THESIS CERTIFICATION

This thesis entitled 'SOME PHYSIOLOGICAL AND MORPHOLOGICAL DETERMINANTS OF GRAIN YIELD IN SORGHUM' by Uchechukwu Felix CHIEZEY meets the regulations governing the degree of Master of Science (Agronomy) of Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

Member, Supervisory Committee

Chairman, Supervisory Committee

Member, Supervisory Committee

Head of Department

Date 5th Dec., 1981

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA.

(AGD/M.Sc-3)

TABLE OF CONTENTS

Contents		PAGE
TABLES OF CONTENTS		(i)
ACKNOWLEDGEMENT		(iii)
DEDICATION		(iv)
ABSTRACT		(v)
CHAPTER I	INTRODUCTION	1
CHAPTER II	LITERATURE REVIEW	4
	a) Leaf Characteristics ...	4
	b) Grain Filling Period ...	7
	c) Plant height	9
	d) Tiller number	12
	e) Head Characteristics ...	13
CHAPTER III	MATERIALS AND METHODS ...	15
CHAPTER IV	RESULTS AND DISCUSSIONS ...	24
	a) Leaf area	24
	b) Effective grain filling period duration	29
	c) Tiller number	33
	d) Plant height	37
	e) Grain number per head ...	40

SOME PHYSIOLOGICAL AND MORPHOLOGICAL DETERMINANTS OF GRAIN YIELD IN SORGHUM (*Sorghum bicolor l. Moench)*

By

UCHECHUKWU p. CHIEZEY

A thesis submitted to the Faculty Of Aqriculture of Ahmadu Bello University in partial fulfilment of the requirements for the degree of Master of Science in Agronomy

DEPARTMENT OF AGRONOMY
Faculty of Agriculture &
Institute for Agricultural Research
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

DECEMBER, 1981

f) 1000 Kernel weight ... 44

g) Stover yield 47

h) Head length 49

i) Grain yield 51

CHAPTER V CONCLUSION 57

CHAPTER VI CORRELATION MATRICES ... 60

a) Correlation matrix showing relation of different attributes in seven sorghum cultivars. (Group 1) 60

b) Correlation matrix showing relation-ship of different attributes in two sorghum cultivars (Group 2) 61

c) Correlation matrix showing relation-ship of different attributes in two sorghum cultivars (Group 3) 62

d) Correlation matrix showing relation-ship of different attributes in all eleven cultivars of sorghum 63

CHAPTER VII: LITERATURE CITED 64-71

ACKNOWLEDGEMENT

I am grateful to Dr. P.N. Egharevba, Principal Research Fellow in Agronomy, who supervised this work- to Dr. I.O.E. Asenime, Senior Lecturer in Agronomy, Dr. Vijay Kumar, Senior Research Fellow in Agronomy and Dr. A.B. Obilana of Plant Science who were instrumental in the production of this work.

My appreciation is also extended to Dr. J.Y. Yayock, Reader and Head of Department of Agronomy, for his valuable criticisms, to Mr. Cyril Egeolu, the Secretary to the Department of Agronomy for his help, Mr. Haruna Kundi of Agronomy Department who helped with typing of earlier drafts and Mr. S.C. Apugo-Nwaosu who did the final typing- and to all members of the technical staff especially Mr. A. Oyilom, Mr. S. Ukata and Mr. C. Madueke who helped in the collection of the data.

I wish to express my gratitude to Mr. Sam Abed who helped with the statistical analysis of the data.

I must thank my senior brothers: Mr. Thomas I. Chiezey and Rev. Fr. Dan Chiezey for their moral and financial aid at a time when things were pretty difficult and the entire Chiezey family for their contributions.

Finally my thanks to my friends Mr. Simon Ebele, Mr. Ndubuisi Uzoigwe and Alhaji Mustafa Ahmed Falaki for their contributions to the success of this work.

DEDICATION

This work is dedicated to my late father,

Mr. Pat Chiezey, and to mother, Mrs. Rose M Chiezey.

ABSTRACT

Eleven cultivars of sorghum were grown during the rainy seasons of 1979 and 1980 to determine the influence of morphological and physiological characters on grain yield.

Leaf area, effective grain filling period duration and grain number per head were all positively and significantly correlated with grain yield. High yielding cultivars like L.1499 and SK 5912 were characterised by high leaf area, longer grain filling period duration and more grains per head than their lower yielding counterparts.

Plant height was negatively correlated with grain yield. Shorter plants like L.1499, SK 5912 and L.75 gave higher grain yield than the taller ones like FFBL, C-7-4 and FD-1.

Tillering did not contribute to grain yield. Tillering was found to reduce the number of grains per head in some cultivars.

Head length was negatively correlated with grain yield. Cultivars with long head like C-7-4 and FD-1 recorded poor grain yield because of few grains on the head when compared with short headed cultivars like L.1499, SK.5912 and L.75.

Grain weight also did not contribute to increased grain yield. Grain weight was negatively correlated with grain number per head thus resulting in reduction of total grain yield.

From the resul-s of the experiment, the highest grain yielders - L.1499 and SK.5912 were characterised by high leaf area, longer grain filling period duration and more grains per head. All were short stemmed and short headed.

INTRODUCTION

Sorghum is one of the most important cereal crops in Africa and Asia where it is used as human food. Hughes and Metcalfe (1972) noted that it was difficult to obtain accurate statistics of world hectarage as sorghum is often included with millet and no recent statistics from Mainland China which probably has the largest hectarage of about 20 million hectares. Purseglove (1976) held that 18 million hectares are sown in India, Africa about 15 million hectares with Nigeria having about 5 million hectares and the United States of America about 7 million hectares.

A more accurate breakdown of sorghum production in the world was probably given by Martin et.al (1976) reporting an annual world production figure of 72 million metric tons from 58 million hectares giving an average of 1.3 metric tons per hectare. Leading world producers are the United States of America, India, Nigeria, Argentina, Mexico and Sudan. Grain production in the United States is 20.4 million metric tons annually, giving 3.45 metric tons per hectare from nearly 5.9 million hectares. Yields from Africa and India vary between 300-2,000 kg/ha with an average of 650-750 kg/ha from rain-fed sorghum. Irrigated hybrid sorghum in India is said

to yield about 1,800 kg/ha while in the United States it ranges between 4,500-6,000 kg/ha (Martin et.al. 1976).

Anonymous (1979) reported that Nigeria's expected yield from 6.5 million hectares was 4.2 million metric tons giving about 650 kg/ha and Oke (1976) noted that about 4 million metric tons were produced in 1969/70, almost all (99%) being produced from the northern States of Nigeria from about 6 million hectares of land. Grain yield in Nigeria is very poor, about 10% from the same land input when compared with yield figures from the United States. Some of the reasons responsible for the low yield could be the use of low yielding varieties, lack of adequate fertiliser and poor crop management. However, recent research findings as a result of breeding and fertiliser trials show that yields could be pushed up to 3,000 kg/ha or more with the use of high yielding varieties, good crop husbandry including adequate pest and disease control.

Sorghum is a major food crop in Nigeria. Its importance as a food crop is demonstrated by the large number of dishes made from it including tuwo, fura, akamu and dawanke (Egharevba 1978). Since sorghum is a major food item and many people depend on it for food, research efforts are continuing on improving its grain yield. Several physiological

determinants of grain yield have been identified mostly in such temperate crops as wheat and barley but little work in this field has been done with tropical cereals like sorghum. High yielding varieties of sorghum are being bred at Samaru and need to be tested for their production potentials. Some of the yield determinants may provide valuable information relating to grain yield which may be used by sorghum breeders to screen and identify high yielding varieties of sorghum.

The objective of the present study was to determine the influence of various morphological and physiological traits like leaf area, grain filling period, seed weight, seed number, head length and the effect of tiller number which influence grain yield.

LITERATURE REVIEW

Most research work on sorghum in Nigeria has concentrated on agronomic practices as they affect grain yield while virtually nothing has been done on the physiological and morphological aspects. Studies on morphological and physiological aspects have been carried out mostly in India and United States of America and it is therefore necessary to review the findings in those places and compare results from them with results obtained in Nigeria.

a) Leaf characteristics:

The leaves of plants are the photosynthetic machinery responsible for the manufacture of carbohydrates utilising the energy of the sun, carbon dioxide and water. The most important leaf characteristic for predicting grain yield appears to be leaf area in barley (Watson 1952), and in Sorghum (Makumbi and Rubaihayo 1978). A small leaf area results in less manufacture of dry matter because a proportionally less incident radiation is intercepted and utilised. On the other hand excessive leaf area will not increase grain yield because top leaves may shade off lower ones which may photosynthesize below the point of compensation.

In an experiment to study the physiological pathways leading to increased grain production in sorghum hybrids, Gould and Sastry (1974) found that increased leaf number and total leaf area contributed to the high heterotic response for grain yield manifested by hybrids. The increased leaf area resulted in bigger ears, more grains and higher yields. Jagannath et. al. (1975) working with 2 sorghum hybrids CBE-X and CSH-1 reported that CBE-X which was superior to CSH-1 in all recorded yield components also recorded higher leaf area and leaf area duration. CBE-X gave a higher grain yield than CSH-1 infering that higher leaf area is associated with high grain yield. Krishramurthy et. al.(1974) while investigating the varietal differences in the growth components of sorghum with the cultivars CSH-1,-CBE-X, Swarna and Local Neerjola reported that CBE-X gave a significantly higher grain yields than the other hybrids and highest dry matter accumulation which were attributed to higher leaf area and longer leaf area duration associated with a moderately high net assimilation rate (NAR)..

