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Response of two Irrigated Wheat (*triticum aestivum* l.) Varieties to Row Spacing and Nitrogen Supply: Yield, Yield Components and N Uptake

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Key words: N supply, N uptake, row-spacing, *Triticum aestivum* L., yield and yield components.

Abstract

Field trials were conducted at Kadawa, Nigeria during 1989-90 and 1990-91 dry seasons to study the response of two irrigated wheat varieties (*Siete Cerros* and *Florence Aurore* 8193) to row-spacing and nitrogen supply in terms of yield, yield components and N uptake and distribution. Using the split plot design two varieties (*Siete Cerros* and *Florence Aurore* 8193); three row spacings (10, 20 or 30 cm) and four N levels (0, 60, 120 or 180 kgN/ha) were compared. The two varieties did not differ with respect to their grain and straw yields, N uptake and most of the yield components. However, var. *Siete Cerros* had more grains per spike (24% more) but smaller grain size (14% smaller) and slightly shorter spikes than var. *Florence Aurore*. Row spacing did not influence grain and straw yields, grain weight, spikelets per spike and spike length but wider rows enhanced productive tillering and grains per spike, albeit only slightly. N uptake was highest under 20 cm row-spacing initially but later on the greatest N uptake occurred under the wider row (30-cm) in 1989-90 season. In 1990-91 season, however, N uptake was highest under the narrower rows. Increasing N supply level significantly increased grain and straw yields, productive tillers, spike length, spikelets per spike, grains per spike, grain weight and N uptake. Although N uptake increased up to the highest N supply level (180 kgN/ha), significant response was only up to 120 kg N/ha. N distribution to different plant parts was a function of both growth stage and N supply level. As the plant's growth cycle advanced, the level of N distributed to the leaves and stem was on the decline while that to the spikes increased. Generally, N uptake either declined or levelled off after the flowering stage. The most beneficial practice for wheat under the conditions of this study is to plant the crop at 20 cm row-spacing and give it a 120 kg N/

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ha fertiliser dressing. Yield increase resulting from N supply was mainly associated with variations in spikelets per spike and grains per spike.

1 Introduction

Wheat production under irrigation is a common practice in the arid and semi-arid parts of developing countries, where water supply is a limited resource and precious input. Even though wheat is essentially a crop of the temperate regions of the world, it is successfully grown at higher altitudes in the tropics and sub-tropics, where it is grown during the cool dry seasons. Consequently, some varieties have either been developed or selected for production under tropical environments (Olugbemi 1973). The fact that wheat production by smallholders in the northern parts of Nigeria under irrigation, usually in the *fadamas* and valley bottoms, has been going on for centuries attests to this (Yayock *et al.* 1986). Nevertheless, certain problems with regard to production under irrigation emanating from farmers' adoption inappropriate agronomic management practices, a situation which depresses yields to great extents, still remain.

Awned wheat varieties constitute a large majority of locally grown wheat while the few awnless varieties that are grown are for their superior grain quality. Local research efforts were therefore aimed at identifying suitable varieties that combine good quality with resistance to diseases and pests while also possessing good responsiveness to nutrient supply (Olugbemi *et al.* 1979). In wheat production wider rows are generally used but there is now increasing interest in the adoption of narrower rows, ostensibly for better use of natural resources by the crop and consequently higher yields. Although Holliday (1963) was unable to establish a positive close relationship between narrow rows and fertiliser use efficiency in wheat plants, Reinerton *et al.* (1984) reported greater N uptake by wheat crop sown in 20 cm rows relative to that in 30 or 40 cm rows apart. Conventionally tall wheat varieties were thought to depend on a high number of either ears or spikelets per ear for grain yield while semi-dwarf ones, which show a greater capacity for grain production than the tall, depend on high spikelet fertility (Feingold et al. 1990).

