983) found that tall millet plants were not necessarily more efficient in grain yield production but there was a positive correlation between grain yield and plant height as was also observed in Dauro and SAMMIL-7 in this study. Plant height was also one of the most contributing factors to yield in Dauro. The physiological basis for this may be associated with the remobilization of stored food in the stem for grain filling (Ong and Monteith, 1985). Thus the taller the plants, the larger the amount of reserves available in the stem and therefore the higher the yield. This has been found to serve as a compensation during adverse weather conditions during grain filling (Ong and Monteith, 1985). This would particularly be of benefit to Dauro which heads late and its grain development is restricted by onset of dry weather conditions which leads to premature drying up of leaves.

The non-significant positive correlation between yield and leaf area (Table 19) and the significant positive correlation between leaf area and leaf area index (Table 22) as well as the fact that the leaf area index and leaf area were the most contributing factors to yield of Dauro in 1992 is supported by Rao and Singh (1978). They expressed the importance of the photosynthetic surface area as they observed that its reduction by shading or defoliation at the time of anthesis causes reduction in grain number per ear, grain size, rate of grain development and the final grain yield almost in proportion to the cut in leaf area. Egharevba (1981) has also shown that the top, middle and bottom zones of leaves of millet contributed 42%, 16% and 6%, respectively to the grain yield. Thus, yield can be limited by leaf area to some extent.

The negative correlation between yield and days to 50% flowering in Maiwa (Tables 20 and 23) shows that in this variety the shorter the time to heading, the higher the grain yield and this factor was one of the most highly contributing factors to yield. This is also closely related to plant height because the plants heading earlier would have shorter heights. The lower the plant height the higher the grain yield. It would appear that earlier heading ensure grain filling well within favourable season after the experience of the right photoperiod and it also limited excessive vegetative growth which may become detrimentatal to grain growth.

In SAMMIL-7 an increase in number of leaves, leaf area and head length led to an increase in yield in 1987-89. In 1992 later heading, head diameter and higher number of heads that set seed correlated positively with yield. This shows that since this variety is an early variety, the number of leaves and leaf area it attains before head emergence when leaf

growth ceases is of utmost importance in determining yield. Yield could be limited by a restriction on the number of leaves and leaf area attained before grain filling commences. This would lead to longer and wider heads giving higher yield. This is closely related to the time taken to reach 50% flowering. The longer the time, the more the leaves that would be formed and higher would be the yield. This was further supported by the fact that days to 50% flowering, number of leaves and headed tillers were the most contributing factors to yield in SAMMIL-7.

The pictorial view of the correlation between grain weight and head length showed a close association between these two parameters (Fig. 6). Though inconclusive, it would appear therefore that the head length could be considered in further studies for the estimation of grain yield when seeds are damaged by external factors such as birds. These attacks often make yield results not to maintain consistency as observed in this study and by Anon (1993) after a 3 years study. This results show that head length could be included in such a formulae when derived.

6. GENERAL DISCUSSION AND CONCLUSION

The work reported in this thesis has shown that there are physiological differences among the three millet varieties regarding their response to reduction in tiller numbers and intra-row spacing of the plants as well as their interactions.

The Maiwa tiller is photoperiod sensitive just like Dauro and it flowered earlier than the latter (Table 1) Grain filling and hence higher yield in Maiwa was therefore usually completed within a favourable condition before depletion of soil moisture. This was not the case in Dauro millet whose seed setting was hindered by premature drying up of plants after late flowering. Reducing the tiller number in Dauro significantly reduced the number of days to its flowering and thus enabled it to complete grain filling before the onset of unfavourable conditions and gave better yield.

Ong and Monteith (1985) also found that the growth of millet can be curtailed by the premature death of all green tissue and the exhaustion of stored material. The earlier flowering due to reduction in tiller number also led to an increase in percentage headed tillers, percentage seed set and grain yield in all the trials especially in Dauro and Maiwa (Table 5, 6, 16 and 17). This may be explained by the reduction in interdependence of the tillers which was observed by Khan and Kassam (1984). It has been shown that in the early life of the millet plant and other cereals (Khan and Kassam, 1984; Clifford *et al*; 1973) the tillers are supported by the mainstem. Therefore it follows that if these tillers (sinks) are reduced, competition between the tillers would be reduced and there would be faster growth and maturity of the remaining tillers. Since perception of the appropriate photoperiod and subsequent transition from vegetative to reproductive phases depends to a large extent on the stage of growth and age of a plant, the Dauro plants with reduced tillers flowered earlier.