Prior and Russel (1976) however found that prolific maize hybrids gave a higher grain yield than the non.prolific hybrid. The highest total dry matter occurred at leaf area

index of 4.1 and 4.0 for the prolific and non-prolific hybrids respectively. The highest grain yield from the prolific hybrid was obtained when leaf area index was 2.9, indicating that leaf area may not necessarily be positively correlated with grain yield. Dharampal and Singh (1973) also noted that grain yield was negatively correlated or associated with leaf breadth in sorghum.

Apart from leaf area and leaf area duration, canopy structure may also determine grain production. Fisher and Wilson (1976) concluded from a trial in which high population density of sorghum variety RS 610 was used, that some of the factors for the superiority of the high density population could be attributed to leaves which were more vertically displayed, more uniformly dispersed, smaller in both length and width and distributed over a greater height of canopy. Light was therefore more uniformly distributed down the profile and the light extinction co-efficients were lower. Associated with these was high leaf area index. The overall consequence was the distribution of intercepted radiation over a large leaf area surface, at lower illuminance and therefore a higher photosynthetic conversion, resulting in greater total photosynthesis.

b.Grain Filling Period:

It is generally agreed that the formation of a black layer at the placental region marks the termination of accumulation of dry matter in the kernel. Daynard and Duncan (1969) reported that the rapid development of a black layer at the placental region of the kernel represents a precise, accurate and simple indicator that maximum kernel dry weight has been achieved and the black layer could be used as an effective selection tool by breeders seeking an extension of the grain filling period in corn. They however noted that the mechanism leading to the formation of the black layer was not yet clear. Rench and Shaw (1971) and Eastin et. al. (1973) upheld the view that maximum kernel dry matter accumulation ends with the formation of a black layer at the placental region of the kernel and this black layer development seems to define physiological maturity better than does dry weight or kernel moisture.

Positive correlations have been reported between time to physiologic maturity and grain yield. Time of physiologic maturity is the period between 50% blooming or when 50% of the plants have shed their pollens and the time when the black layer is formed. This is also known as the effective filling period duration. Collier (1963) reported that there

was a highly positive and significant correlation between grain filling period and 1000 kernel weight in maize. Gunn and Christiansen (1965) reported that late maturity maize hybrids were characterised by longer grain filling period and larger kernels than their earlier maturing counterparts. Gardener (1966) on the physiological basis for yield differences in three high yielding and three low yielding varieties of barley reported that the three high yielding varieties recorded longer grain filling periods than for the three low yielding varieties and Dalton (1967) reported that the yields of grain sorghum hybrids were influenced by duration of the growth and limiting elements of the environment. Relationships between high yields and late maturity in grain sorghum is most evident when environmental conditions are favourable for maximum growth. Collier and Porter (1964) presented evidence of this relationship in hybrid sorghum when they reported that all linear regressions between maturity and grain yield were highly significant. Similar views were also reported by Hanway and Russel (1969) and Daynard et. al. (1971). They all reported a close correlation between grain yield and grain filling period for several sorghum hybrids. Daynard et. al. (1971) went further to explain that 80% of

the differences in grain yield in the first season among the three hybrids used in the trial was due to differences in effective filling period duration. The corresponding value in the second year was 71%. By contrast, less than 16% of these yield differences could be explained by differences in the rate of ear dry matter accumulation in either of the two years.

c. Plant height:

Although it is generally agreed that a positive correlation exists between plant height and stover yield in cereals, differences of opinion arise with regards to the influence of height on grain yield. Some workers have reported a positive correlation between plant height and grain yield, others on the contrary have reported a negative correlation or no correlation at all. In Nigeria, Goldsworthy (1969) testing three varieties of sorghum - tall Farafara, a short American hybrid called NK 300 and a hybrid of the two called short Kaura reported that the variety Farafara with an average height of about 500 cm, gave about 16.5 tonnes/ha of dry matter but the grain yield was poor, about 2420 kg/ha while the variety NK 300 with an average height of about 150 cm producing about half the total dry matter produced by tall

Farafara gave over 4,484 kg/ha of grain. Short Kaura which was intermediate in height (about 250 cm) gave a higher grain yield than the tall Farafara but was not as high yielding as NK 300, indicating that shorter varieties are more efficient in accumulation and storage of dry matter in the grain.

Other workers (Sankaran and Kaliappa 1974; Pasha and Munshi 1974; Louswan and Atkins 1978) have reported positive correlation between grain yield and plant height. Krishnamurthy et. al. (1973) in India reported from their trials with some sorghum hybrids that the hybrid MS 2219 X IS 3541 gave a higher stover and grain yield than other hybrids. The reason advanced for this high stover and grain yields of MS 2219 X IS 3541 was that it was taller and had more leaves. Also earlier in India, Pande et. al. (1971) observed that plant height, number of grains per cob, yield of grains per plant and 1000 grain weight had positive and significant correlations with grain yield in sorghum and the relationship of these characters with grain yield were found to be linear. Polke et. al (1974) also in India while testing 20 sorghum cultivars stated that panicle weight, plant height and leaf area were the important yield components making both direct and indirect

contribution to grain yield. Plant height made a direct contribution to fodder yield while leaf area made an indirect contribution through plant height.

However Gregory (1975) working in the United States of America with 12 varieties of winter barley found Schuyler a short stemmed variety, consistently produced higher grain yields than the 11 other cultivars tested and gave an average yield of 7464 kg/ha from 1970 to 1973. Schuyler was short stemmed and resistant to lodging while others were tall. The same trend was observed by Chang et. al. (1976) in Saudi Arabia with wheat. They observed that short stemmed varieties matured earlier and produced heavier ears than the tall varieties. Ganashan and Whittington (1976) in Sri Lanka also reported that the yield of the shorter cultivars of rice exceeded those of the taller cultivars. Kaul (1972) in India also noted that plant height was negatively correlated with grain yield of rice. Gupta and Sidhu (1972) in a regression correlation analysis found tiller number and grain size to be the major yield components, while hardness and plant height influenced the variability in grain yield. Gupta and Dhillon (1974) found plant height to be positively correlated with grain yield in 264 strains of Pennisetum americanum.

d. Tiller number: Tillering ability is not pronounced in sorghum as it is in millet but some cultivars of sorghum do produce a few tillers. Increase in tiller number will increase biological yield but may not increase grain yield in the same direction. This is because not all tillers produce heads. Egharevba (1977) in Nigeria working on millet reported that 3-5 tillers per stand increased grain yield by about 20%. He found that reduction in the number of tillers had no advantage on biological yield. He attributed the grain yielding advantages of a few tillers to the fact that not all tillers formed produced heads and those that did not produce heads were parasitic on the main shoot for water and nutrients. Secondly there was intra-plant competition for nutrients as more heads were formed, and this intra-plant competition was detrimental to high grain yield. Sakaran and Kaliappa (1974) also working in India and on millet reported that grain yield was positively correlated with the number of productive tillers. Sharma and Sharma (1976) in India working on irrigated barley and using partial correlation analysis found ear length and effective tillers to be the main yield contributing components. The prediction of grain yield from a regression equation based on these two components showed that 98% of yield values

were associated with these two components. Escalada and Plucknett (1975) observed that increase in the number of tillers also resulted in increase in the grain yield of sorghum and Gupta and Sidhu (1972), and Gupta and Dhillon (1974) in India and also working on sorghum found grain yield to be positively correlated with tiller number.

Tillering may become advantageous in cases of poor establishment. Gregory (1974) in the U.S. reported that cold winter temperature reduced barley stands and yields in 1971 but although the stands of the barley variety Schuyler was reduced to about 21%, the cultivar still produced the highest grain yield because of its tillering ability.

e. Head characteristics: The influence of head size, number of grains per head and size of grains on grain yield of sorghum have been reported by various workers (Pande et. al. 1971, Gupta and Sidhu 1972, Krishnamurthy et. al. 1973, and Williams 1976). There appears to be no consensus on the influence of these various characters on grain yield.

Krishnamurthy et.al. (1973) while investigating the varietal differences in sorghum found that the high grain yield of the sorghum variety MS 2219 X IS 3541 was associated with heavier head, which in turn was a consequence of

more number of grains per head. Pande et.al (1971) also upheld that plant height, number of grains per head, yield of grain per plant and 1000-grain weight had positive and significant correlations with grain yield and the relationships of these characters with grain yield were found to be linear in sorghum. Gupta and Sidhu (1972) and Gupta and Dhillon (1974) upheld that grain yield in sorghum were positively correlated with grain size among other characters such as plant height and tiller number. Other workers who have come to similar conclusions include Kaul (1972) for rice, Raghunathan (1974), Pasha and Munshi (1974), Sankaran and Kaliappa (1974), Sharma and Sharma (1976), Abu-el-Gassim and Kambal (1978) for sorghum.

Williams et.al. (1977), however noted that there was a high negative correlation between grain number per panicle and number of panicle per plant. Grain weight was found to be independent of crop density or spacing. The relationship between grain weight and grain number per panicle varied with cultivars attaining a high negative correlation for the sorghum hybrid RS 610.

Louswan and Atkins working in the U.S. reported there was no correlation between grain yield and 1000 grain weight.

