PERFORMANCE OF POPCORN (Zea mays L.) UNDER DIFFERENT POPULATION DENSITIES IRRIGATION INERVALS AND DATES OF SOWING.

BY

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A thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in partial fulfilment of the requirements for the degree of Master of Science in Agronomy.

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DECLARATION

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

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Date:- 8 - 3 - 99

The above declaration is confirmed

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CERTIFICATION

This thesis entitled "PERFORMANCE OF POPCORN (*Zea mays* L.) UNDER DIFFERENT POPULATION DENSITIES, IRRIGATION INTERVALS AND DATES OF SOWING" by Mani, Hamza 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.

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DEDICATION

I dedicate this work to all the decendants of late Bello Mani and Maryam Ibrahim. May their gentle souls rest in perfect peace (Amen).

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ABSTRACT

Field trials were conducted at the Kadawa Irrigation Research Station (11°39'N, 08°02'E and 500m above sea level) located in the Sudan savanna ecological zone of Nigeria during the 1996/97 and 1997/98 dry seasons to study the performance of popcorn under different population density, irrigation interval and date of sowing. Analysed results showed that population density significantly influenced most growth and yield parameters assessed with higher population of 66,666 plants per hectare having an edge over other densities except days to 50% tasseling and silking, ear length, ear diameter, cob diameter, weight of grain per cob and 1000-grain weight which were significantly higher at lower population density. Irrigating popcorn at 7-day interval significantly increased most of growth and yield characters of popcorn. However, no significant effect was observed due to variation in irrigation interval on grain yield (kg/ha) in both seasons and combined analysis. Intermediate sowing at the end of February resulted in significantly higher growth and yield attributes of the crop. Highly significant and positive correlation (P=0 01) were observed between popcorn grain yield (kg/ha) and total dry matter (TDM) kernel depth, weight of grain per cob, 1000 grain weight and number of ears per plot at (P=0.05) in 1996/97 season. In 1997/98 season however, highly significant and positive correlation (P 0.01) were obseived between grain yield (kg/ha) and plant height at 12 weeks after sowing (WAS), Leaf area index (L.VI), TDM, days to 50% silking, number of ears per plot and weight of grain per cob P=0.05. Direct percentage contribution of most characters were greatest through TDM and ear diameter; while combinations of plant height and TDM cob diameter and ear diameter were the highest contributors to popcorn grain yield.

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CHAPTER ONE

INTRODUCTION

Popcorn (*Zea mays* L.) belongs to the large and important family Poeceae. It is believed to have originated in the New-World along with other sub-species including dent, flint, flour and sweet corn (Brunson and Smith, 1948). However, Eldredge and Thomas, (1959) indicated that early history of popcorn is in doubt but the probable centre of origin is Mexico or Central America with possible secondary origin in South America. Smith, (1968) reported that traces of corn, probably popcorn found in the Batcave of Mexico, showed that popcorn was one of the most primitive corn crop. Primitive features associated with the crop includes its ability to produce tillers, production of several ears per plant and small kernels (Jugenheimer, 1976).

The cultivation and use of popcorn was almost entirely restricted to the corn belt of the United States of America. The crop is now grown in many parts of the world (including Nigeria) through the work of traders and explorers (Brunson, 1955). In Nigeria, the demand for popcorn has increased sharply from mid-seventies stimulting production of the crop in some areas of the savanna around Zaria, Jos, Ilorin and few other towns (Iken, 1993).

The crop can be grown on any type of soil that can support the growth of maize but best production should be restricted to more fertile soil that are not too light and preferably sandy loam (Brunson and Smith, 1948). The only difference is in the area of weed control (because of its slow initial growth) and seed rate (due to small nature of the kernel). It can be grown on a soil with a pH range of between 5.5 to 8.0. The best climate for the crop are those which receive an annual rainfall of 600 to 1000mm except where the crop is irrigated (Eldredge and Thomas, 1959). Popcorn is a worm weather crop, grown where mean temperature varies between 21 to 27^{o}C (Iken, 1993).

Popcorn is prepared and used as snacks and confectioneries at amusement parks, around entertainment venues and while traveling in most of West African Countries (Jugenheimer, 1976). In Nigeria popcorn is made into "Gugguru" which is eaten alone or mixed in certain ratios with groundnut. It is also use in making biscuits, cornflakes, tuwo, kunu. Unfit popcorn for consumption are grounded and used in fattening programmes of cattle.

Planting popcorn at optimum population density is one of the basis for high yield, whereas plant population density at sub-normal level is a major constraints in crop production. Most of the studies carried out on popcorn in the savanna were done under rainfed condition. Recommendation for popcorn grown during rainy season may not necessarily be the same for popcorn grown under irrigation. Time of sowing is an important agronomic factor which causes substantial increase or decrease in yield. Optimum time of sowing makes the best use of the available temperature and solar radiation at different stages for higher productivity. Despite the increasing importance of this crop in the Nigerian Savanna, little or no research work has been done to determine the appropriate production practices for improving its yield. In line with this, the study was carried out with the following objectives.

1. To determine the effect of plant population density on growth, yield components and yield of popcorn.
2. To assess the effect of irrigation interval and date of sowing on growth, yield components and yield of popcorn.

CHAPTER TWO

LITERATURE REVIEW

2.1 Effect of Plant Population Density

Popcorn grown at low density levels, usually exhibit higher number of leaves and branches as well as wider plant leaves spread thereby enhancing greater interception of light energy and production of more assimilates (Shamsudeen, 1993). Increasing the density level could decrease productivity per plant due to high degree of competition for available light, water and nutrients among the crops as well as increase shading effect (Roy and Singh, 1986, Yousif and Ali, 1989, Rowland, 1993). Yield of corn increases as population density is raised until one or more factors (such as soil fertility, water supply, soil organic matter content, cultural practices, climate, light etc) become limiting (Owueme and Sinha, 1991). Apart from yield, plant population density affect several other things such as plant and ear characteristics, lodging, tillers, corn borer infestation, stalk rot, plant height and LAI (Brunson and Smith, 1948). Growing popcorn in India at three plant population density levels of 60000, 70000 and 80000 plants per hectare, a highest yield of 3.85t/ha was obtained with the highest population density level (Roy and Singh, 1986). However, a decrease in grain weight per ear with increase in plant density was observed.

Yousif and Ali (1989) recommended a plant population density of 88,888 plants per hectare as the best for maximing popcorn grain yield in Baghdad. Growing popcorn in Brazil at 160,000 plants per hectare gave a higher yield of 2.4t/ha as compared to 1.9t/ha obtained at 80,000 plants per hectare, (Merlo, 1988). However, Filho *et al*, (1988) working in the same area reported a decrease in yield with increase in population. They noted that growing popcorn at 80000 - 240000 plants per hectare led to a decrease in grain yield from 2.34 to 1.93tonnes per hectare, plant height from 2.04 to 1.9m, 100 seed weight from 13.5 to 12.4g, number of grains per ear and number of ears per plants.

Growing maize in Mokwa and Oma-Arom at 24000 and 49000 plants per hectare, Ologunde and Ogunlela (1984) obtained a yield increase of between 48 - 53%. In a separate trial, Ezumah and Lowson, (1990) obtained grain yields from 0.57 tones per hectare at 20,000 plants per hectare to 1.25 tones per hectare at 80,000 plants per hectare. Increasing maize population above 45,000 plants per hectare increased total yield by 13-27%. At Maiduguri, Sharma and Adamu (1984) using four plant density levels 23,000, 30,000, 35000 and 49,000 plants per hectare obtained highest yield at highest density level.

A decrease in ear length, grain size, number of grains per row, number of grain per ear, grain weight per cob and 1000 grain weight with increase in plant population density from 33,333 to 99,999 plants per hectare was observed by Babu and Mitra, 1989. Increasing plant population density from 40000 - 80000 plants per hectare had been reported to decrease weight of grains per ear, number of seeds per ear, 1000 seed weight and length of ear by 36.8, 12.7, 19.8 and 20% respectively (Ologunde, 1974).

A recent study indicated no yield differences when corn is grown at one or two plants per stand using 25 or 50cm within row spacing respectively (Elemo, 1993). However, farmers prefer the wider spacing because planting appears less tedious than at lower spacing (Alofe *et al*, 1988). In the derived and Guinea Savanna zones, it appears that higher plant population are still possible. The highest grain yield was obtained by Alofe *et al*, (1983) with selected maize hybrid was when grown at 66,666 plants per hectare (75 x 20cm) than those grown at lower density of 53,333 plants per hectare (75 x 25cm) at Ilorin. Whereas at Ikenne the lower population was more optimal. For maize grown in the forest zone, two rather than one or three plants per stand at row spacing of 75 and a 30 to 40cms intra-row spacing was necessary for high yield (Pierre *et al*, 1967 and Rowland, 1993).

At high populations silking is delayed by 1 to 5 days whereas tasseling and pollen shedding are usually less affected (Brunson, 1955). Excessive retardation of silking may lead to complete barrenness (Robin and Domingo, 1953). Lodging of maize was found to increase as plant population density increases. For example 22, 31, 39 and 46 percent lodging was observed at for populations of 8000, 12000, 16000 and 20000 respectively (Pierre *et al*, 1967).

Alessi and Power (1975) studied early maturing maize hybrid in the northern region of the great plains of the United State and found that increasing plant population density up to 74,000 plants per hectare produced (LAI) as high as 4.9 depending on hybrid type and the season. Olson and Sander, (1988) observed that increasing plant population density improved the LAI but increased the susceptability of stalk to lodging and did not increase grain yield even if total dry matter production was increased.

2.2 Water Requirement

Corn is an efficient crop so far as the use of water is concerned (Robin and Domingo, 1953). The water requirement of the crop vary with the different stages of its growth (Robin and Rhoades, 1958). According to Rowland, (1993) the crop water requirement varies with the type of soil and the season in which it is grown. In general the crop needs about 620mm. On the other hand, Pierre *et al*, (1967) indicated that the amount of moisture required by maize depends on temperature, relative humidity, insolation, length of growing season and all other factors influencing water loss from the crop and soil.

According to Doss *et al*. (1964), the consumptive use of water for maize crop vary over a wide range of values. They further stated that early in the season, maize crop uses an average of 2.54mm of water per day. During this early stage of growth only a sparse vegetative of maize cover exist, as a result much of the soil moisture is lost by evaporation from few inches of the surface profile (Robin and Domingo, 1953). Water use on average is 4.6mm per day between June to mid-August but after this period water use by the crop gradually decreases because of crop maturity hence less energy available for evaporation (Delorit, 1974).

The early vegetative growth stage (20 - 40 days after sowing), tasseling and silking stages (45 - 60 days after sowing) have been found to be the critical stages of maize in the demand for water (Onwueme and Sinha, 1991).

2.2.1 Effect of Irrigation.

Irrigation is a means of manipulating several important factors in the environment, particularly the nutritional factor in addition to water itself (Gardner *et al,* 1981). He further stated that proper irrigation is imperative and challenges the managerial ability of the farmers. Similar observation was reported by (Pierre *et al,* 1967). Irrigating maize becomes economically feasible when the cost of supplying the water is less than the value of the increased production (Rowland, 1993). In most cases, irrigation should be timed to replenish the soil moisture supply before the crop suffers. Doss *et al,* (1964), reported that in sandy soils with low water holding capacity, irrigation at interval of one week or even less may be necessary during the period of peak use. They further stated that deep finer textured soils hold more available moisture and will sustain the crop for longer period between irrigation. Similar observations were reported by Robin and Domingo, (1953) and Robin and Rhoades, (1958). Enough water should be applied at each irrigation to recharge the root zone to field capacity (Shaw *et al,* (1964).

