EFFECT OF PLANT POPULATION, SOWING DATE AND VARIETY ON TILLER SURVIVAL AND YIELD OF PEARL MILLET (*Pennisetum typhoides* (Burm.) Stapf and Hubbard)

By

IBRAHlM KAFUR YUSUFU

A thesis Submitted to the postgraduate School,

Ahmadu Bello University

in partial fulfilment of the requirement for the

Degree of Master of Science in Agronomy

)

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA

JUNE, 1985

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.

I. K. YUSUFU
Candidate

Date: 10/6/1985

The above declaration is confirmed

PROF. P. N. EGHAREVBA
Major Supervisor

Date: 14/6/85

CERTIFICATION

This thesis entitled 'EFFECT OF PLANT POPULATION, SOWING DATE AND VARIETY ON TILLER SURVIVAL AND YIELD OF PEARL MILLET (*Pennisetum typhoides* (Burm.) Stapf and Hubbard)' by Ibrahim Kafur YUSUFU meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

Prof. P. N. Egharevba
Chairman, Supervisory Committee

Dr. Vijay Kumar
Member, Supervisory Committee

Dr. C. C. Nwasike
Member, Supervisory Committee

Prof. J. Y. Yayock
Head, Agronomy Department

Prof. G. E. Osuide
Dean, Postgraduate School

Date: 4/.X.i./85

AHMADU BELLO UNIVERSITY
ZARIA

DEDICATION

To

My Beloved wife

A'ISHA

ACKNOWLEDGEMENTS

I sincerely wish to express my gratitude and immense appreciation to my major supervisor, Prof. P.N. Egharevba, for his invaluable advice and criticisms throughout the period of the study. The same goes to Dr. Vijay Kumar and Dr. C.C. Nwasike for their friendly guidance and immense contributions towards the success of this work.

My heartfelt appreciation also goes to the members of staff of the Department of Agronomy especially Prof. J. Y. Yayock, Dr. V.B. Ogunlela, Mr. U.F. Chiezey and Mr. D.A. Labe for the continuous advice and encouragement they have given me. Sincere thanks also go to Messrs S. Ukata and A. Gyilom for the technical assistance they have tirelessly rendered during the execution of this project. Gratitude is expressed to Dr. M.M. Kapu of the Department of Biological Sciences for his continuous support and encouragement.

Thanks also go to my brothers Abdullahi Yusufu, Ahmed Yusufu and Atiku Yusufu for the unflinching moral and financial support they have rendered throughout the period. Mr. Cyril O. Egeolu and Mallam Haruna G. Kundi also deserve my appreciation for their clerical assistance.

To my wife A'isha and daughter, Jamila, I am deeply indebted for the love, patience and moral encouragement they

have displayed during the period of my study.

Finally, I wish to extend my gratitude to Katsina Polytechnic for funding this course.

ABSTRACT

With the aim of improving the production of 'Gero' millet, investigations were conducted at Samaru, Zaria, during the 1903 and 1984 wet seasons to study the effects of three plant populations (40,000 (low); 00,000 (medium) and 120,000 plants/ha (high), three sowing dates and two varieties of millet (Ex-Borno and Dwarf-Gero) on tiller survival and grain yield of pearl millet.

At the low plant population tiller contributed maximum (by 60%) to the grain yield. Contribution of the tiller to grain yield at medium, and high plant population was to the extent of 57% and 50%, respectively. The low plant population resulted in relatively higher number of tillers per plant, and low tiller and main-culm mortality.

The earliest sown millet with a mean grain yield of 140 kg/ha, performed better than millet sown at the second and third sowing dates by an average of 10% and 22%, respectively. Grain yield in the early sown plot was determined by the number of harvestable heads, number of tillers per plant, longer time to - 50% - flowering as well as tiller contribution to grain yield.

These results indicated that Dwarf-Gero excelled Ex-Homo as judged by time to 50% flowering to grain yield as well as resistance to drought.

Plant population had significant effect on 'Gero' millet grain yield. The Dwarf-Gero out-yielded Ex-Borno by a margin of almost 50% in grain yield in 1903, while in 1984 when the rainfall was more adequate, they both yielded at par, indicating the drought resistance of Dwarf-Gero.

TABLE OF CONTENTS

Chapter		Page
	Declaration	i
	Certification	ii
	Dedication	iii
	Acknowledgements	iv
	Abstract	vi
	Table of Contents	viii
	List of Tables	xi
	List of Appendices	xiii
1	INTRODUCTION	1
	1.1 Origin and Distribution	1
	1.2 Ecological Adaptation	1
	1.3 Production and Trend in Nigeria	2
	1.4 Economic Importance	2
2	LITERATURE REVIEW	5
	2.1 Plant Population	5
	2.2 Tillering	7
	2.3 Time of Planting	11
3	MATERIALS AND METHODS	15
	3.1 Experimental Site and Soil	15
	3.2 Treatments	15
	3.3 Design and Plot Size	16
	3.4 Measurements and Observations	16
	3.4.1 Meteorological data	16

Chapter			Page
	3.4.2	Per cent seedling emergence	18
	3.4.3	Numbers of tillers per plant	19
	3.4.4	Leaf area	19
	3.4.5	Time to 50% flowering	19
	3.4.6	Tiller mortality	19
	3.4.7	Main-culm mortality	20
	3.4.8	Yield and yield components	20
	3.5	Data Analysis	20
4	RESULTS		21
	4.1	Per cent Emergence	21
	4.2	Stand count at Thinning	21
	4.3	Number of Tillers	24
	4.4	Leaf Area of Main-culm	24
	4.5	Leaf Area of Tillers	27
	4.6	Days to 50% Flowering	27
	4.7	Main-culm Mortality	29
	4.8	Tiller Mortality	31
	4.9	Number of Harvestable Heads	33
	4.10	1000-Grain Weight	35
	4.11	Grain Yield	37
5	DISCUSSION		39
	5.1.	Effect of Plant Population on Physiological Characters and Grain Yield	39
	5.2	Effect of Sowing Date on Tiller Formation and Contribution to Grain Yield	42

Chapter		Page
	5.3 Varieties	44
6	SUMMARY AND CONCLUSION	45
	REFERENCES	47
	APPENDICES	53
	SHORT BIOGRAPHY	66

LIST OF TABLES

Table		Page
1	Physico-Chemical properties of the soil (0-30cm) at the experimental site at Samaru ..	16
2	Details of Management Operation on Millet during the 1983 and 1984 growing seasons at Samaru ..	17
3	Effect of plant population, sowing date and variety on per cent seedling emergence of pearl millet at Samaru, Zaria	22
4	Effect of plant population, sowing date and variety on stand count at thinning of pearl millet at Samaru, Zaria	23
5	Effect of plant population, sowing date and variety on number of tillers per plant of pearl millet at Samaru, Zaria.....	25
6	Effect of plant population, sowing date and variety on leaf area (dm^2) of pearl millet Samaru, Zaria	26
7	Effect of plant population, sowing date and variety on time to - 50% - flowering (days) of pearl millet at Samaru, Zaria	28
8	Effect of plant population, sowing date and variety per cent main-culm mortality of pearl millet at Samaru, Zaria	30
9	Interaction effect of plant population and sowing date on per cent main-culm mortality of pearl millet in 1983	31
10	Effect of plant population, sowing date and variety on per cent tiller mortality of pearl millet at Samaru, Zaria	32
11	Effect of plant population, sowing date and variety on number of harvestable heads per plant of pearl millet at Samaru, Zaria	34
12	Interaction effect of variety and plant population on number of harvestable heads/ plant of pearl millet in 1983	35
13	Effect of plant population, sowing date and variety on 1000-grain weight (gm) of pearl millet at Samaru, Zaria	36
14	[illegible]	[illegible]

Table		Page
14	Effect of plant population, sowing date and variety on grain yield (kg/ha) of pearl millet at Samaru, Zaria	30

LIST OF APPENDICES

Appendix		Page
1	Rainfall data for Samaru (mm) 1983	53
2	Rainfall data for Samaru (mm) 1984	54
3	Mean monthly maximum and minimum temperatures (^{o}C) at Samaru-Zaria, 1983	55
4	Mean monthly maximum and maximum temperatures (^{o}C) at Samaru-Zaria, 1984	56
5	Stem-borer and downymildew calculation formulae	57
6	Individual analyses of variance for seedling emergence and stand count of pearl millet .	58
7	Individual analyses of variance for number of tillers and time to - 50% - flowering of pearl millet	59
8	Individual analyses of variance for tiller and main-culm mortality of pearl millet ...	60
9	Individual analyses of variance for number of harvestable heads and 1000-grain weight of pearl millet	61
10	Individual analyses of variance for grain yield of peal millet	62
11	Combined analyses of variance for seedling emergence, stand count, number of tillers and time-to-50% flowering of pearl millet over 1983 and 1984	63
12	Combined analyses of variance for main-culm and tiller mortality of pearl millet over 1983 and 1984	64
13	Combined analyses of variance for yield characters of pearl millet over 1983 and 1984	65

Chapter 1

INTRODUCTION

1.1 Origin and Distribution

Pearl millet (Pennisetum typhoides S. & H.) originated from Africa particularly the regions of Abyssinia and Sudan (Vavilov, 1951). Krishnaswamy (1962) also states that most of the earlier botanists considered Africa as the centre of origin of pearl millet and that it was later introduced into India and other parts of the world. Other areas of production include China, United States of America, the Near and Far East.

1.2 Ecological Adaptation

Pearl millet thrives on a wide range of soils but it generally prefers well-drained ones and it is particularly well suited to loamy sand soil. It is, however, extensively grown on shallow mixed black red and lighter coloured soils of south India (ICAR, 1961a). Generally, millets are less tolerant of water-logging than sorghum. They are early maturing and resistant to intense heat and drought.

Millet is grown in areas with an annual rainfall range of between 125 to 900mm (Jain and Mathur, 1961; Aiyer, 1947). Where dry matter for fodder is required, Begg (1971) estimated 500mm of rainfall as adequate and in areas where the crop is grown for grain rainfall may be much less, since the crop is reserved for those areas where maize and sorghum fail because

of low rainfall or adverse soil factors (Burton, 1951).

1.3 Production and Trend in Nigeria

The leading producers of millet in Africa are Nigeria, Chad, Niger, Mali, Ethiopia and Tanzania. However, Nigeria is the highest producer. Millet in Nigeria is second only to sorghum among the cereals both in total production and area under cultivation (F.A.O., 1977). Total area under production is estimated at about 5.0 million hectares, while annual production is estimated at about 3.0 million tonnes (F.A.O., 1980). It has been estimated over the years that the average annual production has been on the increase due to increase in production per unit area (F.A.O., 1980).

