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Effect of different irrigation and fertility levels on dynamic growth and yield of late sown wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted at Kumarganj, Faizabad during *Rabi* season of 2016 to evaluate the effect of different irrigation and fertility levels on dynamic growth and yield of late sown wheat (*Triticum aestivum* L.). Results revealed that the irrigation levels significantly affected grain and straw yields as well as most of the growth and their attributes of wheat. Four irrigations recorded highest plant height (74.63cm), number of tillers (81.33 m^{-1} row), dry matter accumulation (93.16 g m^{-1} row) at harvest stage and leaf area index (3.85) at 90 DAS as well as higher grain (23.12 q ha^{-1}) and straw yield (32.37 q ha^{-1}) over two and one irrigation. Among fertility levels application of 25% more than RDF of NPK fertilizer recorded highest plant height (69.65cm), number of tillers (78.41), dry matter accumulation (82.80 g m^{-1} row), leaf area index (3.50) as well as grain (19.65 q ha^{-1}) and straw yield (29.64 q ha^{-1}) over 100% RDF and 25% less than RDF of NPK, respectively.

Keywords: Wheat, growth, yield, NPK fertilizer, CRI (crown root initiation), RDF (recommended dose of fertilizer)

Introduction

Wheat (*Triticum aestivum* L.) is the most important among all cereals used as a food grain in the world. It provides nearly 55% of the carbohydrate and 20% of food calories which is consumed by two billion people (36% of the world population) as staple food. Wheat is more nutritive as compared to the other cereals. It has good nutrition profile with 12.1 percent protein, 1.8 percent lipids, 1.8 percent ash, 2.0 percent reducing sugars, 6.7 percent pentose's, and provides 314 Kcal/100g of food. It ranks first in the world cereal area and production. Globally, wheat covers an area of 220.4 million ha (FAO, 2016) [10] with production of 748.8 million tonnes (Mt) (FAO, 2017) [11]. In India, wheat is cultivated almost all part of the country and occupied 30.22 million ha (DACFW, 2017) [8] with the production of 93.50 million tonne (mt) in 2016-17 (DACFW, 2017a) [9]. Among wheat cultuivated states, Uttar Pradesh rank first with respect to area (9.65 million ha) and production (26.87 Mt) but the productivity is much lower (2786 kg ha^{-1}) than Punjab (4491 kg ha^{-1}) and Haryana (4574 kg ha^{-1}) (DACFW, 2016) [7]. There are many factors responsible for low yield of wheat but insufficient irrigation and poor crop nutrition are the most important. Water is essential at every developmental phase starting from seed germination to plant maturation for harvesting the maximum potential yield of wheat. There is a positive correlation between grain yield and irrigation frequencies (Kumar *et al*., 2012) [16]. Irrigation missing at some critical growth stage sometime drastically reduces grain yield due to lower test weight. Efficient water management, being one of the good agronomic management practices, it not only leads to improve crop productivity but also minimize susceptibility from disease and insect pest under favourable environment for flourishing these biotic stress (Singh *et al*., 2011) [21].

Proper sowing date is an important factor for crop production of wheat. Delay in sowing normally reduces individual plant growth and tiller production (Shivani *et al*., 2003) [20].

Fertilizers play a pivotal role in increasing yield and improving the quality of crops. Application of NPK in balanced level has great impact on late sown wheat yield. Since high yielding varieties of wheat have been found highly responsive to nitrogen fertilization. The efficiency of both nitrogen and phosphorus is greatly enhanced in the presence of each other (Stoeva and Tonev, 2003) [22]. Increased use of N without adding required K in soil has further aggravated K deficiency because, K play important role in improvement of the growth indices.

The present studies were executed to determine astute irrigation levels and NPK requirements for wheat genotypes namely Unnat Halna (K-9423) grown under agro ecological condition of Faizabad.

