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Research Article

Implication of Rate and Time of Nitrogen Application on Nitrogen Status of Barley Plant in Light Textured Soils

BIKRAMJEET SINGH[1]*, A.S. SIDHU[2], KULDIP SINGH[1] AND SUKHJEET KAUR[3]

[1]*Department of Soil Science, PAU, Ludhiana, Punjab*
[2]*PAU, Regional Research Station (RRS), Bathinda, Punjab*
[3]*Department of Climate Change & Agricultural Meteorology, PAU, Ludhiana, Punjab*

ABSTRACT

Scientific and judicious application of nitrogen (N) fertilizer is an important agronomic measure to achieve a high yield and good quality barley, and determining the appropriate N rate along with timing of its application is important for optimizing the two. “DWRUB 52” variety of barley, was grown under three nitrogen levels (75% RDN, 100% RDN, 125% RDN) and four times of their application (T_1- full dose at pre-sowing irrigation, T_2- ½ N at pre-sowing irrigation + ½ tillering stage, T_3- ½ N at pre-sowing irrigation + ¼ tillering stage + ¼ stem elongation (first node detectable) and T_4- ½ N at pre-sowing irrigation + ¼ tillering stage + ¼ flowering stage (½ of inflorescence emerged), during 2017-18 at two experimental sites i.e. Bathinda and Ludhiana. Nitrogen content was highest at the maximum tillering stage after that it decreased toward maturity. Nitrogen concentration in grains was highest with 125% RDN when it was applied in three splits that are 50% at pre-sowing irrigation, 25% at tillering and 25% at the flowering stage.

Key words: Nitrogen levels, N application time, Straw and grain NPK concentration

Introduction

Plant growth and development largely depend on the concentration of mineral nutrients available in the soil (Morgan and Connolly, 2013). Among macro nutrients, nitrogen is an essential nutrient for crops, and its application can be effective in increasing crop yield (Guo *et al*., 2019). Nitrogen application directly influences plant growth, development processes, plant nutrient cycling, and photosynthetic carbon. It is an essential constituent of metabolically active compounds like protein, nucleic acids, chlorophyll and enzymes, etc., results in enhanced crop production (Zhang *et al*., 2007). The challenge here is to identify the specific and most responsive stage to the fertilizer application for efficient nutrient uptake (Sandhu *et al*., 2021). The cereal crops undergoes different stages of growth and development. The rate of nutrient uptake varies with the crop growth stage, variety, and growing conditions (Miller *et al*., 1993). The stage of N addition can be of great importance, influencing the performance and quality of the barley (Jaeger *et al*., 2021) for malt or high protein content, as there is an inverse relation between malt quality and protein content (Yousif and Evans, 2017). A proper understanding of the N uptake patterns of barley crops is required to find out the optimal timing for N applications. Therefore, the present study, aimed to determine the most responsive stage to N application, through N status of the plants at different growth stages.

*Corresponding author,
Email: bikramjeet-1916002@pau.edu

Material and Methods

Experimental site and treatment details

The multilocational field trials were conducted during the winter season of 2017-2018 at PAU, Regional Research Station, Bathinda (30°12′ N, 74°56′ E and 226 m above mean sea level) and Research farm of Department of Soil Science, Punjab Agricultural University (PAU), Ludhiana (30°54′ N, 75°48′ E and 247 m above mean sea level). The initial basic soil physical and chemical properties of the experimental sites are summarized in Table 1. The treatments of experiments were organized in factorial randomized block design having three replications following twelve treatments (three N levels - 75% RDN, 100% RDN, 125% RDN, and four times of their application (T_1- full dose at pre-sowing irrigation, T_2- ½ N at pre-sowing irrigation + ½ tillering stage, T_3- ½ N at pre-sowing irrigation + ¼ tillering stage + ¼ stem elongation (first node detectable) and T_4- ½ N at pre-sowing irrigation + ¼ tillering stage + ¼ flowering stage (½ of inflorescence emerged)).

