GROWTH, YIELD AND NITROGEN UPTAKE OF AWNED AND AWNLESS WHEAT *(Triticum aestivum L)* AS AFFECTED BY NITROGEN AND ROW-SPACING

BY

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DECLARATION

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

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CERTIFICATION

This thesis entitled **"GROWTH, YIELD AND UPTAKE OF AWNED AND AWNLESS WHEAT (*Triticum aestivium L.*) AS AFFECTED BY NITROGEN AND ROW-SPACING"** by Samuel Negedu meets the regulations governing the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to the memory of my father, Mr. Negedu Onukwuega and mother, Madam Alugbe Okai.

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ABSTRACT

Two field experiments were conducted at the Irrigation Research Station, Kadawa, Nigeria, during the 1989-90 and 1990-91 dry seasons, to investigate the effects of two wheat varieties (Siete Cerros and Florence Aurore 8193), three row-spacings (10, 20 and 30 cm) and four nitrogen levels (0, 60, 120 and 180 kg N ha"[1]) on crop growth, yield, yield components and nutrient uptake and also to investigate the effects of two varieties (Siete Cerros and Florence Aurore 8193), three nitrogen levels (60, 120 and 180 kg N ha"[1]) and three times of nitrogen application (seeding, seeding + tillering stage and seeding + flag leaf stage) on yield components and grain crude protein content.

Variety Florence Aurore 8193 produced significantly more tillers, taller plants, greater leaf area and leaf area index and more dry matter than Siete Cerros. Even though the total dry matter accumulated by both varieties increased with crop age till maturity, leaf and stem dry matter decreased after 70 days after sowing (DAS) while spike dry matter continued to increase till crop maturity. The proportions of dry matter in leaf, stem and spike at maturity were 9, 40 and 51 per cent for Siete Cerros and 9,49 and 43 per cent for Florence Aurore. Siete Cerros significantly excelled Florence Aurore in number of grains per spike and grain yield. Florence Aurore however produced grains with higher 1000-grain weight and also had greater N uptake than did Siete Cerros; but the former significantly greater spike N uptake than that of Siete Cerros. Leaf and stem N of both varieties decreased after 70 DAS while spike N continued to increase till crop maturity. Total uptake of N, P, K, Ca and Mg at harvest was signifi-cantly higher in Florence Aurore than in Siete Cerros. Spike uptake of N,

P, K, Ca and Mg was highest followed by that of stem and leaf. Florence Aurore produced grains with significantly higher crude protein content than Siete Cerros.

The 20 and 30 cm row-spacings gave the highest grain yield which were was significantly better than the 10 cm row-spacing. Dry matter accumulation, nutrient uptake and their distribution into component plant parts were greatest at the 20 cm row-spacing.

Grain yield and dry matter accumulation increased with N levels up to 180 kgN ha"[1] though increases in spikelets per spike, number of grains per spike and 1000-grain weight were significant up to 1 20 kg N ha-[1]. The uptake of nitrogen and those of K, Ca and Mg at harvest was significant up to 180 kg N ha'[1] but P uptake at harvest was significant up to 120 kg N ha-[1]. Grain crude protein content also increased with increase in N up to 120 kg N ha-[1] in 1989-90 and up to 180 kg N ha-[1] in 1990-91. Split application of N at seeding time and tillering stage gave the highest grain yield, straw yield, dry matter accumulation and longest spikes. Grain crude protein content was greatest when N was split applied between seeding time and flag leaf stage.

Siete Cerros was more responsive to applied nitrogen than Florence Aurore and N fertilizer requirement was different between the two years.

There were positive relationships between grain yield and spikelets per spike, number of grains per spike, spike length, effective.tillers and 1000-grain weight. The high direct effects of effective tillers, spike length, grains per spike and 1000-grain weight on grain yield were due to their indirect effects through number of spikelets per spike.

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Chapter 1

INTRODUCTION

Wheat (*Triticum* spp.), from which the common wheat evolved, belongs to the Pooideae sub-family of annual grasses. *Triticum aestivum* L. (the common bread wheat), a hexaploid species from which most modern wheats have been developed, is not known in the wild state (Purseglove, 1975). Wheat exhibits a wide range of morphological and physiological variations and ecological adaptations. It is the most important cereal crop in the world in terms of area sown and size of harvest (Arnon, 1972).

Though wheat is essentially a temperate crop, it can be successfully grown at higher altitudes in the tropics and sub-tropics and also in the tropical lowlands, where it is grown during the cool dry season. Consequently, a number of varieties have been developed for these tropical environments. There is evidence in support of the fact that wheat has been grown for many centuries in Nigeria under irrigation by small-holders in the northern parts of the country, usually in the *fadamas* and valley bottoms (Yayock *et al.*, 1986).

As a result of its low temperature requirements, wheat is grown under irrigation during the cold-dry harmattan months of November to February, between latitudes 10 and 14 degrees North, which falls within the Sudan and Sahel savanna ecological zones of Nigeria (Olugbemi, 1973; Kumar and Mayaki, 1987). Attempts to produce this crop under rainfed conditions on the plateaux of Nigeria have met with very limited success due to high relative humidity which promote serious attack of fungal diseases, and because of too high ambient temperatures.

About 98% of wheat produced in Nigeria today is being processed into flour by the flour mills, a product which is used by the numerous bakeries in the country for making bread and confectioneries. It is also used for the production of 'Semolina' for the macaroni industry as well as for breakfast cereals.

Although awned wheat varieties constitute the majority of locally grown wheat, a few awnless varieties are grown for their superior grain qualities. Local research efforts over the years were therefore aimed at identifying varieties that combine good grain quality with resistance to diseases and responsiveness to fertilization (Olugbemi *et al.*, 1979).

The present interest in planting wheat in narrower rows is to exploit the benefits of two-dimensional spatial plant arrangement for higher grain yields. In the past, wider rows were used to facilitate weed control by mechanical means. In Nigeria, a 20 cm row-spacing is recommended for farmers (Palmer, 1988). Though there are reports on the effect of row-spacing on grain yield, information on the influence of row-spacing on growth and nutrient uptake by the crop and its distribution among plant parts is virtually lacking.

One of the principal concerns of the Nigerian wheat farmer is how much fertilizer nitrogen to apply to optimize and maximize yield under a situation of high fertilizer costs and scarcity. To achieve this goal, improvement in fertilizer use efficiency will be needed. This therefore calls for intensive research work on the nitrogen requirement of wheat as affected by rate and time of application.

The optimum nitrogen requirement for wheat is likely to be influenced by variety, plant geometry, and number and time of N applications. Previous studies at the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, on the

nitrogen requirements of local and adapted wheat varieties with rates, source and timing of applications, focused on yield, yield components and grain quality (Chari *et al.*, 1980). Information is however, lacking with respect to crop growth and nutrient uptake and distribution of nitrogen among plant parts.

The present investigations consist of two field experiments conducted during the 1989-90 and 1990-91 dry seasons to (1) study the effect of nitrogen level and row-spacing on growth, yield and yield components and nitrogen uptake and its distribution among plant parts and (2) study the effect of nitrogen level and time of N application on yield, yield components and grain crude protein content.

The main objectives of these studies were therefore:

(1) to evaluate the effect of combination of varying levels of nitrogen and row-spacing on growth, yield and yield components;

(2) to evaluate the effect of N level and row-spacing on N uptake and its distribution among plant parts;

(3) to evaluate the effects of N level and time of N application on yield, yield components and grain crude protein content; and

(4) to evaluate the effects of level of N application on uptake and distribution of N, P, K, Ca and Mg among plant parts at harvest stage.

Chapter 2

LITERATURE REVIEW

Growth, yield, grain quality and nutrient uptake of wheat as influenced by variety, nitrogen fertilization and row-spacing are hereby reviewed.

2.1 Varieties

No single wheat variety has all the desirable characteristics that a grower or processor wants. Characteristics to be considered in selecting a wheat variety include time of maturity, disease and pest resistance, shattering, lodging, yield and grain quality (Schlenhuber and Tucker, 1967). Among the varieties recommended for cultivation in the wheat growing areas of Nigeria, variety Siete Cerros (awned) is noted for its high yields while variety Florence Aurore 8193 (awnless) is for its high grain quality (Kubiczek *et al.*, 1988).

2.1.1 Dry matter accumulation

Accumulation of dry matter in a wheat cultivar indicates its potentiality for yield but its mobilization to the reproductive sink is important for economic yield. In a study of dry matter production of wheat and triticale varieties in India, Lal *et al.* (1978) found that dry matter accumulation in the whole plant followed almost a sigmoid pattern with respect to time. The leaf and culm dry matter increased with crop age but dropped after reaching a maximum, depending on variety. Bauer *et al.* (1987) determined the relations of total aerial dry mass per cent in leaves, stems and spikes, of tillers per plant, fresh and dry leaf mass and leaf area index (LAI) and found that growth stage of the wheat plant accounted for 92, 96 85 and 79 per cent of the change in total

aerial dry mass and in per cent of aerial dry mass in leaves, stems and spikes respectively and 52, 85, 59 and 59 per cent of tillers per plant, leaf area index (LAI), dry leaf mass and fresh leaf mass respectively.

2.1.2 Yield and yield components

Cultivar differences in wheat grain yield have been reported. Angus and Sage (1980) reported that conventional tall wheat varieties were dependent for grain yield on either a high number of ears or a larger number of spikelets per ear whereas the semi-dwarfs were dependent on high spikelet fertility. Feingold *et al.*(1990) also reported that semi-dwarf wheat cultivars showed a greater capacity for grain yield than the tall ones. This they attributed to its higher harvest index, which was associated with higher number of grains per meter square.

2.1.3 Importance of awns

It has been reported that awns significantly increase the photosynthetic rate of the wheat ear and thus contribute 10 - 20% of the assimilate supplied to the grain during its main growth (Teare *et al.*, 1972; Olugbemi *et al.*, 1976a; 1976b). From studies conducted in Texas, USA, Atkins and Norris (1955), working with ten pairs of specially developed isogenic awned and awnless types of wheat, found that the awned lines produced significantly higher yields, heavier kernels and higher bushel weights than the awnless types. They noted that those differences were however, greater under conditions of drought. In Wisconsin, McDonough and Gauch (1959) reported that the contribution of the awns to the dry weight of the grains as compared to that of the flag-leaf blade becomes increasingly important as soil moisture levels were closer

to the wilting point. At a time when the flag-leaf had practically ceased to contribute photosynthates to the developing kernels, the awns were still making substantial contributions to the dry weight of the kernel.

Patterson *et al.*(1962), comparing twelve pairs of near isogenic soft red winter wheat for yield, test weight and kernel weight at Lafayette, Indiana, USA, found that awned lines were generally superior to awnless lines with advantages for kernel weight and test weight than for yield. At Kadawa, Nigeria, Olugbemi *et al.* (1981) found that the yield superiority of Siete Cerros (awned) wheat variety over Florence Aurore 8193 (awnless) was due to higher floret fertility and higher grain to straw ratio.

2.1.4 Nitrogen uptake

Nitrogen distribution to the wheat grain has been found to vary significantly with genotypes. Halloran and Lee (1979), who examined five wheat cultivars for patterns of nitrogen uptake and distribution to the above-ground plant parts at 10 different stages throughout the life-cycle, found that significant differences existed among cultivars in terms of nitrogen percentages of culm, glume and rachis tissues in the mature plant. Halloran (1981) also found that translocation efficiency was significantly different among cultivars. There were marked differences in trend in translocation efficiency between certain cultivars as the soil nitrogen availability increased.

2.2 Nitrogen Fertilization

The effects of levels and time of application of N on wheat with respect to crop growth, yield, yield components, nutrient uptake and N distribution among plant parts of wheat are hereby reviewed.

2.2.1 Crop growth

The growth of crop plants is more often limited by deficiency of nitrogen that of any other nutrient (Tisdale and Nelson, 1975). Plants require nitrogen for their normal growth and reproduction. Nitrogen is a constituent of all proteins, all enzymes, many metabolic intermediates involved in synthesis and energy transfer and even deoxyribonucleic acids that make up the genetic code (Viets Jr, 1965).

Excessive supply of nitrogen can however have adverse effects on the growth of wheat plants. If adequate amounts of all the other essential elements are available, too much supply of nitrogen may result in excessive vegetative growth; tall, weak-stemmed plants that may lead to stem lodging. Crop maturity is also delayed by N deficiency (Chapman and Carter, 1976). Nitrogen deficiency on the other hand causes pale - green colouration, stunted growth and reduced tillering of wheat (Viets Jr, 1965).

Khalifa (1973) reported that early N application effectively increased leaf area duration by increasing the leaf area index at the time of ear emergence while later N supply had very little effect on leaf area index and consequently on leaf area duration.

Pearman *et al.*(1977) reported that leaf area at and after anthesis was increased throughout the range of N of 0 - 200 kg ha^{-1}. Addition of 200 kg N ha^{-1} decreased the amount of grain produced per unit leaf area by 25%. Increase in N application increased leaf dry weight both at anthesis and maturity. Pearman *et al.*(1978) also reported that N in excess of 200 kg ha^{-1} increased straw dry weight at maturity, shoot dry weight at anthesis and leaf area more than it increased grain yield.

2.2.2 Yield and yield components

Nitrogen fertilization is a primary factor influencing grain yield of wheat. Rhodes (1963) and Woodward (1966) reported the effect of N fertilizers on wheat tillering and other yield contributing attributes. They concluded that N application increased tillering and yield, but decreased test and straw weights. Sharma *et al.*(1970) studying the response of dwarf and tall wheat varieties to nitrogen in northwest India, found that irrespective of the wheat type, yields were increased by N application. Dwarf wheat however, gave higher yields than tall wheat at every level of N fertilization. The superiority of the dwarf wheat varieties resulted both from a higher number of ear-bearing shoots per unit row-length and a higher number of fertile spikelets per ear.

In North Dakota, Power and Alessi (1978) reported that N fertilizer application significantly increased grain yield with additions of 80 - 270 kg N ha^{-1}. Most of this resulted from increase in the number of ears per hectare arising from reduced tiller mortality. At Kadawa, Nigeria, however, Olugbemi (1984) reported that the higher grain yield obtained with 100 kg N ha^{-1} than 80 kg N ha^{-1} was not significantly different from that of 150 kg N ha^{-1}.

Differences among wheat cultivars in yield responses to N application have been reported. Bhutta *et al.*(1980) obtained a positive correlation coefficient for the relationship between yield and number of grains per ear. Gehl *et al.* (1990) reported an increase in grain yield with increase in N fertilization but the level of N required for maximum grain yield varied among cultivars.

2.2.3 Protein content

In wheat, both the quantity and the quality of proteins are major factors in determining the quality of wheat flour and its suitability for making various bakery products.

Many studies have shown that protein content of wheat grain may be markedly increased by nitrogen application. Hutcheon and Rennie (1960) reported that additional N in excess of levels required to obtain yield increases, only improved the grain protein content. Hutcheon and Paul (1966) from a growth chamber experiment found that protein content of spring wheat could be controlled by nitrogen supply and soil moisture stress. In a 4-year experiment with semi-dwarf spring wheat varieties, Woodward (1966) reported that grain protein content increased with N levels, the magnitude of increase was however greater with the semi-dwarf than with the tall varieties. In Canada, Alkier *et al.* (1972) obtained large yield increases when 34 or 67 kg N ha^{-1} was applied broadcast to non-fallow land at seeding time but protein content either decreased or increased only slightly. Protein content increased substantially when 101-202 kg N ha^{-1} was applied to non-fallow land whereas grain yields were not increased above that obtained with 67 kg N ha^{-1}. Some other workers have however (Russell *et al.* 1958; Dubetz, 1977) reported that increase in wheat grain protein content, resulted in lower grain yield.

In England, Batey and Reynish (1976) reported that when rates of applied N were increased, grain size decreased but grain N content increased in winter wheat. Patil and Khuspe (1978) also reported that N fertilization improved grain protein content and its grain production up to 100 kg N ha^{-1} while Donald and Johnson (1987) reported that applied N but rather it increased total protein per hectare by increasing yield.

In Australia, Syme *et al.*(1976) working with three wheat cultivars which differed in their grain protein content, found that grain yield and protein content increased with N additions. Protein content was found to be inversely related to grain yields. However, ranking of cultivars on the basis of grain protein content was independent of nutrient regimes.

2.2.4 Nutrient uptake and distribution in plant parts

2.2.4.1 Nitrogen

In wheat, nitrogen economy is principally regulated through nitrogen absorption and partitioning between vegetative structures and the grain (Day *et al.*, 1985). Some of the factors that are likely to affect nitrogen uptake include time and rate of application as well as the environment.

A number of investigators have found that nitrogen absorption does not depend on cultivars (Woodruff, 1972; Day *et al.*, 1985; Heitholt *et al.*, 1990; Sarandon and Caldiz, 1990). Sarandon and Caldiz (1990) from a study on the effect of varying nitrogen supply levels at different stages on nitrogen uptake and partitioning efficiency in two wheat cultivars found that nitrogen content, N uptake and distribution at maturity were significantly different and affected by nitrogen supply but nitrogen content in the grain was similar in both cultivars.

The supply and availability for absorption of nitrogen at the root level is another factor that affects both its uptake and distribution. Singh and Seth (1978) reported that N content and N uptake by different plant parts of a dwarf wheat cultivar increased with increase in N rates from 80 to 200 kg ha^{-1}. Of the total N uptake, 75% was in the grain, 10 - 12% in leaves, 7% in chaff and rachis and 6% in the stem.

Similar findings were reported by Kapur *et al.* (1985) and Regasits and Berecz (1991) who found that N uptake increased with increasing N rates.

The rate of N uptake is influenced by the stage of growth of the wheat plant. Translocation of nitrogen from the vegetative parts into the grain also occurs (Williams, 1955). Austin *et al.* (1977) reported that for all the winter wheat genotypes studied, the plants contained at anthesis 83% of the total N present in the plant at maturity, while at this same growth stage, 68% of the plant nitrogen was present in the grain. Wilhelmi (1976), studying the effect of soil N availability on N uptake and translocation in three winter wheat varieties differing in grain protein content, reported that approximately 85% of the total N absorbed by the roots from the soil was in the plant by the heading stage, and that this increased to 89% at anthesis. Wahhab and Hussain (1957) reported that N uptake by wheat was highest at the tillering stage, followed by a sharp decline at the jointing stage, while at heading, the decline became gradual. This result was confirmed by Monem Balba *et al.* (1972) who reported that fertiliser N absorption was mainly during the period from tillering to ear emergence. McNeal *et al.* (1968) also reported that N percentage in the chaff was about the same level as that in the stems and leaves and that each concentration level decreased with successive sampling dates at nearly the same rate. Grain N percentage levels at the late flowering and milk stages were similar but showed a significant increase by the dough stage.

Some correlation studies had been undertaken for a better understanding of the relationships between nitrogen uptake, dry matter accumulation and grain protein percentage in wheat. Day *et al.*(1985) reported that high N percentage of plant parts tended to correlate positively with grain protein percentage at first node and anthesis

stages but correlated negatively at later stages. Dry weight was important in the accumulation of N, however, neither dry weight nor total plant N correlated with grain protein percentage. Kretschmer (1990) also reported that potential N uptake positively highly correlated with plant dry matter accumulation.

2.2.4.2 Other nutrients (P, K, Ca and Mg)

Nutrient supply is very important in crop production since photosynthesis, an important factor in crop growth, is highly dependent on mineral nutrient supply. Plant nutrient uptake is the best criterion for assessing the availability of mineral nutrients, provided other growth factors are not limiting (Tisdale and Nelson, 1975).

Interactions among mineral elements influence nutrient availability and uptake. A better utilization of P by cereal crops in the presence of N has been reported (Grunes, 1959; Bezdek and Zenesceva, 1979). Walsh and Beaton (1973) reported that when No_3 - N is adsorbed to soil colloids, uptake of Ca, Mg and K is increased when these are present in adequate amounts. Dean (1957) reported that rate of nutrient absorption was not independent of nutrient concentration in the soil solution and that this rate was proportional to the concentration of a specific ion species. Hanway (1962) reported that differences in soil fertility were reflected in the amounts of N, P, and K accumulated in the corn plant, but that these did not markedly influence the distribution pattern of each of the nutrients in the different plant parts. Grewal (1989) however reported that the concentration of P and K in wheat grain and straw and their uptake were not affected by N application.

Page *et al.* (1978) found that concentration of N, P, K, Ca and Mg in the foliage of wheat plant decreased from Feeke's stage 4 but N, P and Mg concentration in the ear increased at Feeke's stage 11. N, P, and Mg accumulated in the ears at the

expense of the foliage during stage 11, maximum uptake occurring at stages 11.3, 11.1, and 11.2 respectively. In contrast, K and Ca uptake ceased at stages 10.1 and 10.5 respectively. Rate of N uptake and soil No_3 - depletion correlated significantly.

Lasztity (1988) also studied nutrient uptake by wheat at 10-day intervals from tillering to harvest. He reported that accumulation of N occurred until maximum ripeness, that of P and Mg was until maturity and of K and Ca was up to flowering. The rate of uptake was greatest for N and P during shoot elongation, that for K and Ca at heading and for Mg at flowering. Most of the absorbed N and P was found in the grain, but more K and Ca was found in the vegetative parts while Mg was distributed equally between both grain and vegetative tissues.

2.2.5 Time of N application

Judicious use of fertilizer nitrogen by wheat requires a good understanding of its total need and an identification of time of its peak requirement during the growing season. Some researchers have observed increases in grain yield and protein content of wheat following N application at various periods after planting (Van Dobben, 1966; Darkwinkel *et al.*, 1986; Vaughan *et al.*, 1990).

Van Dobben (1966) reported that spring dressings with small amounts of N at tillering in addition to that applied at sowing led to shorter and stiffer straw and increased number of kernels per spike in wheat. On the other hand, McClelland and Griffiths (1972) failed to obtain any yield increases when N was applied after seeding.

Darkwinkel *et al.* (1986) reported that best results were obtained by applying N at the end of tillering to supplement soil - N to a total level of 140 kg N ha^{-1}, a second dressing at Feeke's stages 6-7 and a third dressing of 30-50 kg N just before

ear-emergence. Applying a second dressing at stage 5 increased the number of ears but had adverse effects on the crop due to plant lodging.

In the Australian Darling Downs, Strong (1982) found that growth of semi-dwarf wheat under supplementary irrigation was increased by the application of 400 kg N ha^{-1} at planting. N at 50 or 100 kg ha^{-1} applied at the booting stage to supplement the 100 kg ha^{-1} applied at planting increased grain yield by 459 and 478 kg ha^{-1} respectively. In contrast, supplementary N (25, 50 or 100 kg ha^{-1}) at or after flowering, generally did not increase grain yields.

Hunter and Stanford (1973) evaluating the relationship between time and rate of N application found that average protein contents were increased from 10.9% with no - N applied to 14.3% with N fertilizer. Spring applications consistently gave higher protein contents than fall applications though the average differences were small. But Stanford and Hunter (1973) did not find any significant interactions between rate and time of N application on yields of grain, dry matter and N content.

Christenseen and Killorn (1980) reported that when 100 kg N ha^{-1} was split between seeding time and at irrigation, wheat yields decreased from 3.89 to 3.54 and 2.98t ha^{-1} as the amount of N applied at seeding was decreased from 100 to 75 and 80 kg N ha^{-1} respectively. Differential responses to split applications of N were related to differences in number of spikes per unit area at harvest. The number of spikes per unit area decreased as the proportion of N applied at seeding decreased. Hamid and Sarwar (1976) reported that when N fertilizers were applied at a rate of 120 kg N ha^{-1} in a single application (at seeding), two split applications (at seeding and tillering), and six split applications (at seeding, tillering, boot, heading, flowering and milk-ripe), N applied in two-split doses was found to be most productive for grain yield but six split

applications significantly increased the protein content of grain compared with single or two-split applications.

Hamid (1973) working on the effect of time and rate of application on uptake of fertilizer N by wheat found that splitting the application was only beneficial at the maximum rate but two top dressings at tillering and boot stages were better for grain production than basal dressing or single top dressing at stem elongation stage. Uptake of fertilizer N was maximum from a single top dressing.

At Kadawa, Nigeria, Okoh *et al.* (1985) studied the effects of increasing amounts of urea fertilizer (50, 100, 150 kg ha^{-1}) and time of its application on protein content and amino acid composition of seven wheat cultivars grown under irrigation. They found that increase in protein content which occurred with increase in applied nitrogen was more marked when the lowest urea level was applied at the grain filling stage.

Koch and Mengel (1977) reported that higher N levels applied during the reproductive growth phase had a negative rather than a positive effect on grain yield. Additional N supply increased mainly the soluble amino acids, namely, prolamin and glutelin content of the grain.

Effects of time of N application on yield components of wheat have been reported. In England, Ellen (1987) reported that delaying the first N dressings resulted in fewer shoots per plant at both low and high plant densities. Grain number per ear increased but grain number per meter square was hardly affected. The 1000-grain weight decreased as the N dressing was further delayed.

In Colorado, USA, Vaughan *et al.*(1990) found that when fertilizer N was applied in autumn, spring or in split applications, spring applied N increased grain yield and protein content more than did either autumn application or split applied N.

Time of application also influences nitrogen uptake and distribution in plant parts. Baier *et al.*(1989) reported that when N rates of 0, 40, 80 and 120 kg ha^{-1} were applied in split doses, average N uptake increased by 22.3, 39.6 and 55.6 per cent respectively as N rates increased. N uptake was greatest from the N doses applied at Feeke's stage 10. Heitholt *et al.*(1990) also reported that redistribution of vegetative N contributed significantly more to grain N than did post-anthesis N uptake. Vegetative N at maturity increased as a result of supplemental N applied at anthesis, but GNC, total grain N and yield were unaffected.

2.3 Row-Spacing

2.3.1 Yield and yield components

A review of studies on the effect of row-spacing on the yield of cereal crops (Holliday, 1963) led to the following conclusions:

1. At a constant seed rate, decreasing the row width below 17-20 cm has in most cases led to small increases in cereal yields. Conversely, increasing the row width above the standard in most cases resulted in some decrease in yield.
2. There is evidence to show that yield advantages of narrow rows are more pronounced at seed rates that are either below or above that which is considered standard; the decline in yield at wider rows therefore being more pronounced at high seed rates.

Kinra *et al.*(1963) reported that row-spacings wider than 17 cm resulted in fewer culms per square meter in three out of four cases. This was attributed to inhibition of tillering due to the close intra-row spacing of plants in the wider spaced inter-rows. Plant height decreased when the distance between rows was increased from 17 to 27 cm but increased as inter-row spacing was increased to 35 cm due to increased interplant competition. Yield was reduced by increase in row-spacing.

In India, Dubey and Lal (1970) reported that 25 cm row-spacing exerted significant effect on grain yield compared to 30 cm. Others have also reported the effect of closer row-spacing. Ram *et al.*(1988) reported that wheat in 5, 17.5 and 20 cm rows gave yields of 4,08, 3.96 and 3.77 tonnes per hectare respectively. Similar findings were reported by Roth *et al.*(1984) who found greater yield increases when row-spacing was further decreased to 12.7 cm. This increase was attributed to the production of more productive tillers per unit area.

Joseph *et al.*(1985) found that with soft red winter wheat, a 10 cm row-spacing produced grains that were 0.6 to 0.8 tonne ha^{1} higher than the 20 cm row-spacing at similar seed rates. Plants in 10 cm rows produced more productive tillers than a similar number of plants per m^2 in 20 cm rows. This was because there were approximately twice as many plants per unit length of row in the 20 cm rows and thus competition within rows was greater.

Palmer (1988) recommended a standard row-spacing of 20 cm for wheat cultivation under the northern Nigerian conditions though no significant yield differences were recorded between drilling in rows and broadcasting.

Beverlein and Lafever (1990) in studies in Ohio found that when wheat was planted in rows 17.8, 25.4, 35.6 and 50.8 cm apart, average grain yield decreased by approximately 19% as row-spacing increased.

2.3.2 Nitrogen uptake and distribution in plant parts

There is scanty available information on the effect of row-spacing on nutrient uptake by wheat. Holliday (1963) was unable to establish conclusive evidence to suggest a greater efficiency of fertilizer use by wheat plants at narrow row-spacing.

Reinerton *et al.* (1984) reported that in spring wheat sown in 20 cm rows, total Kjeldahl N uptake was greater compared to 30 and 40 cm rows. Singh *et al.* (1988) also reported on the effect of row-spacing on nitrogen uptake by late sown wheat. They found that when wheat was shown in rows 15, 17.5 or 20 cm apart, nitrogen uptake values were 97.9, 98.0 and 92.9 kg ha^{-1} respectively.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Site

The experiments were conducted at the Irrigation Research Station of the Institute for Agricultural Research, Ahmadu Bello University, at Kadawa (11°39'N, 08°02'E; 500 m above sea level), Nigeria during the 1989-90 and 1990-91 dry seasons. Kadawa is located in the Sudan savanna ecological zone of Nigeria. Records of temperature during the period of the experimental are given in Appendices 1,2 & 3.

3.1.1 Soils of Experimental Sites

The soils of the sites used for the experiments have been classified as Eutric Cambisol (FAO/UNESCO) and Typic Ustropept (Ojanuga *et al.*, 1979). The parent material is aoelian sandy drift over iron pan. The soils are moderately deep sandy clays with loamy tops. They are moderately to imperfectly drained to a depth of 89 cm because of the perched water-table resting on the underlying iron pan at depths varying between 91 and 152 cm.

Prior to the establishment of each year's trial, a composite soil sample from 0-15 cm depth was taken for physico-chemical analysis and the results of these are shown in Table 1.

The soil samples were air-dried for several days, mixed thoroughly, and ground to pass through a 2 mm sieve and stored in plastic containers for subsequent analysis.

Particle size distribution was determined by the hydrometer method as described by Day (1965). Soil pH was determined with 1:1 soil-water and

Table 1. Physico-chemical properties of the soil samples taken from the experimental sites at 0 - 15 cm depth at Kadawa in 1989-90 and 1990-91 dry season.

Property	Years	
	1989-90	1990- 1
Chemical property		
pH (H_2O)	6.30	6.40
pH (0.01M Ca Cl_2)	5.80	6.20
Organic carbon (g kg^{-1})	7.0	5.2
Total nitrogen (g kg^{-1})	0.6	0.8
Available P (mg kg^{-1})	17.92	26.88
Exchangeable bases (cmol kg^{-1}) Calcium (Ca)	3.74	5.29
Magnesium (Mg)	0.85	1.89
Potassium (K)	0.29	0.29
Sodium (Na)	0.11	0.37
CEC (cmol kg^{-1})	6.0	6.8
Physical analysis		
Sand (%)	56	64
Silt (%)	26	24
Clay (%)	18	12
Textural class	Sandy loam	Sandy loam

also in 1:2 soil-0.01 Ca Cl_2 pastes applying the method described by Peech (1965). Organic carbon was estimated by the Walkley - Black method (Jackson, 1958). The total percentage nitrogen was estimated by the Kjekdahl method (Bremmer, 1965). Cation exchange capacity and exchangeable K, Na, Ca and Mg were estimated by using the NH_4OAc method as described by Chapman (1965a & b). Na and K in the

extracts were determined with an EEL flame photometer, while Ca and Mg were determined with a Perkin Elmer, Model 290B atomic absorption spectrophotometer. Available P was estimated according to Bray's I sulphuric acid reduction method as described by Olsen and Dean (1965).

3.1.2 Cropping history

The cropping history of the experimental site used in each of the two dry seasons is shown below:

	Wet Season	Dry Season
1989-90 field		
1988	Rice	Wheat
1989	Rice	Wheat
1990-91 field		
1988	Rice	Wheat
1989	Groundnut	Wheat
1990	Millet	Wheat

3.2 Cultural Practices

3.2.1 Land preparation

The land was ploughed and harrowed twice to a fine tilth. The field was then divided into 5 x 3 m basins separated by half-meter dykes to reduce seepage of water and nutrients into adjacent plots. Irrigation channels were constructed for efficient water distribution to the plots.

3.2.2 Varieties

The two wheat varieties used for the experiments were Siete Cerros and Florence Aurore 8193.

Siete Cerros

Siete Cerros is an introduction from Mexico. It has an average height of 72-80 cm. Its spike, which is borne on a kinky neck, has awns that are long, coarse and arranged parallel to one another. This variety is of medium maturity (120 days) and has a yield potential of about 4.5 tonnes ha^{-1}. It is generally tolerant of pests and diseases (F.C. Orakwue, personal communication).

Florence Aurore 8193

Florence Aurore 8193 was released from FAO collection in 1965. It is 99-115 cm tall, with a thick culm. Its spike is long, awnless and cream coloured. It is of medium maturity and has a yield potential of 3.5 tonnes ha^{-1}. It is moderately resistant to pests and diseases (F.C. Orakwue, personal communication).

3.2.3 Seeding

The seeds of these varieties were received from the Institute for Agricultural Research, Ahmadu Bello University's Seed Production Programme and sown at a rate of 100 kg ha^{-1} on 19th and 8th December in 1989 and 1990 respectively. Sowing was by hand-drilling along the rows at a depth of 3 cm. The varieties and row-spacings adopted in each case were as given in the treatments.

3.2.4 Irrigation

The 1989-90 trials were irrigated twice because of the rather high water table in the field. Water table was at a depth of 85 cm. During the 1990-91 cropping season, the trials had to be conducted on a different field from that of the preceding year in order to avoid the high water-table problem. Irrigation during the 1990-91 cropping season was therefore at weekly intervals with a total of eleven irrigations.

3.2.5 Weeding

Two weedings by hand pulling were carried out during the 1989-90 cropping season to control weeds. However, during the 1990-91 cropping season, due to high weed intensity and flushes, two weedings by hand pulling and two hoe-weedings were done to control weeds. Volunteer millet from the preceding crop constituted the major weed problem.