Tillering and yield in wheat were said to increase with N fertilisation (Chandra *et al.* 1992, Singh and Uttan 1992, Ayoub *et al.* 1994). A totally contradictory observation was however made by Zebarth and Sheard (1992) who reported that straw yields were more responsive to N supply than grain yields were. Apart from yield differences among varieties, their relative responsiveness to N fertilisation differed as well (Singh *et al* 1992, Ayoub *et al* 1994) and also in their N uptake (Haneklaus and Schnug 1993). Dwarf varieties having produced higher grain yields than the tall ones at every level of N supply as a result of their higher number of ear-bearing shoots per unit row length and higher number of fertile spikelets per ear. The results of most earlier reported studies have therefore been largely contradictory and somehow inconsistent, thus necessitating some validation through further research work.

While some useful information with respect to how certain wheat varieties respond to different row-spacing and nitrogen supply exists, it is yet to be ascertained how the two most popular well-adapted wheat varieties in Nigeria will respond to these two factors under irrigation. The objective of the present investigation was therefore to study the response of two irrigated wheat varieties to row-spacing and nitrogen supply with respect to yield, yield components and N uptake.

2 Materials and Methods

2.1 *Experimental site and soil*

Field trials were conducted under irrigation during the dry seasons of 1989-91 at the Irrigation Research Station of the Institute for Agricultural Research located at Kadawa (11° 39'N, 08°02'E, 500 m above sea level), Nigeria. Kadawa is located in the Sudan savannah agroecological zone. The soils of the experimental site are moderately to imperfectly drained because of its perched water-table and have been classified as Eutric Cambisol (FAO/UNESCO) and Typic Utropept (Ojanuga *et al.* 1979). Composite soil samples taken from the top soil (0-15 cm depth) of the experimental site in each season were subjected to physio-chemical analyses using common procedures (Black, 1965) and the results were as follows: total N, 0.6 and 0.8 g/kg; organic carbon, 7.0 and 5.2 g/kg, available P, 17.92 and 26.88 mg/kg; exchangeable K, 29.0 and 29.0 mg/kg; Ca, 374 and 529 mg/kg, Mg, 85 and 189 mg/kg; Na, 11.0 and 37.0 mg/kg; CEC, 6.0 and 6.8 meq/100g soil; and pH ($CaCl_2$), 5.8 and 6.2 in 1989-90 and 1990-91 respectively. The soils were classified as sandy loam on the basis of physical analysis.

2.2 *Experimental details*

The experiment was laid out in a split-plot design using four replications with varieties x row-spacings as main plots and nitrogen levels as sub-plots. The plots which were 5 x 3 m in dimension were seeded with var. *Siete Cerros* or *Florence Aurore* 8193 at a seeding rate of 100 kg seed/ha on 19 December 1989 and 8 December 1990. *Siete Cerros* is a awned introduction from Mexico with medium maturity, reasonably high yield potential and tolerance to major pests and diseases. *Florence Aurore* is a awnless variety released from FAO collection over three decades ago with medium maturity, good yield potential and moderate resistance to pests and diseases (F.C. Orakwue, personal communication).

Four levels of N, as urea (46% N), namely, 0, 60, 120 or 180 kg N/ha were tested and split applied, half at sowing and half at four weeks later (crown root initiation stage) by broadcasting. Sowing was done by drilling seed in rows spaced 10, 20 or 30 cm apart. Irrigation water was sparingly applied on the 1989-90 trial because of high water table but the 1990-91 trial received a total of eleven irrigations at weekly intervals. Plots were kept free of weeds by hand pulling and hoe weeding. Each trial received a basal fertiliser dressing of 17.5 kg P/ha (as single superphosphate) ad 50 kgK/ha (as muriate of potash).

