

The Effect of Nitrogen Application Rates and Timings of First Irrigation on Wheat Growth and Yield

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Abstract – The release of wheat cultivars with different nutritional demands and yield potential hinders generalized recommendations for nitrogen (N) fertilization and quality of irrigation. A combination of careful irrigation and nitrogen organization is needed to improve the uptake efficiency and to minimize potential N leaching. This study was designed to investigate the effects of the different nitrogen fertilization levels and irrigation timing on the agronomic performance of wheat, at the farm of Soil and Environmental Sciences, Gomal University, Dera Ismail Khan during 2009-2010. A randomized complete block in split plot arrangements with four replications were used. The different nitrogen doses applied to the soil were 0, 80, 100, 120 and 150 kg ha⁻¹ while, irrigation timings were at 15, 20, 25 and 30 days after germination. Nitrogen applied at 120 and 150 kg N ha⁻¹ while kept the irrigation timing of 25 days after germination achieved the highest plant height, more tillers number, maximum number of fertile tillers and highest yield respectively, as compared to control and other treatments. These results suggest that the irrigation timing of 25 days after germination and 120 kg N ha⁻¹ is suitable for maximum growth and wheat yield. Moreover, the higher performance of yield components was associated with higher nitrogen fertilization levels.

Keyword – Nitrogen, Irrigation, Wheat, Yield and Doses.

I. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the first most important cereal crop in the world and a major source of staple food for the inhabitants in Pakistan [1] and [2]. It provides more protein than any other cereal crop [3]. Despite of being grown on larger area, average yield of farmers' fields is still far below than the potential [4]. The inadequate management of nitrogen fertilization, its non-use, soil type, water, climate and crop management are limiting factors of wheat yield. Among these, water use and fertilizer application are the most limiting factor in determining the yield of wheat crop in Pakistan [5].

Irrigation plays an important role in wheat plant development at any critical stage from seed germination to plant maturation. Earlier studies have shown that moisture stress to wheat crop at spike emergence and anthesis stages reduced yield from 3.3 to 7 tons per hectare [6]. Irrigation applied at a sensitive stage, would be a valuable management practice for improving yield [7, 8]. In Pakistan, wheat is usually irrigated 4 to 5 times after sowing up to its maturity. First irrigation is given at 15-20 days after sowing at crown root initiation (CRI) stage. The subsequent irrigations are provided with an interval of 30-35 days. The water requirements of wheat vary from 180 to 420 mm [9]. Thus, there is sufficient scope to find out the minimum amount of water to be applied for maximum yield per millimeter of water applied. Water stress and nitrogen deficiencies reduce photosynthates production because of stomatal closure and early senescence which ultimately affect grain development processes [10]. The effect of water and nitrogen on physiological responses in wheat indicates that supplemental water is needed for high rates of spring applied N to increase the rate and duration of leaf photosynthesis in winter wheat during grain filling period [11]. Nitrogen plays a vital role in all living tissues of the plant. All vital processes in the plant are associated with protein, of which nitrogen is an essential constituent. Nitrogen is a constituent of proteins, enzymes, coenzymes, nucleic acids, phytochromes and chlorophyll. It plays an important role in the biochemical processes of the plant. Therefore, it is one of the most required nutrients by wheat crops [12]. Consequently to get more crop production, nitrogen application is essential in the form of chemical fertilizer [13]. Yield and yield components of high yielding varieties generally increase with increasing levels of nitrogen [14]. Application of proper amount of nitrogen is considered key to obtain a bumper crop of wheat. [15] reported that the spilt N application had little effect on yield, but decreased lodging and spike population, while grain weight increased. Nitrogen application at 120 kg/ha

