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Research Paper

Performance of bread wheat (*Triticum aestivum*) under different nitrogen levels and its split application under north Gujarat condition

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2013–14 and 2014–15 at the Sardarkrushinagar, Gujarat, to study the effect of different nitrogen levels and its split application on performance of bread wheat *Triticum aestivum*. The experiment consisted of 14 treatment combinations which comprised 2 levels of nitrogen and 7 split application of nitrogen, and was conducted in randomized block design with factorial concept with 3 replications. Significantly higher dry-matter accumulation (g)/m row length at 90 DAS (209.3 g) and at harvesting (221.5 g), leaves/plant (18.7), effective tillers (72.9)/m row length at harvesting, grain yield (4,572 kg/ ha), protein (12.63%), wet gluten (29.79%) and sedimentation value (40.93 ml) were recorded when crop was fertilized with 160 kg N/ha. Plant height at harvesting (94.1 cm), dry-matter accumulation/m row length at 90 DAS (232.5 g) and at harvesting (243.7 g), leaves/plant (20.2), effective tillers (83.4)/meter row length, ear length (9.7 cm), grains/ear (53.4), grain yield (4,964 kg/ha) and straw yield (5,792 kg/ha) were significantly higher when nitrogen was applied as 50% at sowing, 25% at crown-root-initiation (CRI) stage and 25% at 1st node stage. Test weight (41.71 g), protein (12.21%), quality parameters i.e. protein content (12.21%), wet gluten content (29.87%), hectoliter weight (81.57 kg/ml), sedimentation value (41.23 ml) and grain diameter (2.82 mm) were significantly higher under splitting of nitrogen as 10% each at sowing, CRI, 1st node, tillering, flag leaf, heading, flowering, milking, dough and hard dough stage. Nitrogen 160 kg/ha applied 50% at sowing, 25% at CRI stage and 25% at 1st node stage accrued the maximum gross and net realization and benefit: cost ratio.

Key words **:** Bread wheat, Economics, Growth, Nitrogen, Quality, Split application, Yield, Yield attributes

Wheat crop provides 11–12% protein to human and by-product wheat-straw is also a good source of nutrition in animals. We have to increase wheat productivity due to population explosion further to satisfy the need of ever growing population.

There is a wide yield gap (100–150%) between the potential yield and actual yield of variety as per breeder estimation, multi location trial, adaptive trial, frontline demonstration and progressive farmers production data of the different factors responsible for crop production, nutrient management is most important.

Wheat absorbs 75 to 80% up to first and second node stage nitrogen, but very little absorption of nitrogen continues till maturity. As per the biology of wheat crop little fall in nitrogen content in cell, disturbs the biochemical process in plant resulting into low tillering, grain size and ultimately yield (Mengel and Kirkby, 1987).

The fact that high-yielding varieties of wheat possess high yield potential is undoubtedly associated with their tendency to consume high dose of nitrogen. But the utilization efficiency of added nitrogen fertilizer is about 50 to 70%, as applied nitrogen is subjected to various kinds of losses. In order to get maximum benefit from nitrogen nutrient, it should not only be applied in right quantity but also at right time. Application of nitrogen not synchronizing with the demand of the plant may result in various losses (Verma and Srivastava, 1989).

Patel *et al.* (2004) reported that, higher quantity of nitrogen when applied in more number of split, increased the yield and quality parameters in wheat. Similar results were reported by Mattas *et al.* (2011).

Efficient use of nitrogen fertilizer is important for economical wheat production and to the quality of ground and surface waters. Excess application of nitrogen is not only escalating the cost of cultivation but lead to pest-disease in-

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cidence and growth of weeds. The potential for nitrate (NO_3) enrichment of ground and surface waters also increases with excessive nitrogen fertilization. Therefore, judicious use of nitrogen is vital to exploit the production potential of crop.

