EFFECT OF WATER STRESS AT GRAIN DEVELOPMENT STAGE OF WHEAT (Triticum aestivum L.) UNDER DIFFERENT LEVELS OF NITROGEN AND PHOSPHORUS FERTILIZERS

By

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DEPARTMENT OF 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 4/7/83



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CERTIFICATION

This thesis entitled 'EFFECT OF WATER STRESS AT GRAIN DEVELOPMENT STAGE OF WHEAT UNDER DIFFERENT LEVEL OF NITROGEN AND PHOSPHORUS FERTILIZERS' by *Usman B.J. BELLO* 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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ABSTRACT

Investications to find the effect of water stress during the reproductive phase of wheat under different levels of nitrogen and phosphorus fertilizers were carried out at Samaru, Zaria (Lat. 11° 11 N, Long, 07° 38' E).

Water stress was imposed during the flowering, milk, and milk-dough periods. Water stress reduced the grain yield by 31% when stress occured at flowering, and by 15.46% and 14.893' at milk and milk-dough periods, respectively. The yield reduction occured through reduction in the number of grains/spike in case of stress at flowering, and through reduction in grain weight/spike in case of stress at milk and milk-dough periods.

Nitrogen levels used were 0, 60 and 120kg N/ha. Nitrogen positively increased all the parameters examined, especially the vegetative growth. Most of the reproductive components responded significantly to only 60 N kg/ha.

Zero and 30kg P_2O_5/ha levels of phosphorus were used. Phosphorus on its own did not significantly affect most of the parameters except the leaf area/plant and grain yield.

However, the nitrogen-phosphorus interaction showed that nitrogen application without30kg P_20_5 /ha produced little effect above 60kg N/ha. Application of 30kg P_20_5/ha

without nitrogen tended to have negative effect or no significant effect all but the yield of wheat crop responded significantly to the application of 120kg N/ha when 30kg $P_2 0_5$ /ha was applied.

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CHAPTER I

INTRODUCTION

Importance and Uses of Wheat

Bread wheat, (Triticum aestivum L.), is one of the most important food cereals in the world. On global basis, it occupies about 237 million hectres of land with a total output of 420 million tons/annum (Anonymous, 1980). The origin of wheat crop is not very clear, but it was known in the Middle East as far back as four to five centuries B.C.

According to Lewicki, (1974), wheat was introduced into West Africa around the 12th century by the Arab traders through Sudan, and then into the northern states of Nigeria. Here, cultivation was then restricted to small irrigated gardens along the river banks or using residual moisture in 'fadamas' during the cool dry harmattan season. The locally produced wheat is used for preparation of local dishes like 'alkaki' and 'gurasa'.

After the Second World War, the returning soldiers contributed in no small measure to the bread-eating habit in Nigeria. This, coupled with the development of elite groupt and increasing rate of urbanisation led more to the demand on bread and other wheat products. This relative change in food habit accounts for the presence of bread in virtually every corner of Nigeria. Average consumption of wheat/head/day was put at 26.3g in 1977, ranging from

162g/head/day in Lagos town to negligible figures in rural areas inland probably because of reduced income or lack of familiarity.

To meet this demand, the Federal Government of Nigeria resorted to first, flour, and later wheat grain importation at a steadily increasing rate as shown in table 1.1 below.

Table 1.1. Wheat and Wheat Flour importation in Nigeria 1954-1975 (tons).

Year	Grains	Flour	Total (tons)
1954	-	57,000.00	57,000.00
1955	-	48,000.00	48,000.00
1956	-	51,000.00	51,000.00
1957	-	64,000.00	64,000.00
1958	-	67,000.00	67,000.00
1959	-	83,000.00	83,000.00
1960	-	79,000.00	79,000.00
1961	-	96,000.00	96,000.00
1962	2,000.00	96,000.00	98,000.00
1963	39,000.00	34,000.00	73,000.00
1964	53,000.00	4,000.00	57,000.00
1965	72,000.00	2,000.00	74,000.00
1966	136,000.00	3,000.00	139,000.00
1967	165,000.00	5,000.00	170,000.00
1968	125,000.00	5,000.00	130,000.00
1969	143,000.00	1,000.00	144,000.00
1970	214,000.00	-	214,000.00
1971	376,000.00	9,000.00	385,000.00
1972	279,000.00	71,000.00	350,000.00
1973	300,000.00	4,000.00	304,000.00
1974	310,000.00	1,000.00	311,000.00
1975	294,000.00	8,000.00	302,000.00

Sources: Nigeria Trade Journal, Oct. 1961, P. 154 and Report on Wheat Production and Marketing in Nigeria, P.28. AERLS, 1979.

Between 1974 and 1976 imports increased from 400,000 to 733,000 tons, and costing the Federal Government of Nigeria about ₦97 million in foreign exchange, (Anonymous, 1979).

Major Areas of Production

Using temperature as a guide, Kowal and Knabe (1972), defined the wheat zone in the northern states of Nigeria as that area north of latitude 10°N, where the maximum temperatures are consistently below 32.5°C, and the minimum temperatures are mostly below 15°C during the cool dry harmattan period (November to February). Below this latitude, the temperatures are too warm for satisfactory tillering and the development of large spikes necessary for higher yields. The altitude of the wheat growing areas is between 240-360m above sea level (Olugbemi, 1973). This area as defined above, fortunately covers greater part of the northern states of Nigeria. However, the most suitable areas are those where the maximum temperatures of below 32.5°C occur for 70-115 days, and the minimum below 15°C for 80-95 days between November and February (Anonymous, 1979).

Efforts are, therefore, currently being geared towards increase in the local production of wheat crop in the wheat growing areas of the northern states of Nigeria. It is proposed that by 1991, about 345,000 hectres will be under irrigation. About 50% of this area will be

alloted to wheat. It is also estimated that about 500,000 tons over and above 330,000 tons based on the current level of production will be realized (Anonymous, 1979). Thus, though wheat is basically a temperate crop, it can be successfully grown under irrigation during the cool dry harmattan season in the northern states of Nigeria (Fig. 1). Wheat production during the rainy season on the plateau of Jos and Mambilla in Nigeria is handicapped by the disease causing fungal organism (Fusarium), which is associated with cool temperatures and high rainfall (Anonymous, 1979).

Average Yields

The technology of wheat production has increased over the years, but the average yield for all the wheat producing areas of the world is low. For example wheat yields averaged about 1.5 tons/ha between 1969-1971. In the late 1970s world average yields increased to an average of 1.8 tons/ha, (Anonymous, 1980). In the developing countries such as Nigeria, average production/ has reported ranged from 0.75 - 3 tons/ha, (Anonymous, 1979).

These average production figures were reported under different levels of inputs (fertilizer and water) and environmental conditions. It is, therefore, appropriate to investigate the problems associated with wheat

production under the present environment. The grain formation and development period, as identified by Kumar and Yayock (1980), is characterized by high [illegible] evaportranspiration (9.1mm Pan - see Appendix), therefore, any water stress around this time may adversely affect the grains, yields and yield components. The water necessary to avoid this stress is costly. It is, therefore, necessary to examine the effect of this lack of irrigation water especially under different levels of nitrogen and phosphorus, on yield and its components.

An increase in yield must have come with increase of water and fertilizer requirements before components like radiation are considered. This increase, therefore, depends on these resources which are costly and limited. Whether the main limitation is mineral fertilizer - which has to be paid for in foreign exchange - or water pumped from rivers and lakes at considerable expenditure. The use of these costly limited resources should be kept as low as possible, that is to achieve maximum effect with minimum inputs (Langer, 1978).

It is against this background that the present study was initiated to:

1. Assess the effect of water stress on grain formation, development, yield and its attributes.

2. Investigate the effect of nitrogen and phosphorus fertilizers and their interactions on the growth of wheat, grain development and yield and its components.

3. Investigate the interacting effect of NP fertilizers and water stress during grain development stage on yield and its components.

CHAPTER 2

LITERATURE REVIEW

Wheat, basically a temperate crop, requires cool temperatures where the maximum is consistently below 32.5°C and the minimum temperatures mostly below 15°C for satisfactory tillering and large spikes formation which are necessary for satisfactory yield. This crop, however, is successfully grown under irrigation in Arid and Semi Arid areas in the Tropics, including most parts of the northern states of Nigeria. This is because this range of cool temperatures prevails during the cool dry harmattan period. In addition to the required irrigation water, adequate supply of nutrients is essential for satisfactory crop growth and yield. A number of workers, in both the Temperate and the Tropics, have reported their findings on wheat growth and development under essential plant nutrients like nitrogen and phosphorus in the presence of various soil moisture regime..

Different levels of phosphorus and nitrogen under water stress conditions have been reported to affect the vegetative as well as the reproductive phase of the crop by different manifestations on the individual growth components. Tillering, leaf areas, dry matter, plant height as well as grain development and yield components

like the number of spike per square meter, weight of grains, are all affected in various degrees. Some of these findings as they affect the above are cited below.

Effect of Nitrogen on Growth

Growth and all its components generally increase when nitrogen is applied, and this increase in growth with the increasing rate of nitrogen. El-Sharkawy, et al. (1976, 1977), using nitrogen rates of 0, 60, 100 and 140kg N/ha, reported positive linear increase in tiller number/plant, dry matter accumulation and leaf area/plant with increasing rate of nitrogen. Singh and Verma, (1965) also reported that improved growth due to nitrogen fertilization was accompanied by increase in dry matter even at 45kg N/ha. Singh and Gupta, (1970) and Sarkar, et al. (1975) are of the view that the increase in the dry matter accumulation is more rapid between 70 and 120 days after sowing, and the rate falls off thereafter. Saleh, (1981) reported that the increase in dry matter accumulation occured mostly at booting, heading and about 10 days post harvest. Panect (1976) and Saleh (1977), also reported increase in plant height and leaf areas or Leaf Area Index with nitrogen application. Additionally, nitrogen application increases the number of tillers/plant (Sorour, et al., 1977 , Whingwiri, 1980). Results of Cooper (1980), however, showed that the increase in plant height of wheat was at a decreasing rate with the advancement of

growth, but number of tillers/plant responded to nitrogen fertilization even with advance in growth while leaf area/plant and Leaf Area Index (LAI), responded to nitrogen fertilization at a decreasing rate with advance in age. Flag leaf area increased in response to nitrogen application and so was the number of days to 75% heading (Bassioury, 1979). Delay in 50% flowering due to nitrogen application was reported by Verma, et al., (1978); and Rathore and Singh (1973, 1970).

Effect of Nitrogen on Grain Development

Yousef, et al., (1977), using 60, 120 and 180kg N/ha under one, two and three irrigations reported increase in grain number/plant as well as grain weight with increasing levels of nitrogen. El-Sharkawy, et al., (1976 and 1977), and El-Dababy, et al., (1978), also reported increase in the number of grains/plant, grain size as well as ear number/plant as nitrogen levels increase under different moisture regimes. Number of grains/spike was also favourably affected by increase application of nitrogen (Silva, et al., 1975; Gomaa, et al., 1977 and Dougherty, et al., 1978). But Singh and Sharma (1973), could not record any response in this character to nitrogen application, and Hussain, et al., (1978), opined that the response depended on the cultivar.

Spike grain weight is also influenced by the application of nitrogen. Sandhu and Gill (1971), found

that the spike grain weight responded positively to nitrogen application up to 32kg/ha. Similar views were reported by Hagras (1972) and Ibrahim and Assey (1976). However, Mahendra Singh and Sharma (1973) were unable to record significant effect of nitrogen on spike grain weight. Boyles (1977) used 75 and 150kg N/ha in 82 separate experiments. In 51 and 32% of these experiments respectively, he found no evidence of poor grain filling, but in 41 and 71% of the experiments showed evidence of poor filling, manifested in at least one yield attribute, like the 1,000-grain weight. In 9 and 10% of the experiments respectively, 1,000-grain weight increased by nitrogen application. Improvement in grain filling took place with irrigation at high rates of nitrogen suggesting that moisture limitations at those rates could contribute to poor grain filling. He further concluded that varying the time of the nitrogen application has little effect on the grain filling, and that there was no relation with site characteristics like soil texture, residual fertilizer or previous cropping, and reduction in grain filling could even occur in absence of disease and lodging.

Effect of Nitrogen on Yield and Yield Components

Application of nitrogen affects wheat yield and yield components in various degrees. Components such as the number of spikes/m^2, number of grains/spike, length of

spike, spikelets number/spike, number of fertile and sterile spikelets/spike, tiller mortality, 1,000-grain weight, straw and grain yield are all affected. El-Sharkawy, et al., (1977), reported linear increase in ear length, number of grains/ear and the average grain weight, and nitrogen effects on the weight of 1,000-grain. While Misra and Singh (1971); Hussain, et al., (1976) and Ibrahim and Assey (1976), found a significant response in respect of 1,000-grain weight. Jat, et al., (1976) reported a decrease in 1,000-grain weight with increasing nitrogen application.

It is generally reported in the literature that nitrogen application increase the number of spikes produced, and this has direct bearing on the yield since grains develope on the spikes. This was observed by Gomaa, et al., (1977), and Ellen and Spiertz (1980).

Nitrogen fertilization significantly increases spike length which is usually accompanied by increase in the number of fertile spikelets/spike, and the increase is positive with increasing nitrogen levels (Villanuera and Montjoy, 1973). Rathore and Singh (1973), observed that increased nitrogen uptake generally increased dry matter production, but of the yield components ear length and the number of grains per ear were most related to grain yield (Verma, et al., 1970).

The optimum level of nitrogen fertilization depends on the soil type, initial fertility levels, and wheat cultivar. The environmental conditions also vary, so as the availability of growth factors like irrigation. Singh (1968), in India obtained response on a loamy soil up to 84kg N/ha. Misra and Singh (1971) also in India, reported response up to 200kg N/ha. Singh and Srivastava (1971), reported 120kg N/ha as the optimum, while Saleh (1981) working in Egypt, reported significant yield increase even at 142.80kg N/ha. El-Sharkawy, et al., (1977) reported, among other things, grain and straw yield increases from 0.53 tons/ha to 4.65 t/ha and 2.77 to 9.41 t/ha respectively with nitrogen levels ranging from 0 to 120kg N/ha at 0.5 bar moisture stress by Jat, et al., (1976). Singh and Aggarwal, (1976) also reported highest yields of 4.29 t/ha with moisture level and 40 kg N/ha. Others who reported increase in yield and its components with nitrogen application include Agha and Tunio (1973) and Rathore and Singh (1973).