3.2.6 Fertilizers

Commercial urea (46% N) was used as nitrogen source throughout the study. Rates and time of nitrogen applications were as specified in the treatments. A uniform rate of 40 kg P_2O_5 as single superphosphate (SSP) and 60 kg K_2O ha^{-1} as muriate of potash (MOP) were applied to each plot and incorporated before sowing as basal fertilizer dressing.

3.3 Treatments and Experimental Layouts

The studies were carried out in two experiments which were conducted side by side during the period of study. The field layouts for the two experiments are shown in Figures 1 and 2. Details of these are as given below:

3.3.1 Experiment I

Effect of nitrogen levels and row-spacing on growth, yield, yield components and nitrogen uptake and distribution in plant parts.

Varieties

The two varieties used were Siete Cerros (awned) and Florence Aurore 8193 (awnless).

Nitrogen levels

The four levels of nitrogen tested were 0, 60, 120 and 180 kg N ha^{-1}. The nitrogen fertilizer was split into two equal parts and applied first at sowing and four weeks later by hand broadcast.

Row-spacing

The row-spacings compared were 10, 20 and 30 cm making, 30, 15, and 10 rows per plot respectively.

Experimental design

The experiment was laid out in a split-plot design with four replications. The main plots comprised of combination of varieties and row-spacing while subplots were nitrogen levels, making the total number of treatments 24.

3.3.2 Experiment II

Effect of nitrogen level and time of N application on yield, yield components and grain crude protein content.

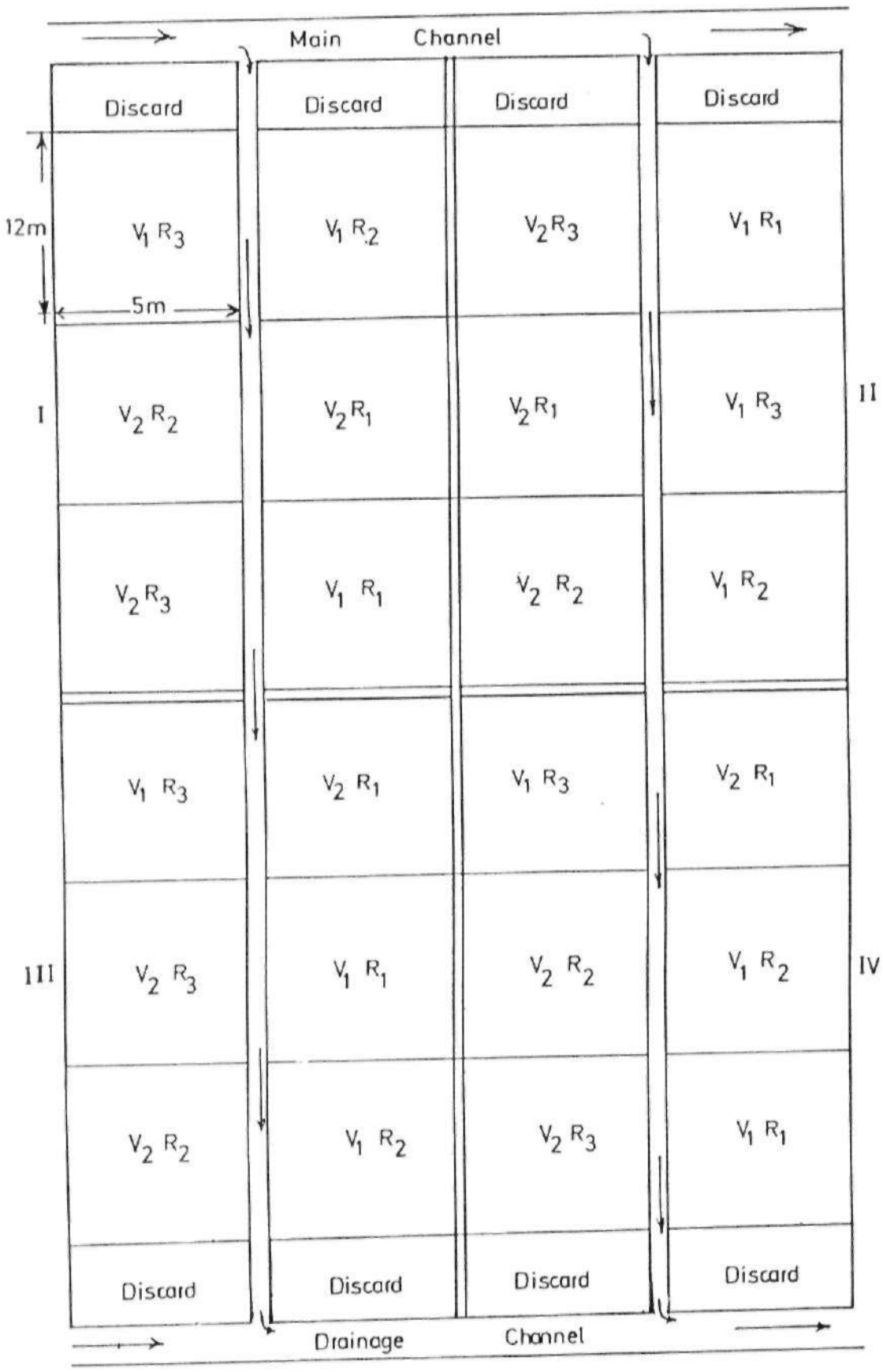


Fig. 1 : Layout of experiment 1

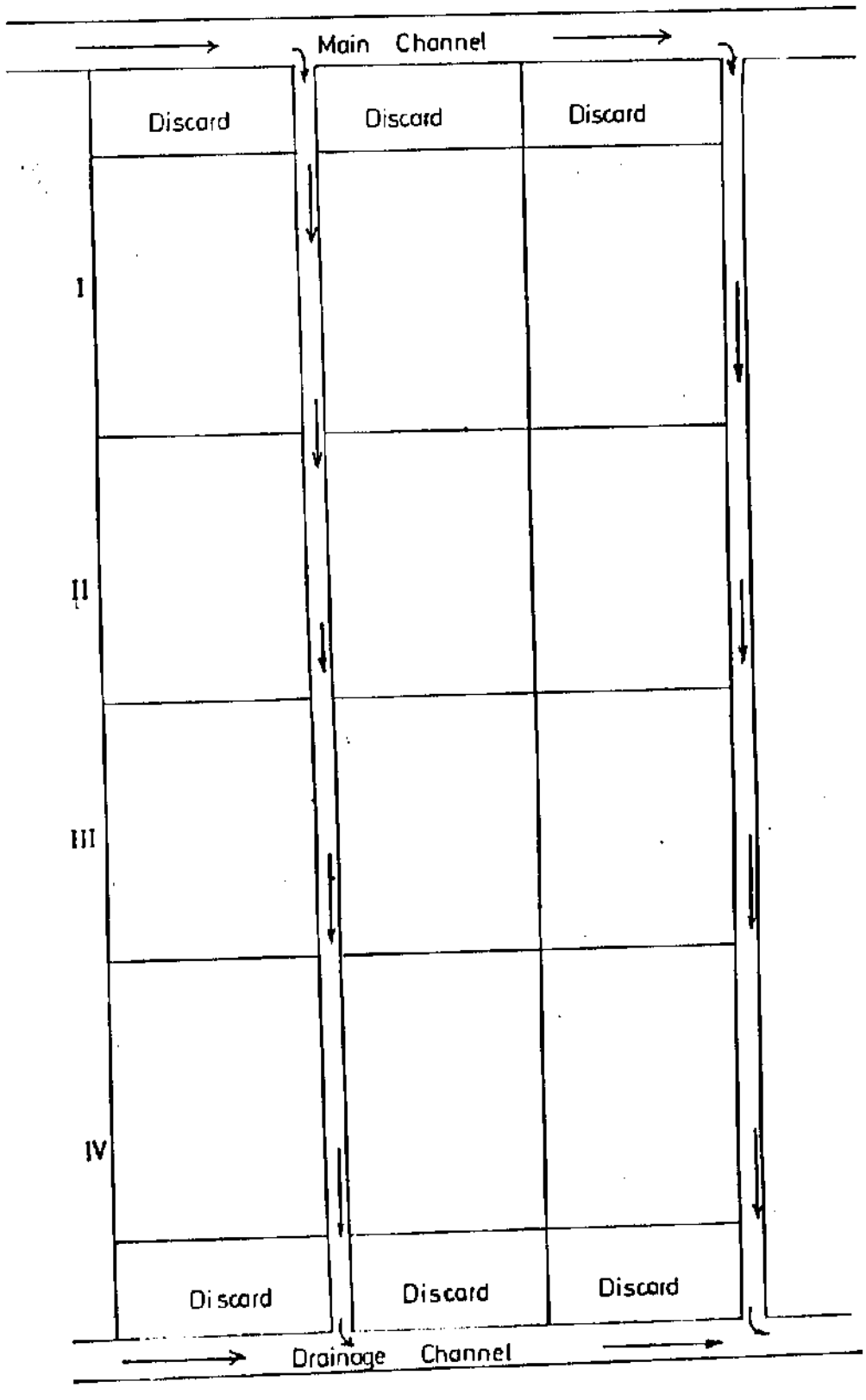


Fig. 2 : Layout of experiment II

Treatments

The total of 18 treatments comprised of factorial combinations of varieties, nitrogen levels and times of nitrogen application as follows:

Varieties

The two varieties used were Siete Cerros (awned) and Florence Aurore 8193 (awnless).

Nitrogen levels

The three levels of nitrogen tested were 60, 120 and 180 kg N ha^{-1}. The fertilizer was applied by broadcasting.

Time of nitrogen application

There were three times of N application:

(a) all nitrogen applied at seeding.

(b) half nitrogen at seeding plus half at tillering stage (4 weeks after sowing).

(c) half nitrogen at seeding plus half at flag leaf stage.

Experimental design

The experiment was laid out in a randomized complete block design with four replications.

3.4 Observations

3.4.1 Emergence count

This was recorded at 15 days after sowing by counting plants from an area of one square meter.

3.4.2 Days to 50% flowering

Days from sowing to the time when about 50% of the plants within each plot had flowered.

3.4.3 Days to physiological maturity

Days from sowing to physiological maturity (i.e when rachis were dried in about 50% of spikes in each plot).

3.4.4 Tillers per plant

Number of tillers per plant was determined by destructive sampling of ten contiguous plants along the row at 36 days after sowing. Tillers with visible greenness, irrespective of size or leaf number, were counted.

3.4.5 Dry matter accumulation and partitioning

Above-ground plant materials from a half meter row-length were harvested starting at 42 days after sowing and at 14-day interval thereafter up to maturity. The harvested plant samples were immediately placed in a polythene bag and transported to the laboratory where they were weighed with a top-loading Mettler balance (Metler P1200). A sub-sample of ten shoots was randomly removed from each bulk sample, weighed and each shoot dissected into component parts of leaves, stems and spikes, as appropriate for developmental stage. The leaf sheaths and prior to onset of heading, the developing inflorescences, were retained as part of the stem. Each component part from the sub-sample was weighed fresh, oven-dried to constant weight at 70°C for 24 hours and weighed again. The remaining bulk sample was also oven-dried to a constant weight at 70°C for 24 hours and weighed. The fractional mass of leaves,

stems and spikes in the total biomass (from half meter length) was estimated from the sub-sample weights.

There were five sampling periods during the 1989-90 cropping season but due to the shorter growth period, there were four sampling periods in the 1990-91 cropping season.

3.4.6 Leaf area per shoot

The total area of green leaves from randomly selected shoots was estimated with an LI 3100 Model area meter (Li-Cor Inc., Lincon, Nebraska) at 42, 56 and 70 days after sowing (DAS).

3.4.7 Leaf area index

This was determined by multiplying the leaf area per shoot by the number of shoots in a square meter and dividing the product by the land area.

3.4.8 Plant height

Ten plants from a one meter row-length were randomly selected at harvest and their culm length measured from the ground level to the tip of the spike. The mean of these measurements was taken as the plant height for the plot.

3.4.9 Effective tillers

Before harvesting, fertile spikes from a half meter row-length were counted at two locations per plot and converted to total effective tillers per square meter.

3.4.10 Length of spike

This was estimated by measuring the length of five spikes from each plot and finding the mean of the sum.

3.4.11 Spikelets per spike

This was determined by counting the number of spikelets per spike from five spikes per plot and finding the mean of the sum.

3.4.12 Grains per spike

This was determined using five spikes from each plot at harvest and counting the total number of grains after threshing.

3.4.13 Thousand-grain weight

Two lots of 1000-grains were counted from each plot and weighed.

3.4.14 Total plant dry matter

Wheat plants within an area measuring 2 x 3 m at the centre of each plot were harvested with a sickle at full maturity, tied, allowed to sun-dry in the field for two days and then weighed with a spring balance to determine total plant dry matter.

3.4.15 Grain yield

The harvest from the 2 x 3 m net plot used for total dry matter determination was threshed with a plot thresher. The grains derived therefrom were winnowed, cleaned and weighed. The grain weight obtained was then used to determine total grain yield per hectare.

3.4.16 Straw yield

This was determined by calculating the difference between total plant dry matter and grain yield.

3.5 Chemical Analyses

3.5.1 Sample preparation

All the dry plant samples collected at various stages were ground with a Wiley mill and sieved with a 0.5 mm sieve, labelled and stored in plastic containers for subsequent chemical analyses.

3.5.2 Total nitrogen

Total percentage nitrogen was determined by the micro-kjeldahl method as described by Bremner (1965). 0.20 g of the plant sample was weighed and placed in a digestion tube. 15 ml of concentrated H_2SO_4 was added and the tube gently swirled until the sample and acid were thoroughly mixed. 5 g of Kjeldahl catalyst mixture was added and the tube heated cautiously until the solution cleared. A few drop of 30% H_2SO_4 was used to wash isolated sample particles down the neck of the tube and then allowed to cool down. The content of the digestion tube was then transfered into 100 ml volumetric flask and diluted with distilled water to where the tube is marked and mixed thoroughly. 10 ml of 2% boric acid and 4 drops of mixed indicator were placed in a 250 ml - Erlenmeyer flask. 10 ml aliquot of the digest was transfered into a distillation flask and attached to the distillation apparatus. 10 ml of 10 N NaOH was added to the distillation flask containing the digest. Nitrogen was distilled into the boric acid/mixed indicator receiver fask until the 150 ml mark was reached. The

distillate was then titrated with standard 0.025 N H_2SO_4 to a pink end point. Per cent N in the sample was calculated

$$\% N = \frac{0.014 \times \text{Titre} \times \text{Vol. of Digest} \times \text{Normality of Acid} \times 100}{\text{Weight of sample} \times \text{Vol. of aliquot used}}$$

Nitrogen uptake was expressed on dry weight basis.

3.5.3 Crude protein

The percentage nitrogen content of the wheat grains was determined by the micro-kjeldahl method (Bremner, 1965). Grain crude protein content was obtained by multiplying percentage nitrogen by a factor of 5.83 (Guiragossian *et al.*, 1977).

3.5.4 Analysis for P, K, Ca and Mg

Plant part samples taken at harvest were analysed for P, K, Ca, and Mg. Total uptake of each of the nutrients was expressed on dry weight basis.

Phosphorus

Phosphorus was determined after wet oxidation with perchloric-nitric acid mixture by the vanadomolydo-phosphoric acid yellow method (Olsen and Dean, 1965). 0.5 g of the ground plant sample was placed in the digestion tubes, 5 ml of the HNO_3 - $HCLO_4$ acid mixture (2:1 by volume) was added to the digestion tube and mixed. The tube was placed in a fume hood at 150°C and content allowed to digest for 1½ hours. The temperature was then increased to 230°C and digested for 30 minutes. The digestor was then switched off. The tube was removed and 30 ml of distilled water added within a few minutes of removing it from the digestor. More distilled water was then added to make up to the mark on the tube and the content mixed. The P in the solution was determined colorimetrically using a spectrophotometer.

K, Ca and Mg

Digested samples used for total P determination were diluted and used for K, Ca and Mg determination. Potassium was determined by flame photometry (Heald, 1965), while Ca and Mg were determined by atomic absorption spectrophotometry (Pratt, 1965).

3.6 Statistical Analysis

All the data collected were subjected to a one-way analysis of variance to test for significance of treatment effects. Where treatment effects were found to be significant, comparison of treatment means was made for the appropriate set of data using the test of least significant difference (LSD) at the 0.05 level of significance (Snedecor and Cochran, 1967). Quadratic regression was developed from data to measure the degree of response of grain yields to applied nitrogen. Coefficients of correlation were computed to find out the relationships of the different yield-attributing characters with grain yield. Wright's path coefficient analysis was used to determine the nature and extent of direct and indirect influence of the component characters in building up the ultimate yield (Dewey and Lu, 1959).

Chapter 4

RESULTS

Experiment I

4.1 Growth Characters

4.1.1 Tillers per plant

Data in respect of the number of tillers per plant for varieties, row-spacings and nitrogen levels are presented in Table 2. The corresponding analysis of variance tables are in Appendices 4, 5 and 6.

Variety Florence Aurore produced significantly more tillers per plant than variety Siete Cerros in each of the two years and the mean of both years. The differences were about 29, 20 and 19 per cent in 1989-90, 1990-91 and mean of years respectively.

Tillers per plant did not differ significantly with changes in row-spacing in both years and mean of years.

Increase in nitrogen levels significantly increased the number of tillers per plant up to 120 kg N ha^{-1} in either of the two years and the mean of both years.

There were no significant interaction of the factors on number of tillers per plant.

4.1.2 Plant height at harvest

The data on plant height at harvest for varieties, row-spacings and nitrogen levels are presented in Table 2. The analysis of variance tables are in Appendices 4, 5 and 6.

Florence Aurore had plants which were significantly taller than those of Siete Cerros in both years and mean of years by of 39, 35 and 37 per cent in 1989-90, 1990-91 and mean of years respectively. Row-spacings did not cause significant differences in plant height in both years.

Plant height increased significantly with nitrogen levels up to 180 kg N ha^{-1} in both years. In 1989-90, 60 kg N ha^{-1} increased plant height by as much as 48 per cent over 0 kg N ha^{-1}, 120 kg N ha^{-1} by 12 per cent over 60 kg N ha^{-1} and 180 kg N ha^{-1} by 4 per cent over 120 kg N ha^{-1}. The corresponding values were 24, 15 and 4 per cent in 1990-91 and 37, 14 and 4 per cent for mean over years.

Variety x nitrogen level interactions were significant in both years (Table 3) and mean over years. Year x nitrogen level interaction was significant (Table 2) in mean value for the two years.

The difference between the plant heights of Florence Aurore and Siete Cerros increased with nigrogen levels.

4.1.3 Leaf area per shoot

Data on the effects of varieties, row-spacings and nitrogen levels on leaf area per shoot at various growth stages are presented in Table 4. The corresponding analysis of variance tables are in Appendices 12 and 13.

Florence Aurore had significantly larger leaf area per shoot than Siete Cerros at 56 and 70 DAS in 1989-90 and at 42 and 56 DAS in 1990-91.

Table 2. Effect of variety, row-spacing and nitrogen level on number of tillers per plant and plant height in wheat at Kadawa, 1989-91.

Treatment	Tillers/plant (No.)			Plant height (cm)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	2.1	2.0	2.1	76.1	69.6	72.9
Florence Aurore	2.6	2.4	2.5	105.8	94.0	99.9
SE ±	0.15	0.06	0.08	1.62	0.94	0.93
LSD (0.05)	0.45	0.18	0.34	4.85	2.82	2.81
Row-spacing (cm)						
10	2.7	2.2	2.4	88.7	81.8	85.3
20	2.1	2.2	2.1	92.3	80.9	86.6
30	2.2	2.3	2.3	91.8	82.6	87.2
SE ±	0.19	0.07	0.10	1.98	1.15	1.14
LSD (0.05)	NS	NS	NS	NS	NS	NS
Nitrogen level (kg N ha^{-1})						
0	1.3	1.0	1.1	61.6	63.3	62.4
60	2.0	1.8	1.9	91.8	78.8	85.2
120	2.9	2.9	2.9	103.0	90.8	96.9
180	3.1	3.1	3.1	107.4	94.5	101.0
SE ±	0.14	0.10	0.09	1.32	1.33	0.95
LSD (0.05)	0.40	0.28	0.26	3.64	3.68	2.64
Interactions				NxV	NxV	NxV YxN

Table 3. Interaction of variety and nitrogen level on plant height (cm) in wheat at Kadawa, 1989-91.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	*Florence Aurore*
	1989-90	
0	54.4	68.8
60	78.1	105.5
120	84.7	121.4
180	87.5	127.4
LSD (0.05)	6.34	
	1990-91	
0	54.0	72.6
60	67.9	89.3
120	77.2	104.3
180	79.2	109.9
LSD (0.05)	5.22	

Effect of row-spacing on leaf area per shoot varied with sampling dates and years. Row-spacing had significant effect on leaf area per shoot at all sampling dates in 1989-90 and at 56 and 70 DAS in 1990-91. Row-spacing of 30 cm gave a significantly greater leaf area per shoot than 10 cm at all sampling dates in 1989-90 and 70 DAS in 1990-91. The 30 cm row-spacing excelled the 20 cm at 70, DAS in 1989-90 and 56 and 70 DAS in 1990-91. Row-spacing at 30 cm however maintained its superiority at all sampling dates in both years.

Leaf area per shoot increased significantly with nitrogen level up to 180 kg N ha^{-1} at all sampling dates in both years. The increase in leaf area with the first increment of N was greater than subsequent ones at the earlier stages of sampling.

Table 4. Leaf area per shoot (cm^2) in wheat at various stages of growth as influenced by variety, nitrogen level and row-spacing at Kadawa, 1989-91.

Treatment	1989-90			1990-91		
	Days after sowing			Days after sowing		
	42	56	70	42	56	70
Variety						
Siete Cerros	49.5	25.6	11.1	26.0	35.6	25.5
Florence Aurore	51.4	41.9	14.7	31.8	40.2	27.2
SE ±	1.00	1.28	0.84	1.09	0.96	1.01
LSD (0.05)	NS	3.85	2.54	3.27	2.87	NS
Row-spacing (cm)						
10	43.7	30.1	10.2	26.8	36.1	24.5
20	53.4	34.2	10.3	30.1	35.0	23.2
30	54.3	37.0	18.2	29.8	42.6	31.3
SE ±	1.22	1.57	1.03	1.33	1.17	1.23
LSD (0.05)	3.66	4.27	3.11	NS	3.52	3.71
Nitrogen level (kg N ha^{-1})						
0	24.4	18.1	3.1	14.6	19.7	14.1
60	48.4	28.7	7.4	26.1	33.5	22.3
120	62.6	39.5	14.4	32.8	43.7	29.9
180	66.5	48.8	26.7	42.0	54.8	39.1
SE ±	1.30	1.14	0.80	0.56	0.13	0.95
LSD (0.05)	3.59	3.15	2.23	1.55	2.02	2.63
Interactions	VxR	VxR	VxR	VxR	VxR	-
	-	RxN	RxN	RxN	RxN	-
	-	VxN	-	VxN	VxN	VxN

In 1989-90, leaf area per shoot decreased after 42 DAS but in 1990-91, it reached its maximum at 56 DAS and decreased thereafter. Leaf area values at 42 DAS were higher in the first year than the second year but the trend was reversed at 70 DAS.

A number of interactions were significant in both years. Variety x row-spacing interactions for leaf area per shoot were significant at all sampling dates in 1989-90

and at 42 and 56 DAS in 1990-91 (Appendices 7 and 8). Row-spacings x nitrogen levels interactions for this parameter at 56 and 70 DAS in 1989-90 and 42 and 56 DAS in 1990-91 (Appendices 9 and 10) and those of variety x nitrogen level at 56 DAS in 1989-90 and all sampling dates in 1990-91 (Appendix 11) were significant.

4.1.4 Leaf area index (LAI)

Leaf area index values as influenced by variety, row-spacing and nitrogen level at various growth stages are presented in Table 5. The corresponding analysis of variance tables are in Appendices 14 and 15.

The leaf area index of Florence Aurore was signifi- cantly higher than Siete Cerros at 56, and 70 DAS in 1989-90 and 42 and 56 DAS in 1990-91. Even at stages for which the differences were not significant in both years, Florence Aurore tended to have greater leaf area index values than Siete Cerros.

Effect of row-spacing on leaf area index varied between sampling dates and years. In 1989-90, LAI values were favourable for the 20 cm row spacing at 42 and 56 DAS but for the 30 cm spacing at 70 DAS. In 1990-91, trends favoured the 20 cm row-spacing at 42 DAS and the 30 cm at 56 and 70 DAS.

Leaf area index values increased significantly with nitrogen level up to 180 kg N ha^{-1} at all sampling dates in both years. The increase in LAI values with the first increment of 60 kg N ha^{-1} gave the highest percentage increase on all dates in both years relative to the other levels of N application.

The maximum leaf area index value was at 42 DAS in 1989-90. In 1990-91, however, the maximum value was attained at 56 DAS. Leaf area index values in 1990-91 were relatively lower than those in 1989-90 at the earlier growth stages (i.e. 42 and 56 DAS).

Table 5. Leaf area index (LAI) values for wheat at various stages of growth as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-91.

Treatment	1989-90			1990-91		
	Days after sowing			Days after sowing		
	42	56	70	42	56	70
Variety						
Siete Cerros	2.60	1.34	0.57	1.20	1.63	1.16
Florence Aurore	2.71	2.22	0.76	1.46	1.84	1.22
SE ±	0.05	0.07	0.05	0.05	0.04	0.04
LSD (0.05)	NS	0.22	0.14	0.15	0.13	NS
Row-spacing (cm)						
10	2.54	1.74	0.59	1.29	1.73	1.15
20	2.95	1.90	0.57	1.44	1.69	1.11
30	2.50	1.70	0.84	1.25	1.79	1.32
SE ±	0.06	0.09	0.06	0.06	0.05	0.05
LSD (0.05)	0.19	NS	0.17	NS	0.16	0.16
Nitrogen level (kg N ha^{-1})						
0	1.28	0.97	0.16	0.66	0.89	0.65
60	2.53	1.52	0.38	1.20	1.52	1.01
120	3.30	2.06	0.74	1.52	2.01	1.33
180	3.53	2.58	1.38	1.94	2.52	1.79
SE ±	0.07	0.06	0.04	0.03	0.03	0.05
LSD (0.05)	0.20	0.17	0.12	0.07	0.09	0.13
Interactions	VxR RxN VxN	VxR RxN VxN	VxR - -	VxR RxN VxN	- RxN VxN	- - VxN

Significant interactions were recorded in both years. Variety x row-spacing interaction for LAI was significant on all sampling dates in 1989-90 and at 42 DAS in 1990-91 (Table 6). Row-spacing x nitrogen level interaction was significant at 42 and 56 DAS in both years (Table 7). Variety x nitrogen level interaction was significant at 42 and 56 DAS in 1989-90 and on all sampling dates in 1990-91 (Tables 8 and 9).

At earlier stages of growth i.e. 42 and 56 DAS the 20 cm row-spacing significantly excelled the 10 and 30 cm row spacings only in the case of Florence Aurore in 1989-90, but in 1990-91 (42 DAS) the 20 cm row-spacing was better than any of the other row-spacings in Siete Cerros (Table 6).

In 1989-90, at 42 and 56 DAS, LAI increased with increasing nitrogen level up to 180 kg N ha^{-1} for the 10 and 20 cm row-spacings and up to 120 kg N ha^{-1} for 30 cm. In 1990-91, LAI changes followed a similar pattern at 56 DAS but not at 42 DAS (Table 7).

In 1989-90, Florence Aurore was significantly superior to Siete Cerros in LAI at lower levels of nitrogen at 42 DAS and higher levels at 56 DAS. In 1990-91, Florence Aurore was significantly better than Siete Cerros at 180 kg N ha^{-1} for 42 and 70 DAS, 120 kg N ha^{-1} and 180 kg N ha^{-1} for 56 DAS but not at the lower levels of nitrogen application (Tables 8 and 9).

4.1.5 Dry matter accumulation

Data on dry matter accumulation as influenced by variety, row-spacing and nitrogen level at various growth stages are presented in Tables 10 and 11. The analysis of variance tables are presented in Appendices 16 and 17.

Table 6. Interaction of variety and row-spacing on leaf area index (LAI) in wheat at Kadawa, 1989-91.

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS (1989-90)	
10	2.64	2.43
20	2.62	3.26
30	2.54	2.45
LSD (0.05)	0.27	
	56 DAS (1989-90)	
10	1.44	2.04
20	1.52	2.64
30	1.42	1.98
LSD (0.05)	0.39	
	70 DAS (1989-90)	
10	0.67	0.51
20	0.28	0.85
30	0.76	0.92
LSD (0.05)	0.24	
	42 DAS (1990-91)	
10	1.06	1.52
20	1.47	1.41
30	1.06	1.44
LSD (0.05)	0.27	

Table 7. Interaction of row-spacing and nitrogen level on leaf area index (LAI) in wheat at Kadawa, 1989-91.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	10	20	30
	42 DAS (1989-90)		
0	1.12	1.41	1.30
60	2.09	2.89	2.61
120	3.28	3.53	3.10
180	3.66	3.94	2.98
LSD (0.05)		0.36	
	56 DAS (1989-90)		
0	1.19	1.06	0.67
60	1.23	1.72	1.60
120	2.04	1.96	2.19
180	2.52	2.85	2.36
LSD (0.05)		0.36	
	42 DAS (1990-91)		
0	0.49	0.73	0.77
60	1.28	1.13	1.19
120	1.52	1.69	1.34
180	1.88	2.23	1.71
LSD (0.05)		0.19	
	56 DAS (1990-91)		
0	0.74	0.84	1.10
60	1.44	1.32	1.80
120	2.05	1.92	2.05
180	2.72	2.67	2.19
LSD (0.05)		0.19	

Table 8. Interaction of variety and nitrogen levels on leaf area index (LAI) in wheat at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS	
0	1.34	1.21
60	2.25	2.81
120	3.27	3.32
180	3.55	3.50
LSD (0.05)	0.28	
	56 DAS	
0	0.72	1.22
60	1.09	1.95
120	1.61	2.51
180	3.55	3.20
LSD (0.05)	0.17	

Table 9. Interaction of variety and nitrogen levels on leaf area index (LAI) in wheat at Kadawa, 1990-91.

Nitrogen level (kg N/ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS	
0	0.59	0.74
60	1.05	1.34
120	1.44	1.59
180	1.71	2.16
LSD (0.05)	0.17	
	56 DAS	
0	0.83	0.96
60	1.49	1.55
120	1.90	2.12
180	2.29	2.76
LSD (0.05)	0.17	
	56 DAS	
0	0.70	0.60
60	0.99	1.04
120	1.39	1.26
180	1.58	1.99
LSD (0.05)	0.19	

Table 10. Periodic dry matter accumulation ($g.m^{-2}$) as influenced by variety, row-spacing and nitrogen level at Kadawa 1989-90.

Treatment	Days after sowing				
	42	56	70	84	98
Variety					
Siete Cerros	289	449	605	632	717
Florence Aurore	286	516	704	725	900
SE ±	11.9	19.7	22.0	17.9	57.7
LSD (0.05)	NS	59.2	66.0	53.7	173.5
Row-spacing (cm)					
10	253	385	553	613	761
20	344	622	721	727	865
30	267	440	690	696	798
SE ±	14.5	24.5	27.0	21.8	70.7
LSD (0.05)	43.6	72.6	81.0	65.6	NS
Nitrogen level (kg N ha^{-1})					
0	162	267	215	293	264
60	278	439	669	599	844
120	359	572	849	838	973
180	353	651	885	985	1151
SE ±	9.0	17.4	23.2	23.2	71.0
LSD (0.05)	24.7	48.0	64.1	64.1	196.2
Interactions	-	VxR	VxR	VxR	-
	RxN	RxN	RxN	RxN	-
	VxN	VxN	VxN	VxN	-

Table 11. Periodic dry matter accumulation ($g.m^{-2}$) as influenced by variety, row-spacing and nitrogen level at Kadawa, 1990-91.

Treatment	Days after sowing			
	42	56	70	84
Variety				
Siete Cerros	136	384	498	611
Florence Aurore	121	323	498	641
SE ±	3.6	11.3	7.2	11.8
LSD (0.05)	10.8	34.1	NS	NS
Row-spacing (cm)				
10	127	392	553	665
20	158	387	541	659
30	101	282	399	555
SE ±	4.4	13.9	8.8	14.5
LSD (0.05)	13.3	41.8	26.3	43.5
Nitrogen level (kg N ha^{-1})				
0	65	131	201	266
60	119	300	375	456
120	144	429	614	771
180	186	554	801	1012
SE ±	3.7	11.3	12.0	15.4
LSD (0.05)	10.3	31.2	33.1	42.6
Interactions	VxR RxN VxN	- RxN VxN	- RxN VxN	VxR RxN VxN

In 1989-90, dry matter accumulated by Florence Aurore was significantly higher than that of Siete Cerros at all sampling growth stages beyond 42 DAS. In 1990-91, however, Siete Cerros was significantly superior to Florence Aurore in dry matter accumulation at 42 and 56 DAS. Amount of dry matter accumulated by both varieties was similar at 70 DAS, but at 84 DAS, Florence Aurore accumulated more dry matter than did Siete Cerros. Varietal differences were greater and more pronounced in 1989-90 than in 1990-91.

Effect of row-spacing on dry matter accumulation was significant at all sampling dates in both years except at 98 DAS in 1989-90. In 1989-90, the 20 cm row-spacing produced the greatest dry matter accumulation on all sampling dates followed in order by 30 and 10 cm row-spacings. In 1990-91, except at 42 DAS when the greatest dry matter accumulation was by plants in 20 cm row-spacing, the 10 and 20 cm row-spacings were similar and produced significantly more dry matter than did 30 cm at 56, 70 and 84 DAS.

