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Research Paper

Performance of bread wheat (*Triticum aestivum*) varieties for productivity, profitability and nutrient uptake under different sowing dates and nitrogen levels

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ABSTRACT

A field experiment was conducted during the winter (*rabi)* seasons of 2015–16 and 2016–17 at Jobner, Rajastha, to evaluate the bread wheat (*Triticum aestivum* L.) varieties for productivity, profitability and nutrient uptake under different sowing dates and nitrogen levels. The experiment was conducted in split-plot design with 3 replications. The experiment consisted of 2 sowing dates (20 November and 10 December), 3 varieties 'Raj 4083', 'Raj 3777' and 'Raj 4037' in main plots and 4 levels of nitrogen (control, 40, 80 and 120 kg/ha) in subplots. Sowing of crop on 20 November resulted in significantly higher growth, yield attributes, yield, nutrient uptake, net returns and benefit: cost (B : C) ratio of wheat than 10 December-sown crop. A reduction of 16.4% in grain yield and 19.7% in straw yield was recorded under 10 December-sown crop as compared to 20 November. Among the varieties, 'Raj 4037' was showed significantly highest total number of tillers/m row length, dry-matter accumulation/m row length, leaf-area index (LAI), crop-growth rate (CGR), test weight, grain yield, straw yield and N, P, K uptake by grain and straw than 'Raj 4083' and 'Raj 3777'. Variety 'Raj 4037' also gave significantly highest net returns (₹72.9 × 10^3/ha) and B : C ratio (3.71) than 'Raj 4083' and 'Raj 3777'. The progressive increase in nitrogen levels up to 120 kg/ha significantly increased the growth, yield attributes and N, P, K uptake by bread wheat and simultaneously higher grain yield by 60.2 and 17.1% and straw yield by 37.8 and 15.1% over the control and 40 kg N/ha respectively. Application of 120 kg N/ha resulted in significantly maximum net returns (₹75.6 × 10^3/ha) and B : C ratio (3.75) but statistically at par with 80 kg N/ha.

Key words: Nitrogen levels, Net returns, Nutrient uptake, Sowing dates, Wheat varieties, Yield

Bread wheat (*Triticum aestivum* L.) is an important cereal crop in India after rice, grown under diverse agro-climatic conditions. It occupied an area of 29.6 million ha, with production of 99.7 million tonnes and productivity of 3,371 kg/ha (GoI, 2018). Weather and nutrients are the 2 factors influencing agricultural production and productivity. The physiological and physical processes of plants are temperature-dependent. As evident, the increase in the rate of these processes corresponds to increase in yield. In general, the weather conditions to which the crop is exposed during its life-cycle is considered to be principal input parameter affecting productivity despite availability of other input and improved crop husbandry. The optimum time of sowing can provide congenial conditions to have maximum light interception, best utilization of moisture and nutrients from early growth stage to grain-filling stage. It governs the crop phenological development and total biomass production along with efficient conversion of biomass into economic yield.

Genetic potential of different varieties varies under different climatic conditions. Being a thermo-sensitive crop, choice of suitable variety for different sowing time further gets prime importance. Because of genetic variation, different varieties of crop may differ in growth and development behaviour and response to different management practices (Singh *et al*., 2010). The development and recommendation of high-yielding adaptable varieties is considered to be the first step to generate maximum production. Among essential plant nutrients, nitrogen plays key role in augmenting agricultural production and its deficiency limits crop production (Pathak *et al*., 2003). Nitrogen is an essential constituent of plant proteins and chlorophyll and is present in many other compounds of greater physiological impor-

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tance in plant metabolism, viz. nucleotides, phospholipids, enzymes, hormones, vitamins. Nitrogen plays major role in early establishment of plant leaf area, increasing photosynthesis and root development to enable more efficient use of weather and water. Growing of suitable variety at an appropriate time and applying optimum nutrient dose is essential for ensuring better productivity.