for wheat has been recommended by various researchers [16] and [17]. [18] reported that spike numbers and grain weight were increased with high level of nitrogen. recorded increased grain yield with an increase in nitrogen level [19]. Nitrogen deficiency affects biomass production and solar radiation use efficiency of the plant, with a great impact on grain yield and its components [20]. The variability in soil and climatic conditions associated with processes that affect nitrogen dynamics in the soil and their relationship with the plant may lead to changes in nitrogen availability and its requirement of the plant [21] and [22]. In addition, the release of new cultivars with different nutritional demands hinders generalized recommendations of nitrogen fertilization of wheat crops [23]. The interest in maximizing wheat yields has encouraged growers to adopt intensive management practices. It should be noted that both an optimized nitrogen management for a less responsive cultivar and a restrictive management for a more demanding cultivar may result in crops with less yield potential. High nutrient levels can also harm crops by making wheat plants more vulnerable to lodging, causing both damages to the environment through leaching [24] and nitrate volatilization [25] and economic losses to farmers, because only 33% of all nitrogen fertilizers applied to cereal crops are absorbed in harvested grain [26]. Thus, the use of nitrogen in wheat crops must be optimized to increase yields. Based on the above information, we performed a short term study with aims to (1) find out the minimum dose of nitrogen fertilizer for maximum wheat yield, (2) determine the minimum required quantity of irrigation water for the maximum wheat yield, (3) find out the most accurate time of irrigation and the most suitable intervals between two irrigations, and (4) to compare different doses, methods and timings of N fertilizer application with that of water.

II. MATERIALS AND METHODS

Experimental site description and treatments

The experiment was carried out at the farm area of the Department of Soil and Environmental Sciences, Faculty of Agriculture, Gomal University, Dera Ismail Khan Pakistan, during 2009-2010. The site is situated at longitude 71.07°E; latitude 31.57°N and 500 m above sea level. It was revealed the maximum temperature (37° C) in April and the minimum (5° C) in December and January/2010 Table I. The soil of the experimental site was classified as Silty clay loam according to the USDA classification. Soil texture, organic matter, total nitrogen, available phosphorous, available potassium, EC_e and pH of soil samples were measured before the start of the experiment. Soil samples were analyzed according to the methods described by the U.S. Salinity Lab. Staff, Agriculture Handbook (Richards 1954), unless otherwise described. Soil pH was determined using a combined electrode and pH meter in a 1:2.5 (soil: distilled water) mixture [27]. The main characteristics of the experimental site are given in Table II. Five doses of nitrogen (N) and four irrigation (I) timings were studied. Nitrogen was

applied at the rate of 0 (control, N1), 80 (N2), 100 (N3), 120 (N4) and 150 (N5) kg/ha. These irrigations were applied at 15 (I1), 20 (I2), 25 (I3) and 30 (I4) days after germination. The experiment was laid out in a split plot arrangement with four replications. Application of N and Irrigation formed a factorial experiment with four replicates for each treatment [(N: 5 × I: 4 × replication 4) = 80 treatments]. The net plot size was 2m × 4m for each treatment.

Plant cultivation, measurement of agronomic parameters and wheat yield

Wheat (variety Bhakkar-2002) was sown on 20 November 2009 at a seed rate of 100 kg/ha. The basal dose of phosphorus 60 kg/ha was applied to each plot, whereas N was applied according to the treatments of current experiment. All other agronomic practices were kept uniform for all treatments. At full maturity of wheat crop, agronomic parameters including plant height (cm), the number of fertile and infertile tillers/m², number of spikelet per spike, number of grains per spike, 1000 grain weight (g), grain yield (t/ha), biological yield (t/ha), straw yield (t/ha), harvest index (%) and economic analysis were measured using standard procedures. Randomly three plants were selected to measure different parameters from each plot. For biological yield, crop was harvested and tied into bundles separately from each treatment. Biological yield was recorded by weighing the bundles of each plot with a spring balance. The bundles were first sun-dried for 4 days and then threshed by a thresher. The grain weight was recorded for each treatment. After threshing, straw yield per plot was determined. The harvest index for each plot was calculated as follows:

$$\text{HI (harvest index)} = \text{grain yield/biological yield} \times 100.$$

The cost benefit ratio was calculated as follows: Cost benefit = total income – total cost for each treatment.

Statistical analysis

The data analyzed statistically using MSTATC computer software, according to Fisher's Analysis of Variance Technique and significant means were separated using Least Significant Difference (LSD) Test at 5 % probability level.

