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Research Paper

Impact of irrigation schedules and nutrient management on growth, yield and root traits of wheat (*Triticum aestivum*) varieties

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ABSTRACT

A field experiment was conducted during the winter season (*rabi*) of 2011–12 and 2012–13 at New Delhi, to find out the impact of irrigation schedules and nutrient management on wheat [*Triticum aestivum* (L.) emend. Firoi & Paol.] varieties. Two nutrient-management practices, i.e. 100% recommended dose of fertilizer (RDF) and 50% RDF + 50% recommended dose of nitrogen (RDN) through FYM were applied and 3 irrigation schedules i.e. irrigation at crown root initiation stage (CRI), CRI + flowering stage and irrigation at all critical stages were allocated to main plots and 4 wheat varieties ('HD 2967', 'WR 544', 'HD 2987' and 'HD 2931') were allocated to sub-plots in split-plot design with 3 replications. Application of 50% RDF + 50% RDN through FYM gave significantly higher number of tillers/m^2, spike length, number of spikelets/spike, grains/spike, 1,000-grain weight and grain yield. Irrigations at all critical stages resulted in significantly higher tillers/m^2, spike length, spikelets/spike, grains/spike, 1,000-grain weight and gain yield. Leaf-area index (LAI), crop-growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were found significantly higher under 50% RDF + 50% RDN through FYM and irrigations at all critical stages. Among the varieties, 'HD 2967' gave significantly higher gross returns (77.6 × 10^3₹/ha) over the other varieties during the first year. However, during the second year the yield was at par with 'HD 2987'. Between irrigations schedules, irrigations at all critical stages and application of 50% RDF + RDN 50% through FYM gave significantly the highest gross returns, net returns and benefit: cost ratio. Root length, volume and dry weight were higher under irrigations at all critical stages and application of 50% RDF + RDN 50% through FYM.

Key word : Growth parameters, Irrigation schedules, Nutrient management, Root traits, Wheat varieties

Wheat is one of the most important cereal crops grown in the Indo-Gangetic plains and central India. Since early 1960s, India witnessed a phenomenal increase in wheat productivity owing to adoption of semi-dwarf, non-lodging, disease-resistant, photo-insensitive and fertilizer-responsive varieties coupled with improved agronomical practices. India, today is, the second largest wheat-producing country in the world. The supply with enough food having sufficiently good quality is one of the most important problems in the world today.

Since mid-eighties, yield has started stagnating or even declining and in the last few years in a row, there has been a wide gap between the target and actual production (Pathak *et al*., 2003). The continuing plateau of wheat production since it reached as high as 93.51 million tonnes in 2012–13. The changes in policy with regard to inputs and globalization circumstances created a questionable situation on achieving the 109 million tonnes target requirement by 2020 (Nagarajan, 2005).

The productivity of wheat in north India varies spatially with latitude and longitude. Since wheat in north India is grown in the post-rainy season and on soils poor in organic carbon and available nitrogen, it is essential to apply irrigation and fertilizers, particularly nitrogen. Adequate and timely water application is a basic pre-requisite for proper plant growth for augmenting crop yield. Though more than 70% of the wheat-grown areas are irrigated today and as cultivars vary widely, fertilizer and irrigation also have got differential responses. To bridge the gaps between the targeted and actual yields of wheat, scientific understanding of these responses across the locations is very much required. Therefore, keeping the above facts in the view, the experiment was conducted to see the performance of wheat varieties under various nutrient management and irrigation schedules.

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MATERIALS AND METHODS

A field experiments was conducted during the winter seasons (*rabi)* of 2011–12 and 2012–13 at the Research Farm, Division of Agronomy, Indian Agricultural Research Institute, New Delhi, (28.4°N, 77.1°E and 228.6 m above mean sea-level). The maximum and minimum temperatures recorded in 2012 were 27.8°C and 10.6°C, and in 2013 were 29.5°C and 6.9°C respectively. The crop received 40.8 and 187.3 mm rain in 15 and 37 rainy days during 2012 and 2013 during crop period respectively. The pH of soil was 7.9 with sandy clay loam texture. The soil was low in available N (168.3 kg/ha), medium in available P (11.9 kg/ha) and available K (241.5 kg/ha) along with 0.68 mg DTPA-extractable available Zn/kg soil. The experiment was laid out in split-plot design with 3 replications. Main plot consisted of 2 nutrient levels, viz. 100% recommended dose of fertilizer (RDF) and 50% RDF + 50% recommended dose of nitrogen (RDN) through FYM, and 3 levels of irrigation, viz. 1 irrigation at crown-root imitation (CRI), 2 irrigation at CRI and flowering and irrigation at all critical stages of crop (CRI, tillering, jointing, flowering and grain filling stage. Sub-plot treatments consisted of 4 varieties, viz. 'HD 2967', 'WR 544', 'HD 2987' and 'HD 2329'. Sowing of wheat was done in rows at 22.5 cm with 10 cm plant to plant spacing. All other recommended practices were followed during crop-growing season. The recommended doses of fertilizers, i.e. 120:60:40 N, P_2O_5 and K_2O kg/ha was applied to wheat as per the treatment.