MATERIALS AND METHODS

The field experiment was conducted at Agronomy Farm, Sri Karan Narendra Agriculture University, College of Agriculture, Jobner (26° 05' N, 75° 28' E, 427 m above mean sea-level) Rajasthan during the winter season (*rabi)* of 2015–16 and 2016–17. Soil of the experimental site was loamy sand in texture and alkaline in reaction (8.3 and 8.2), low in available nitrogen (128.9 and 132.1 kg/ha), medium in phosphorus (15.3 and 14.9 kg/ha) and potassium (148.6 and 149.1 kg/ha) during the 2015–16 and 2016–17 respectively. The experiment was laid out in a split-plot design, replicated 3 times, comprising 24 treatment combinations, keeping 2 sowing dates (20 November and 10 December), 3 varieties ('Raj 4083', 'Raj 3777' and 'Raj 4037') in main plots and 4 levels of nitrogen (control, 40, 80 and 120 kg/ha) in subplots. The seed was sown 5 cm deep with row spacing of 22.5 cm. The seed rate used for sowing was 100 kg/ha for 20 November and 125 kg/ha for 10 December. Nitrogen was applied through urea as per treatment. The recommended dose of phosphorus (30 kg/ha) was applied basal through single superphosphate at the time of sowing. Half dose of nitrogen was drilled basal at the time of sowing and remaining dose of N was top-dressed in 2 equal splits. Other management practices were adopted as per recommendations of the crop under irrigated conditions. The periodic observation on growth, yield attributes and yield of crop were recorded to evaluate the effect of treatments. Five plants were randomly selected in each plot and tagged permanently. Height of main shoot, i.e. from the ground surface to base of fully expanded leaf, was measured by metre scale and average plant height was worked out. For the purpose of recording dry matter accumulation/m row length, the samples were dried in the air for few days and finally in oven at 65 °C temperature till constant weight. The leaf area was measured with the help of portable leaf-area meter at the experimental site. At maturity, after leaving the 2 border rows on each side as well as 50 cm along the width of each side, a net plot area of 3.0 m × 1.35 m was harvested separately for recording the yield**.** After sun-drying, the dried bundles of individual net plots were weighed separately to record biological yield, then threshed and winnowed manually. Estimation of nitrogen was done by colorimetric method, using 'Nesslers' reagent. For phosphorus and potassium concentration, samples after grinding were digested in tri-acid mixture. Phosphorus concentration was determined by vanadomolybdo phosphoric acid yellow colour method and potassium concentration by flame-photometric method. The nutrient uptake by grain and straw at time of harvesting was computed by concentration multiply with yield. Protein content in grain was determined by multiplying per cent of nitrogen concentration in grain with a factor 5.75. The economics was worked out on the basis of prevailing market price of different inputs and final produce.

RESULT AND DISCUSSION

Growth characters

Significant differences were exhibited with date of sowing on growth characters (Table 1). Crop sown on 20 November recorded significantly higher plant height (86.0 cm), total number of tillers/m row (165.4), dry-matter accumulation/m row (198.3 g), leaf-area index (LAI) (2.32) and crop-growth rate (CGR 7.50 g/m^2/day), representing an increase of 16.1, 23.0, 21.9, 17.8 and 27.8%, respectively, over 10 December-sown crop. This was attributed to maximum period available to 20-November-sown crop in comparison to late sowing, resulting in taller plant. In late-sown crop, dry-matter accumulation/m row length was decreased. The reason for higher dry-matter production in the early sowing was because of production of more number of tillers and favourable weather available during the crop period. Normal and late-sown crop of bread wheat was subjected to differential set of environmental conditions. Crop-growth rate was decreased in the delayed sowing. The probable reason for decreasing CGR was the higher night temperature which was experienced during the crop season (Shahzad *et al.,* 2007; Pandey *et al.,* 2010; Amrawat *et al.,* 2014).