Dry matter accumulated at all stages increased significantly with nitrogen levels up to 120 kg N ha^{-1} at 42, 70 and 98 DAS in 1989-90 but up to 180 kg N ha^{-1} at 56 and 84 DAS. In 1990-91, the increase in dry matter accumulation was significant up to 180 kg N ha^{-1} at all sampling dates.

Dry matter accumulation in both years increased with crop age, reaching its maximum at maturity. Dry matter production was higher in 1989-90 than in 1990-91.

Variety x row-spacing interaction was significant at 56, 70 and 84 DAS in 1989-90 (Table 12) and at 42 and 84 DAS in 1990-91 (Table 13) indicating that variety Florence Aurore was significantly superior to Siete Cerros in dry matter accumulated in 20 and 30 cm row-spacings at 56 and 84 DAS and 20 cm row-spacing at 70 DAS. But in 1990-91, variety Florence Aurore excelled Siete Cerros at 10 cm row-spacing.

Row-spacing x nitrogen level interaction was significant at all sampling stages in both years except at 98 DAS in 1989-90 (Tables 14, and 15) indicating that in 1989-90, nitrogen application caused a significant increase in dry matter accumulation up to 120 kg N ha^{-1} at 10 and 30 cm row-spacings and up to 180 kg N ha^{-1} at the 20 cm row-spacing. The 20 cm row-spacing was better than 10 and 30 cm row-spacings

Table 12. Interaction of variety and row-spacing on dry matter accumulation ($g.m^{-2}$) at Kadawa, 1989-90.

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
	56 DAS	
10	418	**351**
20	564	**681**
30	364	**516**
LSD (0.05)	103.2	
	70 DAS	
10	546	559
20	604	**838**
30	666	**713**
LSD (0.05)	115.4	
	84 DAS	
10	600	**626**
20	697	**758**
30	600	**792**
LSD (0.05)	31.5	

Table 13. Interaction of variety and row-spacing on dry matter accumulation ($g.m^{-2}$) at Kadawa, 1990-91.

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS	
10	111	144
20	186	129
30	112	89
LSD (0.05)	19.3	
	84 DAS	
10	621	709
20	641	677
30	572	538
LSD (0.05)	62.6	

at 120 kg N ha^{-1}. In 1990-91, the extent of increase in dry matter accumulation with 180 kg N ha^{-1} over 120 kg N ha^{-1} was higher at 10 and 20 cm row-spacings. The 10 and 20 cm row-spacings were superior to 30 cm row-spacing in dry matter accumulation only at 180 kg N ha^{-1} (Tables 14 and 15).

Variety x nitrogen level interaction was significant at all sampling growth stages in both years except for 98 DAS in 1989-90 (Tables 16 and 17). Variety Florence Aurore was significantly excelled Siete Cerros in dry matter accumulation at 120 and 180 kg N ha^{-1} in 1989-90 and at 120 kg N ha^{-1} in 1990-91 (Tables 16 and 17).

4.1.6 Dry matter partitioning

There were variations in dry matter partitioning between plant parts in the two wheat varieties in each of the two years. In 1989-90, Florence Aurore was significantly superior to Siete Cerros in respect of leaf dry matter at all the growth stages from 42 to 98 DAS, stem dry matter during 56 to 98 DAS and spike dry matter at 98 DAS, while the former was better than the latter with respect to spike dry matter during 56 to 84 DAS. In 1990-91, Florence Aurore was significantly excelled Siete Cerros in leaf and stem dry matter at 70 and 84 DAS. However, Siete Cerros produced significantly more stem dry matter than did Florence Aurore at 42 and 56 DAS and spike dry matter during 56 to 84 DAS (Figure 3).

Row-spacing effect on dry matter partitioning varied with years and sampling dates. In 1989-90, the 20 cm row-spacing was significantly better than 10 and 30 cm in lead dry matter at 56, 84 and 98 DAS. The differences were not significant at 70 DAS. Stem dry matter at 20 cm row-spacing was significantly better than at 30 and 10 cm row-spacings at 56 to 84 DAS. The differences between row-spacings were

Table 14. Interaction of row-spacing and nitrogen level on matter accumulation ($g.m^{-2}$) at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	10	20	30
		42 DAS	
0	126	209	**151**
60	213	379	**242**
120	**341**	375	**361**
180	**331**	411	**315**
LSD (0.05)		55.9	
		56 DAS	
0	235	383	**184**
60	354	571	**392**
120	436	697	**582**
180	513	839	**601**
LSD (0.05)		98.8	
		70 DAS	
0	191	237	**217**
60	504	715	**788**
120	733	859	**957**
180	782	1075	**799**
LSD (0.05)		122.2	
		84 DAS	
0	307	337	**235**
60	578	607	**613**
120	758	792	**963**
180	808	1174	**973**
LSD (0.05)		114.7	

Table 15. Interaction of row-spacing and nitrogen level on dry matter accumulation (g.m^{-2}) at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	10	20	30
		42 DAS	
0	57	68	69
60	118	131	109
120	148	172	112
180	187	259	112
LSD (0.05)		20.5	
		56 DAS	
0	148	145	101
60	314	353	234
120	466	461	360
180	641	591	430
LSD (0.05)		61.8	
		70 DAS	
0	212	200	191
60	409	379	336
120	702	677	463
180	889	910	604
LSD (0.05)		55.6	
		84 DAS	
0	280	285	233
60	471	476	420
120	794	810	708
180	1114	1063	858
LSD (0.05)		75.5	

Table 16. Interaction of variety and nitrogen level on dry matter accumulation ($g.m^{-2}$) at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS	
0	152	172
60	262	294
120	396	322
180	345	361
LSD (0.05)	45.4	
	56 DAS	
0	263	272
60	452	426
120	501	642
180	578	724
LSD (0.05)	80.8	
	70 DAS	
0	224	206
60	587	751
120	829	868
180	781	989
LSD (0.05)	99.2	
	84 DAS	
0	270	316
60	618	581
120	777	898
180	863	1106
LSD (0.05)	93	

Table 17. Interaction of variety and nitrogen level on dry matter accumulation ($g.m^{-2}$) at Kadawa, 1990-91.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS	
0	66	63
60	121	117
120	154	134
180	204	168
LSD (0.05)	16.2	
	56 DAS	
0	154	108
60	364	237
120	450	408
180	568	540
LSD (0.05)	49.3	
	70 DAS	
0	231	172
60	413	336
120	645	582
180	702	901
LSD (0.05)	45.5	
	84 DAS	
0	248	284
60	448	464
120	711	830
180	1038	986
LSD (0.05)	62.4	

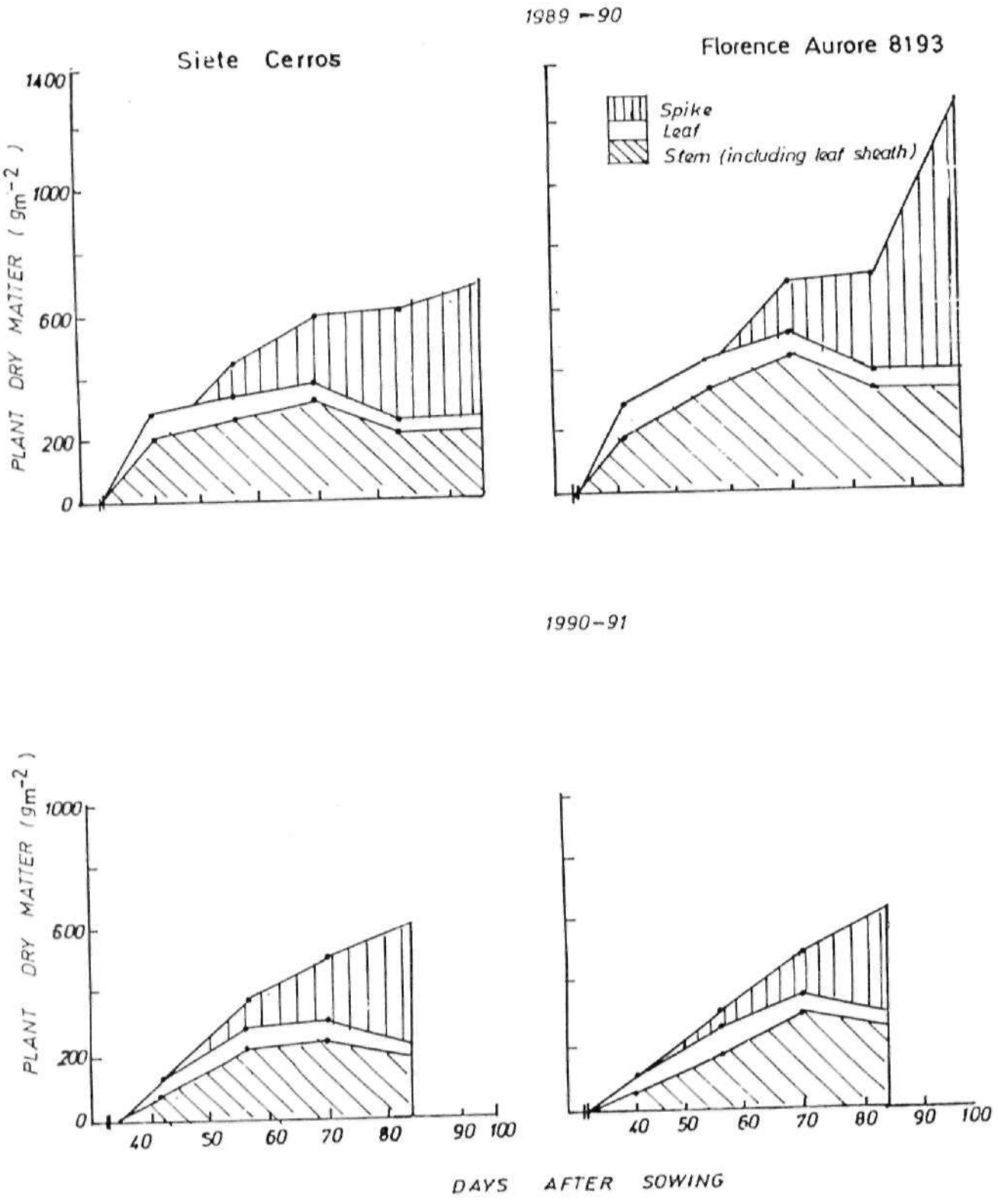


Fig. 3 : Dry matter partitioning in two wheat varieties at various stages of growth at Kadawa, 1989 -91

however not significant at 98 DAS. In 1990-91 leaf dry matter at 20 cm row-spacing was significantly superior to 10 and 30 cm row-spacings at 42 and 70 DAS and 10 cm significantly excelled the 20 and 30 cm row-spacings at 56 DAS. Stem dry matter for the 20 cm row-spacing was significantly greater than that for 10 and 30 cm at 42 DAS. The 10 cm row-spacing was significantly better than the 20 and 30 cm row-spacings at 70 DAS. Spike dry matter for the 20 cm row-spacing was significantly higher than that for 10 cm at 56, 70 and 84 DAS. The 30 cm row-spacing excelled the other two row-spacings in spike dry matter at 98 DAS (Figure 4).

Nitrogen effect on dry matter partitioning varied with years. In 1989-90, there was significant increase in leaf dry matter with nitrogen levels up to 180 kg N ha^{-1} at 42, 56, 84 and 98 DAS. At 70 DAS, there was significant increase up to 60 kg N ha^{-1}. Stem dry matter increased significantly with nitrogen levels up to 180 kg N ha^{-1} at 56, 84 and 98 DAS and up to 120 kg N ha-1 at 42 and 70 DAS. Spike dry matter increased significantly with nitrogen levels up to 180 kg N ha^{-1} at 56, 84 and 98 DAS and up to 120 kg N ha^{-1} at 70 DAS. In 1990-91, leaf, stem and spike dry matter increased significantly with increase in nitrogen levels up to 180 kg N ha^{-1} at all sampling dates (Figures 5 and 6).

In general, leaf and stem dry matter declined after their respective peaks had been reached while spike dry matter continued to increase with advancement in crop age.

In 1989-90, percentage dry matter for leaf, stem and spike at final harvest were 7, 31 and 62 per cent in Siete Cerros and 6, 35, and 59 per cent in Florence Aurore. In 1990-91, the corresponding values were 11, 50 and 39 for Siete Cerros and 12, 60 and 27 per cent for Florence Aurore.

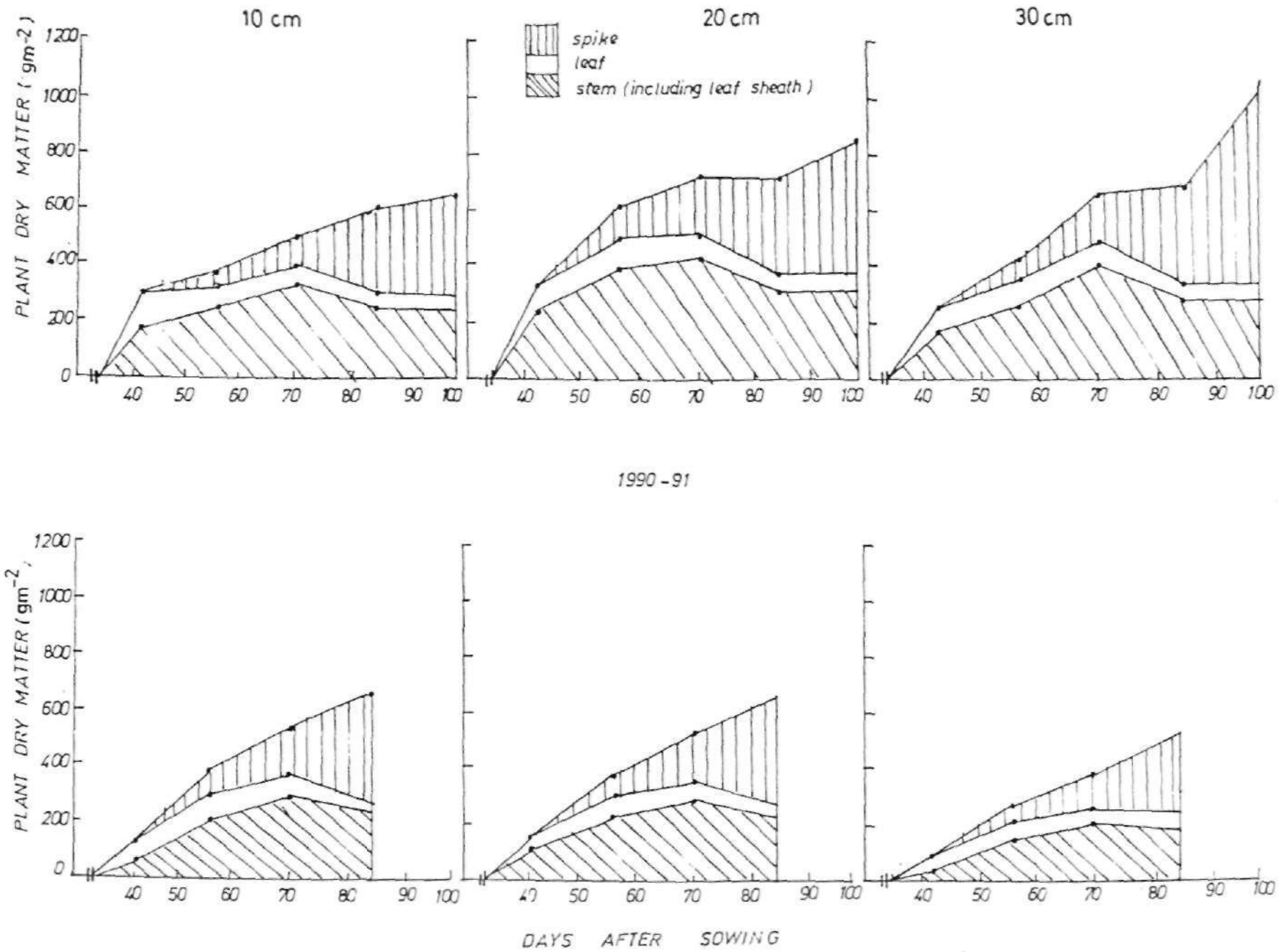


Fig. 4: Effect of row-spacing on dry matter partitioning in wheat at various stages of growth at Kadawa 1989-91

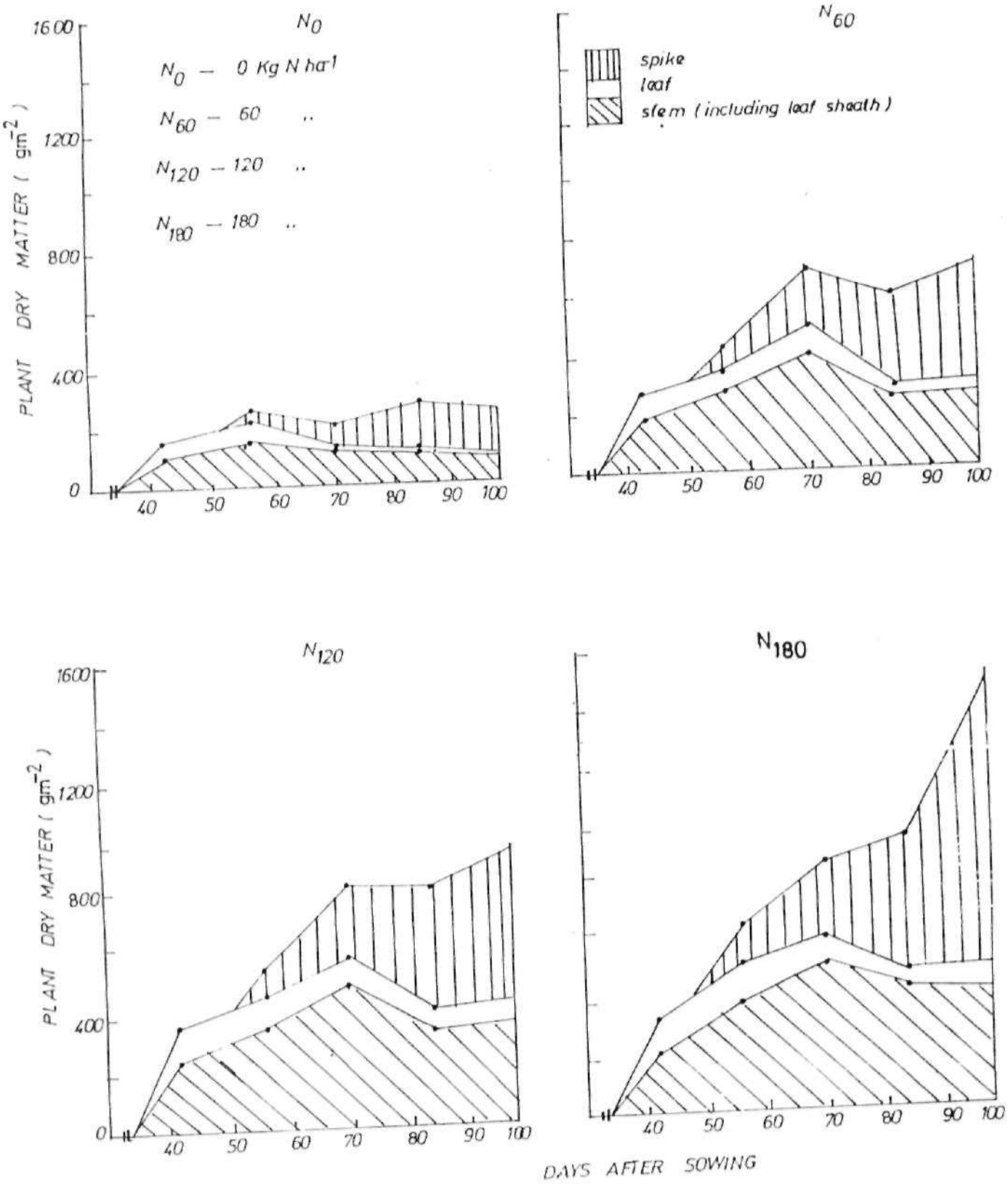


Fig.5: Effect of nitrogen level on dry matter partitioning in wheat at various stages of growth at Kadawa 1989–90.

1990 - 91

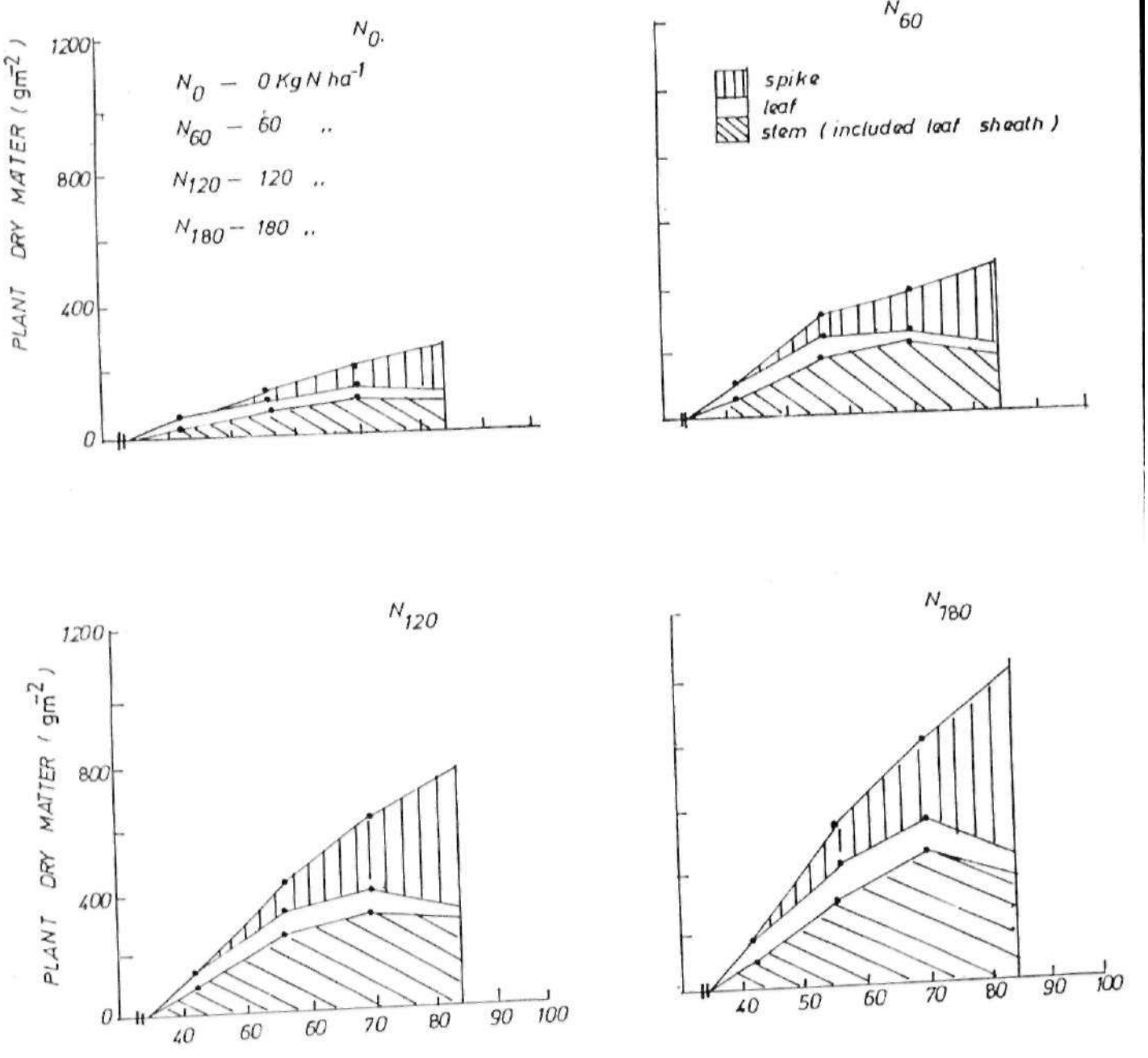


Fig. 6 : Effect of nitrogen level on dry matter partitioning in wheat at various stages of growth at Kadawa. 1990 – 91

4.2 Yield and Yield Components

4.2.1 Grain yield

Data on grain yield as influenced by variety, row-spacing and nitrogen level are presented in Table 18. The analysis of variance tables are shown in Appendices 20, 21 and 22).

Siete Cerros out-yielded Florence Aurore by 15, 22 and 17 per cent in 1989-90, 1990-91 and mean of years respectively. The differences were significant in 1990-91 and mean of years but not in 1989-90.

Row-spacing did not cause significant differences in the grain yield in either of the two years or in mean of the years. The trend, however, favoured the 30 cm row-spacing in 1989-90 and 20 cm in 1990-91. With the for the two years, the 20 and 30 cm row spacings were similar but slightly better than the 10 cm row-spacing.

Grain yield increased significantly with nitrogen levels up to 180 kg N ha^{-1} in 1989-90 and 120 kg N ha^{-1} in 1990-91. A combined analysis over years showed significant increase in grain yield up to 180 kg N ha^{-1}. Application of nitrogen at 180, 120, and 60 kg N ha^{-1} produced 223, 175 and 124 per cent higher grain yields than 0 kg N ha^{-1} in 1989 90. The corresponding increases were 214, 198, and 91 per cent in 1990-91 and 220, 182 and 114 per cent when pooled over the two years.

A combined analysis over years showed significant interaction between year and nitrogen level (Table 18). The level of response to each level of nitrogen was higher in the first year than in the year that followed.

In general, grain yield levels were higher in 1989-90 than in 1990-91.

Table 18. Grain yield of wheat as influenced by varieties, row-spacing and nitrogen level at Kadawa, 1989-91.

Treatment	Grain yields (kg N ha^{-1})		
	1989-90	1990-91	Mean
Variety			
Siete Cerros	2569	1202	1885
Florence Aurore	2233	989	1611
SE ±	133.5	55.6	72.3
LSD (0.05)	NS	167.1	217.2
Row-spacing (cm)			
10	2199	1016	1608
20	2442	1199	1821
30	2561	1071	1816
SE ±	163.5	68.1	88.5
LSD (0.05)	NS	NS	NS
Nitrogen level (kg N ha^{-1})			
0	1042	485	763
60	2335	926	1630
120	2864	1444	2154
180	3362	1527	2445
SE ±	123.7	56.8	67.9
LSD (0.05)	341.8	157.0	187.6
Interactions			YxN

4.2.2 Straw yield

Data on straw yield as influenced by variety, row-spacing and nitrogen level are presented in Table 19. The analysis of variance tables are shown in Appendices 20, 21 and 22.

Varietal differences were not significant in either of the two years or for the mean of the years. The trend was strongly in favour of Florence Aurore in 1989-90 only.

In both years and mean of the years, differences in row-spacing did not cause significant differences in straw yield. The trend was in favour of the 30 cm row-spacing in 1989-90 and mean of the two years.

Table 19. Straw yield and harvest index of wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-91.

Treatment	Straw yields (kg ha^{-1})			Harvest indices (%)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	4049	2030	3040	38.6	39.8	39.2
Florence Aurore	4590	1932	3261	34.5	37.0	35.8
SE ±	243.4	162.7	146.4	1.4	1.4	1.0
LSD (0.05)	NS	NS	NS	NS	NS	2.9
Row-spacing (cm)						
10	4238	1984	3111	33.9	36.9	35.4
20	4058	2042	3050	38.7	40.5	39.6
30	4663	1915	3289	37.2	37.8	37.5
SE ±	298.1	199.2	179.3	1.7	1.7	1.2
LSD (0.05)	NS	NS	NS	NS	NS	NS
Nitrogen level (kg N ha^{-1})						
0	1652	703	1177	39.1	41.8	40.5
60	4443	1535	2989	35.3	39.3	37.3
120	5671	2737	4204	33.9	36.5	35.2
180	5514	2948	4231	38.0	35.9	37.0
SE ±	226.4	136.2	133.2	1.5	1.5	1.1
LSD (0.05)	625.6	376.5	368.1	4.1	4.2	2.9
Interactions			YxN	RxV		

Straw yield increased significantly with nitrogen level up to 120 kg N ha^{-1} in both years and for the mean of the two years.

Year x nitrogen level interaction was significant for the pooled data (Table 19), showing a greater response to levels of nitrogen in the first than second year. Straw yield in 1989-90 was significantly higher than in 1990-91 by about twice as much.

4.2.3 Harvest index

Harvest index values for varieties, row-spacings and nitrogen levels are presented in Table 19. The analysis of variance tables are shown in Appendices 20, 21 and 22.

There were no significant varietal differences in harvest index values in either of the two wheat varieties but Siete Cerros tended to have higher harvest index values than Florence Aurore.

Harvest index values were not significantly influenced by row-spacing in either of the two years or the mean of the two years. The trends were, however, in favour of the 20 cm row-spacing in both years and mean of the two years.

The control (0 kg N ha^{-1}) gave the highest harvest index value in each of the two years and for the pooled data which was significantly higher than 120 kg N ha^{-1} in 1989-90 and 120 and 180 kg N ha^{-1} in 1990-91.

Variety x row-spacing interaction was significant in 1990-91 (Table 20), indicating that Florence Aurore had a higher harvest index at 20 cm than 10 and 30 cm row-spacings whereas there was no significant difference due to row-spacing in Siete Cerros.

4.2.4 Effective tillers

Data on number of effective tillers per square meter as influenced by variety, row-spacing and nitrogen level are presented in Table 21. The analysis of variance tables are shown in Appendices 4, 5 and 6.

Table 20. Interaction of variety and row-spacing on harvest index of wheat at Kadawa, 1989-90.

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
10	41.2	32.2
20	38.0	43.0
30	40.2	35.4
LSD (0.05)	7.1	

There were no significant differences between varieties in both years. The trend, however, was in favour of Florence Aurore.

Row-spacings caused significant differences in number of effective tillers per square meter in both years. The 20 cm row-spacing gave the highest number of effective tillers per square meter in 1989-90 and that of 10 cm in 1990-91. Both the 10 and 20 cm row-spacings produced significantly more effective tillers than the 30 cm row-spacing in both years and mean over years.

The number of effective tillers increased significantly with N levels up to 180 kgN ha^{-1} in both years. In the case of the pooled data over years, 180 kg N ha^{-1} increased the effective tiller number by 85, 39 and 16 per cent over 0, 60 and 120 kg N ha^{-1} respectively.

In general, the number of effective tillers per square meter was higher in 1989-90 than in 1990-91. None of the interaction was however significant.

4.2.5 Spike length

The data on wheat spike length in respect of varieties, row-spacings and nitrogen levels are presented in Table 22. The analysis of variance tables are shown in Appendices 23, 24 and 25.

Table 21. Effect of variety, row-spacing and nitrogen level on effective tillers in wheat at Kadawa, 1989-91.

Treatment	Number of effective tillers (m^{-2})		
	1989-90	1990-91	Mean
Variety			
Siete Cerros	347.4	265.6	306.5
Florence Aurore	358.1	270.9	314.5
SE ±	16.82	9.56	9.67
LSD (0.05)	NS	NS	NS
Row-spacing (cm)			
10	342.9	333.1	338.0
20	401.3	258.1	329.7
30	314.2	213.5	263.8
SE ±	20.60	11.71	11.84
LSD (0.05)	61.91	35.18	35.59
Nitrogen level (kg N ha^{-1})			
0	240.9	188.6	214.8
60	325.9	246.9	286.4
120	396.5	290.6	343.5
180	447.8	347.0	397.4
SE ±	15.23	9.98	8.91
LSD (0.05)	42.10	27.58	24.64

Table 22. Spike length and number of spikelets per spike of wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-91.

Treatment	Spike lengths (cm)			Spikelets per spike		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	7.6	7.4	7.5	13.8	14.5	14.1
Florence Aurore	8.2	8.7	8.5	13.7	14.4	14.0
SE ±	0.09	0.13	0.08	0.22	0.18	0.14
LSD (0.05)	0.26	0.41	0.24	NS	NS	NS
Row-spacing (cm)						
10	7.8	8.0	7.9	13.1	14.1	13.6
20	7.9	8.0	8.0	13.9	14.6	14.3
30	8.0	8.3	8.1	14.2	14.5	14.3
SE ±	0.11	0.17	0.10	0.27	0.22	0.17
LSD (0.05)	NS	NS	NS	0.81	NS	0.52
Nitrogen level (kg N ha^{-1})						
0	5.2	5.5	5.4	8.6	10.8	9.7
60	7.7	7.3	7.5	13.8	13.5	15.7
120	9.1	9.6	9.3	16.1	16.3	16.2
180	9.5	9.9	9.7	16.4	17.1	16.7
SE ±	0.11	0.14	0.09	0.29	0.30	0.20
LSD (0.05)	0.31	0.38	0.24	0.79	0.84	0.60
Interactions	RxN		YxN			
	VxN		YxV			

The average spike of Florence Aurore was significantly longer than that of Siete Cerros in both years and mean of the two years. The margin of difference was however, greater in 1990-91 (18%) than in 1989-90 (8%).

Row-spacing did not have significant effect on spike length in both years and mean of the two years.

Application of nitrogen significantly increased spike length with the trend being strongly in favour of 180 kg N ha^{-1} in 1989-90 and 120 kg N ha^{-1} in 1990-91. Mean values over years also increased significantly up to 180 kg N ha^{-1}. The increase in spike length with 180 over 120 kg N ha^{-1} was smaller than with 60 over 0 or 120 over 60 kg N ha^{-1}.

In 1989-90, *row-spacing x nitrogen level* and *variety x nitrogen level* interactions were significant (Tables 23 and 24). A combined analysis over the years showed significant interactions between year and variety as well as between year and nitrogen level (Table 22).

In 1989-90, spike length at row-spacings of 10 and 20 cm increased significantly up to 120 kg N ha^{-1} and up to 180 kg N ha^{-1} at 30 cm. Spike length for the 20 or 30 cm row-spacing was significantly greater than that for the 10 cm at 180 kg N ha^{-1} respectively. Florence Aurore was significantly superior to Siete Cerros at all the levels of N except 60 kg N ha^{-1} (Table 24).