The farmyard manure (FYM) was applied a week before sowing as per treatment. The FYM contains 0.5% N, 0.2% available P_2O_5 and 0.5% of available K_2O. The N, P and K doses adjusted by subtracting nutrient supply by FYM and remaining N, P and K were compensated in the form of urea, diammonium and muriate of potash respectively. Yield attributes of wheat were recorded from the representative samples taken from each plot. The grain and straw yields were recorded by weight of produce.

The root length and root volume were recorded after washing the roots through the scanning and image analysis using WIN-RHIZO system, operated in a computer mounted with the scanner of RHIZO system. After scanning the root samples were dried at 60°C for 48 hr for recording roots dry weight.

The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique for a split plot design using MSTAT-C software. The results are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Growth

Growth parameters of wheat like leaf-area index, crop-growth rate, relative growth rate and net assimilation rate were significantly higher under irrigation at all critical stages of wheat than irrigation at CRI + flowering and at CRI stage. Under nutrient management, integrated application of 50% RDF + 50% RDN through FYM resulted in significantly higher growth parameters of wheat like LAI, CGR, RGR and NAR than 100% RDF (Table 1). This may be due to balance nutrition of all macro-and micro-nutrient through FYM. Our result confirm findings of Singh and Agarwal (2001).

Root

Root length, Root volume and root dry weight were significantly higher under limited irrigation at CRI stage than irrigation at CRI+ Flowering and irrigation at all critical stages. Under limited water availability plant has diverted a sizable amount of photosynthets to roots, resulting in high root length higher root growth because of low water availability under irrigation at CRI stages than irrigation at CRI + flowering; root starts grow deeper in search of water. Application of 50% RDF + 50% RDN through FYM resulted in significantly higher root volume and root dry weight than 100% RDF. It was owing to low bulk density under 50% RDF + 50% RDN through FYM and root grow deeper due to less resistance provided by soil. FYM application lowers the bulk density of soil (Hemmat *et al.*, 2014). Among the varieties, 'HD 2967' showed significantly higher root length and volume. Root dry weight was significantly higher in 'HD 2987' than the other varieties. (Table 2). This may be attributed varietal characters.

Yield attributes

Significantly higher number of effective tillers/m², spike length, spikelets/spike, grains/spike and 1,000-grain weight were found under irrigations at all critical stages (Table 3). This is because of optimum availability of water at all critical stages of crop growth that provides all available nutrients from the soil. Besides this, it maintained chlorophyll content of wheat or leaves and plant remain stay-green for longer period of time that helped higher photosynthesis of crop through better assimilation of carbon from atmosphere that favours the growth and yield of wheat plant. Chaplot and Sumeriyan (2013) also reported similar results.

Under 2 nutrient managements, nutrient applied through 50% RDF + 50% RDN through FYM gave significantly higher, effective tillers, spike length, spikelets/spike grains/spike and test weight than 100% RDF (Table 3), owing decomposition of FYM that have additive effect on nutrition of wheat plant by providing micronutrient in addition of major nutrient N,P and K, and it also enhanced the organic matter content and water-holding capacity of

Table 1. Effect of irrigation schedules and nutrient management on growth and root parameters of wheat varieties (pooled data of 211-12 and 2012–13)