2.3 Data collection and statistical analysis

For purpose of determining N uptake and N distribution, plant samples were collected from half meter row length at 42, 56, 70, 84, and 98 days after sowing (DAS). Sub-samples were taken from samples and dissected into component parts (leaves, stems and spikes), weighed fresh with a top -loading Metler balance (model P1200) and oven dried at 70°C for 48 hours. Dried sub samples were then ground with a Wiley mill to pass through a 40 mesh sieve. Using duplicate samples, total N was determined by the micro- Kjeldahl method as described by Bremner (1965). Digestion was done with conc. sulphuric acid and a mixture of mercuric chloride and selenium dioxide was used as an indicator. After determining the % total N in samples, nitrogen uptake was expressed on a dry weight basis.

Other data collected include those on grain and straw yields, number of fertile tillers, spike length, number of spikelets per spike, number of grains per spike and 1000-grain weight. While both grain and straw yields were estimated from the net plot area, the other parameters were determined from a sample of 10 plants per plot, except that fertile tillers were estimated from a 0.5 m row length. Data collected were subjected to one-way analysis of variance and in cases where treatment effects were found to be statistically significant, mean values were compared using the test of least significant difference at the 5% probability level (Steel and Torrie 1980).

3 Results

3.1 Grain and straw yields

Although vars *Siete Cerros* and *Florence Aurore* did not differ with respect to their straw yields, the former produced a higher grain yield than did the later by 17 percent (Table 1). The 1989-90 crop yielded about twice as much grain and straw than did the 1990-91 crop. Varying row spacing from 10 to 30 cm did not have significant effect on either grain or straw yield in both seasons. Nitrogen fertilisation significantly positively influenced both yield parameters. Grain and straw yields responded significantly up to 120 kg N/ha as further increment in N supply did not produce a commensurate increase in the two yield parameters (Table 1).

On the basis of pooled data, application of 60, 120, and 180 kg N/ha produced 113.5, 182.0 and 220.0% increases in grain yield over the no N control. Corresponding increases in straw yield were 154.0, 257.0 and 259.4%. Straw yield was more response to N supply than grain yield was.

Table 1: Grain and straw yields of irrigated wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, Nigeria, 1989-91 dry seasons.

Treatment	Grain yields (kg/ha)			Straw yields (kg/ha)		
	1989-90	1990-91	Mean	1989-90	1990-91	Mean
Variety						
Siete Cerros	2569	1202	1885	4049	2030	3040
Florence Aurore	2233	989	1611	4590	1932	3261
SE ±	133.5	55.6	72.3	243.4	162.7	146.4
LSD (0.05)	NS	167.1	217.2	NS	NS	NS
Row-spacing (cm)						
10	2199	1016	1608	4238	1894	3111
20	2442	1199	1821	4058	2042	3050
30	2561	1071	1816	4663	1915	3289
SE±	163.5	68.1	88.5	298.1	199.2	179.3
LSD (0.05)	NS	NS	NS	NS	NS	NS
Nitrogen level (kgN/ha)						
0	1042	485	763	1652	703	1177
60	2335	926	1630	4443	1535	2989
120	2864	1444	2154	5671	2737	4204
180	3362	1527	2445	5514	2948	4231
SE±	13.7	56.8	67.9	226.4	136.2	133.2
LSD (0.05)	341.8	157.0	187.6	625.6	376.5	368.1

NS = not significant

3.2 *Yield components*

Fertile tillers

Both varieties were similar in their numbers of fertile tillers per sq. meter. Their genetic abilities to produce fertile tillers were therefore similar (Table 2). Production of fertile tillers responded significantly to increasing row spacing by declining as row width was increased from 20 to 30 cm, when number of fertile tillers per sq. meter decreased by some 20 per cent. N fertilisation enhanced productive tillering in wheat as each increment in N supply level produced significantly more tillers up to the highest N supply level. Number of fertile tillers per sq. m was increased by 33.5, 55.9 and 85.0% by the application of 60, 120 and 180 kg N/ha respectively relative to the no N control.