Three cultivars of pearl millet are generally grown in Nigeria, namely: the early maturing (75 - 100 days) day-neutral 'Gero' type, the late maturing day length sensitive 'Maiwa'. Both the 'Maiwa' and 'Dauro' are grown in the heavier rainfall areas of northern and southern Guinea savanna while 'Gero' which accounts for well over 80% of all the millet grown in Nigeria (Kassam, 1976) is produced mainly in the Sudan and Sahel savanna parts of northern Guinea savanna.

1.4 Economic Importance

In Nigeria, millet is grown mainly for grains, while in some parts of the world like the United States of America and Australia where it is grown mainly as forage. The protein

content of millet grains has been reported to vary from 10 - 20 per cent (Nwasike, 1977). The grains are used in different ways as source of food. They may be mashed, cooked and eaten with stew (burabusko) or it could be turned into flour and used in making 'tuwo', 'fura' and many other pasteries. In addition, the bran is used in feeding livestock, especially poultry. The stalks are also widely used in thatch making.

Even though Nigeria is a leading producer of millet, yield per unit area is low when compared to other countries like India and China with estimated annual production of 6.0 million tons and 9.0 million tons produced on 4.0 million and 14.0 million hectares, respectively (F.A.O., 1980). Nigeria's low yields are due to poor management of the crop. Other factors responsible for the low yields in Nigeria are low plant population, owing to the fact that millet is usually intercropped with other crops like sorghum, cowpea and groundnuts. Untimely planting is another constraint that results in low yields because farmers often rush to sow their millet without waiting for the rains to get established. The unpredictable weather and limited growing season result in desiccation of the seedlings which consequently affect the final grain yield.

With the aim of introducing an improved variety (Dwarf-Gero) as well as overcoming the above mentioned constraints, a research proposal was initiated with the following objectives:

a) to determine the effect of plant population and sowing date on tiller survival and tiller contribution to grain yield in two cultivars of 'Gero' millet.

b) to determine the most suitable 'Gero' millet variety for the northern Guinea savanna ecological zone.

Chapter 2

LITERATURE REVIEW

Watson (1952) has reviewed that the development and yield of crop plants and their physiological processes depend upon the plant genetic make up and environmental factors, for instance, the number of tillers in millet depends upon the cultivar and the genetic constitution of the crop. Other factors which affect the performance of crops include plant density, time of sowing and the level of disease and pest infestation. These factors, however, do vary in their effect from location to location as well as from one crop species to another. Such information on pearl millet is not easily available.

2.1 Plant Population

Optimum plant population was found to be dependent solely on available moisture, soil nutrient status as well as size and viability of the genotype being sown (Dogget, 1970; Egharevba, 1970). Realization of maximum yield potential of a crop warrants not only optimum level of plant density but also optimum inter as well as intra-row spacings. Gautam (1969), in his studies on hybrid millet in north India, suggested an inter-row spacing of 60 or 45cm with an intra-row spacing of 15cm as the most favourable for getting maximum grain yield of the crop. Patil (1959), and Singh et al. (1963) recommended a plant density of 120,000 plants/ha as optimum for millet and this was found to

give the highest grain and fodder yield. In another study involving three millet genotypes at the Institute for the Semi-Arid Tropics (ICRI-SAT, 1977), Hyderabad, India, it was reported that plant population had no significant effect on grain yield, provided fertility was adequate. In the same study it was reported that the sowing pattern rather than population density had a significant effect on grain yield, and this was independent of both genotype and population.

In a study conducted at Samaru, Nigeria, plant densities ranging from 20,000 to 100,000 plants/ha have been tried (Egharevba, 1978). On the basis of the study, population density of about 20,000 plants/ha was said to be the most ideal for the Sahel savanna while about 60,000 plants/ha was said to be the optimum for the northern Guinea savanna.

Several studies on cereals have indicated that there was increase in grain yield as plant population increased. In sorghum, for example, Seilinger (1926) and Karper (1929) reported increase in grain yield as plant population increased. They explained this increase on the ability of the cereal to form tillers. Anonymous (1980) reported an increase of 19% in grain yield of sorghum when plant population was increased from 33,000 to 50,000 plants/ha. Yield declined when plant population was increased to 66,000 plants/ha.

In maize, it has similarly been found that as plant population increased there was a corresponding increase in grain

yield, leaf area index and total dry matter production until a certain optimum level was reached (Loomis and Williams, 1970; Krishnamurthy et al. 1974b). Individual leaf area has, however, been reported to increase in maize with reduction in plant population (Bishir and Shalaby, 1978). Darrol et al. (1963), in their study on maize also arrived at the conclusion that high plant population caused an increase in the incidence of stalk lodging because of steady decrease in the diameter of the stalk. According to them, increase in planting rates also caused a decrease in ear size and uniformity.

Shimono and Cosaki (1960) in their research on winter wheat concluded that increase in plant density gave increased leaf area index at anthesis, increased number of ears/m^2 at maturity, decreased dry matter in the top leaf blade and decreased number of grains/ear at maturity. Sharma et al. (1960) also found that in wheat higher seed rate than the optimum might give higher number of plants per unit area but would produce weak plants with small grains.

2.2 Tillering

Tillering which is the lateral branching of a plant develops from the buds in the axils of the lower leaves attached to the basal crowded nodes. Tillering occurs commonly among cereal crops. The tiller is an important component of the plant because it contributes both to the grain and dry matter production. Several researchers have reported that the number

of tillers per plant varies among cultivars of millet. While Ramond (1968) reported about 40 in some millet cultivars, Bhardwaj and Webster (1971) reported between eight to four in some locally grown ones.

Egharevba (1977a) has shown tillering to be of tremendous advantage when millet is grown for fodder, whereas tillering could be disadvantageous when grain production is the primary interest. He showed that tiller in millet contributed about 60% of the total dry matter but only about 30% of the total grain yield. Similarly, Kassam et al. (1976) also reported that tillers contributed about 22% of the total yield of grain in millets.

Generally, tillering appears to be regulated by several genes, with low tillering dominant over profuse tillering (Burton, 1951). Several researchers have found that the extent of tiller survival and yield differs with variety, soil fertility and water status of the plant (Barley and Naidu, 1964; Syme, 1967). Kanki and Reitz (1955) reported that significant difference existed among oat varieties in their tillering ability at different population levels. Low temperature, moisture deficit and nitrogen depletion have been reported to cause reduction in tiller production in herbage grasses (Downes, 1968). While Langer (1963) has reported that tillering in pasture grasses is inversely proportional to plant density, Quinlan and Sagar (1965) reported that in spring wheat, higher

mean number of productive tillers are produced at lower population densities. In some varieties of wheat, a large number of tillers were found to die at or before ear emergence and contribute nothing directly to grain yield (Engledow, 1925; Smith, 1933).

Leaf area development follows tiller formation closely with leaf area being positively correlated with number of tillers. Plant characters desired for fodder yield include higher number of leaves, thin stems, profuse tillering and medium plant height. Therefore, the more profuse the tillering the more the numbers of leaves and hence the greater the fodder yield. In Alabama (USA), Hoveland et al. (1967) obtained the highest forage yield in Gahi millet with high seeding rates: 33.6 kg/ha in 15.2cm rows.

Tillering also affects grain yield. The effect of tillering was studied on rainfed pennisetum by Ayyangar and Hariharan (1935c). They found that the main flush of flowering was spread over a period of about 12 days, and the last of the tertiaries may continue flowering even after seeds have ripened on the primaries. It was also observed that flowering in pennisetum usually started with the main culm and proceeded to the primary tillers, then to the secondary and lastly to the tertiary. In terms of grain yield the secondary tillers yielded most with about 50%, while primary tillers yielded about 35%, and the main culm only about 10%. Ayyangar and Hariharan (1935c) further studied tillering pattern in irrigated pennisetum, where secondary

tillers were found to make the least contribution to grain yield of about 15%, while primary tillers produced about 50% of the grain yield. In short-stemmed cereals like rice, wheat, barley and oats, grain yield has been shown to increase gradually with tillering. For example, Yoshida (1972) reported that in rice grain yield increased with tiller production, while Gregory (1975) working on wheat also reported positive correlation between grain yield and tiller number. Stoskopf and Reinbergs (1966), on the contrary, reported that increase in grain yield in barley and oats due to increase in tillering is rather insignificant and actually found tillers/plant to correlate negatively with grains per head.

Egharevba (1977a) concluded that optimum yield was obtained from tiller in millet if the number of tillers ranged between three to five per plant. The contribution of tillers to total grain yield of millet in Nigeria has been found to be between 15 - 22% (Kassam, 1976). Reduced tiller number substantially increased grain yield although reducing to just one tiller per stand had a negative effect. Sankaram and Kaliappa (1974) reported that grain yield of millet is positively correlated with number of productive surviving tillers.

Egharevba and Vanderlip (1983) reported that more functional tillers were formed at lower than higher plant population. While about 47% of the tillers formed at 60,000 plants/ha produced harvestable heads, only 10% at 100,000 plants/ha produced

harvestable heads. They concluded that the magnitude of tillers formed at different plant populations will indicate that whether planted at low or high plant populations pearl millet will produce tillers, but tillers produced at high population densities are mainly rudimentary and they seldom survive.

2.3 Time of Planting

Time of planting has always been known to have a marked effect on growth and yield of crops in different parts of the world. Within the optimum time range, yields usually decline with late planting. In Nigeria, this optimum time range has been assessed to be the beginning of the rains for most crops. Since the length of the rainy season varies from 230-90 days from the southern Guinea savanna to Sudan savanna zones of Nigeria, the optimum time of planting is also expected to vary from the south to the north.

The onset of rains in any given year, however, is difficult to assess with a high degree of accuracy as this varies from year to year and place to place (Kowal and Knabe, 1972). This thus makes it difficult to recommend a definite time for sowing any crop. However, for millet, Marchal (1950) and Egharevba (1979a) have given the conditions that need to be met to be able to ascertain the establishment of rains. The condition which led to considering the differences in the climatological zones state that since the establishment of rains in Nigeria is not the same in the different ecological zones the sowing date varies from

April in the southern Guinea savanna to mid-June in Sudan savanna. Therefore, the most appropriate time to sow in the northern Guinea savanna appears to be early to mid-May.