Effect of phosphorus on Growth

Application and uptake of phosphorus favourably affect the general growth of wheat crop through satisfactory establishment of root system and uptake of nitrogen. The increase in growth is manifested in increase in tiller number, dry matter accumulation, height of the plant and the leaf area. Verma, et al.,

(1970) reported consistent increase in tillering and vigorous root development when phosphorus was applied. They attributed the early root and shoot growth to available phosphorus which might have favoured cell division which is slow in phosphorus deficient soils. However, they found no significant difference between 33.5 and 67kg P_2O_5/ha. Yousef, et al., (1977) also found that phosphorus application increased plant height, number of tillers per plant and dry matter. Rathore and Singh (1973), used 0, and 30kg P_2O_5/ha to achieve an increase in growth. Ibrahim and Assey (1976), using 0, 36.89 and 73.78 P_2O_5kg/ha were unable to find any effect of phosphorus fertilization and different at levels on plant height.

Effect of phosphorus on grain development, Yield and Yield components

Phosphorus, an essential nutrient, affects grain development, yield and yield components of wheat depending on the rate of application. With increase in vigour and growth, grain development potential is expected to be higher. Plumb and well developed grains can only come from plants with sufficient nutrient status. Yousef, et al., (1977), reported favourable grain development with increasing level of phosphorus. Using semi dwarf wheat cultivars, they reported grain yield increase from 1.75 to 2.43 t/ha with increasing phosphorus levels from

zero to 72kg/ha. Ear length; grain weight, number of grain per ear, grain number per plant, all increased with increasing level of phosphorus. Verma, et al., (1970), also reported consistent increase in yield from 22 to 25% over the control by using 33.5 and 67kg P_2O_5/ha. Agha and Tunio (1973) were of the view that the most economical dose is 34.05kg/ha. Rathore and Singh (1973, 1978) and Singh (1981), reported that response was more favourable at 30kg P_2O_5/ha. Rathore and Singh (1978) reported that for every 1kg phosphorus uptake, there was corresponding increase of 132.89kg grain/ha.

Effect of Water stress on Grain Development and Yield and Yield components

Water as a constituent of protoplasm, solvent for nutrients and a reagent is the most important ingredient of plant growth, development and productivity. Its shortage, especially at critical stages like the reproductive phase, has marked effect on grain development, yield and its components. A number of workers like Misra, et al., (1969) and ElDababy, et al., (1978) have reported effects of these stresses during the reproductive phase under various levels of fertility by withholding irrigation water either at flowering, milk or milk-dough stages.

Understandably, waterstress after anthesis will have no effect on the production of spikes because this must

have been determined during the vegetative phase (Cooper, 1980). Assey, et al., (1979) used four, five and six irrigations, and found that six irrigations were superior to four irrigations in terms of 1,000-grain weight. Misra, et al., (1969) demonstrated that withholding irrigation water at either milk-ripe or dough-ripe stages significantly decrease grain size, and irrigating at crown root initiation, late tillering, flowering and dough stages increased 1,000-grain weight. Others like Misra, et al., (1976) and El-Dababy, et al., (1978) are of similar opinion. Assey, et al., (1979) attributed the decrease in grain size to water stress which hastens grain filling, resulting in decreased grain size. Connor (1975), concluded that the reasons could be due to premature yellowing of leaves and spikes. But Cooper (1980), however, argued to the contrary on account that frequent irrigations encourage the formation of late tillers which have less time for grain development and in turn result in smaller grain size.

Shrotriya, et al., (1970) found that withholding irrigation water at either milk-ripe or dough-ripe stages had little effect on the number of grains and spikelets per ear. Hussain, et al., (1978), however, found that the highest number of spikelets was obtained from four to six irrigations and the lowest number of grains per one irrigation. Water stress at three weeks after ear

emergence significantly reduced grain number per ear (Langer, 1978).

Sufficient soil moisture at flowering stage ensures sound and healthy grain development. Withholding irrigation water at this stage, therefore, will directly affect grain development (Verma et al., 1978). Jat, et al., (1976) and Boyles (1977), have reported grain filling improvement due to irrigation at high nitrogen level, and suggested that moisture limitations at these levels could contribute to poor grain filling and development.

Withholding irrigation at different critical stages affect grain yield differently. Bhardwaj, et al., (1971) calculated the reduction in grain yield as 18.2, 1.9, 10.7, 11.8 and zero % as against withholding irrigation at crown root initiation, late tillering, flowering, milk and dough stages respectively. Patel and Patel, (1975) arrange the critical stages for water in wheat crop as milk-ripe, followed by booting, than by late-jointing, crown root initiation and finally by flowering, in this order. They argued that water stress at milk and dough stages lead to premature drying which significantly decrease the 1,000-grain weight. Grain yield is severely reduced especially when the stress is prolonged for two successive stages of plant growth (Shrotriya, et al., 1970). Singh, et al., (1975) arranged the most sensitive

stages to water stress as crown root initiation, late tillering, flowering and milk ripe stages.

Ear length and ear weight, grains per ear, 1,000-grain weight, all increase generally with increase frequency of irrigation (Ibrahim, et al., 1979 and El-Dababy, et al., 1978). Asana, et al., (1971) reported a decrease in the grain/floret ratio with increasing floret number/ear under water stress or no water stress, while grain number depend on the floret number/ear. The uptake of nitrogen is increased while that of phosphorus is decreased under water stress. They opined that water stress reduces grain yield partly through its effect on uptake of phosphorus and proportional protein synthesis.

Dantur, et al., (1973) irrigated at soil moisture deplesion of 40%, 55%, 70% and 85% field capacity and concluded that grain yield was closely correlated with days soil moisture tension was 1.35 atmospheres during jointing and milk-ripe stage and suggested irrigation at moisture depletion of 40% to 50% field capacity.

However, El-Sharkawy, et al., (1976) using soil moisture tension of 60 c bars was unable to record any sngnificant effect of water stress after anthesis on straw and grain yield, number and weight of grains per plant, mumber of ears per plant or 1,000-grain weight as recorded by others.

Interaction Effect of Irrigation, nitrogen and phosphorus on grain yield of Wheat

Applied plant nutrients like nitrogen and phosphorus as well as irrigation do not often exert their influences on growth and development of the crops individually, but interact with one another. For example presence of nitrogen will affect the uptake and use of phosphorus. Presence of soil moisture determines uptake of nitrogen and phosphorus.

Sinha, et al., (1973) reported optimum yields of wheat from combinations of 124kg N + 22kg P_2O_5/ha, and that in the absence of phosphorus, there was no yield response to nitrogen which mostly accumulated in the soil. In fact nitrogen and phosphorus contents of the grains were proportional to the applied nitrogen and phosphorus. But there was no competetion in the uptake of nitrogen and phosphorus, and the wetter the soil the more uptake, when three moisture regimes of 75%, 50% and 25% of field capacity were tried with two levels of nitrogen - 75kg N and 150kg N/ha (Verma, 1976). Wheat can even respond to lower dose of nitrogen significantly (Ibrahim and Assey, 1976). These researchers recorded significant interaction between nitrogen and phosphorus on 1,000-grain weight, grain yield and number of spikes per plant at different levels of nitrogen and phosphorus. Similar results were obtained by Nagre and Bathkal, (1978). However, the interaction and the increase in yield arising thereof was

only recorded for 33.5kg P_2O_5/ha level, giving percentage increase in yield of 15.9%, 37.2% and 20% over the three years trial. After that there was no increase as phosphorus was deficient in the soil and, therefore, could become a limiting factor (Verma, et al., 1970). But Agha and Tunio, (1973) were unable to record any significant interaction between irrigation frequency and fertilizer rates.

Significant interaction between nitrogen and irrigation on grain yield and the number of grains per plant was reported using 0, 100, 150 and 120kg N/ha under 20, 40 and 70 c bar soil moisture tension. Thousand grain weight and grain size all increased as nitrogen rates increased, and soil moisture decreased (El-Sharkawy, et al., 1977). The absence of nitrogen would decrease soil moisture extraction during the grain filling stage (Shimshi and Kafkafi, 1978). These workers also found significant interaction effect between nitrogen and irrigation.

An interaction between soil moisture and applied phosphorus showed an increase in yield with increasing level of phosphorus at low moisture level or with increasing soil moisture at low phosphorus level (Somawanshi and Goswani, 1980).

CHAPTER 3

MATERIALS AND METHODS

Site

The experiment was conducted under irrigation during the 1981-1982 dry season at the irrigation site of the Ahmadu Bello University Farm, Samaru, Zaria (Lat. 11°11 N, Long. 07° 38'E and altitude 686 m). Samaru is located within the Northern Guinea savannah zone. The climatic conditions of the site are reported below in tables 3.1 and 3.2 (also appendix).

The soil is a fertile loamy sand. The result of the chemical and physical analysis of the soil and cropping history are shown in tables 3.3 and 3.4, respectively.

Land Preparation

The experimental field was irrigated, ploughed, harrowed twice and fine cultivated to a fine seed bed. The land was subseqnently divided into required plots with irrigation channels and borders as necessary before planting.

Fertilizer Application

Three levels of nitrogen, 0, 60 and 120kg N/ha in form of urea (46% N), and two levels of phosphorus, 0 and 30kg P_2O_5/ha in form of single super phosphate 18% P_2O_5) were used. The fertilizers, in all possible combinations,

were incorporated into the soil before sowing. This gives six fertilizer treatments in all.

A dwarf Mexican wheat variety, Cieto cerros, was drilled at the rate of 100kg seed/ha in 25cm row spacing on 22 November, 1981.

Irrigation Treatment

Irrigation water was applied at weekly intervals to ensure adequate soil moisture during the vegetative phase. During the reproductive phase, four irrigation treatments were applied by withholding irrigation water and creating water stress at the periods mentioned below.

1. Stress at flowering period
2. Stress at milk period
3. Stress at milk-dough period
4. No stress (control)

Each of the stress periods was of the length of 18-20 days after which irrigation continued till harvest.

Plot size and Experimental design

The experimental layout was a strip-plot design replicated four times. Strips of 2m x 19.5m were alloted to each of the four irrigation treatments at random. Within each of these strips, six plots of 2m x 3m were demarcated, with 0.3m separating adjacent plots. These plots were randomly alloted to fertilizer treatments.

Table 3.1. Mean Maximum and Minimum monthly temperatures (^{o}C) at Samaru, Zaria

		Nov.	Dec.	Jan.	Feb.	March
1981/82	Max	29.1	30.2	29.7	31.6	34.6
	Min	14.1	12.7	13.8	15.6	19.70

Table 3.2. The Mean Maximum and Minimum Temperatures in 10-day periods between 20 November 1981 and 20 March 1982 at Samaru, Zaria

Months	DAS*	Max	Min	Mean
20-30 Nov	8	26.8	13.1	19.98
1-10 Dec	18	30.1	13.4	21.75
11-20 Dec	28	28.8	12.4	20.6
21-31 Dec	39	31.7	12.3	22
1-10 Jan	49	27.8	11.8	19.8
11-20 Jan	59	31.9	15.0	23.45
21-31 Jan	70	29.5	14.7	22.1
1-10 Feb	80	26.8	12.9	19.85
11-20 Feb	90	32.6	14.8	23.7
21-28 Feb	98	35.4	19.3	27.35
1-10 March	108	31.5	16.2	23.85
10-20 March		35.9	20.6	28.25

* Number of days after sowing

Table 3.3. Physical and Chemical characteristics of soils at the experimental site at Samaru

Horizon	Particle Analysis			pH in		Textural
	sand	silt	clay	H_2O	Kcl	class
cm	%	%	%			
0-3-	45	41	14	5.75	4.9	Loamy sand

Total N	P	K	Ca	Mg	Na	CEC
%	ppm	ppm	ppm	ppm	ppm	%
0.05005	113.79	140.0	625.0	100.00	24.00	19.69

Table 3.4. Previous cropping history of the experimental site

Year	History
1979 Rainy Season	Fallow
1979/80 Dry Season	Maize
1980 Rainy Season	Fallow
1981/82 Dry Season	Wheat

The harvest was taken from the net plot size of 2m x 1m.

Data Collected

A. Vegetative phase.

i) Germination count: this was taken 14 days after sowing on four meter length row (i.e. two rows) in each 2m x 3m plot.

ii) Growth Indices

To find the influence of nitrogen and phosphorus on growth, five plants from each plot were taken at random at 46, 53 and 61 days after sowing. Fresh leaves were removed from their base on each plant, their length and breadth (from the widest point) were measured with a ruler. A factor of 0.72 was used in calculating the leaf areas. The length of the stems were measured, and their number counted to determine tillering. From these, successive plant heights, number of tillers, leaf area/plant, Leaf Area Index were all determined. The plants and leaves (including dead ones) from each plot were then over-dried and weighed. The dry matter/plant, dry matter/m^2 were determined.

iii) Flag Leaf Area after ear emergence

Flag leaf area after 100% heading was determined

in a similar manner as described above. Flag leaves from 20 plants were excised from their base at random from each plot for this purpose.

B. Reproductive Phase

After water stress imposition at flowering,

i) Spike grain number (g)

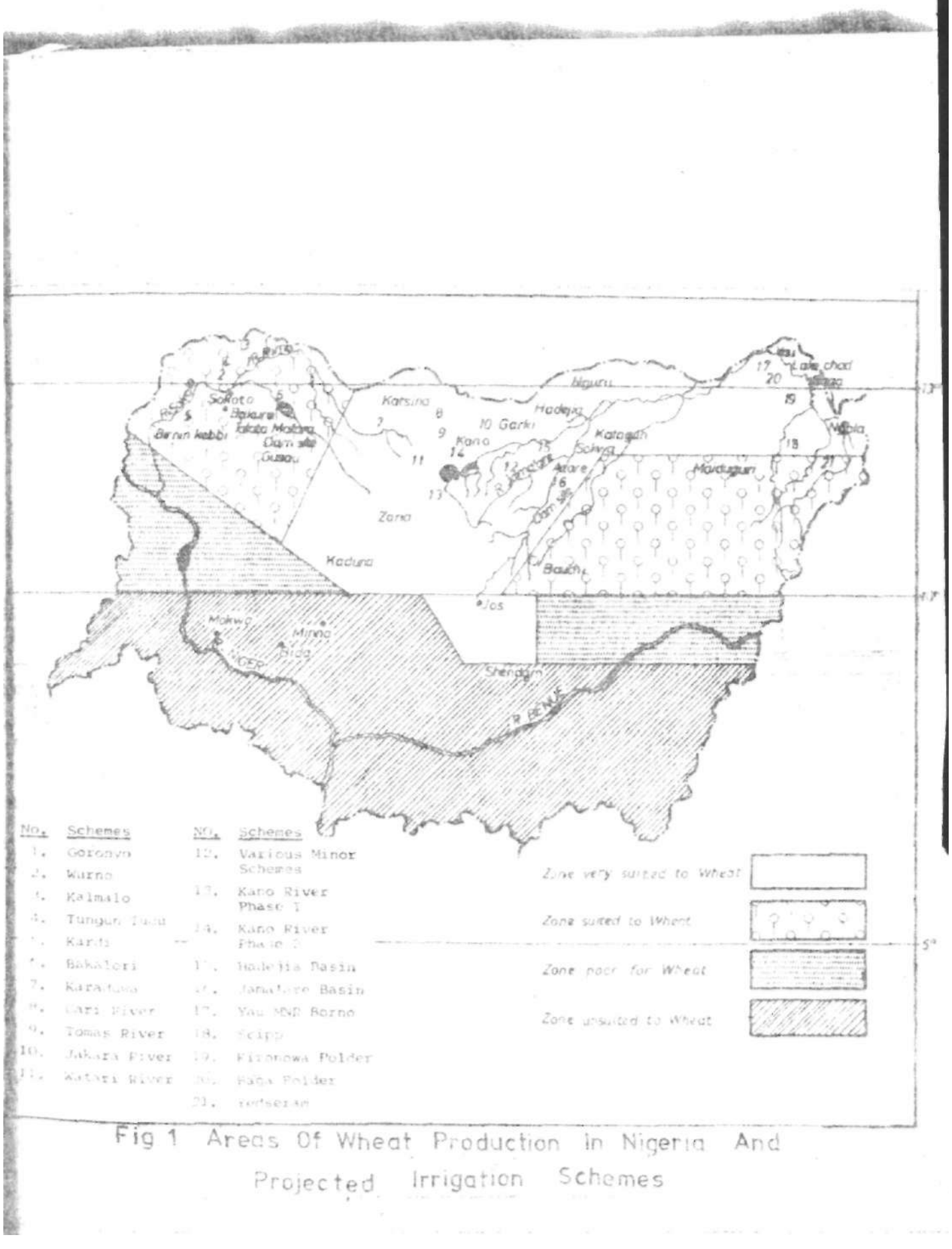
ii) Spike grain weight (g) and

iii) 1,000-grain weight (g) were determined by taking twenty spikes from their base at random from each plot at five days interval. These spikes were then sun-dried, threshed and the grains counted and weighed to progressively follow the grain development.