4.2.6 Spikelets per spike

Number of spikelets per spike as influenced by variety, row-spacing and nitrogen level are presented in Table 22. The corresponding analysis of variance tables are shown in Appendices 23, 24 and 25.

Varieties did not differ significantly in number of spikelets per spike in both years and data pooled over years.

Table 23. Interaction of row-spacing and nitrogen level on spike length (cm) at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	10	20	30
0	5.2	5.1	5.2
60	8.0	7.4	7.8
120	9.0	9.3	9.1
180	9.1	9.8	9.7
LSD (0.05)		0.55	

Table 24. Interaction of variety and nitrogen level on spike length (cm) at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
0	4.7	5.6
60	7.7	7.8
120	8.8	9.5
180	9.1	10.0
LSD (0.05)	0.44	

Effect of row-spacing varied with years. In 1989-90, the 20 and 30 cm row-spacings produced significantly more spikelets per spike than did the 10 cm row-spacing. In 1990-91, although the differences were not significant, the trend was in favour of the 20 cm over 30 cm. An analysis of data pooled over years showed that row-spacings of 20 and 30 cm produced the same number of spikelets per spike that were significantly higher than that of the 10 cm row-spacing.

The number of spikelets per spike increased significantly with nitrogen levels up to 120 kg N ha^{-1} in both years and the mean of the two years.

4.2.7 Grains per spike

Data on the effects of varieties, row-spacings and nitrogen levels on number of grains per spike are presented in Table 25. The corresponding analysis of variance tables are shown in Appendices 23, 24 and 25.

Siete Cerros had a significantly higher number of grains per spike than Florence Aurore in each of the two years and the mean of the years. The observed increases were in the range of 28, 21 and 24 per cent in 1989-90, 1990-91 and mean over years respectively.

Effect of row-spacing was significant in 1989-90 and for the mean data pooled for the years. In 1989-90, the 20 and 30 cm row-spacings resulted in similar number of grains per spike that was significantly more than the 10 cm row-spacing. Though row-spacing had no significant effect in 1990-91, the trend was in favour of the 30 cm row-spacing. The combined analysis also showed that the 30 and 20 cm row-spacing were at par but only the 30 cm row-spacing was significantly higher than 10 cm row-spacing.

Table 25. Grains per spike and 1000-grain weight of wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-91.

Treatment	Grains per spike			1000-grain weight (g)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	39.3	42.0	40.7	32.4	32.6	32.5
Florence Aurore	30.8	34.8	32.8	36.9	37.3	37.1
SE ±	0.93	1.03	0.70	0.40	0.40	0.28
LSD (0.05)	2.80	3.11	2.09	1.20	1.21	0.85
Row-spacing (cm)						
10	31.8	37.2	34.5	33.5	35.1	34.3
20	35.6	38.1	36.8	34.6	35.3	35.0
30	37.3	40.0	38.9	35.8	34.5	35.2
SE ±	1.16	1.27	0.85	0.49	0.49	0.35
LSD (0.05)	3.44	NS	2.56	1.46	NS	NS
Nitrogen level (kg *N* ha^{-1})						
0	15.7	18.1	16.9	31.7	33.8	32.8
60	32.6	31.2	31.9	34.7	34.7	34.6
120	45.7	51.0	48.4	36.1	36.2	36.1
180	46.1	53.4	49.8	36.1	35.2	35.6
SE ±	1.21	1.21	0.89	0.48	0.55	0.36
LSD (0.05)	3.36	3.35	2.50	1.32	1.53	0.98
Interactions	RxN VxN	VxN	NxR YxN VxN			

Nitrogen levels significantly increased the number of grains per spike up to 120 kg N ha^{-1} in both years and the mean for the two years. Nitrogen at 120 kg N ha^{-1} increased the grain number by 52 and 89 per cent over 60 and 0 kg N ha^{-1} respectively.

Row-spacing x nitrogen level interaction was significant in 1989-90 and for mean of the years (Table 26) and variety x nitrogen level interactions in both years and for mean of the years (Table 27). Year x nitrogen level interaction was also found to be significant (Table 25). Response to nitrogen at 120 kg N ha^{-1} over 60 kg N ha^{-1} was higher at the wider row-spacings of 20 and 30 cm than at 10 cm. Differences between narrow (10 cm) and wider (20 and 30 cm) row-spacings were greater at higher levels (120 and 180 kg N ha^{-1}) of nitrogen. Differences between varieties in the number of grains per spike were not significant at 0 kg N ha^{-1} but were significant at the other N levels.

4.2.8 Thousand-grain weight

The effects of variety, row-spacing and nitrogen level on 1000-grain weight in wheat are presented in Table 25. The corresponding analysis of variance tables are shown in Appendices 23, 24 and 25.

Florence Aurore had significantly higher 1000-grain weight than did Siete Cerros in both years and for mean of the years. The margin was 14 per cent in both years and mean of years.

Effect of row-spacing was significant only in 1989-90 when the 30 cm row-spacing produced grains, with significantly heavier grains than the 10 cm row-spacing. In 1990-91, and with respect to mean of the two years, differences due to row-spacing were not significant.

Table 26. Interaction of row-spacing and nitrogen level on number of grains per spike in wheat at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	19	20	30
		1989-90	
0	14.8	14.6	17.8
60	33.0	29.4	35.4
120	41.0	48.0	48.1
180	38.3	50.4	49.6
LSD (0.05)		5.94	
		Combined analysis (pooled data)	
0	15.8	16.4	18.5
60	32.1	28.9	34.8
120	45.3	49.8	80.0
180	44.9	52.2	52.2
LSD (0.05)		3.34	

Table 27. Interaction of variety and nitrogen level on number of grains per spike in wheat at Kadawa, 1989-91.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	*Florence Aurore*
	1989-90	
0	16.1	15.3
60	37.9	27.3
120	52.5	38.9
180	50.7	41.5
LSD (0.05)	1.76	
	1990-91	
0	17.0	19.2
60	35.8	28.7
120	55.7	46.3
180	61.8	45.1
LSD (0.05)	5.0	
	Combined analysis (pooled data)	
0	16.5	17.3
60	35.8	28.0
120	54.1	42.6
180	56.2	43.3
LSD (0.05)	3.34	

In both years and the mean values over years, the 1000-grain weight increased significantly with increase in nitrogen levels up to 120 kg N ha^{-1}. A combined analysis over years showed that year x row-spacing interaction was significant (Table 25).

4.3 Nitrogen Uptake

4.3.1 Total nitrogen uptake

Data on nitrogen uptake by wheat at various stages of growth as influenced by variety, row-spacing and nitrogen level are presented in Tables 28 and 29. The corresponding analysis of variance tables are shown in Appendices 26 and 27.

There were no significant differences between Siete Cerros and Florence Aurore at any of the stages in both years. The trend, however, favoured Florence Aurore at all stages in 1989-90 and at 70 and 84 DAS in 1990-91.

Row-spacing effect on nitrogen uptake was significant at all stages in both years except at 70 DAS in 1989-90. In 1989-90, nitrogen uptake under row-spacings of 20 and 30 cm was significantly higher than that under the 10 cm row-spacing at 42 and 56 DAS and under 30 cm at 70, 84 and 98 DAS. In 1990-91, nitrogen uptake under the 10 and 20 cm row-spacings was higher than that under 30 cm at all stages.

Nitrogen uptake increased significantly with nitrogen levels up to 180 kg N ha^{-1} in both years at all the sampling dates. In 1989-90, nitrogen at 180 kg N ha^{-1} increased N uptake by 482, 94 and 24 per cent over 0, 60 and 120 kg N ha^{-1} respectively at 98 DAS. The corresponding increases in 1990-91 were 376, 159, and 44 per cent respectively.

Nitrogen uptake in 1989-90 increased with crop age up to 70 DAS but decreased thereafter at 84 DAS. No further decline was observed at 98 DAS. In 1990-91, however, nitrogen uptake increased with crop age up to 84 DAS.

Table 28. Uptake of nitrogen (kg N ha^{-1}) by wheat at various stages of growth as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-90.

Treatment	Days after sowing				
	42	56	70	84	98
Variety					
Siete Cerros	35.1	42.7	51.1	41.2	40.7
Florence Aurore	37.1	47.0	52.2	45.0	44.9
SE±	6.6	3.4	3.1	1.8	1.6
LSD (0.05)	NS	NS	NS	NS	NS
Row-spacing (cm)					
10	33.6	37.1	46.9	37.3	39.3
20	43.0	56.3	53.3	43.9	42.8
30	31.7	41.2	54.7	48.1	46.3
SE ±	2.7	4.1	3.8	2.2	1.9
LSD (0.05)	8.0	12.4	NS	6.5	5.7
Nitrogen level (kg N ha^{-1})					
0	12.5	19.6	12.4	14.5	12.0
60	27.7	35.7	43.6	34.3	35.3
120	43.9	54.0	65.6	52.7	55.3
180	60.4	70.1	84.9	71.0	68.6
SE ±	3.0	2.6	2.9	1.8	2.3
LSD (0.05)	8.2	7.3	8.1	5.0	6.5
Interactions		VxN		VxN RxN	VxR

Table 29. Uptake of nitrogen (kg N ha^{-1}) by wheat at various stages of growth as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-90.

Treatment	Days after sowing			
	42	56	70	84
Variety				
Siete Cerros	20.2	44.0	47.8	57.8
Florence Aurore	18.1	43.4	49.1	60.5
SE±	1.6	2.5	1.3	1.3
LSD (0.05)	NS	NS	NS	NS
Row-spacing (cm)				
10	18.8	49.0	53.1	60.5
20	23.7	45.4	53.1	64.9
30	15.0	36.7	39.2	52.1
SE ±	2.0	3.0	1.7	1.5
LSD (0.05)	6.0	9.1	5.6	4.6
Nitrogen level (kg N ha^{-1})				
0	6.9	11.9	16.8	21.7
60	14.0	32.0	33.1	39.8
120	22.2	49.9	59.0	71.9
180	34.5	80.9	85.0	103.2
SE ±	1.1	2.1	1.5	2.4
LSD (0.05)	2.9	5.9	4.3	6.6
Interactions			VxN RxN	

Variety x nitrogen level interactions was significant at 56 and 84 DAS in 1989-90 and at 70 DAS in 1990-91 (Table 30). In 1989-90 at 56 and 84 DAS, differences between Siete Cerros and Florence Aurore in nitrogen uptake was significant at 180 kg N ha^{-1}. In 1990-91, at 70 DAS, differences between the two varieties in nitrogen uptake were significant at 60, 120 and 180 kg N ha^{-1}.

Table 30. Interaction of variety and nitrogen level on nitrogen uptake (kg N ha^{-1}) by wheat at Kadawa, 1989-91.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	*Florence Aurore*
	56 DAS (1989-90)	
0	20.1	19.2
60	37.9	33.5
120	49.5	58.5
180	63.3	76.9
LSD (0.05)	13.0	
	84 DAS (1989-90)	
0	13.7	15.3
60	38.0	30.7
120	54.0	51.5
180	59.2	82.7
LSD (0.05)	8.0	
	70 DAS (1990-91)	
0	19.2	14.3
60	36.5	29.6
120	62.4	55.6
180	73.0	97.1
LSD (0.05)	6.4	

Row-spacing x nitrogen level interaction was also significant at 84 DAS in 1989-90 and at 70 DAS in 1990-91 (Table 31). In 1989-90, at 84 DAS, the difference between row-spacings in N uptake was significant at 180 kg N ha^{-1} while at 70 DAS in 1990-91, the difference was significant at 120 kg N ha^{-1}.

Variety x row-spacing interaction was significant at 98 DAS in 1989-90 indicating that N uptake by Siete Cerros was highest at 10 cm row-spacing though not significantly higher than at 30 cm row-spacing while in Florence Aurore, N uptake at 20 and 30 cm row-spacing were at par but significantly greater than at 10 cm row-spacing (Table 32).

The total uptake at harvest averaged 42.8 and 59.1 kg N ha^{-1} in 1989-90 and 1990-91 respectively. During the first 42 days crop uptake was 84% in first year and 32% in second year. Thus, rate of uptake was maximum during 42-56 DAS period in the 1990-91 season.

Table 31. Interaction of row-spacing and nitrogen level on nitrogen uptake (kg N ha^{-1}) by wheat at Kadawa, 1989-91.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	19	20	30
	84 DAS (1989-90)		
0	13.7	18.4	11.4
60	34.4	33.2	35.3
120	47.3	47.3	63.6
180	54.0	76.8	82.1
LSD (0.05)		9.7	
	70 DAS (1990-91)		
0	18.3	16.6	15.5
60	36.4	32.9	29.9
120	67.5	65.4	44.1
180	90.5	97.5	68.1
LSD (0.05)		7.7	

Table 32. Interaction of variety and row-spacing on nitrogen uptake (kg N ha^{-1}) at 98 DAS by wheat at Kadawa, 1989-90.

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
10	45.4	33.3
20	35.6	50.0
30	41.2	51.4
LSD (0.05)	8.1	

DAS = days after sowing.

4.3.2 Nitrogen distribution in plant parts

There were variations in nitrogen distribution in plant parts of both varieties in both years. In 1989-90, Florence Aurore was appreciably superior to Siete Cerros in leaf nitrogen at 56 and 84 DAS; stem nitrogen at 56, 84 and 98 DAS and spike nitrogen at 56 and 70 DAS. In 1990-91, Florence Aurore excelled Siete Cerros in leaf nitrogen at 70 and 84 DAS; stem nitrogen at 42, 70 and 84 DAS and spike nitrogen at 56 and 70 DAS. In general, nitrogen was higher in component parts of Florence Aurore than in those of Siete Cerros (Figure 7).

Effect of row-spacing on nitrogen in plant component parts varied with years. In 1989-90, leaf nitrogen for the 20 cm row-spacing was significantly higher than that for 10 or 30 cm at 56, 84 and 98 DAS and that for 30 cm significantly higher than for the 20 or 10 cm row-spacings at 70 DAS. Stem nitrogen for the 20 cm row-spacing was significantly higher than that for 30 or 10 cm at 42, 56 and 98 DAS; while that for 30 cm was significantly higher than 20 or 10 cm row-spacings at 84 DAS. Spike

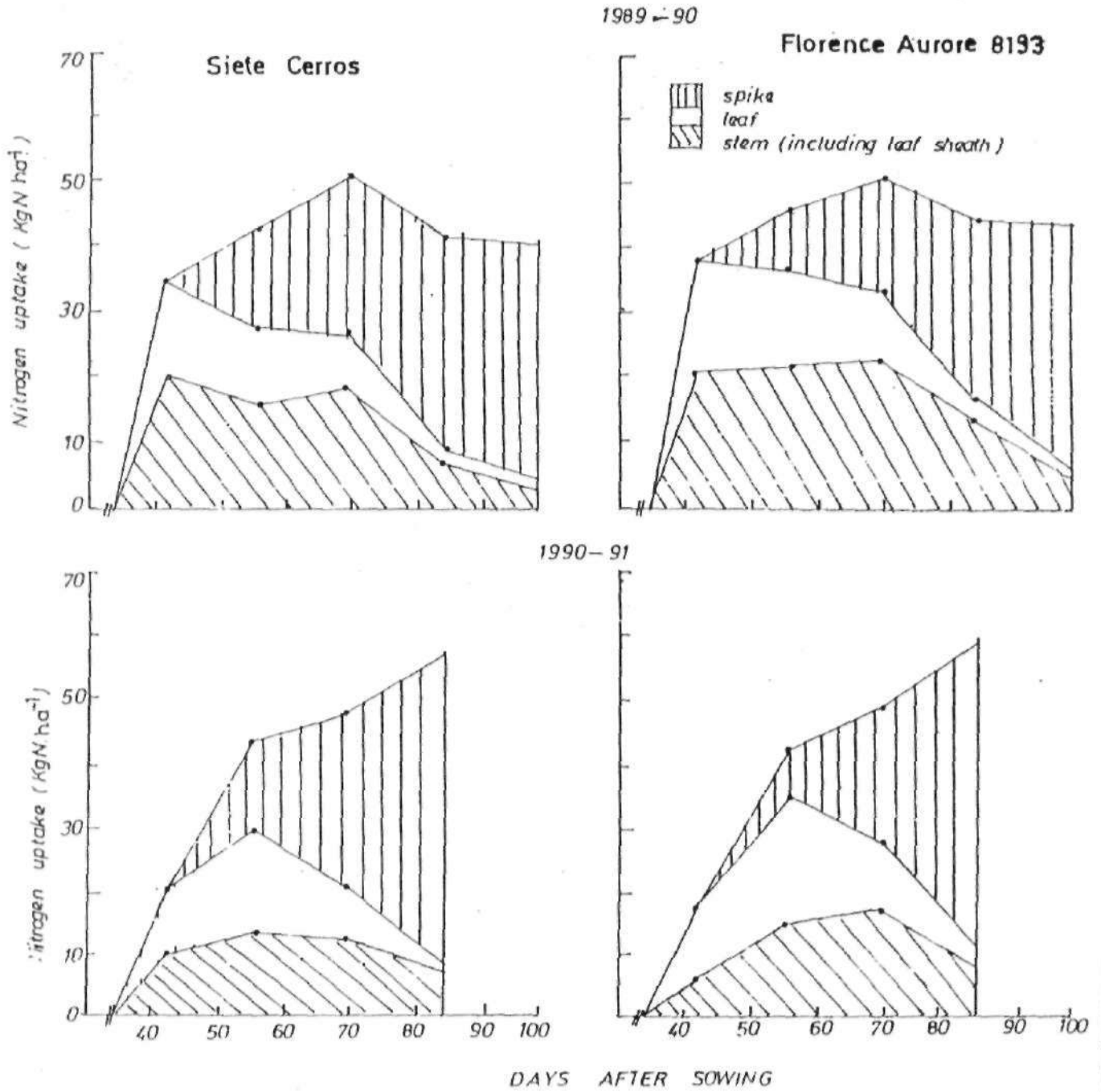


Fig. 7.: Nitrogen distribution in two wheat varieties at various stages of growth at Kadawa 1989 – 91

nitrogen for the 20 cm row-spacing was significantly higher than 30 or 10 cm at 56 and 70 DAS. In 1990-91, leaf nitrogen for the 20 cm row-spacing significantly excelled than that for 10 or 30 cm at 42 and 70 DAS. That for 20 cm was similar to that for 30 cm but significantly higher than that for 10 cm at 84 DAS. Stem nitrogen for the 20 cm row-spacing was significantly higher than that for 30 or 10 cm at 56 DAS; while that for 10 cm was significantly higher than that for 30 cm at 70 DAS. Spike nitrogen was significantly higher for the 20 cm than for 10 or 30 cm row-spacing at 56 and 84 DAS; however that for 10 and 20 cm significantly excelled than that for the 30 cm row-spacing at 70 DAS (Figure 8).

There was significant increase in nitrogen content in all plant parts with increase in nitrogen level up to 180 kg N ha^{-1} in both years (Figures 9 and 10).

In 1989-90, nitrogen content in leaf decreased after 42 DAS and after 70 DAS in stem but continued to increase in the spike with advancement in plant age from 56 DAS. In 1990-91, nitrogen content in leaf decreased after 56 DAS and after 70 DAS in stem but continued to increase in the spike with advancement in plant age from 56 DAS.

4.4 Nutrient Uptake

Data on uptake of different nutrients at harvest as influenced by variety, row-spacing and nitrogen level are presented in Tables 33 and 34. The corresponding analysis of variance tables are shown in Appendices 30 and 31.

4.4.1 Nitrogen

Varietal differences in nitrogen uptake were not significant in both years but the trend was in favour of Florence Aurore. Effect of row-spacing on nitrogen uptake was

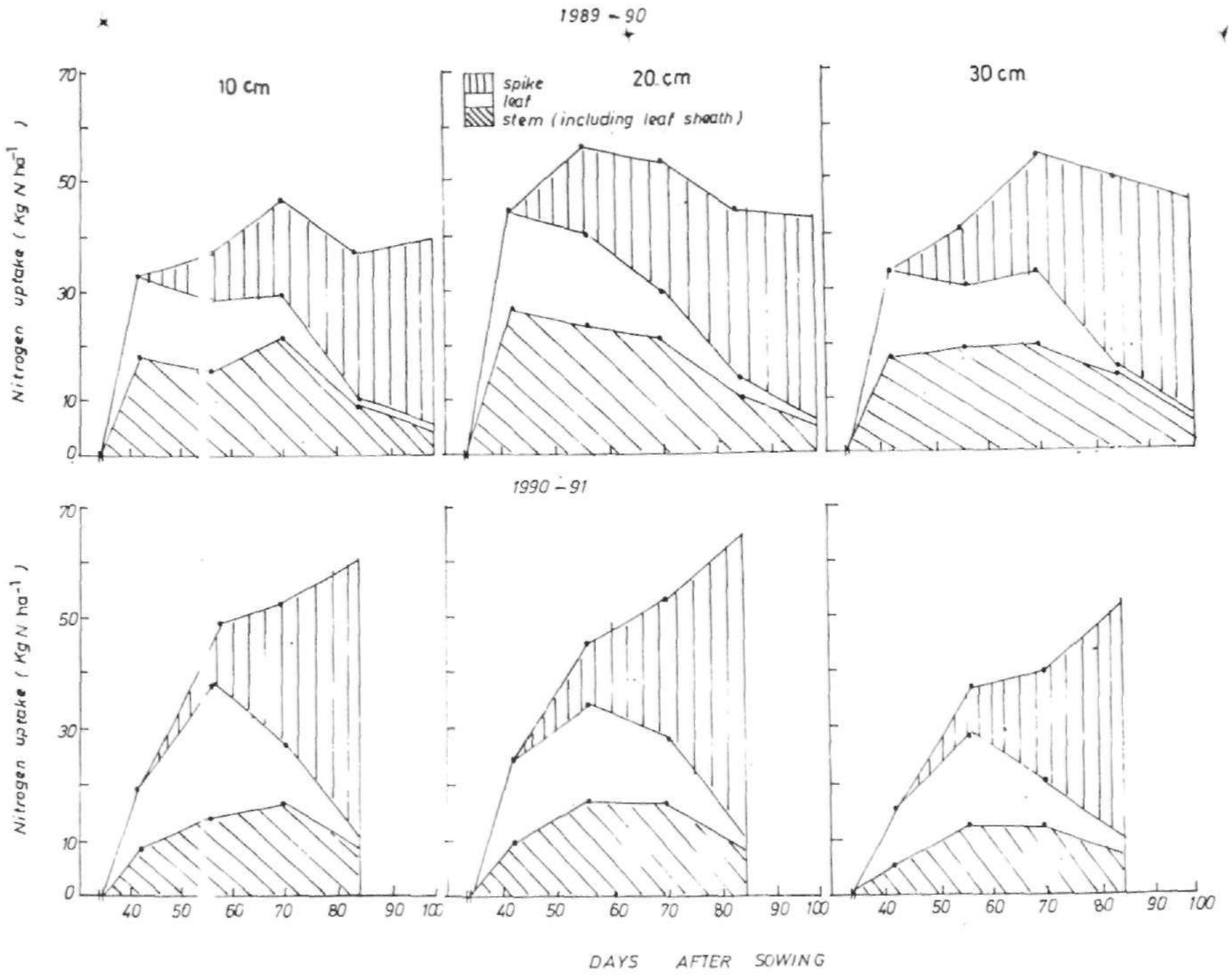


Fig. 8: Effect of row – spacing on nitrogen distribution within wheat plant at various stages of growth at K. dawa *1989 – 91*

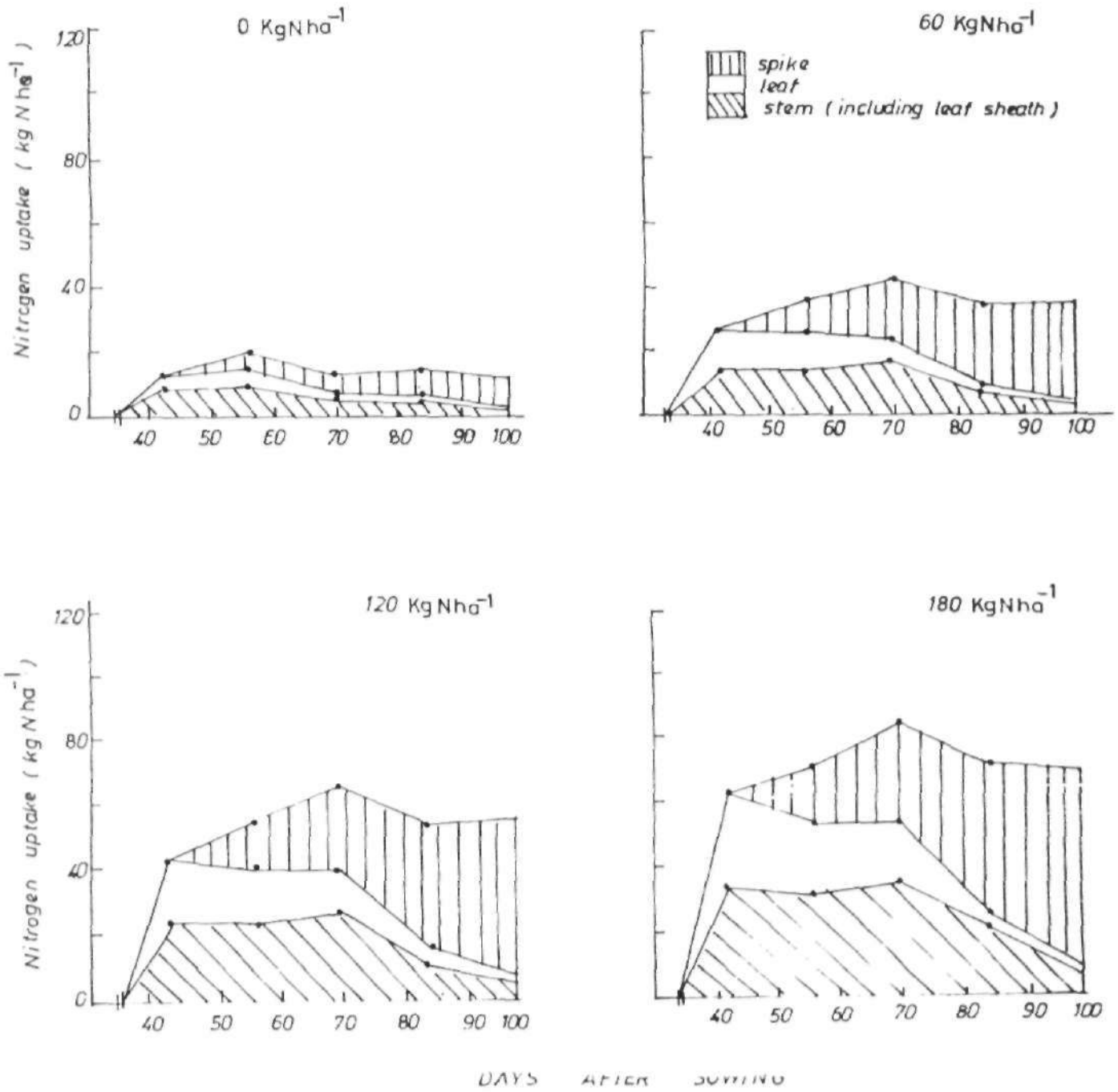


Fig. 9 : Effect of nitrogen level on nitrogen distribution within wheat plant at various stages of growth at Kadawa 1989-90

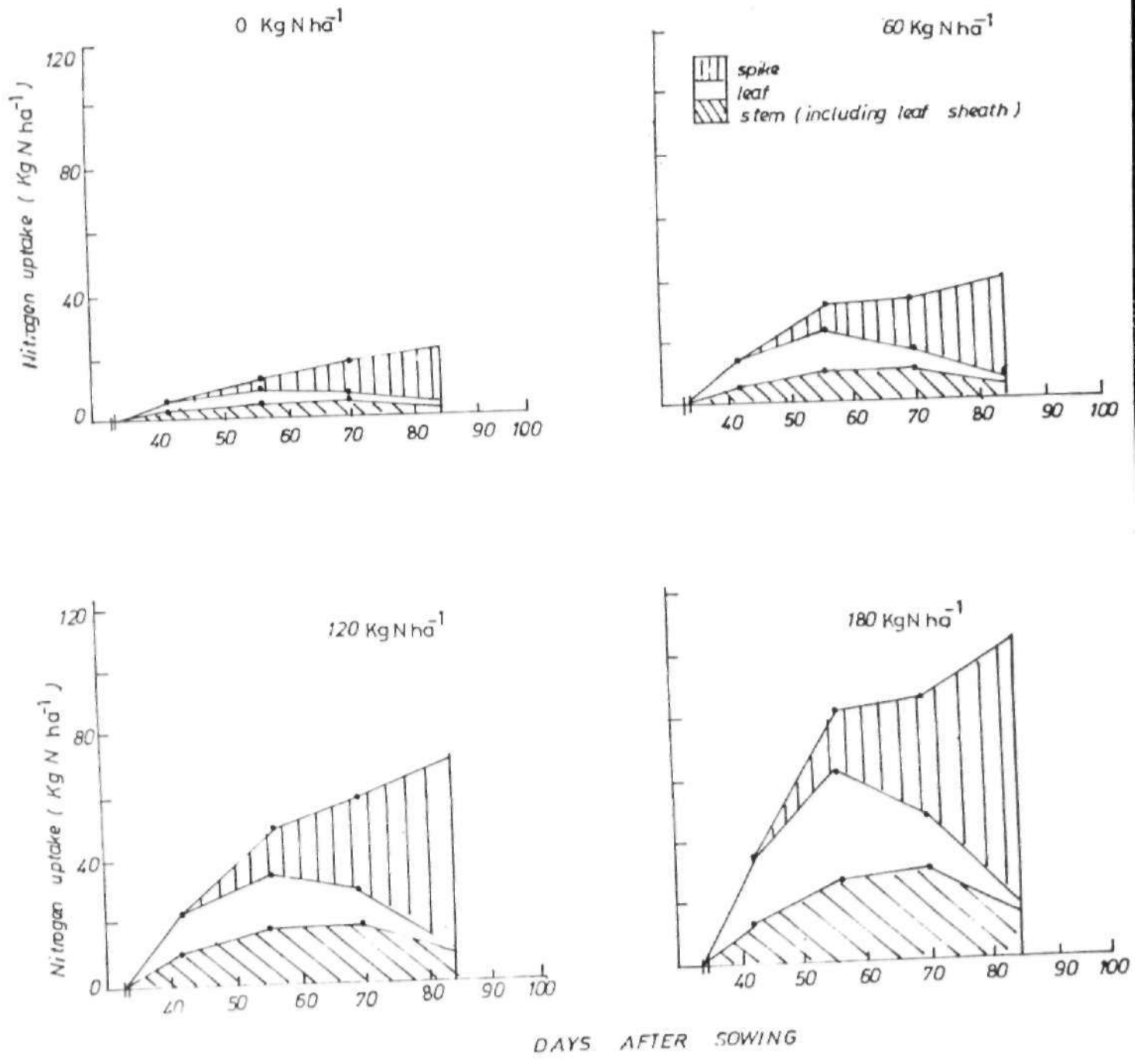


Fig. 10 : Effect of nitrogen level on nitrogen distribution within wheat plant at various stages of growth at Kadawa 1990 – 91

Table 33. Uptake of N,P, and K (kg ha^{-1}) by wheat at harvest as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-91.

Treatment	Nitrogen		Phosphorus		Potassium	
	'89-90	'90-91	'89-90	'90-91	'89-90	'90-91
Variety						
Siete Cerros	40.7	57.8	1.8	9.4	47.4	36.3
Florence Aurore	44.9	60.5	3.3	11.7	58.3	43.9
SE ±	1.6	1.3	0.05	0.6	2.9	0.7
LSD (0.05)	NS	NS	0.20	1.9	8.8	2.2
Row-spacing (cm)						
10	39.3	60.5	2.1	10.2	44.8	42.2
20	42.8	64.9	2.9	9.7	58.8	42.5
30	46.3	52.1	2.6	11.7	54.9	35.7
SE ±	1.9	1.5	0.07	0.8	3.6	0.7
LSD (0.05)	5.7	4.6	0.20	NS	10.7	2.7
Nitrogen level (kg N ha^{-1})						
0	12.1	21.7	1.0	4.8	20.5	16.4
60	35.3	39.8	2.0	8.6	49.2	29.8
120	55.3	71.9	3.5	12.2	66.2	49.0
180	68.6	103.2	3.5	16.7	75.2	65.3
SE ±	2.3	2.4	0.10	0.9	2.9	1.7
LSD (0.05)	6.5	6.6	0.40	2.5	8.8	4.8
Interactions	VxR		VxR RxN VxN		RxN VxN	RxN VxN

Table 34. Uptake of Ca and Mg (kg ha^{-1}) at harvest as influenced by variety row-spacing, and nitrogen level at Kadawa, 1989-91.

Treatment	Calcium (Ca)		Magnesium (Mg)	
	'89-90	'90-91	'89-90	,90-91
Variety				
Siete Cerros	10.8	4.2	6.6	5.4
Florence Aurore	9.3	5.4	7.6	5.9
SE ±	1.1	0.2	0.2	0.1
LSD (0.05)	NS	0.5	0.7	0.4
Row-spacing (cm)				
10	8.0	4.9	6.0	5.9
20	10.0	5.1	7.7	5.8
30	12.1	4.4	7.6	5.2
SE ±	1.3	0.2	0.3	0.2
LSD (0.05)	NS	NS	0.9	0.5
Nitrogen level (kg N ha^{-1})				
0	3.5	2.1	2.8	2.5
60	9.3	3.4	6.3	4.2
120	13.0	6.4	9.0	7.0
180	14.4	7.4	10.3	8.8
SE ±	1.2	0.3	0.4	0.2
LSD (0.04)	3.4	0.7	1.2	0.6
Interactions			VxR	

significant in both years. In 1989-90, the 30 and 20 cm row-spacings resulted in similar but significantly higher in N uptake than for the 10 cm row-spacings. In 1990-91, the 20 cm row-spacing resulted in greater N uptake than that for 10 and 30 cm row-spacings by 4.4 and 12.8 kg N ha^{-1} respectively. Nitrogen level significantly increased N uptake by wheat plants up to 180 kg N ha^{-1} by 472, 94 and 24 per cent in 1989-90 and 376, 159 and 44 per cent in 1990-91. Nitrogen uptake was generally greater in 1990-91. Nitrogen uptake was generally higher in 1990-91 than in 1989-90. Variety x row-spacing interaction for N uptake was significant in 1989-90 (Table 28).