This was further supported by the decrease in number of days taken to flower as spacing was increased. This was because increased spacing resulted in higher and faster growth due to less competition for light and nutrients thereby leading to faster growth, maturity and flowering.

Dauro had the highest percentage of tillers that headed (73.1%) followed by Maiwa (69.8%) and then SAMMIL-7 (53.1%). This was however not reflected in seed formation. Reducing the number of tillers increased the percentage of heads that set seed such that Maiwa had the highest (86.1%) followed by SAMMIL-7 (67.6%) while Dauro had the least(67.6%). The percentage number of heads that set seed is an important factor in determining grain yields since it is positively correlated with the latter. In the early maturing variety, SAMMIL-7, decreased tiller number and closer spacing were not beneficial but in the photosensitive varieties, Maiwa and Dauro, they were of advantage as they increased the percentage seeded heads.

Tiller contribution to grain yield was high, ranging from 66.9% - 73.4% in SAMMIL-7 and Maiwa respectively (Fig1) This was much higher than the 14-33% (Egharevba *et al*, 1983) and 43.7 - 56.8% (Anon, 1988) reported by earlier workers for gero varieties at Samaru. The implication is that the percentage tiller contribution to yield is variable depending on the variety even in the same environment. Reduced tiller numbers increased the tiller contribution to grain yield above the control (Fig 2). In the photosensitive varieties, Maiwa and Dauro, closer spacings of 15cm and 20cm gave higher tiller contribution to yield. Reducing tillers to two in Dauro and two and four in Maiwa increased yield above the control but in SAMMIL-7, there was no added advantage. Since tillers arise

in alternate order, it was the youngest non-head forming tillers that were still parasitic on the main stem (Khan and Kassam, 1984; Egharevba, 1977) when removed led to conservation of photosynthates. These tillers are in a position that they can be shaded by the older tillers therefore their leaves would respire faster than they can photosynthesize due to inadequate light thereby causing them to become parasitic on the other tillers even though should be independent. Reduced tiller number led to less self shading in the plant such that the leaves were able to photosynthesize at a higher rate leading to each tiller left developing grains well and giving a higher contribution to yield.

In combination with closer spacing, reduced tiller numbers gave higher tiller contribution to yield especially in the photosensitive varieties Maiwa and Dauro which due to their long growing period developed a high number of tillers. According to Scarsbrook and Doss (1973), when there are too few plants per unit area, insufficient photosynthate are produced for higher grain yield and with too many plants per unit area, much of the photosynthate may be retained in the stover at the disadvantage of the grain. Therefore, for these varieties spacing of 15cm and 20cm with reduced tillers to two in Dauro and two and four in Maiwa gave the best balance whereby sufficient photosynthate was produced for highest grain yield.

The harvest index (H.I) of SAMMIL-7 was higher than that of Dauro and Maiwa and there was little change under different spacings and tiller numbers. This further showed the implications of excessive tiller production which increases biological yield to the disadvantage of grain yield. The leaf area index (LA1) for Dauro was 8.41, Maiwa 8.10 and SAMMIL-7 2.6. A negative effect of high leaf area on yield has been shown in another cereal, rice var.

1R64 which had lower leaf area but the highest grain yield and agronomic efficiency (Dingkuhn *et al;* 1991). Gregory and squire, 1979 found that leaves from tillers can account for 60 - 70% of the total leaf area in a healthy millet crop, it appears that not all this is useful to the plant in its grain forming process because a high plant biomass at flowering may offer a good basis for high yield potential but is known to pose serious constraints to growth during ripening. This is due to a very productive growth phase and subsequent dilution of foliar nitrogen especially in medium to long duration plants (Dingkuhn et al; 1991). This may have applied especially to Dauro and Maiwa whose leaf area index was high and the reduction in their tiller number to 2 in Dauro and 2 and 4 in Maiwa which led to less LAI, therefore increased their tiller contribution to yield as well as the grain yield.