MATERIALS AND METHODS

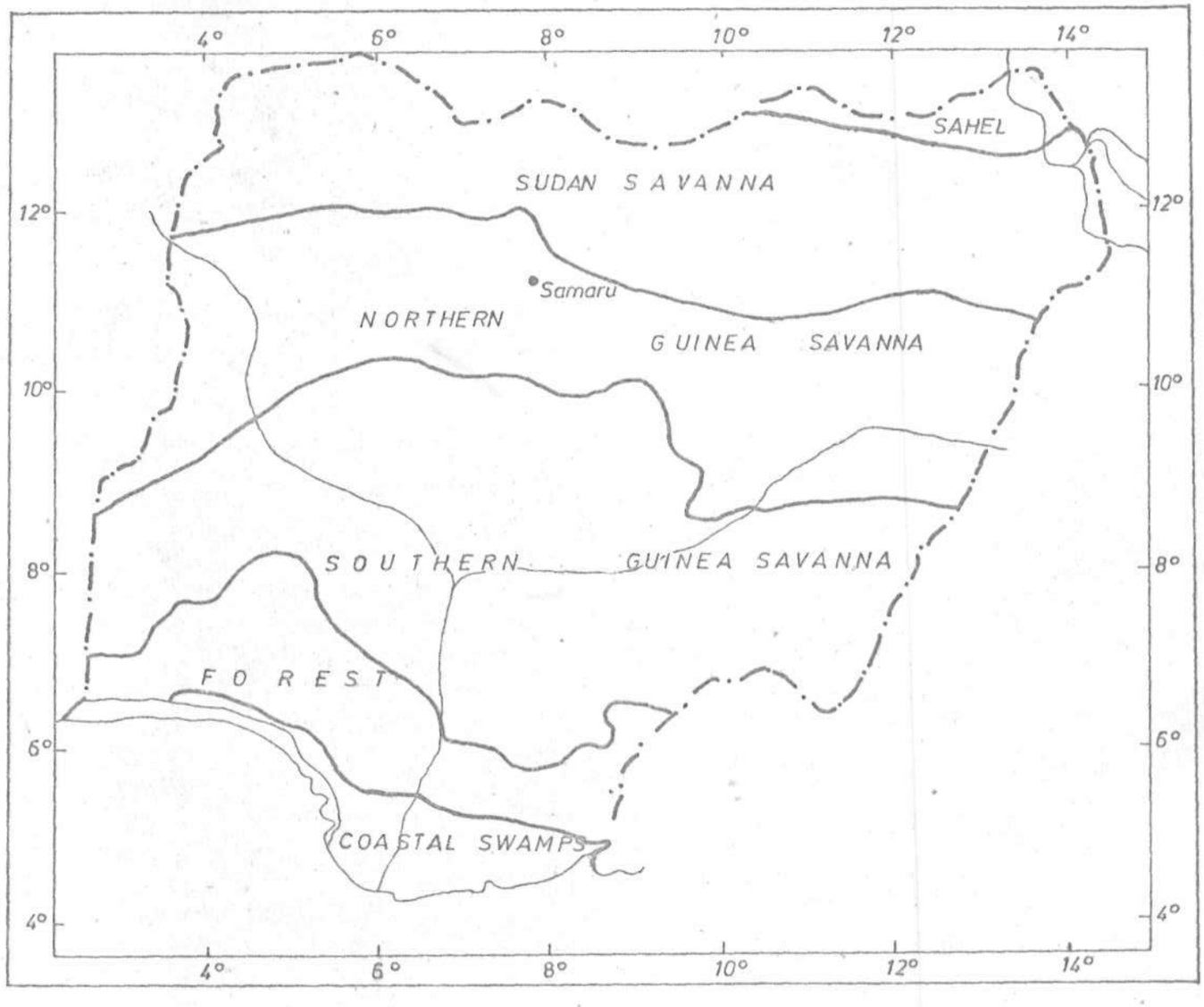
Eleven cultivars of sorghum: Short Kaura (SK.5912), Farafara bulk line (FFBL), Local 187 (L-187), Local 181(L-181), Local 1499 (L-1499), Local 75 (L-75), Local 1500 (L-1500), (C-7-4), (FD-1), Samaru sorghum hybrid I (SSH-1) and Samaru sorghum hubrid 2(SSH-2) of different maturation periods and adapted to Northern and Southern Guinea savanna (Fig.I) were used in the field trials which were conducted during the rainy season of 1979 and 1980 at the experimental farm of the Institute for Agricultural Research, Samaru ($11^{o}11'N$ $7^{o}38'E$). These 11 cultivars were divided into three groups with FFBL, SK 5912, L.187, L.181, L.75, L.1500 and L.1499, all adapted to the Northern Guinea savanna forming "Group I".

FD-1 and C-7-4 which are adapted to the Southern Guinea Savanna are grouped together in "Group 2".

The hybrids - SSH-1 and SSH-2 for comparative purposes were constituted into a different group (Group 3), although both are adapted to the Northern Guinea Savanna.

Descriptions of the various cultivars of sorghum used in the trial at Samaru.

FIG.1. ECOLOGICAL ZONES OF NIGERIA



1. SK.5912: It is a semi-tall cultivar and grows to about 260 cm in height. It heads in 130 days and matures between 170 and 175 days. The head is compact and has bold yellow grains.

2. FFBL : It is a very tall variety reaching about 460 cm at maturity. It heads in 130 days and matures after about 180 days. The head is long and loose and the grains are white.

3. L.187: It is semi-dwarf, very robust in form and grows to about 180 cm in height. The head which is large and compact characteristically bends to the direction of the sun at maturity. The grains are cream coloured.

4. L.181: It is a semi-dwarf cultivar reaching a height of 190 cm at maturity. It heads in 123 days and matures after 160 days. The head is semi-compact, elliptical and pointed at the top. The grains are medium sized and cream coloured.

5. L.1500: It is a semi-dwarf cultivar and grows to about 190 cm in height. It heads after about 123 days and matures after about 160 days. The head is generally compact and the grains are medium sized and cream coloured.

6. L.1499: It is semi-dwarf and grows to about 200 cm at maturity. It heads in 123 days and matures after about 155 days. The head is large and grains are white coloured.

7. L.75: It is semi-dwarf and grows to about 200 cm in height at maturity. The cultivar generally heads in 123 days and matures after 170 days. The head is compact and the grains are small and cream coloured.

8. Samaru Sorghum hybrid I (SSH-1): It is a semi-dwarf hybrid reaching 230 cm at maturity. It heads in about 118 days and matures after about 160 days. The head is open with drooping branches. The seed is cream coloured.

9. Samaru Sorghum hybrid 2 (SSH-2): It is a semi-dwarf hybrid reaching 230 cm at maturity. It heads in 120 days and matures after 160 days. The head is open with drooping branches. The seed is yellow coloured.

10. C-7-4: This is a tall cultivar which reaches 400 cm at maturity. It heads in 150 days and matures after 180 days. The head is large and loose with drooping branches. The grains are white and of medium size.

11. FD-1: It is a tall cultivar about 400 cm at maturity. It heads in about 150 days and matures after about 180 days. The head is large and loose with drooping branches. The grains are yellow and large.

Soil: The soil of the experimental farm is a fine sandy loam which is prone to capping and has been further described as well drained leached vertisol (D'Hoore 1964), the soil properties having been described by Jones (1973).

Climate: The climate of the area is tropical with two major seasons. The rainy season starts between late April to early May and peaks in July/August. It ends in September. The amount of rainfall ranges from 800-1350 mm annually with an average of 1100 mm (Table 1).

The dry season starts in October and ends in April. The hotest months are those preceding the rains - February to April. The harmattan period from the month of October to February is the coldest period of the year and the weather is characterised by a dry cold wind from the North East.

Planting: The sorghum cultivars were planted 30 cm apart on 75 cm row ridges on May 17th, 1979 and May 27th, 1980. There were eight ridges per plot and each ridge was six metres long thus giving a plot size of $36m^2$. As a result of poor germination resulting from a protracted period of drought following planting in 1979, the entire experiment was replanted on 6th June 1979.

Table 1 Rainfall Data (cm) for Samaru in 1979 and 1980

	1979							1980						
DATE	APR.	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	APR.	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.
1	3.0		17.0			9.8	13.3		16.3	5.0	40.2		Tr	Tr
2		7.2	1.4			22.8					5.9	34.4	0.9	12.0
3				5.0		40.4				10.3	3.0	0.2		
4			0.4	23.5	12.2	11.0	Tr					0.9	0.4	
5			39.5				3.8			0.2	5.8	9.1		
6		22.6		13.6					10.3		8.0	27.2	5.8	
7		17.0		33.7	26.8		10.3				1.2		0.6	
8				5.1		7.4				13.0		1.0		
9			3.2	9.2		2.3						3.8	17.4	
10		19.6	23.5	6.8								25.7	7.0	
11			15.5		6.5	0.1			18.9	38.4	70.0		4.2	
12		Tr		3.8	1.2	4.5	3.4				0.4	11.7		
13		Tr			101.6						31.0			Tr
14					0.7						12.0	Tr		
15		6.0	26.8	33.3		12.2						22.0		
16				10.5		5.4					36.8	0.3	9.0	
17			55.4	30.1	7.0						6.4	Tr		
18				Tr	13.5					17.0		Tr		3.7
19			1.0	8.2					26.0		1.6	20.8		0.6
20		4.5	2.0		29.2							3.5		Tr
21			5.2	32.3	10.8	4.2			10.2			16.3	1.2	
22			7.2	19.0	0.5					0.3	40.6	6.7		
23				Tr	6.5	5.5			16.4		1.4			
24			10.9	13.7	2.3	8.1				1.2		10.0	0.6	
25					13.0						8.6	11.2		
26		Tr	11.2	20.4		8.0			2.5		16.5		24.8	
27	Tr	5.2		37.3	49.3				34.0					
28					6.8			2.0			0.2	5.0		
29			Tr		3.1	1.1		1.7				3.6		
30	16.8	4.6		24.3	8.4				19.7		5.0			
31				44.0	0.4						8.0	2.4		
Total	19.8	86.3	220.2	373.8	299.8	142.8	30.8	3.7	154.4	116.4	268.9	215.8	71.9	16.3

Tr = Trace

Treatments were arranged in a complete randomised block design and was replicated three times.