Balasubramanian (1959) has recommended 25mm of rainfall immediately after sowing for good germination in sorghum and millet. The relationship of rainfall to growth and development of millet has been studied by Arakeri (1947). He found that rainfall during the presowing period governs the time of sowing but does not affect the yields. However, heavy rainfall during the germination period, particularly the first three or four days, results in poor germination and lowered yields. Heavy rains during flowering or ripening reduce seed set which subsequently results in low yields, poor grain quality, and lodging.

The time when a crop is sown is known to have a marked effect on its growth and yield. While a lot of work has been done on the influence of sowing date on the growth, maturity and yield of maize, Zea mays L. (Zuber, 1966; Bunting, 1960) and guinea corn, Sorghum bicolor L. (Stickler and Pauli, 1961; Kassam and Andrews, 1975) very little information is available on the effect of sowing date on the performance of millet.

Because millet is regarded as drought tolerant, many farmers rush to sow the crop immediately the first rain falls. However, in most cases there is a long dry spell before another rainfall. During this period, most of the seedlings sown have become

desiccated owing to the intervening drought and inadequate land preparation. The few seedlings that manage to emerge are stunted and by the time the rains begin to be more regular some of the farmers have lost a good percentage of their crop, and at the time they decide to replant, it is already late. As a result of this uncertainty, it is necessary to determine a more reliable period for sowing.

Generally, early planted cereal crops yield higher grains because plants are able to utilize the initial flush of soil nitrate at the onset of the rainy season (Greeland, 1950). However, too early planting can be as bad as too late. Too early planting may result in a crop maturing during the rains with consequent reduction in grain quality due to mouldy head, and attack by insects; and varieties which are planted too late fail to fill their grains completely as a result of lack of water (Kassam, 1974). Stickler and Pauli (1961) have also indicated that early planting in Kansas (USA) increased tillering and number of head per unit area. Similarly, White, 1977, 1970; and Bunting, 1960 reported that early planted maize showed significant effect on grain yield as well as increase in forage quality. In their studies on winter wheat, Martin, 1926; Pittman and Andrews, 1961; and Smid and Jenkinson, 1979, found that seeding dates later than optimum resulted in reduced yields, lower hectoliter weights, delayed heading and late maturity.

Lateness in planting was generally found to be detrimental

to grain yield of crops by many researchers. In their study on maize, Briggs and Attinaw (1979) concluded that sowing dates (depending on the prevailing weather conditions) significantly affected grain yield. Kumar et al. (1982) also reported from a result obtained from Sakura (Sokoto State), that highest maize yield was obtained from plots sown in mid-September, and that grain yield was reduced linearly with time as date of sowing was delayed. Similarly, Greaney (1946) found increased root rot and decreased yield when spring wheat was sown late in Manitoba (USA).

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Site and Soil

Field experiments involving 'Gero' millet were conducted in 1983 and 1984 wet seasons at the Agronomy Research Farm of the Institute for Agricultural Research, Samaru, Zaria ($11^{o}11^{'}$N and $7^{o}38^{'}$E; 650m above mean sea level) in the northern Guinea savanna ecological zone. The soil is a fine textured, well drained sandy loam (Tomlinson, 1965) derived from crystalline basement complex and classified as ferruginous tropical soil. The textural and chemical properties of the soil are given in (Table 1). The soil is slightly alkaline with low content of nitrogen and organic carbon.

3.2 Treatments

Treatments investigated involved two millet varieties, three plant populations and three sowing dates. The millet varieties were: Ex-Borno, an improved local variety which matures early and grows to about 2.5 metres tall; and Dwarf-Gero, a selection from Ex-Borno which grows to about 1.2m tall. The three plant populations tested were 40,000 (low); 80,000 (medium) and 120,000 (high) plants/ha and three sowing dates spaced at three- week intervals soon after the establishment of rains. Details of sowing dates and management operations are given in Table 2.

Table 1: Physico-Chemical properties of the soil (0-30cm) at the experimental site at Samaru.

Soil Character	Composition
Texture (%):	
Coarse sand	20.0
Fine sand	35.2
Silt	30.0
Clay	6.0
pH in water (1:1)	6.4
Total nitrogen, N (%)	0.025
Total phosphorus, P (ppm)	147.39
Organic carbon, C (%)	0.37
Exchangeable cations (Meq/100g soil)	
Sodium, Na	0.05
Potassium, K	0.06
Calcium, Ca + Magnesium, Mg	1.36
Cation exchange capacity, CEC (Meq/100g soil)	4.70
Base saturation (%)	31.28

Table 2: Details of Management Operation on Millet during the 1983 and 1984 growing seasons at Samaru.

S/No	Operation		Date	Remarks
1.	Seed bed preparation		14.5.1983 5.5.1984	75cm ridge 75cm ridge
2.	Fertilizer application		20.5.1983 24.5.1984	Band placed on ridges at about 10cm deep just before sowing at the rate of 65kg N/ha and 45kg P_2O_5/ha as calcium ammonium nitrate and single super-phosphate, respectively.
3.	Sowing dates:	Date I Date II Date III	25.5.1983 27.6.1983 19.7.1983	To be spaced at three weeks interval, but the pattern of rainfall caused modification in time of sowing.
	Sowing dates:	Date I Date II Date III	29.5.1984 19.6.1984 10.7.1984	As the rainfall was more regular in 1984 the sowing was more timely than in 1983.
4.	Weed Control	-		Pre-emergence application of atrazine (GESAPRIM 500FW) at 0.5kg a.i./ha followed by hoe weeding at 3 and 6 weeks after sowing.
5.	Spacing	-		Inter-row spacing of 75cm and intra-row spacing of 33.3; 16.6 and 11.1cm to give 40,000; 80,000 and 120,000 plants/ha, respectively.
6.	Pest control at 6 weeks after sowing	-		Vetox '05' was sprayed at the rate of 1.12kg a.i./ha in 255 litres of water to control spittle bugs (Locris ruben) and stem-borer (Acigona ignefusalis Hamps).

Table 2 (Contd.)

S/No	Operation		Date	Remarks
7.	Birds control from flowering to harvest		-	Birds were scared away by hired men.
8.	Harvesting	Date I	3.9.1983 7.10.1983 29.10.1983	For the respective sowing dates in 1983.
		Date I	4.9.1984 25.9.1984 15.10.1984	For the respective sowing dates in 1984.

3.3 Design and Plot Size

The experiment was laid out in a Randomised Complete Block design with three replications. The plot size was 6.0m x 6.0m while the total experimental area was 54m long and 36m wide (0.19/ha). The gross plot contained eight ridges of which the inner four rows were used as the net plot.

3.4 Measurements and Observations

3.4.1 Meteorological data

The 1983 rainfall was sub-optimal. The meteorological data records of 1983 and 1984 at the experimental site include the mean annual rainfall and air temperatures as indicated in Appendices 1 - 4.

3.4.2 Per cent seedling emergence

Per cent seedling emergence was recorded within the first

week after sowing. This was scored by counting the number of seedlings that have emerged within each plot.

3.4.3 Number of tillers per plant

The number of tillers per plant was recorded from a pre-determined area of $1m^2$ in each plot starting from the third week up to the eighth week after sowing at weekly intervals. Tiller formation was complete by the time the plant started heading and the number recorded then was regarded as the total number of tillers formed.

3.4.4 Leaf area

Leaf area and leaf area index were determined at full vegetative stage from three randomly selected plants taken from different plant stands in the inner four rows and their mean values were calculated. The linear method of length x width (at the broadest point) was adopted for leaf area (Egharevba, 1977a) while for the leaf area index (LAI) it was L x W x K divided by land area, where K = a correction factor of 0.75 (Egharevba, 1977a).

3.4.5 Time to 50% flowering

This was determined by recording the number of days to 50% flowering, beginning from time to 50% seedling emergence. The 50% flowering which was regarded as when 50% of the plants in a plot had flowered was scored by counting.

3.4.6 Tiller mortality

Tiller mortality in this study is defined as the difference in number of established tillers at full vegetative stage (heading

stage) and those recorded at harvest. Like the total number of tillers formed, tiller mortality was determined from a pre-determined $1m^2$ plot inside each net plot.

3.4.7 Main-culm mortality

Main-culm mortality was also determined from the difference between the number of plants at thinning and the number of plants at harvest. This was also calculated from a pre-determined $1m^2$ plot inside each net plot.

3.4.8 Yield and yield components

Heads were harvested only from the net plot on 3rd September, 7th October and 28th October, 1983, for the first, second and third sowing dates, respectively. In 1984, harvesting started on 4th September, 1984, for the first sowing date, while 25th September and 15th October, were the harvesting dates for the second and third sowing dates, respectively. The heads were sundried, threshed, winnowed and the air dry grains weighed and recorded as grain yield. The grain yield per net plot was divided by the number of heads from which the grain were obtained and recorded as grain weight per weight per harvestable head. All the harvestable heads for each net plot were counted, weighed and recorded accordingly for the number and weight of harvestable heads. The 1000-grain weight was sampled from each net plot, weighed and recorded as 1000-grain weight.

3.5 Data Analysis

The data were subjected to statistical analysis with all the factorial arrangements as described by LeClerg et al. (1962). Where F values showed statistical significant differences, the means of such treatments were compared using the Least Significant Difference (LSD) at five per cent level of probability.

Chapter 4

RESULTS

4.1 Per cent Emergence

Although sowing date had no significant effect on per cent seedling emergence (Table 3) for both years, the number of seedlings that emerged from the first sowing date was lower than those that emerged from the second and third sowing dates for 1983. Per cent emergence from the first sowing date was 70% as against 86% and 84%, respectively, for the second and third sowing dates. The per cent seedling emergence for 1984 was, however, higher at the first sowing date than at the subsequent sowing dates.

In both years the per cent seedling emergence was significantly affected by plant population. The highest per cent seedling emergence occurred at 40,000 plants/ha in both varieties.

Treatment interactions did not have any significant effect on per cent emergence. There was no year effect either.

4.2 Stand Count at Thinning

Stand count which was meant to confirm the actual number of plants that were established was recorded at the time of thinning. Sowing date did not have any significant effect on the number of plants that were finally established for both years (Table 4).

Plant population had significant effect on stand count at thinning in both years with the high plant population having higher

Table 3: Effect of plant population, sowing date and variety on per cent seedling emergence of pearl millet at Samaru, Zaria.