C. Post harvest yield and yield components

i) Length of Spike: Ten spikes were selected at random in each plot. An average length from the base to apex of the ten spikes was taken, using a ruler.

ii) Spikes number/m^2: The number was determined by counting the spikes from four meter length in each plot. This also facilitated calculation of tiller motarlity by comparing this spike number with the germination count.



No.	Schemes	No.	Schemes
1.	Goronyo	10.	Various Minor Schemes
2.	Wurno	13.	Kano River Phase I
4.	Kalmalo	14.	Kano River Phase II
5.	Tungun Tudu	17.	Hadejia Basin
6.	Kardi	18.	Jamaare Basin
7.	Bakalori	19.	Yau NNR Borno
8.	Karaduwa	20.	Scipp
9.	Gari River	21.	Fitinowa Polder
10.	Tomas River	22.	Hadejia Polder
11.	Jakara River	23.	Tudjeran
	Kafuri River		

Fig 1 Areas Of Wheat Production In Nigeria And Projected Irrigation Schemes

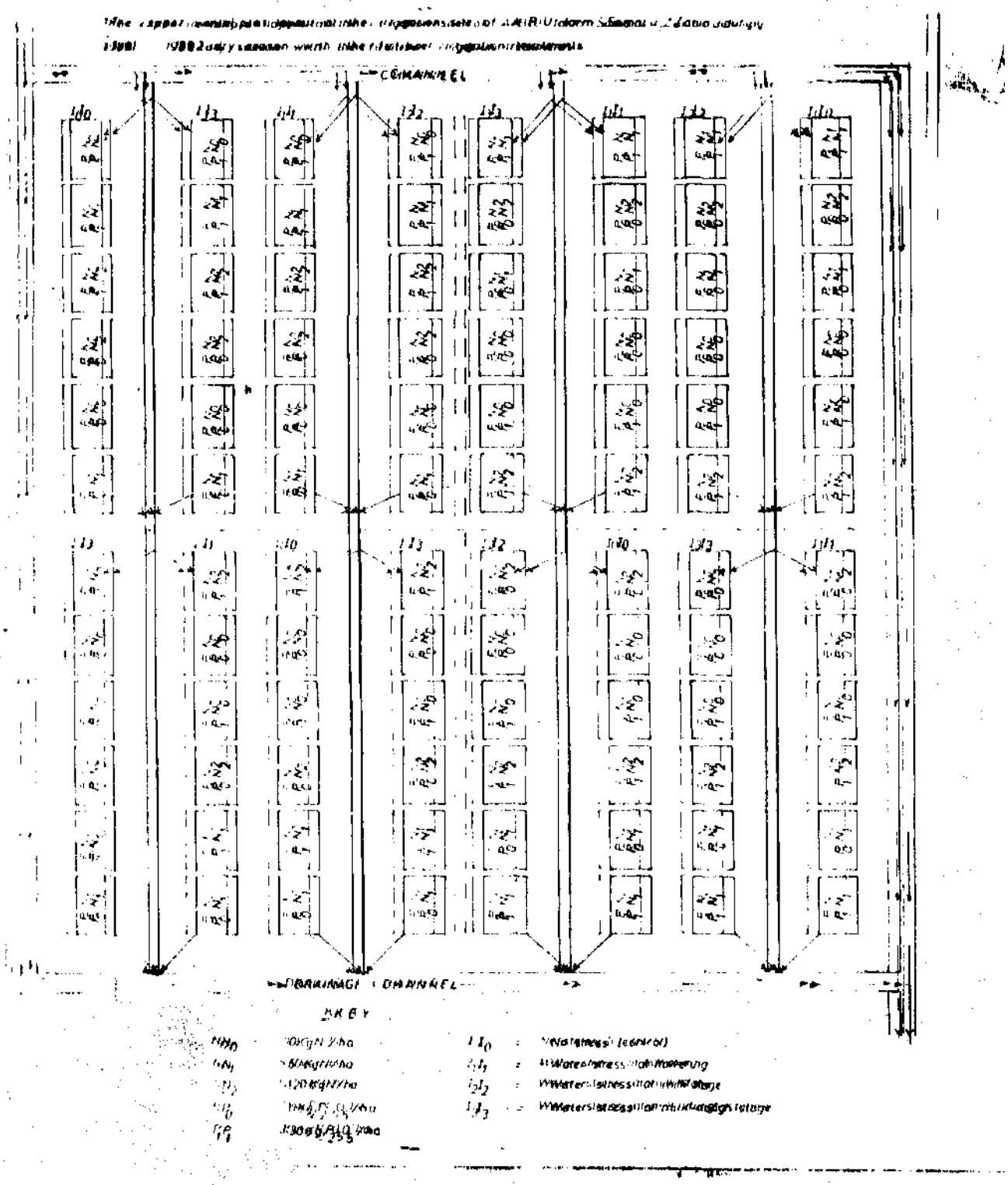
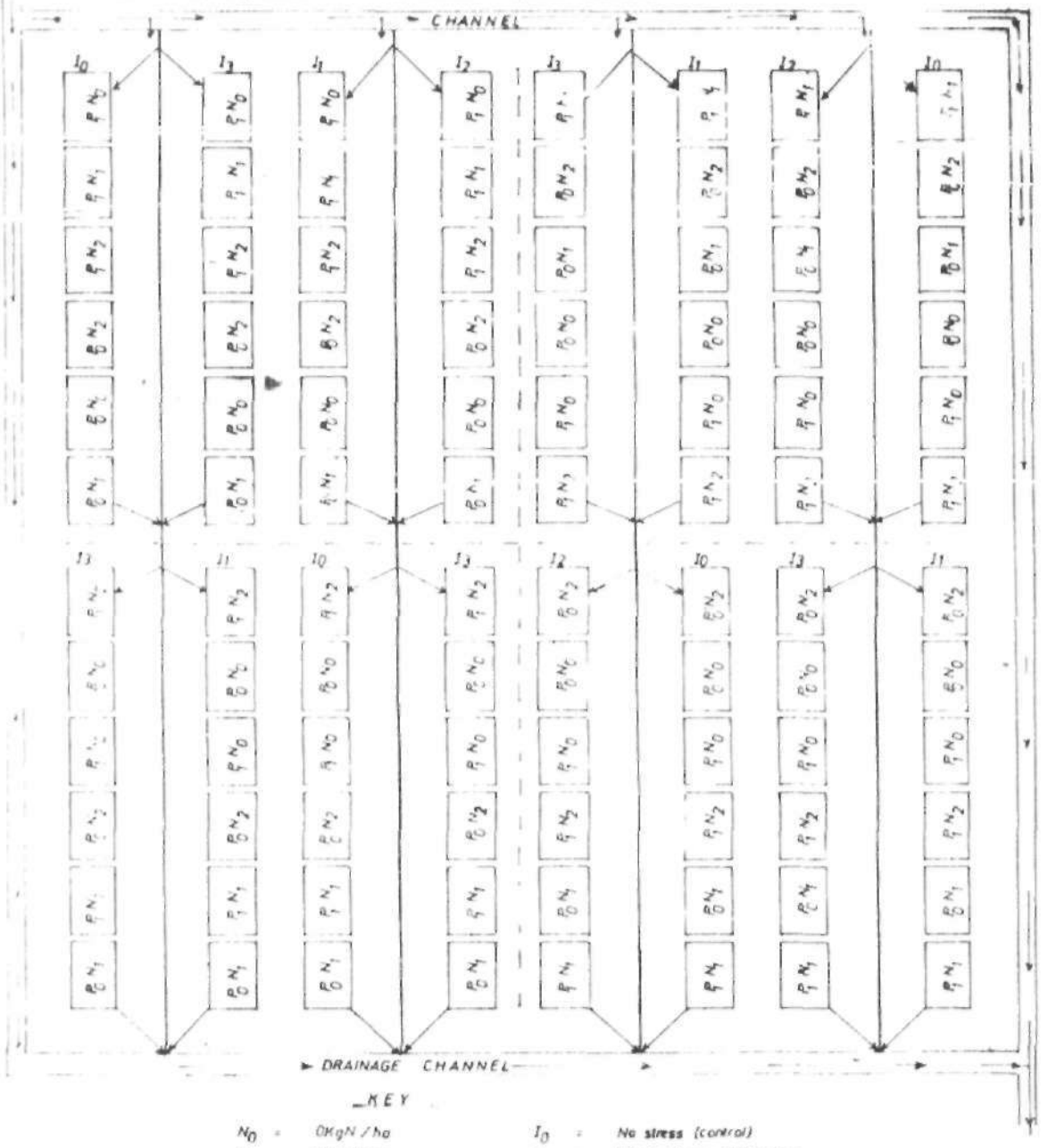


Fig 2

The experimental plot layout at the irrigation site of A B U farm Samaru, Zaria during 1981 1982 dry season with the fertilizer irrigation treatments



KEY

N_0	= 0KgN/ha	I_0	= No stress (control)
N_1	= 60KgN/ha	I_1	= Water stress at flowering
N_2	= 120KgN/ha	I_2	= Water stress at milk stage
P_0	= 0Kg P_2O_5/ha	I_3	= Water stress at milk-dough stage
P_1	= 30Kg P_2O_5/ha		

iii) Number of grains/spike: This was obtained by counting all the grains in twenty spikes randomly selected from each plot after drying and threshing. This number of grains was then divided by 20 to find the average.

iv) Weight of grains/spike: Twenty spikes were taken at random from each plot. These were air-dried, threshed and weighed. The weight of grains/spike was determined by dividing the weight by the number of spikes used.

v) Thousand grain weight: This was obtained by taking grains at random from the yield of each plot and weighed using the metler balance.

vi) Fertile and Sterile Spikelets/Spike: Ten spikes selected at random from each plot. Spikelets with and without grains were counted and recorded.

vii) Grain yield (kg/ha): This was calculated from the yield of individual plot which was recorded in gm/plot.

viii) Straw Yield (kg/ha): After harvest, the straw was cut at about two centimeters above the ground level and weighed for each plot. Statistical analysis was carried out on the strip plot design as described by Gomez and Gomez (1976).

CHAPTER 4

RESULTS

A. EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH OF WHEAT

i) Plant height

There was a positive and significant response in the height of plants to the application of nitrogen. The differences were highly significant. The plant height increased with an increase in the level of nitrogen up to the heighest dose of 120kg N/ha (Table 4.1). This was true for all the sampling periods of 46, 53 and 61 days after sowing. This can be seen in plates I, II, III and IV.

There was no significant response to the application of 30kg P_2O_5/ha at the three sampling stages.

However, there was a significant interaction effect between nitrogen and phosphorus at 46 days after sowing, but none was recorded at 53 and 61 days after sowing (Table 4.2). This table shows that in the absence of phosphorus, there was response to nitrogen application up to 60kg N/ha whereas when 30kg P_2O_5/ha was applied, the crop responded up to 120kg N/ha.



Plate I. Shows the vigorous vegetative growth effect of nitrogen (60kg N/ha) in combination with 30kg P_2O_5/ha (P_1N_1), and 30 kg P_2O_5/ha with 0kg N/ha combination.



Plate II

The same plots shot at a later date when heading started. The effect of 60kg N/ha is clearly visible on the right side of the photograph.



Plate III

A general view of a 'Strip' showing differential vegetative growth due to the different fertilizer treatments



Plate IV

A closer view of part of the 'Strip'. The plot with the yellowish colour and stunted growth is P_oN_o (i.e. no fertilizer applied).

ii) Number of tillers

The influence of nitrogen and phosphorus levels on the number of tillers/plant of wheat in Samaru at different sampling periods are presented in tables 4.3 and 4.4.

There was a positive increase in the number of tillers per plant as rates of nitrogen increased. This increase was highly significant at all the three nitrogen levels, and at all the sampling periods with the highest number of tillers per plant occuring at 53 days after sowing under the level of 120kg N/ha. However, the tiller number tend to reduce towards 61 days after sowing.

No significant difference was observed between the control and 30kg P_2O_5/ha. However a tendency of increase in the number of tiller could be seen as a result of phosphorus application (Table 4.3).

A significant interaction effect between nitrogen and phosphorus was observed at 46 and at 53 days after sowing (Table 4.4). At 46 days after sowing, under zero nitrogen level treatment, there was a negative response to the application of 30kg P_2O_5/ha. There was no significant response to phosphorus application under 60kg N/ha, but at 120kg N/ha, the response was positively high.

Table 4.1. Plant height (cm) of wheat as influenced by nitrogen and phosphorus levels at Samaru during the 1981-82 dry season sampled at 46, 53 and 61 days after sowing (DAS).

Treatments	46 DAS	53 DAS	61 DAS
Nitrogen			
0 kg N/ha (control)	16.79	30.19	38.41
60 kg N/ha	20.69	30.19	38.41
120 kg N/ha	22.47	37.60	52.01
F Test	**	**	**
L.S.D.	1.36	3.40	2.47
Phosphorus			
0 kg P_2O_5/ha (control)	19.63	33.83	46.20
30 kg P_2O_5/ha	20.21	35.5	47.02
F Test	N.S	N.S	N.S
Interactions			
N X P	**	N.S	N.S

* Sig 5%

** Sig %

N.S = Not Significant

L.S.D. = Was computed at 5% level of significance

Table 4.2. Interaction effect of nitrogen and phosphorus on plant height (cm) of wheat at Samaru during the 1981-82 dry season sampled at 46 days after sowing.