2.2.2 Effect of Irrigation on Plant Growth

Corn is one of the best crop for irrigation because of the yield obtained according to Rowland (1993). the crop can withstand moderate drought without reduction in yield provided moisture is abundant at tasseling and silking stages. Robin and Domingo, (1953) stated further that grain production is dependent on adequate water supply from tasseling to maturity. Plants which suffer from water deficiency during their early growth are often able to recover and produce good yield if optimum available soil moisture is restored in the root zone during the reproductive stages.

Maize is more sensitive than sorghum to mild water stress during growth stages partly because the leaves are not as strongly cutinized (Rowland, 1993). However, Waldren (1983) indicated that with only mild to moderate moisture stress, the stomata close and the leaves roll in upon themselves. He further stated that it occurs as the leaf water potential reaches - 15 bars.

Leaf elongation is severely curtailed at leaf water potential of about - 7 to -9 bars, though photosynthesis is not severely reduced until - 12 bars (Boyer, 1970).

The slow growth rate as reported by Kemper *et al*, (1961) induced by moisture stress is partly offset by a rapid growth rate after soil moisture stress is removed. This has been attributed to the accumulation of simple sugar during the stress period. Moisture stress at grain filling stage reduced total dry matter production (Wilson and Allison, 1978). Increasing irrigation interval increased plant height and extended growth period but reduced leaf area and water use efficiency (Nnadi, 1975).

The high sensitivity of the seedlings to excess moisture conditions is partly explained by the fact that growing point of the plants is below the surface of the soil up to the period of 3 to 4 weeks from planting (Lal, 1973). Excess soil moisture condition during seedling stage tend to reduced plant stand and growth is retarded to such an extent of reducing grain yield of the crop (Sanchez, 1976).

2.2.3 Effect of Irrigation on Yield

How much water to be applied and at what time of the life cycle of the crop determines the yield. Withholding irrigation at any of the critical stages of corn crop affect the yield (Robin and Domingo, 1953). Field trials in 1976, 1977 and 1978 in United State by Robin and Rhoades, (1953) using drip irrigation at different intensities during growth, the grain yield response to irrigation were greatest with frequent irrigation during the whole growing period (15mm of water applied whenever the soil moisture deficit reached 15mm). Next highest grain yield was obtained by frequent irrigation from flowering to ear development and less frequent at other times (Gnergerson, 1978).

In the same vein, Michael, (1978) working in Ibadan, Nigeria showed that providing 50mm of water per hectare at 7-days interval produced highest grain yield than at 3, 5 or 10 days intervals.

Kaliappa *et al,* (1974) obtained a highest maize grain yield of 2.15t/ha with 382mm water applied at 58 and 75% depletion of available soil moisture at reproductive and vegetative stages respectively. Morey *et al,* (1980) observed no significant yield difference when maize was grown on a loamy sand soil which was irrigated at 25, 50 and 75% of available soil moisture in the top 45cm of soil.

A yield reduction of 37% when maize was subjected to excess moisture condition for five days at knee - high and silking stages was observed by Rowland, (1993). This was due to oxygen stress caused by the anaerobic environment created by water logging (Bhan, 1977). Nwa, (1979) found that 330mm of water from sprinkler irrigation at seven - day interval or evenly distributed rainfall produced high yield of maize.

At Bakura, Nigeria Anon. (1981) in an experiment on irrigation requirement of dry season maize in sandy soil obtained best yield with three day irrigation interval. The five-day interval reduced yield by 25.3% but did not differ significantly from the seven and nine-day intervals. In Kadawa, Nigeria soils with significant water table fluctuations (80 - 120cm) can give wheat grain yield of 5t/ha with 30mm water at seven or ten-day irrigation interval. Wider irrigation intervals are likely to depress yield (Anon, 1981).

Water deficits during tasseling and silking are known to reduce grain yield more than at any other period (Denmead and Shaw, 1960). Moisture stress during vegetative growth, silking and grain development of maize reduced yield by 25, 50 and 21 percent respectively. Robin and Domingo, (1953) indicted that drought during grain filling stages has been shown to reduce translocation of photosynthate from the leaves. This lead to the reduction of photosynthesis and grain yield of the crop.

2.3 Effect of Sowing Date

Time of sowing is an important agronomic factor which can cause substantial increase or decrease in yield of maize crop (Rowland, 1993) optimum time of sowing makes the best use of the available temperature and solar radiation parameters at different stages of maize growth for higher productivity (Pierre *et* al, 1967). They further affirmed that early planting enables sowing of the succeeding crops thus improving productivity and fertilizer use efficiency of the crop.

The dry season (October - May) in Northern Nigeria is characterised by wide fluctuations of day and night temperatures. The temperature decreases from October to January and increases from February to April or May. The abrupt rise in temperature in March or April limits the growing season of maize and the crop yield decreases in relation to date of sowing (Kumar, *et al*, 1982).

They further reported that very high temperature 35^0c or above and low humidity during tasseling and silking stage of maize may result in floret sterility inspite of frequent irrigation. The ideal temperature requirement for popcorn growth and development is 24 to 30^0c.

The initial growth of late planted crop is generally poor (mainly attributed to excess moisture condition and poor aeriation). Subsequent relative growth stages could be good but the plant fails to catch up. It thus remain small with low carbohydrate production during grain filling stages (Venon, 1953 and Jones, 1974). However, Pierre *et al,* (1967) indicated that early planting get the crop tasseled and silked with larger and deep root system and the ears more developed before moisture becomes limiting later in the season.

Kamel *et al,*(1979) observed sowing date to have a significant effect on the percentage of barren plants, number of ears per plant, weight of grains per ear and grains per plant, shelling percentage and grain yield. Nagase and Takemura, (1965), Dachev, (1974), and Bolan, (1977) have reported that early sowing produced the highest dry matter yield of irrigated maize.

It is evident from literature (Hemingway, 1955, Evans, 1963, Akehurst and Streedharan, 1965, Turner, 1966 and Elemo, 1993) that maize yield decline with lateness of planting after an optimum time. The environment with cool night (14-18^0c) and moderate day temperature (25-30^0c) is more favourable to maize grain development (Tsala, 1985). He further affirmed that sowing date has to be fixed in a way, so that the growth of plant coincide with temperatures favourable to the plant especially during grain formation period. Bolan, (1977) observed longer cob, having a mean length of 24cm with early sowing. He also reported that early sowing gave higher mean 1000 grain weight of 330g as compared to 220g of late planted maize.

Many workers have reported that date of sowing significantly influences the yield of maize. The general consensus is in favour of early sowing. George, (1943), El-Sharkewy *et al*, (1975), Bolan, (1977), Briggs and Attinaw, (1979) and Kamel *et al*, (1979) observed that date of sowing significantly affected grain yield. The highest grain yield was obtained from the earliest sowing date. There was a continuous reduction in yield with delay in sowing date.

A loss of 25 percent in yield was reported by Venon, (1953) with each week delay in sowing. A decrease in yield was reported by Benoit *et al*,(1965) with late planting independently of soil moisture level. Kumar, *et al*, (1982) reported from a result obtained at Bakura, that highest grain yield of maize was obtained from plots planted in Mid-September and that grain yield was reduced linearly with time as date of sowing was delayed up till mid-February. Farworth and Said, (1983) observed when they planted maize between February and April that highest yield of 7.33t/ha was obtained by the earliest date of sowing of February and the lowest yield was obtained by penultimate date of sowing of March.

2.4 Popping Percentage

Popping expansion refers to the volume of popped kernels obtained from a unit volume of unpopped kernels. The ability to pop is the unique characteristics that distinguishes popcorn from other types of corn (Brunson, 1955). It should be noted that some corn especially flint corn pops fairly well.

Exactly why popcorn pops is not well under stood. Weatherwax, (1922) believed that the ability to pop is conditioned by the relative proportion of the honey endosperm where the grains are embedded in a tough elastic colloidal material that confines and resist steam pressure generated within the granule upon heating, until it reaches explosive force.

Best result with popping was obtained when the grains contain about 13-14% moisture (Delorit, 1974). He further stated that, greatest expansion (28%) was obtained in small grain and at the moisture content of 11.0%.

Poor popping may result from insufficient or excessive amount of moisture (Delorit, 1974). The best temperature for popping as reported by Jugenheimer, (1975) ranges from 350^{0}f (176.7^{0}c) to 530^{0}f (276^{0}c) depending on the amount of popcorn popped at one time.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Experimental site

The experiment were conducted under irrigation during 1996/97 and 1997/98 dry seasons at Kadawa Irrigation Station of the Institute for Agricultural Research, Ahmadu Bello University, Zaria. The site is located in the Sudan savanna ecological zone of Nigeria (11^0 39'N, 08^0 02'E and 500m above sea level).

The soil of the experimental site is sandy loam, slightly acidic and low in organic carbon, total nitrogen, exchangeable cations and moderately high in available phosphorus. Details of the soil analysis are presented in Appendix I. The meteorological data for Kadawa during 1996/97 and 1997/98 dry seasons are presented in Appendix 2.

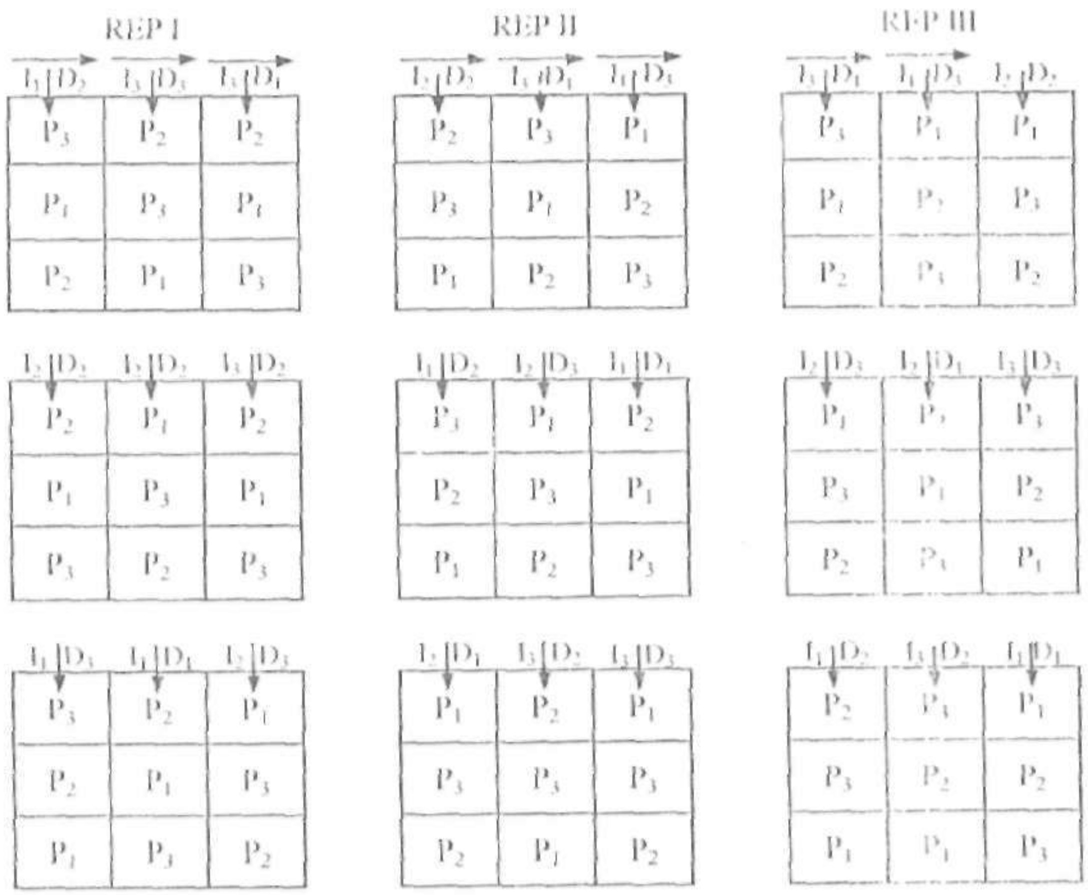
3.1.1 Treatments and Experimental Design

The treatments were made up of the combinations of three plant populations (44444, 53333 and 66666 plants per hectare), three irrigation intervals (5, 7 and 9 days) and three dates of sowing (Mid and End of February and Mid-March). The treatments were laid out in a split-plot design with the combination of irrigation interval and date of sowing in the main plots and plant population density assigned to the sub-plots. The treatments were replicated three times. (Figure 1).