Spike length and spikelets per spike:

Var. *Florence Aurore* had spikes which were slightly longer than these of var. *Siete Cerros* but both varieties were identical with respect to number of spikelets per spike (Table 3). Row-spacing influenced neither spike length nor number of spikelets per spike. However, both parameters were increased significantly by increasing N supply level up to 120 kg N/ha. In the case of number of spikelets per spike, the greatest influence came from the application of 60 kg N/ha.

Number of grains per spike and grain weight

Number of grains per spike was significantly higher (by 24%) in var. *Siete Cerros* than in var. *Florence Aurore*, which in turn had larger grains (by 14%) than the former. Among the three row-spacings, the 30 cm row width produced slightly more grains per spike relative to the 10 cm row width. Average grain weight (1000-grain wt) was not influenced by row-spacing based on pooled data (Table 4). Both parameters were enhanced significantly by increase N fertilisation up to 120 kg N/ha as additional N increment produced no tangible increase in either number of grains per spike or 1000- grain weight.

Table 2: Effects of variety, row-spacing and nitrogen level on tillering in irrigated wheat at Kadawa, Nigeria, 1989-91 dry seasons

Treatment	No. fertile 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 (kgN/ha)			
0	240.9	188.6	214.8
60	325.9	246.9	286.4
120	296.5	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

NS = not significant

3.3 *N uptake*

In 1998-90 season, N uptake was not influenced by variety at any of the five growth stages (Table 5). However, row spacing influenced significantly N uptake which was determined at 42, 56, 84 and 98 DAS. At the two former growth stages (i.e. 42 and 56 DAS), N uptake was highest at the 20 cm row width, whereas at the two latter stages, it was highest at the 30 cm row width. Invariably, N uptake was least at the narrowest row width i.e. 10 cm. Nitrogen supply significantly positively influenced N uptake in 1989-90 season. N uptake increased progressively with each increment in nitrogen supply from 60 kg N/ha through 180 kg N/ha (Table 5). N uptake was severely depressed by the nitrogen stress conditions presented by the no N control treatment. Relative to the 60 kg N/ha treatment, the application of 180 kg N/ha doubled the N uptake.

In the 1990-91 season, wheat variety did not influence N uptake (Table 6). Conversely, however, row-spacing and nitrogen supply significantly influenced N uptake by wheat plants. N uptake levels determined at 56, 70 and 84 DAS under the 10 and 20 cm row widths were similar but higher than that under the 30 m row width. At 42 DAS, N uptake was highest under the 20 cm row width (Table 6). Nitrogen supply progressively in-

Table 3: Spike length and number of spikelets per spike in irrigated wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, Nigeria, 1989-91 seasons

Treatment	Spike length (cm)			No. 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	1.13	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 (kgN/ha)						
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

NS = not significant

creased N uptake with each increment as determined at all four growth stages. N uptake by wheat plants corresponded closely with the level of nitrogen supply received by plants.

3.4 *N distribution*

The patterns of N distribution to different plant parts with time a function of nitrogen supply level in the 1989-90 and 1990-91 seasons are illustrated in figure 1. As the season advanced, the amounts of N distributed to the leaf and stem diminished while that to the spike increased, reaching a maximum level at anthesis. The level of N in each of the three plant parts at any given growth stage is directly a function of nitrogen supply level. In 1989-90 season, for instance, the level of N in each plant part remained extremely low under nitrogen stress conditions (Fig. 1). As nitrogen supply level was increased the relative amount nitrogen in each plant part increased markedly. Under the highest nitrogen supply level (i.e. 180 kg N/ha), the growth stage at which N level in the spike levelled off was a little later than those of the lower nitrogen supply levels. In the 1990-91 season, even past the anthesis stage, nitrogen distribution into the spike continued to increase without levelling off, at least under either 120 or 180 kg N/ha treatment (Fig 1aand Fig1b). Nitrogen partitioning into the spike increased as the season advanced whereas N in the leaf began to decline correspondingly past the jointing stage.