Bread wheat varieties showed significant difference for plant height, total number of tillers, dry-matter accumulation, LAI and CGR (Table 1). Variety 'Raj 4037' showed significantly higher total number of tillers/m row, dry matter accumulation/m row, LAI and CGR over 'Raj 4083' and 'Raj 3777' and represented an increase of 15.2, 8.1, 7.9 and 82.7% over 'Raj 4083' and 24.0, 34.0, 20.1 and 79.3% over 'Raj 3777', respectively. However, Variety 'Raj 3777' bread wheat revealed significantly higher plant height, showing an increase of 9.6% over 'Raj 4037' and remained on a par with variety 'Raj 4083'. The differences in plant height of varieties are due to their genetic constitution (Musaddique *et al*., 2000; Mattas *et al*., 2011). The significant increase in biomass production under variety 'Raj 4037' could be ascribed to its higher tillering potential, which might have facilitated larger canopy development thus, LAI. The improvement in these growth parameters might have led to higher interception and absorption of radiant energy, resulting in higher photosynthesis and finally dry-matter accumulation (Musaddique *et al*., 2000; Jat and Singh, 2004).

The results revealed that, growth attributes of bread wheat were significantly influenced by nitrogen fertilization (Table 1). Application of 120 kg N/ha significantly enhanced the plant height, total number of tillers/m row, dry-matter accumulation/m row, LAI and CGR by 9.0, 10.4, 14.2, 8.5 and 10.9% over 40 kg N/ha and 14.5, 21.8, 35.6, 19.8 and 76.0% over the control respectively, but remained at par with 80 kg N/ha. Increased nitrogen supply thus might have helped in rapid cell multiplication and accelerated chlorophyll formation, thereby increasing the photosynthetic rate and eventually increased supply of assimilates to the plant and finally growth in terms of plant height, tillers/plant, dry-matter production and LAI. The findings are in close conformity with those of Khichar and Niwas (2007) and Jat *et al.* (2014).

Yield attributes and yield

Significant variations in yield attributes were observed under different sowing dates (Table 1). Crop sown on 20 November exhibited higher spike length and test weight than the late-sown crop. Spike length and test weight were significantly reduced under 10-December-sown crop by 44.07 and 10.84%, respectively, as compared to 20-November-sown crop. The behaviour exhibited by different dates of sowing may be explained by the fact that, normal sown crop was exposed to favourable weather during the whole life-cycle and thus the different phases of plant life were completed at appropriate timings. Our results support those of Shirpurkar *et al*. (2008), Mukherjee (2012) and Dar *et al*. (2019).

Different varieties showed significant variation for yield attributes (Table 1). Test weight was the highest with 'Raj 4037' and was significantly superior to 'Raj 4083' and 'Raj 3777' varieties. However, spike length did not differ significantly among the tested varieties. The differences in yield attributes of varieties might be attributed due to their genetic makeup (Jat and Singh, 2004; Mattas *et al*., 2011). Among the different nitrogen levels, the application of 120 kg N/ha significantly increased the ear length and test weight over the control and 40 kg N/ha and was found statistically at par with 80 kg N/ha. The increase in spike length and test weight owing to the 120 kg N/ha was 55.9 and 11.0% over the control and 16.8 and 6.3% over 40 kg N/ha respectively.

Grain and straw yields significantly differed with different dates of sowing, varieties and nitrogen levels (Table 2). Grain yield obtained under 20 November sowing was significantly higher over 10 December sowing. Crop sown on 20 November gave 16.4 and 19.7% higher grain and straw yield, respectively, over 10 December sowing. Late-sown crop was exposed to higher mean temperature during reproductive phase as against the mean temperature under 20-November-sown crop. This shortened the crop period

Table 1. Effect of sowing dates, varieties and nitrogen levels on growth and yield-attributing characters of wheat wheat (pooled data of 2 years)