Materials and methods

The field experiment was conducted at Agronomy Research Farm, Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj) Faizabad (U.P.), during the *rabi* season from January 8, 2016 to April 23, 2016. The experimental site falls under sub-tropical zone in Indo-gangatic plains and lies between $26^0.47$ North latitude, $82^0.12$ East longitudes, at an altitude of about 113.0 meter from mean sea level. The soil of experimental field was low in available nitrogen (204.00 kg ha^{-1}) and organic carbon (0.34%), medium in available phosphorus (15.35 kg ha^{-1}) and high in potassium (267.00 kg ha^{-1}). The reaction of the soil was slightly alkaline. The total rainfall during course of experimentation was 124.0 mm. During the crop season, the lowest temperature (5.9^0C) was recorded in the month of December to January and the maximum (36.8^0C) in the month of April. Studies were carried out at the Agronomy farm, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during the *rabi* season from January 8, 2016 to April 23, 2016. The experiment was laid out in a split plot design replicated four times with main plot treatments four irrigation levels *viz.* I_1 at CRI stage, I_2 at CRI and flowering stages, I_3 at CRI, late jointing and milking stages, I_4 at CRI, tillering, flowering and milk stages were randomized in the main plots while fertility levels *viz.* D_1 25% less than RDF of NPK (90:45:30), D_2 100% RDF of NPK (120:60:40), D_3 25% more than RDF of NPK (150:75:50) kg ha^{-1} were allocated to subplots.

Wheat variety Unnat Halna (K-9423) was sown on 8^{th} January 2016 and harvested at 23^{rd} April 2016. Seed rate 120 kg ha^{-1} was taken with 20 cm row spacing. Crop was raised with recommended package of practices of weed management, viz. application of total (sulfosulfuron 75% + metsulfuron methyl 5% WG.) @ 39.566 g ha^{-1} at 30 days after sowing was used. The field plots were separated with plot border of 0.5m size. Irrigations applied as per treatment on the basis of critical levels as per schedule approach using 5 cm depth of irrigation water. A recommended dose of fertilizer was 120:60:40 kg ha^{-1} and Nitrogen, phosphorus and potassium of different fertility levels were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Whole of P and K and half of N was applied as basal dose and remaining nitrogen was top-dressed after first irrigation. All other agronomic practices were kept normal for all the treatments.

Observations regarding growth like plant height (cm), number of tillers (m^{-1}), dry matter accumulation were recorded at 30, 60, 90 DAS and at harvest stage (g m^{-1}row) while observations regarding leaf area index (LAI) were taken at 30, 60 and 90 DAS interval. Plant height was recorded by selecting 5 random plants from each net plot and tagged and height of plant was measured with the help of meter scale from soil surface to apex of the plant at 30, 60, 90 DAS and at harvest of the crop and mean value from all the recorded data was worked out. Similarly the leaf area of five plants was measured by automatic leaf area meter at 30, 60 and 90 DAS of the crop and Leaf area index was calculated by dividing the leaf area per unit land area. For dry matter accumulation, plants falling within 50 cm row length from second row marked were cut close to the ground surface and dried in a hot air oven maintained at 70±2 °C till constant dry weight. Dry matter of plants was recorded and expressed in gram per metre row length.

Harvesting of individual plot was done at physiological maturity when crop turned yellowish as like straw colour. Harvested plants were sun dried for few days in same plots followed by carefully bundled, tagged and finally brought to threshing floor. The bundle weight of net plot was recorded individually. Whole biomass was weighted just before the threshing. Threshing was done by power thresher plot wise and cleaned separately for taking the grain weight from the net plots. Straw yield was recorded by subtracting grain weight from total biomass yield. All the data were recorded in kg $plot^{-1}$ which were finally converted into q ha^{-1}. Data collected on different growth, yield and quality parameters were analysed statistically by Fisher's analysis of variance technique and the least significant difference (LSD) test at 5% probability level was employed to test the significance of treatment means (Gomez & Gomez, 1984) [12].

Results and discussion

Data regarding dynamic growth and their attributes and yield of wheat as influenced by different irrigation and fertility levels are presented in Tables and discussed in different sections.

Plant height (cm)

The irrigation levels affected the plant height significantly at all the stages of crop growth except at 30 DAS. At advance stages (60 DAS, 90 DAS at harvest stages) plant height increased with increasing the levels of irrigation from one to four irrigation. The highest plant height was recorded (54.31 cm), (75.51 cm) and (74.63 cm) at 60, 90 DAS and at harvest, respectively with four irrigation (I_4) which was superior over three (I_3), two (I_2) and one (I_1) irrigation level. It might be due to the maximum irrigation level scheduled with 4 irrigations at critical stages *i.e.* (CRI, tillering, flowering, milking stage) crops were provided with adequate moisture to meet their various requirements, which resulted into higher plant height. Increase in plant height at higher level of irrigation could be possible due to maintenance of constant water supply to the plants, which maintained various metabolic processes. The results are in agreement with the findings of Rahman *et al*., (2006) [18] and Brahma *et al.,* (2007) [6].