Kg P_2O_5/ha	Kg N/ha		
	0	60	120
0	17.37	20.03	21.48
30	16.22	20.95	23.46

L.S.D. = 1.91

Again under zero phosphorus level (control) tiller number did increase by the application of 60kg N/ha, and above this, the response was not significant. When 30 kg P_2O_5/ha was applied, the parameter responded positively to the application of nitrogen up to 120kg N/ha.

At 53 days after sowing also there was significant interaction effect between nitrogen and phosphorus. The observed effect was similar to the one described at 46 days after (Table 4.4).

iii) Leaf Area per plant

The effect of nitrogen and phosphorus on leaf area (cm) per plant of wheat at Samaru at different sampling periods is presented in tables 4.5 and 4.6.

Table 4.3. Tiller number per plant as influenced by nitrogen and phosphorus levels at Samaru during the 1981-82 dry season sampled at 46, 53 and 61 days after sowing (DAS).

Treatments	46 DAS	53 DAS	61 DAS
Nitrogen			
0 kg N/ha (control)	2.23	1.93	1.25
60 kg N/ha	3.07	3.00	2.05
120 kg N/ha	3.39	3.88	2.75
F Test	**	**	**
L.S.D.	0.34	0.85	0.52
Phosphorus			
0 kg P_2O_5/ha (control)	2.81	2.73	1.92
30 kg P_2O_5/ha	2.98	3.13	2.12
F Test	N.S	N.S	N.S
Interactions			
N X P	*	*	N.S

Table 4.4. Tiller number per plant as influenced by the interaction effect of nitrogen and phosphorus at Samaru during the 1981-82 dry season sampled at 46 and 53 days after sowing (DAS).

Kg N/ha	Kg P_2O_5/ha			
	46 DAS		53 DAS	
	0	30	0	30
0	2.40	2.06	2.15	1.70
60	2.96	3.18	3.00	3.00
120	3.08	3.70	3.05	4.70
L.S.D.	0.23		1.19	

Table 4.5. Leaf area per plant (cm^2) of wheat as influenced by nitrogen and phosphorus levels at Samaru during the 1981-82 dry season sampled at 46, 53 and 61 days after sowing (DAS).

Treatments	46 DAS	53 DAS	61 DAS
Nitrogen			
0 kg N/ha (control)	80.09	73.90	32.05
60 kg N/ha	128.49	137.98	68.54
120 kg N/ha	168.79	207.25	99.06
F Test	**	N.S	**
L.S.D.	25.91	N.S	16.98
Phosphorus			
0 kg P_2O_5/ha (control)	115.32	122.63	54.08
30 kg P_2O_5/ha	136.26	156.79	79.04
F Test	**	N.S	**
Interactions			
N X P	*	N.S	**

Table 4.6. Interaction effect of nitrogen and phosphorus on the leaf area per plant (sq. cm.) of wheat at Samaru during the 1981-82 dry season sampled at 46 and 61 days after sowing (DAS).

Kg N/ha	Kg P_2O_5/ha			
	46 DAS		61 DAS	
	0	30	0	30
0	80.96	79.22	35.06	29.10
60	124.36	132.62	53.29	83.79
120	140.65	196.92	54.08	79.04
L.S.D.	36.64			24.00

As the nitrogen rate increased, the leaf area per plant also increased. This increase was highly significant at 46 and at 61 days after sowing. The highest leaf area recorded (207.25 sq. cm.) was recorded at 53 days after sowing sampling period.

A highly significant response was also recorded at 46 and at 61 days after sowing when 0 and 30kg P_2O_5/ha was applied (Table 4.5).

There was a significant interaction effect between nitrogen and phosphorus at 46 and at 61 days after sowing. At 53 days after sowing, however, there was only a tendency in leaf area increase (Table 4.6).

At 46 days after sowing, nitrogen effect was only significant at 60kg N/ha with 30kg P_2O_5/ha, and phosphorus with zero level of nitrogen has little effect on leaf area per plant. Also there was non-significant difference between 60kg N/ha and 120kg N/ha when no phosphorus was applied. At 61 days after sowing, the same trend was observed as that of 46 days after sowing except that this time, there was a positive response to nitrogen application up to 120kg N/ha when 30kg P_2O_5/ha was applied.

iv) Leaf Area Index (LAI)

Data partaining to leaf area index of wheat as influenced by nitrogen and phosphorus at Samaru are presented in table 4.7.

Application of nitrogen has a highly significant effect on the leaf area index at the periods of vegetative growth examined, that is at 46, 53 and 61 days after sowing. The highest leaf area index (5.07) occured at 53 days after sowing, and the value reduced after this period (Table 4.7).

Application of 0 and 30kg P_2O_5/ha has no significant effect on leaf area index, though there was a tendency to increase when 30kg P_2O_5/ha was applied.

There was no nitrogen-phosphorus interaction observed on this character.

v) Dry matter per plant

The influence of nitrogen and phosphorus levels on dry matter accumulation (g/plant) for wheat at Samaru sampled at 46, 53 and at 61 days after sowing is presented in tables 4.8 and 4.9

There was a highly significant increase in dry matter accumulation due to the application of

Table 4.7. Leaf area index of wheat as influenced by nitrogen and phosphorus levels at Samaru during the 1981-82 dry season sampled at 46, 53 and at 61 days after sowing (DAS).

Treatments	46 DAS	53 DAS	61 DAS
Nitrogen			
0 kg N/ha (control)	1.89	1.53	0.67
60 kg N/ha	3.15	3.27	1.59
120 kg N/ha	3.87	5.07	2.45
F Test	**	**	**
L.S.D.	0.57	1.50	0.75
Phosphorus			
0 kg P_2O_5/ha (control)	2.87	3.17	1.14
30 kg P_2O_5/ha	3.07	3.41	1.71
F Test	N.S	N.S	N.S
Interaction			
N X P	N.S	N.S	N.S

Table 4.8. Dry matter accumulation/plant of wheat (g/plant) as influenced by nitrogen and phosphorus levels at Samaru during the 1981-82 dry season sampled at 46, 53 and 61 days after sowing (DAS).

Treatments	46 DAS	53 DAS	61 DAS
Nitrogen			
0 kg N/ha (control)	0.61	0.97	1.28
60 kg N/ha	1.01	1.66	1.83
120 kg N/ha	1.18	1.93	2.22
F Test	**	**	**
L.S.D.	0.12	0.44	0.68
Phosphorus			
0 kg P_2O_5/ha (control)	0.87	1.41	1.67
30 kg P_2O_5/ha	0.99	1.63	1.88
F Test	*	N.S	N.S
Interaction			
N X P	*	*	N.S

Table 4.9. Interaction effect of nitrogen and phosphorus on the dry matter accumulation/plant (g/plant) of wheat at Samaru during the 1981-82 dry season sampled at 46 and 53 days after sowing (DAS).

Kg N/ha	Kg P_2O_5/ha			
	46 DAS		53 DAS	
	0	30	0	30
0	0.64	0.59	1.08	0.87
60	0.93	1.08	1.61	1.71
120	1.05	1.30	1.55	2.32
L.S.D.	0.16		0.62	

nitrogen up to 61 days after sowing. The highest dry matter accumulation(2.22g) occured at 61 days after sowing under 120kg N/ha, and the lowest (0.61g) occured under zero nitrogen treatment at 46 days after sowing sampling period. Application of phosphorus was observed to significantly affecting dry matter accumulation only at 46 days after sowing, though there was a positive but non-significant tendency of increase at 53 and 61 days after sowing (Table 4.8).

However, there was a significant nitrogen-phosphorus interaction at 46 and at 53 days after sowing. At 46 days, when no phosphorus was applied, response to nitrogen application was only up to 60kg N/ha, but when 30kg P_2O_5/ha was applied, plants responded to nitrogen application up to 120kg N/ha (Table 4.9).

Thirty kg P_2O_5/ha without nitrogen tend to depress dry matter accumulation/plant. A similar situation could be seen at 53 days after sowing sampling period.

vi) Dry matter per square metre

The influence of nitrogen and phosphorus levels on the dry matter accumulation/square metre

(g/m^2) of wheat at Samaru sampled at 46, 53 and 61 days after sowing (DAS) is presented in table 4.10.

There was a positive increase in dry matter accumulation/m^2 as nitrogen and phosphorus rates increased. Nitrogen effect was highly significant at 46, 53 and 61 days after sowing. Phosphorus has no significant effect, but there was a tendency for increase (except at 61 days after sowing) when 30kg P_2O_5/ha was applied (Table 4.10).

There was no nitrogen and phosphorus interaction effect observed.

vii) Flag Leaf Area

The effect of nitrogen and phosphorus levels on the flag leaf area (sq. cm.) of wheat at Samaru during the 1981-82 dry season after 100% head emergence is presented in, Tables 4.11 and 4.12.

There was a highly significant response to nitrogen application with 47.85% increase in flag leaf area over the control.

Application of phosphorus 30kg P_2O_5/ha, did not have any significant effect on the flag leaf area (Table 4.12).

Table 4.10. Dry matter accumulation/m^2 of wheat (g/m^2) as influenced by nitrogen and phosphorus levels at Samary during the 1981-82 dry season sampled at 46, 53 and 61 days after sowing (DAS).

Treatment	46 DAS	53 DAS	61 DAS
Nitrogen			
0 kg N/ha (control)	145.10	200.79	267.38
60 kg N/ha	247.83	390.81	428.50
120 kg N/ha	286.48	470.78	546.22
F Test	**	**	**
L.S.D.	38.33	114.93	186.56
Phosphorus			
0 kg P_2O_5/ha (control)	217.48	352.19	417.73
30 kg P_2O_5/ha	235.45	356.06	410.09
F Test	N.S	N.S	N.S
Interactions			
N X P	N.S	N.S	N.S

Table 4.11. Flag leaf area (cm^2) of wheat as influenced by nitrogen and phosphorus levels after 100% head emergence at Samary during the 1981-82 dry season.

Treatments	Area (sq cm)
<u>Nitrogen</u>	
0 kg N/ha (control)	11.87
60 kg N/ha	14.55
120 kg N/ha	17.55
F Test	**
L.S.D.	1.78
<u>Phosphorus</u>	
0 kg P_2O_5/ha (control)	14.14
30 kg P_2O_5/ha	15.18
F Test	N.S
<u>Interactions</u>	
N X P	**

Table 4.12. The interaction effect of nitrogen and phosphorus on the flag leaf area (sq cm) of wheat after 100% head emergence at Samaru during the 1981-82 dry season.

Kg P_2O_5/ha	Kg N/ha		
	0	60	120
0	12.00	15.06	15.35
30	11.75	14.05	19.74

L.S.D. = 2.51

A highly significant interaction effect between nitrogen and phosphorus was observed (Table 4.12). It is clear that the response to nitrogen application was only up to 68 kg N/ha in the absence of phosphorus application, but when 30kg P_2O_5/ha was applied, significant response was observed up to 120kg N/ha. On the other hand, plants responded to phosphorus application only when as much as 120kg N/ha was applied. Under no nitrogen treatment, there was no effect of application of 30kg P_2O_5/ha.

B. THE INFLUENCE OF IRRIGATION, NITROGEN AND PHOSPHORUS LEVELS ON SPIKE GRAIN WEIGHT AND THOUSAND GRAIN WEIGHT AT FIVE DAYS INTERVALS.

i) Spike Grain Weight

The irrigation treatment effects were not pronounced at the early stages of grain development, that is, at 72 and 77 days after sowing. The no stress treatment and the stress at milk stage produced the lightest spike grain weight at 72 and 77 days after sowing, while in both the stress intervals, the heaviest spike grains occured when the water stress occured at the milk-dough stage. The differences between treatments at both stages were not significant. At 82 and 87 days after sowing, irrigation treatments significantly affected the grains/spike. At these sampling periods, stress at milk-dough stage gave the highest spike grain weight, followed by the control (no stress), then stress at flowering and finally stress at milk-stage gave the lowest spike grain weight. Note that at 82 and 87 days after sowing, the no stress treatment was fast gaining weight. However, at 92 days after sowing, the differences between the irrigation treatments were not statistically significant, but the control (no stress) treatment continued to show that the

grains gained more weight in accumulated substrates. This led to the production of the heaviest spike grain weight (733.50 mg), followed by the stress at milk-dough stage. The least spike grain weight were recorded for stress at flowering and milk stages.

Nitrogen application significantly affected the spike grain weight throughout the grain filling period. At 72, 82, 87 and 92 days after sowing there was more response to the application of 60kg N/ha than to the 120kg N/ha, however, differences due to 60 and 120kg N/ha were not significant. At 77 days after sowing, the application of 120kg N/ha produced the heaviest spike grain weight than did 60kg N/ha. At all the stages, the central (no nitrogen) treatment consistently gave the lowest spike grain weight over the other nitrogen treatments. Generally, the 60kg N/ha treatment gave the heaviest spike grain weight at the sampling periods.

Phosphorus application of 30kg P_2O_5/ha had no significant effect on the spike grain weight at any of the stages examined. Though treatment differences were non-significant at any one stage, application of 30kg P_2O_5/ha tended to depress spike grain weight at the early stages of grain

development, but consistently tended to increase spike grain weight thereafter (Table 4.13).

However, phosphorus application interacted significantly with the nitrogen levels (except at early stages of grain development). At 77 days after sowing, there was a negative response to phosphorus application in the absence of nitrogen, but when 60kg N/ha was applied, the response was highest, even higher than when 120kg N/ha was applied. In the absence of phosphorus, a positive response was obtained up to 120kg N/ha. At 82 and 87 days sowing, an exactly the same picture emerged as that of 77 days after sowing (Table 4.14).

However, at 92 days after sowing, a slightly different picture was obtained. As the other stages, under no nitrogen treatment, 30kg P_2O_5/ha phosphorus application tended to have a negative effect on the spike grain weight. When nitrogen was applied, spike grain weight responded up to 120kg N/ha in presence of 30kg P_2O_5/ha. But when no phosphorus was applied, the response to nitrogen application was only to 60kg N/ha.

ii) Thousand grain weight

The effect of irrigation, nitrogen and phosphorus treatments on grain filling of wheat

Table 4.13. Spike grain weight (mg) recorded at 5-day interval to show grain development as affected by irrigation treatment, nitrogen and phosphorus levels at Samaru during the 1981-82 dry season at 72, 77, 82, 87 and 92 days after sowing (DAS).