Crop management practices

Seed (87 kg ha^{-1}) of 'DWRUB 52' barley variety was sown at row spacing 22.5 cm. Nitrogen and phosphorus fertilizers were added through urea and single super phosphate. The weeds, insect-pest, and diseases were controlled by following the recommended package of practice of Punjab Agricultural University, Ludhiana. The crop was harvested at physiological maturity in month of April at both locations, Bathinda, and Ludhiana.

Table 1. Initial physico-chemical properties of experimental sites

Properties	Locations	
	RRS, Bathinda	PAU, Ludhiana
Mechanical analysis (%)		
Sand	79.4	78.9
Silt	79.4	15.5
Clay	79.4	5.6
Texture	Loamy sand	Sandy loam
pH	8.09	7.15
EC (dS/m)	0.42	0.35
Soil organic carbon (%)	0.34	0.45
Available N (kg/ha)	164.6	184.4
Available P (kg/ha)	18.1	20.6
Available K (kg/ha)	224.9	209.6

Plant samples

Plant samples were collected at different growth stages, then oven-dried, grounded and analyzed for NPK through different procedures. The total N from the plant sample was determined by the Kjeldahl method (Bremner and Mulvaney, 1982). A sample of 0.5 g of grains/straw was digested in conc. H_2SO_4 and digestion mixture (Se powder + HgO + $CuSO_4$ + K_2SO_4) to detect total N content. For determining total phosphorous (P) and potassium (K), a diacid mixture of nitric acid and perchloric acid in the ratio of 3:1 as given by Piper (1966) was used to digest the grain and straw samples. The total P from plant samples was determined by the Vanadomolybdate P yellow color method in the nitric acid system as reported by Jackson (1973) and the yellow color intensity was detected by spectronic 20 colorimeter at 470 nm wavelength. A flame photometer was used to detect the total K content of grain and straw samples.

Statistical analysis of field data

Data on nutrient content was analyzed by using statistical methods as per Gomez and Gomez (1984) and the software used was SAS 9.1 (SAS Institute, CA).

Results and Discussion

Nitrogen content in barley straw and grains

The N levels and their time of application significantly affected the plant N content at maximum tillering, jointing, and flowering stage (Table 2). As the level of N increased, the N content in crop also increased at every growth stage. Higher N content at maximum tillering, jointing and the flowering stage was found in the 125% RDN (3.11, 1.72, and 1.01%, respectively) followed by 100% RDN (2.88, 1.46 and 0.90%, respectively) and 75% RDN (2.49, 1.18 and 0.63%) at Bathinda. Similar trends to Bathinda were seen in Ludhiana, where a rise in N levels

Table 2. Effect of different N levels and time of application on N content (%) in straw (at different growth stages) and grains of barley

Treatment	At maximum tillering stage		At jointing stage		At flowering stage		At harvesting stage		N in grain (%)	
	Bathinda	Ludhiana	Bathinda	Ludhiana	Bathinda	Ludhiana	Bathinda	Ludhiana	Bathinda	Ludhiana
Nitrogen levels										
75 % recommended dose of nitrogen (N_1)	2.49	2.98	1.18	1.71	0.63	0.85	0.14	0.23	1.23	1.34
100 % recommended dose of nitrogen (N_2)	2.88	3.27	1.46	1.93	0.90	1.04	0.22	0.30	1.40	1.48
125 % recommended dose of nitrogen (N_3)	3.11	3.44	1.72	2.11	1.01	1.16	0.27	0.34	1.50	1.57
CD (p=0.05)	0.34	0.27	0.29	0.20	0.12	0.14	0.06	0.04	0.13	0.11
Time of Application										
Full dose at pre-sowing irrigation (T_1)	2.90	3.29	1.24	1.70	0.65	0.81	0.13	0.21	1.20	1.33
½ N at pre-sowing irrigation + ½ tillering stage (main shoot and one tiller) (T_2)	3.12	3.46	1.47	1.92	0.82	1.02	0.20	0.29	1.38	1.45
½ N at pre-sowing irrigation + ¼ tillering stage (main shoot and one tiller) +¼ stem elongation (first node detectable) (T_3)	2.72	3.09	1.73	2.14	0.88	1.03	0.24	0.31	1.42	1.51
½ N at pre-sowing irrigation + ¼ tillering stage (main shoot and one tiller) +¼ flowering stage (½ of inflorescence emerged (T_4)	2.57	3.07	1.37	1.89	1.03	1.20	0.27	0.34	1.50	1.56
CD (p=0.05)	0.39	0.31	0.33	0.23	0.14	0.16	0.07	0.05	0.15	0.13