III. RESULTS AND DISCUSSION

Plant height

Plant height was significantly affected by different nitrogen levels and irrigation timings Table III. Maximum plant height (96.60 cm) was recorded from N5 (150 kg N /ha) and N4 (irrigated 30 days after germination) treatments as compared with other treatments. While, minimum plant height (46.10 cm) was observed in N1 treatments, where no nitrogen was applied. The results of nitrogen doses of 120 kg/ha were applied and irrigated 20 days after germination were statistically at par with those treatments where 150 kg nitrogen was applied and irrigated 30 days after germination. These results are in accord with those of [28], [29], [30]. They also observed an increase in plant height after nitrogen fertilization. Our result further supported by [31] that nitrogen levels of 140 kg ha⁻¹ significantly augmented germination

percentage and seed size by weight. Effect of irrigation was also significant on plant height. In those treatments where irrigation is applied after 15 days of germination statistically produced higher plant height (79.54 cm) as compared to those treatments where irrigation was applied 30 days after germination (77.0 cm). [32] also found that irrigation frequencies had a significant effect on plant height. [33] detected that irrigation has a positive effect on plant height. It may be attributed to the irrigation effect on the encouragement of cell elongation, cell division and consequently, increased meristematic growth.

Number of fertile and infertile tillers

Numbers of tillers were significantly affected by nitrogen levels and irrigation application. All the treatments receiving nitrogen produced a significantly more total number of tillers m^{-2} after those treatments where no nitrogen was applied. The maximum number of fertile tillers ($402/m^2$) was produced in those treatments where nitrogen was applied at the rate of 150 kg/ha and irrigated 20 and 25 days after germination and minimum number of fertile tillers ($92/m^2$) was observed in those treatments where no nitrogen was applied and irrigated 30 days after germination. The number of fertile tillers in those plots where nitrogen was applied at the rate of 120 kg/ha and irrigated 25 days after germination were statistically at par with those treatments where nitrogen was applied at the rate of 150 kg/ha and irrigated 15, 20, and 25 days after germination, which were significantly higher than those where irrigation was applied 30 days after germination Fig I. [34], [35], [36] reported that the number of spikes increased as irrigation increased. [37] also observed that irrigation at critical growth stages and the application of 150 kg N/ha gave the highest number of productive tillers. These results are quite in line with those of [29], [31], [41], [42] observed that productive tillers m^{-2} , 1000-grain weight and grain yield of wheat enhanced with the application of 150 kg N ha^{-1} . Various levels of nitrogen and irrigation timings significantly affected the number of infertile tillers. The maximum number of infertile tillers ($12/m^2$) was found where no nitrogen was applied while the minimum infertile tiller ($2/m^2$) in those treatments where nitrogen was applied at the rate of 120 and 150 kg N/ha. The treatments in which nitrogen was applied at the rate of 120 and 150 kg N/ha but irrigated 30 days after germination produced significantly more infertile tillers ($3/m^2$) as compared to those which were irrigated 15, 20 and 25 days after germination. Irrigation timings also significantly affected the infertile tillers. The treatments which were irrigated 30 days after germination produced significantly more infertile tillers m^{-2} as compared to those which were irrigated earlier. There was no difference between those treatments in which nitrogen was applied at the rate of 120 and 150 kg/ha and irrigated at 15, 20 and 25 days after germination. Fertilizer nitrogen is found to affect the number of tillers m^{-2} , number of spikelet's $Spike^{-1}$, number of Grains $spike^{-1}$, spike length and 1000-grain weight [13]. The increase in the number of tillers with an increase in nitrogen levels could be attributed to the well-accepted role of nitrogen in accelerating the vegetative

growth of plants. [34] also observed the significant effect of varying irrigation levels on the number of tillers. [28], [39], [43] also stated that increasing nitrogen application increased the number of tiller m^{-2} .

Number of spikelets per spike

Almost all the treatments produced a significantly more number of spikelets per spike as compared to control Table IV. Means Comparison in the case of nitrogen levels indicates that the spikelets per spike increase significantly with increasing of nitrogen. Maximum numbers of spikelets per spike (18) were produced from those treatments in which nitrogen was applied at the rate of 150 kg/ha and irrigated 25 days after germination, but these were statistically at par with those treatments in which nitrogen was applied at the rate of 120 kg/ha and irrigated 20 and 25 days after germination. Minimum numbers of spikelets per spike (9) were produced from those treatments in which no nitrogen was applied. The irrigation timings also significantly affected the number of spikelets per spike. Those treatments in which irrigation was applied 15 days after germination produced more number of spikelets per spike as compared to those which were irrigated after 20, 25 and 30 days of germination. [31] showed that the spikelets per spike increase significantly with increasing levels of nitrogen. Several investigators documented a beneficial effect of nitrogen application on wheat [44], [45], [46]. They reported that the number of spikelets increased with increasing N level.