Treatments	72 DAS	77 DAS	82 DAS	87 DAS	92 DAS
Irrigation					
No stress (control)	131.00	285.20	408.70	561.50	733.50
Stress at flowering stage	138.90	282.30	370.00	455.70	631.70
Stress at milk-stage	149.70	272.30	367.30	434.40	642.30
Stress at milk-dough stage	185.00	312.60	473.00	606.20	712.20
F Test	N.S	N.S	*	*	N.S
L.S.D.	-	-	92.00	117.20	-
Nitrogen					
0 kg N/ha (control)	117.50	224.90	215.80	413.50	571.70
60 kg N/ha	173.30	314.90	452.90	581.40	742.80
120 kg N/ha	162.70	324.50	437.60	548.40	726.70
F Test	*	*	*	*	*
L.S.D.	44.50	61.90	77.80	104.90	112.90
Phosphorus					
0 kg P_2O_5/ha (control)	155.20	267.70	380.70	476.90	656.00
30 kg P_2O_5/ha	147.20	308.50	428.60	552.00	704.80
F Test	N.S	N.S	N.S	N.S	N.S
Interactions					
I X N	N.S	N.S	N.S	N.S	N.S
I X P	N.S	N.S	N.S	N.S	N.S
N X P	N.S	*	*	*	*
L.S.D.	-	72.10	110.00	148.30	159.60

Table 4.14. The interaction effect of nitrogen and phosphorus levels on the spike graom weight (mg) development of wheat at Samaru during the 1981-82 dry season sampled at five-day intervals of 77, 82, 87 and 92 days after sowing (DAS).

Kg N/ha	Kg P_2O_5/ha							
	77 DAS		82 DAS		87 DAS		92 DAS	
	0	30	0	30	0	30	0	30
0	237.30	212.50	349.20	298.30	431.80	395.30	607.90	535.60
60	269.40	360.30	394.70	511.10	506.40	556.40	697.40	788.10
120	296.30	352.60	398.80	476.40	492.60	604.30	662.80	790.70
L.S.D.	72.10		110.00		149.30		159.60	

(1,000-grain weight) recorded at five-day intervals is presented in tables 4.15, 4.16 and 4.17 in gm.

The effect of irrigation treatments was pronounced at 72 days after sowing, the no stress treatment produced the lowest 1,000-grain weight (5.71g), followed by the treatment at milk-dough stage. The other two treatments (stress at flowering and at milk stages) produced the heaviest grains and the differences were statistically significant. At 77 days after sowing, the no stress (control) treatment continued to give the lowest value among the four treatments, but the differences were not significant. At 82 days after sowing, the treatment of stress at milk-dough stage was superior to the other three treatments. The same trend was also observed at 87 days after sowing, but the differences were not statistically significant. However, at 92 days after sowing, the differences were significant. The no stress treatment emerged to have the highest 1,000-grain weight (33.39g). All the other stress treatments did not differ among themselves significantly.

Nitrogen application affected significantly the 1,000-grain weight only at the early stages

of grain development. The application of 120kg N/ha caused increase in the 1,000-grain weight over either that of control or the 60kg N/ha treatment. This was the case at 72 days after sowing, but at 77 days, the response recorded was at 60kg N/ha and there was no response to the additional 60kg N/ha (120kg N/ha treatment). Thereafter, no significant difference was observed at any of the later stages (at 82, 87 and 92 days after sowing).

Application of 30kg P_2O_5/ha had no significant effect on the 1,000-grain weight at any of the sampling periods (Table 4.15).

However, the phosphorus application interacted significantly with the levels of nitrogen. This was the case in all the sampling periods examined (Table 4.16). At 72 days after sowing, there was negative response to the application of 30kg P_2O_5/ha under zero level of nitrogen, positive response under 60kg N/ha and no response under the highest level of nitrogen (120kg N/ha). Again under no phosphorus application, there was negative response to the application of 60kg N/ha. When 30kg P_2O_5/ha phosphorus was applied, the response was positive. The same picture was observed at 77 days sowing,

and it is worth mentioning here, that application of 120kg N/ha caused a reduction in the 1,000-grain weight under 30kg P_2O_5/ha. At 82, 87 and 92 days after sowing, similar trends were observed, and the negative or positive response were statistically significant. The negative response to the application of 120kg N/ha was observed only when no phosphorus was applied, and the response was up to 60kg N/ha under 30kg P_2O_5/ha treatment.

There was interaction effect between irrigation treatments and nitrogen levels observed at 77 days after sowing (Table 4.17). Under no stress treatment (I_o), there was a positive response to nitrogen application up to 60kg N/ha. When the stress occured at flowering (I_1), the response was also up to 60kg N/ha, when 120kg N/ha was applied, the 1,000-grain weight reduced significantly. When irrigation was missed at milk stage (I_2), the response was up to 60kg N/ha, and there was no difference between 60 and 120 N/ha treatments. Under water stress at milk-dough stage (I_3), there was response up to 120kg N/ha (Table 4.17).

Table 4.15. Thousand grain weight (g) recorded at 5-day interval to show grain development of wheat as affected by irrigation treatment, nitrogen and phosphorus levels at Samaru during the 1981-82 dry season at 72, 77, 82, 87 and 92 days after sowing (DAS).

Treatments	72 DAS	77 DAS	82 DAS	87 DAS	92 DAS
Irrigation					
No stress (control)	5.71	10.73	16.91	25.05	33.39
Stress at flowering stage	6.38	11.79	16.70	24.25	31.33
Stress at milk stage	6.38	11.77	16.75	23.83	29.59
Stress at milk-dough stage	6.06	11.75	18.58	26.25	29.55
F Test	*	N.S	*	N.S	**
L.S.D.	0.27	-	1.19	-	1.86
Nitrogen					
0 kg N/ha (control)	6.06	10.91	16.73	24.07	30.96
60 kg N/ha	5.94	11.78	17.12	24.67	31.31
120 kg N/ha	6.43	11.87	17.86	25.79	30.63
F Test	*	*	N.S	N.S	N.S
L.S.D.	0.21	0.30	-	-	-
Phosphorus					
0 kg P_2O_5/ha (control)	6.18	11.55	17.31	25.17	31.13
30 kg P_2O_5/ha	6.09	11.49	17.16	24.52	30.00
F Test	N.S	N.S	N.S	N.S	N.S
Interactions					
I X N	N.S	*	N.S	N.S	N.S
I X P	N.S	N.S	N.S	N.S	N.S
N X P	*	*	*	*	**
L.S.D.	0.25	0.43	0.73	0.93	1.32

Table 4.16. The interaction effect of nitrogen and phosphorus levels on the 1,000-grain weight (g) of wheat at Samaru during the 1981-82 dry season sampled at five-day intervals of 72, 77, 82, 87 and 92 days after sowing (DAS).

Kg N/ha	Kg P_2O_5/ha									
	72 DAS		77 DAS		82 DAS		87 DAS		92 DAS	
	0	30	0	30	0	30	0	30	0	30
0	6.67	5.45	11.90	9.91	18.26	15.21	26.21	21.93	32.51	29.41
60	5.41	6.47	10.74	12.82	15.60	18.65	23.06	26.28	30.89	31.73
120	6.45	6.35	12.00	11.75	18.07	17.64	26.24	24.35	29.41	31.26
L.S.D.	0.25		0.43		0.73		0.93		1.32	

Table 4.17. The interaction effect of irrigation treatments and nitrogen levels on the 1,000-grain weight (g) of wheat at Samaru during the 1981-82 dry season sampled at 77 days after sowing.

Kg N/ha	Irrigation treatments			
	I_o	I_1	I_2	I_3
0	10.54	9.86	11.48	11.74
60	10.85	12.96	12.26	11.07
120	10.95	12.54	11.57	12.44
L.S.D.		0.28		

I_o = no stress (control)

I_1 = stress at flowering

I_2 = stress at milk stage

I_3 = stress at milk-dough stage

C. THE EFFECT OF IRRIGATION TREATMENTS, NITROGEN AND PHOSPHORUS LEVELS ON YIELD AND YIELD COMPONENTS

i) Plant height at harvest

Irrigation treatments did not affect the final plant height significantly (Table 4.18).

However, nitrogen effect was highly significant, with the maximum height (53.34 cm) occuring under 60kg N/ha, but the difference between the two nitrogen levels was not significant.

Though application of phosphorus tended to increase plant height, there was no significant difference between the zero and 30kg P_2O_5/ha.

Finally, all the factors acted independently on plant height, since no interaction of any order was found to be significant statistically (Table 4.18).

ii) Spike length

The effect of irrigation treatments, nitrogen and phosphorus levels on the spike length (cm) of wheat at harvest is presented in tables 4.19 and 4.20.

Irrigation did not statistically affect the length of spike. The spike length under no

stress (control) was almost at par with the spike length when water stress was imposed at milk stage.

However, nitrogen application has highly a significant effect on spike length. The significant response recorded was up to 60kg N/ha only, and there was no significant interaction between nitrogen and irrigation (I X N), irrigation and phosphorus (I X P). However, there was a significant interaction effect between nitrogen and phosphorus (N X P). In the absence of phosphorus application, response to nitrogen was only up 60kg N/ha, after this dose, the response was not significant. With the application of 30kg P_2O_5/ha, significant response up to 120kg N/ha was observed.. At zero level of nitrogen, application of 30kg P_2O_5/ha did not improve spike length, in fact it tended to depress it (Table 4.20).

iii) Spike number per square metre

The effect of irrigation, nitrogen and phosphorus levels on the spike number/m^2 of wheat at Samaru is presented in tables 4.21 and 4.22.

There was no significant effect of irrigation recorded, though least number of spike per square metre occured under water at milk-stage which is

Table 4.18. Plant height (cm) of wheat at harvest as influenced by irrigation, nitrogen and phosphorus levels in Samaru during the 1981-82 dry season.

Treatments	Height (cm)
Irrigation	
No stress (control)	49.74
Stress at flowering stage	47.67
Stress at milk stage	51.21
Stress at milk-dough stage	52.80
F Test	N.S
Nitrogen	
0 kg N/ha (control)	45.98
60 kg N/ha	53.34
120 kg N/ha	51.74
F Test	**
L.S.D.	3.19
Phosphorus	
0 kg P_2O_5/ha (control)	49.36
30 kg P_2O_5/ha	51.35
F Test	N.S
Interactions	
I X N	N.S
I X P	N.S
N X P	N.S

Table 4.19. Spike length (cm) of wheat at harvest as influenced by irrigation, nitrogen and phosphorus levels at Samaru during the 1981-82 dry season.

Treatments	Length (cm)
Irrigation	
No stress (control)	8.15
Stress at flowering stage	8.09
Stress at milk stage	8.17
Stress at milk-dough stage	8.03
F Test	N.S
Nitrogen	
0 kg N/ha (control)	7.49
60 kg N/ha	8.13
120 kg N/ha	8.70
F Test	**
L.S.D.	0.40
Phosphorus	
0 kg P_2O_5/ha	8.20
30 kg P_2O_5/ha	8.02
F Test	N.S
Interactions	
I X N	N.S
I X P	N.S
N X P	*

Table 4.20: The interaction effect of nitrogen and phosphorus levels on the spike length (cm) of wheat at harvest in Samaru during the 1981-82 dry season.

Kg P_2O_5/ha	Kg N/ha		
	0	60	120
0	7.70	8.34	8.46
30	7.21	7.89	8.94

L.S.D. = 0.57

is 21% less spikes than the control.

Similarly, there was no significant effect of nitrogen and phosphorus application (Table 4.21). However, significant interaction effect between irrigation and nitrogen, and irrigation and phosphorus were observed. Under no nitrogen application, missing irrigation at milk stage increased the mortality of the spikes. When 60kg N/ha was applied, the stress at milk and milk-dough stages adversely affected the spike number per square metre. However, under full dose of nitrogen fertilizer (120kg N/ha), all stress treatments had significantly less number of spike as compared to the control. On the other hand, wheat responded positively to the

Table 4.21. Spike number/square metre of wheat as influenced by irrigation, nitrogen and phosphorus levels at Samaru during the 1981-82 dry season.

Treatments	Number
Irrigation	
No stress (control)	263.46
Stress at flowering stage	225.33
Stress at milk stage	208.00
Stress at milk-dough stage	234.29
F. Test	N.S
Nitrogen	
0 kg N/ha (control)	229.19
60 kg N/ha	237.59
120 kg N/ha	231.91
F Test	N.S
Phosphorus	
0 kg P_2O_5/ha (control)	237.50
30 kg P_2O_5/ha	228.29
F Test	N.S
Interactions	
I X N	*
I X P	*
N X P	N.S

application of only 60kg N/ha under the no stress treatment. Negative responses were observed when 60kg N/ha was applied under the stress at flowering and milk-dough stages. But under stress at milk stage, positive response was recorded up to 60kg N/ha (Table 4.22).

The second significant interaction was that of irrigation and phosphorus. Under no phosphorus fertilizer treatment, the superiority over the other treatments of no stress (control) treatment was observed. This is followed by the stress occuring at milk-dough stage. With 30kg P_2O_5/ha phosphorus treatment, however, the no stress treatment had the highest spike number per square metre followed by the stress at both flowering and milk-dough stages, and the least number of spikes was recorded under stress treatment at milk stage. On the other direction, positive response to 30kg P_2O_5/ha was observed only under stress treatment at flowering stage. Negative responses to phosphorus application were seen at no stress (I_c) stress at milk-stage (I_2) and stress at milk-dough stage (I_3).

iv) Spike grain number

The effect of irrigation, nitrogen and phosphorus levels on the spike grain number of

Table 4.22. Interaction effect between irrigation and nitrogen and irrigation and phosphorus fertilizer levels on the spike number per square meter of wheat at Samaru during the 1981-82 dry season.

Fertilizer	Irrigation Treatments			
	I_o	I_1	I_2	I_3
Kg N/ha				
0	243.63	237.38	196.63	239.13
60	272.00	220.50	217.75	240.13
120	274.75	218.13	209.88	224.88
L.S.D.		12.52		
Kg P_2O_5/ha				
0	271.75	215.92	218.67	243.67
30	255.17	234.75	197.50	225.75
L.S.D.		10.23		

wheat at harvest in Samaru is presented in table 4.23 and 4.24.

The grain number per spike was significantly affected by irrigation, with the least grain number (31.45) occuring at stress during the flowering stage.

Nitrogen application has a highly significant effect on the grain number per spike. The highest grain number (37.34) occured under nitrogen rate of 120kg N/ha as compared to both control and 60kg N/ha.

There was no significant effect of phosphorus application of 30kg P_2O_5/ha on this character.

There was a marginal nitrogen and phosphorus interaction. There was no significant response to nitrogen application under zero level of phosphorus, but under 30kg P_2O_5/ha, a positive and significant response to the application of 120kg N over the control was observed. On the other hand, there was no response to the application of phosphorus under 60kg N/ha level as far as this character is concerned.

v) Spike grain weight at harvest

The effect of irrigation, nitrogen and

Table 4.23. Grain number per spike of wheat as influenced by irrigation, nitrogen and phosphorus levels at Samaru during the 1981-82 dry season.