Fertiliser application: Fertilisers were applied in two split doses. The first application was made at planting at the rate of 100 kg/ha of each of Nitrogen and P_2O_5. Second application was made 8 weeks later as a side dressing at the rate of 50 kg/ha of Nitrogen only.

Thinning: Thinning to one plant per stand and supplying of missing stands were done 2 weeks after planting.

Pest control: The plants were sprayed at weekly intervals beginning from the 8th week after sowing with vetox 85 at the rate of 1.12 kg/ha.

Hoe weeding was done twice, at three and at eight weeks after planting.

Measurements taken: The following measurements were made: 3 samples were taken.

1. Leaf area: Leaf area was measured at 50% bloom stage i.e. when half of the plants have shed their pollen. Leaf area was calculated by multiplying the length of each leaf blade by its maximum width and further multiplied by a correction factor of 0.70 (Egharevba, personal communication).

2. Effective Grain filling period duration (EFPD): Was measured as the period from 50% bloom stage to physiologic maturity noted by the appearance of a black layer at the placental region.

3. Plant height: Was measured in cm from the ground level to the tip.

4. Number of grains per head: Number of seeds per head was counted at harvesting, using 3 heads per plot.

Length of head: was measured in cm from the base of the head to the tip.

5. 1000 kernel weight: It was determined by counting 1000 seeds and weighing them.

6. Grain yield: The four inner rows of each plot were hand harvested, dried and threshed for yield determination. Grain yield was expressed in kilograms or tonnes per hectare at 14% moisture. Grain yield per head (gm) was determined by dividing the grain yield per plot by the number of heads harvested.

7. Stover yield: It was determined by subtracting the grain yield from the total dry matter.

8. Tiller number: Tiller number was measured by finding the means of tillers for 3 stands per plot.

Statistical treatment of data:

The data collected was subjected to statistical analysis of variance as described by Snedercor and Cockran (1967). The least significant difference was used to compare the means.

RESULTS AND DISCUSSIONS

a) Leaf area:- There were significant differences in leaf area among the cultivars in both 1979 and 1980 (Table 2). During the first year (1979), the cultivars in order of the magnitude of their leaf area were C-7-4, FD-1, SK.5912, SSH-2, FFBL, L.181, SSH-1, L.1499, L.1500, L.181 and L.75. Differences were statistically significant among all the cultivars except between FFBL and L.187.

Whereas C-7-4 produced the highest leaf area in 1979, SK.5912 recorded the highest leaf (91.4 dm^2) in 1980, followed by SSH-1, L.187 and SSH-2. When both years were combined, SK.5912 still recorded the highest leaf area suggesting that SK 5912 is superior to all other varieties in terms of leaf area production.

When total leaf area for both years were compared, total mean leaf area for 1980 was statistically different from total mean leaf area for 1979. It appears that due to late planting in 1979 as a result of a protracted period of drought after the first planting was responsible for the lower leaf area recorded in 1979. The rains came and were established in 1980 earlier and so planting was earlier. The plants therefore had adequate water and enough period for

Table 2. Mean leaf area (dm^2) of the different cultivars of sorghum at 50% flowering.

Cultivar	1979	1980	Mean
SK 5912	74.60	91.40	83.00
FFBL	63.20	49.30	56.25
L. 187	62.00	85.10	73.55
L. 181	46.60	59.30	52.95
L. 1500	54.90	67.60	61.25
L. 1499	58.90	63.60	61.25
L. 75	38.60	60.50	49.55
C-7-4	92.00	68.00	80.00
FD-1	81.35	57.10	69.20
SSH-1	60.10	86.70	73.40
SSH-2	67.40	82.60	75.00
LSD (0.05)	1.26	2.00	1.14

the development of an adequate leaf area.

A study of the correlation between leaf area and grain yield for cultivars in group 1 (SK 5912, FFBL, L 187, L 181, L.1500, L.1499 and L.75) showed that leaf area was positively correlated ($r = .39^{X}$) with grain yield (Table 11). This relationship had earlier on been reported by Watson (1952) who reported an increase in total grain yield of barley with an increase in leaf area. Jagannath et. al (1975), Gould and Sastry (1974), and Makumbi and Rubaihayo (1978) all reported positive correlation between leaf area and grain yield in sorghum. Krishnamurthy et.al (1974), had also observed while investigating the varietal differences in the growth components of sorghum with the cultivars CSH-1, CBE-X, Swarna and local Neerjola that CBE-X gave a higher grain yield than the other cultivars as a result of its higher leaf area. A similar conclusion can be reached here that the high yield of SK 5912 in comparison to other cultivars (Table 10) can be attributed to the high leaf area of SK.5912.

Other attributes that showed significant relationship with leaf area for cultivars in group I included number of grains per head ($r = .51^{XX}$), and effective grain filling period duration ($.54^{XX}$).

Of the two cultivars in group 2, C-7-4 produced significantly higher leaf areas than FD-1 in both years (Table 2). When leaf area and grain yield were analysed for correlation, a negative non-significant relationship between grain yield and leaf area was obtained (Table 12). This relationship had earlier on been noted by Dharampal and Singh (1973) in certain varieties of sorghum. The reason they gave to explain the behaviour was that due to the short internodes, the upper leaves must have completely shaded the lower leaves thereby making them less photosynthetic and parasitising on assimilates produced by the upper leaves and subsequently reducing the assimilates for grain filling. Although C-7-4 produced higher leaf area in both years, its grain yield was poorer (Table 10). It may be necessary to note that in the present study, varieties in question were tall with long internodes and so it could not have been a case of shading but a case of photosynthetic inefficiency of the leaves of the varieties. This suggestion of photosynthetic inefficiency is supported by the findings of Prior and Russel (1976) that the leaves of certain varieties of maize were more efficient photosynthetically than others. Also it could have been that most of the assimilates produced in these tall varieties were

translocated to the straw resulting in high stover yield but less grain yield (Tables 6 and 10 respectively).

With SSH-1 and SSH-2 - the two hybrids forming plants in group 3 - leaf area showed a positive correlation with grain yield (r = 0.08) (Table 13). Leaf area production was inconsistent in both years (Table 2) for the two varieties. Although SSH-2 produced a higher leaf area in 1979 (67.40 dm^2) against 60.10 dm^2 for SSH-1, the situation was reversed in 1980 with SSH-1 having a leaf area of 86.70 dm^2 and 82.60 dm^2 for SSH-2. In both years, differences were statistically significant. The mean leaf area for both cultivars for both years however showed SSH-2 having a higher leaf area of 75.00 dm^2 against 72.40 dm^2 for SSH-1.

Analysis of variance for all the varieties showed SK 5912 had the highest leaf area (Table 2). Correlation studies also showed a positive but non-significant relationship between leaf area and grain yield (Table 14), implying generally that increased leaf area may increase grain yield.

From the results, it is obvious that leaf area is positively correlated with grain yield in certain cultivars of sorghum but not in all of them. Possible explanation for this behaviour as far as this study is concerned is that with

cultivars in group 1, high leaf area resulted in high grain yield because a high source was matched by an equally high sink capable of accumulating and storing most of the assimilates manufactured and translocated to the head for grain filling.

For cultivars in group 2, although leaf area was high, grain yield was low. Stover yield on the other hand was however very high. It appears that the assimilates produced here were not fully utilised for grain filling but were translocated to the straw resulting in high stover yield.

b) Effective Grain filling period duration:

There were significant differences in grain filling period duration among the cultivars in both years (Table 3). Whereas the cultivar SK 5912 recorded the longest grain filling period - 31 days in 1979, L.1499 recorded the highest in 1980 - 31 days. Difference between these two cultivars was statistically significant in 1979 but was not in 1980 (Table 3). When the data for both years were pooled together and analysed analysis of variance showed SK.5912 to still have maintained

Table 3. Time (days) from 50% bloom stage to black layer formation (EFPD) in the different cultivars of sorghum.

Cultivar	1979	1980	Mean
SK 5912	30.67	30.00	30.33
FFBL	21.33	22.67	22.00
L.187	22.67	22.67	22.67
L.181	20.67	20.67	20.67
L.1500	20.00	25.33	22.67
L.1499	24.67	31.00	27.84
L.75	18.00	23.00	20.50
C-7-4	22.67	22.33	22.50
F-D-1	25.00	23.33	24.17
SSH-1	20.33	27.67	24.00
SSH-2	22.33	20.33	21.33
Mean	22.58	24.45	23.52
LSD (0.05)	3.16	1.12	

Mean grain filling period for all cultivars in 1980 was 24 days as against 23 days recorded in 1979. The difference was statistically significant. The possible reason may be due to the late planting in 1979 caused by a dry spell after the initial planting in May. This caused a replanting in June - a late planting time for sorghum in this zone.