3.1.2 Plot size

Each treatment was accomodated in a gross and net plots of 18 and $9m^2$ respectively. Each plot had four ridges at inter-row spacing of 75cm. Grain yield and other yield variables were estimated from the two inner ridges. While the two border rows formed the discard for sampling purposes.

FIG. 1: FIELD LAYOUT



I = IRRIGATION	**D = SOWING DATE**	**P = POPULATION**
I_1 = 5 days intervals	D_1 = Mid February	P_1 = 44,444
I_2 = 7 days intervals	D_2 = End of February	P_2 = 53,333
I_3 = 9 days intervals	D_3 = Mid-March	P_3 = 66,666

3.1.3 Variety

The popcorn variety used for the trials was pearl type, it is short, with thick kernel either rounded or flattened but always round at the crown and deep yellow in colour.

3.2 Cultural Practices

3.2.1 Land preparation

The experimental site was ploughed, harrowed to a fine tilth and ridged 75cm a part. The ridged land was then divided into the required plot sizes with channels provided for irrigation.

3.2.2 Population density

Three population densities 44,444, 53,333 and 66,666 plants per hectare were used.

3.2.3 Planting

The seeds were sown by hand at the rate of 3-4 seeds per hole. The crop was thinned to one plant per stand at 2 WAS.

3.2.4 Irrigation

Three irrigation intervals were used i.e. 5, 7 and 9-days, respectively. Irrigation treatment was imposed beginning from 4 WAS. At each irrigation the soil was brought to field capacity.

3.2.5 Weed control

Weed were manually controlled in the experimental plots at 3, 6 and 9 WAS.

3.2.6 Fertilizer application

Compound fertilizer (20:10:10) was applied at the rate of 120kgN, 60kgP_2O_5 and 60kg K_2O per hectare. Nitrogen was applied in two split doses, half at planting and the remaining half at 6 WAS by top dressing using urea.

3.2.7 Diseases and Pest Control

During the 1996/97 dry season, no serious diseases were observed. However, a mild stemborer infestation occurred and a broad spectrum insecticide (Perfeckthion) was used to control the pest. During 1997/98 season, mild cases of corn smut and rust damage were recorded at harvest.

3.3 Data Collection

3.3.1 Growth characters

Five plants were randomly picked from each sub-plot and tagged for the purpose of collecting data for certain growth and yield attributes.

3.3.2 Plant height (cm)

Plant height was measured from the tagged plants (using meter rule) from the ground level to the tip of the tallest leaf before tasseling at 4, 8 and 12 WAS.

3.3.3 Number of leaves per plant

Number of leaves per plant from the five tagged plants were counted and recorded at 4, 8 and 12 WAS.

3.3.4 Total dry matter(g)

Total dry matter per plant was determined at harvest, by sampling five plants per plot and oven-dried at 75^0C for two days.

3.3.5 Leaf area index (LAI)

This was determined at tasseling stage. The length and maximum breadth of a functional leaf were taken and multiplied by a factor 0.75. Five plants were sampled in each plot. The leaf area obtained from the individual leaves were added and then divided by the number of plant sampled. The resultant leaf area per plant was then multiplied by the total number of plants in one square meter ($1m^2$) and divided by the land area.

3.3.6 Days to 50% tasseling

The number of days when 50% of the plants in each plot had tasseled was recorded.

3.3.7 Days to 50% silking

This was taken when 50% of popcorn plant had silked.

3.3.8 Lodging count

It was taken on the day of harvest. A plant was considered lodged when it is inclined more than 45^0 from the vertical position or the stem broken below the ear. The lodged plant were counted.

3.4 Yield Components and Yield

3.4.1 Number of ears per plot

The number of ears from the net plot were hand harvested and counted.

3.4.2 Ear length (cm)

From the five tagged plants in each sub-plots treatment, five ears were randomly taken and their mean length taken and recorded.

3.4.3 Ear diameter (cm)

Five ears from the five tagged plants per plot were randomly taken and their mean diameter measured using vernier caliper.

3.4.4 Cob diameter (cm)

Mean cob diameter was measured from the five tagged plants. In each sub-plot treatment five cobs were randomly taken and their mean diameter measured and recorded using vernier caliper.

3.4.5 Kernel depth (cm)

This parameter was obtained by subtracting cob diameter from ear diameter and dividing by two (0logunde, 1982).

3.4.6 Grain weight per ear (g)

Grain obtained from five ears of the five tagged plants per plot were randomly taken and their mean weight measured and recorded.

3.4.7 1000-grain Weight (g)

1000 seeds from each treatment were randomly taken, weighed and their mean weight measured and recorded.

3.4.8 Shelling percentage

Shelling percentage of popcorn plant was obtained by:-

$$\text{Shelling \%} = \frac{\text{grain weight after shelling}}{\text{cob weight (un-shelled)}} \times 100$$

3.4.9 Popping percentage

To determine this parameter, 100 seeds were randomly sampled in each plot and popping was performed using 20ml vegetable oil per 100 seeds sample for a period of 3 minutes. Number of popped seeds were then counted and expressed as a popping percentage.

3.4.10 Popping expansion

To determine popping expansion, 100 seeds were randomly sampled in each plot and their volume measured. The seed were popped and the volume taken. Popping expansion was expressed as the ratio of the volume of popped kernel to unpopped one.

3.4.11 Harvest Index

It is the ratio of the seed yield to the total dry matter (TDM) calculated from the equation;

$$K = \frac{\underline{\text{grain yield from sample of TDM}} \times 100}{\text{x kg of TDM sample}}$$

Where k = harvest index

3.4.12 Grain yield (kg/ha)

The grain yield was computed by weighing the cleaned grains from the net plot. The values obtained were later expressed on per hectare basis.

3.5 Statistical analysis of data

The data collected were subjected to statistical analysis of variance and where 'F' test showed significant difference, the means of such treatments were then compared using Duncan Multiple Range Test (Duncan, 1955). Correlation co-efficient were worked out as described by Snedecor and Cochran, (1967) to determine the relationship between growth characters, yield components and grain yield. The direct and indirect contributions of the selected characters to popcorn growth and yields were determined using path-coefficient analysis.

CHAPTER FOUR

RESULTS

4.1 Plant Height

The mean plant height of popcorn during 1996/97 and 1997/98 dry seasons as influenced by population density, irrigation interval and date of sowing are shown in Table 1.

The variation due to population density was significant on plant height at all the sampling periods in 1997/98 but not in 1996/97 season. Each increase in population density was accompanied with an increase in plant height.

There was no significant difference observed in plant height throughout the sampling periods of 1996/97 dry season due to variation in irrigation intervals. However, the reverse occurred in all the sampling periods of 1997/98 dry season where significant differences were recorded. At 4 WAS, increasing irrigation interval from 5 to 7-days did not affect plant height significantly; a further increase to 9-day interval significantly increased plant height. At 8 and 12 WAS however, increasing irrigation interval from 5 to 7 or 7 to 9 were all found to be at par, but the 9-day interval produced significantly taller plants than the 5-day treatment.

The influence of dates of sowing on plant height was significant in all the sampling periods. At 4 WAS in 1996/97 season, delayed sowing from Mid to end of February or end of February to Mid-March were all found to be at par with each other though mid-March sowing produced significantly taller plants than end - of Feb. sowing; while at 4 WAS in 1997/98 season each delay in sowing from mid-February to Mid-March was accompanied with a significant increase in plant height. At 8 and 12 WAS in 1996/97 and 1997/98 seasons, delayed sowing from mid to end of February significantly increased plant height, a further delay to Mid-March did not affect this parameter. At 12 WAS in 1997/98 season, delayed sowing from mid to end of February did not affect plant height, a further delay to mid March significantly increased this parameter. There was no significant treatment interactions on plant height observed.

Table 1: Effect of population density, irrigation interval and date of sowing on plant height(cm).

Treatment	1996/97	1997/98	1996/97	1997/98	1996/97	1997/98
Population Density. (P)	4 WAS		8 WAS		12 WAS	
66,666	29.8	34.7a	95.9	82.3a	150.7	130.7a
53,333	29.3	30.5b	95.7	79.1b	150.5	125.8b
44,444	29.6	26.9c	95.7	75.7c	147.4	120.8c
SE ±	0.46	0.29	0.31	0.32	1.70	0.47
Irrigation Intervals days (I)						
5	29.1	29.4b	96.1	71.2b	150.3	123.9b
7	29.0	30.0b	95.4	76.2ab	147.6	124.6ab
9	29.4	32.7a	96.0	81.1a	150.8	129.7a
SE ±	0.93	0.81	0.87	0.86	3.28	1.50
Sowing date (D)						
Mid-Feb.	24.9b	26.3c	93.9b	77.0b	134.6b	124.7b
End of Feb.	30.5ab	31.8b	96.0a	79.9a	156.2a	125.0b
Mid-March	32.0a	34.0a	97.5a	80.3a	158.0a	130.6a
SE ±	0.93	0.81	0.87	0.86	3.28	1.50
Interactions						
I x D	NS	NS	NS	NS	NS	NS
I x P	NS	NS	NS	NS	NS	NS
D x P	NS	NS	NS	NS	NS	NS
I x D x P	NS	NS	NS	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS= Not significant.

4.2 Number of leaves per plant

The effect of plant population density, irrigation interval and date of sowing on number of leaves per plant are shown in Table 2.

The effect of varying population density on number of leaves per plant was significant at 4 WAS in both seasons, and at 8 and 12 WAS in 1997/98 seasons. At 4 WAS in 1996/97 season, increase in population density from 44,444 to 53,333 or 53,333 to 66,666 plants per hectare were found to be statistically similar but leaf number at 66666 plant density was significantly more than at 44444 plant/ha. At 4, 8 and 12 WAS in 1997/98 season each decrease in population density was accompanied with a significnt increase in number of leaves per plant.

Irrigation interval had no significant effect on number of leaves per plant at 4 WAS in 1997/98 and at 8 WAS in both seasons. But significant at 4 WAS in 1996/97 season and at 12 WAS in both seasons. At 4 WAS in 1996/97 season, increasing irrigation interval from 5 to 7-day interval or 5 to 9 - day were found to be at par with each other but leaf number at 7 day was significantly more than at 9-day interval. At 12 WAS in 1996/97 season, seven-day irrigation interval significantly resulted in higher number of leaves per plant than 5 or 9-days interval. However, 5 and 9-days irrigation intervals were found to be at par with each other, though leaf number at 5-day was significantly higher than at 9- day interval . Similarly in 1997/98 season, seven day irrigation interval resulted in significantly higher number of leaves per plant, followed by 5-day interval. The least number of leaves per plant was significantly observed with 9-day irrigation intervals.

Date of sowing was significant on number of leaves per plant at all the sampling periods except at 8 and 12 WAS in 1996/97 season. At 4 WAS in both seasons, delayed sowing from mid to end of February significantly increased number of leaves per plant; a further delay to mid-March did not affect this parameter. At 8 and 12 WAS in 1997/98 season, delayed sowing from mid to end of Febrary significantly increased the number of leaves per plant; a further delay to mid-March reduced this parameter significantly.

Table 2: Effect of population density, irrigation interval and date of sowing on number of leaves per plant.