4.4.2 Phosphorus

Florence Aurore had significantly higher phosphorus uptake than Siete Cerros in both years. There was significant effect of row-spacing on phosphorus uptake in 1989-90. The 20 cm row-spacing resulted in significantly greater uptake than 30 and 10 cm row-spacings. Phosphorus uptake increased significantly with increase in nitrogen up to 120 kg N ha^{-1} in 1989-90 and 180 kg N ha^{-1} in 1990-91. Phosphorus uptake was higher in 1990-91 than 1989-90 though values were generally very low.

In 1989-90 variety x row-spacing, variety x nitrogen level and row-spacing x nitrogen level interactions were significant (Tables 35, 36 and 37). There were no significant interactions in 1990-91.

Phosphorus uptake by Siete Cerros did not change with row-spacing, whereas the 20 cm row-spacing significantly increased P uptake in Florence Aurore (Table 35).

Superiority of Florence Aurore in P uptake was greater than that of Siete Cerros at 120 and 180 kg N ha^{-1} than at 0 and 60 kg N ha^{-1} (Table 36).

Table 35. Interaction of variety and row-spacing on phosphorus uptake (kg P ha^{-1}) at harvest by wheat at Kadawa, 1989-90.

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
10	1.8	2.3
20	1.6	4.3
30	1.9	3.3
LSD (0.05)	0.30	

Table 36. Interaction of variety and nitrogen level on phosphorus uptake (kg P ha^{-1}) by wheat at harvest at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
0	0.7	1.4
60	1.4	2.7
120	2.4	4.7
180	2.6	4.4
LSD (0.05)	0.60	

Table 37. Effect of row-spacing x nitrogen level interaction on phosphorus uptake (kg P ha^{-1}) by wheat at harvest at Kadawa, 1989-90.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	10	20	30
0	0.7	1.1	1.3
60	1.9	2.0	2.1
120	2.6	5.0	3.0
180	3.0	3.6	3.9
LSD (0.05)		0.80	

Superiority of 20 cm row-spacing with respect to P uptake was significant over 10 and 30 cm at 120 kg N ha^{-1} in 1989-90 (Table 37).

4.4.3 Potassium

Potassium uptake by Florence Aurore was significantly greater than that by Siete Cerros in both years with margins of 23 and 21 per cent in 1989-90 and 1990-91 respectively. The 20 and 30 cm row-spacings resulted in significantly greater potassium uptake than the 10 cm row-spacing in 1989-90, with margins of 14.0 and 10.1 kg K ha^{-1} respectively. In 1990-91, row-spacings of 10 and 20 cm were at par and had significantly greater K uptake than 30 cm with an increase of 7.0 kg K ha^{-1}. Potassium uptake increased significantly with increase in nitrogen levels up to 180 kg N ha in both years. Variety x nitrogen levels and row-spacing x nitrogen level interactions were significant in both years (Tables 38 and 39). The K uptake levels by the wheat crop averaged 52.9 and 40.1 kg ha^{-1} in first and second years respectively.

Florence Aurore was significantly better than Siete Cerros only at 120 and 180 kg N ha^{-1} in both years (Table 38).

Table 38. Interaction of variety and nitrogen level on potassium uptake (kg K ha^{-1}) by wheat at Kadawa, 1989-91.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
	1989-90	
0	17.2	23.7
60	51.6	46.8
120	53.7	78.6
180	67.0	84.1
LSD (0.05)	14.0	
	1990-91	
0	14.3	18.5
60	27.7	32.0
120	42.5	55.5
180	60.8	69.8
LSD (0.05)	6.0	

In 1989-90, a row-spacing of 20 cm was significantly better than the 10 and 30 cm row-spacings at 120 kg N ha^{-1} and 20 and 30 cm row-spacings better than 10 cm row-spacing at 180 kg N ha^{-1} (Table 39). In 1990-91, the differences between row-spacings were significant at 120 and 180 kg N ha^{-1}. At 120 kg N ha^{-1} however, 20 cm row-spacing was significantly better than 30 cm row-spacing but at 180 kg N ha^{-1}, 10 cm was significantly better than 20 cm, which was superior to the 30 cm row-spacing (Table 39).

Table 39. Interaction of row-spacing and nitrogen level on potassium uptake (kg K ha^{-1}) by wheat at harvest at Kadawa, 1990-91.

Nitrogen level (kg N ha^{-1})	Row-spacings (cm)		
	10	20	30
		1989-90	
0	19.2	20.1	22.1
60	46.9	49.1	51.7
120	49.0	85.3	64.2
180	63.9	80.9	81.7
LSD (0.05)		17.0	
		1990-91	
0	14.9	18.6	15.7
60	30.1	31.5	28.0
120	48.4	54.1	44.4
180	75.2	65.9	54.8
LSD (0.05)		7.7	

4.4.4 Calcium

Calcium uptake by Siete Cerros was greater than that by Florence Aurore in 1989-90 but lower than that by Florence Aurore in 1990-91. The difference in uptake was significant in 1990-91. Row-spacing had no significant effect on calcium uptake in either of the two years but results favoured 30 and 20 cm row-spacings in 1989-90 and 1990-91 respectively. Nitrogen levels significantly enhanced calcium uptake up to 120 kg N ha^{-1} in 1989-90 and 180 kg N ha^{-1} in 1990-91. Calcium uptake in 1989-90 (10.0 kg ha^{-1}) was higher than that in 1990-91 (4.8 kg ha^{-1}). No interaction was significant in both years.

4.4.5 Magnesium

Magnesium uptake by Florence Aurore plants was significantly greater than that by Siete Cerros by 15 and 9 per cent in 1989-90 and 1990-91 respectively. Row-spacing effect was significant in both years. The 20 and 30 cm row-spacings gave significantly greater magnesium uptake than the 10 cm row-spacing in 1989-90. In 1990-91, however, 10 and 20 cm had greater uptake of Mg than 30 cm row-spacing. Increase in nitrogen levels significantly increased magnesium uptake up to 180 kg N ha^{-1} in both years; magnesium uptake being greater (7.1 kg ha^{-1}) in 1989-90 than in 1990-91 (5.6 kg ha^{-1}). Varieties x row-spacing interaction was significant in 1989-90 (Table 40) indicating that Siete Cerros did not vary significantly in magnesium uptake with changes in row-spacing, whereas uptake levels by Florence Aurore at 20 and 30 cm row-spacing were significantly greater than at the 10 cm row-spacing.

Table 40. Interaction of variety and row-spacing on magnesium uptake (kg Mg ha^{-1}) by wheat at harvest at Kadawa, 1989-90.

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
10	6.4	5.7
20	6.5	8.9
30	6.9	8.2
LSD (0.05)	1.2	

4.4.6 Nutrient distribution in plant parts at harvest

Leaf

In 1989-90, there were no significant differences between the two varieties in terms of nutrient uptake with the exception of Mg. Florence Aurore, however, had greater uptake values than Siete Cerros. Potassium uptake was highest followed by Ca, N, Mg and P in that order in both varieties. In 1990-91, uptake by Florence Aurore was significantly higher than that by Siete Cerros for all the nutrient elements. In both varieties, K uptake was highest followed by N, Ca, Mg and P in that order (Figure 11).

Effect of row-spacing on leaf nutrient uptake varied with years. In 1989-90, uptake of all nutrients was highest at 20 cm row-spacing, which was significantly higher than 30 and 10 cm for N, P and Mg. The 30 cm row-spacing was significantly better than that of 10 cm for P and Mg. In general, uptake was highest for K followed by Ca, N, Mg and P in that order. In 1990-91, there were significant differences between row-spacings with respect to uptake of N, K and Mg, the 10 cm row-spacing being better than 30 and 20 cm for K and Mg. At all row-spacings, K uptake was highest followed by N, Ca, P and Mg (Figure 11).

In 1989-90, application of nitrogen increased significantly the uptake of N and P up to 180 kg N ha^{-1} and that of K, Ca and Mg up to 120 kg N ha^{-1}. Potassium uptake was highest followed by Ca, N, Mg and P in that order. In 1990-91, uptake of all the elements significantly increased with increase in nitrogen level up to 180 kg N ha^{-1} though P uptake at 0 and 60 kg N ha-1 were not significantly different. Potassium uptake was highest, followed by N, Ca, P and Mg (Figure 11).

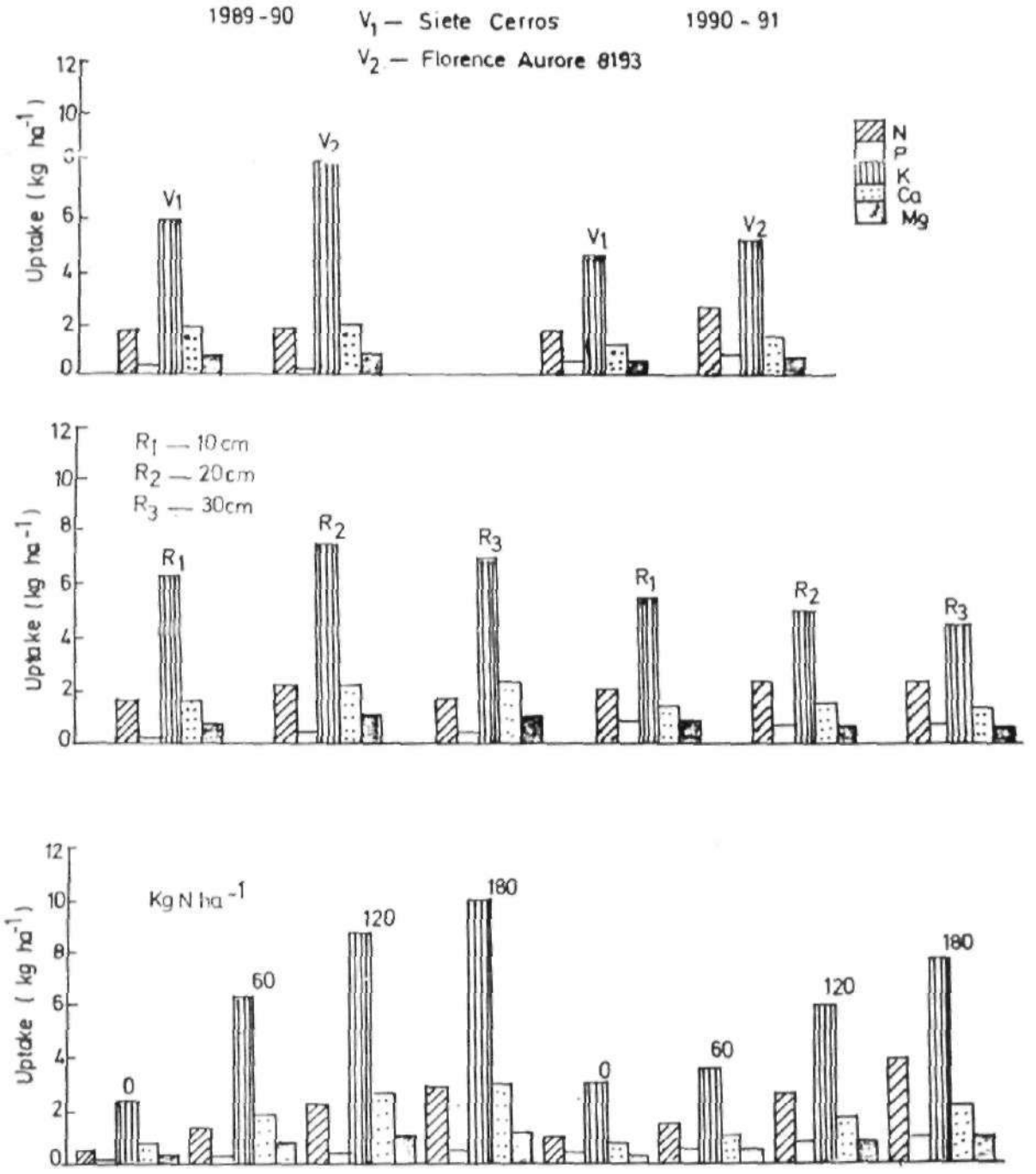


Fig.11: Leaf nutrient uptake at harvest as influenced by variety , row-spacing and nitrogen level at Kadawa 1989-91

Stem

In 1989-90, uptake of all nutrients in the stem by Florence Aurore was significantly higher than that by Siete Cerros. The highest uptake was for K, followed by N, Ca, Mg and P in both varieties. In 1990-91, Florence Aurore was significantly higher than Siete Cerros in uptake of all the nutrients. In Siete Cerros, the uptake of nutrients was in decreasing order of K, N, Ca, Mg and P. The order in the case of Florence Aurore was K followed by N, P, Ca and Mg (Figure 12).

Effect of row-spacing on nutrient uptake by stem varied with years. In 1989-90, 20 cm was equal to 30 cm but significantly higher than 10 cm in uptake of N and Mg and 30 cm was higher than 10 cm in P uptake. The uptake was highest in the case of K followed by N, Ca, Mg and P at all row-spacings. In 1990-91, the differences between row-spacings were significant only in the case of K uptake, when row-spacings of 10 and 20 cm were at par but caused significantly more uptake of K than at 30 cm (Figure 12).

In 1989-90, application of nitrogen caused significant increase in uptake of N and Ca up to 180 kg N ha^{-1} and for K, P and Mg up to 120 kg N ha^{-1}. Calcium uptake at 60 and 120 kg N ha^{-1} were not significantly different. At all levels of nitrogen, uptake was highest for K followed in order by N, Ca, Mg and P. In 1990-91, uptake of N, K, Ca and Mg increased significantly with increase in levels of nitrogen up to 180 kg N ha^{-1}. Phosphorus uptake was significant up to 120 kg N ha^{-1} but difference between 0 and 60 kg N ha^{-1} was not significant. At 0, 60 and 180 kg N ha^{-1}, the uptake was highest for K followed in order by N, P, Ca and Mg. The order at 120 kg N ha^{-1} was K followed by N, Ca, P and Mg (Figure 12).

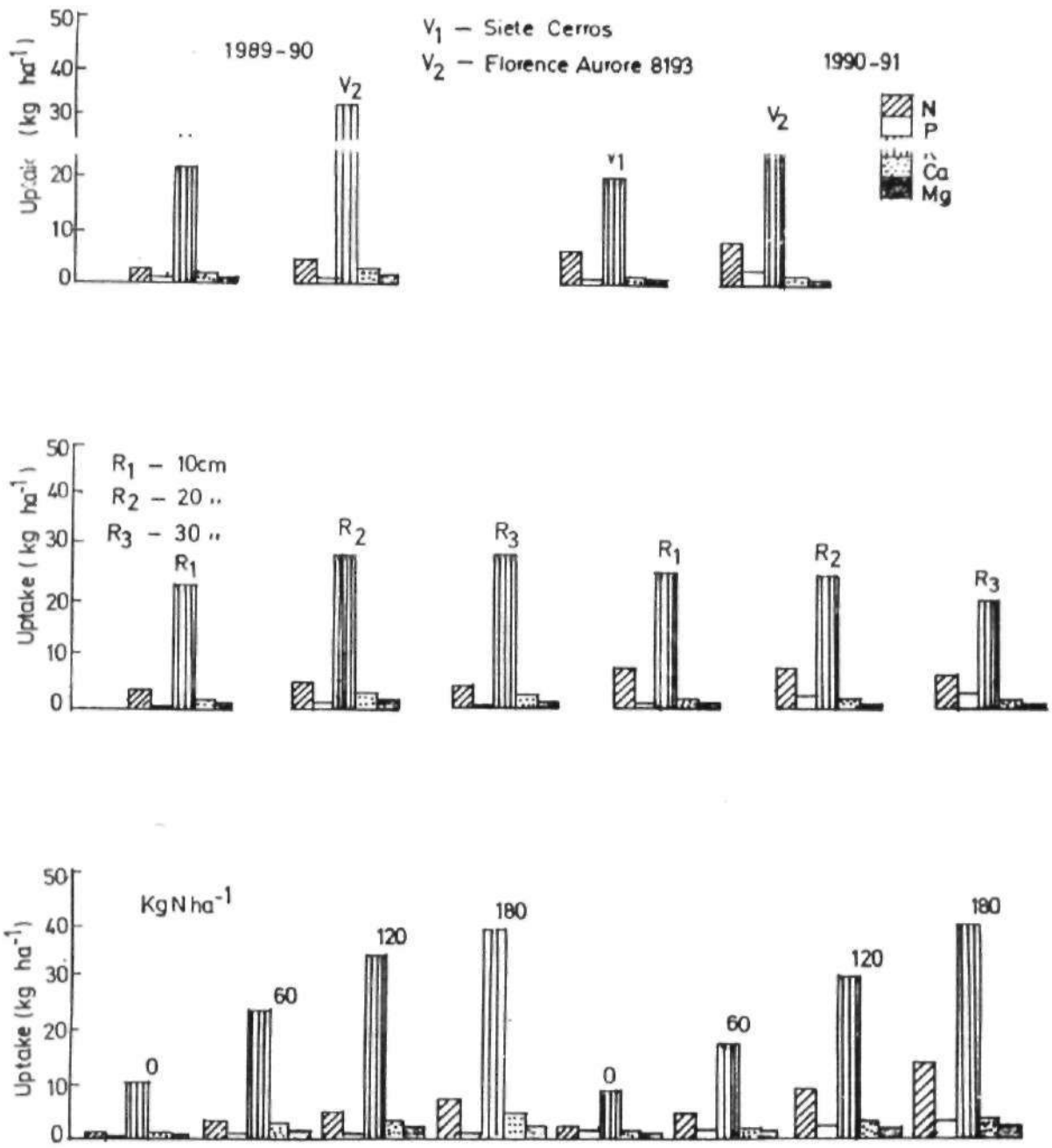


Fig. 12: Stem nutrient uptake at harvest as influenced by variety , row-spacing and nitrogen level at Kadawa 1989 –91

Spike

In 1989-9), the differences between varieties were significant only for P when Florence Aurore was signifi-cantly better than Siete Cerros in spike P uptake. The order of uptake was N, K, Ca, Mg and P in Siete Cerros and N, K, Mg, Ca and P in Florence Aurore. In 1990-91, the two varieties differed significantly in Ca uptake; the uptake by Siete C erros being significantly higher than that by Florence Aurore. In both varieties, the uptake was highest for N followed by K, P, Mg and Ca (Figure 13).

In 1989-9(, effect of row-spacing was significant on spike uptake of P, K and Mg. For P, a row- spacing of 20 cm was significantly better than those of 30 and 10 cm. For K, 20 an 30 cm row-spacings caused significantly greater uptake than the 10 cm row-spacir j. The 20 and 30 cm were at par in Mg uptake but significantly better than 10 cm ow-spacing. Amongst the nutrients, highest uptake was for N at all spacings, and it was generally followed by K, Ca, Mg and P in that order. In 1990-91, there was sigr ficant

effect of row-spac ig on all the nutrients except P. Uptake of N and K at 20 cm was significantly higher than that at 10 cm and 10 cm greater than that at 30 cm. Calcium and Mg uptake leve s at 10 and 20 cm were similar but significantly higher than at 30 cm row-spacing. he uptake was highest for N followed by K, P, Mg and Ca at all row-spacings (Figu e 13).

In 1989-90 spike nutrient uptake increased significantly with increase in nitrogen levels up t 180 kg N ha^{-1} for N, up to 120 kg N ha^{-1} for P, K and Mg and to 60 kg N ha^{-1} for Ca At 0, 120 and 180 kg N ha^{-1}, N uptake was highest followed by K, Ca, Mg and P. The order at 120 kg N ha^{-1} was N followed by K, Mg, Ca and P. In

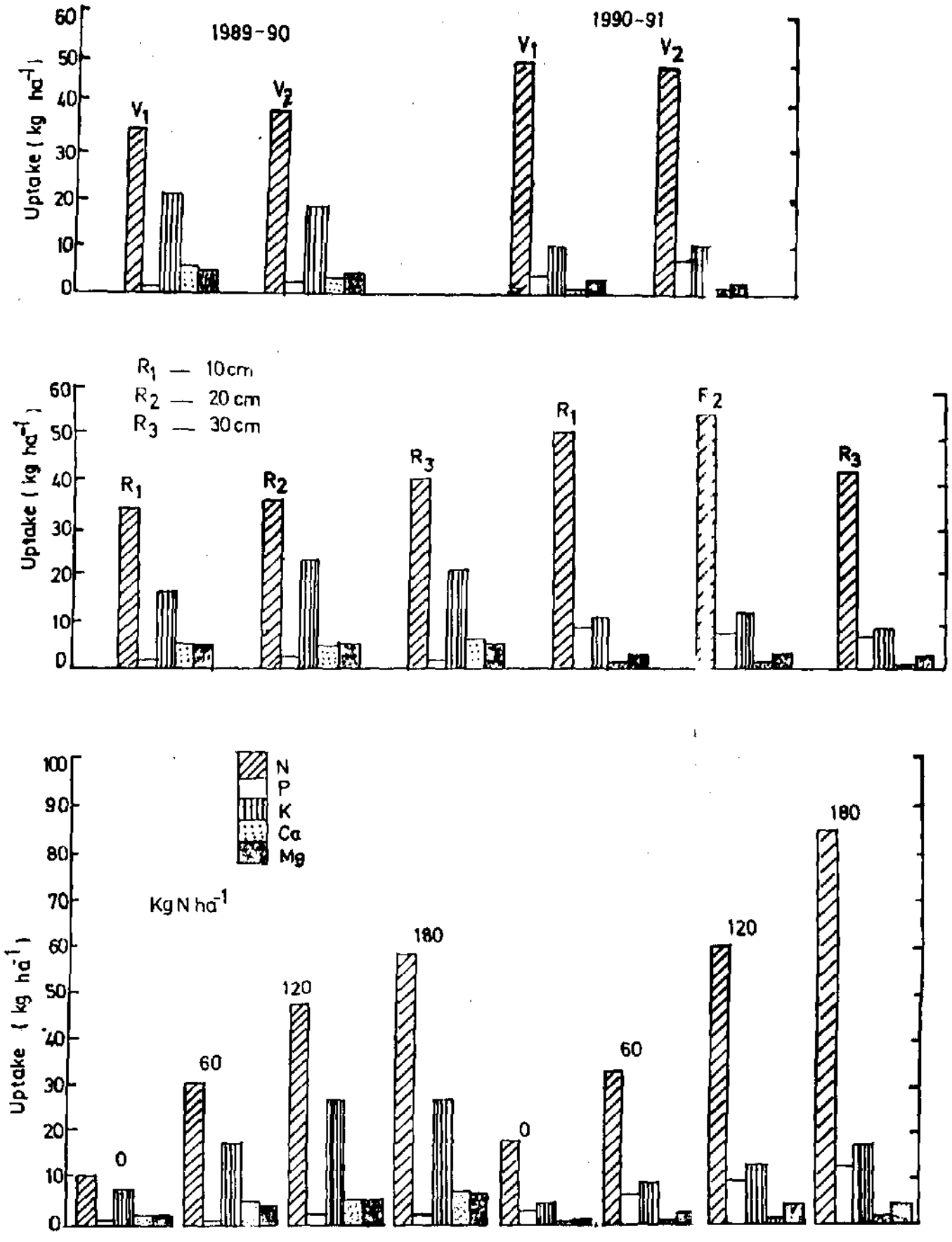


Fig.13: Spike nutrient uptake at harvest as influenced by variety row-spacing and nitrogen level at Kadawa 1989-91

1990-91, uptake of all the nutrients increased significantly with increase in nitrogen levels up to 180 kg N ha^{-1}.

The uptake was highest for N followed by K, P, Mg and Ca at all the levels of nitrogen (Figure 13).

4.5 Regression Studies

Regression of grain yield on nitrogen fertilizer levels for 1989-90, 1990-91 and combined analysis are presented in Figures 14 and 15. As depicted by the regression curves, grain yields of Siete Cerros and Florence Aurore increased with increase in nitrogen levels. Siete Cerros however had a greater response at all N levels in both years and mean over years. Responses to N levels in 1990-91 was about 50 per cent of those of 1989-90.

Nitrogen levels that produced maximum grain yields were calculated from the mean response functions of Siete Cerros and Florence Aurore (Figures 14 and 15). The nitrogen rates for Siete Cerros were 196, 241 and 208 kg N ha^{-1} in 1989-90, 1990-91 and combined analysis respectively while those of Florence Aurore were 217, 186 and 202 kg N ha^{-1} for the same periods. The corresponding maximum yields were 3583, 1829 and 2691 kg ha^{-1} for Siete Cerros and 3168, 1356 and 2230 kg ha^{-1} for Florence Aurore. The response ratios (kg grain per kg N) were 18.3, 7.6 and 12.9 for Siete Cerros and 14.6, 7.3 and 11.0 for Florence Aurore in 1989-90, 1990-91 and combined analysis respectively at those nitrogen levels that gave rise to maximum grain yields.

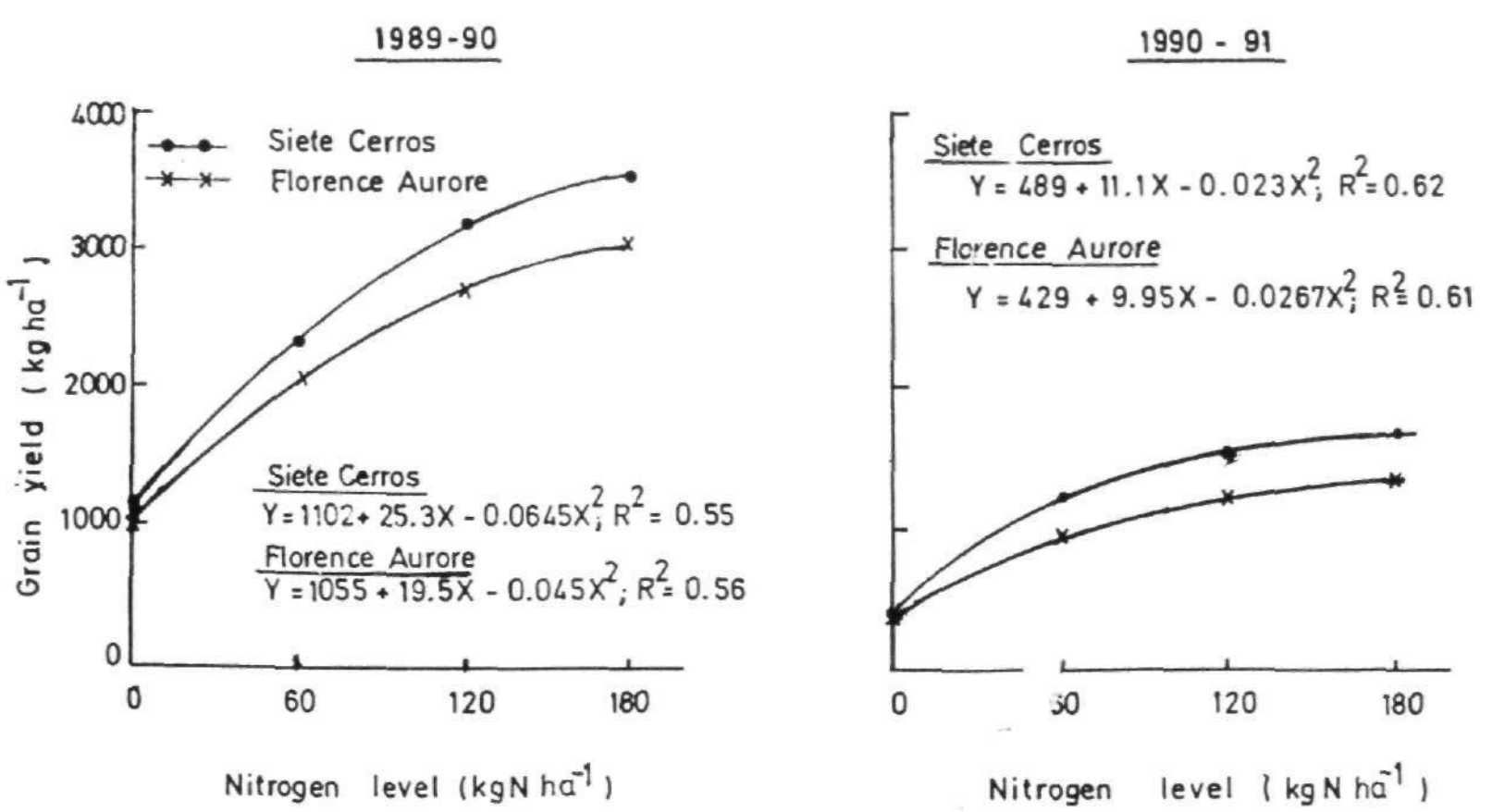


Fig. 14 : Regression of grain yield on nitrogen fertilizer level : 1989 - 91

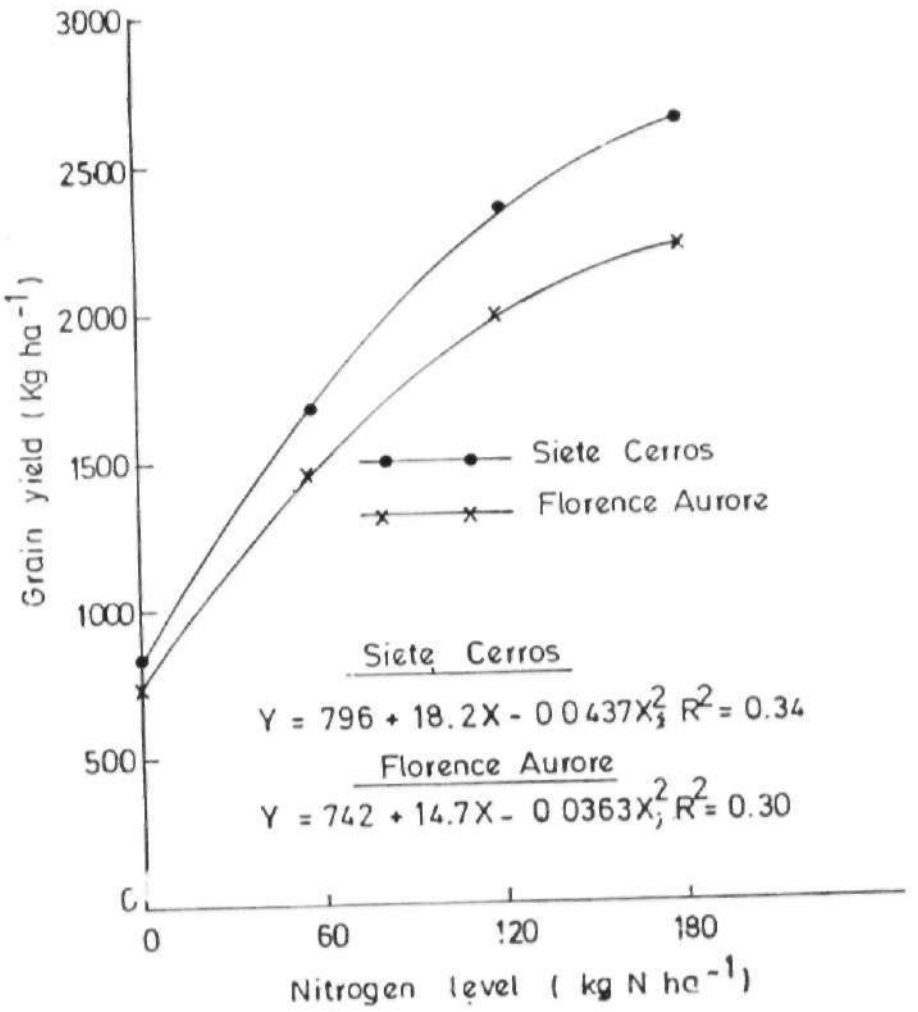


Fig.15: Regression of grain yield on nitrogen fertilizer level. Combined analysis 1989-91

4.6 Correlation and Path-Coefficient Analyses

4.6.1 Correlation

A correlation analysis was done to determine the relationships among six agronomic characters (Table 41). There was significant positive correlations between grain yield and effective tillers, spike length, spikeletsper spike, grains per spike and 1000-grain weight. Spikelets per spike and grains per spike had the highest correlation coefficients (0.985 and 0.984) and 1000-grain weight (0.469) the lowest correlation coefficient with grain yield. The 1000-grain weight also had the lowest correlations with the other agronomic characters tested.