Number of grains per spike and grain yield (t/ha)

Number of grains per spike was significantly affected by various nitrogen levels and irrigation timings Table V. The treatments receiving N produced a significantly more number of grains per spike as compared to those in which no nitrogen was applied. Maximum number of grains per spike (47) were recorded in those treatments were 120 and 150 kg N/ha was applied and irrigated 25 days after germination that were statistically greater than those where 80 and 100 kg N/ha were applied. Minimum number of grains per spikes (23) were obtained from those plots where no nitrogen was applied and irrigated 30 days after germination of first irrigation. These findings are in agreement of findings of earlier studies [28], [29], [31], [35], [37], [41]. Grain yield was significantly affected by nitrogen levels and irrigation timings Table VI. Maximum grain yield ($3.10 t ha^{-1}$) was produced in those treatments where nitrogen levels were 120 and 150 kg/ha and the crop was irrigated after 20 and 25 days of germination. Minimum grain yield ($1.69 t ha^{-1}$) was found in those plots where nitrogen levels were zero. Higher grain yield was determined in the case where nitrogen levels were 120 and 150 kg/ha and crop was irrigated after 20 and 25 days of germination which might be due to supply of nitrogen starting from the early vegetative growth to flowering that synchronized the crop need for nitrogen and produced the highest number of fertile tillers per unit area and higher filled grains spike. From the result of current study, it is clear that grain yield increased significantly with the increase of irrigation and nitrogen levels. These findings are in line with ealier studies [8],[35],[37],[38],[47],[48].

1000-grain weight

1000-grain weight was significantly affected by various nitrogen levels and irrigation timings. All the treatments produced significantly higher 1000-grain weight over those treatments where no nitrogen was applied. The maximum 1000-grain weight (43.80 g) was recorded in those treatments where nitrogen doses were applied at 120 and 150 kg/ha and irrigation timings were 25 days after germination. Minimum 1000-grain weight (39.80 g) was observed in those treatments where nitrogen was not applied. These findings are in conformity with those of previous studies [29], [38], [41], [47], [49]. Those treatments in which irrigation was applied at 15, 20 and 25 days after germination produced more 1000-grain weight as compared to those treatments which were irrigated 30 days after germination in *Table VII*. The results were similar to the findings of previous reports [47], [50].

Biological yield and straw yield ($t\ ha^{-1}$)

Biological yield (total biomass produced by a crop from the unit area) was significantly affected by nitrogen levels and irrigation timings *Table VIII*. Maximum biological yield ($8.99\ t\ ha^{-1}$) was observed in those plots where the nitrogen level was kept 150 kg/ha and the crop was irrigated 25 days after germination. Minimum biological yield ($6.13\ t\ ha^{-1}$) was recorded in those plots where nitrogen levels were zero. Our results confirmed the results [51] who obtained maximum biological yield in plots treated with 285 kg nitrogen per hectare. In 2011, [52] conducted an experiment in which he observed that biological yields were increasingly affected by the available water and N fertilizer. The finding indicated that the biological yield response to N was associated with water application levels.

Straw yield ($t\ ha^{-1}$)

Straw yield was significantly affected by nitrogen levels and irrigation timings. Maximum straw yield ($5.88\ t\ ha^{-1}$) was observed in those plots where the nitrogen level was 150 kg/ha and crop was irrigated 25 days after germination. Minimum straw yield ($4.36\ t\ ha^{-1}$) was recorded in those plots where the nitrogen level was 80 kg/ha *Table IX*. There was no statistically difference between those treatments in which 120 kg nitrogen per hectare was applied and those in which 150 kg N/ha was applied. The results are in accordance with the findings of earlier studies [35], [38], [47].

Harvest index

Data pertaining to harvest index as affected by various nitrogen levels and irrigation timings presented in *Table IO*. The data showed that harvest index was significantly affected by nitrogen levels and irrigation timings. Maximum harvest index (39.16 %) was recorded in those treatments where nitrogen levels was 120 kg/ha and the crop was irrigated 25 days after germination and the minimum harvest index (28.17%) was observed in those treatments where no nitrogen was applied. Statistically there was no difference between those treatments in which 150 kg N/ha was applied. The results of [50] collaborate with the results obtained regarding irrigation and regarding nitrogen the findings are in conformity with those of [29].