Treatment	Plant height at 90 DAS (cm)	Total tillers/m row at 90 DAS	Dry-matter accumulation/m row at 90 DAS (g)	LAI at 60 DAS	CGR at 90–harvest ($g/m^2/day$)	Spike length (cm)	Test weight (g)
Sowing dates							
20 November	86.0	165.4	198.3	2.32	7.50	10.20	42.95
10 December	74.1	134.5	162.7	1.97	5.87	7.08	38.75
SEm±	0.9	1.8	2.2	0.02	0.07	0.10	0.48
CD (P=0.05)	2.7	5.3	6.6	0.07	0.20	0.29	1.42
Varieties							
'Raj 4083'	81.3	146.0	187.5	2.16	5.21	8.66	40.78
'Raj 3777'	83.1	135.6	151.3	1.94	5.31	8.39	39.03
'Raj 4037'	75.8	168.2	202.7	2.33	9.52	8.86	42.73
SEm±	1.1	2.2	2.7	0.03	0.09	0.12	0.59
CD (P=0.05)	3.3	6.5	8.1	0.09	0.25	NS	1.74
Nitrogen (kg/ha)							
0	74.5	133.2	148.7	1.92	4.38	6.39	38.55
40	78.0	146.9	176.6	2.12	6.95	8.53	40.25
80	82.9	157.4	195.1	2.26	7.68	9.67	41.80
120	85.0	162.2	201.6	2.30	7.71	9.96	42.80
SEm±	1.0	1.9	2.3	0.03	0.09	0.12	0.46
CD (P=0.05)	2.9	5.3	6.6	0.08	0.25	0.33	1.30

DAS, Days after sowing; LAI, leaf-area index; CGR, crop-growth rate and caused forced maturity, resulting in shriveled grain ultimately low grain yield as well as straw yield under late-sown crop (Dhaka *et al*., 2006; Mukherjee, 2012; Amrawat *et al.,* 2014).

The varieties tested in the experiment had significant influence on grain and straw yield (Table 2). Variety 'Raj 4037' gave significantly highest grain (4.46 t/ha) and straw yield (5.68 t/ha) than 'Raj 4083' and 'Raj 3777', whereas variety 'Raj 3777' the lowest grain and straw yield compared with other varieties. Variety 'Raj 4037' revealed 15.7 and 25.1% higher grain yield, 7.8 and 12.3% straw yield over 'Raj 4083' and 'Raj 3777' respectively. Variety 'Raj 3777' gave low grain yield due to lower biomass accumulation as a result of less number of tillers. Our results confirm the findings of Mishra *et al*. (2003) Jat and Singh (2004) and Dhaka *et al*. (2006).

Significant increase in grain and straw yields were recorded by increasing the rate of nitrogen application (Table 2). Application of 120 kg N/ha to wheat fetched significantly higher grain and straw yields than 40 kg N/ha and the control, while it remained at par with 80 kg N/ha. The corresponding increases were 17.1 and 60.2% in grain yield as well as 15.1 and 37.8% in straw yield over 40 kg N/ha and control respectively. As grain yield is primarily a function of cumulative effect of yield-attributing characters, the higher values of these attributes could be assigned as the most probable reason for significantly higher grain yield. Improved biomass per plant at successive growth stages and increase in various morphological parameters like plant height, number of tillers etc could be probable reason for higher straw yield (Chaturvedi, 2006; Gupta *et al.,* 2007; Gupta *et al.,* 2019). Harvest index did not differ significantly due to different sowing dates, varieties and nitrogen levels treatment.

Quality parameter

The protein content in grain exhibited under different sowing dates varied significantly (Table 2). Crop sown on 10 December exhibited significantly higher protein content than 20-November-sown crop, with an increase of 3.8%. A decrease in nitrogen and protein content under 20 November sowing could be explained on the basis of dilution effect owing to higher grain yield than 10-December-sown crop (Yadav, 2005). Protein content in grain was found non-significant among the varieties.