Researchers have been looking for ways and means to increase the efficiency of fertilizer nitrogen use, but there are several constraints to come on conclusion because response of nitrogen varies with soil type, variety and management practice. The research on changing climate towards global warming has created more confusion among the researcher to finalize the line of research for yield potential as well as quality. In recent years, intensive management studies have shown that split top-dressing of fertilizer nitrogen recommendation may improve N efficiency *vis-a-vis* enhance yield levels and quality.

As per the literature, nitrogen should be split in 2 installments after sowing. The research studies in nitrogen management indicate positive response to more than 2 split in light-textured soil. The response varies with temperature window of the crop and therefore there is a tendency in farmer's community to split nitrogen up to hard dough stage because they believe this causes improvement in quality and luster of the grain. No scientific information is available for North Gujarat wheat-growing area in relation to multi splitting of nitrogen and its effect on yield and quality of wheat. In the context of above observation, present investigation was carried out to study the performance of bread wheat under different nitrogen levels and its split application under north Gujarat condition.

MATERIALS AND METHODS

The field experiment was laid out in Plot C-9 at the Sardarkrushinagar (24°-19' N latitude and 72° 19' E and 154.52 m above the mean sea-level) during the winter (*rabi*) seasons of 2013–14 and 2014–15. This centre is located in the North Gujarat Agro-climatic Zone (AES-IV) of Gujarat. The experimental field has an even topography with a gentle slope having good drainage. The soil samples were taken randomly from experimental plot to a depth of 0–15 and 15–30 cm. The soil was loamy sand in texture, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash. The experiment was conducted in randomized block design with factorial concept with 3 replications. Wheat variety 'GW 322' was sown in the experiment. The treatments consisted of 2 levels of nitrogen (120 kg/ha and 160 kg/ha) and 7 split applications of nitrogen, viz. S_1, 50% at sowing and 50% at crown-root initiation (CRI) stage; S_2, 50% at sowing, 25% at crown-root-initiation (CRI) stage and 25% at 1st node stage; S_3, 25% at sowing, 25% at 1st node stage; 25% at tillering stage and 25% at heading stage; S_4, 25% at CRI, 25% at 1st node stage, 25% at flag leaf stage and 25% at milking stage; S_5, 20% at sowing, 20% at CRI, 20% at 1st node stage, 20% at flag leaf stage and 20% at flowering stage; S_6, 20% at sowing, 20% at 1st node stage, 20% at flag leaf stage, 20% milking stage and 20% at dough stage; and S_7, 10% each at sowing, CRI, 1st node stage, tillering stage, flag leaf stage, heading stage, flowering stage, milking stage, dough stage and hard dough stage. Nitrogen application from urea as per the treatments and common application of phosphorus and potash at 60 kg P_2O_5/ha and 30 kg/ha K_2O as a basal dose were done for all the treatments respectively. The sowing of wheat was done on 22 November during the first year and 25 November during the second year with hand sowing in dry moist soil. Seeds were treated with Fipronil 5% @ 6 g/kg seed for termite and white grub control. Pendimethalin @ 1 kg a.i. /ha was sprayed as pre-emergence for weed control 24 h after sowing. The left-over weed was controlled by spraying Metsulfuron methyl @ 4 g/ha. Irrigation was applied as per requirement. Wheat was harvested on 3 April during first year and 20 March in second year. Growth and yield attributing characters, viz. plant height (cm) at harvesting, dry-matter accumulation at 90 DAS and at harvest/m row length, leaves/plant, effective tillers/m row length, ear length (cm), grains/ear, test weight (g) were recorded. Grain and straw yield and harvest index were recorded at harvesting of the crop. Protein content of grain was computed by multiplying the value of nitrogen content with conversion factor 6.25 (Jones, 1931). Moisture per cent, Starch (DM) per cent, sedimentation value (ml) analyzed by INFRATEC™ 1241 Grain Analyzer (FOSS, Hilleroed, Denmark) from wheat grain. Hectoliter weight (kg/ml) was analyzed by Hectoliter weight kit (Greenway *et al.,* 1971). Wet gluten content, hardness (HI) and diameter (mm) were analyzed by Single Kernel Characterization System (SKCS 4100) (Perten Instruments) controlled by the MicroSoft Windows software SK4100, v. 2,1,0,1. from wheat grain. The net profit was worked out by deducting the total cost of cultivation from gross realization for each treatment and recorded accordingly.