Economic Analysis

Economic analysis showed that by spending Rupee (Rs.) 2900 ha^{-1} irrigated after 25 days + nitrogen 150 $Kg\ ha^{-1}$ was the best economical treatment with the highest net benefit of Rs.83241. Other treatment combinations such as irrigated after 20 days + nitrogen 150 $Kg\ ha^{-1}$ gave the net benefit of Rs. 83072 and irrigated after 25 days + nitrogen 120 $Kg\ ha^{-1}$ gave the net benefit of Rs. 81493. Another treatment i.e. Irrigated after 25 days + nitrogen 0 $Kg\ ha^{-1}$ gave the net benefit of Rs. 52068.

IV. CONCLUSION

Nitrogen fertilization management and irrigation (rate and timing) offers the opportunity for increasing the wheat production. In the present investigation, wheat variety Bhakkar-2002 achieved a higher number of tillers, plant height, 1000-grain weight and maximum grain yield in 120 $kg\ ha^{-1}$ nitrogen level and first irrigation interval of 25 days after germination. So it is possible to get maximum growth and wheat yield just in 120 $kg\ N\ ha^{-1}$ and irrigation timing of 25 days after germination. However, excess applications of N are not economically efficient and can create environmental problems.

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Previous publications:

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Previous publications:

1/ Mohammed E. E. Mahmoud*¹, Suliman A. Ibrahim¹, Hassbelrasul A. Mohamed² Recommendation of Cruiser 350 FS (Thiamethoxam) against the green bug *Schizaphis graminum* (Rondani) and termite on Wheat in 80th meeting of the national pests and diseases committee , June 2009 in Agricultural Research Corporation ,Wad Medani , Sudan.

2/ Hassbelrasul A. Mohamed¹ and Suliman A. Ibrahim Ali¹ Evaluation of a new formulation of Gaucho 600 FS (Imidacloprid) and Raxil 120 FS (Tebuconazole) as mixture for control of aphids, termites and damping off on wheat in 81st meeting of the national pests and diseases committee , December 2009 in Agricultural Research Corporation ,Wad Medani , Sudan.

3/ Suliman Abdalla Ali^{1*}. Detection and Monitoring of Some Tephritidae of Fruit Trees and their Host range in Abugubeiha, South Kordofan State, Sudan. Arab Journal of Plant Protection Volume 27, Special Issue October,26/2009.

4/Mohammed E. E. Mahmoud*¹, Suliman A. Ibrahim¹, Hassbelrasul A. Mohamed² and Francis Leju Oji¹ Prospects of Using Cruiser[®]350 FS (thiamethoxam) to Control Greenbug *Schizaphis graminum* (Rond.) on Wheat. Persian Gulf Crop Protection Volume 1 Issue 4, December 2012 Pages 1-4.

5/Suliman A. Ibrahim Ali*¹, Mohammed E. E. Mahmoud¹WangMan-Qun² and Diakite Mory Mandiana². Survey and Monitoring of Some Tephritidae of Fruit Trees and heir Host Range in River Nile State, Sudan. Persian Gulf Crop Protection Volume 2 Issue 3, September 2013Pages 32-39.

6/ Mohaned, M. A. Mohamed¹, Mohamed, H. Zein Elabdeen² and Suliman Abdalla I. Ali^{3*} Host Preference of the Melon Worm, *Diaphania hyalinata* L. (Lepidoptera: Pyralidae), on Cucurbits in Gezira State, Sudan. Persian Gulf Crop Protection Volume 2 Issue 3, September 2013 Pages 55-63.

7/Abdalla. M. Abdalla Salim¹, El- I mam Elkhidir²and Suliman Abdalla.I.Ali^{3*} Incidence of the Whitefly, *Bemisia tabaci* (Genn.) on Two Cotton Varieties, Pubescent and Glabrous Grown under Field Conditions in Sudan. Persian Gulf Crop Protection Volume 2 Issue 3, September 2013 Pages 47-54.