Treatments	Per cent seedling emergence		
	1983	1984	Mean
Plant populations			
40,000 plants/ha	72.23	77.67	74.95
80,000 plants/ha	84.19	82.67	83.43
120,000 plants/ha	91.53	97.83	94.60
SE (±)	2.85	2.96	2.47
LSD (P = 0.05)	10.05	10.51	8.77
Sowing dates			
Date I	78.20	87.17	82.69
Date II	86.19	86.00	86.09
Date III	83.56	85.00	84.28
SE (±)	2.85	2.96	2.47
LSD (P = 0.05)	NS	NS	NS
Varieties			
Ex-Borno	85.13	87.89	86.51
Dwarf-Gero	86.00	84.22	85.11
SE (±)	2.58	2.63	2.10
Yearly means	83.38	86.06	
SE (±)	2.11		

Table 4: Effect of plant population, sowing date and variety on stand count at thinning of pearl millet at Samaru, Zaria.

Treatments	Stand count at thinning		
	1983	1984	Mean
Plant populations			
40,000 plants/ha	81.61	88.50	85.05
80,000 plants/ha	119.17	128.67	123.92
120,000 plants/ha	169.28	179.50	174.39
SE (±)	4.07	4.67	4.61
LSD (P = 0.05)	14.45	16.58	16.37
Sowing date			
Date I	127.39	135.83	131.61
Date II	123.78	136.50	130.14
Date III	118.89	124.33	121.61
SE (±)	4.07	4.67	4.61
LSD (P = 0.05)	NS	NS	NS
Varieties			
Ex-Borno	123.89	133.44	128.67
Dwarf-Gero	122.81	133.00	127.91
SE (±)	3.33	3.96	4.16
Yearly means	123.35	132.47	
SE (±)	3.51		

stand count than the medium and low plant populations. Generally, stand count was not affected by variety, but Ex-Borno had a slightly higher stand count than Dwarf-Gero.

There was no significant interaction effects on stand count, neither was there any year effect.

4.3 Number of Tillers

The first sowing date produced higher number of tillers per plant than the second and third sowing dates in both years, but only in 1984 was a statistically significant difference obtained (Table 5). Tiller number per plant decreased as plant population increased. Thus, while plants at 40,000 plants/ha gave an average of seven tillers per plant, plants at 80,000 and 120,000 plants/ha gave four and three tillers per plant, respectively. Variety had no significant effect on number of tillers formed.

Neither the treatment interaction nor the year had any significant effect on number of tillers formed.

4.4 Leaf Area of Main-Culm

Plants of the first sowing date gave higher leaf area than those of subsequent sowing dates in both years. However, it was only in 1984 that a significant difference was recorded (Table 6). Plant population had a significant effect on leaf area of main-culm only in 1984. The mean leaf area of the main-culm for the 40,000 plants/ha was about 40% of the total leaf area of the

Table 5: Effect of plant population, sowing date and variety on number of tillers per plant of pearl millet at Samaru, Zaria.

Treatments	Number tillers per plant		
	1983	1984	Mean
Plant populations			
40,000 plants/ha	6.00	7.83	6.92
80,000 plants/ha	4.00	4.50	4.25
120,000 plants/ha	2.89	3.00	2.95
SE (±)	0.39	0.41	0.38
LSD (P = 0.05)	1.38	1.46	1.35
Sowing dates			
Date I	4.68	5.83	5.26
Date II	4.64	5.67	5.15
Date III	3.63	3.83	3.73
SE (±)	0.39	0.41	0.38
LSD (P = 0.05)	NS	1.46	1.35
Varieties			
Ex-Borno	4.33	4.67	4.50
Dwarf-Gero	4.48	5.56	5.02
SE (±)	0.36	0.38	0.34
Yearly means	4.31	5.11	
(SE (±)	0.29		

Table 6: Effect of plant population, sowing date and variety on leaf area (dm^2) of pearl millet at Samaru, Zaria.

Treatments	1983			1984		
	Leaf area, (dm^2)			Leaf area, (dm^2)		
Plant populations	Main-culm	Tiller	Total	Main-culm	Tiller	Total
40,000 plants/ha	58.19	88.16	146.35	65.97	98.17	164.14
80,000 plants/ha	56.13	66.23	122.23	57.21	68.85	126.06
120,000 plants/ha	53.01	52.76	105.77	56.21	52.83	108.15
SE (±)	2.01	2.96	3.41	2.36	2.98	3.63
LSD (P = 0.05)	NS	10.51	NS	NS	10.58	12.89
Sowing dates						
Date I	57.16	71.29	128.45	68.56	99.81	168.37
Date II	56.04	70.84	126.88	52.14	67.23	119.27
Date III	54.13	65.02	119.15	58.60	52.11	110.71
SE(±)	2.01	2.96	3.41	2.36	2.98	3.63
LSD (P = 0.05)	NS	NS	NS	8.38	NS	12.89
Varieties						
Ex-Borno	55.16	86.93	142.09	61.76	93.18	154.94
Dwarf-Gero	56.19	88.16	144.35	54.44	93.81	147.45
SE (±)	1.83	2.63	3.19	2.15	2.66	3.31
Yearly means	55.75	73.67		59.35	70.04	

whole plant while the main-culm leaf areas of the 80,000 and and 120,000 plants/ha corresponded to 45% and 50% of the total leaf area. Variety did not have any effect on the leaf area of the main culm.

There was no significant interaction effect and year effect on the leaf area of main-culm.

4.5 Leaf Area of Tillers

Like in the main-culm, higher leaf area was recorded among tillers of the first sowing date than among those of subsequent sowing dates in both years. However, sowing date had no significant effect on the leaf area of tillers (Table 6). Plant population had significant effect on leaf area of tillers in both years. Over the two years, the leaf area of tillers for the low plant population was found to have contributed about 60% of the total leaf area of the plant, while tillers of the medium and high populations contributed 54% and 50%, respectively.

There was no significant interaction or year effect on leaf area of tillers.

4.6 Days to 50% Flowering

This is the actual number of days recorded from emergence to when about 50% of the plants had started flowering. For both years sowing dates had significant effect on time - to - 50% flowering (Table 7). The first sowing date took about 59 days

Table 7: Effect of plant population, sowing date and variety on time to - 50% - flowering (days) of pearl millet at Samaru, Zaria.

Treatments	Days to - 50% - flowering		
	1983	1984	Mean
Plant populations			
40,000 plants/ha	54.12	56.30	55.21
80,000 plants/ha	51.90	55.82	53.91
120,000 plants/ha	50.71	54.01	52.41
SE (±)	0.96	0.98	0.95
LSD (P = 0.05)	NS	NS	NS
Sowing dates			
Date I	58.41	59.41	58.91
Date II	53.20	57.72	55.51
Date III	45.02	49.20	47.70
SE (±)	0.96	0.98	0.95
LSD (P = 0.05)	3.41	3.48	3.37
Varieties			
Ex-Borno	55.33	55.96	55.65
Dwarf-Gero	52.44	53.77	53.12
SE (±)	0.67	0.68	0.64
Yearly means	52.64	55.27	
SE (±)	1.14		

to reach 50% flowering as against the respective 56 and 48 days recorded for the second and third sowing dates. Plant population had no significant effect on days - to - 50% flowering. Ex-Borno was also observed to take more number of days - to - 50% flowering than Dwarf-Gero in both years, but only in 1983 was there a significant effect.

There was no significant interaction effect on days - to - 50% flowering was significantly higher in 1984 than in 1983.

4.7 Main-Culm Mortality

Main-culm mortality as used in this study, is the difference in the number of established plants at thinning and those recorded at harvest.

Main-culm mortality was found to be affected by sowing date. The third sowing date had a higher per cent main-culm mortality than the second and first sowing dates. The mean per cent main-culm mortality for the third sowing date was 20% as compared to 15% and 6% for the second and first sowing dates, respectively (Table 8). Plant population had a significant effect on per cent main-culm mortality. The 40,000 plants/ha gave a mean per cent main-culm mortality of 7% as against 10% and 23% for the 80,000 and 120,000 plants/ha, respectively. Variety did not have any significant effect on per cent main-culm mortality; however, Dwarf-Gero had a lower mortality than Ex-Borno.

There was a significant interaction between plant population

Table 8: Effect of plant population, sowing date and variety per cent main-culm mortality of pearl millet at Samaru, Zaria.

Treatments	Per cent main-culm mortality		
	1983	1984	Mean
Plant populations			
40,000 plants/ha	8.44	6.14	7.29
80,000 plants/ha	8.73	11.82	10.28
120,000 plants/ha	28.51	18.31	23.41
SE (±)	1.87	2.01	2.11
LSD (P = 0.05)	6.64	7.14	7.49
Sowing dates			
Date I	5.93	5.51	5.72
Date II	17.63	12.34	14.99
Date III	22.12	18.52	20.32
SE (±)	1.87	2.01	2.11
LSD (P = 0.05)	6.64	7.14	7.49
Varieties			
Ex-Borno	15.67	15.19	15.43
Dwarf-Gero	14.23	11.40	12.02
SE (±)	1.53	1.88	1.93
Yearly means	15.16	12.40	
SE (±)	1.64		

and sowing date (Table 9). The main-culm mortality for each sowing date increased significantly with increase in plant population. The year 1984 gave a lower per cent main-culm mortality than 1983, but the difference was not significant.

Table 9: Interaction effect of plant population and sowing date on per cent main-culm mortality of pearl millet in 1983.

Sowing dates	Plant populations		
	40,000 plants/ha	80,000 plants/ha	120,000 plants/ha
	Per cent main-culm mortality		
Date I	4.58	7.61	8.16
Date II	6.91	9.31	11.17
Date III	10.23	16.16	20.03
SE (±)		2.47	
LSD (P = 0.05)		8.78	

4.8 Tiller Mortality

Tiller mortality was meant to assess the difference in the number of established tillers at full vegetative stage (heading stage) and those recorded at harvest. Sowing date significantly affected per cent tiller mortality (Table 10). Over the two years the plants sown on the first date had a lower tiller

Table 10: Effect of plant population, sowing date and variety on per cent tiller mortality of pearl millet at Samaru, Zaria.