Treatment	1996/97	1997/98	1996/97	1997/98	1996/97	1997/98
Population Density. (P)	4 WAS		8 WAS		12 WAS	
66,666	5.32b	6.28c	9.29	8.77c	9.74	8.93c
53,333	5.45ab	6.46b	9.39	9.03b	9.79	9.17b
44,444	5.54a	6.72a	9.39	9.31a	9.79	9.41a
SE ±	0.05	0.02	0.07	0.02	0.06	0.02
Irrigation Intervals day (1)						
5	5.38ab	6.40	9.38	9.00	9.77b	9.16b
7	5.49a	6.80	9.40	9.20	9.86a	9.24a
9	5.11b	6.30	9.37	8.90	9.67b	9.10c
SE ±	0.10	0.17	0.08	0.11	0.00	0.01
Sowing date (D)						
Mid-Feb.	5.17b	6.03b	9.20	8.92b	9.73	9.00b
End of Feb.	5.47a	6.74a	9.47	9.49a	9.82	9.47a
Mid-March	5.67a	6.70a	9.39	8.70b	9.79	9.04b
SE ±	0.10	0.17	0.08	0.11	0.04	0.01
Interactions						
I x D	NS	NS	NS	**	NS	NS
I x P	NS	NS	NS	NS	NS	NS
D x P	NS	NS	NS	NS	NS	NS
I x D x P	NS	NS	NS	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS= Not significant.

3. **=significant at P = 0.01.

Table 3: Interaction between irrigation interval and date of sowing on number of leaves per plant at 8 WAS in 1997/98 season.

	Sowing dates		
	Mid-Feb.	End of Feb.	Mid-March
Irrigation intervals days (1)			
5	8.70d	9.30b	8.70d
7	9.30b	9.70a	9.00c
9	8.70d	9.00c	8.30c
SE $\pm$	0.09		

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

A significant interaction between irrigation interval and date of sowing at 8 WAS in 1997/98 season was observed (Table 3). At the same date of sowing when irrigation interval were varied, it showed a significant increase in number of leaves per plant with increase in irrigation interval from 5 to 7 -days; a further increase to 9-day interval significantly reduced the number of leaves per plant. When the various dates of sowing were considered at fixed irrigation intervals, it was observed that delayed sowing from mid to end of February significantly increased the number of leaves per plant; a further delay to Mid-March reduced this parameter significantly.

4.3 Total dry matter

Differences due to population density, irrigation interval and date of sowing as they affect TDM per plant at harvest are presented in Table 4.

The differences in TDM per plant at harvest was significant during 1997/98 and combined analysis but not in 1996/97. Decreasing population density from 66,666 to 53,333 plants per hectare was not significant; a further decrease to 44,444 plants per hectare significantly reduced TDM per plant.

There was no significant difference in TDM per plant observed due to variation in irrigation interval in both seasons including combined analysis.

The influence of date of sowing on TDM per plant was significant during 1997/98 season only. Delayed sowing from Mid to end of February were found to be at par with each other but TDM at end of February sowing was significantly higher than at Mid-February sowing; a further delay to mid-March significantly reduced TDM per plant at harvest.

A significant interaction was observed between irrigation interval and date of sowing on TDM per plant for combined analysis (Table 5). When the same date of sowing was examined at different irrigation intervals; it was observed that increaseing irrigation interval from 5 to 7- day resulted in a significant increase in TDM per plant; a further increase to 9-day, significantly decreased this parameter. In case of date of sowing; delayed sowing from mid-to end of February did not affect this parameter at 5 and 7-day interval; a further delayed to mid-March significantly reduced this parameter. At 9-day interval however , delay sowing from mid-February to mid-March did not affect this parameter.

4.4 Leaf area index

Mean of LAI at tasseling as influenced by population density, irrigation interval and date of sowing in both seasons and combined analysis are presented in Table 6.

Analysed data revealed that the differences due to population density was significant in both seasons and combined analysis. Each increase in population density from 44,444 to 66,666 plants per hectare was accompanied with a significant increase in LAI at tasseling.

Similarly irrigation interval significantly influenced LAI in both seasons and combined analysis. Increasing irrigation from 5 to 7-day interval significantly increased LAI, a further increase to 9-day did not affect this parameter in 1996/97 season. In 1997/98 season however, increase in irrigation interval from 5 to 9 or 7 to 9 were all found to be at par with each other though 7 and 9 - days interval singnificantly produced higher LAI than at 5 - day. For combined analysis, 7-day irrigation interval resulted in a significantly higher LAI than 9-day, the least LAI was recorded at 5-day interval.

The influence of date of sowing on LAI at tasseling was significant in both seasons. In 1996/97 season delayed sowing from mid-to end of February or mid- February to mid-March were all found to be at par with each other but LAI at end of February sowing was significantly more than at mid-February sowing. In 1997/98 season however, delayed sowing from Mid to end of February significantly increased the LAI; a further delay to Mid-March decreased this parameter.

Interaction between irrigation interval and date of sowing in 1996/97 season was observed (Table 7). When the same date of sowing was considered at varying irrigation interval, it showed an increase in LAI from 5 to 7-day interval; a further increase to 9-day interval significantly decreased this parameter. When the various date of sowing were considered, a significant increase in LAI was observed as date of sowing were delayed from mid to end of February, a further delay to mid-March did not affect this parameter significantly at 7-day irrigation interval. At 5 and 9-days intervals changes in date of sowing from mid to end of February did not affect the LAI significantly; however, change in date of sowing to mid-March significantly increased the LAI.

Table 4: Effect of population density, irrigation interval and date of sowing on TDM(g) per plant at harvest.

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	119.6	97.3a	105a
53,333	113.5	97.1a	104a
44,444	108.9	81.2b	97.2b
SE ±	3.70	0.94	2.70
Irrigation Intervals days(1)			
5	113.5	90.4	99.7
7	115.4	92.4	106.0
9	113.1	88.2	100.9
SE ±	7.00	2.46	5.20
Sowing date (D)			
Mid-Feb.	111.1	90.0a	96.9
End of Feb.	124.8	97.3a	107.9
Mid-March	106.1	82.7b	101.7
SE ±	7.00	2.46	5.20
Interactions			
I x D	NS	NS	*
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

3. * = Significant at P = 0.05.

Table 5: Interaction between irrigation interval and dates of sowing on TDM per plant at harvest of popcorn (Combined analysis)

Treatment	Sowing date		
	Mid-Feb.	End of Feb.	Mid-March
Irrigation intervals days (1)			
5	88.12cd	98.9bcd	79.60d
7	134.9a	115.7ab	108.0bc
9	92.8bcd	92.0bcd	84.4cd
SE ±	5.2		

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Irrigation interval and date of sowing interaction for combine analysis was significant (Table 8). At the same date of sowing, when compared at varying irrigation interval; increase in irrigation interval from 5 to 9 day, at mid-February sowing did not affect this parameters; at end of February sowing, increase in irrigation interval from 5 to 7-day significantly increased this parameter; a further increase to 9-day decreased the LAI; at mid-March sowing however, increase in irrigation interval from 5 to 7-day interval significantly increased this parameter; a further increase to 9-day did not affect the LAI. When the various date of sowing were considered, a significant increase in the LAI was observed as date of sowing were delayed from mid to end of February; a further delay to Mid-March decreased this parameter at 7-day irrigation interval. At 5 and 9-day intervals changes in date of sowing from mid to end of February did not affect this parameter; however; change in date of sowing to mid--March significantly increased the LAI

4.5 Days to 50% tasseling

Mean days to 50% tasseling as influenced by population density, irrigation interval and date of sowing of popcorn in 1996/97 and 1997/98 and combined analysis are presented in Table 9.

Table 6: Effect of population density, irrigation interval and date of sowing on LAI at tasseling.

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	3.49a	3.37a	3.42a
53,333	3.37b	3.30b	3.37b
44,444	3.32c	3.22c	3.29c
SE ±	0.02	0.06	0.013
Irrigation Intervals days (I)			
5	3.37b	3.26b	3.29c
7	3.44a	3.29ab	3.32a
9	3.39a	3.29ab	3.32b
SE ±	0.02	0.02	0.02
Sowing date (D)			
Mid-Feb.	3.39ab	3.28b	3.32
End of Feb.	3.44a	3.56a	3.38
Mid-March	3.37b	3.25b	3.33
SE ±	0.02	0.02	0.02
Interactions			
I x D	**	NS	**
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

3. ** = Significant at P = 0.01.

Table 7: Interaction between irrigation interval and dates of sowing on LAI at tasseling in 1996/97 season.

Treatment	Sowing date		
	Mid-Feb.	End of Feb.	Mid-March
Irrigation intervals days (1)			
5	3.26e	3.30e	3.40cd
7	3.34de	3.60a	3.53abc
9	3.30e	3.30e	3.49bc
SE ±	0.03		

Table 8: Interaction between irrigation interval and dates of sowing on LAI at tasseling (combined analysis).

Treatment	Sowing date		
	Mid-Feb.	End of Feb.	Mid-March
Irrigation intervals days (1)			
5	3.25e	3.31de	3.40c
7	3.31de	3.62a	3.53b
9	3.28de	3.34cd	3.49b
SE ±	0.02		

Means followed by the same letter(s) within a tretment group are not significantly different at 0.05 level of probability using DMRT.

The variation in days to 50% tasseling due to population density were significant in 1997/98 and combined analysis but not in 1996/97. Each increase in population density from 44,444 to 66,666 plants per hectare were accompanied with a significant decrease in number of days to 50% tasseling.

Irrigation interval significantly affected days to 50% tasseling in 1997/98 season only. Increasing irrigation interval from 5 to 7-day significantly increased number of days to 50% tasseling, a further increase to 9-day did not affect this parameter.

The influence of date of sowing were significant on days to 50% tasseling in 1997/98 and combined analysis but not in 1996/97. In 1997/98 season, Mid-February sowing took significantly higher number of days to 50% tasseling, the least number of days to 50% tasseling was observed with the end of February sowing. For combined analysis each delay in sowing from mid-February to Mid March was accompanied with a significant decrease in number of days to 50% tasseling.

Interaction between irrigation interval and date of sowing in 1997/98 season was significant (Table 10). At the same date of sowing when varying irrigation interval; it showed no significant difference, on days to 50% tasseling from 5 to 9 day interval. When the various dates of sowing were considered, a significant decrease in number of days to 50% tasseling was observed as date of sowing were delayed from mid to end of February; a further delay to mid-March did not affect this parameter at 5 and 9-day irrigation intervals. At 9-day irrigation interval however, neither delay in sowing from mid to end of February or end of February to mid-March affected this parameter.

4.6 Days to 50% Silking

Mean number of days to 50% silking as affected by population density, irrigation interval and date of sowing in 1996/97 and 1997/98 seasons and combined analysis are presented in Table 11.

The effect of population density on number of days to 50% silking were significant in 1997/98 season and combined analysis and not in 1996/97. In 1997.98 season, each increase in population

density was accompanied with a significant reduction in days to 50% silking. For combined analysis, no significant difference observed between 66,666 and 53,333 plants per hectare; a further decrease in population to 44,444 plants per hectare significantly increased days to 50% silking.

The difference in days to 50% silking due to variation in irrigation interval were significant during 1997/98 season and combined analysis and not in 1996/97. Varying irrigation interval from 5 to 7-day significantly increased this parameter, a further increase to 9-day interval decrease number of days to 50% silking significantly. For combined analysis, varying irrigation interval from 5 to 7 - day, were found to be at par with each other though days to 50% silking was significantly higher at 7-day than at 5-day interval; a further increase to 9-day interval significantly decreased this parameter.

The variation in days to 50% silking due to date of sowing were significant in both seasons and combined analysis. In 1996/97 season, delayed sowing from mid to end of February or mid- of February to mid-March were all found to be at par with each other but days to 50% silking at end of Feb. Sowing was significantly more than at mid-February sowing. In 1997/98 season and combined analysis, each delay in sowing form mid-February to mid-March were accompanied with a significant decrease in days to 50% silking. None of the treatment interactions were significant.