Table 4: Grains per spike and grain weight in irrigated wheat as influenced by variety, row-spacing and nitrogen level at Kadawa, Nigeria, 1989-91 dry seasons.

Treatment	No. grains per spike			1000-grain wt (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	0.41	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	34.2	35.2
SE±	1.16	1.27	0.85	0.49	0.49	0.35
LSD (0.05)	3.44	NS	2.56	NS	NS	NS
Nitrogen level (kgN/ha)						
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

NS = not significant

Table 5: Uptake of nitrogen (kg N/ha) by irrigated wheat at various growth stages as influenced by applied N, row-spacing and variety at Kadawa, Nigeria, 1989-90 dry season.

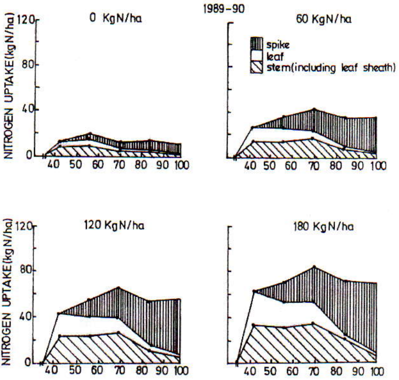
Treatment	Days after sowing				
	42	56	70	84	98
Nitrogen level (kgN/ha)					
0	12.5	19.6	12.4	14.5	12.0
60	27.7	35.7	43.6	34.3	35.3
120	43.9	54.0	65.6	52.7	55.3
180	60.4	70.1	84.9	71.0	68.6
SE±	3.0	2.6	2.9	1.8	2.3
LSD (0.05)	8.2	7.3	8.1	5.0	6.5
Row-spacing (cm)					
10	33.6	37.1	46.9	37.3	39.3
20	43.0	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
Variety					
Siete Cerros	35.1	42.7	51.1	41.2	40.7
Florence Aurore	37.1	47.1	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

Table 6: Uptake of nitrogen (kg N/ha) by irrigated wheat at various growth stages as influenced by applied N, row-spacing and variety at Kadawa, Nigeria, 1990-91 dry season.

Treatment	**Days after sowing**			
	42	**56**	**70**	**84**
Nitrogen level (kgN/ha)				
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
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
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

NS = not significant

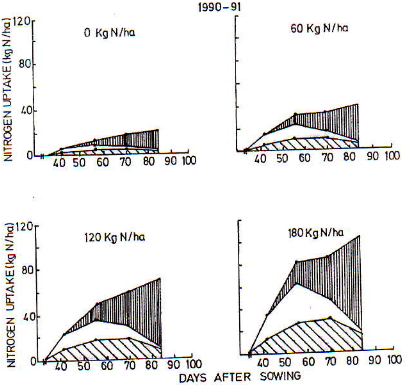
Figure 1a:Effect of nitrogen rate on nitrogen distribution within wheat plant at various growth stages at Kadawa, Nigeria, 1989-90 dry season.



4 Discussion

The yield performance of the wheat crop in both seasons differed markedly due to the variation in prevailing mean air temperatures. The average daily air temperatures during the 1990-91 season were unseasonally high, making the weather unfavourable for optimum wheat growth and productivity. During the period February-March 1991, mean daily maximum temperatures were in excess of 30°C for 49 days. The uncharacteristically high air temperatures which prevailed during the most sensitive phase of the growth cycle caused a shortening of the growth duration of the crop (by 14 days) relative to the more favourable season. Relatively lower grain and straw yields in the 1990-91 season were the consequence of the weather vagaries. Negative effects of high temperatures on wheat growth and performance, especially if occurrence is during the reproductive phase, which also result in premature senescence, have been reported elsewhere (WARDLAW *et*

Figure 1b:Effect of nitrogen rate on nitrogen distribution within wheat plant at various growth stages at Kadawa, Nigeria, 1990-91 dry season.



al 1980). Some 30 percent reduction in length of total growth cycle in wheat occurred when it experienced mean daily temperatures ranging from 17.5º to 32ºC during post-flowering period (Marcellos and Single, 1972).