Treatments	Per cent tiller mortality		
	1983	1984	Mean
Plant populations			
40,000 plants/ha	19.56	25.04	22.30
80,000 plants/ha	25.01	27.52	26.27
120,000 plants/ha	30.52	33.31	31.92
SE (±)	2.75	3.01	2.89
LSD (P = 0.05)	9.76	NS	NS
Sowing dates			
Date I	18.63	17.11	17.87
Date II	22.04	23.63	23.24
Date III	33.62	45.23	39.43
SE (±)	2.75	3.01	2.89
LSD (P = 0.05)	9.76	10.69	10.26
Varieties			
Ex-Borno	23.09	35.76	29.43
Dwarf-Gero	16.82	28.06	22.44
SE (±)	2.39	2.73	2.46
Yearly means	23.76	29.46	
SE (±)	2.03		

mortality (18%) as against 23% and 39% recorded, respectively, for the second and third sowing dates. Plant population had significant effect on per cent tiller mortality only in 1983, but did not show any effect in 1984 (Table 10). Over the two years the mean per cent tiller mortality recorded for the low plant population was lower than that for medium and high plant populations by 4% and 10%, respectively. Varietal differences in tiller mortality were not significant. However, Dwarf-Gero had a lower per cent tiller mortality of 23% as against 30% for Ex-Borno.

4.9 Number of Harvestable Heads

The number of harvestable heads was significantly affected by sowing dates. In both years the first sowing date recorded higher number of harvestable heads than the second and third sowing dates by 5% and 51%, respectively (Table 11). The number of harvestable heads per plant was also affected by plant populations. The mean number of harvestable heads per plant over the two years for the 40,000 plants/ha was five as against three and two, respectively, for 80,000 and 120,000 plants/ha. Dwarf-Gero gave a higher number of harvestable heads than Ex-Borno, but the difference was not significant.

There was a significant interaction effect between variety and plant populations (Table 12). At all the plant populations, Dwarf-Gero gave a higher number of harvestable heads per plant than Ex-Borno. No year effect was obtained.

Table 11: Effect of plant population, sowing date and variety on number of harvestable heads per plant of pearl millet at Samaru, Zaria.

Treatments	Number of harvestable heads/plant		
	1983	1984	Mean
Plant populations			
40,000 plants/ha	4.82	5.94	5.38
80,000 plants/ha	3.03	3.32	3.18
120,000 plants/ha	2.01	2.33	2.17
SE(±)	0.31	0.32	0.30
LSD(P =0.05)	1.10	1.14	1.07
Sowing data			
Date I	3.84	4.84	4.34
Date II	3.70	4.51	4.11
Date III	2.32	2.24	2.28
SE (±)	0.31	0.32	0.30
LSD (P = 0.05)	1.10	1.14	1.07
Varieties			
Ex-Borno	3.33	3.00	3.17
Dwarf-Gero	3.373	4.00	3.07
SE (±)	0.28	0.29	0.27
Yearly mean	3.35	3.77	
SE (±)	0.28		

Table 12: Interaction effect of variety and plant population on number of harvestable heads/plant of pearl millet in 1983.

Plant Populations	Varieties	
	Ex-Borno	Dwarf-Gero
40,000 plants/ha	3.72	3.81
80,000 plants/ha	2.91	3.01
120,000 plants/ha	1.82	2.95
SE (±)	0.29	
LSD (P = 0.05)	1.03	

4.10 1000-Grain Weight

The first sowing date in both years gave a higher 1000-grain weight than the subsequent dates for both tiller and main-culm, but the differences were not significant (Table 13). Although plant population had no significant effect on 1000-grain weight of both tiller and main-culm, the low plant population in both cases recorded a higher 1000-grain weight than medium or high plant populations. The variety had no significant effect on 1000-grain weight either, but in both cases Ex-Borno recorded a lower 1000-grain weight than Dwarf-Gero.

There was no significant interaction effect on 1000-grain weight and no year effect.

Table 13: Effect of plant population, sowing date and variety on 1000-grain weight (gm) of pearl millet at Samaru, Zaria.

Treatments	1000-Grain Weight			
	1983		1984	
Plant population	Main-culm	Tiller	Main-culm	Tiller
40,000 plants/ha	10.70	10.14	10.90	10.20
80,000 plants/ha	10.53	9.71	10.72	10.04
120,000 plants/ha	10.31	9.53	10.43	9.51
SE (±)	0.23	0.22	0.24	0.23
LSD (P = 0.05)	NS	NS	NS	NS
Sowing dates				
Date I	10.82	9.91	10.81	10.02
Date II	10.50	9.84	10.63	9.91
Date III	10.22	9.63	10.61	9.82
SE (±)	0.23	0.22	0.24	0.23
LSD (P = 0.05)	NS	NS	NS	NS
Varieties				
Ex-Borno	10.00	9.17	10.26	9.05
Dwarf-Gero	10.36	9.38	10.57	10.16
SE (±)	0.19	0.19	0.20	0.19
Yearly means	10.43	9.66	10.62	9.94

4.11 Grain Yield

Sowing date had significant effect on total grain yield only in 1983. The highest total grain yield was recorded at the first sowing date while the third date recorded the lowest (Table 14). On the average the first sowing date in both years yielded about 1,487 kg/ha as against 1,321 kg/ha and 1,140 kg/ha, respectively, for the second and third sowing dates. Tiller grain yield was also affected by sowing dates. The first sowing date consistently recorded the highest tiller grain yield, while the third date recorded the lowest.

Plant population had significant effect on total grain yield in both years. The mean grain yield over the two years recorded at 40,000 plants/ha was 1,506 kg/ha as against 1,295 kg/ha and 1,147 kg/ha for the 80,000 and 120,000 kg/ha, respectively. In a similar trend, tiller grain yield was also significantly affected by plant population in both years. The highest tiller grain yield was obtained at the low plant population. At this density, tillers contributed about 61% to total grain yield as against 57% and 50% for the medium and high plant population, respectively. Varietal effect on tiller and total grain yield was observed only in 1983, when Dwarf-Gero gave higher yields than Ex-Borno. In 1984, the differences were not significant but Dwarf-Gero still maintained higher tiller/total grain yield than Ex-Borno.

The treatment interaction and year effect were not significant.

Table 14: Effect of plant population, sowing date and variety on grain yield (kg/ha) of pearl millet at Samaru, Zaria.

Treatments	1983			1984		
	Grain yield, (kg/ha)			Grain yield, (kg/ha)		
Plant populations	Main-culm	Tiller	Total	Main-culm	Tiller	Total
40,000 plants/ha	555.06	901.94	1457.00	580.11	976.30	1556.41
80,000 plants/ha	551.22	739.13	1290.35	566.33	734.21	1300.54
120,000 plants/ha	546.21	546.91	1093.12	551.44	650.28	1201.72
SE (±)	50.06	51.24	70.13	51.06	53.14	76.42
LSD (P = 0.05)	NS	181.90	248.40	NS	188.65	271.29
Sowing dates						
Date I	601.35	883.82	1485.17	540.32	948.13	1488.45
Date II	584.12	700.34	1284.46	551.52	807.15	1358.67
Date III	467.02	603.82	1070.84	606.14	605.41	1211.55
SE (±)	50.06	51.24	70.13	51.06	53.14	76.42
LSD (P = 0.05)	NS	181.90	NS	NS	188.65	271.29
Varieties						
Ex-Borno	500.23	549.23	1049.46	608.27	699.29	1307.56
Dwarf-Gero	751.61	881.48	1570.09	612.10	732.60	1344.78
SE (±)	46.18	47.31	57.26	46.90	49.14	61.37
Yearly means	569.60	727.95	1287.61	577.04	769.17	1293.43
SE (±)			79.32			

Chapter 5

DISCUSSION

5.1 Effect of Plant Population on Physiological Characters and Grain Yield

Per cent emergence as determined by counting the seedlings a week after sowing was significantly affected by plant population. More plants emerged as plant population increased. The per cent emergence was relatively higher in the second year than in the preceeding year. This could be attributed to the adequate rainfall recorded at the period of emergence which resulted in vigorous germination. This agrees with the finding by Pal and Sikka (1961) who attributed good germination of wheat seeds to adequate moisture supply.

Stand count at thinning which was done a week after emergence was significantly affected by plant population. It exhibited similar pattern as plant emergence; as plant population increased higher stand count at thinning was obtained. The lower stand count recorded during the 1983 growing season could also be attributed to the inadequate moisture supply after sowing.

Although plant population had no discernible effect on time to 50% flowering, a clear trend was established whereby time to 50% flowering was longer in 1984 (55 days) than in 1983 (52 days). Higher temperature and severe moisture stress during the vegetative phase in 1983 might have hastened the onset of

reproductive phase among the plants. A similar observation was made on maize by Hunter et al. (1975) who observed that low and high temperatures retard and accelerate the formation of reproductive organs, respectively.

Leaf area was markedly affected by plant population as total leaf area per plant decreased with increase in plant population. Generally, the higher leaf area advantage was mainly realised from the bigger and more vigorous tillers formed at the lower plant population. However, there was no significant difference in the leaf area of the main-culm. The reason for the lower leaf area obtained from among the plants from the higher plant population could be explained on the basis of inter-plant competition for nutrients, space and other factors necessary for growth.

In this study an average of seven tillers were formed at low plant population as against four and three tillers, respectively, at the medium and high plant populations (Table 5). A possible explanation for the decreasing number of tillers formed per plant as plant population increased is the inter-plant competition for space, water, nutriants and other growth factors.

The per cent tiller mortality recorded at 120,000 plants/ha over the two years was higher than that recorded at lower plant populations. Colville and McGill (1962) observed in wheat Triticum aestivum L. that an increase in plant population density

brought about general increase in stalk breaking and tiller mortality. The high per cent tiller mortality among the higher plant population could be explained by a number of reasons. The high plant population could have caused inter-tiller competition, moisture depletion due to closer spacing as well as competition for other necessary factors for tiller survival. This agrees with the conclusion reached by Barley and Neidu (1964) and Syme (1967) that the extent of tiller survival and small grains produced was dependent on soil fertility and water status of the soil. There was also a higher disease incidence among the higher plant populations which might have contributed to the higher tiller mortality.

The number of harvestable heads obtained from the low plant population over the two years was higher than that from the medium and high plant population. Apart from the fact that there was lower tiller and main-culm mortality in the low plant population, there was also the fact that not all tillers formed at the high plant population produced harvestable heads. This is in agreement with the earlier findings by Ramond (1968) and Egharevba (1976) who reported that not all tillers automatically produced harvestable heads in millet.

The mean grain yield from the low plant population was 14% and 24% higher than the mean from the medium and high plant populations, respectively. This confirms an earlier finding by Egharevba (1978) that increase in plant population beyond 80,000

plants/ha may be detrimental to grain yield in millet. At the low plant population, there were more developed plants that produced more harvestable heads which contributed to the high grain yield. Plant mortality, a reference to plants established but which either being dead, stunted or rudimentary did not contribute to final grain yield, was lowest at the low plant population. The finding in this study (Table 14) that low plant population produced heavier grains is in agreement with the earlier conclusion reached for wheat by Sharma et al. (1969) that grains from higher seed rate were smaller and of poorer quality than grains from plants of lower seed rate.