Treatments	Number
Irrigation	
No stress (control)	36.07
Stress at flowering stage	31.45
Stress at milk-dough stage	35.50
F Test	*
L.S.D.	3.02
Nitrogen	
0 kg N/ha (control)	33.03
60 kg N/ha	33.64
120 kg N/ha	37.34
F Test	**
L.S.D.	2.61
Phosphorus	
0 kg P_2O_5/ha (control)	34.54
30 kg P_2O_5/ha	34.80
F Test	N.S
Interactions	
I X N	N.S
I X P	N.S
N X P	*

Table 4.24. Interaction effect of nitrogen and phosphorus on grain number per spike of wheat at Samaru during the 1981-82 dry season taken at harvest.

Kg P_2O_5/ha	Kg N/ha		
	0	60	120
0	32.97	34.88	35.79
30	33.10	32.40	38.89

phosphorus levels on the spike grain weight (g) at harvest of wheat at Samaru is reported in table 4.25.

This character was significantly affected by irrigation treatment. The highest spike grain weight (1.42g) was obtained under no stress treatment (control). The lowest spike grain weight occured under water stress at milk stage, but differences between stress at flowering, milk and milk-dough stages were not statistically significant.

Application of 60 and 120kg N/ha of nitrogen did not affect this parameter significantly. However, a positive response was observed up to 120kg N/ha.

Phosphorus application up to 30kg P_2O_5/ha did not significantly affect spike grain weight (Table 4.25).

vi) Thousand grain weight at harvest

The effect of irrigation, nitrogen and phosphorus levels on the 1,000-grain weight (g) of wheat at harvest in Samaru is presented in tables 4.26 and 4.27.

Thousand grain weight was significantly affected by irrigation treatment. The highest 1,000-grain weight (36.969) was obtained under no stress treatment (control), followed by water stress at flowering. The lowest 1,000-grain weight occured under water stress treatment at milk stage. Water stress at flowering did not have significantly different effect with control, but stress at milk and milk-dough stages significantly differ with control. Nitrogen application did not significantly affect 1,000-grain weight. In fact, there was a tendency that nitrogen application reduced the 1,000-grain weight because both 60kg and 120kg N/ha were less than control, even though the differences were not statistically significant.

Similar results were obtained when 30kg P_2O_5/ha phosphorus was applied. The tendency was

Table 4.25. Spike grain weight (g) of wheat at harvest as influenced by irrigation, nitrogen and phosphorus levels at Samaru taken at harvest during the 1981-82 dry season.

Treatments	Weight (g)
Irrigation	
No stress (control)	1.42
Stress at flowering stage	1.20
Stress at milk stage	1.09
Stress at milk-dough stage	1.61
F Test	*
L.S.D.	0.20
Nitrogen	
0 kg N/ha (control)	1.14
60 kg N/ha	1.21
120 kg N/ha	1.29
F Test	N.S
Phosphorus	
0 kg P_2O_5/ha (control)	1.25
30 kg P_2O_5/ha	1.18
F Test	N.S
Interactions	
I x N	N.S
I X P	N.S
N X P	N.S

Table 4.26. Thousand grain weight (g) at harvest as influenced by irrigation, nitrogen and phosphorus levels at Samaru during the 1981-82 dry season.

Treatments	Weight (g)
Irrigation	
No stress (control)	36.96
Stress at flowering stage	35.85
Stress at milk stage	33.89
Stress at milk-dough stage	34.12
F Test	*
L.S.D.	2.11
Nitrogen	
0 kg N/ha (control)	35.93
60 kg N/ha	34.89
120 kg N/ha	34.79
F Test	N.S
Phosphorus	
0 kg P_2O_5/ha (control)	35.46
30 kg P_2O_5/ha	34.95
F Test	N.S
Interactions	
I X N	N.S
I X P	N.S
N X P	*

towards lower 1,000-grain weight with the application of 30kg P_2O_5/ha, though differences with control were not significant.

However, there was some interaction between nitrogen and phosphorus fertilizers. Application of 30kg P_2O_5/ha without nitrogen significantly reduced the 1,000-grain weight. The same tendency was observed at 60kg N/ha, but the difference was not significant. Only at a higher dose of nitrogen (120kg N/ha) did 1,000-grain weight responded positively to the application of 30kg P_2O_5/ha. It was also observed that under zero phosphorus, 1,000-grain weight kept on declining with increasing rate of nitrogen.

Table 4.27. Interaction effect between nitrogen and phosphorus levels on the 1,000-grain weight (g) at harvest at Samaru during the 1981-82 dry season.

Kg P_2O_5/ha	Kg N/ha		
	0	60	120
0	36.91	35.45	33.84
30	34.95	34.33	35.57

vii) Fertile Spikelets per Spike

The effect of irrigation, nitrogen and phosphorus on the fertile spikelets per spike of

wheat at Samaru during the 1981-82 dry season is presented in table 4.28.

Irrigation treatment did not have any significant effect on fertility of spikelets, though higher fertility was recorded under no stress treatment.

Nitrogen application effect was highly significant for both 60 and 120kg N/ha, but the difference between the two nitrogen treatments levels was not significant (Table 4.28).

Application of 30kg P_2O_5/ha phosphorus had no significant effect on the fertility of spikelets per spike.

No significant interaction effect was observed.

viii) Sterile Spikelets per Spike

The effect of irrigation, nitrogen and phosphorus on the sterile spikelets per spike of wheat at Samaru during the 1981-82 dry season is presented in table 4.29.

Irrigation did not significantly affect the number of sterile spikelets per spike.

Nitrogen and phosphorus had significant effect on this character. Application of 60kg N/ha

Table 4.28. Fertile Spikelets/spike of wheat as influenced by irrigation, nitrogen and phosphorus at Samaru during the 1981-82 dry season.

Treatments	Number
Irrigation	
No stress (control)	15.30
Stress at flowering stage	14.73
Stress at milk stage	14.91
Stress at milk-dough stage	14.73
F Test	N.S
Nitrogen	
0 kg N/ha (control)	13.96
60 kg N/ha	15.00
120 kg N/ha	15.79
F Test	**
L.S.D.	1.04
Phosphorus	
0 kg P_2O_5/ha (control)	15.00
30 kg P_2O_5/ha	14.84
F Test	N.S
Interaction	
I X N	N.S
I X P	N.S
N X P	N.S

Table 4.29. Sterile Spikelets/spike of wheat as influenced by irrigation, nitrogen and phosphorus at Samaru during the 1981-82 dry season.

Treatments	Number
Irrigation	
No stress (control)	2.06
Stress at flowering stage	1.83
Stress at milk stage	1.95
Stress at milk-dough stage	2.00
F Test	N.S
Nitrogen	
0 kg N/ha (control)	1.89
60 kg N/ha	2.21
120 kg N/ha	1.77
F Test	**
L.S.D.	0.20
Phosphorus	
0 kg P_2O_5/ha (control)	1.87
30 kg P_2O_5/ha	2.04
F Test	*
Interactions	
I X N	N.S
I X P	N.S
N X P	N.S

increased the number of sterile spikelets, but this number decreased as nitrogen level increased to 120kg N/ha. However, application of 30kg P_2O_5/ha did increase sterile spikelets per spike significantly. No interaction effect was recorded.

ix) Grain yield

The effect of irrigation, nitrogen and phosphorus on the grain yield of wheat at Samaru during the 1981-82 dry season is presented in tables 4.30 and 4.31.

Irrigation treatment affected the grain yield significantly. The lowest yield (1,324.00 kg/ha) was recorded under the treatment of water stress at flowering. However, the yields obtained in stress treatments at milk stage and milk-dough stage were significantly lower than that recorded under no stress (control).

The response to nitrogen application was significant only when 60kg N/ha was applied and there was no significant difference between the yield of the two nitrogen levels (60 and 120kg).

Phosphorus application of 30kg P_2O_5/ha has also affected the grain yield significantly.

Table 4.30. Grain yield (kg/ha) of wheat as influenced by irrigation, nitrogen and phosphorus at Samaru during the 1981-82 dry season.

Treatments	Yield kg/ha
Irrigation	
No stress (control)	1,922.30
Stress at flowering stage	1,324.00
Stress at milk stage	1,625.00
Stress at milk-dough stage	1,636.00
F Test	**
L.S.D.	213.50
Nitrogen	
0 kg N/ha (control)	1,275.70
60 kg N/ha	1,721.80
120 kg N/ha	1,883.51
F Test	**
L.S.D.	171.00
Phosphorus	
0 kg P_2O_5/ha (control)	1,533.90
30 kg P_2O_5/ha	1,720.00
F Test	**
Interactions	
I X N	N.S
I X P	N.S
N X P	*

Table 4.31. Interaction effect of nitrogen and phosphorus on grain yield (kg/ha) of wheat at Samaru during the 1981-82 dry season.

Kg P_2O_5/ha	Kg N/ha		
	0	60	120
0	1,254.60	1,646.40	1,701.00
30	1,296.80	1,797.20	2,066.10

L.S.D. = 241.80

A significant interaction effect between nitrogen and phosphorus was observed. The interaction table (table 4.31) shows that grain yield responded to nitrogen application up to 60kg N/ha when no phosphorus was applied, but in the present of 30kg P_2O_5/ha, the response to nitrogen was up to 120kg N/ha. Phosphorus in the absence of nitrogen and under 60kg N/ha had no effect on the grain yield, but under the higher level of nitrogen 120kg there was sngmificant and positive response to the application of 30kg P_2O_5/ha.

x) Straw yield

Effect of irrigation, nitrogen and phosphorus on straw yield (kg/ha) of wheat at Samaru is presented in tables 4.32 and 4.33.

Table 4.32. Straw yield (kg/ha) of wheat as influenced by irrigation, nitrogen and phosphorus at Samaru during the 1981-82 dry season.

Treatments	Yield kg/ha
Irrigation	
No stress (control)	4,496.00
Stress at flowering	3,584.00
Stress at milk stage	3,542.00
Stress at milk-dough stage	3,816.00
F Test	N.S
Nitrogen	
0 kg N/ha (control)	1,711.00
60 kg N/ha	2,912.00
120 kg N/ha	3,094.00
F Test	**
L.S.D.	396.00
Phosphorus	
0 kg P_2O_5/ha (control)	2,441.00
30 kg P_2O_5/ha	2,706.00
F Test	N.S
Interactions	
I X N	N.S
I X P	N.S
N X P	*

Table 4.33. The interaction effect of nitrogen and phosphorus levels on straw yield (kg/ha) of wheat at Samaru during the 1981-82 dry season.

Kg P_2O_5/ha	Kg N/ha		
	0	60	120
0	1,681.00	2,962.00	2,680.00
30	1,782.00	2,365.00	3,511.00

L.S.D. = 560.00

Water stress at reproductive phase had no significant effect on the straw yield, though least straw yield (3,542.00 kg/ha) was recorded under water stress at milk stage.

The effect of nitrogen application on straw yield was highly significant. Straw yield increased by the application of all levels of nitrogen.

Application of 30kg P_2O_5/ha has no significant effect on straw yield though there was positive increase.

There was nitrogen and phosphorus interaction in respect of straw yield (Table 4.33). There was a response up to 60kg N/ha under zero level of

phosph rus. Application of 30kg P_2O_5/ha without nitrogen had little effect on straw yield. This response to nitrogen application under 30kg P_2O_5/ha was up to 120kg N/ha.

CHAPTER 5

DISCUSSION

A. EFFECT OF NITROGEN AND PHOSPHORUS ON THE VEGETATIVE GROWTH OF WHEAT.

i) Nitrogen

Nitrogen is one of the major elements in crop production. Cereal crops require the application of nitrogen fertilizer since most of the crop land under cereals worldwide are not in a position to supply these crops with their requirements of nitrogen for their potential production. Nitrogen deficiency affects the vegetative growth examined in the different growth parameters. The vigour of vegetative growth is decided, to a far extent, by the nitrogen level in the soil. The plant height measured at different periods of vegetative phase was influenced by different levels of nitrogen. This effect was clear and pronounced during all the three sampling periods. It is worth mentioning here, that the rate of increase in plant height under no nitrogen treatment was faster as the initial stages. At later stages, the rate was about 38% for nitrogen level of 120kg N/ha when compared to the control

(27%). This probably indicates that high nitrogen levels may cause slowing down growth, and consequently delaying it for more accumulation of dry matter as can be seen how nitrogen levels finally and significantly affected plant height at harvest. This is similar to what Ibrahim and Assey (1976) observed.

Production of tillers is also another important character to examine in the vegetative growth because of its important relation to yield. The application of nitrogen at 120kg N/ha resulted in significant increase in the tiller number per plant (from about 2 - 4) as can be seen in table 4.3. It is to be noted here, that with the progress in plant age, a reduction in the tiller number per plant was observed. At 46 days after sowing, the average tiller number was reduced to 2.02. This was due tiller mortality,and this aspect is very important as about 30%of grain yield might come from tillers (Rawson and Bremner, 1978). The rate of the tiller reduction observed was different among the different levels of nitrogen. The number of tillers reduced by 49% under the control treatment. The figures for 60 and 120kg N/ha were 32% and 18% respectively, indicating the need for high level of nitrogen for effective

tiller vitality. Similar views were expressed by Verma, et al., 1970; and El-Sharkawy, et al., 1976, 1977.

Leaf area recorded per plant was also affected by the application of nitrogen fertilizers (Table 4.5). The response was significant at 46 and 61 days after sowing up to the highest fertilizer level. As with the tiller number, leaf area went on decreasing with the progress in age, incicating that leaf area ceiling took place around 46 days after sowing. The rate of decrease also differed under the various nitrogen levels. It amounted to 49, 46 and 41% under control, 60kg and 120kg N/ha treatments, respectively. This indicates the favourable effect of nitrogen in keeping larger photosynthetic surface for longer period. This agrees with findings and views of El-Sharkawy, et al., (1976); and Evans, et al., 1975.

Similarly, leaf area index (LAI) responded to the application of nitrogen up to 120kg/ha (Table 4.7). The favourable effect was significant at all the sampling periods. Plant height and tiller number per plant were increased with nitrogen application. These two parameters decide the number of leaves per plant, leading to

higher leaf area per plant and consequently larger leaf area index which reached its peak just before head emergence, and progressively fell off after that. These results are in agreement with the observations of Evans, et al., 1975 and Cooper, 1980.

The favourable effect of nitrogen on plant height, tiller number and leaf areas led to the favourable effect of nitrogen application on the dry matter accumulation which was recorded as dry matter per plant (Table 4.8). Nitrogen application up to 120kg N/ha increased the dry matter accumulation, but the response was significant only to 60kg N/ha treatment. The accumulation of dry matter per square metre showed the same effect (Table 4.10). Other workers who reported increased in dry matter to nitrogen application include Sigh and Verma, 1965, and Singh and Gupta, 1970.