In Dauro, there was a significant positive correlation (P=0.05) between grain yield and leaf area index indicating that the net assimilation rate (NAR) of Dauro was below optimum. This is because it is known that a decrease in LAI where NAR is in excess of the optimum can increase the dry matter (Watson, 1952). By this explanation, it implies that the reduction in tiller number led to a decreased LAI but higher NAR and therefore yield because NAR was in excess. Closer spacing increased LAI and yield because it led to an increase in NAR which was below the optimum.

Nodal tiller production occurred in all the varieties but it was most prevalent in the early variety SAMMIL-7. Only Maiwa showed increased nodal tiller as spacing was increased. The earlier a variety ripens in wet weather, the more the nodal tillers developed. They are unproductive and constitute a drain on the nutrients available to the plant. Their elimination during breeding programme is desirable as they contribute to a higher ratio of straw dry weight to grain yield (Egharevba *et al;* 1983).

All the varieties responded to increased spacing by developing more tillers (Table 4). Closer spacing can cause less tillers to be formed as desired saving the problem of manual removal of tillers. Since reduced tillers have been found to increase yield, this must have been the reason why closer spacing was found to increase grain yield in all the varieties. The practice of wide spacing of millet because of intercrop may therefore be detrimental to yield.

Head length was the most closely related parameter to grain yield and should be included in breeding programmes. There is also a need to derive an equation to estimate yield when seed is damaged during an experiment and head length should be included in such when derived.

The study has therefore brought out the various ways tiller reduction and intra-row spacing of plants affects different physiological aspects leading to the overall performance of these three millet varieties, Maiwa, Dauro and SAMMIL-7.

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APPENDIX I

MEAN TEMPERATURE AND RAINFALL AT ZARIA 1987-89, 1992

MONTH	1987		1988		1989		1992	
	Mean Rainfal (mm)	Mean Air Temp. °C	Mean Rainfal (mm)	Mean Air Temp. °C	Mean Rainfal (mm)	Mean Air Temp. °C	Mean Rainfal (mm)	Mean Air Temp. °C
JAN.	-	21.5	-	21.2	--	17.7	--	19.5
FEB.	-	24.7	3.5	24.8	--	20.7	--	22.5
MARCH	-	27.3	-	28.4	--	26.1	--	27.3
APRIL	-	29.0	34.6	29.2	--	28.4	32.3	28.9
MAY	135.7	29.5	94.4	28.7	113.0	26.7	73.1	27.6
JUNE	146	25.9	133.2	25.4	124.4	25.4	112.4	24.7
JULY	276	25.2	181.5	23.8	158.7	24.5	243.6	22.1
AUG.	268.3	24.5	402.5	23.4	170.4	23.7	286.7	23.0
SEPT.	102.1	25.4	192.3	24.6	118.3	24.5	229.7	22.7
OCT.	42.6	24.3	144.7	23.4	52.9	23.6	39.2	22.7
NOV.	-	22.1	--	21.8	--	21.9	2.6	19.8
DEC.	-	21.2	--	20.0	--	20.7	-	19.3
TOTAL	970.7		1156.7		737.7		1019.8	