5.2 Effect of Sowing Date on Tiller Formation and Contribution to Grain Yield

A relatively higher per cent of plant emergence was recorded for the second sowing date as compared to first and third sowing dates in 1983 season (Table 3), however higher number of tillers per plant were formed on plants seeded at the first sowing date than the subsequent ones. This could be explained by the fact that the early sown plants had the advantage of higher temperatures which was close to optimum; with a mean of 28°C as against 25°C and 24°C (Appendix 3) for the second and third sowing dates, respectively. This caused retardation of general vegetative growth and development, and subsequently a reduction in growth potential including the ability to form tillers. Secondly, the plants sown during the first sowing date might have had an advantage of utilizing the

initial flush of soil nitrate which encouraged vigorous growth, and this might have led to higher number of tillers being formed.

The first sowing date recorded the lowest per cent tiller mortality when compared to subsequent sowing dates. That is as the season progressed there was an increase in tiller mortality. This increased tiller mortality could have resulted from the fact that most tillers formed from the late sown crops did not get the advantage of adequate moisture to develop, coupled with poor ability to compete for available nutrients. Subsequently, many of these tillers either died or become rudimentary, either of these conditions being detrimental to tiller survival.

The highest tiller contribution to grain yield (63%) was obtained from the first sown millet. The second and third sown crops contributed 59% and 50% of total grain yield, respectively, from their tillers. The lower tiller contribution to grain yield by the late-sown crops could have resulted from the high incidence of diseases during the period, which might have reduced the tiller grain yield through reduction in the number of harvestable heads per stand. This observation agrees with Harris (1962) who reported that late sown millets suffer severe stem-borer attack, and that stem-borer damage is one of the major factors limiting grain yield in pearl millet. The number of harvestable heads was also lowest among the late-sown plants. Furthermore, the highest tiller/main-culm mortality occured among the late sown plants.

5.3 Varieties

Millet variety Dwarf-Gero excelled in some agronomic and physiological characters. Among the characters assessed, Dwarf-Gero reached time to - 50% - flowering about three days earlier than Ex-Borno; whereas the former took about 53 days the latter took 56 days. Higher tiller and total grain yield was also recorded among the Dwarf-Gero. Infact, the final grain yield obtained for Dwarf-Gero in 1983 (a relatively dry year) was about 50% higher than that obtained for Ex-Borno indicating the drought resistance of the former. In the second season when rainfall was more favourably distributed, both varieties yielded at par.

Chapter 6

SUMMARY AND CONCLUSION

Two varieties of 'Gero' millet (Ex-Borno and Dwarf-Gero) were seeded directly in the field at three different sowing dates with three weeks interval between each date and at three plant populations (40,000; 80,000 and 120,000 plants/ha).

Of the three plant populations the 40,000 plants/ha had the highest number of tillers per plant, the lowest per cent tiller and main-culm mortality and the highest tiller contribution to grain yield. Over the two years the mean grain yield for the low plant population was 14% and 24% higher than the mean yields for medium and high plant populations, respectively. In terms of tiller contribution to grain yield the 40,000 plants/ha recorded the highest with 61% as against 57% and 50% for the 80,000 and 120,000 plants/ha, respectively.

Among the three sowing dates tried, millet sown earliest (on 25.5.1983 and 29.5.1984) out yielded that sown on 27.6.1983 and 19.6.1984, and the late sown (on 19.7.83 and 10.7.1984) by 10% and 22%, respectively. The grain yield in the early sown plot was determined by the highest number of harvestable heads, highest number of tillers, longer time to 50% flowering as well as greater tiller contribution to grain yield. Delayed sowing resulted in high tiller mortality.

Dwarf-Gero variety appeared to be superior to Ex-Borno in terms of number of tillers, tiller and main-culm mortality, time to 50% flowering as well as total grain yield.

From the foregoing, it can be concluded that among the plant populations tried, the 40,000 plants/ha was the most suitable for the optimum production of pearl millet under the soil and climatic conditions at Samaru, Zaria. Planting millet early with the establishment of rain (end of May) outyielded moderately late sown crop (June 19th and 27th) and late sown crop (July 10th and 19th) by a margin of 10% and 22%, respectively. Millet variety Dwarf-Gero out yielded Ex-Borno by about 50% in terms of grain yield in 1983, indicating the drought resistance of the former. In the second season when the rainfall was more favourably distributed both varieties yielded at par.

LITERATURE CITED

Aiyer, A.K.Y.N. (1947). 'Field crops of India with special reference to Mysore', Manager of Publications, Delhi pp. 24-60.

Arakeri, H.R. (1947). 'The influence of rainfall during the different growth phases on the yield of bajra in Puna for fourteen years'. Indian Ecol., 2(1): 21-26.

Ayyangar, G.N.R. and Hariharan, P.V. (1935c). 'The tillers of the pearl millet - Pennisetum typhoideum (Rich.) Madras Agric. Journal, 23: 477-477.

Balasubramanian, C. (1959). 'Crop weather relations in rainfed sorghum. Indian J. Agron., 3: 247-251.

Barley, K.P. and Naidu, N.A. (1964). 'The performance of three Australian wheat varieties at high levels of nitrogen supply'. Aust. J. ex. Agric. Annual Husb., 4: 39-41.

Begg, J.E. (1971). Productivity of bulrush millet (Pennisetum typhoides S. & H.) Proc. 12th Congress Pacific Sci. Ass., Camberra, Australia, 1971 pp. 1, 72.

Chardwaj, B.D. and Webster, D.J. (1971). 'Studies of hybrids between photoperiod sensitive and non-sensitive pennisetum millets'. Crop Sci., 24: 289-291.

Bishir, M.A. and Shelaby, Y. (1978). 'Some factors affecting dry matter accumulation in stem of maize plant'. Agric. Res. Review, 54(9): 49-56.

Briggs, K.C. and Attinew, A. (1979). 'The effect of seeding rate, sowing date and location on growing yield, maturity, protein per cent of some spring wheats in Central Alberta, Can. J. of Plant Sci., 59(4): 1139-1145.

Bunting, E.S. (1968). 'The influence of date of sowing on development and yield of maize in England'. J. Agric. Sci. Camb., 71: 117-125.

Burton, G.W. (1951). 'Quantitative inheritance in pearl millet (Pennisetum glaucum)'. Agron. J. 43: 409-417.

Colville, W.L. and McGill, D.P. (1962). 'Effect of rate and method of planting on several plant characters and yield of irrigated wheat'. Agron. J. 54: 235-237.

Darrel, D.T., Shank, D.B. and Dirks, V.A. (1963). 'Effect of population levels on yield and maturity of maize hybrids grown on the Northern Great Plains'. Agron. J. 54: 240-248.

Dogget, H. (1970). Sorghum: Tropical Agriculture series. Longmans & Co., London, and Harlow, pp. 202-204.

Downes, R.W. (1968). 'Effect of temperature and moisture stress on yield of grasses'. Aust. J. Agric. Res., 19: 59-64.

Egharevba, P.N. (1977a). 'Tiller number and millet grain productivity'. Cereal Res. Comm., 5: 235-241.

Egharevba, P.N. (1976b). 'A correction factor in the estimation of leaf area in millet'. Samaru Agric. Newsletter, 19(2): 84-86.

Egharevba, P.N. (1978). 'A review of millet work at the Institute for Agricultural Research, Samaru'. Samaru Misc. Paper, 77: 18-28.

Egharevba, P.N. (1979). Trends and constraints in millet production. Third NAFPP meeting at I.A.R. Samaru, Zaria.

Egharevba, P.N. (1979a). 'Agronomic practices for improved sorghum and millet production'. Samaru Misc. Paper, 90:

Egharevba, P.N. and Vanderlip, R.L. (1983). Effect of seed size and plant population on plant development and grain yield in pearl millet (Pennisetum americanum (L.) K. Schum). A report submitted for the fourth annual report of improvement of pearl millet. Kansas State University, Manhattan, Kansas, U.S.A.

Engledow, F.L. (1925). 'Investigation on yield in the cereals II. A spacing experiment with wheat'. J. Agric. Sci. 15: 130-134.

F.A.O. (1977). Production Year Book. Food and Agriculture Organisation, Rom, 31: 104-105.

F.A.O. (1980). Production Year Book. Food and Agriculture Organisation, Rom, 34(2): 106-107.

Gautam, R.C. (1969). 'A note on optimum plant population and spacing for hybrid 'Bajra' (Pennisetum typhoides S & H)'. Indian J. of Agron., 15(4): 395-396.

Greeny, F.J. (1946). 'Influence of time, rate and depth of seeding on the incidence of root rot in wheat'. Phytopathology, 36: 251-263.

Greenland, D.J. (1959). 'Nitrate fluctuations in tropical soils'. J. Agric. Sci., 50: 82-92.

Gregory, D.J. (1975). Performance of water barley varieties: Research Report, Agric. Exptl. Station, New Mexico State University, No. 307: 5 - 12.

Harris, K.M. (1962). 'Lepidopterous stem-borers of cereals in Nigeria'. Bulletin Ent. Res., 53: 139-171.

Haveland, C.S., Anthony, D.B. and Scarbrough, G.C. (1967). 'Effect of management on yield and quality of Sudan sorghum - Sudan hybrid and Sahi-I pearl millet: Abs. Agric. Exptl. Stn. Leafl. (Auburn Univ.): pp. 76-78.

Hunter, R.B., Hunt, L.A. and Kannenberg, L.W. (1976). 'Photoperiod and temperature effects on corn'. Can. J. Plant Sci., 54(1): 71-79.

ICAR (1961a). Handbook of Agriculture. Indian Council of Agriculture Research, Government of India.

ICRISAT (1977). International Cereal Research Institute for Semi-Arid Tropics, Annual Report, Hyderabad, India, pp. 108-112.

Jain, G.V. and Mathur, C.M. (1961). 'Efficiency of different nitrogen fertilizers for bajra production in desert soils of Rajasthan'. Indian J. Agron. 5(3): 151-156.

Kanki, K. and Reitz, L.P. (1955). 'Tillering and yield of oats plants grown at different spacings'. Agron. J. 47: 147-152.