8/Akaram.S.S.Muhammed *¹, H.U.R.R. MEMON², S.K. Baloch³, Khalid Abdalla Osman⁴ and Suliman A. Ibrahim Ali⁴ Effect of Bio-organic and Inorganic Fertilizers on The Growth And Yield Of Wheat (*Triticum aestivum* L.) Persian Gulf Crop Protection Available online on: www.cropprotection.ir ISSN: 2251-9343 (Online) Volume 2 Issue 4,

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9/ Nagm Eldeen .D. A. Dafalla¹, M.S. A.EL-Sarrag¹, Khalid Abdalla Osman² and Suliman Abdalla.I.Ali² * Determination of Flavonoids in Sudanese Honey Samples and Plant Sources Collected from Different Places in Sudan . International Journal of Agriculture Innovations and Research Volume 2, Issue 4, ISSN (Online) 2319-1473.


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Previous publications:

1. Osman, K. A., A. M. Mustafa and A. S. Ibrahim., 2006.(Genetic Variability And Interrelationships Of Grain Yield And Its Components Of Irrigated Rice In Gezira. gezera journal. of Agric. Sci.5(2) :154-166. 2007.

2. Khalid A. Osman, Bin Tang, Yaping Wang, Juanhua Chen, Feng Yu, Liu Li, Xuesong Han, Zuxin Zhang, Jianbin Yan, Yonglian Zheng, Bing Yue, Fazhan Qiu . 2013. Dynamic QTL Analysis and Candidate Gene Mapping for Waterlogging Tolerance at Maize Seedling Stage. PLoS ONE 8(11): e79305. doi:10.1371/journal.pone.0079305.

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Previous publications:

1. Awadalla Abdalla Abdelmula and Salih Adam Ibrahim Sabiel (2007). Genotypic and Differential Responses of Growth and Yield of some Maize (*Zea mays* L.) Genotypes to Drought Stress. Tropentag, Conference on International Agricultural Research for Development, University of Kassel-Witzenhausen and University of Göttingen, October 9-11, 2007, Germany.

2. Elfadil Bashir, Bettina Haussmann, Abdelbagi Ali, Adam Ali, Mohamed Ismail, Elgailani Abdalla, Omer Bakht, Salih Sabeel, Peter Muth, Heiko Parzies (2011). Genetic Analysis and Biofortification of Pearl Millet for Nutritional Values. Conference of Development on the margin, Tropentag 2011, October 5 - 7, Bonn, Germany.

3. Elfadil Bashir, Adam Ali, Mohamad Ismail, Elgailani Abdalla, Omar Bakht, Salih Sabeel, Abdelbagi Ali, Bettina I.G. Haussmann (2012). Characterisation of Sudanese Pearl Millet Germplasm as Source in Breeding for Adaptation to Climate Change. Conference on Resilience of agricultural systems against crises, Tropentag, September 19-21, 2012, Göttingen -Kassel/Witzenhausen, Germany.

Table I: Average monthly and seasonal meteorological data during 2009-2010

Month	Temperature (C ⁰)		Relative Humidity		Rainfall (Mm)
	Max	Min	Hrs.	Hrs	
October	33	16	82	57	13
November	25	10	80	55	--
December	22	5	81	63	--
January	16	5	88	76	9.2
February	22	8	76	58	1.1
March	30	15	63	63	22
April	37	19	74	45	--

Table II: Physico-Chemical properties of experimental site

Items	Units	Value
pH	-	8.5
EC _c	(dS/m)	3.50
OM	(%)	0.60
Total N	(%)	0.030
Avail. P	(mg/kg)	7.50
Avail. K	(mg/kg)	102
Cl ⁻	(meq/L)	2.60
Ca ⁺² + Mg ⁺²	(meq/L)	2.80
Textural Class	-	Silty clay

Table III: Plant height (cm) as influenced by different nitrogen levels and timings of first irrigation

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	48.70 h	73.70 f	85.75 e	92.10 cd	94.50 ab	79.54 a
Irrigation 20 DAG	48.40 hi	72.55 f	85.10 e	94.75 ab	93.55 bc	78.92 ab
Irrigation 25 DAG	46.60 hi	73.15 f	85.70 e	90.45 d	96.05a	78.41 b
Irrigation 30 DAG	46.10 i	66.05 g	85.15 e	94.40 abc	96.60 a	77.0 c
Mean	47.45 e	71.36 d	85.42 c	92.92 b	95.17 a	