caused an increase in N concentration, 125% RDN resulted in higher N content at maximum tillering (3.44%), jointing (2.11%) and at flowering stage (1.16%), respectively. The considerable rise in N content in straw with higher N rates has also been reported by Ahmad *et al.* (2015).

At Bathinda, under N splitting treatments at different growth stages, T_1 treatment with a full dose of N applied at pre-sowing had a lower amount of N content in plants at maximum tillering (2.90%), jointing (1.24%) and at flowering stage (0.65%), respectively over T_2 treatment. A higher amount of N content was observed in the T_2 treatment (3.12 % at the maximum tillering stage). At the jointing and flowering stage, a higher amount of N content was observed in T_3 (1.73%) and T_4 (1.03%) treatments, respectively. At Ludhiana, among the treatments with a time of N application, lower N content in plants was observed in T_1 treatment at jointing (1.70%) and flowering stages (0.81%), whereas treatments with higher N content were T_2 (3.46%), T_3 (2.14%) and T_4 (1.20%) at maximum tillering, jointing and at flowering stage, respectively. At harvesting stage higher nitrogen content in barley straw was observed with 125% RDN (0.27 and 0.34%) when applied in four splits (T_4) (0.27 an 0.34%) at both research locations, Bathinda and Ludhiana, respectively. The maximum N content in plants was recorded at the maximum tillering stage which reduced towards harvesting. This indicates barley plants need higher N demand at the tillering stage to support the grand growth period of development. Higher N application at tillering stage results in more number of effective tillers which helps in getting higher yields (Singh *et al.*, 2022). Data showed a reduction in N concentration with increasing plant age. This reduction in N concentration at the harvesting stage compared to the tillering stage may be due to the difference between the rate of N absorption and the rate of growth, which is well-known as the dilution effect. N concentration in barley plant at tillering stage was several times as much as its content at harvesting stage. Mehrotra *et al*. (1967) also reported that the rate of N uptake was maximum up to the tillering stage, about 45%, 25% from jointing to ear initiation stages and 30% up to the time of grain formation in wheat crop. Thus, they concluded that N is required by the plant up to the end of vegetative growth and a split application will be highly beneficial from a yield point of view. Taalab *et al*. (2015) also observed that the barley plant needs most of the N demand in the early growing stage.

Cereals may accumulate most of their N in vegetative organs before ear emergence and then redistribute it during grain development (Hortensteiner, 2002). Moreover, grain filling is the period when the N content of different plant parts is substantially reduced (Lopes *et al.*, 2006) as a consequence of protein hydrolysis, which remobilizes amino acids for export to developing grains (Feller and Fischer, 1994). In this experiment N content also mobilized from vegetative parts into grains, that is why plant N content decreased from tillering to harvesting. N concentration in grain increased by 22% at Bathinda and 17.2% at Ludhiana, with increasing the N level from 75% RDN to 125% RDN. In the case of timing of N application, grain N content was significantly higher (25% at Bathinda and 17.3% at Ludhiana) when N was applied in three split doses (T_4 treatment) as compared with application of N in single dose (T_1 treatment) but the values were statistically at par with treatment when N was applied in two splits (T_2 treatment). The increase in N concentration by split application of N may be related to an increase in efficiency and reduced leaching losses of N in loamy sand and sandy loam soils of Bathinda and Ludhiana, respectively. Similar results were observed by Ali (2010).