Harper, H.E. (1929). 'The contrast in response of Kaffir and milo to variation in spacing'. J. Amer. Soc. Agron., 21: 344-354.

Kassam, A.H. and Andrews, D.J. (1975). 'Effect of sowing date on growth, development and yield of photosensitive sorghum at Samaru, Nigeria'. Exp. Agric., 11: 327-340.

Kassam, A.H. (1976). Crops of the semi-arid tropics. ICRISAT, Hyderabad, India, pp. 16-20.

Kassam, A.H., Featherstone, N., Alagarswamy, G. and Maiti, R.K. (1976). Sorghum and millet project report. ICRISAT, 1976. In-house Review.

Kassam, A.H. (1974). 'Effect of sowing date on the length and development phase in photosynthetic sorghum'. Samaru Agric. Newsletter, 16(1): 23-29.

Kowal, J.M. and Knabe, D.T. (1972). An agro-climatological atlas of the northern states of Nigeria, with explanatory notes. Ahmadu Bello University, pp. 11-113.

Krishnaswamy, N. (1962). 'Bajra'; (Pennisetum typhoides S. & H). Indian Council of Agric. Research Cereal Crop Serv. II, pp. 100.

Krishnamurthy, K., Gommegouda, A., Jagannath, M.K., Venugopal, M., Ramachandia, T.V., Raghunatha, G. and Rajashekara, B.G. (1974b). 'Relative production of yield in hybrid, composite and local maize as influenced by nitrogen and population levels II. Temporal changes in growth component'. Mys. J. Agric. Sci., 8: 500-508.

Kumar, V., Gwanubi, J.J. and Aremu, J.A. (1982). Optimum planting time for crops during the dry season in the Sudan and Northern Guinea savanna zones of Nigeria. A paper prepared for the irrigation committee of Institute for Agricultural Research, Ahmadu Bello University, Zaria, pp. 1 - 19.

Langer, R.H.M. (1963). 'Tillering in herbage grasses'. Herb. Abstr., 33(3): 141-148.

Le Clerg, E.L., Leonard, W.H. and Clark, A.G. (1962). Field plot Technique (second edition). Burgess Publishing Company, Minneapolis, U.S.A. pp. 373-375.

Loomis, R.S. and Williams, W.A. (1963). 'Maximum crop productivity: An estimate'. Crop Sci., 3: 67-72.

Marchal, A. (1950). 'The pennicillaria cultivars in Niger'. Agron. Trop. 5: 582-572.

Martin, J.H. (1926). 'Factors influencing results from rate and date of seeding experiments with wheat in the Western United States'. J. Am. Soc. Agron. 18: 193-225.

Nwasike, C.C. (1977). M.Sc. Dissertation, Purdue University, West Lafayette, Indiana.

Pal, B.P. and Sikka, S.M. (1961). Wheat. Handbook of agriculture. I.C.A.R. New Delhi, pp. 130-131.

Patil, J.A. (1959). 'Bajra' in Bombay, Poona Agric. College Mag., 49(4): 265-267.

Pittman, U.J. and Andrews, J.E. (1961). 'Effect of date of sowing on winter survival, yield and bushel weight of winter wheat cultivars grown in Ontario'. Can. J. Plant Sci., 59: 939-943.

Quinlanand Sagar (1965). 'Grain yield in two contrasting varieties of spring wheat'. Ann. of Bot., 29: 683-692.

Remond, C. (1968). 'For better understanding of the growth and development of pennisetum millets'. Agronomic Tropicale, France, 23: 844-863.

Sankaram, S. and Kaliappa, R. (1974). 'The relationship between grain yield with measurable morphological characteristics in pearl millet'. Madras Agric. J., 61(8): 359-364.

Seilinger, J.D. (1926). 'The spacing of grain sorghum'. J. Amer. Soc. Agron., 18: 525-529.

Sharma, K.C.; Misra, R.D. and Singh, V.P. (1969). 'Response of Dwarf and Tall wheat to nitrogen and plant population'. Indian J. of Agron., 15(12): 131-135.

Shimono, K. and Dosaki, I. (1980). 'Effect of sowing density and nitrogen application on growth and yield of winter wheat in Abashiri district'. (Bulletin of Hokkaido Prefectual). Agric. Exp. Station., 44: 12-24.

Singh, S.; Lashiri, A.N. and Singh, S. (1968). 'Studies on plant-water relationship IV. Impact of water deprivation on the plant metabolism of (Pennisetum typhoides S. & H.)'. Proc. Nat. Inst. Sci. Ind. Pt. B., 34(6): 313-322.

Smid, A.E. and Jenkinson, R.C. (1979). 'Effect of rate and date of seeding on yield and yield components of two winter wheat cultivars grown in Ontario'. Can. J. Plant Sci., 59: 939-943.

Smith, H.F. (1933). 'Physiological relations between tillers of a wheat plant'. Journ. Coun. Sci. Industr. Res. Aust., 6: 350-352.

Stickler, F.C. and Pauli, A.W. (1961). 'Influence of date of sowing on yield and yield components in grain sorghum'. Agron. J., 53; 20-22.

Stoskopf, N.C. and Reinbergs, E. (1966). 'Breeding for yield in spring cereals'. Plant Sci., 46: 513-519.

Syme, J.R. (1967). 'Growth and yield of irrigated wheat varieties at several rates of Nitrogen fertilizer'. Aust. Journ. Exp. Agric. Animal Hus., 7: 337-339.

Tomlinson, P.R. (1965). 'Soils of Northern Nigeria'. Samaru Miscellaneous Paper II. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, pp. 12.

Vavilov, N.I. (1951). The origin, variation, immunity and breeding of cultivated plants (Chronica Botanica), Vol. 13: 382-384.

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

White, R.P. (1977). 'Effects of planting dates on forage corn yields and maturity on Prince Edward Island'. Can. J. Plant Sci., 57: 563-569.

White, R.P. (1978). 'Cultural practices affecting maturity and yield of corn (Zea mays) for whole plant silage in short seasoned areas'. Can. J. Plant Sci., 58: 629-642.

Yoshida, S. (1972). 'Physiological aspects of grain yield'. Ann. Rev. Plant Physiol., 23: 437-464.

Zuber, M.S. (1956). 'Rates of planting studies with corn'. Missouri Agricultural Station Research Bulletin, pp. 610-623.

Appendix 1: Rainfall data for Samaru (mm) 1983.

DAYS OF THE MONTH	J	F	M	A	M	J	J	A	S	O	N	D
1	-	-	TR	-	-	-	-	2.1	2.0	-	-	-
2	-	-	-	-	-	9.8	11.0	35.0	-	-	-	-
3	-	-	-	-	-	4.0	TR	14.5	-	-	-	-
4	-	-	-	-	-	-	9.7	1.1	1.1	-	-	-
5	-	-	-	-	-	-	6.6	0.8	21.0	-	-	-
6	-	-	-	-	-	-	-	-	11.3	-	-	-
7	-	-	-	-	-	-	0.9	27.0	-	-	-	-
8	-	-	-	-	-	0.2	0.3	0.5	16.3	-	-	-
9	-	-	-	-	TR	-	-	-	-	-	-	-
10	-	-	-	-	-	TR	10.2	17.0	-	-	-	-
11	-	-	-	-	35	7.4	0.8	-	2.6	-	-	-
12	-	-	-	-	16.4	-	-	-	-	-	-	-
13	-	-	-	-	-	-	0.3	-	7.4	-	-	-
14	-	-	-	-	16.9	-	-	-	-	-	-	-
15	-	-	-	-	-	6.6	-	-	12.0	-	-	-
16	-	-	-	-	8.9	-	6.0	-	10.0	-	-	-
17	-	-	-	-	0.1	-	-	-	-	-	-	-
18	-	-	-	-	-	TR	-	40.4	4.6	-	-	-
19	-	-	-	-	TR	-	-	21.0	1.6	-	-	-
20	-	-	-	-	17.2	-	1.2	14.6	-	-	-	-
21	-	-	-	-	-	TR	-	-	-	-	-	-
22	-	-	-	-	-	-	18.4	0.5	-	-	-	-
23	-	-	-	-	2.0	-	-	6.2	TR	-	-	-
24	-	-	-	-	3.0	24.5	-	-	TR	-	-	-
25	-	-	-	-	-	1.0	0.5	26.3	3.5	-	-	-
26	-	-	-	-	1.3	-	-	24.7	-	-	-	-
27	-	-	-	-	-	-	0.3	-	-	-	-	-
28	-	-	-	-	-	17.1	27.0	19.2	-	-	-	-
29	-	-	-	-	-	3.7	6.3	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	4.0	-	-	-	-	-	-	-
					73.3	74.3	107.5	259.7	93.4			= 608.2 mm
	-	-	-	-	10	9	15	16	12	-	-	- 62 days

TR = Trace, Number of rainy days = 62, Mean annual rainfall = 608.2 mm, Mean for 1982 = 768mm, Mean for the last 50 years = 960mm.

Appendix 2: Rainfall data for Samaru (mm) 1984.

DAYS OF THE MONTH	J	F	M	A	M	J	J	A	S	O	N	D
1	-	-	-	-	-	3.7	8.1	-	16.0	-	-	-
2	-	-	-	-	-	-	-	-	-	49.0	-	-
3	-	-	-	-	-	-	-	-	-	15.0	-	-
4	-	-	-	-	-	-	7.0	-	31.5	-	-	-
5	-	-	-	-	39.0	2.2	3.0	23.3	0.7	-	-	-
6	-	-	-	-	-	0.6	-	-	13.5	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	18.0	-	-	49.0	-	50.5	-	-
9	-	-	5.2	-	2.6	-	-	-	-	9.2	-	-
10	-	-	-	-	-	-	-	7.8	-	0.0	-	-
11	-	-	-	-	-	-	17.9	-	-	-	-	-
12	-	-	-	-	-	18.3	0.9	-	-	-	-	-
13	-	-	-	-	-	19.8	13.0	-	-	-	-	-
14	-	-	-	-	-	-	28.1	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	8.1	-	-	-	-
17	-	-	-	-	25.0	-	-	10.0	27.0	53.0	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	0.4	7.2	14.4	-	-	-	-
20	-	-	-	TE	-	-	7.4	-	-	-	-	-
21	-	-	-	1.3	-	-	-	12.6	33.6	-	-	-
22	-	-	-	-	-	10.0	4.2	-	-	-	-	-
23	-	-	-	3.9	-	0.2	0.4	-	-	-	-	-
24	-	-	-	0.2	-	-	23.5	5.7	-	-	-	-
25	-	-	-	-	5.7	-	1.2	0.6	-	-	-	-
26	-	-	-	14.0	3.5	0.4	-	TR	25.5	-	-	-
27	-	-	-	-	-	-	6.5	-	3.0	-	-	-
28	-	-	-	1.7	4.6	-	18.6	-	2.1	-	-	-
29	-	-	-	-	-	TR	-	14.5	35.5	-	-	-
30	-	-	-	9.0	0.5	-	34.1	12.1	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-
			5.2	30.1	98.9	55.4	173.8	158.1	189.0	177.5=888.0mm		

TR = Trace, Number of rainy days = 67,

Mean annual rainfall = 888.0mm.