Data further indicated that different nitrogen levels significantly influenced the protein content in wheat grain (Table 2). Application of 120 kg N/ha resulted in the maximum protein content in grain which remained at par with 80 kg N/ha but significantly higher over the control and 40 kg N/ha. The treatment 120 kg N/ha registered an increase of 24.0 and 11.0% in protein content over the control and 40 kg N/ha respectively. Higher nitrogen concentration in grain owing to increasing levels of N upto 80 kg/ha resulted in significantly higher protein content (Gupta *et al.,* 2007; Singh *et al*., 2010).

Economics

Table 2. Effect of sowing dates, varieties and nitrogen levels on yield, harvest index, protein content and economics of bread wheat (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Protein content (%)	Net returns (× 10^3₹/ha)	Benefit: cost ratio
Sowing dates						
20 November	4.26	5.81	42.05	11.38	70.7	3.66
10 December	3.66	4.85	42.67	11.81	55.7	3.04
SEm±	0.03	0.06	0.56	0.14	0.74	0.05
CD (P=0.05)	0.09	0.18	NS	0.40	2.17	0.13
Varieties						
'Raj 4083'	3.85	5.26	42.11	11.64	61.2	3.28
'Raj 3777'	3.56	5.05	41.20	11.42	55.5	3.06
'Raj 4037'	4.46	5.67	43.76	11.73	72.9	3.71
SEm±	0.04	0.08	0.68	0.17	0.90	0.06
CD (P=0.05)	0.11	0.22	NS	NS	2.66	0.17
Nitrogen (kg/ha)						
0	2.86	4.34	39.70	10.13	41.3	2.59
40	3.91	5.19	42.94	11.41	62.0	3.34
80	4.48	5.82	43.46	12.19	73.8	3.73
120	4.58	5.97	43.32	12.66	75.6	3.75
SEm±	0.04	0.06	0.51	0.13	0.85	0.05
CD (P=0.05)	0.11	0.17	NS	0.35	2.38	0.14

Net returns (₹75.6 × 10^3/ha) and B : C ratio (3.66) were markedly higher under 20-November-sown crop than 10-December-sown crop owing to higher yield at same cost of cultivation. Among all varietal treatments, 'Raj 4037' fetched the maximum net returns (₹72.9 × 10^3/ha) and B : C ratio (3.71) which proved significantly superior to 'Raj 4083' and 'Raj 3777'. The lowest net returns and B : C ratio were obtained under 'Raj 3777'. Data also indicated that, treatment 120 kg N/ha resulted in the maximum net returns (₹75.6 × 10^3/ha) and B : C ratio (3.75), being significantly superior to the control and 40 kg N/ha, while remained at par with 80 kg N/ha. The minimum net returns (₹41.3 × 10^3/ha) and B : C ratio (2.59) were obtained under the control. The treatment 120 kg N/ha fetched higher net returns by ₹34.2 × 10^3/ha and 13.6 × 10^3/ha over the control and 40 kg N/ha respectively.

Nutrient-uptake

Nutrient-uptake pattern by grain and straw varied distinctly with different treatments and showed significant response with date of sowing, varieties and nitrogen levels (Table 3). Higher N, P and K uptake by grain and straw were observed with 20-November-sown crop which was significantly superior to 10-December-sown crop. The increase in nitrogen, phosphorus and potassium uptake by grain and straw under 20-November-sown crop could be ascribed owing to higher production of total biomass under this treatment, as reported by Mukherjee (2012).

The significant difference among the varieties for N, P and K uptake by grain and straw at harvesting were observed (Table 3). The highest nitrogen, phosphorus and potassium uptake by grain and straw were recorded under variety 'Raj 4037' which was significantly superior to 'Raj 4083' and 'Raj 3777'. The magnitude of increase in N uptake was 16.8 and 28.7% in grain, 6.6 and 12.0% in straw, P uptake 16.8 and 27.4% in grain, 9.0 and 15.6% in straw and K uptake 16.5 and 26.7% in grain, 8.0 and 13.3% in straw over 'Raj 4083' and 'Raj 3777', respectively. Nutrient uptake is dependent on concentration of nutrients at cellular level and dry-matter production, hence might be reason for significantly higher uptake by 'Raj 4037' (Mukherjee, 2012; Balwan *et al*., 2017).