Fertility levels profoundly affected the plant height with the age of the crop. A minute difference in plant height at initial age of the crop was due to less time available for growth and development of plants. On the other hand increased cell division due to proper availability of nutrients, increased the plant height at later stages of the crop growth. At harvest, the tallest plant *i.e.* 69.65 cm was recorded with the application of D_3 which was 2.67, and 15.87% superior over D_2 and D_1, respectively during course of investigation. Increased NPK fertilizer doses from 100% RDF to 25% more than RDF could not influence the plant height but increases significantly over 25% less than RDF of NPK. The results are in agreement with the findings of Kale *et al*. (2015) [14].

Number of tillers (m^{-1})

Number of tillers m^{-1} row length was not influenced significantly due to irrigation levels at 30 DAS. However, the effect of irrigation on number of tillers m^{-1} row length at 60 DAS and 90 DAS was found to be significant. At 60 DAS the four irrigation being at par with three irrigation, recorded maximum number of tillers m^{-1} (82.00) which was significantly superior over two and one irrigation level, respectively. The maximum number of tillers m^{-1} row length (84.28) was recorded with four irrigation and minimum (71.75) with one irrigation at 90 DAS. It might be due to timely supply of at critical stages *i.e*. CRI, tillering, flowering and milk stage. Constant moisture level in field maintained the various metabolic processes which led to profuse tillering, the results are in agreement with the findings of Aslam *et al.* (2015) [3] and Kumar *et al.* (2016) [15].

Significantly higher number of tillers m^{-1} row length were observed when we move from D_1 (25% less than RDF of NPK) to D_2 (100% RDF of NPK) and D_3 (25% more than RDF of NPK) at all the growth stages except 30 DAS *i.e*. 60DAS, 90DAS and at harvest stage. At later stages, maximum number of shoots were noticed under D_3 (25% more than RDF of NPK fertilizer) treatment which was statistically at par with D_2 (100% RDF of NPK) but, significantly higher over D_1 (25% less than RDF of NPK). Minimum number of shoots m^{-1} row length recorded with D_1 (25% less than RDF of NPK) at all the stages during course of study. The higher number of tillers associated with increasing levels of NPK fertilizer at later stages might be due to enhanced cell expansion and various metabolic processes in the presence of abundant supply of nutrients which resulted into increased tillering. However, at initial stage these activities were very slow and had a little effect on number of tiller under various levels of NPK fertilizer. The results confirms the findings of Hussain, (2002) [13].

Leaf area index (LAI)

Data on progressive leaf area index at the successive stages of crop growth as influenced by different irrigation and fertility levels. In general, at 30 DAS different irrigation and fertility levels could not affect leaf area index which might be due to similar and slower growth rate at initial crop age. It is quite evident from the data that leaf area index increased successively till 60 DAS under different irrigation levels. Among the irrigation levels four irrigation recorded significantly higher leaf area index at 60 DAS and 90 DAS as compared to one and two irrigation levels but significantly at par to three irrigation level. Increase in LAI under increased moisture availability might be due to fact that moisture and nutrient supply contributed to more number of green leaves, size of leaves, etc., led to higher leaf area and leaf area index. The lowest LAI was recorded under one irrigation. It is quite evident that leaf expansion is normal, if relative water content is about 90 to 100 percent. If it falls below 70-75 percent, leaf expansion stops, cell expansion is more affected by moisture stress than cell division. The results were in close proximity to those of Saren *et al.* (2004) [19] and Rahman *et al.* (2006) [18].

In case of fertility levels effect on leaf area index, the maximum and minimum of these characters were credited to 25% more than RDF of NPK fertilizers (D_3) and 25% less than RDF of NPK fertilizers (D_1), respectively. Adequate supply of nutrients favored the nutrient uptake and nutrient utilization towards protein which favored vertical and lateral growth of the plant and ultimately increase the area of leaves, the results are in agreement with the findings of Bondey *et al.* (2004) [5] and Laghari (2010) [17].