Both wheat varieties appear to have slightly similar genetic potential for grain and straw yields, although var. *Siete Cerros* tended to yield better than var. *Florence Aurore*. The basis for the slight similarity in grain production lies in the fact that var. *Siete Cerros* has greater capacity for more grains per spike but its grains are smaller, while var. *Florence Aurore* has larger grains, thus able to compensate slightly. Since grain number per spike is a more important yield determinant than grain size (Ayoub *et al.* 1994) in wheat automatically var. *Siete Cerros* has the greater yield potential between the two varieties. The direct contribution in carbon assimilates by the awns in var. *Siete Cerros* cannot be ignored in the understanding of the higher photosynthetic capacity in awned wheat ears as has been recognised for quite sometime (Olugbemi *et al.* 1976). Furthermore, var.

Siete Cerros is semi-dwarf, therefore more efficient in translocating assimilate to its spikes relative to tall var. *Florence Aurore*, as reported by 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.

Row-spacing failed to influence grain yield significantly because responses of yield determining parameters to row-spacing were compensatory in nature. Both intra- and inter- plant competitions are operating when row-spacings are varied as the former type of competition is predominant under wider row-spacings as opposed to under narrower rows. However, grain yields under the 20 and 30 cm row spacing were modestly better than under the 10 cm row widths. Similar results, which are corroborated by the present one, were reported by Teich *et al.* (1993). However, our result contradicts the results of Kumar *et al.* (1991) and Singh and Srivastava (1991) who reported increase in wheat yield with reduction in row widths because of more fertile tillers per unit area caused by less inter-plant competition while it was also observed that some level of yield increase resulted from increasing row-spacing. The present result however confirms the finding that number of fertile tillers per unit area increased, as row-spacing became narrower in spite of the fact that this did not translate into a higher yield. Increased plant lodging, which is often a consequence of narrower spacing or increase plant population would justifiably account for the lack of increase in grain yield even though number of fertile tillers per unit area increased. The difficulty in achieving uniformity in seed distribution over the plot area, which is inherent in the use of hand seed drilling at narrower row widths, is probably implicated in this scenario.

The relatively cooler weather which prevailed for most of the crop growth period in 1989-90 season invariably favoured the growth of wheat plants thus also enhancing the crop's utilisation of applied nitrogen. The observed higher grain yields with higher N supply levels was largely a result of variation in number of spikelets per spike, number of grains per spikelets and fertile tillers per unit area, thereby corroborating earlier observations reported by Ayoub *et al.* (1994). The physiological explanation offered by Ostapenko (1993) on the basis of the findings of his work on winter wheat in Russia was that the final yield, which was a result of N application, correlated with photosynthetic potential. Our present result however corroborates the observation by Sharma *et al.* (1970) to the effect that increasing rates of N fertiliser application would increase wheat grain yield regardless of the variety. Increases in number of ears per unit area and reduced tiller mortality appear to generally explain why increasing N supply brings about increased grain yield in wheat, an assertion which has some bearing on the claim by Entz and Fowler (1989) that higher number of kernels per unit area accounted for yield increase. Earlier reported work which was done by Olugbemi (1984) done in the same location as the present study found that even though an application of 100 kg N/ha to wheat produced only some 10 per cent increase in yield over 50 kg N/ha, this treatment did not differ from 150 kg N/ha in its effect on grain yield. In spite of the fact that Singh and Uttan (1992), Singh *et al.* (1992), Chandra *et al.* (1992) and Ostapenko (1993) independently conducted their wheat fertiliser experiments under conditions different from ours, they similarly found that the optimum response to N supply was obtained from 120 kg N/ha. There was no significant response to N supply levels higher than this, possibly as result of increasing lodging of wheat plants (Ayoub *et al.* 1994).