Benefit : cost ratio (BCR) is the ratio of gross realization to the total cost of cultivation was calculated by using the following formula.

$$\text{Benefit : cost ratio} = \frac{\text{Gross realization (₹/ha)}}{\text{Total cost of cultivation (₹/ha)}}$$

RESULTS AND DISCUSSION

Nitrogen levels

Application of 160 kg N/ha significantly increased the dry matter accumulation at 90 DAS and at harvesting in meter row length (209.3 g and 221.5 g, respectively) than 120 kg N/ha (Table 1). All these favourable attributes have geared up the photosynthetic rate of plant leading to increase in the nutritional environment and ultimately resulted in more nutrient uptake and increased the meristematic activity of plant. Leaves per plant (18.7) of wheat were significantly higher with 160 kg N/ha. It was owing to more tillering of crop with higher level of nitrogen. Application of 160 kg N/ha helped to increase higher number of effective tillers per meter row over 120 kg N/ha. The higher number of effective tillers per plant may be owing to higher and sufficient availability of available nitrogen to the root because of the crop. It might be because of higher availability of nitrogen which may have increases the nutrition to active growing part of plant which have the ability of multi shooting with favourable condition and that is why ultimately leads to higher shooting of the tillers to the base of the plant (Kachroo and Rajdan 2006; Singh *et al.,* 2007; Gupta *et al.,* 2011; Mattas *et al.,* 2011). The data on plant height, ear length, number of grains per ear, straw yield and test weight (g) were non-significant due to nitrogen levels because both the characters are genetically controlled; there is little chance to alter with nutrients. Higher dose of nitrogen, i.e. 160 kg/ha (N_2), brought significant increase in grain yield. On pooled data basis, the treatments N_1 and N_2 recorded 4,260 and 4,573 kg/ha grain yield respectively (Table 2). The magnitude of increase in yield under application of 160 kg N/ha was to the tune of 7.35% over application of 120 kg N/ha.

The remarkable increase in yields with higher levels of nitrogen might be attributed to favourable effect on yield attributes, viz. plant height, dry-matter accumulation, number of leaves/plant, effective tillers/m row length. The increase in yield owing to nitrogen application might have ultimately resulted in higher photosynthetic activities and in production of more photosynthates. This readily supplied food to growing parts of plant that might have helped in improvement of growth and yield attributes like plant height, number of tillers/m row. As a result of cumulate performance of all these attributes, application of 160 kg N/ha resulted in better response of grain yield in the present study (Patel *et al.,* 2004; Kachroo and Rajdan 2006; Singh *et al.,* 2007; Gupta *et al.,* 2011 and Mattas *et al.,* 2011). On the other hand, straw yield and harvest index were non-significant.

Among the quality parameters, the protein content (12.63%) (Table 2), wet gluten (29.73%) and sedimentation value (40.93 ml) (Table 3) were significantly superior

Table 1. Plant height (cm) at harvesting, leaves/plant, dry-matter accumulation (g) at 90 DAS and harvesting, effective tillers and ear length (cm) as influenced by nitrogen levels and its split application (pooled data over 2 years)