Table 9: Effect of population density, irrigation interval and date of sowing on days to 50% tasseling .

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	66.6	62.2c	64.6c
53,333	66.8	64.9b	65.9b
44,444	67.2	67.1a	66.9a
SE ±	0.38	0.13	0.28
Irrigation Intervals days(1)			
5	67.0	63.7b	65.2
7	66.7	65.3a	66.2
9	67.0	65.2a	65.9
SE ±	0.56	0.33	0.46
Sowing date (D)			
Mid-Feb.	69.5	66.8a	68.1a
End of Feb.	64.2	62.9c	65.8b
Mid-March	67.0	64.5b	63.5c
SE ±	0.56	0.33	0.46
Interactions			
I x D	NS	**	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

3. ** = Significant at P = 0.01.

Table 10: Interaction between irrigation interval and dates of sowing on days to 50% tasseling in 1997/98 dry seasons..

Treatment	Sowing date		
	Mid-Feb.	End of Feb.	Mid-March
Irrigation intervals days (1)			
5	66.3ab	64.5bc	63.6cd
7	67.6a	64.5bc	63.6cd
9	66.4ab	64.7bc	63.2cd
SE ±	0.76		

Means followed by the same letter(s) within a treatment group are not significantly different at 0.05 level of probability using DMRT.

4.7 Lodging count

The effect of population density, irrigation interval and date of sowing on the number of popcorn lodged in both seasons and combined analysis are presented in Table 7.

Population density had significant effect on lodging count in 1997/98 season and combined analysis and not in1996/97 Each increase in population density from 44,444 to 66,666 plants per hectare were accompanied with a significant increase in number of plants that lodged.

Table 11: Effect of population density, irrigation interval and date of sowing on days to 50% silking.

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	72.7	69.6c	71.2b
53,333	73.4	71.9b	72.9b
44,444	73.7	74.7a	74.3a
SE ±	0.79	0.19	0.31
Irrigation Intervals days (1)			
5	95.0	70.9b	72.5a
7	72.1	73.9a	73.9a
9	73.6	71.3b	71.9b
SE ±	0.62	0.55	0.53
Sowing date (D)			
Mid-Feb.	97.1ab	76.0a	76.6a
End of Feb.	95.1a	72.5b	73.4b
Mid-March	68.6b	67.7c	68.3c
SE ±	0.62	0.55	0.53
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

The effect of irrigation interval on lodging count during 1996/97 season was significant but not in 1996/97 and combined analysis. Increase in irrigation interval from 5 to 7 - day did not affect lodging count, a further increase to 9-day interval significantly decreased this parameter.

Date of sowing had significant effect on lodging count in both seasons. In 1996/97 season delayed sowing from mid to end February significantly increase lodging count; a further delay to mid-March significantly decreased number of plant that lodged. In 1997/98 season however, delayed sowing from mid to end of February or end of February to Mid-March were all found to be at par with each other though end of February sowing produced significantly higher lodging count than mid-March sowing. There was no significant treatment interactions on lodging count.

4.8 Number of ears per plot

Mean number of ears per plot as influenced by population density, irrigation interval and date of sowing are shown in Tables 13.

The effect of varying population density on number of ears per plot were significant in both seasons and combined analysis. In 1996/97 season increase in population density from 44,444 to 53,333 plants per hectare did not affect this parameter, a further increase to 66,666 plants per hectare significantly increased number of ears per plot. In 1997/98 season and combined analysis, each increase in population from 44,444 to 66,666 plants per hectare were accompanied with a significant increase in number of ears per plot.

Irrigation interval significantly affected number of ears per plot during 1996/97 season only. Increasing irrigation interval from 5 to 7-day significantly increased number of ears per plot; a further increase to 9-day interval significantly reduced this parameter.

Table 12: Effect of population density, irrigation interval and date of sowing on lodging count.

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	9.37	7.50a	9.33a
53,333	8.87	4.22b	6.35b
44,444	8.23	2.07c	4.48c
SE ±	0.49	0.18	0.29
Irrigation Intervals days(1)			
5	10.9a	4.90	6.59
7	9.07a	4.70	6.96
9	6.60b	4.30	6.61
SE ±	0.99	0.47	0.84
Sowing date (D)			
Mid-Feb.	8.04b	3.72b	5.93
End of Feb.	10.2a	5.15a	7.63
Mid-March	8.30b	4.93ab	6.61
SE ±	0.99	0.47	0.84
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 13: Effect of population density, irrigation interval and date of sowing on number of ears per plot.

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	30.7a	24.3a	34.5a
53,333	28.0b	27.3b	27.9b
44,444	27.5b	21.1c	22.4c
SE ±	0.60	0.50	0.59
Irrigation Intervals days (1)			
5	28.6b	27.7	28.9
7	34.0a	28.8	27.7
9	23.8c	26.3	28.2
SE ±	1.46	1.90	1.71
Sowing date (D)			
Mid-Feb.	27.3	28.2	28.2
End of Feb.	31.9	28.8	29.9
Mid-March	27.0	25.7	26.8
SE ±	1.46	1.90	1.71
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

The influence of date of sowing on number of ears per plot were not significant in both seasons and combined analysis. Similarly none of the treatments interactions on number of ears per plot were significant.

4.9 Ear length

The variation in ear length due to population density, irrigation interval and date of sowing are shown in Table 14.

Population density had significant effect on ear length in 1997/98 and combined analysis. Increase in population density from 44,444 to 53,333 plants per hectare did not affect this parameter, a further increase to 66,666 plants per hectare significantly reduced ear length.

Irrigation interval significantly affected ear length in 1997/98 season only and not in 1996/97 and combined analysis. Increase in irrigation interval from 5 to 7 - day did not affect this parameter; a further increase to 9-day interval decreased this parameter significantly.

There was no significant variation in ear length observed due to date of sowing in both seasons and combined analysis. Similarly, there were no significant treatment interactions on ear length.

4.10 Ear diameter

Mean ear diameter as influenced by population density irrigation interval and date of sowing in both seasons and combined analysis are presented in Table 15.

Population density had significant effect on ear diameter in both seasons and combined analysis. In 1996/97 season. Increase in population density from 44,444 to 53,333 plants per hectare significantly increased ear diameter; a further increase to 66,666 plants per

Table 14: Effect of population density, irrigation interval and date of sowing on ear length (cm).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	13.4	20.4b	16.8b
53,333	13.8	22.8a	18.0a
44,444	13.6	21.7a	17.8a
SE ±	0.27	0.18	0.22
Irrigation Intervals days(1)			
5	13.2	21.6a	17.5
7	14.4	22.5a	18.0
9	13.1	21.1b	17.2
SE ±	0.42	0.32	0.37
Sowing date (D)			
Mid-Feb.	13.7	21.9	17.8
End of Feb.	13.7	22.0	17.3
Mid-March	13.4	21.1	17.6
SE ±	0.42	0.32	0.37
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 15: Effect of population density, irrigation interval and date of sowing on ear diameter (cm).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	2.70b	2.29c	2.53b
53,333	2.71b	2.53b	2.64a
44,444	2.81a	2.70a	2.72a
SE ±	0.03	0.02	0.03
Irrigation Intervals days (1)			
5	2.74	2.54a	2.62
7	2.76	2.55a	2.64
9	2.72	2.43b	2.62
SE ±	0.03	0.03	0.03
Sowing date (D)			
Mid-Feb.	2.73	2.53b	2.66a
End of Feb.	2.77	2.61a	2.68a
Mid-March	2.73	2.36c	2.55b
SE ±	0.03	0.03	0.03
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 16: Effect of population density, irrigation interval and date of sowing on cob diameter (cm).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	2.38b	1.99c	2.21
53,333	2.38ab	2.17b	2.37
44,444	2.46a	2.37a	2.78
SE ±	0.03	0.02	0.02
Irrigation Intervals days (I)			
5	2.39	2.16b	2.26
7	2.43	2.29a	2.32
9	2.31	2.08b	2.27
SE ±	0.04	0.03	0.04
Sowing date (D)			
Mid-Feb.	2.41	2.15b	2.28a
End of Feb.	2.42	2.29a	2.35a
Mid-March	2.38	2.08b	2.24b
SE ±	0.04	0.03	0.04
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Varying population density had significant effect on cob diameter in both seasons. Increase in population density from 44,444 to 53,333 or 53,333 to 66,666 plants per hectare were found to be at par with each other but 44444 plants/ha produced significantly higher cob diameter than 53,333 plants/ha. In 1997/98 season however, each increase in population density from 44,444 to 66,666 plants per hectare was accompanied with a significant decrease in cob diameter.

Irrigation interval significantly influenced cob diameter during 1997/98 season only. Increasing irrigation interval from 5 to 7-day significantly increased cob diameter, a further increase to 9-day reduced this parameter significantly.

The influence of date of sowing on cob diameter were significant in 1997/98 and combined analysis but not in 1996/97. In 1997/98 season, delayed sowing from mid to end of February significantly increased cob diameter, a further delay to mid-March decreased cob diameter significantly. For combined analysis delayed sowing from mid to end of February did not affect this parameter; a further delay to mid-March significantly decreased this parameter. None of the treatments interactions on cob diameter were significant.

4.12 Shelling percentage

Mean shelling percentage of popcorn as influenced by population density, irrigation interval and dates of sowing in both seasons and combined analysis are shown in Table 17.

Population density had significant effect on shelling percentage in 1997/98 season only. Each increase in population density from 44,444 to 66,666 plants per hectare was accompanied with a significant increase in shelling percentage.

Variation in irrigation interval had no significant effect on shelling percentage in both seasons and combined analysis .

The effect of date of sowing on shelling percentage was significant in 1997/98 season only. Delayed sowing from mid to end of February did not affect this parameter; a further delay to mid-March significantly reduced shelling percentage. There was no significant treatment interactions on shelling percentage.

4.13 Kernel depth

The effect of population density, irrigation interval and date of sowing on kernel depth are shown in Table 18.

Analysis of the data, showed a non-significant effect of all the treatments on kernel depth. Similarly there was no significant treatment interactions on kernel depth.

4.14 Popping percentage

The data on popping percentage in 1996/97 and 1997/98 and combined analysis as influenced by population density, irrigation interval and date of sowing are presented in Table 19.

Population density had significant effect on popping percentage in 1997/98 season and combined analysis. Each increase in population density from 44,444 to 66,666 plants per hectare significantly increased popping percentage.

Variation in irrigation interval had significant effect on popping percentage in 1997/98 season and combined analysis but not in 1996/97. Increasing irrigation interval from 5 to 7-day significantly increased popping percentage; a further increase to 9-day decreased this parameter significantly in 1997/98 season. For combined analysis however, increase in irrigation interval from 5 to 7-day did not affect this parameter; a further increase to 9-day significantly decreased popping percentage.