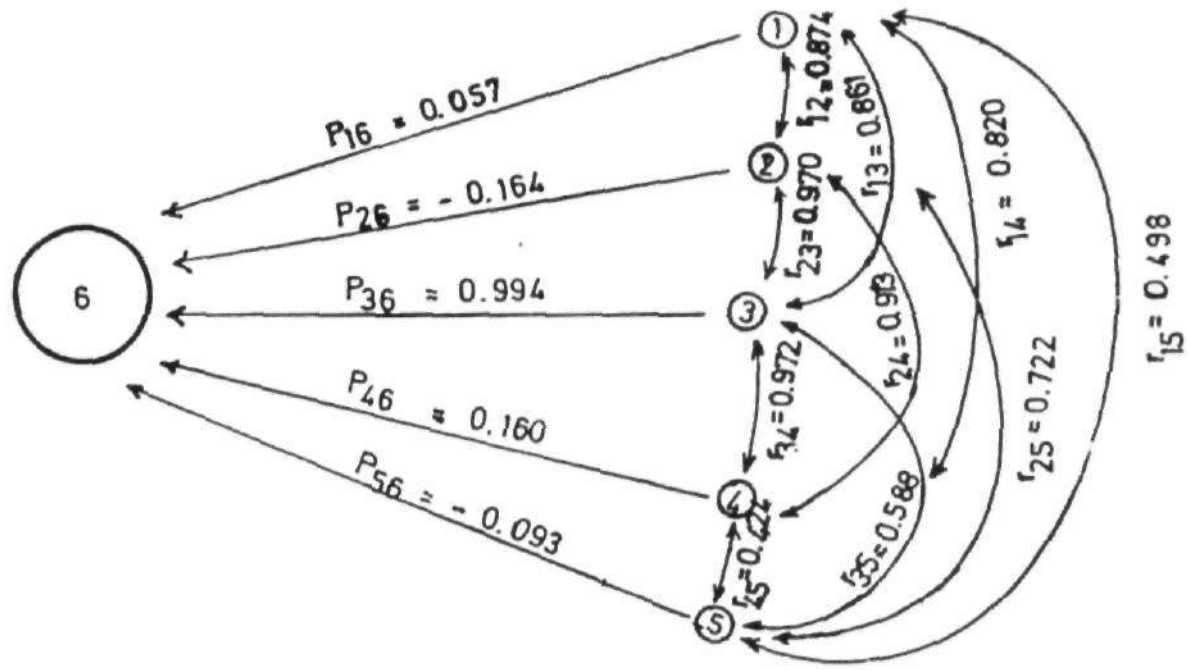
Table 41. Correlation coefficients among six agronomic characters in wheat.

Characters	Effective tillers	Spike length	Spikelets/ spike	Grains/spike	1000-grain wt.
Grain yield	0.855**	0.929**	0.985**	0.984**	0.469**
Effective tillers		0.874**	0.861**	0.820**	0.498**
Spike length			0.970**	0.913**	0.722**
Spikelets/spike				0.972**	0.058**
Grains/spike					0.424**
1000-grain wt.					-

***Significant at P=0.01.*

4.6.2 Path-coefficient analysis

The path coefficient analysis of the interrelationships of effective tillers, spike length, spikelets per spike, grains per spike and 1000-grain weight with grain yield is shown diagrammatically in Figure 16. Estimates of both direct effects and indirect effect path-coefficients are presented in Table 42.



(1) Effective tillers (2) Spike length (3) Spikelets / spike (4) Grains / spike (5) 1000-grain weight

Fig 16 : Path coefficient diagram of five components of yield in wheat. Double-arrowed lines indicate correlation cofficients and the single-arrowed lines indicate direct path coefficients.

Table 42. Path coefficient analysis showing direct and indirect effects of the yield components in characters in wheat.

Characters	Effective tillers	Spike length	Spikelets/ spike	Grains/spike	1000-grain wt.
Effective tillers	0.057	-0.143	0.856	0.131	-0.046
Spike length	0.050	-0.164	0.964	0.146	-0.067
Spikelets/spike	0.049	-0.159	0.994	0.156	-0.055
Grains/spike	0.047	-0.150	0.966	0.160	-0.039
1000-grain weight	0.028	-0.118	0.584	0.068	-0.093

Underlined values denote the direct effects.

Spikelets per spike was found to have the greatest direct (0.994) and total (0.985) effects on grain yield. Its indirect effects through effective tillers and grains per spike were positive even though small. Its effects through spike length and 1000-grain weight were negative and small. Grains per spike had a large total effect (0.984) but small direct effect (0.16). Its effect through spikelets per spike was large (0.966); its effect through effective tillers was positive but negligible; and that through 1000-grain weight was negative and small. Effective tillers had a negligible direct effect (0.057) but a large positive total effect (0.855). Its effect through spikelets per spike (0.856) was large and positive. The effect of grains per spike on grain yield was positive but small, while those of spike length and 1000-grain weight were small and negative. Spike length had a large total effect (0.929) but negative direct effect (-0.164). Its indirect effect through spikelets per spike was positive and quite large (0.964); its effects through effective tillers (0.05) and grains per spike (0.146) were both small; its effect through 1000-grain weight was negative and small. The 1000-grain weight had the lowest total effect (0.469) and a negligible direct effect (0.093).

Its positive effect through spikelets per spike (0.584) was large; while those through effective tillers (0.028) and grains per spike (0.068) were negligible. Its effect through spike length was negative and small.

Experiment II

4.7 Yield and Yield Components

4.7.1 Grain yield

Grain yields as influenced by varieties, nitrogen levels and times of nitrogen application are presented in the data shown in Table 43. The corresponding analysis of variance tables are presented in Appendices 34, 35 and 36.

Siete Cerros significantly out-yielded Florence Aurore by margins of 24, 34 and 28 per cent in 1989-90, 1990-91 and the pooled year data respectively. The superiority of the former over the latter variety was more pronounced in the second year.

Nitrogen had significant effect on grain yield in both years. Grain yield increased significantly with increase in nitrogen level up to 180 kg N ha^{-1} in 1989-90 but was up to 120 kg N ha^{-1} in 1990-91. Combined data for the two years showed significant increase in grain yield with nitrogen level up to 180 kg N ha^{-1}. In 1989-90, application of 120 kg N ha^{-1} increased grain yield by 63 per cent over 60 kg N ha^{-1} while 180 kg N ha^{-1} application increased grain yield by 20 per cent over the 120 kg N ha^{-1}.

Table 43. Grain and straw yields for varieties and levels and times of nitrogen application in wheat at Kadawa, 1989-91.

Treatment	Grain yields (kg ha^{-1})			Straw yields (kg ha^{-1})		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	2246	1692	1969	3356	2304	2830
Florence Aurore	1816	1260	1538	3023	2059	2541
SE ±	84	63	52	166	140	111
LSD (0.05)	231.5	174.4	143.7	NS	NS	306.3
Nitrogen level (kg N ha^{-1})						
60	1300	1195	1247	2216	1625	1920
120	2118	1601	1859	3313	2378	2846
180	2675	1633	2154	4040	2541	3290
SE ±	103	77	64	204	171	136
LSD (0.05)	283.6	213.6	176.0	562.5	472.4	375.3
Time of N application						
S	1723	1535	1629	2721	2353	2537
S + T	2322	1433	1878	3811	2164	2988
S + F	2047	1460	1753	3036	2027	2531
SE ±	103	77	64	204	171	136
LSD (0.05)	283.6	NS	176.0	562.5	NS	375.3
Interactions	VxN	VxT	VxN YxT			YxT

S = all N at seeding; S + T = half N at seeding + half at tillering; S+ F = half N at seeding + half at flag leaf stage.

Effect of time of nitrogen application varied with years. In 1989-90, split application of N at seeding plus tillering gave significantly more grains than a single application at seeding time by 35% and that of split applications at seeding plus flag leaf stage by 13%. In 1990-91, the differences between times of application were not significant but the trends were in favour of application of a single application of nitrogen at seeding time. Grain yields in 1989-90 were generally higher than those in 1990-91.

A combined analysis over the years showed that variety x nitrogen level and year x time of nitrogen application interactions were significant. The yields of Siete Cerros increased significantly with levels of nitrogen up to 180 kg N ha^{-1} but those of Florence Aurore were increased up to 120 kg N ha^{-1} (Table 44).

Table 44. Interaction of varieties and nitrogen level on grain yield (kg ha^{-1}) in wheat at Kadawa (pooled data for 1989-91).

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
60	1370	1125
120	2014	1706
180	2523	1785
LSD (0.05)	250.2	

4.7.2 Straw yield

Data in respect of straw yields for varieties, nitrogen levels and times of nitrogen application are given in Table 43. The analysis of variance tables are presented in Appendices 34, 35 and 36.

Although there were no significant differences between both years, higher values for Siete Cerros in both years resulted in significantly higher yields of this variety over Florence Aurore when the two-year yield data were pooled.

Straw yield increased significantly with increase in nitrogen level up to 180 kg N ha^{-1} in 1989-90 and 120 kg N ha^{-1} in 1990-91. The magnitudes of yield increase with the application of 120 over 60 kg N ha^{-1} were to the tunes of 1097 and 753 kg ha^{-1} in the first and second years respectively. A further increase in nitrogen application to 180 kg N ha^{-1} increased yields over 120 kg N ha^{-1} additionally by 727 and 163 kg ha^{-1} respectively. Analysis of means data pooled over two years showed that wheat straw yields increased significantly with increase in N application up to 180 kg N ha^{-1}. Application of 120 kg N ha^{-1} increased the yields over 60 kg N ha^{-1} by 48 per cent and application of 180 kg N ha^{-1} over 120 kg N ha^{-1} was by 16 per cent.

Effect of time of nitrogen application varied with years. The interaction between time of N application and years was therefore significant. In 1989-90, application of nitrogen in splits at seeding plus tillering produced 40 and 26 per cent greater straw yields than a single application at seeding and application in splits at seeding plus flag leaf stage respectively. The yield differences in 1990-91 were not significant but trends were in favour of a single application at seeding time.

Combined analysis of data over years showed that there were higher yields in the first year than in the second year; that there were significantly higher straw yields

with application of nitrogen in split doses at seeding time and at tillering stage than a single application at seeding; split application at seeding time plus flag leaf stage, and that there was significant interaction between years and times of nitrogen application as earlier reported (Table 43).

4.7.3 Dry matter

Data in respect of dry matter production at harvest as influenced by variety, nitrogen level and time of nitrogen application are presented in Table 45. The corresponding analysis of variance tables are in Appendices 34, 35 and 36.

Siete Cerros produced significantly more dry matter than Florence Aurore in both years and mean of the two years. The differences were 16, 21 and 18 per cent in the first, the second and the combined years respectively.

Dry matter production increased significantly with increase in nitrogen level up to 180 kg N ha^{-1} in the first year but up to 120 kg N ha^{-1} in the second year. Pooled data for both years showed that there was significant increase up to 180 kg N ha^{-1}. The first and second increment N application levels produced 49 and 15% increases respectively.

Time of nitrogen application had significant effect on dry matter yield in 1989-90 when split application of nitrogen at seeding time and at tillering stage produced the maximum amount of dry matter and was significantly better than a single application at seeding time or a split application at seeding time plus flag leaf stage. In 1990-91, differences were not significant but the trends were in favour of a single application at seeding stage.

Table 45. Dry matter yields at harvest and harvest index values as influenced by variety N, level and time of nitrogen application in wheat at Kadawa, 1989-91.

Treatment	Dry matter yields (kg ha^{-1})			Harvest index (%)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	5602	3995	4799	40.5	44.4	42.5
Florence Aurore	4839	3292	4065	37.4	39.2	38.3
SE ±	232	193	152	0.91	0.94	0.66
LSD (0.05)	640.7	533.7	420.8	2.52	2.60	1.83
Nitrogen level (kg N ha^{-1})						
60	3515	2820	3167	36.8	43.2	40.0
120	5431	3979	4705	39.9	42.2	41.1
180	6715	4132	5424	40.0	40.1	40.1
SE ±	284	236.5	186.5	1.11	1.15	0.81
LSD (0.05)	784.8	653.7	515.5	NS	NS	NS
Time of N application						
S	4445	3889	4167	38.6	39.9	39.3
S + T	6133	3597	4865	37.9	41.0	39.5
S + F	5083	3444	4264	40.3	44.6	42.4
SE ±	284	237	187	1.11	1.15	0.81
LSD (0.05)	784.8	NS	515.5	NS	3.19	2.24
Interactions			YxT YxN			YxN

S = all N at seeding; S+T = half N at seeding + ½ at tillering;
S+F = half N at seeding + ½ at flag leaf stage.

The combined data over the two years revealed that dry matter production in 1989-90 was significantly higher than 1990-91; and that there were significant year x time of nitrogen application and year x nitrogen level interactions (Table 45).

4.7.4 Harvest index

Harvest index values for varieties, nitrogen levels, and times of nitrogen application are presented in Table 45. The corresponding analysis of variance tables are shown in Appendices 34, 35 and 36.

Siete Cerros had significantly higher harvest index values than Florence Aurore in each of the two years and the mean for both years. Nitrogen levels did not cause significant differences in the harvest index values, the trends however, were in favour of higher rates in first year and lowest in second year. Time of nitrogen application caused significant differences only in 1990-91 when split application of nitrogen at seeding time plus flag leaf stage produced a significantly higher harvest index than a single application at seeding or a split application at seeding time plus tillering stage. Mean values for years also showed that trends was similar to that of 1990-91. There were significant year x nitrogen level interactions (Table 45).

4.7.5 Spike length

Effects of varieties, nitrogen levels and times of nitrogen application on spike length at maturity are shown in Table 46. The corresponding analysis of variance tables are presented as Appendices 37, 38 and 39.

Florence Aurore produced significantly longer spikes than Siete Cerros in both years with margins of 8, 15 and 11 per cent in the first, the second and combined for

both years, respectively. Spikes of both varieties were longer in 1990-91 than in 1989-90.

Spike length increased significantly with increase in nitrogen levels up to 180 kg N ha^{-1} in 1989-90 but only up to 120 kg N ha^{-1} in the succeeding year. In 1989-90, there was an increase of 0.5 cm in spike length for every increase of 60 kg N ha^{-1}. In 1990-91, increase in spike length with application of 120 kg N ha^{-1} over 60 (1.4 cm) was greater than that between 120 and 180 kg N ha^{-1} (0.2 cm).

Time of nitrogen application had significant effect on spike length only in 1989-90. Application of nitrogen in split doses at seeding time plus tillering stage produced the longest spikes.

A combined analysis over the two years indicated that Florence Aurore produced significantly longer (11%) spikes than Siete Cerros; that spike length increased with increase in nitrogen level; that spikes were longer in 1990-91 than in 1989-90; and that varieties x nitrogen levels and years x nitrogen levels interactions were significant (Tables 46 and 47).

The spike length of Siete Cerros increased significantly with nitrogen application up to 180 kg N ha^{-1} but that of Florence Aurore was only up to 120 kg N ha^{-1} (Table 47).

4.7.6 Spikelets per spike

The data on number of spikelets per spike as influenced by variety, nitrogen level and time of N application are given in Table 46. The corresponding analysis of variance tables are in Appendices 37, 38 and 39.

Table 46. Spike length and number of spikelets per spike for varieties, levels and times of nitrogen application in wheat at Kadawa, 1989-91.

Treatment	Spike lengths (cm)			Spikelets per spike		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	7.8	8.2	8.0	15.2	17.7	16.4
Florence Aurore	8.4	9.4	8.9	14.3	17.3	15.8
SE ±	0.13	0.13	0.09	0.28	0.19	0.17
LSD (0.05)	0.37	0.37	0.26	0.76	NS	0.47
Nitrogen level (kg N ha^{-1})						
60	7.6	7.8	7.7	13.8	16.3	15.0
120	8.1	9.2	8.7	14.7	18.0	16.3
180	8.6	9.4	9.0	15.8	18.2	17.0
SE ±	0.16	0.16	0.12	0.34	0.24	0.21
LSD (0.05)	0.45	0.45	0.31	0.93	0.65	0.58
Time of N application						
S	8.1	8.8	8.5	15.1	17.7	16.4
S + T	8.4	8.7	8.5	15.1	17.5	16.3
S + F	7.8	8.9	8.4	14.0	17.2	15.6
SE ±	0.16	0.16	0.12	0.34	0.24	0.21
LSD (0.05)	0.45	NS	NS	0.93	NS	0.58
Interactions			VxN YxN	VxN		VxN

S = all N at seeding; S+T = half N at seeding + ½ at tillering;
S+F = half N at seeding + ½ at flag leaf stage.

Table 47. Interaction of variety and nitrogen level on spike length (cm) in wheat at Kadawa (data pooled for 1989-90 and 1990-91.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
60	7.3	8.1
120	8.0	9.3
180	8.7	9.3
LSD (0.05)	0.44	

Siete Cerros produced significantly more (6%) spikelets per spike over Florence Aurore during 1989-90 and also based on means of two years (4%). Even in 1990-91, the trend was strongly in favour of Siete Cerros.

Effect of nitrogen levels on number of spikelets per spike was significant in both years. Spikelet number increased significantly with increase in nitrogen level up to 180 kg N ha^{-1} in 1989-90 and up to 120 kg N ha^{-1} in 1990-91. The mean values for two years showed that number of spikelets increased significantly up to 180 kg N ha^{-1} by 9 per cent from 60 to 120 kg N ha^{-1} and 4 per cent from 120 to 180 kg N ha^{-1}.

Number of spikelets per spike was significantly affected by time of nitrogen application in 1989-90. Single dose application of N at seeding time and split application at seeding time plus tillering stage produced similar numbers of spikelets per spike in both years and mean of the two years but these were significantly more than that of split application at seeding plus flag leaf stage.

The combined analysis for both years showed, significant interaction between varieties and nitrogen level (Table 48). The number of spikelets per spike increased

with increase in nitrogen levels up to 180 kg N ha^{-1} in the case of Siete Cerros but up to 120 kg N ha^{-1} in the case of Florence Aurore.

Table 48. Interaction of variety and nitrogen level on number of spikelets per spike in wheat at Kadawa (data pooled for 1989-90 and 1990-91).

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
60	15.6	14.5
120	16.2	16.5
180	17.5	16.4
LSD (0.05)	0.83	

4.7.7 Grains per spike

The data on number of grains per spike for varieties, nitrogen levels and times of nitrogen application are presented in Table 49. The corresponding analysis of variance tables are presented in Appendices 37, 38 and 39.

Siete Cerros produced significantly more grains per spike than did Florence Aurore by margins of 28% in 1989-90, 37% in 1990-91 and 33% in mean of the two years.

Nitrogen levels had significant effect on number of grains per spike. The number of grains per spike increased significantly with increase in nitrogen level up to 180 kg N ha^{-1} in 1989-90 and to 120 kg N ha^{-1} in 1990-91. The mean value for two years showed significant increase up to 180 kg N ha^{-1}. Application of 120 kg N ha^{-1} increased it by 21% over 60 kg N ha^{-1} and 180 kg N ha^{-1} by 9% over 120 kg N ha^{-1}.

Table 49. Number of grains per spike and 1000-grain weight as influenced by variety, level and time of nitrogen application in wheat at Kadawa, 1989-91.

Treatment	Grains/spike			1000-grain weight (g)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	39.2	45.9	42.5	30.9	32.7	31.8
Florence Aurore	30.6	33.4	32.0	37.0	37.2	37.1
SE ±	1.39	1.21	0.93	0.49	0.57	0.37
LSD (0.05)	3.84	3.33	2.56	1.36	1.57	1.03
Nitrogen level (kg N ha^{-1})						
60	31.1	32.3	31.7	32.1	33.3	32.7
120	33.8	42.8	38.3	34.2	36.1	35.1
180	39.8	43.9	41.9	35.6	35.5	35.5
SE ±	1.70	1.48	1.13	0.60	0.70	0.46
LSD (0.05)	4.70	4.08	3.13	1.66	1.92	1.27
Time of N application						
S	32.8	39.9	36.4	33.4	34.5	33.9
S + T	36.5	38.1	37.3	34.7	35.5	35.1
S + F	35.4	41.0	38.2	33.8	34.8	34.3
SE ±	1.70	11.48	1.13	0.60	0.70	0.46
LSD (0.05)	NS	NS	NS	NS	NS	NS
Interactions		VxN				

S = all N at seeding; S+T = half N at seeding + ½ at tillering;
S+F = half N at seeding + ½ at flag leaf stage.

Time of N application had no significant effect on number of grains per spike in both years. Mean values for the two years showed a trend that seemed to favour split application over a single dose application at seeding time.

Varieties x nitrogen level for number of grains per spike interactions were significant in 1990-91 (Table 50) indicating that the differences between the two varieties were significant at 120 and 180 kg N ha^{-1} and greater by 12.5 and 20.2 grains per spike as against no significant differences (4.7) at 60 kg N ha^{-1}.

4.7.8 1000-grain weight

Thousand-grain weight values for varieties, nitrogen levels and times of nitrogen application are given in Table 49. The analysis of variance tables are presented in Appendices 37, 38 and 39.

Varietal differences were significant in both years, Florence Aurore had significantly greater 1000-grain weight than did Siete Cerros by margins of 23, 14, 17 per cent in 1989-90, 1990-91 and the two years mean values respectively.

Table 50. Interaction of variety and nitrogen level on grains per spike in wheat at Kadawa, 1990-91.

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
60	34.7	30.0
120	49.0	36.5
180	54.0	33.8
LSD (0.05)	5.8	

Nitrogen level had a significant effect on 1000-grain weight in both years. It was observed that 1000-grain weight increased with levels of nitrogen up to 120 kg N ha^{-1} in both years and mean values for the two years.

Time of nitrogen application had no significant effect on 1000-grain weight. However, the trends were in favour of split applications at seeding time plus tillering stage.

4.8 Grain Crude Protein Content

The grain crude protein content values for varieties, nitrogen levels and times of nitrogen application are presented in Table 51. The analysis of variance tables are in Appendices 40 and 41.

Florence Aurore produced grains with significantly higher protein content than Siete Cerros in both years and mean of two years. Protein content increased significantly with increase in nitrogen levels up to 120 kg N ha^{-1} in 1989-90 and 180 kg N ha^{-1} in 1990-91. Combined mean values for the two years showed significant increase in grain crude protein content up to 180 kg N ha^{-1}. Analysis of data for individual years and the means of two years showed that split application of nitrogen at seeding plus flag leaf stage produced significantly higher grain crude protein than a single dose applications of N at seeding time or split application at seeding plus tillering.

There were significant variety x time of nitrogen application and year x time of application interactions. Varietal differences were significant with nitrogen split application at seeding time plus tillering stage and split application at seeding time plus flag leaf (Table 52) but not when single dose of N was applied at seeding. Effects of time of nitrogen application were significant at 120 and 180 kg N ha^{-1} (Table 53). Grain crude protein content was significantly higher in 1990-91 than in 1989-90 (Table 51).

Table 51. Grain crude protein content as influenced by variety, level and time of nitrogen application in wheat at Kadawa, 1989-91.

Treatment	Grain crude protein (%)		
	1989-90	1990-91	Mean
Variety			
Siete Cerros	6.08	8.19	7.14
Florence Aurore	6.57	8.75	7.66
SE ±	0.08	0.09	0.07
LSD (0.05)	0.24	0.24	0.20
Nitrogen level (kg N ha^{-1})			
60	5.68	7.77	6.72
120	6.62	8.25	7.44
180	6.68	9.40	8.04
SE ±	0.10	0.10	0.09
LSD (0.05)	0.28	0.29	0.24
Time of N application			
S	5.73	8.32	7.03
S + T	6.25	8.06	7.15
S + F	7.00	9.03	8.02
SE ±	0.10	0.10	0.09
LSD (0.05)	0.27	0.29	0.24
Interactions	VxT TxN	VxT TxN	VxT TxN YxT

S = all N at seeding; S+T = half N at seeding + ½ at tillering;
S+F = half N at seeding + ½ at flag leaf stage.

Table 52. Interaction of variety and time of nitrogen application on grain crude protein content (%) in wheat at Kadawa (data combined for 1989-90 and 1990-91).

Time of N application	Varieties	
	Siete Cerros	Florence Aurore
S	7.03	7.03
S + T	6.93	7.38
S + F	7.46	8.57
LSD (0.05)	0.34	

Table 53. Interaction of nitrogen level and time of N application on grain crude protein content (%) in wheat at Kadawa (data pooled for 1989-90 and 1990-91).

Time of N application	Nitrogen level (kg N ha^{-1})		
	60	120	180
S	6.74	6.83	7.51
S + T	6.57	7.19	7.70
S + F	6.86	8.29	8.90
LSD (0.05)		0.42	

Chapter 5

DISCUSSION

In the present study, the effects of variety, row-spacing and nitrogen supply on growth, dry matter accumulation, yield, yield components and nutrient uptake of wheat were investigated.

5.1 Growing Season Condition

The growth and yield of wheat in the wheat growing areas of Nigeria are very much influenced by prevailing air temperatures during the growing season. Wheat yields varied with the growing seasons. During the period of this study, daily air temperatures were relatively more conducive for wheat growth in 1989-90 than the 1990-91 growing season. Growth duration in 1990-91 was therefore shorter than that of the 1989-90 growing season by about fourteen days. This resulted in higher grain yields in 1989-90. Similar effects of high temperatures on wheat growth were earlier reported by Asana and Williams (1965); Ford *et al.*(1976) and Wardlaw *et al.* (1980) who found that high temperatures experienced between anthesis and maturity increased growth rate of the ear and therefore decreased that of the stem and these hastened senescence of the ear and therefore decreased final grain yield. Marcellos and Single (1972) reported that an increase in the mean daily temperature from 17.5°C to 22.0°C during the post-flowering period reduced the duration of this developmental phase by about 30 per cent.

5.2 Effect of Variety

5.2.1 Growth characters

The superiority of variety Florence Aurore over variety Siete Cerros in leaf area, leaf area index (LAI), plant height and number of tillers per plant may be explained by the fact that these characters are genetically controlled. Crop growth was better in 1989-90 than in 1990-91 when daily air temperatures were generally high, especially during the grain filling period. Similar finding was reported by Ford *et al.*(1976) who reported reduction in wheat growth under high temperatures.'

5.2.2 Dry matter accumulation and partitioning

It was observed that dry matter accumulation by the two wheat varieties varied with sampling periods in both years. Florence Aurore however had a greater dry matter accumulation at harvest in both years. The increase in dry matter accumulation by both varieties with advancement in crop age until maturity shows that both varieties continued to absorb nutrients and synthesize carbohydrates until maturity (Pal, 1966; Lal and Sharma, 1973),. Varietal differences in dry matter accumulation in wheat has been reported by Asana and Williams (1965); McNeal *et al.*(1966); Asana and Sarin (1968); Lal and Sharma (1973) and Lal *et al.*(1978). The low level of dry matter accumulated in the 1990-91 growing season may be due to the high temperatures which persisted throughout the season and which adversely affected crop growth. Similar finding were reported by Ford *et al.*, (1980) who found that high temperatures reduced wheat crop growth and dry matter accumulation.

The present result shows that leaf and stem dry matter of both varieties increased with advancement in crop age but declined after reaching a maximum level.

These loss in weight by the leaf and stem may be attributed to the translocation of assimilates to the spike since the decrease in leaf and stem dry matter was accompanied by an increase in spike dry matter. Leaf losses through senescence and death also contributed to the loss of leaf dry weight with increase in crop age. Similar varietal differences in dry matter partitioning were reported by McNeal *et al.*(1966); Lal and Sharma (1973); Lal *et al.*(1978); Waldren and Flowerday (1979) and Bauer *et al.*(1987) who attributed losses in dry matter to the translocation of photosynthates from the leaf and stem to the spike. Significant varietal differences were observed in dry matter partitioning. Translocation of dry matter from leaf and stem to the spike was higher in Siete Cerros than in Florence Aurore. This was ultimately reflected in the higher harvest index and grain yields of variety Siete Cerros. This varietal difference was said to be due to the introduction of Norin 10 dwarfing genes into Siete Cerros which is responsible for its reduced vegetative growth and greater partitioning of photosythates to the spikes. Such findings were reported by McClung *et al.*(1986); Perry and D'Anthuono (1989) and Feingold *et al.*(1990) who found that higher yield potential in wheat is associated with efficient partitioning of dry matter in favour of the reproductive organs.

5.2.3 Yield and yield components

Siete Cerros out-yielded Florence Aurore by margins of 15 and 22 per cent in 1989-90 and 1990-91 respectively, though these differences were significant only in 1990-91. The higher grain yields of Siete Cerros is attributed to its higher number of spikelets and grains per spike. The observed superiority of Siete Cerros (awned) over Florence Aurore (awnless) may be due to one or more of the following reasons; (i) introduction of Norin 10 dwarfing genes which reduced excessive vegetative growth

and enhanced partitioning of more dry matter to the developing spike and (ii) the direct role of awns in the supply of assimilates through increase in the photosynthetic rate of the wheat ear (Patterson *et al.*, (1962; Teare *et al.*, 1972; Olugbemi *et al.*, 1976a, 1976b). Similar varietal differences had been reported by Angus and Sage (1980); Olugbemi *et al.*(1981); Gents and Kiyomoto (1985); Perry and D'Anthuono (1989) and Feingold *et al.* (1990) who found that the yield superiority of the semi-dwarf variety is due to a better allocation of dry matter into the reproductive organs.

5.2.4 Nitrogen uptake and distribution

The decline in N uptake in 1989-90 after 70 DAS may be due to crop senescence resulting in N losses from the leaf and stem. The lower N uptake in 1989-90 may be due to the dilution effect resulting from a greater dry matter production since total dry matter was higher in 1989-90 than in 1990-91. The higher N uptake by Florence Aurore may be due to its greater potential for soil and fertilizer N extraction or its higher N requirement for growth. McNeal *et al.* (1968); Woodruff (1972); Austin *et al.* (1977) and Day *et al.*(1985) had reported significant genetic variations in most of the component attributes determining N uptake and that N uptake of the whole plant was more closely related to dry weight than to nitrogen concentration. Dry matter was found to be important in nitrogen accumulation (Day *et al.*, 1985).

The present result suggests that varietal differences exists in wheat with respect to the proportionate allocation of nitrogen to the component parts of the wheat plant. Florence Aurore had more nitrogen in all its component parts at all stages of growth than did Siete Cerros. This difference may be due to differing genetic capacities of the varieties for N uptake and allocation of plant nitrogen to component parts of the plant. Varietal differences in efficiency of translocation of N from plant to

the grain have been reported by Johnson *et al.* (1967); Lal *et al.* (1978) and Halloran and Lee (1979). Halloran and Lee (1979) reported significant differences between cultivars in the N percentages of culm, glume and rachis tissue in the mature plant. The rapid increase in spike nitrogen of both varieties which was accompanied by a decrease in leaf and stem nitrogen indicate that N was translocated from leaf and stem to the spike. The results are similar to those of McNeal *et al.* (1968); Lal and Sharma (1973); Lal *et al.* (1978) and Feingold *et al.* (1990) who reported that a rapid increase in N accumulation of the kernels was accompanied by its decrease in stem and leaf and that the losses owing to translocation from different plant parts to the grains varied depending of variety.

5.2.5 Nutrient uptake and distribution at harvest

Significant varietal differences in nutrient uptake at harvest were observed. The higher uptake of these nutrients by Florence Aurore may be attributed to its higher dry matter production. The low phosphorus uptake by both wheat varieties may be attributed to the low basal application of phosphorus (40 kg P_2O_5 ha^{-1}) as against the recommended rate (40 kg P_2O_5 ha^{-1}) for Kadawa. The varietal differences in leaf, stem and spike uptake may be attributed to differences in their dry matter partitioning abilities. While Florence Aurore had greater leaf and stem nutrient concentration, Siete Cerros had greater spike nutrient concentration.

5.2.6 Grain crude protein content

Varietal differences in grain crude protein content were observed. The greater distribution of plant N to the spike of Florence Aurore may be responsible for its higher grain crude protein content (Day *et al.*, 1985). The lower grain crude protein content

of Siete Cerros may be attributed to the dilution of grain N by grain dry matter as a consequence of its higher grain yield. Varietal differences in grain protein content were reported by Austin *et al.*(1977); Terman (1979); McClung *et al.* (1986), and Feingold *et al.* (1990) who reported cultivar variations in grain protein concentrations.

The lower grain crude protein content in 1989-90 may be attributed to a dilution of grain N by grain dry matter as a consequence of higher grain yields.

5.3 Effect of Row-Spacing

5.3.1 Growth characters

The highest tiller production associated with the 10 cm row-spacing may be attributed to low interplant competition between the wheat plants along the rows thereby providing an environment conducive for tiller production. The tallest plants at 30 cm row-spacing may be due to interplant competition in the denser stands while the shorter plants of both wheat varieties in 1990-91 compared to those of 1989-90 may be due to stress resulting from the high temperatures that prevailed during the 1990-91 growing season. According to Kinra *et al.* (1963) row-spacings wider than 17 cm resulted in fewer culms per square metre may be attributed to inhibition of tillering due to close intra-row spacing of plants in the wider spaced inter-rows. The increase in plant height with increase in inter-row spacing is due to interplant competition.

5.3.2 Dry matter accumulation and partitioning

Significant differences between row-spacings in dry matter accumulation were observed. The higher dry matter accumulated at closer row-spacings may be attributed to increased tiller production resulting from reduced interplant competition. Similar

finding was reported by Roth *et al.* (1984) who found greater yield increases when row-spacings were decreased. They attributed this to the production of more tillers per unit area.

Though leaf, stem and spike dry matter were greatest at 20 cm row-spacing in 1989-90 and 10 and 20 cm row-spacings at par in 1990-91, the percentage composition of dry matter in the component parts did not change with changes in row-spacings.

5.3.3 Yield and yield components

Though differences between row-spacings in grain yields were not significant, the highest grain yield at 30 cm row-spacing is associated with spike length, number of spikelets per spike, number of grains per spike and 1000-grain weight which were greatest at 30 cm row-spacing. This observation does not agree with the findings of most workers who reported that grain yields increased with decrease in row-spacings. Holliday (1963) reported increases in grain yield by reducing inter-row spacing. He suggested that increased interplant competition at wider row-spacing (at the same seed rate) may reduce the number of spikes per unit area and grain weights. Dubey and Lal (1970); Roth *et al.* (1984) and F[illegible] 988) reported increases in grain yield with decrease in row-spacing. They attributed this to the production of more productive tillers per unit area resulting from reduced inter plant competition. The difference observed in this study may be attributed to poor seed distribution when drilled by hand in narrower rows (10 and 20 cm). Hand drilling was therefore most efficient at 30 cm row-spacing.