Treatment	Plant height	Leaves/ plant	Dry-matter accumulation tillers		Effective length	Ear length
			90 DAS	At harvest		
Levels of nitrogen (N)						
N_1 (120 kg/ha)	88.1	17.5	202.3	213.0	67.7	9.0
N_2 (160 kg/ha)	89.6	18.7	209.3	221.5	72.9	9.2
SEm±	0.9	0.29	2.0	2.3	1.4	0.1
CD (P=0.05)	NS	0.81	5.7	6.6	3.9	NS
Split application of nitrogen (S)						
S_1, 50% at sowing and 50% at CRI stage	92.2	19.5	224.8	235.9	79.5	9.4
S_2, 50% at sowing, 25% at CRI stage and 25% at 1st node stage	94.1	20.2	232.5	243.7	83.4	9.7
S_3, 25% at sowing, 25% at 1st node stage, 25% at tillering stage and 25% at heading stage	91.2	18.8	218.0	229.7	75.6	9.2
S_4, 25% at CRI, 25% at 1st node stage, 25% at flag leaf stage and 25% at milking stage	82.6	16.5	176.0	188.2	58.3	8.6
S_5, 20% at sowing, 20% at CRI, 20% at 1st node stage, 20% at flag leaf stage and 20% at flowering stage	93.5	19.9	225.7	237.3	78.9	9.5
S_6, 20% at sowing, 20% at 1st node stage, 20% at flag leaf stage, 20% milking stage and 20% at dough stage	85.4	17.7	191.6	202.4	67.6	8.7
S_7, 10% each at sowing, CRI, 1st node stage, tillering stage, flag leaf stage, heading stage, flowering stage, milking stage, dough stage and hard dough stage	83.0	14.2	171.9	183.6	48.9	8.6
SEm±	1.8	0.54	3.8	4.4	2.5	0.2
CD (P=0.05)	5.0	1.52	10.7	12.3	7.2	0.6
Interaction						
N × S	NS	NS	NS	NS	NS	NS
CV%	6.9	10.2	6.4	6.9	12.5	7.6

NS, Non-significant.

under the application of 160 kg N/ha over 120 kg N/ha. Rest of the parameters were non-significant. The increase in protein content of wheat grain was to the extent of 10.98% due to application of 160 kg N/ha over 120 kg N/ha (N_1). This increase in protein content of wheat could be attributed to increase in nitrogen content in plant along with increase in nitrogen application which might have helped in synthesis of more protein as nitrogen being a constituent of various metabolites including protein and amino acids. Patel *et al.* (2004) have also reported increase in protein content with increase in level of nitrogen in wheat grain. Application of 160 kg N/ha significantly increased the wet gluten content than 120 kg N/ha. 160 kg/ha N gave significantly the highest sedimentation value (40.93 ml). The result is supported by Patel *et al.* (2004).

Nitrogen splits

The growth in plants has various phases, which starts with activation of embryo and ends with maturity of crop. The various processes involved in plant growth and development are more often limited by deficiency of nitrogen. Proper dosage and time of application of nitrogen to crop to maintain availability in adequate amounts at active growth stages of plant can check not only their losses but also increase the efficiency of added nitrogen use and also efficient uptake and utilization. In the present study, the number of split application of nitrogen were increased. Plant height (94.1 cm) was significantly higher with treatment S_2 (50% at sowing, 25% at CRI stage and 25% at 1st node stage) than rest of treatments at harvest (Table 1). The increase in plant height with the increase in nitrogen levels up to certain levels is established fact and is observed. In initial stage, i.e. up to 30 DAS the two splitting of nitrogen (50% at sowing and 50% at CRI stage) was found better, because in initial stage plant growth is relatively slow, hence requires little low nitrogen but as crop growth advanced i.e. from 30 DAS to 60 DAS, the nitrogen splitting as 50% at sowing, 25% at CRI stage and 25% at 1st node stage was found better. It might be due to after establishment of crop, wheat crop take maximum nitrogen from soil up to 1st node stage and that is reflected in results (Patel *et al.,* 2004 and Mattas *et al.,* 2011. Dry matter accumulation (232.5 g) and 243.7 g/meter row length at 90 DAS and at harvest (Table 1), respectively were significantly higher with treatment S_2 (50% at sowing, 25% at CRI stage and 25% at 1st node stage). Split application may be attributed