Table 17: Effect of population density, irrigation interval and date of sowing on shelling percentage (%).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	48.5	74.8a	59.9
53,333	47.1	69.8b	59.5
44,444	47.0	63.5c	56.0
SE ±	2.06	0.74	1.54
Irrigation Intervals days (I)			
5	48.5	68.5	57.9
7	50.1	70.6	58.8
9	44.1	68.7	58.6
SE ±	2.58	2.08	2.33
Sowing date (D)			
Mid-Feb.	46.9	71.5a	60.2
End of Feb.	49.0	74.4a	60.6
Mid-March	46.9	62.1b	54.5
SE ±	2.58	2.08	2.33
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 18: Effect of population density, irrigation interval and date of sowing on kernel depth (cm).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	0.19	0.33	0.26
53,333	0.18	0.32	0.25
44,444	0.16	0.27	0.22
SE ±	0.10	0.02	0.02
Irrigation Intervals days (I)			
5	0.18	0.31	0.22
7	0.18	0.35	0.27
9	0.17	0.27	0.24
SE ±	0.02	0.03	0.03
Sowing date (D)			
Mid-Feb.	0.18	0.31	0.24
End of Feb.	0.18	0.35	0.25
Mid-March	0.17	0.27	0.23
SE ±	0.02	0.03	0.03
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 19: Effect of population density, irrigation interval and date of sowing on popping percentage (%).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	76.9	76.7a	79.3a
53,333	75.9	69.0b	72.8b
44,444	75.0	51.2c	60.4c
SE ±	1.57	1.55	1.32
Irrigation Intervals days (1)			
5	76.3	63.3b	70.2a
7	77.4	73.1a	74.6a
9	74.0	60.5b	67.8b
SE ±	1.71	2.34	2.12
Sowing date (D)			
Mid-Feb.	97.4a	64.2	71.0a
End of Feb.	78.8a	69.7	73.6a
Mid-March	71.5b	63.0	67.9b
SE ±	1.71	2.34	2.12
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

The influence of date of sowing on popping percentage in 1996/97 and combined analysis were significant. Delayed sowing from mid to end of February did not affect this parameter; a further delay to mid-March decreased this parameter significantly. None of the treatment interactions were significant on popping percentage.

4.15 Popping expansion

The mean popping expansion as influenced by population density, irrigation interval, and date of sowing are presented in Table 20.

Population density had significant effect on popping expansion in 1997/98 season and combined analysis but not in 1996/97. Each increase in population density from 44,444 to 66,666 plants per hectare were accompanied with a significant increase in popping expansion.

There was no significant effect on popping expansion due to variation in irrigation interval in both seasons and combined analysis.

The influenced of date of sowing on popping expansion were significant in both seasons. Delayed sowing from mid to end of February significantly increased popping expansion; a further delay to mid-March decreased this parameter significantly. There was no significant treatments interaction on popping expansion.

4.16 Weight of grain per ear

Weight of grain per ear in 1996/97 and 1997/98 seasons and combined analysis as influenced by population density irrigation interval and date of sowing are presented in Table 21.

The effect of population density on weight of grain per ear was significant in 1997/98 season only. Each increase in population density from 44,444 to 66,666 plants per hectare was accompanied with a significant decrease in weight of grain per ear.

Similarly variation in irrigation interval on weight of grain per ear was significant in 1997/98 season only. Increasing irrigation interval from 5 to 7-day did not affect this parameter; a further increase to 9-day decreased this parameter significantly.

Date of sowing significantly influenced weight of grain per ear in 1997/98 season only. Delayed sowing from mid to end of February did not affect this parameter; a further delay to mid-March decreased weight of grain per ear significantly. None of the treatment interactions on weight of grain per ear were significant.

4.17 <u>1000-grain weight</u>

The data on 1000-grain weight in 1996/97 and 1997/98 seasons and combined analysis as influenced by population density, irrigation interval and date of sowing are presented in Table 22.

Population density significantly affected 1000 grain weight and combined analysis. Each increase in population density from 44,444 to 66,666 plants per hectare was accompanied with a significant decrease in 1000 grain weight.

Varying irrigation interval had no significant effect on 1000-grain weight in both seasons and combined analysis.

Date of sowing significantly affected 1000 grain weight in 1997/98 season and combined analysis but not in 1996/97. In 1997/98 season, delayed sowing from mid to end of February significantly increased 1000 grain weight, a further delay to mid-March significantly decreased this parameter. For combine analysis end of February sowing resulted in significantly higher 1000 grain weight than mid-February sowing. The least 1000 grain weight was significantly recorded with mid-March sowing. None of the treatment interactions on 1000 grains weight were significant.

Table 20: Effect of population density, irrigation interval and date of sowing on popping expansion (cm^3).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	10.0	9.80a	10.4a
53,333	9.94	7.20b	8.52b
44,444	9.34	5.10c	6.85c
SE ±	0.27	0.23	0.19
Irrigation Intervals days(I)			
5	9.67	7.30	8.31
7	10.0	7.60	8.82
9	9.63	7.20	8.62
SE ±	0.39	0.38	0.39
Sowing date (D)			
Mid-Feb.	9.60b	7.23b	8.38
End of Feb.	10.2a	8.58a	9.10
Mid-March	9.50c	6.34c	8.28
SE ±	0.39	0.38	0.39
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 21: Effect of population density, irrigation interval and date of sowing on Weight of grain per ear (g).

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	29.1	26.1c	28.4
53,333	29.3	31.8b	31.4
44,444	30.3	37.9a	32.1
SE ±	1.97	0.77	1.49
Irrigation Intervals days(1)			
5	30.6	33.1a	31.1
7	31.1	33.5a	31.3
9	27.0	29.1b	29.5
SE ±	2.81	0.91	2.15
Sowing date (D)			
Mid-Feb.	29.1	33.5a	32.2
End of Feb.	31.8	35.5a	32.3
Mid-March	27.7	26.9b	27.4
SE ±	2.81	0.91	2.15
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

4.18 Harvest index

Mean harvest index as influenced by population density, irrigation interval and date of sowing during both seasons and combined analysis are presented in Table 23.

Population density had significant effect on harvest index during 1997/98 season and combined analysis but not in 1996/97. In 1997/98 season, each increase in population density from 44,444 to 66,666 plants per hectare was accompanied with a significant increase in harvest index. For combined analysis, increase in population density from 44,444 to 53,333 plants per hectare did not affect this parameter; a further increase 66,666 plants per hectare significantly increased harvest index.

The influence of irrigation interval and date of sowing on harvest index were not significant in both seasons and combined analysis. Similarly there was no significant treatment interactions on harvest index.

4.19 Grain yield

The variation in grain yield (kg/ha) during 1996/97 and 1997/98 and combined analysis as affected by population density, irrigation interval and date of sowing are shown in Table 24.

Population density had significant effect on grain yield (kg/ha) in 1997/98 season and combined analysis but not in 1996/97. In 1997/98 season, each increase in population density from44,444 to 66,666 plants per hectare was accompanied with a significant increase in grain yield (kg/ha). For combined analysis, increase in population density from 44,444 to 53,333 were found to be at par with each other; but grain yield at 53,333 plant density was significantly more than at 44,444 plant/ha a further increase to 66,666 plants per hectare significantly increased grain yield (kg/ha).

Table 22: Effect of population density, irrigation interval and date of sowing on 1000 grain Weight.

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	137.8	141.2c	137.2c
53,333	138.6	150.0b	146.7b
44,444	140.0	159.1a	155.6a
SE ±	2.27	1.28	1.18
Irrigation Intervals days(1)			
5	139.6	150.5	146.2
7	140.2	150.6	146.9
9	136.2	149.5	146.4
SE ±	3.38	1.28	1.42
Sowing date (D)			
Mid-Feb.	136.3	147.1b	146.0b
End of Feb.	144.4	154.9a	150.9a
Mid-March	135.3	146.3b	142.6c
SE ±	3.38	1.28	1.42
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 23: Effect of population density, irrigation interval and date of sowing on harvest index (g) .

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	0.18	0.38a	0.28a
53,333	0.17	0.33b	0.25b
44,444	0.17	0.26c	0.22b
SE ±	0.01	0.01	0.013
Irrigation Intervals days(1)			
5	0.18	0.33	0.25
7	0.19	0.34	0.26
9	0.17	0.30	0.24
SE ±	0.02	0.12	0.014
Sowing date (D)			
Mid-Feb.	0.18	0.32	0.25
End of Feb.	0.18	0.35	0.26
Mid-March	0.17	0.31	0.25
SE ±	0.02	0.12	0.014
Interactions			
I x D	NS	NS	NS
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

Table 24: Effect of population density, irrigation interval and date of sowing on grain yield (kg/ha)

Treatment	1996/97	1997/98	Combined
Population density (P)			
66,666	1288.3	1414.1a	1387.1a
53,333	1254.7	1246.0b	1218.7b
44,444	1249.1	1031.0c	1116.2b
SE ±	55.8	31.3	44.2
Irrigation Intervals days(1)			
5	1231.1	1194.0	1228.1
7	1360.1	1333.7	1311.0
9	1200.8	1163.7	1182.9
SE ±	114.7	59.3	94.1
Sowing date (D)			
Mid-Feb.	1243.5b	1367.9a	1309.4a
End of Feb.	1424.7a	1532.4a	1478.6a
Mid-March	1123.8b	791.3b	934.0b
SE ±	114.7	59.3	94.1
Interactions			
I x D	NS	NS	*
I x P	NS	NS	NS
D x P	NS	NS	NS
I x D x P	NS	NS	NS

1. Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significant using DMRT.

2. NS = Not significant.

3. * = Significant at P = 0.05.

Table 25: Interaction between irrigation interval and dates of sowing on grain yield (kg/ha), (Combined analysis).

Treatment	Sowing date		
	Mid-Feb.	End of Feb.	Mid-March
<u>Irrigation intervals days (1)</u>			
5	1150.5c	1492.8ab	1082.7c
7	1308.0abc	1553.0a	1062.3c
9	1293.6abc	1227.3bc	1085.1c
SE ±	94.1		

Means followed by the same letter(s) are not significantly different at 0.05 level of probability using DMRT.

Irrigation interval had no significant effect on grain yield (kg/ha) in both seasons and combined analysis.

The effect of varying date of sowing on grain yield (kg/ha) was significant in both seasons and combined analysis. In 1996/97 season, delayed sowing from mid to end of February significantly increased grain yield (kg/ha); a further delay to mid-March reduced this parameter. In 1997/98 season and combined analysis however, delayed sowing from mid to end of February were found to be at par with each other; though grain yield at end of February sowing was significantly higher than sowing at mid-February, a further delay to mid-March decreased this parameter significantly.

A significant interaction was observed between irrigation interval and date of sowing on grain yield for combined analysis(Table 25). When the same date of sowing was examined at different irrigation interval; it showed no significant difference when irrigation interval was varied from 5 to 9-day, at mid-February and mid-March sowing. At end of February sowing however, varying irrigation interval from 5 to 7-day were found to be at par with each other; a further increase to 9-day significantly reduced this parameter. When date of sowing are considered, delayed sowing from mid to end of February at 5-day irrigation intervals significantly increased grain yield (kg/ha), a further increase to 9-day reduced this parameter. At 7-day irrigation interval, delayed sowing from mid to end of February did not affect grain yield (kg/ha), a further delay to mid-March decreased this parameter. No significant difference observed as date of sowing were delayed from mid-February to mid-March at 9- day irrigation interval.

4.20 Correlation studies

The simple correlation matrices among some yield and growth parameters of popcorn in 1996/97 and 1997/98 seasons are shown in Tables 26 and 27 respectively. In 1996/97 season, popcorn grain yield was highly significant and positively correlated (P=0.01) with TDM, kernel depth, weight of grain per ear and 1000 grain weight. The number of ears per plot was significant and positively correlated (P=0.05) with grain yield (kg/ha). However, no significant correlation was observed between grain yield (kg/ha) and plant height at 12 WAS, number of leaves per plant, LAI, days to 50% silking, ear length, ear diameter, cob diameter, shelling percentage, weight of grain per ear and harvest index. In 1997/98 season however, a highly significant and positive correlation (p=0.01) were obtained between popcorn grain yield (kg/ha) and plant height at 12 WAS, LAI, TDM, days to 50% silking, number of ears per plot and weight of grain per cob was significant and positively correlated (p=0.05) with grain yield (kg/ha). Similarly, there was no significant correlation between popcorn grain yield (kg/ha) and number of leaves per plant, ear length, ear diameter, cob diameter, kernel depth, shelling percentage, 1000 grain weight and harvest index.