With increasing N application, it is expected that the average decline in agronomic deficiency will become larger. As earlier concluded by Doyle and Holford (1993) from results of 53 fertiliser experiments on wheat, the highest fertiliser N increment was always the least efficient for increasing grain yield. In the face of ever-increasing cost per unit weight of nitrogen fertiliser, coupled with the higher risk of environmental pollution under excessive nitrogen fertiliser applications it is advisable that caution be taken not to over-apply N fertiliser to this crop. Both economic and environmental considerations are the driving force here.

N uptake by wheat plants in the 1989-90 trial declined rather sharply and prematurely after 70 DAS, possibly due to the high water-table, such that N losses occurred in the leaves and stem and nutrient translocation was impeded. Whereas in the 1990-91 trial, N uptake by plants was highest at about 84 DAS (anthesis), two weeks later than it did in the 1989-90 trial. This observation further reinforced the observation by Palta and Fillery (1993) on the basis of 15 N-urea application experiment, that most N accumulation in wheat occurred at anthesis, with no additional accumulation thereafter. Uptake of N from the soil applied fertiliser, however, was most between tillering and stem elongation, two pre-anthesis stages when crop growth is presumed to occur at relatively fast rates. Applied fertiliser N is also believed to interact with soil N by increasing the uptake of the latter source of N by wheat (Hamid and Ahmad, 1994) and even at some development stages, N uptake by the wheat plant could be more than is required to achieve maximum growth rates (Fischbeck *et al.* 1992)

Var. *Florence Aurore* plants, due to their stature, would require a higher level of N in order to maintain their vegetative frame and thus have a greater uptake of N than semi-dwarf var. *Siete Cerros* plants. This would support the view expressed by Haneklaus and Schnug (1993) that N uptake was related to the genetic factors of the crop and that varietal differences are clearly important in uptake of minerals. Even in earlier studies Day *et al.* (1985) had also reported similar genetic variations in most of the component attributes which interplay to determine N uptake. They concluded that N uptake was more closely related to plant dry weight than to N concentration as such. It is worth noting that in the 1990-91 trial, N uptake levels under the 10 and 20 cm row widths were at par at each of the growth stages, an observation which closely corroborates the result of Reinerton *et al.* (1984) that at 20 cm row spacing total N uptake was higher than at 30 or 40 cm row-spacing. N supply level enhanced N uptake significantly through its positive effects on dry matter production. Results of studies on irrigated wheat in Nigeria and elsewhere showed increased N uptake with increasing N supply (Singh *et al.* 1979) but positive effect was not significant for N supply levels higher than 80 kg N/ha in the case of the work done outside Nigeria (Singh *et al.* 1979). Their result is contradicted by ours, having observed consistent increase in N uptake up to the highest N supply level. Pattern of dry matter accumulation in different plant parts dictated the pattern of N distribution to these parts. Preferential distribution of N to the spikes towards the end of the plant's growth cycle was consistent with the grain yield increase which resulted from increasing N supply level.

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Die Auswirkung von unterschiedlichen N Gaben und Reihenabständen auf Weizen im Bewässerungslandbau

Zusammenfassung

Die Feldversuche mit den Weizensorten *Siete Cerros* und *Florence Aurore* 8193 durchgeführt in Kadawa, Nigeria in den Jahren 1989-90 und 1990-91 hatten die Reihenabstände 10, 20 und 30 cm und vier Stufen der N-Gabe 0, 60, 120 und 180 kg N/ha. Untersucht wurden der Korn- und Strohertrag, die Bestockung, die Ähren, das Tausendkorngewicht und die N- Aufnahme.

Das beste Versuchsergebnis wurde mit einem Reihenabstand von 20 cm und einer 120 kgN/ha Gabe erzielt.

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