An application of 120 kg N/ha resulted in the maximum nitrogen, phosphorus and potassium uptake by grain and straw which was significantly superior to the control and 40 kg N/ha. Additional application of N beyond 80 kg/ha did not increase the nutrient uptake by grain and straw significantly. Higher biomass production of crop together with higher concentration of nutrients might have associated with significantly higher uptake of nutrients under increasing rates of N fertilization (Gupta *et al.,* 2007; Singh *et al*., 2010).

Interactive effect

Interactive effects of varieties and nitrogen levels on grain yield and net returns were found significant (Table 4). The treatment combination, variety 'Raj 4037' at 120 kg N/ha recorded significantly the highest grain yield (5.26 t/ha) and net returns (88.4 × 10^3/ha) over rest of the treatment combinations. However, the effect of nitrogen level 120

Table 3. Effect of sowing dates, varieties and nitrogen levels on nutrient uptake by grain and straw of bread wheat (pooled data of 2 years)

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw
Sowing dates						
20 November	78.7	36.7	18.3	9.6	17.3	67.6
10 December	70.2	32.3	16.3	8.4	16.0	59.7
SEm±	0.9	0.3	0.2	0.2	0.1	0.8
CD (P=0.05)	2.7	0.9	0.6	0.5	0.4	2.5
Varieties						
'Raj 4083'	72.6	34.3	16.8	8.9	16.2	62.9
'Raj 3777'	65.9	32.7	15.4	8.4	14.9	60.0
'Raj 4037'	84.8	36.6	19.6	9.7	18.9	68.0
SEm±	1.1	0.4	0.2	0.2	0.2	1.0
CD (P=0.05)	3.3	1.1	0.7	0.6	0.5	3.0
Nitrogen (kg/ha)						
0	46.3	26.7	11.6	6.6	10.9	47.7
40	71.4	33.3	16.9	8.6	16.1	61.9
80	87.4	38.4	20.0	10.1	19.6	71.4
120	92.7	39.7	20.5	10.6	20.1	73.7
SEm±	0.9	0.4	0.2	0.2	0.2	0.8
CD (P=0.05)	2.4	1.1	0.5	0.4	0.6	2.4

Table 4. Interactive effect of varieties and nitrogen levels on grain yield and net returns in bread wheat (pooled mean)

Nitrogen (kg/ha)	Varieties		
	'Raj 4083'	'Raj 3777'	'Raj 4037'
		Grain yield (t/ha)	
0	2.81	2.60	3.15
40	3.82	3.54	4.37
80	4.37	4.04	5.03
120	4.41	4.06	5.26
		SEm±	*CD (P=0.05)*
Variety at same or different levels of nitrogen		0.07	0.18
Nitrogen levels at same or different variety	0.13	0.39	
		Net returns (× 10^3₹/ha)	
0	40.3	36.2	47.5
40	60.2	54.7	71.1
80	71.6	65.3	84.5
120	72.6	65.8	88.4
	SEm±	*CD (P=0.05)*	
Variety at same or different levels of nitrogen	1.5	4.1	
Nitrogen levels at same or different variety	3.1	8.8	

kg/ha was similar to that of 80 kg N/ha with 'Raj 4037' for net returns but significant difference was observed with 'Raj 4083' and 'Raj 3777'.

Based on the 2 years of experimentation, it was concluded that sowing of wheat on 20 November with variety 'Raj 4037' and fertilized at 80 kg N/ha can achieve higher yields and better economic returns under semi-arid eastern plain zone of Rajasthan.

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