The last parameter measured during the vegetative phase was the flag leaf area. The role of the flag leaf area in the contribution of assimilates towards the spikes was reported by various workers who only differed in the magnitude of the contribution. Archbold's investigations, as cited by Rawson and Bremner

(1978), conclusively showed that grain filling was overwhelmingly the product of current assimilation (that is materials stored before grain setting plays little role). This means areas and duration of organs most active in photosynthesis during the grain filling are the flag leaf, the ear and the upper part of the stem. The flag leaf contributes the main source of carbohydrate to the grains (Evans, et al., 1975; and Rawson and Bremner, 1978). In this study, the effect of nitrogen was clear on the flag leaf area. Nitrogen at all levels increased the flag leaf area (Table 4.11). As previously mentioned that nitrogen favourably affected plant height and the number of tillers per plant, which led one to expect that larger number of leaves were carried by single plants. Here, the area of individual leaf which was also influenced favourably by high level of nitrogen, coupled with larger leaf number, resulted ultimately in larger leaf area per plant and consequently the leaf area index.

ii) Phosphorus

Phosphorus, another essential element though present in relatively large quantities, its availability to the crops is restricted in most

soils, making it a problem element (Buckman and Braddy, 1969). Nonetheless, its application at the rate of 30kg P_2O_5/ha in this study did not make it exert independent and significant effects on most of the parameters examined in what crop at Samaru during the 1981-82 dry season. Except for leaf area per plant, the application of 30kg P_2O_5/ha phosphorus only tended to increase the plant height, tiller number per plant, leaf area index, dry matter accumulation, (all measured at different periods) and the flag leaf area, but the differences were not statistically significant.

Leaf area per plant was significantly increased by the application of 30kg P_2O_5/ha at 46 and 61 days after sowing (Table 4.5). The maximum leaf area per plant was obtained just before heading when the flag leaf has full emerged, as also observed by Evans, et al., (1975).

iii) Nitrogen and Phosphorus interaction

Although the application of 30kg P_2O_5/ha phosphorus did not independently affect most parameters measured (except grain yield and the leaf area per plant), yet it interacted significantly in most cases with the different

levels of nitrogen. These interaction were observed in the case of plant height, tiller number per plant, and the flag leaf area. In all cases application of 30kg P_2O_5/ha under zero level of nitrogen treatment cause either no positive effect or a reduction in the value of the parameter measured. Under 60kg N/ha nitrogen, the application of 30kg P_2O_5/ha phosphorus had not significant change on the parameter except the leaf area per plant at 46 days after sowing. However, at higher level of nitrogen (120 kg/ha) a significant effect was evident. On the other direction these parameters which were significantly influenced by nitrogen-phosphorus interaction did respond only to 60kg N/ha under zero level of phosphorus. But with the application of 30kg P_2O_5/ha, the affected parameters mentioned above did respond to the application of 120kg N/ha. This indicate that probably the soil was able to supply the crop with some phosphorus when only 60kg N/ha was applied. When this level was increased to 120kg N/ha, phosphorus level should also increase in order to obtain further positive response. This further indicates the need for a nutrient balance in the soil, and therefore, should be considered seriously in any

fertilizer programme. Similar observation was reported by Verma, et al., (1970), and Rathore and Singh (1978) who attributed the need for more phosphorus as nitrogen level increase for the production of more dry matter with more increase in nitrogen content in the plant, which lead to dilution of the absorbed phosphorus.

B. EFFECT OF IRRIGATION TREATMENTS, NITROGEN AND PHOSPHORUS LEVELS ON GRAIN FILLING AND DEVELOPMENT OF WHEAT CROP.

i) Irrigation

Water as a constituent of protoplasm, solvent for nutrients and reagent, is the most important factor for plant growth, development and yield. The shortage of water at critical stages, especially the reproductive phase, had a marked effect on grain development, yield and yield components. In this study, the effect of water stress at flowering, milk and milk-dough stages on the spike grain weight taken at 5-day interval (Table 4.13) was significant. When a plant is faced with unfavourable environmental constraint (like water stress), it tends to complete its life cycle as soon as possible by accelerating the rate of different physiological processes like the grain filling (Slatyer, 1973).

This was evident in this study, that the rate of translocation of assimilates towards the grains under the stress treatment was faster than the no stress treatment. In the control, maximum accumulation of assimilates in the grains occured between 87-92 days after sowing, in the stress treatments it occured earlier between 82-87 days after sowing. When water stress occured at milk-dough stage, the rate of accumulation of assimilates into the grains was higher than the other stress treatments.

Likewise, the 1,000-grain weight recorded at 5 days interval (Table 4.15) of wheat was influenced by the water stress treatments. At an early stage (72 days after sowing) all the stress treatments resulted in heavier grain weight than the control (no stress). This may be due to hastening of maturation as observed by Slatyer (1973). At later stages, however, the situation changed, and the no stress treatment gave the heaviest 1,000-grain weight followed by the treatment of early stress at flowering, and then stress at milk and milk-dough treatments. It is generally accepted that post flowering conditions in influencing the weight of grains. The assimilates stored during the vegetative phase contribute little to the growth

of seeds which mainly depend on current photosynthesis (Slatyer, 1973, Rawson and Bremner, 1973) of the flag leaf and the ear or translocation from stored reserve in stems under prolonged water stress (Evans, et al., 1975). It is clear, therefore, that water stress by reducing photosynthesis at this time may lead to reduced yield through direct effect of photosynthesis in the ear, leaves and the stem. This may possibly lower the grain weight in the stressed plants. Grain filling, being a relatively rapid and terminal process, and because most of the increase in weight after anthesis involve grain development, it follows that the reduced photosynthesis at any point of the post anthesis may have effect on grain weight which may not be compensated for by activity of any other stages of grain filling. Slatyer (1973), is also of the view that hastened senescence of leaves of stressed plants occuring late in the grain filling stage may not be compensated for by calling reserve stored in stems unless the stress occured early enough in which case enhanced translocation of assimilates from the stem may help (Asana and Basu, 1963). Photosynthesis, therefore, may be said to be affected by water stress in this study, which affected grain development.

Despite the fall in photosynthesis, the grain filling in this study progressively increased up to a point by the time the grains matured. Thereafter, the rate of translocation of the assimilates started to decrease. This is observable in both the spike grain weight and the 1,000-grain weight sampled at 5-day interval (Tables 4.13 and 4.15). This behaviour was also reported by Evans et al., (1975) and Rawson and Bremner, (1978). It was also clear that water stress hastened grain filling, and this, as these workers argued may also be due to increase rate of cell division at the initial rate of grain growth, but lead to final reduction in grain weight.

Though the duration and rate of grain growth may have been hastened by water stress as observed, it was unlikely to be affected by the prevailing temperatures since they did not exceed 30^{o}C (Rawson and Bremner, 1978) at the time of the grain filling.

Similar effects of water stress on grain filling and development were reported by Asana and Bagga, (1966) and Wardlaw, (1967).

ii) Nitrogen

The effect of nitrogen application on the spike grain weight development was significant all through (Table 4.13). The favourable effect of nitrogen on the spike grain weight could be observed during the period of 72-92 days after sowing. Spike grain weight increased significantly dur to the application of 60kg N/ha, and additional application of another 60kg N/ha did not cause significant change. This positive response to nitrogen application is rather explainable in the present investigations. Reference to the growth parameters measured in this study would reveal that the plants fertilized with nitrogen were more vigorous and healthy than the control (no nitrogen). In particular, the leaf area which was enlarged as a result of nitrogen application (Table 4.5) may have contributed to the heavier spikes produced in the fertilized plots. Ibrahim, et al., (1979) also found similar result on spike grain weight of two wheat cultivars (one tall and one dwarf) which differed in their growth habit.

The thousand grain weight taken at different stages was also influenced by nitrogen application. The effect was significant only at the early stages

of grain development (Table 4.15), that is at 72 and 77 days after sowing. A positive and significant response was observed when 120kg N/ha and 60kg N/ha were applied at 72 and 77 days after sowing respectively. This may be due to the faster rate of grain development at early stages of water stress as observed earlier. At 77 days after sowing, there was no significant effect of nitrogen on the 1,000-grain weight.

iii) Phosphorus

Both characters, that is the spike grain weight and the 1,000-grain weight sampled at 5-day interval were not influenced significantly by the application of 30kg P_2O_5/ha phosphorus. This was true for all the sampling periods (Tables 4.13 and 4.15).

iv) Nitrogen and phosphorus interaction

It is true that the favourable effect of nitrogen independently from phosphorus was significant in all the stages examined, but phosphorus application did not affect the spike grain weight independently. However, phosphorus interacted significantly with the two nitrogen levels (60 and 120kg N/ha). Under the control (0kg N/ha) treatment, the application of

30kg P_2O_5/ha phosphorus tended to decrease the spike grain weight with non-significant difference. The effect of phosphorus was significant only when 60kg N/ha was applied. On the other direction, spike grain weight did respond to 60kg N/ha only when phosphorus fertilizer was added. In all cases, there was no response to the application of 120kg N/ha under both phosphorus levels. In other words, 60kg N/ha coupled with 30kg P_2O_5/ha was the only fertilizer combination which caused significant response. This may be explained that applying either fertilizers alone may cause nutrient imbalance, especially with the macro-nutrients elements which are required in relatively larger quantities. The effect of NP interaction was also significant on most of the physiological parameters measured during the vegetative growth phase as already observed. The continuation of this effect on the spike grain weight throughout most of the grain formation stage is to be expected especially when the flag leaf area was also influenced significantly by such interaction. The difference in the response was that the vegetative growth parameters did respond to as much as 120kg N/ha under 30kg P_2O_5/ha. This may be explained that nitrogen

generally encourages the vegetative growth (Tisdale and Nelson, 1975), so that response to higher nitrogen levels is not unexpected.

Likewise, the 1,000-grain weight was influenced significantly by the same interaction. Application of phosphorus fertilizer without nitrogen reduced significantly the 1,000-grain weight. This was true at all the stage. Response to phosphorus application was positive and significant when 60kg N/ha was applied. Application of 30kg P_2O_5/ha had inconsistent effect on this parameter under 120kg N/ha treatment, but toward the later stage, the effect was significant and positive. This is is line with findings of Sinha, et. al., 1973; Ibrahim and Assey, 1976.

C. EFFECT OF IRRIGATION, NITROGEN AND PHOSPHORUS LEVELS ON YIELD AND YIELD COMPONENTS OF WHEAT

i) Irrigation

The number of spikes per square metre (Table 4.21) determines the quantity of grains to be carried, hence the yield. This parameter was not significantly affected by water stress treatment at any stage from the flowering to milk-dough stages though there were more spikes

per square metre under control than when water stress was imposed. This, of course, may be expected since the number of spikes must have been determined before flowering when the water stress commenced.

The number of ears on a mature plant is as a result of a sequence of tiller production and tiller death without production of grains, and the death of productive tillers begin soon after tillering has stopped and goes on to anthesis (Rawson and Bremner, 1978). This parameter, therefore, might not have been affected by irrigation after anthesis. This was also observed by El-Dababy, et al., (1978).

Spike length indicates the number of the grains which may lodge there, and possibly the size. Irrigation treatment did not significantly affect this parameter probably because after flowering any appreciable increase in dry matter is diverted to the grain development (Table 4.19). Abdel-Gawad, et al., (1979) also reported a similar result.

Spike grain number at harvest (Tables 4.23 and 4.24) were significantly affected by the irrigation treatment. It can be seen that the

grain number per spike under the no stress treatment (36.07) was higher than other stress treatments, though at par with the stress at milk-dough stage (35.50). Water stress at flowering produced the least number of grains (31.45) per spike. This represents 13% reduction in grain number over the control as against 6.7% and 3% for stress at milk and milk-dough stages respectively. Though Shrotriya, et al., (1978) did not observe this significant effect, they reported that witholding irrigation at either milk ripe or dough stages had little or no effect in the grain number per spike.

Spike grain weight at harvest was significantly affected by irrigation treatment (Table 4.25). The heaviest spike grain weight occured under water stress at milk-dough stage (but this did not significantly differ from that of the control). The lowest grain weight occured under stress treatment at milk stage, followed by stress at flowering (these two did not differ significantly as well). This observation may be explained as water stress occuring at late stages of grain filling led to more rapid and accelerated senescence and yellowing of leaves, ears and stem than earlier stages of grain filling, and this can not be compensated for by rapid translocation

of substrates from the stem. Similar results were also reported by Slatyer, (1973) and Ibrahim, et al., (1979).

The thousand grain weight at harvest (Table 4.26) showed exactly the same picture as that of the spike grain weight at harvest. The reasons may be the same - that of accelerated sencence. Withholding irrigation at those stages of grain development have been shown to reduce the 1,000-grain weight by Misra, et al., (1969, 1976).

Fertile and sterile spikelets number per spike were not significantly affected by water stress treatment at any of the grain development stages (Tables 4.28 and 4.29). In both cases, the highest number of fertile and sterile spikelets per spike occured under the no stress treatment, and the lowest number tended to appear under stress at flowering. Though differences between stress treatments were not significant, this observation reflects the spike length as well as the grain number per spike. They all followed a similar pattern.

The grain yield (Table 4.30 and 4.31) was influenced significantly by withholding irrigation at one of the critical stages during grain formation

and filling phase. The least yield was obtained when irrigation was not given at flowering, and the yield was reduced by 31%. Withholding irrigation at milk or milk-dough stages reduced the grain yield by about 15%. This marked reduction in yield when water stress was imposed at flowering was opined by Slatyer (1973) as due to reduced fertilization and grain set, and because of dehydration of pollen grains or probably poor germination of the pollen or failure of growth of the tube from the stigma to the ovules. Verma, et al., (1970), further asserted that irrigation at flowering stage ensures fertilization, sound and healthy grain development is only possible when there is sufficient moisture in the soil. The reduction of yield when irrigation was missed at flowering may also be attributed to the reduction in the number of grains per spike.

Thousand grain weight was not affected by withholding irrigation at flowering as was also reported by El-Sharkawy, et al., (1976). The spike grain weight was significantly affected. The 15% reduction in grain yield when no irrigation was given at milk or milk-dough stages may be due to reduced grain size. Reference to the 1,000-grain weight and consequently spike grain weight

clearly reveal this. Reduction in grain yield due to water stress at flowering was more severe than the subsequent stages (Bhardwaj, et al., 1971; and Singh, et al., 1975). Others who found either milk flowering or milk and milk-dough stages followed by flowering as the most critical stages for water stress to occur in order to reduce yield by various degrees, are Shrotriya, et al., 1970, and Patel and Patel, 1975.

Since irrigation treatments commenced during the reproductive phase, and after the vegetative has presumably ceased, it is expected that straw yield (a function of vegetative growth), may not be affected by missing irrigation at any of the grain filling stages. Data in table 4.32 show this and the differences were statistically not significant.

ii) Nitrogen

Though nitrogen did not significantly affect spike number per square meter, a positive trend up to 60kg N/ha was obtained (Table 4.21). This is in line with the earlier observation on the favourable effect of nitrogen application in tiller survival. Other workers who reported increase in spike number per unit areas as the result of application of nitrogen includes Sharma, et al.,

(1970), and Ellen and Spiertz (1980).