Appendix 2: **Head Measurements for yield estimation experiment**

Serial No.	Wt of Grains(g)	Head Length(cm)	Head Diameter(cm)	Wt of Chaff
A97	14.86	17.3	2.93	4.83
A100	15.02	23.7	1.53	4.49
A44	16.03	16.4	1.78	5.16
A76	17.78	24	2.28	5.98
A45	18.36	26	2.19	6.74
A80	19.90	18	2.14	7.56
A1	19.88	22	2.28	1.62
A114	20.33	23	2.08	6.24
A18	22.56	26.5	2.72	5.35
A73	24.18	25.8	2	10.03
A118	25.83	35.7	2.57	8.22
A71	27.08	26.5	2.4	4.87
A69	27.72	26.3	2.43	9.45
A87	28.08	31	2.17	1.61
A95	28.29	25	2.8	2.91
A55	28.51	37	2.4	8.66
A96	28.53	23.5	2.24	5.46
A66	30.58	26.9	1.9	2.5
A99	31.07	24.5	2.53	1.97
A101	31.18	23.8	2.36	7.71
A61	31.34	29.5	2.43	6.79
A43	31.51	23	2.46	9.96
A40	31.7	25.5	2.93	1.14
A36	31.86	33.6	2.53	11.83
A106	31.92	31.4	2.25	6.46
A49	32.07	29	2.54	9.66
A74	32.09	22.7	2.1	5.24
A105	32.13	31	2.2	5
A12	32.16	31	1.86	3.17
A72	32.25	28.5	2.2	8.2
A107	32.58	30	2.22	9.44
A19	32.66	25.5	2.24	1.76
A108	34.39	32	2.97	7.19
A113	34.8	33.7	2.22	9.73
A4	35.59	29	2.27	9.89
A67	35.91	31.7	2.3	5.33
A93	34.92	26.2	3.64	7.88
A94	36.56	31	2.1	3.98
A82	36.9	31.2	2.09	1.44
A117	37.36	35.7	2.25	13.41
A119	37.65	30.5	2.87	2.64
A42	37.92	37.2	2.16	11.28
A6	38.25	31.6	2.18	9.71
A115	38.36	42	2.35	13.41
A51	38.36	39	2.82	7.27
A22	38.56	29	2.29	8.73

A41	51.71	39.2	2.49	5.19
A84	51.71	38.2	2.56	8.4
A48	53.21	30	2.48	5.46
A89	53.34	35	2.19	14.31
A70	53.93	34	3.8	12.74
A52	53.97	49.9	2.37	10.73
A59	54.08	33.7	2.97	15.81
A53	54.2	37.2	2.42	4.97
A25	54.39	35	2.26	11.1
A11	54.83	41.5	2.4	14.42
A28	54.85	41.2	2.43	5.75
A39	54.91	38.3	2.98	9.43
A27	56.47	34.5	2.44	13.37
A110	56.54	35	3.79	13.69
A77	58.37	37.2	2.28	14.76
A10	58.96	41	2.36	13.41
A86	59.13	32	3.78	10.77
A2	59.73	45.5	2.25	9.9
A8	60.51	42	3.65	8.81
A85	60.77	31.4	2.1	9.76
A57	60.8	40.4	2.36	3.36
A98	60.88	45.5	3.19	12.82
A38	62.17	38.4	3.93	15.55
A14	64.18	36.5	2.57	10.43
A15	67.85	35.3	2.46	10.16
A116	74.91	46.5	2.3	17.12
A83	77.09	45.8	3.92	17.92
AVERAGE	41.94	32.67	2.54	8.81

BIOGRAPHY

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MARITAL STATUS Married with four children.

SCHOOL ATTENDED WITH DATES:

Igyemwase Primary School, Sankera	-	1961 - 1964
Uavande Girls School, Gboko L.G.A.	-	1965 - 1966
Girls High School, Gindiri	-	1967 - 1971
Boys Secondary School, Gindiri	-	1972 - 1973
Ahmadu Bello University, Zaria	-	1973 - 1976
Ahmadu Bello University, Zaria (Part-time)	-	1979 - 1981
Ahmadu Bello University, Zaria (Part-time)	-	1986 - 1996

QUALIFICATION WITH DATES

First School Leaving Certificate	-	1966
West African School Certificate (O'Level)	-	1971
Higher School Certificate (A'Level)	-	1973
Bachelor of Science (B.Sc.) Botany	-	1976
Master of Science (M.Sc.) Botany	-	1981

POST HELD SINCE FIRST DEGREE:

Biology Tutor (NYSC) G.G.S.S.		-	1976 - 1977
Graduate Assistance	)Department of	-	1977 - 1979
Assistant Lecturer	)Biological Sciences,	-	1979 - 1981
Lecturer II	)Ahmadu Bello University		1981 - 1987
Lecturer I	)Zaria	-	1987 - 1996