Means sharing the same letter in a column do not differ significantly at p = 0.05

LSD_{0.05} for Nitrogen = 1.18 , LSD_{0.05} for Irrigation = 1.06

Table IV: Number of spikelets per spike as influenced by different nitrogen levels and timings of first irrigation

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	11 f	13.50 e	15.50 d	17.50 ab	17.00 bc	14.60 b
Irrigation 20 DAG	10.00 g	13.50 e	15.00 d	17.50 ab	16.50 c	14.10 c
Irrigation 25 DAG	9.00 h	13.50 e	15.50 d	18.00 a	18.00 a	14.90 b
Irrigation 30 DAG	9.00 h	13.50 e	17.00 bc	16.50 c	18.00 a	15.40 a
Mean	9.75 d	13.50 c	15.75 d	17.37 a	17.37 a	

Means sharing the same letter in a column do not differ significantly at p = 0.05

LSD_{0.05} for Nitrogen = 0.37

LSD_{0.05} for Irrigation = 0.33

Table V: Number of grains per spike as influenced by different nitrogen levels and timings of first irrigation

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	30.00 e	33.00 d	39.00 b	46.00 a	46.50 a	37.50 b
Irrigation 20 DAG	25.50 f	34.50 cd	40.50 b	46.00 a	44.50 a	37.80 b
Irrigation 25 DAG	23.50 f	34.50 cd	40.00 b	47.00 a	46.00 a	38.40 b
Irrigation 30 DAG	23.00 f	36.00 c	40.50 b	46.00 a	46.00 a	39.90a
Mean	25.50 d	34.50c	40.00 b	46.25 a	45.75 a	

Means sharing the same letter in a column do not differ significantly at p = 0.05

LSD_{0.05} for Nitrogen = 1.38

LSD_{0.05} for Irrigation = 1.24

Table VI: Grain yield (t ha⁻¹) as influenced by different nitrogen levels and timings of first irrigation

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	1.75 i	2.16 g	2.34 e	3.07 c	3.06 c	2.47 bc
Irrigation 20 DAG	1.69 k	2.14 h	2.35 de	3.10 a	3.10 a	2.47 bc
Irrigation 25 DAG	1.73 j	2.19 f	2.36 d	3.10 a	3.10 a	2.49 a
Irrigation 30 DAG	1.73 j	2.14 h	2.34de	3.09 ab	3.08 bc	2.48 ab
Mean	1.72 d	2.16 c	2.35 b	3.08 a	3.09 a	

Means sharing the same letter in a column do not differ significantly at p = 0.05

LSD_{0.05} for Nitrogen = 2.0

LSD_{0.05} for Irrigation = 2.0

Table VII: 1000-grain weight (g) as influenced by different nitrogen levels and timings of first irrigation

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	40.20 i	41.30 h	42.50 de	42.90 bcd	43.20 b	41.71 c
Irrigation 20 DAG	39.88 i	41.90 g	41.90 g	43.20 b	43.20 b	41.82 c
Irrigation 25 DAG	39.80 i	42.35ef	42.90 bcd	43.80 a	43.80 a	42.07 b
Irrigation 30 DAG	38.90 j	41.95 fg	40.95 h	42.71 cde	42.95 bc	42.31 a
Mean	39.68 d	41.87 c	42.06 c	42.97 b	43.28 a	

Means sharing the same letter in a column do not differ significantly at p = 0.05

LSD_{0.05} for Nitrogen = 0.21

LSD_{0.05} for Irrigation = 0.19

Table VIII: Biological yield (t ha⁻¹) as influenced by different nitrogen levels and timings of first irrigation

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	6.33 h	6.91 efgh	7.80 cdef	8.20 abcd	8.98 a	7.64 a
Irrigation 20 DAG	6.13 h	6.81 fgh	8.01 abcd	7.89 bcde	8.94 a	7.56 a
Irrigation 25 DAG	6.29 h	6.56 gh	8.16 abcd	8.33 abcd	8.99 a	7.67 a
Irrigation 30 DAG	6.53 gh	7.39 defg	8.01 abcd	8.69 abc	8.89 ab	7.91 a
Mean	6.32 d	2.92 c	8.00 d	8.28 b	8.95 a	