The percentage contribution of individual growth parameters as well as combination of characters to yield (Table 28) revealed that moderate individual contributions were made by TDM and LAI which ranges from13.8 to 15.6 and 1.57 to 24.6%. The lowest contribution of -5.04 and 7.73% was made by plant height. The combination of plant height and LAI, plant height and TDM, LAI and plant height, LAI and TDM, TDM and plant height and TDM and LAI contributed 0.12 and 0.05, 1.82 and 1.10, -0.37 and 1.90- 0.69 and -2.40, 0.24 and 0.06, and -1.02 and 0.55% to the grain yield respectively. The remaining unaccounted residual was 88.2 and 50.8% respectively.

When the percentage contribution of each yield character as well as combination of the characters were examined (Table 29); the highest individual contribution of 11.9 and 18.5% was made by ear diameter; while the lowest contribution of -0.23 and 0.08% was made by cob diameter. Weight of grain per cob contributed 5.77 and 11.5% to the grain yield. Combination of ear diameter and cob diameter, ear diameter and weight of grain per cob, cob diameter and ear diameter, cob diameter and weight of grain per cob, weight of grain per cob and ear diameter, and weight of grain per cob and cob diameter contributed -0.01 and 0.08, 0.18 and -4.47, 0.71 and 1.77, -0.69 and -1.51, -0.009 and - 0.01 and 0.36 and -0.76 to the grain yield respectively. The remaining unaccounted residual were 81.0 and 70.9%.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	1.000														
2.	0.050	1.000													
3.	0.027	0.027	1.000												
4.	0.148	0.276**	0.202	1.000											
5.	0.320**	0.363**	0.190	0.223*	1.000										
6.	0.031	0.245**	0.157	0.282*	0.058	1.000									
7.	0.226*	0.206	0.169	0.238*	0.137	0.615	1.000								
8.	0.060	0.285**	0.108	0.182	0.026	0.012	0.011	1.000							
9.	0.086	0.073	0.215	0.082	0.320**	0.153	0.062	0.243*	1.000						
10.	0.096	0.171	0.214	0.088	0.420**	0.040	0.0125	0.055	0.218	1.000					
11.	0.437**	0.090	0.036	0.036	0.0393**	0.031	0.035	0.032	0.149	0.635**	1.000				
12.	0.065	0.125	0.225*	0.088	0.096	0.022	0.046	0.078	0.063	0.490**	0.348**				
13.	0.291**	0.110	0.063	0.064	0.551**	0.054	0.126	0.175	0.206	0.387**	0.389**	0.042	1.000		
14.	0.291**	0.130	0.092	0.003	0.596**	0.089	0.130	0.178	0.316**	0.352**	0.446**	0.061	0.876**	1.000	
15.	0.034	0.032	0.058	0.187	0.015	0.118	0.036	0.445**	0.053	0.064	0.013	0.037	0.030	0.116	1.000

1. Grain yield
2. Plant height at 12 WAS
3. No. Of leaves per plant
4. LAI
5. TDM (at harvest)
6. Days to 50% silking
7. Number of ears per plot
8. Ear length
9. Ear diameter
10. Cob diameter
11. Kernel depth
12. Shelling percentage
13. Weight of grain per ear
14. 1000-grain weight.
15. Harvest index

Degree of freedom (d=80)
* = Significant at P=0.05
** = Significant at P=0.01
NS = Not significant.

Table 27: Correlation matrix between grain yield and other plant characters in 1997/98 season.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	1.000														
2.	0.405**	1.000													
3.	0.121	0.213	1.000												
4.	0.369**	0.496**	0.014	1.000											
5.	0.493**	0.266*	0.040	0.542**	1.000										
6.	0.508**	0.443**	0.428**	0.368**	0.440**	1.000									
7.	0.557**	0.210	0.290**	0.138	0.434**	0.643**	1.000								
8.	0.019	0.105	0.443**	0.096	0.208	0.405**	0.411**	1.000							
9.	0.038	0.293**	0.352**	0.397**	0.241*	0.532**	0.171	0.308**	1.000						
10.	0.032	0.478**	0.344**	0.540**	0.180	0.234*	0.037	0.451**	0.464**	1.000					
11.	0.146	0.520**	0.191	0.546**	0.287*	0.242*	0.041	0.427**	0.190	0.444**	1.000				
12.	0.107	0.065	0.156	0.047	0.100	0.029	0.075	0.033	0.276**	0.078	0.365**	1.000			
13.	0.242*	0.200	0.451**	0.084	0.029	0.108	0.123	0.203	0.312**	0.362**	0.557**	0.442**	1.000		
14.	0.125	0.294**	0.543**	0.379**	0.067	0.264*	0.010	0.401**	0.385**	0.465**	0.745**	0.595**	0.260*	1.000	
15.	0.046	0.347**	0.599**	0.236*	0.201	0.500**	0.245*	0.414**	0.537**	0.477**	0.558**	0.456**	0.179	0.474**	1.000

1.	Grain yield	6.	Days to 50% silking	11.	Kernel depth
2.	Plant height at 12 WAS	7.	Number of ears per plot	12.	Shelling percentage
3.	No. of leaves per plant	8.	Ear length	13.	Weight of grain per ear
4.	LAI at tasseling	9.	Ear diameter	14.	1000-grain weight
5.	TDM at tasseling	10.	Cob diameter	15.	Harvest index.

Degree of freedom (80)

* = Significant at P=0.05
** = Significant at P=0.01
NS= Not significant.

Table 28: The percentage contributions of different growth characters to yield

Growth attributes	Percentage contribution	
	1996/97	1997/98
Individual contributions		
Plant height(cm)	-5.04	7.73
LAI	1.57	24.6
TDM (g)	13.8	15.6
Combined contribution		
Plant height and LAI	0.12	0.05
Plant height and TDM	1.82	1.10
LAI and plant height	- 0.37	1.90
LAI and TDM	0.69	- 2.40
TDM and plant height	0.24	0.06
TDM and LAI	- 1.02	0.55
Total	11.2	49.2
Residual	88.2	50.8
	100.00	100.00

Table 29: The percentage contributions of different yield characters to yield in 1996/97 and 1997/98 seasons.

Yield attributes	Percentage contribution	
Individual contributions		
Ear diameter	11.9	18.5
Cob diameter	-0.23	0.08
Weight of grain/cob	5.77	11.5
Combined contribution		
Ear diameter and cob diameter	- 0.01	0.08
Ear diameter and weight of grain/cob	0.18	- 0.47
Cob diameter and ear diameter	0.71	1.77
Cob diameter and weight of grain/cob	-0.69	-1.51
Weight of grain/cob and ear diameter	-0.009	-0.011
Weight of grain/cob and cob diameter	0.36	-0.76
Total	18.2	29.1
Residual	81.8	70.9

Figure 2: Path diagram showing interrelations of popcorn grain yield [kg/ha] and some growth components in 1997/98 season.

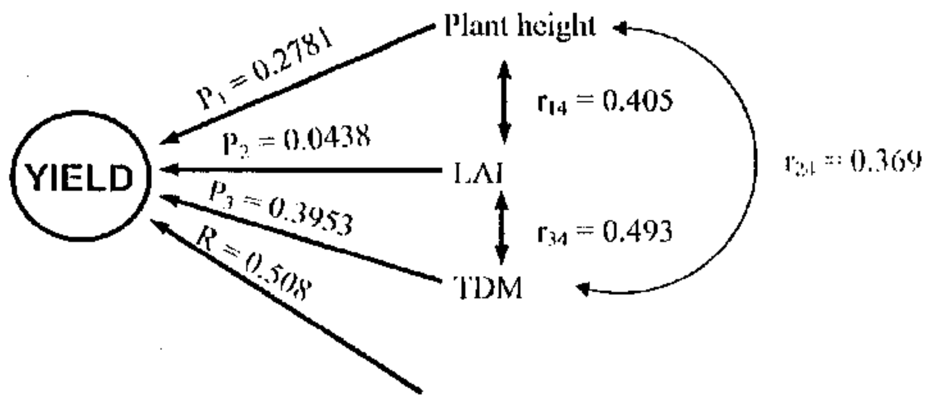
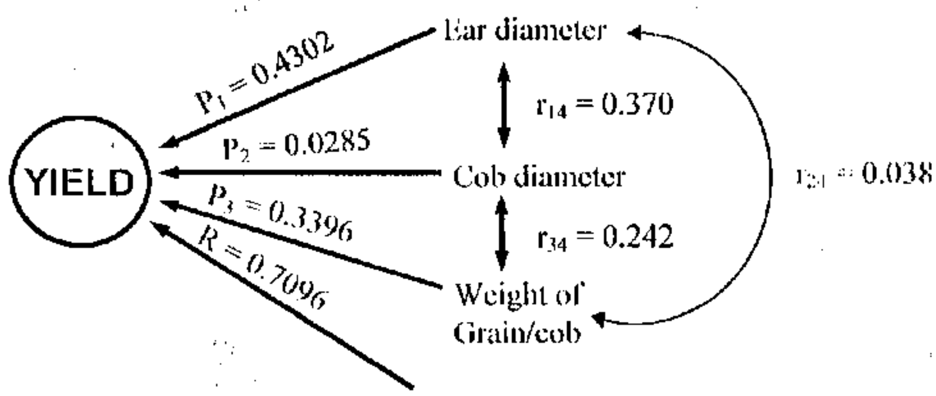


Figure 3: Path diagram showing interrelations of popcorn grain yield [kg/ha] and some yield components in 1997/98 season.



CHAPTER FIVE

DISCUSSION

5.1 Effect of population density

The increase in plant height with increasing population density could be ascribed to competition among plants for available light, water and nutrients as well as increased shading. Similar results were reported by Shun *et al*, (1968), Alessi and Power, (1975) and Olson and Sander, (1988), who observed an increase LAI, internode length and plant height with increase in population density but in conflict to what was reported by Hefni *et al*, (1984) and Filho *et al*, (1988) who reported a decrease in plant height with increasing population density. The reduction in number of leaves per plant at higher population density was due to competition between and within plants for moisture and nutrients. This results were in agreement with those of Filho *et al*, (1988) and Shamsudeen, (1993) who reported a higher number of leaves per plant and branches as well as wider plant leaf spread thereby enhencing greater interception of light energy and production of more assimilates at low population density levels.

The increase in LAI at tasseling and TDM per plant at harvest with increasing population density could be due to the presence of more plants per unit area. This confirms the finding of Olson and Sander, (1988), who reported an increase in TDM and LAI with increase in population density but may not necessarily increase grain yield even if total dry matter is increased.

The delay in days to 50% silking at lower population density could be attributed to the fact that since the plant were widely spaced, there was a tendency of space, light and moisture being unlimited. This encourages extended vegetative growth period. Similar observation were reported by Pierre *et al,*(1967) that silking is delayed by 1 to 5 days with increase in population density.

Lodging of popcorn plants increased with rise in population density, this could be ascribed to higher degree of competition for available light, water and nutrients among the crops. As well as increased shading effect which resulted in production of taller plants susceptible to lodging the results were in agreement with that of Olson and Sander, (1988) who reported that increasing population density increased the susceptibility of stalk to lodging.

The increase in grain yield (kg/ha) with increased population density in this study could be due to more cobs per unit area which compensate for the reduction in yield of individual plants. Similar observation were reported by Roy and Singh, (1986), Yousif and Ali, (1989) and Onwueme and Sinha, (1991), who obtained highest popcorn grain yield at the higher population density of 80000 and 88000 plants per hectare respectively.

The increase in shelling and popping percentage with increase in population density follow similar trend with grain yield. This was ascribed to the production of more number of cobs per unit area, thus translate to more grains. Similar effect were reported by Brunson and Smith, (1948) and Brunson, (1955) that popping and shelling percentage increased with population density.

The decrease in weight of grain per ear, 1000-grain weight, ear diameter, cob diameter and ear length with increasing population density could be ascribed to interplant competition for growth factors thereby affecting the translocation of assimilates to the ear. Similar effect were reported by Filho *et al,* (1988), who observed a decrease in weight of grain per ear and 1000-grain weight with increase in population density.