Dry matter accumulation

Analogous to growth characters, the dry matter production increased at successive growth stages of the crop. Among various growth stages the highest value of dry matter was recorded at harvest stage. The rate of increase in dry matter was observed more between 30 to 60 DAS followed by 60 to 90 DAS and 90 DAS to harvest stage, respectively. Dry matter accumulation observed during various crop growth stages are presented in Table- 4. It clearly reveals that different irrigation schedules could not influence the dry matter accumulation g m^{-1} row length at 30 DAS because one irrigation was given to all the plots during that period. However, at later stages irrigation levels significantly affected the dry matter accumulation g m^{-1} row length. Higher dry matter accumulation was recorded under four irrigation (I_4) which was at par with three irrigation level (I_3) but significantly superior over one and two irrigation level at 60, 90 DAS and at harvest stage. The maximum dry matter accumulation (93.16 g m^{-1} row length) was obtained under four irrigation (I_4) and minimum (57.53 gm^{-1} row length) under one irrigation (I_1) at harvest stage during course of investigation. It might be due to increase in plant height, LAI and uptake of nutrients through adequate moisture supply under four irrigation. All these factors contributed for full turgidity and opened leaves, which increased the photosynthetic activity of crops, resulting in higher dry matter accumulation while under one irrigation lack of optimum moisture, which resulted in reduced plant height, leaf area and nutrient uptake and led to reduced photosynthetic activity which ultimately reflected in lowest dry matter accumulation, the results are in agreement with the findings of Saren *et al.* (2004) [19] and Kumar *et al.* (2012) [16].

Dry matter accumulation was not significantly influenced due to fertility level at 30 DAS because of the fact that leaves being unable to manufacture sufficient food materials and plant had to depend principally on the stored food in the seed along with little food manufactured by young leaves, which did not increased the dry matter accumulation to the level of significance. Further, scanning of table reveals that at later stages (60, 90 DAS and at harvest stage) higher dry matter accumulation recorded with D_3 (25% more than RDF of NPK) which was at par with D_2 (100% RDF of NPK fertilizer) and both were significantly superior over D_1 (25% less than RDF of NPK fertilizers), respectively. The higher dry matter at higher fertility level might be due to proper nutrition availability which resulted in increased vegetative growth of plants. Similar results also reported by Laghari *et al.* (2010) [17] and Kale *et al.* (2015) [14].

Days taken to 50% ear emergence and maturity

It is evident from data that irrigation and fertility levels could not influence the days taken to 50% ear emergence significantly. However, the maximum days taken to 50% ear emergence (66.00) was noted with four irrigation (I_4) and the minimum (64.17) with one irrigation (I_1). Different fertility level also had non-significant effect on days taken to 50% ear emergence. However, the maximum days taken to 50% ear emergence (65.50 days) was recorded with D_3 and minimum (64.31 days) with D_1 during the course of experimentation.

Crop with four and three irrigation levels took statistically more days to maturity that was higher than that recorded at one and two irrigation. Under one and two irrigation lesser number of days taken to maturity might be due to moisture stress at later stages and inability to cope up with hot winds in the month of March-April. The differences among fertility levels for days taken to maturity were non-significant. It might be due to days taken to maturity is a genetically governed character and not affected under normal condition.

Yield

Grain and Straw yield

Grain and straw yield was significantly influenced by different irrigation levels. Data presented in table-3 revealed that highest grain yield (23.12 q ha^{-1}) and straw yield (32.37 q ha^{-1}) was recorded under four irrigation levels. This might be due to adequate moisture availability, which contributed to better growth parameters and yield attributes. Productivity of crop collectively determined by vigor of the vegetative growth and yield attributes. Better vegetative growth coupled with higher yield attributes resulted in higher grain and straw yield. One irrigation level recorded lowest grain yield (11.32 q ha^{-1}) and straw yield (22.86 q ha^{-1}) due to poor moisture supply during growth period and also the forced maturity due to hot wind during grain filling and maturity stage. Similar finding were reported by Bahera *et al.* (2002) [4].

The maximum grain yield (19.65q ha^{-1}) and straw yield (29.64 q ha^{-1}) was obtained under (D_3) 25% more than RDF of NPK fertilizers and minimum grain yield (14.83 q ha^{-1}) and straw yield (25.55 q ha^{-1}) under (D_1) 25% less than RDF of NPK fertilizer. Further, scanning of table reveals that (D_3) 25% more than RDF of NPK fertilizers increased the grain yield significantly over (D_1) 25% less than RDF of NPK fertilizers but remained at par with (D_2) 100% RDF of NPK fertilizers. It might be due to increasing fertilizer levels encouraged the grain and straw yields. Higher grain and straw yields associated with higher level of fertilizer were consistently because of enhanced growth and yield attributes. The positive response of increased fertilizer levels was also reported by Laghari *et al.* (2010) [17].