5.3.4 Nitrogen uptake and distribution

Significant effect of row-spacing on N uptake and distribution in component plant parts were observed in this study but there were no definite trends in the relationship between row-spacing and N uptake and distribution. The relationship between row-spacing and N uptake in 1990-91 when the 10 and 20 cm row-spacings were at par in N uptake is similar to that reported by Reinerton *et al.*(1984) who found that 20 cm row-spacing increased total N uptake when compared to 30 and 40 cm rows. The percentage of N in component parts did not change with changes in row-spacings.

5.3.5 Nutrient uptake and distribution at harvest

Effect of row-spacing on the uptake of N, P, K and Mg at harvest was significant, even though no definite trend was established in the relationship between their uptake and row-spacings. The distribution of the nutrient elements in component plant parts is closely associated with their dry matter content; spike uptake of both wheat varieties was greatest followed by stem and leaf.

5.4 Effect of Nitrogen

5.4.1 Growth characters

It was observed in both years of the present study that number of tillers per plant, plant height, leaf area and leaf area index increased significantly with increase in N levels. The greater effect of incremental N on all growth characters in 1989-90 compared to 1990-91 may have been due to stress created by the high daily temperatures in the 1990-91 growing season which might have reduced the plant growth cycles. Similar effects of incremental N levels on growth characters were

reported by Khalifa (1973); Pearman *et al.*(1977); Graham *et al.*(1983); Puri *et al.*(1988) and Jadhav (1990). According to Pearman *et al.*(1977) leaf area at and after anthesis was increased throughout the range of N of 0 to 200 kg ha^{-1}. Puri *et al.*(1988) reported that increasing N rate increased tiller number up to 360 kg N ha^{-1} but the increments in tiller number beyond 180 kg N ha^{-1} were of progressively smaller magnitude.

5.4.2 Dry matter accumulation and partitioning

The study established that there was variability between growth stages and years in the effect of incremental N on dry matter accumulation. The observed increase in dry matter accumulation with incremental N may be due to increased photosynthetic apparatus by increasing tillering, leaf area and chlorophyll concentration in the wheat plants to capture energy and hence produce more dry matter. This result corresponds with those of Singh and Seth (1978) and Jadhav (1990). Singh and Seth (1978) reported that dry matter production of a dwarf wheat cultivar increased with applied N and with increases in N rates from 80-200 kg ha^{-1}. Jadhav (1990) also reported that dry matter increased with increase in N fertilizer application. The increase in leaf, stem and spike dry matter with incremental N may be attributed to increased tillering and increase in leaf area. This is similar to the findings of Singh and Seth (1978) who reported that dry matter production by different plant parts increased with increase in applied N.

5.4.3 Yield and yield components

Seasonal variations in the effect of incremental N levels on grain yields were observed. This difference in response may be attributed to the seasonal variations in

air temperature. Air temperatures were lower during the 1989-90 growing season thereby providing a conducive environment for wheat growth and greater utilization of soil and fertilizer N. The increase in grain yield with incremental N is attributed to the corresponding increases in spikelets per spike, number of grains per spike and 1000-grain weight. Results of this study agree with those of others. Sharma *et al.*(1970) had earlier found that irrespective of variety, grain yields increased with N application. Power and Alessi (1978) also reported that N fertilizer application significantly increased grain yield with additions of 80-270 kg N ha^{-1}. They attributed such an increase to increase in number of ears per hectare and reduced tiller mortality. Olugbemi *et al.*(1984) found at Kadawa, Nigeria that 100 kg N ha^{-1} increased grain yield over 50 kg N ha^{-1} by 10% but was not significantly different from that of 150 kg N ha^{-1}. Balasubramanian and Singh (1982) reported that grain and dry matter yields increased significantly with increasing levels of N application. Entz and Fowler (1989) reported that increase in grain yields due to incremental N was attributed to a higher number of kernels per m^2.

5.4.4 Nitrogen uptake and distribution

The present study show an increase in N uptake with increase in N levels. This is closely associated with increase in dry matter production with increase in N levels. This observation is in agreement with those of Singh *et al.*(1979) and Balasubramanian and Singh (1982). Singh *et al.*(1979) reported that N uptake increased with increase in N rate but was not significantly affected by N rates greater than 80 kg N ha^{-1}. According to Balasubramanian and Singh (1982) N uptake of wheat at different stages increased significantly with increasing levels of N application.

The increase in the N uptake of component plant parts with incremental N is attributed to increase in dry matter production. This observation is similar to that of Grewal (1989) who found from a two-years study that N concentra-tion of grain and straw increased up to 120 kg N ha^{-1} while total N uptake increased up to 180 and 120 kg N ha^{-1} in the first and second years respectively.

5.4.5 Nutrient uptake and distribution at harvest

Observed increase in the uptake of N, P, K, Ca and Mg at harvest with incremental N is due to increase in dry matter production. The highest nutrient uptake by the spike with incremental N is associated with its dry matter content at harvest. This result agrees with those of Sarandon and Caldiz (1990) who reported that N distribution at maturity were significantly affected by N supply. Grewal (1989), however reported that the concentration and total uptake of P and K in wheat grain and straw was not affected by N application.

5.4.6 Grain crude protein content

It was observed that grain crude protein content increased with N levels. This is associated with greater uptake of fertilizer nitrogen and its translocation to the spike with increase in fertilizer nitrogen. This make more nitrogen available in the grain for protein synthesis thereby resulting in an increase in the grain crude protein content. The result agrees with those of Batey and Reynish (1976); Balasubramanian and Singh (1982) and Okoh *et al.*(1985) who reported increases in grain protein content with increase in N.

5.5 Effect of Time of N Application

5.5.1 Yield and yield components

The highest grain yield associated with split application of N at seeding plus tillering is attributed to the corresponding increases in spike length and number of spikelets per spike. The N applied at the tillering stage increased vegetative and grain growth resulting in higher grain yield. This result agrees with those of Hamid (1973); Hamid and Sarwar (1976) and Randhawa *et al.*(1976) who reported that two split applications (at seeding and tillering) was most productive in grain yield.

5.5.2 Grain crude protein content

It was observed that crude protein content was highest with split application of N at seeding time and flag leaf stage. This is because most of the N applied at the flag leaf stage is translocated into the developing spike thereby providing the N needed for protein synthesis. Similar results were reported by Koch and Mengel (1977); Hunter and Stanford (1973) and Okoh *et al.*(1985) who found that grain protein content increase with increase in N applied at the reproductive stage.

5.6 Interactions

5.6.1 Variety x row-spacing

The interaction between variety and row-spacing was significant on leaf area, leaf area index, dry matter accumulation and uptake of N, P and Mg. The interaction is due to the morphological differences of the varieties. Though no definite trend was established in the course of this study, Florence Aurore which has greater vegetative

growth is more prone to interplant competition at wider row-spacings. The two wheat varieties differ in growth with changes in row-spacing.

5.6.2 *Variety x nitrogen*

The interaction between variety and N was significant on grain yield, spike length, spikelets per spike and number of grains per spike. Grain yield of Siete Cerros was significant up to 180 kg N ha^{-1} and 120 kg N ha^{-1} for Florence Aurore. Spikes of Florence Aurore were significantly longer than those of Siete Cerros at 120 and 180 kg N ha^{-1}. However, Siete Cerros had significantly more spikelets per spike and grains per spike at the same levels of N. Variety x nitrogen interaction was also significant on leaf area, leaf area index, plant height and dry matter accumulation. These interactions indicate that the two wheat varieties differ in their ability to absorb and utilize applied nitrogen. The significant interaction between variety and nitrogen in the uptake of N, P and K is due to enhance vegetative growth at higher levels of N, resulting in greater dry matter production.

5.6.3 *Row-spacing x nitrogen*

Significant row-spacing x nitrogen interactions were observed on leaf area, leaf area index and dry matter accumulation. Also significant were those on spike length and number of grains per spike. The differences between row-spacings were however greater at higher levels of N. The observed differences may be due to increased vegetative growth at higher N levels thereby creating differing levels of interplant competition at the respective row-spacings.

5.6.4 *Variety x time of nitrogen application*

The nitrogen x time of N application interaction was significant only on grain crude protein content. Varietal differences were significant with N split between seeding time and flag leaf stage with Florence Aurore producing higher grain crude protein.

5.6.5 *Nitrogen x time of N application*

The interaction between N levels and time of N application was significant for grain crude protein content. The interaction was significant when N was split between seeding time and tillering stage at 120 and 180 kg N ha^{-1} when split between seeding time and flag leaf stage.

5.7 Regression Studies

Results of the regression studies show that Siete Cerros was more responsive to N fertilizer application than did Florence Aurore. The response ratios in 1989-90 and combined analysis show that Siete Cerros has a higher efficiency in grain production for every kilogram of nitrogen applied. The harsh weather conditions caused by high temperatures in 1990-91 were responsible for the poor response ratios. The results also show that the optimum N requirement for both varieties is beyond the highest level of N (180 kg N ha^{-1}) used for the study. This agrees with the finding of Gehl *et al.* (1990) who reported an increase in grain yield with increase in N fertilization but the level required for maximum grain yield varied among cultivars.

The high optimum N requirement indicate that there was a higher N demand under the harsh growth conditions as a result of the high temperatures. The quantity

of N required for the very short growth duration is therefore higher to enable for the attainment of an optimum production.

5.8 Correlation and Path-Coefficient Analysis

The correlation coefficients highlighted the importance of yield components studied in determining wheat yield. The result is similar to that of Bhutta *et al.* (1980) who computed simple correlation coefficient among yield per plant, 1000-grain weight, grains per spike and fertile tillers and found high positive correlation for relationship between yield and number of grains per spike.

The high positive direct effect path-coefficient of spikelets per spike, which is more than the total correlation coefficient and the relatively unimportant indirect effect path-coefficient values indicated that the majority of the variation in grain yield was accounted for by its association with number of spikelets per spike. Path analysis was able to show that the high simple correlation coefficients of yield versus effective tillers, spike length, grains per spike and 1000-grain weight are not due to their direct effects but indirect effects through spikelets per spike. The apparent contradiction in correlation and direct path-coefficient values is due to the fact that the correlations simply measure mutual association without regards to causation, whereas the path-coefficient analysis specifies the causes and measures their relative importance. Asana and Mani (1958) also emphasized the importance of spikelets per spike. They believed that with adequate water supply spikelets per spike had the most potent effect on grain yield. Bhatt (1973) found from a simple correlation and path-coefficient analysis that spike number and kernel weight are important primary components of grain yield in wheat.

Chapter 6

SUMMARY AND CONCLUSION

6.1 Summary

Two field experiments were conducted side by side at the irrigation Research Station, Kadawa during the 1989-90 and 1990-91 dry seasons to investigate the effects of varieties (Siete Cerros and Florence Aurore 8193), row-spacings (10, 20 and 30 cm) and nitrogen levels (0, 60, 120 and 180 kg N ha^{-1}) on growth, yield, nutrient uptake and distribution in component plant parts; and also to deter-mine the effects of varieties (Siete Cerros and Florence Aurore 8193), nitrogen levels (60, 120 and 180 kg N ha^{-1}) and times of N application (seeding, seeding + tillering and seeding + flag leaf stage) on yield, yield components and grain crude protein content.

In experiment I, variety Siete Cerros out-yielded variety Florence Aurore by margins of 15, 22 and 17 percent in 1989-90, 1990-91 and mean of the two years respectively. This is attributed to the significantly higher number of grains per spike of Siete Cerros. Florence Aurore however produced significantly heavier grains, more tillers, taller plants, greater leaf area, and leaf area index and greater dry matter than did Siete Cerros. Total dry matter accumulated by both varieties increased with crop age but leaf and stem dry matter decreased after 70 DAS while spike dry matter continued to increase till maturity. Averaged over the two years of the study, percentage dry matter of leaf, stem and spike at harvest were 9, 40 and 51 per cent for Siete Cerros and 9, 49 and 43 per cent for Florence Aurore. There was no significant difference between the varieties in total nitrogen uptake and distribution into component plant parts. Leaf and stem nitrogen decreased after 70 DAS while spike nitrogen increased till maturity. Florence Aurore had significantly greater uptake of N,

P, K, Ca and Mg than did Siete Cerros at harvest. The spikes of both wheat varieties had the greatest uptake of N, P, K, Ca and Mg.

Even though row-spacing did not cause significant differences in grain yield, in both years, the two years mean showed that 20 and 30 cm row-spacings were at par but significantly higher than the 10 cm row-spacing. This was closely associated with number of spikelets per spike, leaf area and leaf area index whose means were highest at 20 and 30 cm row-spacings. Dry matter accumulation, uptake of N, P, K, Ca and Mg and their distribution into plant parts were greatest at the 20 cm row-spacing.

Grain yield was significantly increased with nitrogen levels up to 180 kg N ha^{-1} though increases in number of spikelets per spike, grains per spike and 1000-grain weight were significant up to 120 kg N ha^{-1}. Dry matter accumulation and uptake of N, K, Ca and Mg increased significantly with nitrogen levels up to 180 kg N ha^{-1} while P uptake was significant up to 120 kg N ha^{-1}.

The effect of variety x nitrogen interaction was significant on plant height, leaf area, leaf area index, dry matter accumulation, spike length and number of grains per spike. Variety x row-spacing interaction was significant on leaf area, leaf area index, dry matter accumulation, N and Mg uptake at harvest in 1989-90 and P uptake at harvest. Interaction effect of nitrogen x row-spacing was significant on leaf area, leaf area index, dry matter accumulation, number of grains per spike and the uptake of N, P and K.

Variety Siete Cerros was more responsive to nitrogen levels than Florence Aurore, having a response ratio of 12.9 compared to 10.8 for Florence Aurore. The quantity of fertilizer nitrogen required to produce maximum grain yield varied among varieties and years.

There was a significant positive correlation between grain yield and a number of yield components. The high effects of effective tillers, spike length, grains per spike and 1000-grain weight on grain yield was due to their indirect effects through number of spikelets per spike.

In experiment II, variety Siete Cerros out-yielded variety Florence Aurore by margins of 24 and 34 per cent in 1989-90 and 1990-91 respectively. Total dry matter, harvest index, spikelets per spike and grains per spike of Siete Cerros were also significantly greater than that of Florence Aurore. Florence Aurore, however, produced longer spikes and heavier grains. The grain crude protein content of Florence Aurore was significantly higher than that of Siete Cerros.

Increases in nitrogen level caused significant increases in grain and straw yields, total dry matter, spike length, spikelets per spike, grains per spike, 1000-grain weight and grain crude protein content up to 180 and 120 kg N ha^{-1} in 1989-90 and 1990-91 respectively.

In 1989-90, split application of nitrogen at seeding time and tillering stage was significantly better than other times of application in grain and straw yields, total dry matter, and spike length. A single application at seeding and split at seeding time and tillering stage were at par in spikelets per spike but significantly higher than split at seeding time plus flag leaf stage. Times of nitrogen application did not cause significant differences in yield and yield components in 1990-91. Application of nitrogen at seeding time and flag leaf stage produced significantly more grain crude protein than other times of application.

6.2 Conclusion

Based on the results of these experiments, it can be concluded that:

1. The higher grain yield of the awned Siete Cerros over the awnless Florence Aurore 8193 is attributed to its ability to translocate more assimilates to the spike thereby resulting in a higher number of spikelets and grains per spike.
2. The total N uptake and distribution in Siete Cerros and Florence Aurore 8193 show that the greater gain crude protein content of Florence Aurore is attributed to its ability to translocate more plant N to the spike.
3. The 20 cm row-spacing was appropriate for crop growth, grain yield and nutrient uptake.
4. Crop growth, grain yield and nutrient uptake increased with N levels over the range of 0 - 180 kg N ha^{-1}. The increases were most significant between 0 and 60 kg N ha^{-1}.
5. Response of wheat to N levels vary with seasonal changes in temperatures.
6. Grain yield is greatest when N is split between seeding time and tillering stage.
7. Grain crude protein content is greatest when N is split between seeding time and tillering stage.
8. The high direct effect of effective tillers, spike length, grains per spike and 1000-grain weight on grain yield is due to their indirect effects through number of spikelets per spike.

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APPENDICES

Appendix 1

Mean maximum and minimum monthly temperatures (^{0}C) at Irrigation Research Station, Kadawa, 1989-91

	November	December	January	February	March	April
1989-90						
Max.	31.8	28.5	28.8	27.6	30.1	38.0
Min.	14.9	13.1	14.0	13.1	15.2	23.0
Mean	23.4	20.8	21.4	20.4	22.7	30.5
1990-91						
Max.	34.0	34.3	27.4	33.3	33.1	37.1
Min.	18.8	16.3	14.2	16.9	19.7	23.5
Mean	26.4	25.3	20.8	25.1	26.4	30.3

Appendix 2

Maximum and minimum daily temperatures (^{0}C) at Irrigation Research Station, Kadawa for November 1989 through April, 1990.

Day of month	November		December		January		February		March		April	
	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
1	31	16	27	14	32	12	29	14	28	13	37	20
2	31	14	32	16	32	12	29	14	29	14	36	17
3	32	16	31	14	29	13	25	13	30	16	38	16
4	32	19	29	14	28	14	27	12	31	16	38	18
5	32	19	29	14	31	13	25	16	33	15	39	16
6	33	16	27	13	29	14	23	13	37	13	39	21
7	33	16	28	12	27	13	26	11	32	16	38	19
8	34	16	28	12	27	13	26	11	30	14	39	19
9	32	16	31	13	24	16	26	12	29	14	37	19
10	32	16	29	11	24	15	26	12	29	14	37	21
11	31	15	31	11	27	13	25	12	29	14	37	19
12	31	16	33	9	27	13	25	12	27	13	38	24
13	30	14	33	12	28	11	26	13	28	13	39	23
14	30	14	31	15	29	13	29	14	29	13	39	23
15	29	21	32	14	30	11	30	13	30	15	39	22
16	31	13	32	13	31	14	32	16	32	17	39	28
17	30	13	28	12	32	16	32	17	33	16	38	32
18	32	14	26	12	32	16	32	16	32	16	38	27
19	33	14	26	12	32	16	32	16	32	16	38	27
20	33	14	26	12	34	15	29	15	29	18	36	28
21	33	14	27	13	33	13	29	14	27	13	38	28
22	33	13	26	13	35	14	29	13	29	13	38	28
23	33	13	26	12	33	15	30	13	29	14	40	20
24	32	16	26	13	31	14	28	11	29	14	39	27
25	32	17	23	13	30	14	27	10	30	14	39	22
26	32	15	25	12	22	14	25	11	30	14	39	23
27	31	11	27	13	25	13	27	11	32	17	38	26
28	32	11	29	13	22	16	27	11	34	17	38	23
29	32	13	29	17	23	16	-	-	36	18	39	24
30	32	13	28	14	25	14	-	-	21	19	39	23
31	-	-	28	12	29	18	-	-	22	20	-	-
x	31.8	14.9	28.5	13.1	28.8	14.0	27.6	13.1	30.1	15.2	38.0	23.0

Appendix 3

Maximum and minimum daily temperatures (°C) at Irrigation Research Station, Kadawa for November 1990 through April, 1991.

Day of month	November		December		January		February		March		April	
	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
1	34	28	34	18	26	13	31	14	33	18	37	23
2	35	24	35	18	24	11	29	14	34	20	38	24
3	36	22	35	19	23	12	28	16	33	20	38	26
4	34	24	35	17	25	13	29	14	32	21	37	24
5	35	16	33	17	28	16	33	16	31	19	37	24
6	35	16	33	16	29	17	34	17	28	17	38	24
7	33	16	33	16	30	13	32	16	29	16	38	22
8	33	17	34	17	28	14	34	17	29	17	37	22
9	34	16	34	16	29	14	32	15	29	16	35	27
10	34	17	35	16	27	14	30	14	31	16	33	21
11	35	16	34	16	29	16	28	16	33	17	38	22
12	35	17	36	19	24	13	33	18	35	18	35	23
13	35	18	37	18	26	13	34	16	36	21	37	24
14	35	23	35	17	25	14	33	17	36	24	37	22
15	35	24	36	18	23	13	35	17	37	23	36	23
16	34	24	36	17	28	13	36	18	28	22	37	23
17	35	24	35	17	29	13	37	18	32	22	37	23
18	34	22	35	17	28	14	36	18	33	21	38	25
19	34	16	33	16	27	13	35	17	33	19	38	26
20	31	16	34	17	27	16	35	18	34	21	38	24
21	32	16	34	16	28	13	35	19	36	22	38	25
22	32	16	34	16	26	14	37	15	32	23	37	22
23	33	16	35	17	27	14	37	19	33	22	38	22
24	34	16	36	18	29	16	37	18	35	21	38	22
25	34	16	35	13	28	14	35	17	33	17	39	25
26	34	16	34	13	26	16	32	18	34	18	33	26
27	34	18	34	12	26	17	33	18	36	19	38	22
28	33	17	32	14	29	13	33	19	33	18	39	22
29	33	18	33	16	30	15	-	-	35	19	37	23
30	34	19	32	16	32	16	-	-	37	21	38	24
31	-	-	33	12	32	16	-	-	37	22	-	-
x	34.0	18.8	34.3	16.3	27.4	14.2	33.3	16.9	33.1	19.7	37.1	21.5

Appendix 4

Mean sum of squares for tillers/plant, plant height and effective tillers as affected by variety, row-spacing and nitrogen level: 1989-90

Source of variation	df	Tillers/ plant	Plant height (cm)	Effective tillers (cm^2)
Replications	3	0.74	420.33	30622
Variety (N)	1	6.00*	21066.34**	2763
Row-spacing (R)	2	3.03	124.72	63028*
VxR	2	0.22	139.23	27310
Residual	15	1.09	124.55	13500
Nitrogen level (N)	3	17.63	10247.14**	193297**
RxN	6	0.86	37.86	4158
VxN	3	0.64	786.67**	1496
VxRxN	6	1.86	170.91**	1228
Residual	54	0.49	41.39	5538
Total	)5	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 5

Mean sum of squares for tillers/plant, plant height and effective tillers as affected by variety, row-spacing and nitrogen level: 1990-91

Source of variation	df	Tillers/ plant	Plant height (cm)	Effective tillers (cm^2)
Replications	3	0.18	56.09	9518
Variety (N)	1	2.34**	14359.49**	677
Row-spacing (R)	2	0.07	23.04	116887
VxR	2	0.22	64.27	6071
Residual	15	0.17	42.11	4359
Nitrogen level (N)	3	24.09	4757.69**	107994**
RxN	6	0.16	30.28	3577
VxN	3	0.45	176.27**	2299
VxRxN	6	0.25	23.78	1774
Residual	54	0.24	42.21	2376
Total	95	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 6

Mean sum of squares of combined analysis for tillers per plant, plant height and effective tillers as affected by variety, row-spacing and nitrogen level: 1989-91

Source of variation	df	Tillers/ plant	Plant height (cm)	Effective tillers (cm^2)
Replications	3	0.70	240.28	1.37×10^4
Year (Y)	1	0.63	4024.17*	3.43×10^5*
Residual	3	0.21	236.16	2.65×10^4
Variety (V)	1	7.92**	35105.49**	3.09×10^3*
Row-spacing (R)	2	1.29	66.06	1.06×10^5**
VxR	2	0.11	18.99	2.00×10^4
YxR	2	1.82	81.70	7.43×10^4**
YxV	1	0.42	320.33	352
YxRxV	2	0.33	184.51	1.36×10^4
Residual	30	0.63	83.33	8.93×10^3
Nitrogen level (N)	3	41.42**	14371.14**	2.94×10^5
RxN	6	0.62	38.30	3.96×10^3
VxN	3	1.01	834.96**	1.46×10^3
YxN	3	0.30	633.68**	7.14×10^3
VxRxN	[illegible]	0.69	120.71*	2.14×10^3
VxRxN	6	0.40	29.84	3.77×10^3
YxVxN	3	0.09	126.98*	2.34×10^3
Residual	114	0.42	43.49	3.79×10^3
Total	191	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 7

Interaction of variety and row-spacing on leaf area per shoot (cm^2) at Kadawa, 1989-90

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS	
10	45.6	41.9
20	47.6	59.2
30	53.3	53.3
LSD (0.05)	5.17	
	56 DAS	
10	24.9	35.2
20	21.0	47.4
30	31.0	43.0
LSD (0.05)	6.67	
	70 DAS	
10	11.5	8.8
20	5.2	15.4
30	16.5	19.9
LSD (0.05)	4.39	

Appendix 8

Interaction of variety and row-spacing on leaf area per shoot (cm^2) at Kadawa, 1990-91

Row-spacing (cm)	Varieties	
	Siete Cerros	Florence Aurore
	42 DAS	
10	22.1	31.6
20	30.7	29.5
30	25.3	34.3
LSD (0.05)	5.68	
	56 DAS	
10	33.4	38.8
20	32.0	38.0
30	31.4	43.7
LSD (0.05)	4.99	

Appendix 9

Interaction of row-spacing and nitrogen level on leaf area per shoot (cm^2) at Kadawa, 1989-90

Nitrogen level (kg N ha^{-1})	Row-spacing		
	10	20	30
		56 DAS	
0	20.4	19.3	14.5
60	21.2	30.2	34.7
120	35.2	35.5	47.7
180	33.4	51.9	51.2
LSD (0.05)		6.41	
		70 DAS	
0	2.8	1.2	5.4
60	5.6	5.4	11.2
120	10.5	11.5	21.1
180	21.8	23.1	35.1
LSD (0.05)		4.39	

Appendix 10

Interaction of row-spacing and nitrogen level on leaf area per shoot (cm^2) at Kadawa, 1990-91

Nitrogen level (kg N ha^{-1})	Row-spacing		
	10	20	30
		42 DAS	
0	10.3	15.1	18.3
60	26.6	23.5	28.3
120	31.4	35.2	31.9
180	39.0	46.5	40.7
LSD (0.05)		4.37	
		56 DAS	
0	15.3	17.4	26.2
60	29.9	27.6	42.9
120	42.6	39.5	48.9
180	56.6	55.6	52.2
LSD (0.05)		4.42	

Appendix 11

Interaction of variety and nitrogen level on leaf area per shoot (cm^2) at Kadawa, 1989-91

Nitrogen level (kg N ha^{-1})	Varieties	
	Siete Cerros	Florence Aurore
	56 DAS (1989-90)	
0	13.4	22.8
60	21.2	36.2
120	31.3	47.7
180	36.7	60.9
LSD (0.05)	5.22	
	42 DAS (1990-91)	
0	12.9	16.3
60	23.1	29.1
120	31.2	34.5
180	37.0	47.1
LSD (0.05)	3.57	
	56 DAS (1990-91)	
0	18.1	21.2
60	32.8	34.1
120	41.6	45.7
180	49.9	59.6
LSD (0.05)	3.62	
	70 DAS (1990-91)	
0	15.3	13.0
60	21.8	22.7
120	30.3	29.6
180	34.7	43.4
LSD (0.05)	2.76	

Appendix 12

Mean sum of squares for leaf area per shoot (cm^2) at various growth stages as affected by variety, row-spacing and nitrogen level, 1989-90

Source of variation	df	Days after sowing (DAS)		
		42	56	70
Replications	3	0.40	18.68	218.53
Varieties (V)	1	89.13	6344.00**	323.03**
Row-spacings (R)	2	1103.00**	391.93*	679.35**
VxR	2	560.68*	618.26**	333.02**
Residual	15	47.25	78.35	34.05
Nitrogen level (N)	3	8716.40**	4251.89**	2538.68**
VxN	3	190.58*	222.24**	40.21
RxN	6	144.48*	214.76**	50.00
VxRxN	6	84.57	173.58**	167.82**
Residual	54	40.17	30.90	15.46
Total	95	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 13

Mean sum of squares for leaf area per shoot (cm^2) at various growth stages as affected by variety, row-spacing and nitrogen level, 1990-91

Source of variation	df	Days after sowing (DAS)		
		42	56	70
Replications	3	5.86	25.51	270.46
Varieties (V)	1	786.04**	492.77**	69.53
Row-spacings (R)	2	103.59	532.35**	602.10**
VxR	2	289.75*	39.42	64.76
Residual	15	56.54	43.65	48.44
Nitrogen level (N)	3	3210.11**	5364.50**	2727.23**
VxN	3	60.04	78.23**	142.80**
RxN	6	77.58	169.71**	18.19
VxRxN	6	79.47	187.00**	72.90**
Residual	54	7.52	12.72**	21.56
Total	95	-	-	

* significant at P=0.05.
** significant at P=0.01.

Appendix 14

Mean sum of squares for leaf area index (LAI) at various growth stages as affected by variety, row-spacing and nitrogen level, 1989-90

Source of variation	df	Days after sowing (DAS)		
		42	56	70
Replications	3	0.01	0.05	0.60
Varieties (V)	1	0.28	18.50**	0.86*
Row-spacings (R)	2	1.92**	0.34	0.73**
VxR	2	1.69**	2.19**	1.04**
Residual	15	0.13	0.25	0.10
Nitrogen level (N)	3	24.72**	11.51**	6.88**
VxN	3	0.57**	0.58**	0.10
RxN	6	0.63**	0.47**	0.04
VxRxN	6	0.24	0.53**	0.46**
Residual	54	0.12	0.09	0.05
Total	95	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 15

Mean sum of squares for leaf area index (LAI) at various growth stages as affected by variety, row-spacing and nitrogen level, 1990-91

Source of variation	df	Days after sowing (DAS)		
		42	56	70
Replications	3	5.86	25.51	270.46
Varieties (V)	1	786.04**	492.77**	69.53
Row-spacings (R)	2	103.59	532.35**	602.10**
VxR	2	289.75*	30.42	64.76
Residual	15	56.54	43.65	48.44
Nitrogen level (N)	3	3210.11**	5364.50**	2720.23**
VxN	3	60.04**	78.23**	142.80**
RxN	6	77.58**	167.71**	18.19
VxRxN	6	79.47**	187.71**	72.90**
Residual	54	7.52	12.72	21.56
Total	95	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 16

Mean sum of squares for dry matter accumulation ($g.m^{-2}$) at various growth stages as affected by variety, row-spacing and nitrogen level, 1989-91

Source of variation	df	Days after sowing (DAS) 42	56	70	84	98
Replications	3	11753	68849	414613	106819	103510
Varieties (V)	1	101	108676*	231939**	209291**	803974*
Row-spacings (R)	2	75943**	494569**	257279**	112106**	89106
VxR	2	20563	111449*	112981*	60885	61583
Residual	15	6713	18547	23108	15192	158941
Nitrogen level (N)	3	201262**	676659**	2273935**	2192662**	352274**
RxN	6	8364**	20361*	78307**	92958**	29531
VxN	3	14314**	46985**	66769**	84714**	132800
VxRxN	6	15639**	44526**	111863**	40826*	220651
Residual	54	1911	7191	12846	12824	120285
Total	95	-	-	-		

* significant at P=0.05.
** significant at P=0.01.