Table 2. Grain and straw yield (kg/ha), grains/ear, test weight (g), harvest index (%) and protein (%) as influenced by nitrogen levels and its split application (pooled data over 2 years)

Treatment	Yield (kg/ha)		Grains/ ear	Test weight	Harvest index	Protein
	Grain	Straw				
Levels of nitrogen (N)						
N_1 (120 kg/ha)	4,259	5134	47.0	39.70	45.6	11.38
N_2 (160 kg/ha)	4,572	5275	48.8	39.29	46.6	12.63
SEm±	58	108	1.0	0.258	0.7	0.03
CD (P=0.05)	165	NS	NS	NS	NS	0.09
Split application of nitrogen (S)						
S_1, 50% at sowing and 50% at CRI stage	4,570	5739	51.4	36.55	44.4	11.66
S_2, 50% at sowing, 25% at CRI stage and 25% at 1st node stage	4,964	5792	53.4	37.25	46.2	11.99
S_3, 25% at sowing, 25% at 1st node stage, 25% at tillering stage and 25% at heading stage	4,494	5649	48.7	39.19	44.4	11.92
S_4, 25% at CRI, 25% at 1st node stage, 25% at flag leaf stage and 25% at milking stage	3,905	4461	43.5	39.74	46.8	11.99
S_5, 20% at sowing, 20% at CRI, 20% at 1st node stage, 20% at flag leaf stage and 20% at flowering stage	4,844	5771	52.6	41.52	45.6	12.14
S_6, 20% at sowing, 20% at 1st node stage, 20% at flag leaf stage, 20% milking stage and 20% at dough stage	4,249	4747	43.8	40.49	47.4	12.11
S_7, 10% each at sowing, CRI, 1st node stage, tillering stage, flag leaf stage, heading stage, flowering stage, milking stage, dough stage and hard dough stage	3,884	4274	42.2	41.71	47.7	12.21
SEm±	109	202	1.8	0.482	1.4	0.06
CD (P=0.05)	309	574	5.0	1.37	NS	0.16
Interaction						
N × S	NS	NS	NS	NS	NS	NS
CV%	8.56	13.47	12.9	4.23	10.3	1.64

NS, Non-significant.

to the sustained higher availability of nitrogen in the soil throughout the growing season. The variations could be attributed to the fact that the time of N application in 3 splits coincided with critical stages of crop growth, namely crown roots and tiller primordial formation (CRI) and 1st node stage, which in turn helped in maintaining the higher level of available nitrogen in the soil at these growth phases and throughout growing period in wheat which is utilized by the plant and worked as catalyst in dry matter accumulation at various plant parts, ultimately plant as a whole (Patel *et al.,* 2004; Gupta *et al.,* 2011; Mattas *et al.,* 2011). Significantly higher leaves per plant (20.2) were recorded (Table 1) when nitrogen applied as 50% at sowing, 25% at CRI stage and 25% at 1st node stage. Treatment S_2 recorded 83.4 effective tillers per meter row length at harvesting (Table 1), followed by treatment S_5 (20% at sowing, 20% at CRI, 20% at 1st node stage, 20% at flag leaf stage and 20% at flowering stage). It may be owing to continuous and sufficient availability of nitrogen around the vegetative growth period resulting in better shoot generation environment in plant itself and turned into more effective tillers. Ear length (9.7 cm) and grains per ear (53.4) were significantly higher when nitrogen applied as 50% at sowing, 25% at CRI stage and 25% at 1st node stage. This is owing to constant supply of nitrogen which leads to higher nitrogen content in plant at 1st node stage therefore better formation of ear. The ear starts to grow and develop with the initiation of tiller as a minute thin thread like and comes out after flag leaf as spike and that is why the constitution of spike always depends upon nitrogen content and status of soil. Test weight (41.71 g) was significantly higher when nitrogen was applied as 10% each at sowing, CRI, 1st node stage, tillering stage, flag leaf stage, heading stage, flowering stage, milking stage, dough stage and hard dough stage (S_7).