Treatment	Leaf-area index (90 DAS)	Crop-growth rate at 60-90 DAS ($g/m^2/day$)	Relative growth rate at 60-90 DAS (mg/g/day)	Net assimilation rate at 60-90 DAS (g/dm^2 leaf area/day)	Root length density (cm/ 1,000 cm^3)	Root volume density (cm^3/ 1,000 cm^3)	Root dry weight (mg/ 1,000 cm^3)
Irrigation schedule							
CRI	4.89	9.22	37.81	2.87	236.9	6.15	330.1
CRI + flowering	5.73	11.53	42.97	3.27	212.7	5.50	291.8
At all critical stages	6.39	13.33	45.79	3.51	198.4	5.11	266.0
SEm±	0.06	0.18	0.53	0.04	1.6	0.04	2.8
CD (P=0.05)	0.18	0.56	1.67	0.13	5.1	0.14	8.7
Nutrient management							
100% RDF	5.39	10.72	41.57	3.17	216.0	5.42	270.7
50% RDF + 50% RDN	5.95	12.00	42.81	3.27	216.0	5.76	321.2
SEm±	0.05	0.14	0.43	0.03	1.3	0.04	2.2
CD (P=0.05)	0.15	0.46	1.36	0.11	4.2	0.12	7.1
Variety							
'HD 2967'	5.50	11.24	43.94	3.35	223.2	5.75	300.1
'WR 544'	5.79	11.18	39.18	2.98	210.1	5.47	287.7
'HD 2987'	5.76	11.80	44.09	3.37	221.4	5.72	311.0
'HD 2931'	5.63	11.21	41.55	3.17	209.3	5.42	285.0
SEm±	0.02	0.07	0.34	0.03	0.9	0.03	1.5
CD (P=0.05)	0.06	0.20	0.97	0.08	2.7	0.09	4.4

CRI, Crown-root imitation; RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; DAS, days after sowing

Table 2. Effect of irrigation schedules and nutrient management on root parameters and economic returns and benefit: cost ratio of wheat varieties (Pooled data of 2 years)

Treatment	Effective tillers/m^2	Spike length (cm)	Spikelet/ spike	Grains/ spike	1,000-grains weight(g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Net returns (× 10^3₹/ha)	Benefit : cost ratio
Irrigation schedule										
CRI	285.8	9.59	19.4	33.8	35.6	3.33	5.49	8.82	41.23	1.90
CRI + flowering	315.1	10.60	20.5	36.6	38.1	3.67	5.95	9.62	47.33	2.19
At all critical stages	348.9	11.16	22.5	41.2	40.8	4.31	7.70	12.01	61.91	2.87
SEm±	0.2	0.09	0.5	0.5	0.5	0.04	0.23	0.24	1.0	0.05
CD (P=0.05)	0.7	0.29	1.5	1.6	1.7	0.14	0.72	0.74	3.1	0.15
Nutrient management										
100% RDF	306.3	10.49	20.6	36.8	37.2	3.70	6.36	10.07	51.03	2.56
50% RDF + 50% RDN	326.9	10.41	21.0	37.6	39.1	3.84	6.40	10.24	49.29	2.09
SEm±	0.2	0.08	0.4	0.4	0.4	0.04	0.19	0.19	0.818	0.04
CD (P=0.05)	0.5	0.24	1.2	1.3	1.4	0.11	0.59	0.61	2.577	0.12
Variety										
'HD 2967'	341.0	11.40	22.6	39.3	40.1	4.08	6.57	10.65	54.82	2.54
'WR 544'	303.4	10.14	20.2	36.4	37.4	3.56	5.89	9.44	45.58	2.11
'HD 2987'	313.5	10.42	20.7	37.5	38.0	3.98	7.05	11.03	55.21	2.55
'HD 2931'	308.4	9.85	19.7	35.6	37.1	3.48	6.01	9.49	45.00	2.08
SEm±	0.2	0.11	0.2	0.3	0.3	0.04	0.10	0.13	0.736	0.03
CD (P=0.05)	0.7	0.31	0.6	1.0	0.9	0.11	0.29	0.36	2.11	0.09

CRI, Crown-root imitation; RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; DAS, days after sowing soil that is essential for better growth and development of crop. These results confirm the findings of Singh (2001). Among varieties, 'HD 2967' gave significantly higher number of effective tillers/m^2, spike length, spikelets/spike, grains/spike than the others.

Yield of wheat

Under different irrigation schedules, irrigation at all critical stages resulted significantly higher grain, straw and biological yields than irrigation at CRI + flowering and CRI stages, confirm the findings of Ghanbari *et al.* (2011). In nutrient management, integrated approach of 50% RDF + 50% RDN through FYM gave significantly higher grain yield than 100% RDF in the second year, because of complete decomposition of FYM in the second year that have additive effect on nutrition of wheat plant by providing micronutrient in addition of major nutrient N, P and K, and it also enhanced the organic matter content and water-holding capacity of soil that is essential for better growth and development to crop (Table 4). The results confirm findings of Khan *et al*. (2013). Among the varieties, 'HD 2967' gave significantly higher grain yield during both the years than the others varieties and 'HD 2987' showed significantly higher straw and biological yields than the other varieties (Table 4).