Appendix 3: Mean monthly maximum and minimum temperatures (^{o}C) at Samaru-Zaria, 1983.

Temperature	J	F	M	A	M	J	J	A	S	O	N	D
Maximum	23.6	32.4	33.0	37.5	34.7	31.9	28.8	28.4	29.9	31.8	32.0	31.0
Minimum	13.8	18.1	17.0	19.9	21.6	19.6	23.4	16.7	17.3	14.3	12.6	12.9

Source: Meteorological Unit, Institute for Agricultural Research, Samaru-Zaria, Nigeria.

Appendix 4: Mean monthly Maximum and Minimum Temperatures (^{0}C) at Samaru-Zaria, 1984.

Temperature	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Maximum	28.3	31.7	35.5	35.0	31.9	31.5	28.9	29.8	29.5	30.5	31.2	27.6
Minimum	11.8	14.8	20.7	22.7	21.3	20.5	19.2	19.5	19.2	18.6	13.6	12.8

Source: Meteorological Unit, Institute for Agricultural Research, Samaru-Zaria, Nigeria.

Appendix 5: Stem-borer and downymildew calculation formulae.

Stem-borer and downymildew incidences were scored from the total number of plants per net plot and calculated as follows:

$$\text{Incidence (\%)} = \frac{\text{Number of plants attached/netplot}}{\text{Total number of plants/Net plot}} \times 100$$

$$\text{Incidence (\%)} = \frac{\text{Number of smutted heads}}{\text{50 randomly selected heads}} \times 100$$

$$\text{Infection index (\%)} = \frac{Y(1-1)+Y(2-1)+Y(3-1)+Y(4-1)+Y(5-1)}{4N} \times 100$$

Y = Number of heads in each category of scale

1 = No symptoms

2 = Smutted grains covering 1 - 5% of the head

3 = Smutted grains covering 6 - 20% of the head

4 = Smutted grains covering 21 - 50% of the head

5 = Smutted grains covering more than 50% of the head

N = Total number of heads.

Appendix 6: Individual analyses of variance for seedling emergence and stand count of pearl millet.

Source of Variation	Degree of freedom	Mean squares			
		% Seedling emergence		Stand count	
		1983	1984	1983	1984
Replications (R)	2	430.01	386.01	232.25	256.14
Sowing dates (D)	2	396.36	406.22	327.58	301.41
Plant populations (P)	2	24681.14*	27181.63*	34820.96*	38916.17*
Varieties (V)	1	158.31	160.98	15.58	17.78
V x P	2	368.18	389.28	491.43	563.43
V x D	2	201.62	402.36	20.35	29.34
D x P	4	108.61	211.44	119.10	134.38
D x P x V	4	485.63	514.28	363.93	419.51
Error	34	501.31	489.39	298.75	303.14

* Denotes statistical significance at 0.05 level of probability.

Appendix 7: Individual analyses of variance for number of tillers and time to - 50% - flowering of pearl millet.

Source of Variation	Degrees of freedom	Mean squares			
		Number of tillers formed		Time to - 50% - flowering	
		1983	1984	1983	1984
Replications (R)	2	0.44	0.76	0.22	0.27
Sowing dates (D)	2	0.66	4.91*	4.16*	5.23*
Plant populations (P)	2	5.81*	6.72*	2.07	2.16
Varieties (V)	1	0.06	0.07	20.16*	3.06
V x P	2	1.81	2.01	0.67	0.73
V x D	2	0.16	0.19	1.06	1.11
D x P	4	2.48	2.33	2.02	2.01
V x D x P	4	0.52	0.61	.0.17	0.19
Error	34	0.81	0.92	0.58	0.61

* Denotes statistical significance at 0.05 level of probability.

Appendix 8: Individual analyses of variance for tiller and main-culm mortality of pearl millet.

Source of Variation	Degrees of freedom	Mean squares			
		Tiller mortality		Main-culm mortality	
		1983	1984	1983	1984
Replications (R)	2	1.15	1.01	18.67	17.61
Sowing dates (D)	2	13.03*	12.63*	3390.17*	3291.32*
Plant populations (P)	2	10.72*	3.62	14541.06*	13621.92*
Varieties (V)	1	0.11	0.13	88.17	8.03
V x P	2	2.09	1.99	343.39	341.72
V x D	2	1.99	1.76	453.49	451.36
D x P	4	0.41	0.38	782.78	763.64
V x D x P	4	1.13	1.21	287.73	288.16
Error	34	1.18	1.09	214.01	216.23

* Denotes statistical significance at 0.05 level of probability.

Appendix 9: Individual analyses of variance for number of harvestable heads and 1000-grain weight of pearl millet.

Source of Variation	Degrees of freedom	Mean squares			
		Number of harvestable heads		1000-grain weight	
		1983	1984	1983	1984
Replications (R)	2	496.46	886.34	0.56	0.61
Sowing dates (D)	2	4274.01*	5131.17	0.63	0.72
Plant populations (P)	2	3617.41*	4189.20	1.39	1.41
Varieties (V)	1	216.83	281.40	4.35	4.01
V x P	2	4131.62*	882.18	0.71	0.81
V x D	2	781.66	516.12	2.93	2.96
D x P	4	160.05	190.42	1.25	1.31
V x D x P	4	232.16	301.60	1.68	1.72
Error	34	343.18	807.32	1.16	1.21

* Denotes statistical significance at 0.05 level of probability.

Appendix 10: Individual analyses of variance for grain yield of pearl millet.

Source of variation	Degrees of freedom	Mean squares	
		1983	1984
Replications (R)	2	26134.2	21143.7
Sowing dates (D)	2	34312.3	585075.0*
Plant populations (P)	2	585075.8*	376214.3*
Varieties (V)	1	496731.7*	49483.2
V x P	2	20713.4	64151.0
V x D	2	41462.3	12450.3
D x P	4	24374.3	10251.0
V x D x P	4	31373.4	103415.0
Error	34	24813.0	72832.2

* Denotes statistical significance at 0.05 level of probability.

Appendix 11: Combined analyses of variance for seedling emergence, stand count, number of tillers and time-to-50% flowering of pearl millet over 1983 and 1984.

Source of Variation	Degrees of freedom	Mean squares			
		Seedling emergence	Stand count	No. of tillers	Time to-50% flowering
Replications (R)	2	286.12	116.21	0.51	0.31
Sowing dates (D)	2	301.16	411.32	3.06*	6.21*
Plant populations(P)	2	20317.31*	19305.40*	7.36*	2.61
Varieties (V)	1	207.36	113.62	0.06	1.70
Years (Y)	1	581.43	587.32	1.21	5.12*
Y x V	1	119.63	102.87	0.96	1.16
Y x P	2	406.32	309.36	0.75	2.07
Y x D	2	501.43	404.28	1.21	1.63
V x P	2	216.32	119.37	2.01	0.76
V x D	2	101.78	98.13	1.01	0.04
P x D	4	102.36	56.42	0.98	1.03
Error	68	309.26	181.36	0.56	0.07

* Denotes statistical significance at 0.05 level of probability.

Appendix 12: Combined analyses of variance for main-culm and tiller mortality of pearl millet over 1983 and 1984.

Source of Variation	Degrees of freedom	Mean squares	
		Main-culm mortality	Tiller mortality
Replications (R)	2	11.33	1.03
Sowing dates (D)	2	1736.20*	11.63*
Plant populations (P)	2	908.16	9.90*
Varieties (V)	1	59.32	0.12
Years (Y)	1	873.14	1.05
Y x V	1	150.16	0.90
Y x P	2	374.17	2.16
Y x D	2	463.08	0.97
V x P	2	119.42	1.02
V x D	2	209.37	0.46
P x D	4	402.91	1.73
Error	60	198.46	0.92

* Denotes statistical significance at 0.05 level of probability.

Appendix 13: Combined analyses of variance for yield characters of pearl millet over 1983 and 1984.

Source of Variation	Degrees of freedom	Mean squares		
		No. of harvestable heads	1000-grain weight	Grain yield
Replications (R)	2	506.27	0.36	10012.42
Sowing dates (D)	2	2676.13*	0.42	80163.50
Plant populations (P)	2	2013.42*	1.02	241232.10*
Varieties (V)	1	114.40	2.43	32416.21
Years (Y)	1	1090.20	0.98	10142.36
Y x V	1	1012.63	1.01	9126.30
Y x P	2	986.24	0.62	8124.42
Y x D	2	848.16	0.81	10724.63
V x P	2	701.44	0.35	8812.30
V x D	2	341.26	1.56	7231.61
P x D	4	106.73	0.82	100231.64
Error	60	249.43	1.04	35621.20

* Denotes statistical significance at 0.05 level of probability.

SHORT BIOGRAPHY: Ibrahim Kafur YUSUFU

Name : I. K. Yusufu

Date of Birth : 15th June, 1954

Business Address : Department of Agriculture, Katsina Polytechnic, P.M.B. 2052, Katsina.

Home Address : c/o Alhaji Yusufu Audi, Koranic School Supervisor, L.A. Works Department, Katsina.

Previous Qualifications:

Institutions attended	From	To	Cert./Dip./Degree
Tunau Primary School, Malumfashi	1961	1967	Primary Leaving Certificate.
G.S.S. Malumfashi	1960	1972	W.A.S.C.
College of Arts, Science and Technology, Zaria	1973	1975	IJMB Examination
Department of Biological Sciences, A.B.U., Zaria.	1975	1978	B.Sc. (Hons.) Botany.

Posts held since the Award of First Degree

Organisation	From	To	Position
N.Y.S.C., Ondo State	1978	1979	Teacher
Ministry of Agriculture & Co-operatives, Kaduna	1979	1980	Agric. Officer II
Katsina Polytechnic	1980	Date	Lecturer I

Year of Admission for Postgraduate Studies: 1983

Admission Number: M.Sc./Agric./2059/82-83.