Harvest index

Harvest index indicates the relationship between economical yield and biological yield as influenced by different irrigation and fertility levels is presented in Table-3. The perusal of data reveal that maximum harvest index (41.99%) was recorded with four irrigation (I_4) and minimum harvest index (33.65%) with one irrigation (I_1). This might be due to the fact that adequate moisture supply under the higher irrigation levels increased the grain yield than that of biological yield. Further scanning of data presented in Table-3 reveal that different fertilizer doses also influenced the harvest index. Harvest index numerically increased with the increasing levels of fertilizer. Higher grain production because of increased number of effective tiller population resulted into higher value of harvest index. More grain and less biological yield was observed under higher level of fertilizer led to higher harvest index.

Table 1: Plant height and number of tillers as affected by different irrigation and fertility levels at successive growth stages of late sown wheat.

Treatments	Plant Height (cm)				Number of tillers (m^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
(A) Irrigation level (main plot factor)								
I_1	20.89	41.27	55.08	54.35	23.00	70.10	71.75	69.33
I_2	21.01	42.76	63.99	63.11	24.33	73.08	76.00	73.67
I_3	21.20	48.35	70.15	69.34	24.88	76.25	79.88	76.43
I_4	22.14	54.31	75.51	74.63	25.33	82.00	84.28	81.33
SEm±	1.061	1.681	2.529	2.442	0.917	1.693	1.960	1.777
CD (P=0.05%)	NS	6.602	9.931	9.588	NS	6.646	7.697	6.976
(B) NPK fertilizer dose (sub plot factor)								
D_1	20.60	43.30	59.51	58.63	23.53	71.00	73.03	70.98
D_2	21.23	47.63	68.56	67.79	24.54	76.80	79.04	76.19
D_3	22.10	49.10	70.48	69.65	25.10	78.20	81.88	78.41
SEm±	0.717	0.731	1.015	1.658	0.614	0.766	1.020	0.817
CD (P=0.05%)	NS	2.112	2.932	4.789	NS	2.213	2.946	2.359

Note- DAS: Days After Sowing, CD: Critical Difference and NS: Non Significant

Table 2: Effect of different irrigation and fertility levels on leaf area index (LAI) and dry matter accumulation at successive growth stages of late sown wheat.

Treatment	Leaf area index			Dry matter accumulation (g m^{-1})			
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	At harvest
(A) Irrigation level (main plot factor)							
I_1	1.09	3.42	2.68	12.23	40.32	55.83	57.53
I_2	1.11	3.68	3.19	12.43	44.87	61.92	70.81
I_3	1.12	3.91	3.53	13.17	52.92	70.10	85.59
I_4	1.13	4.38	3.85	13.60	58.80	78.00	93.16
SEm ±	0.051	0.124	0.163	0.606	2.265	2.828	4.111
CD (P=0.05)	NS	0.487	0.641	NS	8.894	11.104	16.142
(B) NPK fertilizer dose (sub plot factor)							
D_1	1.07	3.38	3.04	12.48	44.68	61.85	68.03
D_2	1.11	4.03	3.40	12.83	50.44	67.63	79.50
D_3	1.16	4.14	3.50	13.28	52.56	69.91	82.80
SEm ±	0.038	0.060	0.052	0.313	1.116	1.796	2.824
CD (P=0.05)	NS	0.173	0.151	NS	3.224	5.186	8.157

Table 3: Effect of different irrigation and fertility level on days taken to 50% ear emergence, maturity and yield parameters (Grain, straw yield and harvest index) of late sown wheat.

Treatment	50% ear emergence	Maturity	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index
(A) Irrigation level (main plot factor)					
I_1	64.17	97.00	11.32	22.86	33.65
I_2	64.50	99.90	15.97	26.27	37.05
I_3	65.33	102.00	20.51	30.29	40.50
I_4	66.00	105.25	23.12	32.37	41.99
SEm $\pm$	1.180	1.168	1.235	1.132	
CD (P=0.05)	NS	4.586	4.847	4.446	
(B) NPK fertilizer dose (sub plot factor)					
D_1	64.31	99.44	14.83	25.55	36.55
D_2	65.19	101.31	18.71	28.55	38.94
D_3	65.50	102.36	19.65	29.64	39.39
SEm $\pm$	0.962	1.018	0.456	0.481	
CD (P=0.05)	NS	NS	1.317	1.389	

Conclusion

Based on the results discussed above of investigation, it can be concluded that four irrigation level at CRI, tillering, flowering and milking stages with 25 percent more than RDF of NPK (150:75:50 kg ha^{-1}) was found to be most suitable and brought about higher yield (grain, straw and biological) and also most effective for dynamic growth and their attributes. Application of four irrigation with higher doses of fertilizer i.e. 25 percent more than RDF is appropriate to overcome the late sowing impact on crop performance.

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