5.2 Effect of irrigation

Providing water to popcorn at 7-day irrigation interval resulted in significantly higher plant height, number of leaves per plant, LAI and days to 50% tasseling and silking. This was attributed to moderate irrigation interval which provides more favourable moisture condition for growth and development with better leaf development, accumulation of dry matter and overall plant growth. Similar observation were reported by Nnadi, (1975), Michael, (1978) and Anon, (1983) who obtained higher plant height, number of leaves per plant, and LAI at 7-day irrigation intervals and extended the growth period but reduced water use efficiency.

Increase in LAI with irrigation interval up to 7-day interval could be ascribed, to the availability of water which promote photosynthetic activity with large number of leaves and dry matter production. This confirms the findings of Nadi, (1975) who reported an improvement in LAI with increase in irrigation interval up to 7-day.

Similarly irrigating popcorn at 7-day interval resulted in significantly higher number of ears per plot, ear length, cob diameter, weight of grain per cob and popping percentage. This could be ascribed to presence of favourable moisture condition for growth and development with rapid photosynthetic capacity and overall plant growth. Besides shallow rooting which the moderate irrigation interval of 7-day might have induced, could have enabled the plants to have access to adequate irrigation water provided throughout the growth and reproductive period. Similar effect were reported by Michael (1978) and Anon, (1983) who obtained best grain yield and its attributes at 7-day irrigation interval than at 3, 5 or 10-day.

Five day irrigation interval yielded higher ear length and cob diameter, this was due to presence of more favourable growth conditions during pollination in terms of water availability within the effective root zone of the crop. This confirms the findings of Robin and Domingo, (1953), Denmead and Shaw, (1960) and Claassen and Shaw, (1964) who reported a significant reduction in ear lengh, cob diameter and weight of grain per ear with moisture stress at grain filling stages.

The non significant difference observed due to variation in irrigation interval on some growth, yield components and grain yield of popcorn could be ascribed to closer irrigation intervals which may induced an artificial water table thereby affecting growth and development of the crop. As well as presence of abnorxious weeds which interfere with efficient performance of the crop. As such popcorn is very sensitive to weed infestation at early stage of its growth because of its slow initial growth. Similar findings were reported by Bhan, (1977), Onwueme and Sinha (1991) and Rowland, (1993) that submergence of the soil for 3-5 days during seedling or flowering period reduced the grain yield considerably. This was attributed to anaerobic environment created by water logging.

5.3 Effect of date of sowing

The increase in plant height, number of leaves per plant, TDM, LAI and days to 50% tasseling and silking with end of February sowing could be attributed to the optimum temperature condition, solar radiation and relative humidity during the period of flowering and fertilization. The low yield of the early sown popcorn in mid-February was attributed to low temperature and excessive cloud cover at initial growth stage of the crop, thereby affecting the performance of the crop. Similarly the low yield of late sown popcorn in mid-March could be ascribed to higher temperature, low relative humidity during vegetative and reproductive stages of the crop. Similar observations were reported by Kumar *et al.* (1982), Onwueme and Sinha, (1991) and Rowland, (1993) who indicated that optimum sowing makes the best use of the available temperature and solar radiation during the period of flowering and grain filling stages.

End of February sowing, significantly resulted in higher grain yield and its attributes. A high yield in this case could be explained in the light of favourable temperature, relative humidity and solar radiation during the period of flowering and fertilization. The low yield of early sown popcorn however, was attributed to low temperature, high relative humidity and excessive cloud cover at early growth stages of the crop. Similarly, low yield recorded with late sowing in Mid-March was attributed to higher temperature and low relative humidity during flowering and grain development. This confirms the findings of Kumar *et al,* (1982), Anon, (1983) and Onwueme and Sinha, (1991); where they reported that optimum sowing makes the best use of the available temperature and solar radiation during the period of flowering and fertilization. They explained further that the environment with cool night (14-18^{0}c) is more favourable to maize grain production. For every rise in 1^{0}C in minimum temperature (night temperature) beyond 14^{0}C decreased grain yield by 153kg/ha. While each 1^{0}C increase in mean temperature beyond 30^{0}C (Max. temperature 38^{0}C) decreased grain yield by more them 211kg/ha. This indicate that miaze fertilization and grain growth is a function of optimum temperature during the day and night.

5.4 Interaction

The significant interaction between irrigation interval and date of sowing on number of leaves per plant, TDM per plant at harvest, LAI at tasseling, days to 50% tasseling and grain yield (kg/ha) were observed. In all cases 7-day irrigation interval and sowing at the end of February significantly produced higher of these parameters. This could be attributed to the presence of favourable moisture condition for growth and development which resulted in better leaf development and overall plant growth provided by moderate irrigation interval as well as optimum temperature condition, solar radiation and relative humidity provided by end of February sowing.

5.5 Correlation studies and path-coefficient analysis.

The highly significant and positive correlation ($P=0.01$), existed between popcorn grain yield and growth characters such as plant height, LAI at tasseling, TDM per plant at harvest, days to 50% tasseling and silking is probably due to the fact that these vegetative characters directly determined the extent of photosynthesis and the amount of assimilates that were available for plant growth and ultimately to grain yield.

The highly significant and positive correlation ($P=0.01$) between popcorn grain yield and its attributes such as weight of grain per cob, kernel depth, 1000 grain weight and number of ears per plot ($P=0.05$) revealed the importance of yield components to popcorn grain yield. The result indicated that an increase in any of these parameters would contribute to increase in grain yield indirectly.

The path analysis and percentage contribution (Table 28) showed that most of the growth characters made their greatest contribution to yield through the TDM and LAI. This could be due to the fact that increased dry matter and LAI are virtually synonymous with increased photosynthetic surface and thus greater photosynthate which translated into higher yield.

Yield components make their greatest contribution through ear diameter and weight of grain per cob (Table 29). This showed that ear diameter and weight of grain per ear, are the greatest yield determinant factors.

CHAPTER SIX

SUMMARY AND CONCLUSION

Field trials were conducted during the dry seasons of 1996/97 and 1997/98 at the Institute for Agricultural Research Station Kadawa (11^0 39'N, 08^0 02'E and 500m above sea level) to study the effect of population density, irrigation interval and date of sowing on the growth, yield components and yield of popcorn (*Zea mays* L.) the treatments consisted of three irrigation intervals (5, 7 and 9-days) and three date of sowing (Mid and end of February and mid- March) randomised in the main plot and three population density (44,444, 53,333 and 66,666 plants per hectare) in the sub-plot. The experiments was replicated three times in a split-plot design.

The analysed data revealed that higher population density of 66,666 plants per hectare was significantly superior to all other population densities in all growth and yield characters studied except 1000-grain weight, weight of grain per cob, ear diameter and cob diameter which were significantly higher at lower density level of 44,444 plants per hectare.

Irrigating popcorn at 7-day interval resulted in significantly higher growth and yield parameters studied except plant height, LAI and days to 50% tasseling which were found to be at par with 9-day irrigation interval.

Sowing popcorn at the end of February was significantly superior to all other dates of sowing in all the growth and yield attributes examined.

Significant interaction were recorded on some of the characters such as number of leaves per plant, LAI, TDM, days to 50% tasseling and grain yield (Kg/ha).

The results of correlation analysis revealed significant association between some of the characters studied. The correlation was also positive for most of the characters, although plant height in 1996/97 and kernel depth in 1997/98 was negatively correlated with grain yield (kg/ha).

Path analysis revealed that percentage individual contribution of growth characters to yield was highest via total dry matter. Yield characters contributed more via ear diameter; while combine contribution of plant height and TDM make the highest combined contribution to yield. When the percentage of the major yield contributors were examined, ear diameter was observed to contribute the highest percentage to yield, while the combination of cob diameter and ear diameter was the highest contributor to yield.

Based on the results obtained in this study it could be suggested that sowing popcorn at higher population density of 66,666 plants per hectare, at 7-day irrigation interval and sowing at the end of February are appropriate in enhancing proper growth and yield of popcorn in the Sudan savanna ecology of Nigeria.

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Appendix 1: Physical and chemical properties of the soil (up to 30cm depth of the experimental plot at kadawa.

Soil Characteristics	1996/97	1997/98
pH in water (1:2.5)	6.4	6.10
pH in 0.1m $Cacl_2$ (1:2.5)	5.7	5.80
Organic carbon (gkg-1)	5.5	5.3
Total nitrogen (gkg-1)	1.0	1.1
Available phosphorus (mgkg-1)	5.35	5.32
Bases (cmol kg-1)		
Ca	5.3	6.20
Mg	0.68	0.70
K	0.23	0.24
Na	0.24	0.23
Al	0.11	0.10
CE	8.10	8.30
Particle size distribution		
Sand (%)	58	54
Silt (%)	25	28
Clay (%)	17	18
Textural Class	Sandy loam	Sandy loam

Soil samples as analysed at Soil Science Department, IAR-ABU Samaru, Zaria.

Appendix 2: Maximum and Minimum Temperature (^{o}C) and Relative humidity at Bagauda.

Months	Days	Temperature (°C)				Relative humidity			
		Max.		Min.		Max.		Min.	
		1996/97	1997/98	1996/97	1997/98	1996/97	1997/98	1996/97	1997/98
Feb.	1-10	33.3	38.7	14.2	15.3	15	16	8	7
	11-20	29.8	30.1	14.5	16.0	14	15	8	10
	21-28	30.0	31.0	15.0	16.6	14.	15	8	10
Mar.	1-10	30.5	30.6	16.5	17.1	14	15	9	10
	11-20	34.0	35.1	17.5	19.4	13	14	7	8
	21-31	35.2	36.0	18.5	19.5	13	14	7	8
Apr.	1-10	35.2	40.1	19.0	21.4	15	17	9	7
	11-20	36.5	41.9	20.5	23.3	16	49	8	7
	21-30	35.4	37.3	18.5	25.4	13	82	7	29
May	1-10	35.5	37.2	22.5	24.9	18	87	8	32
	11-20	37.7	38.5	23.0	26.2	16	51	7	32
	21-31	35.8	37.5	22.7	25.4	15	41	7	38
June	1-10	30.5	33.1	20.4	22.9	35	43	9	40
	11-20	31.2	34.2	19.5	22.2	37	70	11	43
	21-30	30.9	33.6	20.0	22.6	39	91	10	50

Source: ICRISAT Meteorological station. Bagauda, (6 kms from Kadawa), Kano, Nigeria

BIOGRAPHY

PERSONAL DATA

SURNAME	:	MANI
OTHER NAMES	:	HAMZA
DATE OF BIRTH	:	10th December, 1967
LOCAL GOVT. AREA	:	Batsari
MARITAL STATUS	:	Married with two children

EDUCATION QUALIFICATIONS

Institutions Attended	Year of Graduation	Certificate Obtained
YANDAKA RUMAH PRI. SCH. KATSINA	1981	School Leaving Cert.
GOVT. SEC. SCH. MANI KATSINA STATE	1986	G.C.E. '0' Level.
COLLEGE OF ADVANCE STUDIES (CAS), ZARIA	1988	I.J.M.B
AHMADU BELLO UNIVERSITY, ZARIA	1992	B. Agric.

WORKING EXPERIENCE

(I) Secretary Caretaker Committee, National Republican Convention (NRC) Dan-Alhaji -Yangaiya Ward, Katsina State, - October 1992 to April, 1993.

(ii) Class -room Teacher Igbo Elerin Grammar School Ibadan (NYSC) 1993/94.

(iii) Lecturer and Head of Agricultural Education Section Isah Kaita College of Education Dutsin-Ma, Katsina State. 1994/95.

(iv) Assistant Research Fellow, (ARF), Institute for Agricultural Research, Ahmadu Bello University, Zaria, December, 1995 to date.

POSTGRADUATE REGISTRATION NUMBER: M.Sc./Agric./12351/95-96