An analysis of the correlation between effective filling period duration and grain yield showed a highly positive significant relationship ($r = .45^{xx}$) Table 11) for cultivars in group 1. This agreed with an earlier observation by Collier (1973) when he noted a highly significant correlation between grain filling period duration and total grain yield. Gardener (1966) on physiological basis for yield differences in three high yielding and three low yielding varieties of barley also observed that the three high yielding varieties were characterised by longer grain filling period duration than the three low yielding ones. Hanway and Weber (1965) working on soybean varieties also observed that seed yields and duration of the dry seed weight accumulation were closely related. Other workers who have observed similar trends include Collier and Porter (1964) for

sorghum, Dalton (1967) for sorghum, and Daynard et. al. (1971) for corn.

For the cultivars in group 2, ana analysis of the correlation showed a positive but not significant relationship between grain filling period and grain yield (r = .14, Table 12). There was also a positive but not significant correlation between grain filling period duration and grain yield (r = .24) when all the cultivars were combined (Table 14).

The cultivars in group 3 showed a negative trend. Difference in effective filling period duration between the two cultivars was not significant in 1979 but was significant in 1980 (Table 3). SSH-1 had a longer grain filling period of 28 days and SSH-2 had 20 days in 1980. A combined analysis of variance for 1979 and 1980 showed SSH-1 to have a higher grain filling period. There was a negative but not significant correlation between EFPD and grain yield (r = -.47) in this group (Table 13). The SSH-2 with a shorter grain filling period gave a higher mean grain yield of 2.95 tonnes/ha compared with SSH-1 with 2.50 tonnes/ha. It may be that SSH-2 has a shorter duration but higher rate of grain filling. Grain filling rate was not measured in this study. However the fact that most of the high

yielding cultivars (L.1499 and SK 5912) had a longer filling period, it can be tentatively inferred that a longer grain filling period is essential for increased grain yield.

c) Tiller Number:- Significant differences were found in tiller number among the varieties in both years (Table 4) with the cultivar L.181 having the highest number of tillers. Tiller number however had no effect on grain yield. For example when cultivars in group 1 were evaluated for grain yield, SK.5912 and L. 1499 that recorded the highest grain yield had on the average one tiller per stand. The only variety in this group that combined tiller number with high grain yield is the variety L.187 with a mean tiller number of 2 and mean grain yield of 3.04 tonnes/ha. Correlation analysis showed a positive ($r = .10$) but not significant relationship between tiller number and grain yield for cultivars in this group (Table 11). However there was a negative correlation between number of grains per head and number of tillers per stand with cultivars in this group (Table 11). This implies that tillering may reduce the number of grains per head and consequently grain yield. In this group, L.181 with the highest number of tillers in both years with about three tillers per stand recorded a grain yield of 2.82 tonnes per hectare.

Table 4. Number of tillers per plant in different Sorghum cultivars.

Cultivar	1979	1980	Mean
SK 5912	1.34	1.67	1.5
FFBL	1.34	2.33	1.67
L.187	1.00	1.00	1.00
L.181	3.67	2.67	3.17
L.1500	1.00	1.00	1.00
L.1499	1.33	1.00	1.17
L.75	3.33	1.82	2.33
C-7-4	2.00	1.67	1.83
FD-1	2.33	2.67	2.50
SSH-1	1.00	1.00	1.00
SSH-2	1.00	1.00	1.00
MEAN	1.73	1.62	
LSD (0.05)	1.54	1.20	

When compared with L. 1499 with only one tiller and a grain yield of 3.33 tonnes per hectare, the tillering influence appears to have been negative.

No significant differences were found in tiller number between the cultivars in group 2. FD-1 with a higher number of tillers than C-7-4 also had a higher grain yield but these differences in both tiller number and grain yield were not statistically significant. A negative relationship was observed between tiller number and grain number per head and also between tiller number per stand and grain yield (Table 12).

It appears that in both groups 1 and 2, tillering tends to reduce the number of grains per head which appears to be an important yield component. The result of this action may be decrease in total grain yield possibly resulting from intra-plant competition for assimilates.

Plants in group 3 did not tiller so it was not possible to determine the influence of tillers on grain yield for this group.

When all the cultivars were grouped together and subjected to correlation analysis, tiller number showed a positive but not significant relationship with grain yield but a negative

relationship with grain number per head (Table 14). Egharevba (1977) observed that reduced tillering increased grain yield in millet but reducing to less than 3 per stand led to a decrease in grain yield. Some researchers who have noted that tillering increased grain yield in some crops include Sharma and Sharma (1976) on barley. Sakaran and Kalliappa (1974) observed that grain yield was positively correlated with the number of productive tillers in barley. Escalada and Plucknett (1975) however noted that increase in the number of tillers also increased the grain yield of sorghum, possibly, the result of varietal differences. The negative effect of tillering on total grain yield in this study may be due to the effect of tillering on number of grains per head.

Plants in 2 out of 3 groups showed a negative correlation between tiller number and number of grains per head. So tillering in sorghum may not have much influence on grain yield, more so when it is realised that a large percentage of sorghum varieties either do not tiller or have a few tillers per stand.

d) Plant height: There were significant differences in plant height among the cultivars in both 1979 and 1980 (Table 5). FFBL, C-7-4 and FD-1 were the tallest plants.

Among the cultivars in group 1, FFBL was the tallest with a height of more than 4 metres. The shortest cultivar was L.187 with a height of about 1.75 metres. Matching plant height with grain yield, it seems that the taller the plant were, the less productive. While L.187 with a plant height of 175 cm produced a mean grain yield of 2.99 tonnes/ha (0.38 gm/cm of height), Farafara that is 471 cm produced 2.77 tonnes/ha (0.13 gm/cm of height) an indication of negative relationship between plant height and grain. This is substantiated by a regression analysis that showed plant height to be negatively correlated with grain yield ($r = -0.21$) (Table 11). This observation agrees with that of Goldsworthy (1969) who observed that a short American hybrid NK.300 gave a higher grain yield (4484/ha) when compared with a taller Farafara with a grain yield of 2242 kg/ha. Some other workers who have reported similar findings include Kaul (1972), Gregory (1972), Ganashan and Whittington (1976) for rice and Chang et.al. (1976) for wheat.

Table 5. Mean plant height (cm) at harvesting of different cultivars of sorghum

Cultivar	1979	1980	Mean	Grain yield per unit height (cm)
SK 5912	273.3	273.3	273.3	0.27
FFBL	493.3	449.7	471.5	0.13
L.187	172.3	178.0	175.2	0.38
L.181	208.3	218.7	213.5	0.20
L.1500	250.0	322.7	286.3	0.20
L.1499	229.7	222.7	226.1	0.33
L.75	198.3	209.7	204.0	0.34
C-7-4	426.7	438.7	432.7	0.11
FD-1	435.0	425.3	430.2	0.13
SSH-1	241.7	244.0	242.8	0.23
SSH-2	257.7	287.7	272.7	0.24
MEAN	289.66	297.3	302.57	
LSD (0.05)	39.96	44.34	27.97	

For the cultivars in group 2 (C-7-4 and FD-1) differences in height between them were not significant in both 1979 and 1980. Differences in grain yield were not significantly different in both years although FD-1 yielded more grains in both years. There was a positive but not significant correlation between height and grain yield for this group (r = .51, Table 12). Pasha and Munshi (1974), Louswan and Atkins (1978) working with sorghum noted that plant height of certain cultivars correlated positively with grain yield. Gupta and Dhillon (1974) and Sakaran and Kalliappa (1974) working with pearl millet also noted the same trend. Krishnamurthy et.al (1973) attributed that the sorghum hybrid MS 2219 X IS 3541 gave a higher grain yield than the other cultivars he studied because MS 2219 X IS 3541 was so much taller than the other varieties.

For the hybrids of group 3, SSH-2 was significantly taller and its grain yield though higher was not statistically significant from SSH-1. There was a positive but not significant correlation between plant height and grain yield (r = .18, Table 13).

From the result of these 3 groups a clear picture does not emerge on the influence of height on grain yield. When all the cultivars were combined and subjected to correlation analysis, height showed a negative but not significant relationship with grain yield (Table 14) but based on their different groups, each group responded differently. Some responded positively while others showed a negative response.

In terms of production efficiency, that is grain yield per unit height, the short stemmed cultivars out-yielded the long stemmed ones (Table 5). This notwithstanding, recommendation of the short varieties to farmers in this country should be made with other points in mind such as the usefulness of the straw in fencing, tatching and as source of fuel.

e) Grain number per head:

There were no significant differences in grain number per head among all cultivars in 1979 but there were significant differences in 1980 (Table 6). A combined analysis of the two years' data showed that there were significant differences among the cultivars with regards to number of grains per ear with the cultivars L.1499 and SK 5912 having the highest number of grains per head.

Table 6. Mean number of grains per head in different sorghum cultivars

Cultivar	1979	1980	Mean
SK 5912	2440	2910	2680
FFBL	1740	2160	1950
L.187	2150	2740	2450
L.181	2200	2020	2120
L.1500	2110	3050	2590
L.1499	2970	4030	3510
L.75	2210	2510	2360
C-7-4	1870	2470	2170
FD-1	2360	2860	2620
SSH-1	2320	2700	2520
SSH-2	2050	2910	2480
MEAN	2020	2669.0	
LSD (0.05)	N S	820	

During the 1980 growing season, L.1499 maintained the highest grain number of 4030 per ear followed by L.1500 and SK.5912. SSH-2 had the least number of grains with 1910 per ear. Grain number per ear was generally higher in 1980 than 1979. This again may be attributed to the more favourable weather condition in 1980.