Table 3. Effect of irrigation schedules and nutrient management on N, P and K uptake of wheat varieties (pooled data of 2 years)

Treatment	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Irrigation schedule			
CRI	69.4	19.8	100.6
CRI + flowering	81.4	26.8	116.3
At all critical stages	102.9	35.8	170.7
SEm±	1.0	0.4	4.4
CD (P=0.05)	3.2	1.3	14.0
Nutrient management			
100% RDF	83.6	26.9	127.4
50% RDF + 50% RDN	85.5	28.0	131.0
SEm±	0.8	0.3	3.6
CD (P=0.05)	2.6	1.1	11.4
Variety			
'HD 2967'	92.6	29.9	142.0
'WR 544'	75.6	25.0	113.4
'HD2987'	95.8	30.3	147.8
'HD 2931'	74.2	24.6	113.6
SEm±	1.0	0.4	3.1
CD (P=0.05)	2.9	1.1	8.8

CRI, Crown-root imitation; RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; DAS, days after sowing

Interaction effect of irrigation schedules, nutrients and varieties on grain yield of wheat

Wheat variety, 'HD 2967' gave significantly higher yield under irrigation at all critical stages with 100% RDF than other the varieties during both the years. 'HD 2987' gave significantly higher than the other varieties under limited irrigation with 50% RDF + 50% RDN through FYM. However, during the second year 'HD 2987' showed significantly higher yield than the other varieties under limited irrigation with 100% RDF (Table 5).

Economics

Under different irrigation schedules, irrigations at all critical stages resulted in significantly higher gross, net returns and benefit: cost ratio than the other irrigation schedules. Of the different varieties, 'HD 2987' gave significantly highest gross returns, net returns and benefit: cost ratio. It might be owing to high rainfall during the second year that was unfavourable for varieties except 'HD 2987'. Variety, 'HD 2987' performance was good in

Table 4. Interaction effect of irrigation, nutrient management and varieties on grain yield of wheat (pooled data of 2 years)

Treatment	CRI		CRI + flowering		Irrigation at all stages		Mean
	100% RDF	50% RDF + 50% RDN	100% RDF	50% RDF + 50% RDN	100% RDF	50% RDF + 50% RDN	
'HD 2967'	3.23	3.45	3.91	3.49	5.24	5.13	4.08
'WR 544'	3.13	3.17	3.54	3.52	3.92	4.06	3.56
'HD 2987'	3.62	3.86	3.76	4.13	4.14	4.35	3.98
'HD 2931'	2.85	3.33	3.25	3.77	3.84	3.83	3.48
Mean	3.21	3.45	3.62	3.73	4.29	4.34	
Mean irrigation	3.33		3.67		4.31		
Mean NM	100% RDF	50% RDF + 50% RDN					
	3.7	3.84					
CD (P=0.05)		0.19		0.18		0.15	0.26
SEm±		0.061		0.06		0.052	0.090

CRI, Crown-root imitation; RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; DAS, days after sowing the second year because of its high tolerance ability to high rainfall. Performance of 'HD 2987' was good under limited irrigation condition like irrigation at CRI and CRI + flowering stages than the others varieties, because of minimum cost of irrigation as well as better performance under low irrigation condition.

Nutrient uptake

Under different irrigation schedules, irrigation at all critical stages reveled significantly higher nitrogen, phosphorus and potash uptake than the other irrigation schedules (Table 5). It might be due to optimum moisture in soil that enhanced availability of nutrient to plant through high transpiration that leads to mass flow of nutrient. Between 2 nutrient levels, 50% RDF + 50% RDN through FYM revealed significantly higher amount of phosphorus. The reason of high phosphorus uptake by wheat plant may be due to high availability of phosphorus in FYM applied plot through high solubility of unavailable phosphorus to available form. Similar results were reported by Zsolt *et al.,* (2014). Among the varieties, 'HD 2987' exhibited significantly higher nitrogen uptake than the other varieties. Phosphorus and potash were significantly higher in 'HD 2987' than 'WR 544' and 'HD 2931'. This may be due to varietal characters.

It was concluded that wheat variety, 'HD 2967' showed higher yield attributes and yield with irrigation at all critical stages and application of 50% RDF + 50% RDN through FYM. 'HD 2987' performance was good under limited irrigation and adverse condition like high rainfall but other varieties were found sensitive. 'HD 2987' gave higher net returns and benefit: cost ratio than other varieties.

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