Means sharing the same letter in a column do not differ significantly at p = 0.05

LSD_{0.05} for Nitrogen = 0.52

LSD_{0.05} for Irrigation = 0.46

Table IX: Straw yield ($t\ ha^{-1}$) as influenced by different nitrogen levels and timings of first irrigation

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	4.58 efg	4.75 cdefg	5.46 abcdef	5.12 abcdefg	5.92 a	5.17 a
Irrigation 20 DAG	4.44 fg	4.66 defg	5.66 abcd	4.80 bcdefg	5.85 a	5.08 a
Irrigation 25 DAG	4.56 efg	4.36 g	5.80 ab	5.26 abcdefg	5.88 a	5.17 a
Irrigation 30 DAG	4.80 bcdefg	5.25 abcdefg	5.67 abcd	5.59 abcde	5.79 abc	5.42 a
Mean	4.60 d	4.76 cd	5.65 ab	5.19 bc	5.86 a	

Means sharing the same letter in a column do not differ significantly at $p = 0.05$

LSD_{0.05} for Nitrogen = 0.52

LSD_{0.05} for Irrigation = 0.46

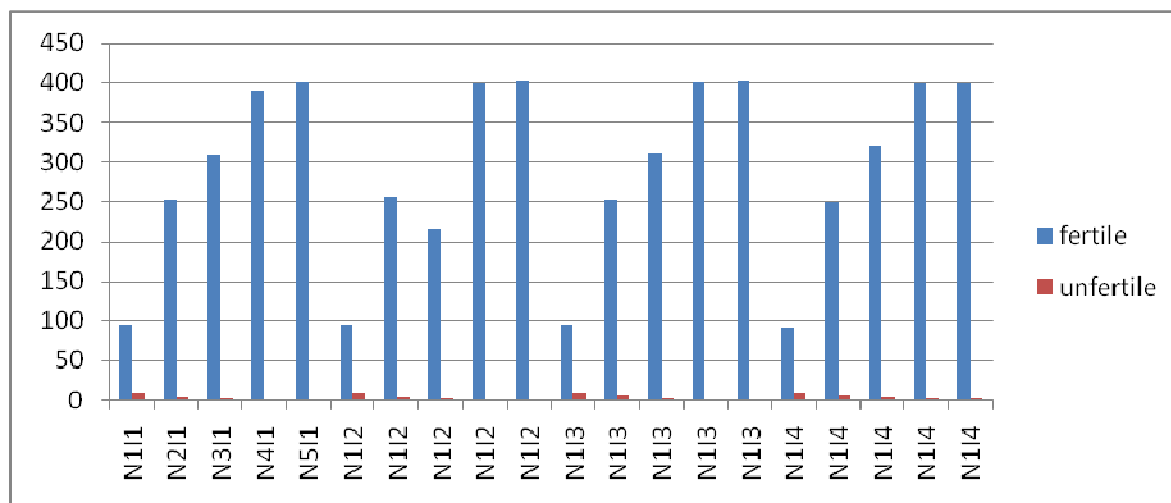
Table X: Harvest Index as influenced by different nitrogen levels and timings of first irrigation.

Irrigation Timings	Nitrogen Levels					Mean
	N ₁	N ₂	N ₃	N ₄	N ₅	
	Control	80 kg/ha	100 kg/ha	120 kg/ha	150 kg/ha	
Irrigation 15 DAG	28.93 efg	32.24 cdef	30.64 defg	37.57 ab	34.27 bcd	32.73 a
Irrigation 20 DAG	28.17 g	32.44 cde	29.53 efg	36.97 ab	34.48 bcd	32.75 a
Irrigation 25 DAG	28.71 efg	34.75 bc	28.99 efg	39.16 a	34.52 bcd	32.79 a
Irrigation 30 DAG	28.40 fg	29.32 efg	29.38 efg	35.97 abc	34.89 bc	31.60 a
Mean	28.55 d	32.19 c	29.63 d	37.42 a	34.54 b	

Means sharing the same letter in a column do not differ significantly at $p = 0.05$

LSD_{0.05} for Nitrogen = 1.96

LSD_{0.05} for Irrigation = 1.75


Fig.1 . Number of fertile and infertile tillers (m^{-2}) as influenced by different nitrogen levels and timings of first irrigation