Application of nitrogen significantly improved spike length (Table 4.19 and 4.20). The positive response observed was up to 120kg N/ha. This observation fit into the pattern that nitrogen application increased plant height, leaf areas and general vigour of the plants as observed earlier. These vigorous plants are, therefore, capable of producing larger spikes. This is confirmed by the works of Verma, et al., 1970, and Goma'a, et al., 1977, who also reported that spike length increased with increasing rate of nitrogen.

Nitrogen application significantly increased the number of grains per spike (Table 4.23). This parameter is a function of fertile spikelets per spike, and nitrogen deficiency has been suggested as the most probable cause of failure of upper florets (Evans, et al., 1975; and Rawson and Bremner, 1978). This also means higher number of fertile spikelets is required to give a good number of grains per spike. The highest grain number per spike (37.34) was observed under 120kg N/ha, followed by 60kg N/ha. This finding comforms to that of Sandhu and Gill (1971) and Silva, et al., (1975).

Spike grain weight at harvest (Table 4.25) did not significantly increase with increasing level of nitrogen. Nonetheless, a positive response was observed. The heaviest grains per spike was observed under the heaviest dose of nitrogen (120kg N/ha), and lightest spike grain weight occured under no nitrogen. This is because as nitrogen application significantly increased spike grain number (as earlier discussed), the grains had to share whatever assimilates they got, hence they become lighter as the grain number increased. This agrees with the works of Sandhu and Gill (1971); and Ibrahim and Assey (1976).

A similar picture emerged in 1,000-grain weight as that of the spike grain weight (Table 4.25). There was a negative response when 120kg N/ha was applied. This is expected since large number of grains as significantly influenced by nitrogen application had to be filled with assimilates, the effect would manifest itself in decreasing 1,000-grain weight. This also explains why the control (no nitrogen) has higher 1,000-grain weight. This was also the view of El-Sharkawy, et al., (1976).

The effect of nitrogen application was highly significant on both fertile spikelets/spike and

sterile spikelets/spike (Tables 4.28 and 4.29). The differences between application of 60 and 120kg N/ha were not statistically significant as far as fertile spikelets/spike is concerned. Nitrogen application, when compared to no nitrogen treatment, the effect was highly significant. Nonetheless, there is a positive response as nitrogen level increased. Similarly, in the sterile spikelets/spike, it can be observed that as nitrogen level is increased from 60 to 120kg N/ha, the number of sterile spikelets/spike decreased from 2.21 to 1.77. This is because nitrogen increased plant fertility and its capacity to produce grains hence increase in yield through increase in grains number per spike, that is reducing sterility of spikelets. This observation agrees with earlier discussed results of increased grains number per spike by nitrogen application because if nutrients become limiting, grain set will be poor and this may lead to reduced yield Rawson and Bremner (1978), Ibrahim and Assey, (1976) also made the same observations.

The effect of nitrogen was also significant. As was shown earlier, that the grain yield responded significantly to the application of 60kg N/ha, but not when 120kg N/ha was applied. Application of 60kg N/ha increased the grain

yield over the control by about 35%. Most workers recorded increase in yield with application of nitrogen. They include Agha and Tunio (1973); Singh (1973 and 1978) and Jat, et al., (1976)

As it was shown earlier that application of nitrogen was in favour of all the growth parameters mentioned in this study, it is expected that straw yield may also be favoured by nitrogen application. Straw yield did respond significantly to the application of even 60kg N/ha, and the increase over the control was about 70%. A reference to the plant height, dry matter per plant, dry matter per square meter and tiller number per plant all taken at different periods, and to the data of plant height recorded at harvest, would reveal that all these parameters were significantly increased by the application of nitrogen. Therefore, a 70% increase in straw yield due to the application of even 60kg N/ha and 80% for 120kg N/ha is not unexpected.

iii) Phosphorus

Spike number per meter square was not significantly affected by application of 30kg P_2O_5/ha. This is because right from vegetative growth periods of 46, 53 and 61 days after sowing phosphorus application did not significantly

affect plant height (Table 4.1) and number of tillers/plant (Table 4.3).

A similar trend is presented in respect of spike length, with a similar reasoning.

Application of phosphorus did not significantly affect spike grain number at harvest (Table 4.23). Nonetheless, a positive response was obtained from phosphorus application. The plants might have used the small quantity of P_2O_5 and N in protein synthesis in grains. This positive increase in spike grain weight was also reported by Youssef, et al., (1977).

Application of 30kg P_2O_5/ha did not significantly affect both spike grain weight and 1000-grain weight at harvest (Tables 4.25 and 4.26), but there was a positive trend as for the 1,000-grain weight was concerned. As phosphorus was concerned with protein synthesis and meristematic growth, perhaps only small quantities of it is used in grain production. Other workers who recorded positive response of 1,000-grain weight to phosphorus application were Ibrahim, et al., (1979).

Fertile spikelets per spike were not significantly affected by phosphorus application

(Table 4.28). This observation was also made by Ibrahim and Assey (1976). But in this study, application of 30kg P_2O_5/ha tended to increase spikelets sterility (Table 4.29).

Application of 30 kg P_2O_5/ha increased significantly the grain yield by about 12%. Though application of phosphorus fertilizer did not affect all the growth parameters measured in this study except that of leaf area per plant, and though this application has not affected any of the yield components significantly on its own, yet is affected the grain yield significantly, as explained below:

Similarly, these parameters of growth have not been significantly influenced by the application of 30kg P_2O_5/ha alone. Also, it is not strange that straw yield which is a function of these parameters, is not significantly affected by phosphorus application.

iv) Irrigation and nitrogen interaction

Interaction effect of these two factors was significant (Table 4.21) on spike number per square meter. It was observed that when no nitrogen was applied, water stress at milk stage increased spike motality. Negative response occured under 60kg N/ha

under stress conditions. Even 120kg N/ha under waterstress conditions had less number of spikes per square meter than under no stress conditions when response was favourable to even 60kg N/ha. It may, therefore, be advisable to use less nitrogen under dry conditions. This may be because, water as a solvent, may not be available to dissolve enough nitrogen for translocation. Transpiration will be less and so less water intake. Furthermore, if the water stress occured late in the season (at milk-dough) the plants had sufficient water to dissolve the nitrogen, hence comparatively more spikes/meter square were recorded under stress at milk-dough than under milk or flowering stages.

v) Irrigation and phosphorus interaction

Number of spikes/meter square responded significantly to the interaction between irrigation and phosphorus. It can be observed that under 30kg P_2O_5/ha control treatment had the highest number of spikes per square meter compared to all the stress treatments. This suggests the importance of phosphorus as an essential element, but only when there is enough moisture in the soil can its presence in the soil be useful to the crop. It may, therefore, be unwise to apply high

doses of phosphorus when water source is not assured because of possible reduced phosphorus uptake under water stress conditions as observed by Asana, et al.,(1971).

vi) Nitrogen and phosphorus interaction

A significant interaction effect was noticed between nitrogen and phosphorus in respect of the spike length (Table 4.20). When 30kg P_2O_5/ha phosphorus was applied, response to nitrogen application was up to 120kg N/ha as against only 60kg N/ha in the absence of phosphorus. And in the absence of nitrogen, application of 30kg P_2O_5/ha even tended to suppress spike length. This result further emphasizes the need for balanced nutrients in the soil, in the absence of which yield and all its components may be affected. Spike length is related to the number of grains that would lodge there, production of longer spikes is an advantage, but only vigorous and healthy growing plants can produce such spikes. This may explain the tendency for nitrogen and phosphorus interactions from plant height, tiller number per plant, leaf area per plant, dry matter accumulation and the flag leaf area as previously seen.

Nitrogen and phosphorus interacted significantly on the spike grain number at harvest (Table 4.24). It was clear that no significant response to nitrogen application was obtained in the absence of phosphorus application, but with 30kg P_2O_5/ha, the response was up to 120kg N/ha. On the other hand, there was no response to 30kg P_2O_5/ha if the level of nitrogen was not above 60kg N/ha. This again complements the spike length. These spikes have to carry grains for better yield, and this needed balanced nutrients like nitrogen and phosphorus in the soil. For higher spike grain number, therefore, the best fertilizer combination may be 30kg P_2O_5/ha plus 120kg N/ha.

Throughout this study, which was classified into three phases, namely, vegetative, grain filling and post harvest stages, the interaction effect of nitrogen and phosphorus levels was significant. The grain yield responded to the application of phosphorus only when 60kg N/ha was applied, and only significantly so when 30kg P_2O_5/ha was applied. Almost the same conclusion was drawn when the data of the three phases were studied. For example, flag leaf area data gave exactly the same trend. Grain number per spike and spike grain weight showed similar trend. This indicates that high level of nitrogen alone may

produce dense vegetative growth and may have no effect at all on the grain yield. High nitrogen level should, therefore, be coupled with the application of phosphorus. On the other hand, application of 30kg P_2O_5/ha did nothing significant when no nitrogen was applied or applied at 60kg N/ha. A similar nitrogen phosphorus interaction on grain yield was also obtained by Verma, et al., 1970; Sinha, et al., 1973; and Nagre and Bathkal, 1978.

However, almost all these parameters were influenced by the nitrogen-phosphorus interaction (Table 4.31). It means that phosphorus effect was dependent on the presence and level of nitrogen. Straw yield responded to 120kg N/ha when 30kg P_2O_5/ha was applied, and responded to only 60kg N/ha under zero phosphorus treatment. On the other direction, straw yield responded to the application of 30kg P_2O_5/ha and 120kg N/ha was applied. These same trend were observed with the growth parameters data. This indicates the need for nutrient balance in the soil when deciding on any fertilizer programme for crops. Other workers who made similar observation on straw yield include El-Sharkawy, et al., 1976 and El-Dababy, et al., 1978.

CHAPTER 6

SUMMARY AND CONCLUSION

This investigation was carried out at the irrigation site of the Ahmadu Bello University Farm, Samaru (Lat. $11^{o}11^{1}$N, Long $07^{o}38^{1}$E and altitude 646m), Zaria, in the Northern Savannah zone during the dry season of 1981-82. Maximum temperatures during the growing season do not exceed 32.5°C and the minimum not above 15°C.

The design used was the strip plot design replicated four times on a fertile loamy sand. Four levels of irrigation were used, missing irrigation at flowering, milk stage, milk-dough stage, and control. Six levels of nitrogen and phosphorus fertilizer treatments were used. Zero, 60kg and 120kg/ha for nitrogen plus control. Zero and 30kg P_2O_5/ha was used for phosphorus. The fertilizer treatments were randomized within each of the irrigation treatments which take the full length of the strips. The wheat variety used was Sieto Cerros at the rate of 100kg seed/ha.

As bread wheat is assuming a new dimension in the economy of this country, it is necessary to examine some problems of local production, therefore, the aims and objectives of this study are as follows:

1. Assess the effect of water stress on grain formation,

development, yield and its attributes.

2. Investigate the effect of nitrogen and phosphorus fertilizers and their interactions on the growth of wheat, grain development and yield and its components.

3. Investigate the interaction effect of NP fertilizers and water stress treatments during the grain development stage on yield and its components.

Wheat crop requires both nitrogen and phosphorus fertilizers. In some cases they act independently, but in most cases they interact and supplement each other.

Nitrogen was found to increase significantly, the plant height, tiller number/plant, dry matter accumulation, all at different stages. Leaf area Index, flag leaf area and leaf area/plant measured at 46 and 61 days after sowing were all affected. Spike grain weight taken at different times (that is at 72, 77, 82, 87, 92 and at harvest) were all significantly affected by nitrogen application. Thousand grain weight was affected at 72 and 77 DAS only. Similarly, plant height at harvest, length of spike, grain number/spike, fertile and sterile spikelets/spike, grain and straw yield were all significantly affected by nitrogen levels.

Application of 30kg P_2O_5/ha only significantly affected leaf area/plant at 46 and 61 DAS, and also dry matter accumulation at 46 DAS, sterile spikelets/spike and grain yield.

However, NP interactions were observed on tiller number/plant at 46 and 53 DAS and on dry matter accumulation only at 46 and 53 DAS. Phosphorus has also significantly affected the flag leaf area. During the grain development stages, NP interaction was observed to affect significantly the spike grain weight and the 1,000-grain weight throughout. Spike length, spike grain number, grain weight/spike, 1,000-grain weight at harvest, grain yield and straw yield were all significantly affected by the phosphorus-nitrogen interaction.

Irrigation-nitrogen interaction was only recorded on the 1,000-grain weight at 77 DAS during the grain development stage. Spike number/m^2 was also significantly affected by this interaction.

Irrigation-phosphorus interaction also occured in respect of spike number per square metre.

Irrigation treatment significantly affected spike grain weight taken at 82, 87 DAS and at harvest as well as 1,000-grain yield taken at 72, 82, 92 DAS and at harvest. Grain weight/spike, and grain yield were also significantly affected by irrigation, so was grain number/spike.

In most cases (for example the grain yield), response to nitrogen application was only up to 60kg N/ha in the absence of 30kg P_2O_5/ha, and no significant effect is obtained when the dose is pushed up to 120kg N/ha, unless phosphorus is supplied.

Application of 30kg P_2O_5/ha in the absence of nitrogen did not produce any significant effect.

It is, therefore, clear that nitrogen application alone has limited use, unless phosphorus is also applied. When phosphorus is not available do not use high dose of nitrogen.

If irrigation water or its cost of application becomes a limiting factor, missing irrigation at flowering stage has more serious effect on yield reduction (31%) than either missing irrigation at milk stage (15.50%) or at milk-dough stage (14.90%).

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Appendix . 10-day intervals of means of R.H., Pan Evaporation, wind run and sunshine hours during the growing season at Samaru, 1981-82 dry season.
(All readings at 10.00 a.m.)

Month	DAS	Mean R H (%)	Class A Pan Evaporation (mm)	Wind Run (km)	Mean Sunshine Hrs (Hr)
21 - 30 Nov	8	23.4	10.4	160.3	6.4
1 - 10 Dec	18	20.6	9.4	121.76	9.1
11 - 20 Dec	28	16.7	8.6	109.68	9.7
21 - 31 Dec	39	25.6	9.0	119.30	9.1
1 - 10 Jan	49	19	9.1	147.19	8.2
11 - 20 Jan	59	22.2	8.4	91.66	8.9
21 - 31 Jan	70	15.4	9.5	141.81	8.6
1 - 10 Feb	80	14.1	10.10	203.14	5.9
11 - 20 Feb	90	17.6	11.9	133.11	9.2
21 - 28 Feb	98	24	11.2	110.28	8.6
1 - 10 March	108	11.5	14.9	384.67	8.1

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