For the cultivars in group 1 (Table 11) grain number was positively correlated ($r = 0.47^{xx}$) with grain yield. L.1499 with mean grain number of 3510 had a grain yield of 3.33 tonnes/ha. SK 5912 had 2680 grains per head and grain yield of 3.24 tonnes/ha, L.1500 had 2590 with a mean grain yield of 2.62 tonnes/ha. FFBL with 1950 grains per head, the least in the group gave a mean grain yield of 2.77 tonnes/ha. This positive relationship between number of grains per head and grain yield in sorghum had earlier been reported by Krishnamurthy et.al. (1973) while investigating the varietal differences in grain yield of sorghum. They observed that the high grain yield of the sorghum variety MS 2219 X IS 3541 was associated with heavier ear which in turn was a consequence of more number of grains per head. Pande et.al.(1971) also noted that number of grains per head had positive and significant relationship with total grain yield in sorghum.

An interesting observation noted in group 1 cultivars during the study was that leaf area and effective grain filling period individually correlated positively with grain number per head. Both characters contributed positively with grain yield. It appears that a high leaf area and long grain filling period result in more grains per head which eventually resulted in higher total grain yield. The two cultivars - SK 5912 and L.1499 - which recorded the highest grain yield were observed to be characterised by very high leaf area, longer grain filling period duration and more grains per head.

For the cultivars C-7-4 and FD-1, although C-7-4 produced more grains than FD-1, the difference in grain number was not significant neither in 1979 nor 1980. Grain number also showed a significant positive correlation ($r = .77^{xx}$) with grain yield (Table 12).

Between the hybrids, differences in grain number in both years were never significant. In 1979, SSH-1 produced more grains than SSH-2 but the trend was reversed in 1980. SSH-2 however gave a higher total grain yield. Correlation between grain number per head and grain yield was positive in this group.

From the studies it is obvious that increase in grain number results in increase in total grain yield.

f) 1000 Kernel weight: There were significant differences in kernel weight among the cultivars in both 1979 and 1980 (Table 7). Although SSH-1 produced heavier grains in both years, it was one of the poorest in total grain yield - an indication that grain weight may not necessarily be an indication of total grain yield.

Analysis of variance for the cultivars in group 1 showed that L.187 produced the heaviest kernels with 1000 kernels weighing 34.4 gm, the cultivar L.75 with 1000 kernel weighed just 25.77 gm. Although L.187 produced heavier kernels in this group, cultivars like L.1499 and SK.5912 with lower 1000 kernel weight but more grains produced higher total grain yield. Correlation analysis showed kernel weight to be positively but not significantly correlated with grain yield (Table 11). Gupta and Sidhu (1972), and Gupta and Dhillon (1974) had earlier reported grain size was positively correlated with grain yield. Similar findings were reported by Kaul (1972), Raghunatha (1974), Sharma and Sharma (1976) and Abu-el-Gassim and Kambal (1978) for rice, sorghum, barley and sorghum respectively.

Table 7. Mean 1000 Kernel weight (gm) among different sorghum cultivars

Cultivars	1979	1980	Mean
SK 5912	32.97	33.33	33.14
FFBL	33.93	31.70	32.84
L.187	33.50	35.40	34.45
L.181	27.83	36.40	27.14
L.1500	23.63	32.80	28.20
L.1499	26.33	26.70	26.52
L.75	25.17	26.40	25.77
C-7-4	27.13	24.40	25.57
FD-1	32.30	24.40	28.35
SSH-1	36.50	35.80	36.15
SSH-2	34.77	30.60	32.69
MEAN	30.37	29.81	30.10
LSD (0.05)	4.43	4.61	

For the cultivars in group 2, FD-1 produced heavier grains and higher grain yields in both years. Relationship between grain weight and grain yield was however negative but non significant (Table 12). This same non significant relationship between grain weight and total grain yield was shown by cultivars in group 3(Table 13). Although SSH-1 produced heavier grains, SSH-2 gave a higher total grain yield. Williams (1977) noted that the relationship between grain weight, grain number and total grain yield varied with cultivar and actually obtained a significant negative correlation with the sorghum hybrid RS 610. If grain weight correlates negatively with grain number, but grain number increased total grain yield, then it becomes obvious that very heavy grains may not increase total grain yield because of the few grains.

Although SSH-1 produced the heaviest grains when all the cultivars were compared, but because the number of grains per head was very few, the total grain yield of SSH-1 was lower than those cultivars with lighter grain weight but higher grain number. So grain number appears to be a better index for predicting grain yield, although if both characters - heavier grains and more grains can be combined in a genotype, total grain yield will be greatly increased.

g) Stover yield:

There were significant differences in stover yield among all the cultivars (Table 8). In both 1979 and 1980 FD-1 produced the highest yield of stover followed by C-7-4. The least stover yield was produced by L.187 and L.75. However the cultivars that produced the highest stover yeild were not necessarily the highest grain yielders in spite of the fact that there was a significant positive correlation between stover yield and grain yield.

Among the cultivars in group 1 FFBL had the highest stover weight followed by L.1499 (Table 8). There was significant positive correlation between stover yield ($r = .55^{xx}$) and grain yield among the cultivars in this group.

A similar positive and significant correlation ($r=.75^{xx}$) was found between stover weight and grain yield for cultivars in group 2 (Table 12). FD-1 in both years produced a higher stover yield than C-7-4 but the differences were only significant in 1979. In both years FD-1 gave higher grain yields although the differences were not statistically significant.

For cultivars in group 3, the relationship between stover yield and grain yield was positive ($r = 0.20$) but non significant. Although SSH-1 gave a higher stover yield than SSH-2 in 1979 (Table 8) grain yield was higher for SSH-1.

Table 8. Stover yield (tonnes/ha) dry weight of different cultivars of sorghum

Cultivars	1979	1980	Mean
SK 5912	5.73	11.03	8.38
FFBL	7.23	15.35	11.29
L.187	3.92	7.69	5.81
L.181	5.36	8.51	6.94
L.1500	7.72	10.83	9.28
L.1499	5.95	12.69	9.33
L.75	5.24	7.55	6.40
C-7-4	9.15	16.57	12.86
FD-1	15.93	16.71	16.33
SSH-1	6.37	10.20	8.29
SSH-2	6.05	14.42	10.24
Mean	7.16	11.96	9.56
LSD (0.05)	2.53	2.54	

SSH-2 gave a higher grain yield in 1980. Difference in grain yield was not significant in 1979 but was significant in 1980. Similar results were obtained by Chauhan and Singh (1975), Krishnamurthy et.al. (1973) and Polke et.al. (1974). It is safe to assume robust plants tend to produce higher grain yields.

Combined stover yield for all cultivars was significantly higher for 1980 than for 1979. Grain yield followed the same pattern being higher in 1980 than 1979. The differences may be attributed to early planting and better establishment of plants in 1980.

h) Head length: There were significant differences in head length among all the cultivars (Table 9) in both 1979 and 1980 with the very tall cultivars like C-7-4, FD-1 and FFBL having the longest heads.

The cultivars with the longest heads did not necessarily produce the highest number of grains nor did they produce the highest number of grains per unit length of head (Table 9). For example while the mean head length and the mean grain number per unit cm of length in cultivar L.1499 over the two years were 42 cm and 51 grains respectively, corresponding figures for L.187 was 38 cm and 83 grains, an indication that grains are normally more compact in the shorter heads.

Table 9. Mean head length (cm) and number of grains per unit length in different sorghum cultivars

Cultivar	1979			1980		
	Head Length (cm)	No.of grains/ head	No. of grains/ unit length	Head length (cm)	No. of grains/ head	No. of grains per unit length
SK 5912	32.33	2440	75	34.40	2910	85
FFBL	38.77	1740	45	37.20	2160	58
L.187	29.67	2150	72	29.60	2740	93
L.181	30.87	2200	71	28.30	2020	71
L.1500	34.47	2110	61	36.30	3050	84
L.1499	36.67	2970	81	37.20	4030	108
L.75	29.47	2210	75	28.10	2510	89
C-7-4	43.23	1870	43	41.10	2470	60
FD-1	37.80	2360	62	39.90	2860	72
SSH-1	37.40	2320	62	29.40	2700	69
SSH-2	34.90	2050	59	39.50	2910	74
Mean	35.05	2020		35.55	2669	
LSD (0.05)	4.58	NS		4.18	820	

It was observed in some of these cultivars with long heads that the lower one-third of the heads contained very few seeds.

Generally, head length was negatively correlated with grain yield except for cultivars in group 1 (Table 11) where head length was psotively but not significantly correlated with grain yield. So long heads which are not completely filled may not necessarily result in higher grain yield. A more ideal condition would be to have compactly filled long heads.

i) Grain yield:

While there were no significant differences in grain yield among the cultivars in the year 1979, there were significant differences in 1980 with SK.5912, L.1499 and L.75 having the highest total grain yield (Table 10). When the 1979 and 1980 data were pooled together, cultivars L.1499, SK.5912 and L.75 gave the highest grain yields of over 3 tonnes per hectare.

Among the cultivars in group 1, the three highest grain yielders were L.1499 with mean grain yield of 3.33 tonnes/ha, SK.5912 with 3.24 tonnes/ha and L.75 with 3.04 tonnes/ha.