Split application as 50% at sowing, 25% at CRI stage and 25% at 1st node stage recorded 4,964 and 5,793 kg/ha grain and straw yield (Table 2), respectively, on pooled basis which was at par with treatment S_5 (4,844 kg/ha grain yield). Based on pooled data under S_2, the percentage increase in grain yield was to the tune of 27.77, 27.09, 16.8, 10.46, 8.60 and 2.48 over S_7, S_4, S_6, S_3, S_1 and S_5 respectively. A similar trend was observed in case of straw yield. Harvest index was found to be non-significant. It might be attributed to favourable effect on yield attributes, viz. plant height, dry matter accumulation, number of leaves per

Table 3. Wet gluten content (%), hectoliter weight (kg/ml), sedimentation value (ml), starch (DM) (%), moisture (%), hardness index (%) and grain diameter (mm) as influenced by nitrogen levels and its split application (pooled data over 2 years)

Treatment	Wet gluten	Hectoliter weight	Sedimentation value	Starch (DM)	Moisture	Hardness index	Grain diameter
Levels of nitrogen (N)							
N_1, (120 kg/ha)	28.83	80.57	39.92	63.93	10.79	83.03	2.75
N_2, (160 kg/ha)	29.79	80.53	40.93	63.94	10.79	82.84	2.76
SEm±	0.07	0.102	0.133	0.08	0.045	0.256	0.01
CD (*P*=0.05)	0.21	NS	0.38	NS	NS	NS	NS
Split application of nitrogen (S)							
S_1, 50% at sowing and 50% at CRI stage	28.67	79.07	39.72	64.01	10.88	82.28	2.71
S_2, 50% at sowing, 25% at CRI stage and 25% at 1st node stage	28.84	79.69	40.07	64.21	10.77	82.34	2.71
S_3, 25% at sowing, 25% at 1st node stage, 25% at tillering stage and 25% at heading stage	28.95	80.19	40.28	63.94	10.80	82.67	2.73
S_4, 25% at CRI, 25% at 1st node stage, 25% at flag leaf stage and 25% at milking stage	29.68	80.72	40.49	63.78	10.74	83.12	2.76
S_5, 20% at sowing, 20% at CRI, 20% at 1st node stage, 20% at flag leaf stage and 20% at flowering stage	29.83	81.53	41.13	63.83	10.78	83.47	2.80
S_6, 20% at sowing, 20% at 1st node stage, 20% at flag leaf stage, 20% milking stage and 20% at dough stage	29.35	81.09	40.08	63.90	10.78	82.96	2.77
S_7, 10% each at sowing, CRI, 1st node stage, tillering stage, flag leaf stage, heading stage, flowering stage, milking stage, dough stage and hard dough stage	29.87	81.57	41.23	63.88	10.78	83.72	2.82
SEm±	0.14	0.190	0.249	0.15	0.085	0.478	0.01
CD (*P*=0.05)	0.39	0.54	0.71	NS	NS	NS	0.04
Interaction							
N × S	NS	NS	NS	NS	NS	NS	NS

NS, Non-significant.