Appendix 17

Mean sum of squares for dry matter accummulation (gm^2) at various growth stages as affected by variety, row-spacing and nitrogen level, 1990-91

Source of variation		Days after sowing (DAS)			
	df	42	56	70	84
Replications	3	46.9	3991	1814	31328
Varieties (V)	1	5772.2**	88246**	0	21606
Row-spacings (R)	2	26009.6**	125093**	237383**	122667**
VxR	2	16844.8**	19815	8220	29550*
Residual	15	619.0	6139	2445	6680
Nitrogen level (N)	3	61930.1**	784671**	1668237**	2629016**
RxN	6	8670.3**	11578**	48829*	21158**
VxN	3	1545.7**	12113**	105986**	29589**
VxRxN	6	3123.4**	21227**	55172**	53207**
Residual	54	329.1	3036	3439	5674
Total	95	-	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 18

Dry matter partitioning (gm^{-2}) at various growth stage of wheat as influenced by variety, row-spacing nitrogen level at Kadawa: 1989-90

Treatment	Leaf					Stem					Spike				
	Days After Sowing (DAS)					Days After Sowing (DAS)					Days After Sowing (DAS)				
	42	56	70	84	98	42	56	70	84	98	42	56	70	84	98
Variety															
Siete Cerros	82.3	79.2	58.5	42.8	50.1	205.8	268.8	324.7	220.3	222.9	100.7	222.2	368.5	441.0	
Florence Aurore	97.1	103.5	88.2	56.5	60.4	192.2	340.5	465	354.9	254.7	71.5	158.9	314.2	604.0	
SE ±	3.11	3.70	8.33	1.52	0.82	9.04	13.15	13.47	8.3	7.38	4.61	6.59	9.65	133.6	
LSD (0.05)	9.36	10.91	25.04	4.57	2.45	NS	39.51	120.7	116.3	22.18	13.85	19.8	29	NS	
Row-spacing (cm)															
10	84.9	79.3	59.7	44.4	48.6	171.8	240.3	336.1	256.2	241.9	53.9	156.6	312.2	368.0	
20	102.2	114.3	84.7	55.1	62.9	241.3	391.4	434.3	316.4	329.8	116.6	217.4	356.9	469.0	
30	82.1	80.3	75.6	49.3	54.2	283.8	282.9	414.1	291.3	294.7	77.9	197.5	354.9	730.0	
SE ±	3.81	4.53	10.21	1.86	1.00	11.00	16.10	16.50	10.16	9.04	5.65	8.06	11.82	163.6	
LSD (0.05)	11.44	13.62	NS	5.60	3.00	33.29	46.37	49.67	30.54	27.17	16.96	24.23	35.52	NS	
Nitrogen level (kg N ha^{-1})															
0	43.2	57.4	23.2	19.9	19.3	123.4	167.3	120.7	116.3	91.5	48.6	71.2	156.8	153.0	
60	82.4	[illegible]	[illegible]	[illegible]	53.5	195.8	284.3	411.1	246.2	264.7	75.9	193.7	309.9	385.0	
120	106.9	103.7	89.0	64.7	69.8	250.6	364.2	515.9	351.7	361.8	102.6	243.6	421.6	541.0	
180	126.5	131.4	96.6	70.8	78.3	266.1	402.4	531.7	436.2	436.1	117.3	253.7	477.1	1011.1	
SE ±	3.62	4.29	10.30	1.79	2.81	7.19	10.51	14.30	9.07	12.15	3.92	9.20	14.35	188.8	
LSD (0.05)	10.00	11.86	28.46	4.94	7.76	19.87	29.04	39.51	25.07	33.57	10.84	25.42	39.67	521.8	

Appendix 19

Dry matter partitioning (gm^{-2}) at various growth stage of wheat as influenced by variety, row-spacing and nitrogen level at Kadawa: 1990-91

Treatment	Leaf				Stem				Spike			
	Days After Sowing (DAS)				Days After Sowing (DAS)				Days After Sowing (DAS)			
	42	56	70	84	42	56	70	84	42	56	70	84
Variety												
Siete Cerros	54.4	66.2	53.0	34.2	80.9	217.8	249.1	193.2	100.0	195.7	384.3	
Florence Aurore	55.4	85.1	64.4	42.7	65.9	185.6	302.4	269.1	52.5	132.6	329.4	
SE ±	1.19		1.15	0.92	2.67	5.62	5.42	4.18	2.05	2.79	7.88	
LSD (0.05)	NS	NS	3.47	2.72	8.09	16.90	16.28	12.57	6.16	8.40	23.38	
Row-spacing (cm)												
10	55.1	98.1	59.1	38.8	72.3	213.4	312.8	247.5	80.8	181.3	378.8	
20	64.3	72.0	66.6	38.1	93.2	228.6	294.6	237.1	86.5	182.8	383.3	
30	45.3	56.9	50.3	38.4	53.9	163.2	219.7	208.9	61.4	128.4	308.3	
SE ±	1.46	10.47	1.41	1.12	3.28	6.89	6.64	5.12	2.51	3.42	9.65	
LSD (0.05)	3.39	31.45	4.25	NS	9.85	20.71	19.95	15.39	7.54	10.27	28.98	
Nitrogen level (kg N ha^{-1})												
0	27.8	25.8	22.3	18.9	36.8	79.3	110.5	94.6	25.8	72.5	152.6	
60	48.8	63.1	38.9	[illegible]	[illegible]	171.9	212.3	167.7	65.5	123.3	260.1	
120	61.1	88.9	71.9	45.9	83.0	246.9	329.9	291.2	93.2	211.3	433.8	
180	82.0	124.9	101.6	61.3	104.2	308.7	450.2	371.2	120.4	249.5	580.9	
SE ±	1.63	4.74	1.26	1.35	2.37	7.23	7.07	5.26	2.26	5.11	10.43	
LSD (0.05)	4.49	13.11	3.48	3.74	6.55	19.97	19.54	14.54	8.29	14.11	28.81	

Appendix 20

Mean sum of squares for grain yield, straw yield and harvest index as affected by variety, row-spacing and nitrogen level: 1989-90

Source of variation	df	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Replications	3	5.25×10^6	7.51×10^6	434.11
Variety (V)	1	2.71×10^6	7.02×10^6	400.98
Row-spacing (R)	2	1.09×10^6	3.09×10^6	197.26
RxV	2	2.45×10^5	3.40×10^6	72.62
Residual	15	8.50×10^5	2.83×10^6	93.07
Nitrogen level (N)	3	2.39×10^{7}**	8.31×10^{7}**	140.05*
RxN	6	1.62×10^5	1.73×10^5	55.15
VxN	3	3.50×10^5	1.16×10^6	32.96
VxRxN	6	1.78×10^5	2.36×10^6	83.96
Residual	54	3.65×10^5	1.22×10^6	52.00
Total	95	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 21

Mean sum of squares for grain yield, straw yield and harvest index as affected by variety, row-spacing and nitrogen level: 1990-91

Source of variation	df	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Replications	3	3.88×10^5	3.37×10^6	46.23
Variety (V)	1	1.09×10^6*	2.31×10^5	183.71
Row-spacing (R)	2	2.83×10^5	1.29×10^6	111.57
RxV	2	1.51×10^5	3.82×10^6	395.60*
Residual	15	1.48×10^5	1.26×10^6	88.62
Nitrogen level (N)	3	5.68×10^6**	2.67×10^7**	177.72*
RxN	6	9.37×10^4	4.90×10^5	62.22
VxN	3	1.24×10^5	8.10×10^4	57.05
VxRxN	6	9.92×10^4	8.42×10^5	65.83
Residual	54	7.69×10^4	4.43×10^5	54.27
Total	95	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 22

Mean sum of squares of combined analysis for grain yield, straw yield and harvest index as affected by variety, row-spacing and nitrogen level: 1989-91

Source of variation	df	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Replications	3	3.64×10^5	9.70×10^6	110.79
Years (Y)	1	8.18×10^{7}**	2.63×10^{8}**	115.88
Residual	3	2.00×10^6	1.18×10^6	369.55
Variety (V)	1	3.62×10^{6}*	2.35×10^6	285.41
Row-spacing (R)	2	9.48×10^5	9.90×10^5	563.76*
VxR	2	2.78×10^4	2.40×10^6	180.82
YxR	2	4.20×10^5	2.23×10^6	23.43
YxV	1	1.81×10^5	4.90×10^6	20.94
YxRxV	2	3.68×10^5	4.83×10^6	287.40
Residual	30	4.99×10^5	2.04×10^6	90.84
Nitrogen level (N)	3	2.61×10^{7}**	9.91×10^7	232.59**
RxN	6	1.95×10^5	7.93×10^5	83.76
VxN	3	4.02×10^5	5.37×10^5	60.81
YxN	3	3.45×10^{6}**	1.06×10^{7}**	85.18
VxR	6	8.17×10^4	2.11×10^{6}*	109.86
YxRxN	6	6.07×10^4	1.43×10^6	33.60
YxVxN	3	7.89×10^4	7.08×10^5	29.19
Residual	114	2.20×10^5	8.47×10^5	52.44
Total	191	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 23

Mean sum of squares for spike length, spikelets per spike, grains per spike and 1000-grain weight as affected by variety, row-spacing and nitrogen level: 1989-90

Source of variation	df	Spike length (cm)	Spikelets per spike spike	Grains per spike	1000-grain weight (g)
Replications	3	1.49	11.13	526.24	27.13
Variety (V)	1	10.14**	0.38	1751.04**	469.49
Row-spacing (R)	2	0.22	10.32	292.89**	43.14
VxR	2	0.48	0.84	25.45	3.51
Residual	15	0.37	2.29	41.57	7.56
Nitrogen level (N)	3	93.60**	308.85**	4924.13**	101.70
RxN	6	0.69*	0.67	102.51*	3.05
VxN	3	0.87*	1.46	182.07**	3.37
VxRxN	6	0.26	0.30	22.35	5.98
Residual	54	0.30	1.96	35.21	5.42
Total	95				

* significant at P=0.05.
** significant at P=0.01.

Appendix 24

Mean sum of squares for spike length, spikelets per spike, grains per spike and 1000-grain weight as affected by variety, row-spacing and nitrogen level: 1990-91

Source of variation	df	Spike length (cm)	Spikelets per spike spike	Grains per spike	1000-grain weight (g)
Replications	3	0.35	6.69	49.93	0.14
Variety (V)	1	39.53**	0.38	1254.26**	516.62**
Row-spacing (R)	2	0.73	2.17	65.07**	5.61
VxR	2	0.39	3.88	103.20	7.20
Residual	15	0.87	1.49	51.01	7.71
Nitrogen level (N)	3	102.00	198.69**	6789.96**	22.95
RxN	6	0.85	1.74	16.85	15.39
VxN	3	0.06	4.64	372.76**	9.61
VxRxN	6	0.58	2.14	94.78*	4.55
Residual	54	0.45	2.21	35.07	7.33
Total	95				

* significant at P=0.05.
** significant at P=0.01.

Appendix 25

Mean sum of squares of combined analysis for spike length, spikelets per spike, grains per spike and 1000-grain weight as affected by variety, row-spacing and nitrogen level: 1989-91

Source of variation	df	Spike length (cm)	Spikelets per spike spike	Grains per spike	1000-grain weight (g)
Replications	3	1.28	2.13	286.76	15.11
Year (Y)	1	1.80	22.69	556.92	5.07
Residual	3	0.56	15.69	290.41	12.15
Variety (V)	1	44.85**	0.75	2984.63**	985.55**
Row-spacing	2	0.83	10.41*	306.77**	12.57
VxR	2	0.23	2.08	60.40	9.92
YxR	2	0.12	2.08	51.19	36.18*
YxV	1	4.81**	0.00	20.67	0.56
YxRxV	2	0.64	2.64	68.25	0.79
Residual	30	0.62	1.89	46.29	7.64
Nitrogen level (N)	3	193.24**	494.52**	11542.48**	105.33**
RxN	6	0.47	0.56	88.45*	12.24
VxN	3	0.52	2.06	447.73**	8.31
YxN	3	2.36**	13.02	171.60**	19.31*
VxRxN	6	0.61	1.86	35.99	3.61
YxRxV	6	1.07*	1.85	30.91	6.20
YxVxN	3	0.41	4.08	107.10*	4.66
Residual	114	0.36	2.00	37.56	6.09
Total	191				

* significant at P=0.05.
** significant at P=0.01.

Appendix 26

Mean sum of squares for total nitrogen uptake (kg N ha^{-1}) at various growth stages as affected by variety, row-spacing and nitrogen level, 1989-90

Source of variation	Days after sowing (DAS)					
	df	42	56	70	84	98
Replications	2	0.98	9.79	35.00	4.46	5.47
Varieties (V)	1	0.76	3.31	0.23	2.64	3.08
Row-spacings (R)	2	8.81*	24.46*	4.13	7.09*	2.88
VxR	2	0.49	7.88	5.30	4.60	2.24**
Residual	10	1.71	4.06	3.48	1.13	0.87
Nitrogen level (N)	3	76.82**	86.36**	174.20**	105.83**	109.57**
RxN	3	0.98	3.15	2.75	8.31**	1.13
VxN	6	0.60	1.64	2.73	4.15**	0.89
VxRxN	6	3.93*	3.97*	6.58**	1.38	2.80*
Residual	36	1.56	1.23	1.52	0.60	0.98
Total	71	-	-	-		

* significant at P=0.05.
** significant at P=0.01.

Appendix 27

Mean sum of squares for total nitrogen uptake (kg N ha^{-1}) at various growth stages as affected by variety, row-spacing and nitrogen level, 1990-91

Source of variation		Days after sowing (DAS)			
	df	42	56	70	84
Replications	2	0.22	0.68	1.98	7.51
Varieties (V)	1	0.85	0.07	0.31	1.27
Row-spacings (R)	2	4.60*	9.72*	15.59**	10.15**
VxR	2	1.06	3.42	1.99	1.86
Residual	10	0.96	2.19	0.65	0.57
Nitrogen level (N)	3	26.69**	154.28**	161.44**	232.98**
VxN	3	0.46	2.03	10.39**	2.66
RxN	3	2.14**	1.09	3.45**	2.21
VxRxN	6	0.53	2.76*	3.86**	4.18**
Residual	36	0.21	0.79	0.43	1.02
Total	71	-	-	-	-

* significant at P=0.05.
** significant at P=0.01.

Appendix 28

Nitrogen distribution (kg N ha^{-1}) in different plant parts at various growth stages in wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, 1989-90

Treatment	Leaf					Stem					Spike				
	Days After Sowing (DAS)					Days After Sowing (DAS)					Days After Sowing (DAS)				
	42	56	70	84	98	42	56	70	84	98	42	56	70	84	98
Variety															
Siete Cerros	15.1	12.0	8.9	2.1	1.8	19.9	15.9	18.2	6.5	3.2	-	14	24	32.6	35.7
Florence Aurore	18.1	15.8	11.3	2.9	1.9	20.4	22.1	23.1	14.3	5.2	-	9.3	17.8	28.7	37.8
SE ±	1.3	1.0	1.0	0.1	0.1	1.3	1.6	2.1	0.6	0.2	-	1.1	0.9	1.4	1.4
LSD (0.05)	NS	3.1	NS	0.4	NS	NS	4.9	NS	1.7	0.6	-	3.3	2.7	NS	NS
Row-spacing (cm)															
10	16.2	13.4	8.4	2.0	1.6	16.8	14.8	21.2	8.3	3.6	-	9.0	17.3	27.2	34.2
20	18.2	17.5	8.7	3.0	2.2	26.3	23.2	21.2	10.0	4.6	-	15.8	23.4	31.1	36.0
30	15.4	10.7	13.2	2.4	1.7	17.3	19.1	19.5	13.0	4.4	-	11.5	22.0	33.6	40.1
SE ±	1.6	1.3	1.2	0.2	0.1	1.6	2.0	2.5	0.7	0.2	-	1.3	1.1	1.7	1.8
LSD (0.05)	NS	3.8	3.7	0.5	0.4	4.8	6.0	NS	2.1	0.7	-	4.0	3.3	NS	NS
Nitrogen level (kg N ha^{-1})															
0	4.7	5.6	1.9	0.6	0.5	8.1	8.2	3.9	4.1	1.0	-	5.8	6.7	10.9	10.5
60	12.7	10.7	6.4	1.	[illegible]	15.2	17.3	6.9	3.3	-	10.0	20.1	26.0	30.6	
120	20.3	16.0	13.4	3.1	2.4	23.0	23.2	26.1	11.2	5.5	-	14.8	26.2	38.4	47.4
180	28.7	23.3	18.8	4.5	3.0	34.2	29.4	35.4	19.5	7.0	-	17.7	30.7	47.2	58.6
SE ±	1.5	1.1	0.9	0.2	0.1	1.8	1.1	1.6	0.9	0.2	-	0.9	1.3	1.6	2.1
LSD (0.05)	4.1	3.1	2.6	0.5	0.4	4.9	3.2	4.4	2.5	0.7	-	2.4	3.7	4.3	5.9

Appendix 29

Nitrogen distribution (kg N ha^{-1}) in different plant parts at various growth stages in wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, 1990-91

Treatment	Leaf				Stem				Spike			
	Days After Sowing (DAS)				Days After Sowing (DAS)				Days After Sowing (DAS)			
	42	56	70	84	42	56	70	84	42	56	70	84
Variety												
Siete Cerros	11.1	15.7	8.3	1.8	10.0	14.7	13.0	6.20	-	13.6	26.5	50.0
Florence Aurore	12.1	21.5	10.9	2.8	6.0	14.6	18.0	8.2	-	7.4	20.2	49.1
SE ±	0.30	2.3	0.4	0.07	1.1	0.6	0.7	0.3	-	0.5	0.4	1.1
LSD (0.05)	NS	NS	1.3	0.20	3.2	NS	2.1	1.0	-	1.6	1.3	NS
Row-spacing (cm)												
10	10.1	23.6	9.3	2.1	9.3	14.3	17.5	7.9	-	11.5	26.4	50.6
20	14.5	16.4	11.3	2.4	9.50	17.2	16.9	7.6	-	11.8	25.0	54.9
30	10.3	25.9	8.3	2.4	5.1	12.6	12.2	6.6	-	8.3	18.7	43.1
SE ±	1.0	2.9	0.6	0.1	1.3	0.7	0.8	0.4	-	0.6	0.5	1.3
LSD (0.05)	3.3	NS	1.6	0.3	NS	2.1	2.5	NS	-	1.9	1.5	4.0
Nitrogen level (kg N ha^{-1})												
0	4.1	4.1	2.3	0.9	3.5	4.7	5.2	2.2	-	3.2	9.40	18.8
60	[illegible]	[illegible]	5.3	1.5	5.9	10.7	10.7	4.6	-	8.5	17.4	34.0
120	13.2	20.7	11.4	2.7	9.9	17.2	18.0	8.7	-	12.4	29.7	60.6
180	21.1	36.9	19.5	4.1	13.4	25.1	28.2	14.1	-	18.0	37.4	85.1
SE ±	0.7	1.6	0.5	0.1	0.9	0.7	0.5	0.4	-	0.5	1.0	2.0
LSD (0.05)	2.0	4.4	1.4	0.4	2.4	2.0	1.4	1.2	-	1.6	2.7	5.5

Appendix 30

Mean sum of squares for N,P,K,Ca and Mg uptake (kg N ha^{-1}) at harvest as affected by variety, row-spacing and nitrogen level: 1989-90

Source of Variation	df	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Replications	2	6.47	0.0222	6.53	6.89	0.31
Varieties (V)	1	3.08	0.4141**	21.39*	0.41	0.16**
Row-spacing (R)	2	2.88	0.0452**	12.66*	0.98	0.21**
V×R	2	2.24**	0.0772**	12.32	0.58	0.14*
Residual	10	0.87	0.0011	3.04	0.43	0.03
Nitrogen level (N)	3	109.57**	0.2670**	105.18**	4.29**	1.98**
V×N	3	1.13	0.0182*	7.51*	0.43	0.01
R×N	6	0.89	0.0245**	4.59*	0.19	0.06
V×R×N	6	2.80*	0.0176**	2.30	0.33	0.09*
Residual	36	0.98	0.0038	1.89	0.26	0.04
Total	71	-	-	-	-	-

* significant at P=0.05
** significant at P=0.01.

Appendix 31

Mean sum of squares for N,P,K Ca and Mg uptake (kg N ha^{-1}) at harvest as affected by variety, row-spacing and nitrogen level: 1990-91

Source of Variation	df	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Replications	2	7.51	0.83	6.89	0.11	0.04
Varieties (V)	1	1.27	0.90*	10.45**	0.23**	0.04*
Row-spacing (R)	2	10.15**	0.24	3.51**	0.03	0.04*
VxR	2	1.86	0.81	1.53*	0.01	0.00
Residual	10	0.57	0.15	1.50	0.01	0.01
Nitrogen level (N)	3	232.98**	4.65**	82.90**	1.08**	1.44**
VxN	3	2.66	0.06	0.78	0.02	0.02
RxN	6	2.21	0.17	1.54*	0.02	0.01
VxRxN	6	4.18**	0.33	1.64*	0.05**	0.03*
Residual	36	1.02	0.15	0.55	0.01	0.01
Total	71	-	-	-	-	-

* significant at P=0.05
** significant at P=0.01.

Appendix 32

Uptake of N,P,K,Ca and Mg (kg N ha^{-1}) in plant parts of wheat at harvest as influenced by variety, row-spacing and nitrgen level at Kadawa, 1989-90

Treatment	Leaf					Stem					Spike				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Variety															
Siete Cerros	1.8	0.3	6.1	1.9	0.8	3.2	0.3	22.1	2.0	1.2	35.7	1.2	21.3	6.1	4.6
Florence Aurore	1.9	0.3	7.8	2.2	0.9	5.2	0.6	31.8	3.3	1.9	37.8	2.4	18.8	3.9	4.7
SE ±	0.1	0.01	0.60	0.20	0.02	0.2	0.02	2.10	0.40	0.09	1.4	0.04	0.90	0.90	0.20
LSD (0.05)	NS	NS	NS	NS	1.05	0.06	0.05	6.4	1.10	0.30	NS	0.10	NS	NS	NS
Row-spacing (cm)															
10	1.6	0.2	6.4	1.7	0.7	3.6	0.3	23.5	1.7	1.1	34.2	1.6	16.7	4.7	4.2
20	1.4	0.4	7.5	2.2	1.0	4.6	0.6	28.7	3.4	1.6	36.0	2.0	22.6	4.5	4.9
30	1.7	0.3	6.9	2.3	0.9	4.4	0.4	28.6	2.7	1.7	40.1	1.8	20.9	5.8	4.9
SE ±	0.1	0.01	0.80	0.20	0.02	0.2	0.02	2.60	0.50	0.10	1.8	0.05	1.10	1.10	0.20
LSD (0.05)	0.4	0.04	NS	NS	0.06	0.7	0.6	NS	NS	0.30	NS	0.20	3.30	NS	0.80
Nitrogen level (kg N ha^{-1})															
0	0.5	0.1	2.4	0.7	0.3	1.0	0.1	10.4	0.9	0.5	10.5	0.8	7.9	2.0	2.0
60	1.4	0.3	6.4	1.9	0.8	3.3	0.4	24.4	2.5	1.4	30.8	1.4	18.2	4.9	3.9
120	2.4	0.4	8.8	2.7	1.1	5.5	0.6	34.4	2.9	2.0	47.4	2.5	27.1	5.9	5.9
180	3.0	0.5	10.0	3.0	1.2	7.0	0.6	36.[illegible]	4.2	2.3	58.6	2.5	[illegible]	[illegible]	6.8
SE ±	0.1	0.03	0.7	0.20	0.07	0.2	0.03	2.30	0.50	0.10	2.1	1.50	1.50	0.70	0.30
LSD (0.05)	0.4	0.10	2.0	0.60	0.20	0.7	0.10	6.30	1.50	0.40	5.9	4.10	4.10	2.00	1.00

Appendix 33

Uptake of N,P,K,Ca and Mg (kg N ha^{-1}) in plant parts of wheat at harvest as influenced by variety, row-spacing and nitrgen level at Kadawa, 1990-91

Treatment	Leaf					Stem					Spike				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Variety															
Sieta Cerros	1.8	0.6	4.7	1.2	0.6	6.2	0.8	20.3	1.5	1.0	50.0	8.0	11.3	1.6	3.8
Florence Aurore	2.8	0.8	5.4	1.6	0.7	8.2	3.0	27.6	2.3	1.4	49.1	7.9	11.0	1.4	3.7
SE ±	0.07	0.03	0.20	0.04	0.02	0.3	0.60	0.50	0.08	0.04	1.1	0.30	0.30	0.07	0.10
LSD (0.05)	0.20	0.10	0.50	0.10	0.06	1.0	1.80	1.40	0.20	0.20	3.10	NS	NS	0.20	NS
Row-spacing (cm)															
10	2.1	0.8	5.4	1.4	0.7	7.9	1.0	25.7	2.0	1.3	50.6	8.5	11.1	1.6	3.3
20	2.4	0.6	5.1	1.5	0.6	7.6	1.2	24.9	2.0	1.2	54.9	7.9	12.5	1.6	4.0
30	2.4	0.7	4.6	1.4	0.6	6.6	3.4	21.3	1.7	1.1	43.1	7.6	9.8	1.3	3.4
SE ±	0.1	0.04	0.20	0.05	0.02	0.4	0.70	0.60	0.10	0.05	1.3	0.40	0.30	0.08	0.10
LSD (0.05)	0.3	NS	0.60	NS	0.07	NS	NS	1.70	NS	NS	4.0	NS	1.00	0.20	0.40
Nitrogen level (kg N ha^{-1})															
0	0.9	0.4	2.6	0.7	0.3	2.2	0.9	9.0	0.8	0.5	13.5	3.5	4.9	0.6	1.6
60	1.5	0.5	3.7	1.0	0.5	4.5	1.4	17.3	1.3	0.8	34.0	6.6	8.8	1.1	2.9
120	2.7	0.8	6.1	1.8	0.8	8.7	2.0	29.6	2.6	1.5	60.6	9.4	13.3	1.9	4.7
180	4.1	1.0	7.8	2.3	1.0	14.1	3.2	40.0	3.0	1.9	85.1	12.5	17.6	2.4	5.9
SE ±	0.10	0.06	0.20	0.08	0.04	0.40	0.60	0.10	0.10	0.05	2.30	0.50	0.50	0.70	0.30
LSD (0.05)	0.4	0.20	0.70	0.20	0.10	1.20	1.60	3.20	0.30	0.10	5.50	1.40	1.40	0.20	0.50

Appendix 34

Mean sum of squares for grain yield, straw yield, dry matter and harvest index as affected by variety, level and time of N application: 1989-90

Source of variation	df	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Dry matter (kg ha^{-1})	Harvest index (%)
Replications	3	1.51×10^{6}	3.50×10^{6}	8.95×10^{6}	85.68
Variety (V)	1	3.33×10^{6}*	2.0×10^{6}	1.05×10^{7}*	177.03*
Time (T)	2	2.16×10^{6}*	7.55×10^{6}**	1.75×10^{7}**	35.66
Nitrogen level (N)	2	1.14×10^{7}**	2.02×10^{7}**	6.22×10^{7}**	78.66
VxT	2	2.10×10^{5}	2.45×10^{6}	3.83×10^{6}	28.71
TxN	4	5.63×10^{5}	2.22×10^{6}	4.49×10^{6}	49.91
VxN	2	7.97×10^{5}	1.10×10^{6}	3.31×10^{6}	2.79
VxTxN	4	3.76×10^{4}	1.48×10^{6}	1.72×10^{6}	37.56
Residual	51	2.51×10^{5}	9.88×10^{5}	1.92×10^{6}	29.77
Total	71	-	-	-	-

* significant at P=0.05
** significant at P=0.01.

Appendix 35

Mean sum of squares for grain yield, straw yield, dry matter and harvest index as affected by variety, level and time of N application: 1990-91

Source of variation	df	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Dry matter (kg ha^{-1})	Harvest index (%)
Replications	3	8.95×10^4	1.22×10^6	1.76×10^6	90.32
Variety (V)	1	$3.35 \times 10^{6*}$	1.08×10^6	$8.91 \times 10^{6*}$	485.68**
Time (T)	2	6.74×10^4	6.46×10^5	1.22×10^6	144.43*
Nitrogen level (N)	2	1.43×10^4	$5.74 \times 10^{6*}$	$1.24 \times 10^{7**}$	57.53
VxT	2	$6.17 \times 10^{5*}$	2.06×10^6	$4.09 \times 10^{6*}$	8.79
TxN	4	6.47×10^4	5.24×10^5	8.38×10^5	48.62
VxN	2	2.43×10^5	1.68×10^5	1.01×10^6	5.72
VxTxN	4	1.43×10^5	7.11×10^5	1.43×10^6	21.47
Residual	51	2.38×10^5	6.97×10^5	1.33×10^6	31.78
Total	71	-	-	-	-

* significant at P=0.05
** significant at P=0.01.

Appendix 36

Mean sum of squares of combined analysis for grain yield, straw yield, dry matter and harvest index as affected by variety, level and time of N application: 1989-91

Source of variation	df	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Dry matter (kg ha^{-1})	Harvest index (%)
Replications	3	8.12×10^{5}	1.94×10^{6}	4.75×10^{6}	94.33
Years (Y)	1	1.10×10^{7}*	3.66×10^{7}**	8.95×10^{7}*	306.54
Residual	3	7.90×10^{6}*	2.78×10^{6}	5.96×10^{6}	81.67
Variety (V)	1	6.68×10^{6}*	3.00×10^{6}*	1.94×10^{7}**	624.58**
Time (T)	2	7.41×10^{5}	3.29×10^{6}*	6.87×10^{6}*	151.84
Nitrogen level (N)	2	1.03×10^{7}**	2.35×10^{7}**	6.38×10^{7}**	17.41
VxT	2	1.44×10^{5}	1.95×10^{6}	3.18×10^{6}	8.32
TxN	4	1.59×10^{5}	9.70×10^{5}	1.42×10^{6}	58.84
VxN	2	8.58×10^{5}	7.41×10^{5}	3.18×10^{6}	4.47
YxT	2	1.48×10^{6}*	4.91×10^{6}**	1.18×10^{7}**	28.25
YxV	1	10	7.03×10^{4}	3.16×10^{4}	38.13
YxN	2	2.65×10^{6}*	2.52×10^{6}	1.08×10^{7}**	118.78*
VxTxN	4	7.66×10^{4}	3.62×10^{5}	7.16×10^{5}	12.57
YxTxV	2	6.84×10^{5}	2.56×10^{6}	5.34×10^{6}	29.18
YxTxN	4	4.69×10^{5}	1.78×10^{6}	3.91×10^{6}	39.69
YxVxN	2	1.82×10^{5}	5.24×10^{5}	1.14×10^{6}	4.04
Residual	106	1.93×10^{5}	8.80×10^{5}	1.66×10^{6}	31.37
Total	71	-	-	-	-

* significant at P=0.
** significant at P=.01

Appendix 37

Mean sum of squares for spike length, spikelets per spike, grains per spike and 1000-grain weight as affected by variety, level and time of N application: 1989-90.

Source of Variation	df	Spike length (cm)	spikelets/ spike	Grains/spike	1000-grain weight (g)
Replications	3	0.15	0.17	53.79	78.10
Variety (V)	1	8.00**	14.22*	1326.13**	678.96**
Time (T)	2	1.89	10.13*	87.26	11.64
Nitrogen level (N)	2	6.05**	23.04**	478.93**	73.83**
VxT	2	0.28	0.51	141.54	4.21
TxN	4	0.83	5.29	61.54	17.94
VxN	2	0.81	9.78*	100.04	17.27
VxTxN	4	2.01*	8.06	163.02	7.17
Residual	51	0.63	2.72	69.16	8.66
Total	71	-	-	-	-

* Sigr ... 0.05
** significant at P=0.01.

Appendix 38

Mean sum of squares for spike length, spikelets per spike, grains per spike and 1000-grain weight as affected by variety, level and time of N application: 1990-91.

Source of Variation	df	Spike length (cm)	spikelets/ spike	Grains/spike	1000-grain weight (g)
Replications	3	1.34	3.80	133.19	6.88
Variety (V)	1	23.46**	2.72	2787.56**	356.89**
Time (T)	2	0.30	1.51*	52.17	6.29
Nitrogen level (N)	2	18.14**	25.35**	976.17**	54.57*
VxT	2	1.34	1.76	54.06	45.31*
TxN	4	0.35	2.06	26.08	2.24
VxN	2	1.57	1.10	360.39**	7.16
VxTxN	4	0.09	0.14	7.14	5.97
Residual	51	0.62	1.33	52.01	11.62
Total	71	-	-	-	-

* significant at P=0.05
** significant at P=0.01.

Appendix 39

Mean sum of squares of combined analysis for spike length, spikelets per spike, grains per spike and 1000-grain weight as affected by variety, level and time of N application: 1989-91.

Source of variation	df	Spike length (cm)	spikelets/ spike	Grains/spike	1000-grain weight (g)
Replications	3	0.58	1.46	66.41	48.23
Years (Y)	1	17.29*	266.78**	817.01	36.40
Residual	3	0.92	2.50	120.56	36.75
Variety (V)	1	29.43**	14.89*	3979.51**	1010.18**
Time (T)	2	0.41	9.38*	41.26	17.52
Nitrogen level (N)	2	21.68**	45.86**	1268.80**	114.77**
TxV	2	0.24	1.51	19.84	11.19
TxN	4	0.73	3.09	70.19	12.94
VxN	2	2.12*	8.53*	80.30	17.51
YxT	2	1.78	2.26	98.17	0.41
YxV	1	2.03	2.25	134.17	25.67
YxN	2	2.51*	2.53	186.30	13.63
TxVxN	4	0.91	4.72	89.44	6.46
YxTxV	2	1.38	0.77	175.76	38.33
YxTxN	4	0.45	4.26	17.34	7.25
YxVxN	2	0.26	2.33	380.13**	6.92
Residual	106	0.65	2.08	61.35	10.01
Total	71	-	-	-	-

* significant at P=0.05
** significant at P=0.01.

Appendix 40

Mean sum of squares for grain crude protein content as affected by variety, level and time of N application: 1989-90 and 1990-91

Source of variation	df	Crude protein (per cent)	
		1989-90	1990-91
Replications	3	0.15	0.49
Variety (V)	1	4.35**	5.58**
Time (T)	2	9.77**	6.12**
Nitrogen level (N)	2	7.57**	16.79**
TxV	2	1.01*	3.06**
TxN	4	1.67**	1.63**
VxN	2	0.07	0.32
TxVxN	4	1.40**	3.52**
Residual	51	0.25	0.26
Total	71	-	-

* significant at P=0.05
** significant at P=0.01.

Appendix 41

Mean sum of squares of combined analysis for grain crude protein content as affected by variety, level and time of N application: 1989-91

Source of variation	df	Mean square
Replications	3	0.30
Year (Y)	1	165.27**
Residual	3	0.34
Variety (V)	1	9.90**
Time (T)	2	13.92**
Nitrogen level (N)	2	20.81**
VxT	2	3.72**
TxN	4	2.36**
VxN	2	0.27
YxT	2	1.97**
YxV	1	0.04
YxN	2	3.55**
VxTxN	4	1.73**
YxTxV	2	0.35
YxTxN	4	0.96*
YxVxN	2	0.12
Residual	106	0.37
Total	143	-

* significant at P=0.05
** significant at P=0.01.

BIOGRAPHY

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Previous Qualifications	:	BSc (Agric) ABU, Zaria MS (Soil and Water) University of Arizona Tucson, Arizona, USA

Institutions Attended	From	To	Certificate/Degree
Ochaja Secondary School Ochaja	1964	1968	West African Sch. Certificate
Offa Grammar School, Offa	1969	1970	Higher School Certificate
Ahmadu Bello University Zaria	1971	1974	BSc (Agric) 2nd Class Upper Div.
University of Arizona, USA	1977	1978	MS (Soil & Water)

Positions held since the award of First Degree

Organization	From	To	Position
NYSC, Agric. Dev. Authority, Enugu	1974	1975	Agric. Officer
College of Agriculture Bakura	1975	1976	Graduate Assistant
College of Agriculture Bakura	1976	1978	Assistant Lecturer
College of Agriculture Bakura	1978	1980	Lecturer II
University of Sokoto	1980	1981	Lecturer I
Lower Benue River Basin Development Authority	1982	1983	Principal Irrigation Agronomist

Lower Benue River Basin Development Authority	1983 1985	Assistant Chief Irrigation Agronomist
Federal Agric. Coordinating Unit (FACU)	1985 1993	Deputy Agric. Research Coordinator
Federal Agric. Coordinating Unit (FACU)	1993–to–date	Regional Coordinator, Crop Research

Year of Admission: March, 1989

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