Table 10. Grain yield (tonnes/ha) at 15% moisture content of different sorghum cultivars

Cultivar	1979	1980	Mean
SK 5912	2.54	3.95	3.24
FFBL	2.43	3.12	2.77
L.187	2.63	3.23	2.93
L.181	2.72	2.91	2.82
L.1500	1.87	2.77	2.62
L.1499	2.79	3.87	3.33
L.75	2.74	3.32	3.04
C-7-4	1.92	2.41	2.17
FD-1	2.57	2.50	2.54
SSH-1	3.04	1.97	2.50
SSH-2	2.79	3.12	2.95
Mean	2.51	3.02	2.81
LSD (0.05)	NS	0.85	

These high grain yielders were characterised by a moderately high leaf area, longer grain filling period and they also had more grains per head. They were also short stemmed. The poorest yielders in this group were FFBL and L.1500 with 2.77 and 2.62 tonnes/ha respectively. These poor yielders had less leaf area, fewer grains per head and shorter grain filling period. Farafara was exceedingly tall and height was found to reduce grain yield among cultivars in this group.

There were no significant differences in grain yield for cultivars in group 2 both in 1979 and 1980 and when yields for both years were pooled together. However FD-1 consistently gave higher grain yield than C-7-4 and this could have been due to the number of grains and higher kernel weight.

For the hybrids of group 3, difference in grain yield was not significant in 1979 but was significant in 1980 with SSH-2 having a higher grain yield of 31.2 tonnes/ha compared with 1.97 tonnes/ha for SSH-1. SSH-1 was severely attacked by stem borer in 1980 and this could have been responsible for the very low yield. Notwithstanding this low yield, when the yield data for the hybrids were pooled over the two years, there were no significant differences.

From correlation studies, it appears that the most important plant characters for predicting grain yield are leaf area, effective grain filling period duration and number of grains per head.

Leaf area have been reported by various workers as an important parameter influencing grain yield; Watson (1952), Jagannath et.al. (1975), Gould and Sastry (1974), Makumbi and Rubaihayo (1978). A good canopy development is essential for efficient solar energy interception for the manufacture of assimilates. However excessive leaf area has also been found to have a negative effect on grain yield as lower leaves tend to parasitise on upper ones for assimilates meant for grain filling. Prior and Russel (1976) noted that grain yield was higher at leaf area index of 2.9 than at 4.1 in maize.

Effective grain filling period duration was also found to be positively correlated with grain yield. This trend was observed by workers like Collier (1963), Collier and Porter (1964), Gardener (1966), Dalton (1967), and Daynard et.al. (1971). A long grain filling period duration appears to be essential to ensure that grains have sufficient time to accumulate and store maximum quantity of assimilates. All the high yielding cultivars like L.1499 and SK.5912 used in

this experiment confirmed this. Both were characterised by longer grain filling period than their lower yielding counterparts.

Number of grains per head also was found to exert much influence on grain yield. Krishnamurthy et.al. (1973) and Pande et.al. have also reported number of grains to be positively correlated with grain yield of sorghum. The high yielding cultivars were found to have more grains per head. SK 5912, L.1499 and L.75 recorded very high grain number per head which resulted in higher total grain yield than others with fewer grains per head.

Kernel weight was found not to exert much influence on total grain yield. Heavier kernels tend to reduce the number of grains per head and hence resulted in reduced total grain yield.

Plant height showed a negative relationship with grain yield. The dwarf cultivars yielded more grains than the taller ones. It appears that the assimilates produced during grain filling period were more efficiently utilised in the shorter cultivars for grain filling than the tall ones. In the tall ones, the assimilates might have been used to increase straw yield.

Head length was negatively correlated with grain yield. Most of the cultivars with very long heads had very few grains. The heads looked loose and incompletely filled with grains, while the short heads were compact and had more grains.

Tillering was also not conducive to increase grain yield. The cultivars that tillered did not produce much grains. Tillers were found to reduce grain number and hence total grain yield. The cultivars that produced the highest grain yield virtually had no tillers.

CONCLUSION

From the studies carried out, three important parameters have been identified which could be used for predicting grain yield in sorghum. These parameters are leaf area, effective grain filling period duration and number of grains per head.

Leaf area showed positive and significant correlation with grain yield in the high yielding cultivars. These cultivars like L.1499 and SK.5912 recorded a moderately high leaf area. Apart from the direct contribution of leaf area to increased grain yield, leaf area also influenced some other yield promoting characters. Leaf area was positively correlated with effective grain filling period duration and number of grains per head. It is therefore very essential to maintain a moderately high leaf area in order to achieve high grain yield- the leaves being the machinery for the manufacture of assimilates which are then translocated and stored in the grains.

Effective grain filling period duration also played a very important role in the determination of total grain yield. The cultivars that recorded the highest grain yield were found to be characterised by longer grain filling period.

A longer filling period ensures that the grains have enough time to maximise accumulation and storage of assimilates. It is therefore necessary to identify those cultivars with longer and higher rates of grain filling period duration.

Grain number per head was more important in determining grain yield than grain weight. Grain number per head was found to correlate positively with grain yield and the high yielding cultivars were found to have more grains on the head than the lower yielding ones. Increase in grain number ensures an adequate sink size capable of accumulating and storing available assimilates.

1000 kernel weight had little or no effect or even negative effect on grain yield. SSH-1 with the heaviest grains yielded poorly. Grain density was found to be negatively correlated with grain number which was found to be a major yield contributing character. A more desirable situation would have been a combination of more grains and heavier grains. These two would undoubtedly have increased total grain yield.

Height was negatively correlated with grain yield. Shorter plants showed their superiority in grain yield over taller ones as exemplified by L.1499, SK 5912 and L.75

as against tall cultivars like FFBL, C-7-4 and FD-1. The taller cultivars are characterised by a higher stover to grain ratio. Most of the assimilates must have been translocated to the culm instead of being used for grain filling.

Tillering does not appear to contribute much to grain yield. Correlation studies showed either a non significant positive correlation or negative relationship. The cultivar L.181 which tillered more than any other cultivar in both years did not produce as much grains as the cultivars without tillers. It appears that intra-plant competition in tiller plants reduce total grain yield in sorghum.

Table 11. Correlation matrix showing relation of different attributes in seven sorghum cultivars (Group 1)

LAI	.97419^{xx}									
EFPD	.5428^{xx}	.54738^{xx}								
No. of TILLERS	-.3455	-.3455	-.29164							
PLANT HEIGHT	.05187	-.00149	.02327	-.075						
STOVER YLD.	.11009	.02996	.33567^{x}	-.0466	.464^{xx}					
KWT.	.51175^{xx}	.49153^{xx}	.28658	-. 290	.291	0.64				
LHD.	.09453	.11568	.34038^{x}	-. 231	.633^{xx}	.475^{xx}	.180			
No. OF GRAINS/HD	.31813^{x}	.31871^{x}	.55954^{xx}	-. 134	-.236	.333^{x}	.087	.383^{x}		
TDM	.20231	.11959	.37815^{x}	-. 032	.359^{x}	.980^{xx}	.096	.390^{x}	.397^{x}	
GRAIN YIELD	.39218^{x}	.34619^{x}	.44736^{xx}	.102	-.021	.553^{xx}	.050	.106	.465^{xx}	.672^{xx}
	LA	LAI	EFPD	No. of TILLERS	PLANT HT	STOVER YIELD	1000 KWT	LHD	No. of GR/HD.	TDM

ABBREVIATIONS USED

LA = Leaf area
LAI = Leaf Area Index
EFPD = Effective grain filling period duration
HT = Height
TDM = Total dry matter
KWT = Kernel weight
LHD = Length of head
GR = Grains
HD = Head

Table 12. Correlation matrix showing relation of different attributes in two sorghum cultivars (Group 2)

LAI	.99929^{xx}								
EFPD	.28965	.29422							
No. of TILLERS	-.29248	-.27060	-.17269						
PLANT HEIGHT	.15938	.15567	.01851	-.13883					
STOVER YIELD	-.63277^{x}	-.64077^{x}	.03620	.07552	.26170				
KWT	.43893	.44661	.35489	-.31737	-.13778	-.09948			
LHD	.11435	.10834	-.29184	-.06053	-.21202	-.50749	-.20840		
GRAIN NO./HEAD	-.57742^{x}	-.58957^{xx}	.02834	-.18971	.28444	.44535	-.29529	.02392	
TDM	-.73842^{xx}	-.74336^{xx}	-.08164	.05565	.22484	.88186^{xx}	-.28206	-.35788	-.48038
GRAIN YIELD	-.42506	-.44541	.13997	-.13801	.51308	.74616^{xx}	-.00419	-.30605	.77313^{x} .65832^{x}

	LAI	EFPD	No. of TILLERS	PLANT HEIGHT	STOVER YIELD	KWT	LHD	GRAIN No./HD.	TDM

Table 13. Correlation matrix showing relationship of different attributes in two sorghum cultivars (Group 3)

	LA	LAI	EFPD	TILLER NO.	PLANT HEIGHT	STOVER YD.	KWT	HD LENG-TH	GRAIN No.	TDM
LAI	.99^{x}									
EFPD	.32	.32								
TILLER NO.	99.00	99.00	99.00							
PLANT HEIGHT	.06	.03	-.29	99.00						
STOVER YIELD	.60^{x}	.60^{x}	.02	99.00	.56					
KERNEL WEIGHT	--.31	-.30	.38	99.00	-.62^{x}	-.54				
HEAD LENGTH	.33	.33	.32	99.00	.36	.67^{x}	-.21			
GRAIN NO.	.52	.54	.39	99.00	-.44	.04	.41	.06		
TDM	.59^{x}	.58^{x}	-.02	99.00	.50^{x}	.98^{xx}	-.50	.62$_{x}$	.04	
GRAIN YIELD	.08	.07	-.46	99.00	.19	.20	-.004	-.14	.15	.33

Table 14. Correlation matrix showing relationship of different attributes in all Eleven Cultivars of sorghum

	LAI	EFPD	No. of TILLERS	PLANT HEIGHT	STOVER YIELD	1000 KWT	LHD	No. GR/ HEAD	TDM
LAI	.99030^{xx}								
EFPD	.40326^{xx}	.39838^{xx}							
No. of TILLER	-.28756^{x}	-.27538^{x}	-.21217						
PLANT HEIGHT	.16504	.13562	-.00828	.09862					
STOVER YIELD	.19886	.16415	.16593	.09312	.61390^{xx}				
KWT	.36503^{xx}	.34811^{xx}	.21630	-.31567^{x}	-.06138	-.17263			
LHD	.30151^{xx}	.29725^{x}	.15855	-.11497	.63455^{xx}	.51284^{xx}	.03897		
No. OF GR/HD.	.14377	.13648	.49509^{xx}	-.09495	-.17490	.20467	.00795	.15027	
TDM	.20237	.16873	.20381	.08043	.51755^{xx}	.96362^{xx}	-.15539	.44352^{xx}	.27703^{x}
GRAIN YIELD	.10910	.10573	.24050	.01845	-.18186	.17694	.07915	-.18555	.42425^{x} .32505

LITERATURE CITED

Abu-el-Gassim, E.H. and A.E. Kambal (1978). Variability and inter-relations among characters in indigenous sorghums of the Sudan. East African Agric. and For. J.41: 125-133.