Table 4. Economics as influenced by different treatment combinations on economics of wheat

Treatment	Yield (kg/ha)		Total cost of cultivation (₹/ha)	Realization (₹/ha)		Benefit: cost ratio
	Grain yield	Straw yield		Gross realization	Net realization	
$N_1 S_1$	4,472	5,729	30,737	81,745	51,008	2.66
$N_1 S_2$	4,689	5,769	30,887	85,473	54,586	2.77
$N_1 S_3$	4,326	5,648	31,037	79,182	48,145	2.55
N_1S_4	3,842	4,228	31,037	69,534	38,497	2.24
$N_1 S_5$	4,469	5,755	31,187	81,719	50,532	2.62
$N_1 S_6$	4,209	4,625	31,187	76,169	44,982	2.44
$N_1 S_7$	3,809	4,187	31,937	68,931	36,994	2.16
$N_2 S_1$	4,669	5,749	31,283	85,113	53,830	2.72
$N_2 S_2$	5,239	5,816	31,433	94,871	63,438	3.02
N_2S_3	4,663	5,650	31,583	84,912	53329	2.69
$N_2 S_4$	3,969	4,694	31,583	72,158	40,575	2.28
$N_2 S_5$	5,219	5,788	31,733	94,502	62,769	2.98
$N_2 S_6$	4,290	4,870	31,733	77,791	46,058	2.45
$N_2 S_7$	3,960	4,362	32,483	71,673	39,190	2.21

Details of treatments are given in Table 1.

plant, total tillers and effective tillers per meter row length, ear length and no. of grains/ear. The average increase in yield might be owing to continuous and sufficient availability of nitrogen during the formation of spikelets in miniature plant around the first node stage. The increase in grain and biological yield may be owing to the availability of nitrogen at various critical growth stages in optional amount that might have increased the yield attributes of wheat thus resulting in the increased grain and biological yield. Because of which, nitrogen yielded better response grain yield in the present study. Earlier works have also reported such response of nitrogen to wheat (Patel *et al.,* 2004; Kachroo and Rajdan 2006; Singh *et al.,* 2007; Kaur *et al.,* 2010; Gupta *et al.,* 2011; Mattas *et al.,* 2011).

Effect on quality of wheat grain (Table 2) indicated that protein content 12.21% being at par with splitting treatment S_5 (12.14) and S_6 (12.11) was recorded under splitting treatment S_7 (10% each at sowing, CRI, 1st node stage, tillering stage, flag leaf stage, heading stage, flowering stage, milking stage, dough stage and hard dough stage). Similarly wet gluten content 29.87% being at par with S_5 (29.83) and S_4 (29.68), hectoliter weight 81.57 kg/ml being at par with S_5 (81.53) and S_6 (81.09), sedimentation value 41.23 being at par with treatment S_5 (41.13) and grain diameter 2.82 being at par with S_5 (2.80) was recorded under the split application of nitrogen as 10% each at sowing, CRI, 1st node stage, tillering stage, flag leaf stage, heading stage, flowering stage, milking stage, dough stage and hard dough stage (S_7) (Table 3). While rest of the quality parameters like starch per cent, moisture per cent and hardness index were found to be non-significant. All the quality parameters are closely associated with amino acid concentration and bounding with each other and formation of amino acid. It depended on nitrogen availability of crop at each growth stage, although the treatment S_7 not reflected in grain yield but application of nitrogen up to last stage has kept the biochemical processes in grain up to last stage resulting in higher values for quality straits. Patel *et al.* (2004) and Kaur *et al.* (2010) also reported similar positive changes with multiple splitting of nitrogen.

Economics

Nitrogen application of 160 kg N/ha accrued maximum gross and net realization of ₹83,003/ha and ₹51,313/ha, respectively, along with the B : C ratio of 2.62 (Tables 4). The treatment S_2 (split application of nitrogen as 50% at sowing, 25% at CRI stage and 25% at 1st node stage) realized maximum gross and net income of ₹90,172/ha and ₹59,012/ha, respectively, with benefit : cost ratio 2.89.

It can be concluded that for getting higher yield apply 160 kg N/ha as 50% basal, 25% at CRI and @ 25% at 1st node stage, while for good quality wheat with higher yield apply 160 kg N/ha as 20% at sowing, 20% at CRI, 20% at 1st node stage, 20% at flag leaf stage and 20% at flowering stage.

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