Anonymous, (1979). Introduction. Notes on Cereal Cropping Scheme meeting. I.A.R., A.B.U., Zaria.

Chang, W.L., H.Y. Huang, A.R. Al-Mudaib and A.A. Zaid (1976). Adaptability of some bread and durum wheat cultivars in Eastern Saudi Arabia. J. of Agric. Res. of China 21: 53-56 Referred to in Field Crop Abstract 30: 150

Chauhan, B.P.S. and S.P. Singh (1975). Correlation of different morphological characters with fodder and grain yield in sorghum. Crop Sci. 24: 87-92.

Collier, J.W. (1963). Caryopsis development in several grain sorghum varieties and hybrids. Crop Sci. 3: 419-422.

Collier, J.W. and K.B. Porter (1964). Performance of grain sorghum hybrids in the Rolling and High Plains of Texas. Texas Agric. Exp. Sta. Prog. Rep. 2305: 7-14.

Dalton, L.G. (1967). A positive regression of yield on maturity in sorghum. Crop Sci. 7: 271.

Daynard, T.B. and W.G. Duncan (1969). The black layer and grain maturity in corn. Crop Sci. 9: 437-476.

Daynard, T.B., J.W. Tanner and W.G. Duncan (1971). Duration of the grain filling period and its relation to grain yield in corn, *Zea mays* L. Crop Sci. 11: 45-48.

Dharampal, S. and U. Singh (1973). Genetic association in *Sorghum vulgare Pers.* Madras Agric. J. 6: 1222-1224.

D'Hoore, J.L. (1964). Soil map of Africa Joint Project II. Com. for Tech. Co-op. in Africa, Lagos.

Eastin, J.D., J.H. Hultquist and C.Y. Sullivan (1973). Phys-ological maturity in grain sorghum. Crop Sci. 13: 175-178.

Egharevba, P.N. (1977). Tiller number and millet grain productivity. Cereal Res. Comm. 5: 235-242.

Egharevba, P.N. (1978). Sorghum production in Northern Savannah. Samaru Conf. Paper No. 29. 15pp.

Escalada, R.G. and D.C. Plucknett (1975). Ratoon cropping of sorghum 2. Effect of day-length and temperature on tillering and plant development. Agron. J. 67: 479-484.

Fisher, K.S. and G.L. Wilson (1976). Studies of grain production in *Sorghum bicolor L. (Moench)*. Profile of photosynthesis, illuminance and foliage arrangement. Aust. J. of Agric. Res. 27: 35-44.

Ganashan, P. and W.J. Whittington (1976). The stability of rice yields in Sri Lanka. Exp. Agric. 12: 361-368.

Gardener, C.C. (1966). The physiological basis for yield differences in three high and three low yielding varieties of barley. M.Sc. Thesis, University of Guelph.

Goldsworthy, P.R. (1969). The growth and yield of tall and short sorghum in Nigeria. Ph.D. Thesis. University of Reading.

Gould, J.V. and K.S.K. Sastry (1974). Heterosis for vegetative and grain yield components in sorghum. Ind. J. of Agric. Sci. 44: 253-256.

Gregory, E.J. (1975). Performance of winter barley varieties. Res. Rep. Agric. Exp. Sta. New Mexico State University 307:5.

Gunn, R.B. and R. Christensen (1965). Maturity relationships among early and late hybrids of corn. Crop Sci. 5: 299-302.

Gupta, V.P. and B.S. Dhillon (1974). Variation and covariation of some plant and grain trials in pearl millet. Ind. J. of Agric. Sci. 44: 213-216.

Gupta, V.P. and P.S. Sidhu (1972). Component analysis for grain yield. Plant Sci. 4: 12-13.

Hanway, J.J. and F.R. Weber (1965). Dry matter accumulation in different soybean (*Glycine max* L.) varieties. Agron. J. 57: 7-12.

Hanway, J.J. and W.A. Russell (1969). Dry matter accumulation in corn (*Zea mays* L.) plants: Comparison among single cross hybrids. Agron. J. 61: 947-951.

Hughes, H.D. and D.S. Metcalfe (1972). Crop Production. The MacMillan Co., New York. 3rd Ed.

Jones, M.J. (1973). Time of application of nitrogen fertiliser to maize at Samaru, Nigeria. Exp. Agric. 9: 83-90.

Kaul, M.L.H. (1972). Performance, inter-relationships and heritability estimates of certain morphological traits of *Oryza sativa* L. J. of the Ind. Bot. Soc. 44: 628-629.

Krishnamurthy, K., B.G. Rajashekara, G. Raghunathan, M.K. Jagannath, N. Venugopal and A. Bommegowda (1973). Investigations on varietal differences in grain yield of sorghum (*Sorghum vulgare Pers.*). Mys. J. Agric. Sci. 7: 1-5.

Krishnamurthy, K., B.G. Rajashekara, G. Raghunathan, M.K. Jagannath, N. Venugopal and A. Bommegowda (1974). Investigations on the varietal differences in the growth components of sorghum (*Sorghum vulgare Pers*). Mys. J. Agric. Sci. 8: 52-59.

Louswan, P. and R.E. Atkins (1978). Genetic effects for grain yield and yield components and relationships among agronomic characters in converted exotic sorghum. Iowa J. of Res. 53: 291-298.

Makumbi, V. and P.R. Rubaihayo (1978). A study of physiological determinants of yield in sorghum. Zeischrift fur Acker-und Pflazenbau 146: 137-142.

Martin, J.H., W.H. Leonard and D.L Stamp (1976). Principles of field crop production. MacMillan Pub. Co. Inc., 3rd Ed.

Oke, O.C. (1976). The potential of millet and sorghum as food in Nigeria. Proceedings of a symposium on sorghum and millets for human food. Inter. Assoc. for Cereal Chem. 7 pp.

Pande, R.C., V.S. Rajput and R.C. Tiwari (1971). Studies on yield and yield components in different hybrids, composites and local varieties of maize, (*Zea mays L.*). Mys. J. of Agric. Sci. 5: 181-186.

Pasha, M.A.M. and Z.A. Munshi (1974). Correlation studies on *Sorghum bicolor L. (Moench.)*. Agric. Pakistan 24: 245-259.

Polke, Y.S., Y.N. Patil and W.Y. Zode (1973). Inter-relationships and path co-efficient analysis between fodder and grain yield in jowar (*Sorghum vulgare Pers.*). Naghur Agric. College magazine 46: 22-25. Referred to in Field Crop Abstract 39(9): 631.

Prior, C.L. and W.A. Russel (1976). Leaf area index and grain yield for non-prolific and prolific single crosses of maize. Crop Sci. 16: 304-305.

Purseglove, J.W. (1976). Tropical crops. Monocots. Longmans Group Ltd. 3rd Ed.

Jagannath, M.K., K. Krishnamurthy, B.G. Rajashekara, G. Raghunatha, A. Bommegowda, N. Venugopal. (1975). Path analysis of some growth parameters in sorghums. Current Sci. 44: 628-629.

Raghunathan, G. (1974). Growth and yield of dwarf and tall sorghum hybrids in relation to plant population and stand geometry. Ph.D. Thesis. University of Agric. Sci. Bengalore, India.

Rench, W.E. and R.H. Shaw (1971). Black layer development in corn. Agron. J. 63: 303-305.

Sankaran, S. and R. Kalliappa (1974). Relationships between grain and straw yield with measurable morphological characters in pearl millet. Madras Agric. J. 61: 359-364.

Sharma, H.M. and G. Sharma (1976). Correlation and regression studies between grain yield and yield attributing characters in irrigated barley. Ind. J. Agron. 21: 156-157.

Snedecor, G.W. and W.G. Cochran (1976). Statistical methods; 6th Ed. Iowa State Univ. Press. Ames, Iowa, U.S.A.

Watson, D.J. (1952). The physiological basis of variation in yield. Adv. in Agron. 4: 101-145.

Williams, R., C.A.P. Boundy, and A.J. Millington (1977). The effect of sowing date on the growth and yield of three sorghum cultivars in the Ord River Valley 2. The components of growth and yield. Aust. J. Agric. Res. 28: 381-387.