P and K content in barley straw and grains

Increased N application improves P and K concentration in grains and straw (Table 3), which may be due to the fact that the N application increases the plant root growth hence the larger surface area of the roots which enables more exploitation of P and K from soil. In addition to this, it may also be due to that the N additions affect plant metabolism and may change the ability of unit areas of the root surface to absorb P and K. Hence, N application can cause a measurably higher P and K level inside the straw and then from straw into developing grains. Hamner and Kirchmann (2015) found a positive correlation between N and P uptake. Kumar *et al*. (2013) also observed that K concentration in wheat grain (12.7%) and straw (5.8%) was significantly

Table 3. Effect of N treatments on P and K content (%) in straw and grains of barley

Treatment	P content in straw (%)		K content in straw(%)		P content in grain (%)		K content in grain(%)	
	Bathinda	Ludhiana	Bathinda	Ludhiana	Bathinda	Ludhiana	Bathinda	Ludhiana
Nitrogen levels								
75 % recommended dose of nitrogen (N_1)	0.018	0.022	1.19	1.06	0.214	0.251	0.40	0.38
100 % Recommended dose of nitrogen (N_2)	0.027	0.032	1.47	1.28	0.240	0.271	0.47	0.44
125 % recommended dose of nitrogen (N_3)	0.033	0.038	1.57	1.35	0.252	0.284	0.54	0.48
CD (p=0.05)	0.007	0.007	0.15	0.14	0.022	0.018	0.10	0.05
Time of application								
Full dose at pre-sowing irrigation (T_1)	0.018	0.023	1.21	1.06	0.213	0.251	0.39	0.37
½ N at pre-sowing irrigation + ½ tillering stage (main shoot and one tiller) (T_2)	0.025	0.030	1.39	1.22	0.231	0.265	0.44	0.43
½ N at pre-sowing irrigation + ¼ tillering stage (main shoot and one tiller) +¼ stem elongation (first node detectable) (T_3)	0.028	0.033	1.47	1.31	0.240	0.275	0.50	0.46
½ N at pre-sowing irrigation + ¼ tillering stage (main shoot and one tiller) +¼ flowering stage (½ of inflorescence emerged (T_4)	0.033	0.037	1.57	1.34	0.256	0.285	0.54	0.48
CD (p=0.05)	0.008	0.008	0.18	0.16	0.026	0.021	0.11	0.05

increased under N application of 180 kg ha^{-1} as compared to control.

At Bathinda, P concentration in grains under 100% RDN and 125% RDN increased by 12.1% and 17.8% as compared to 75% RDN whereas straw P concentration increased by 50% and 83.3%, respectively. At Ludhiana, P concentration in grains increased by 8% and 13.1% under 100% RDN and 125% RDN as compared to 75% RDN whereas straw concentration increased by 45.5% and 72.7%. Among time of N application treatments at Bathinda, P concentration under T_2, T_3, and T_4 treatments, each increased by 8.5, 12.6, and 20.2% in grains and 38.8, 55.5, and 83.3% in barley straw, respectively as compared to T_1 treatment, whereas at Ludhiana P concentration under T_2, T_3 and T_4 treatments, each increased by 5.6, 9.6 and 13.5% in grains and 30.4, 43.5 and 60.9% in barley straw respectively as compared to T_1 treatment. At Bathinda, under 100% RDN and 125% RDN K concentration in barley grains was significantly increased by 17.5 and 35%, respectively over 75% RDN, similarly, straw K concentration increased by 23.5 and 31.9%, respectively. At Ludhiana, potassium concentration in grains under 125% RDN and 100% RDN treatments significantly increased by 15.8 and 26.3 % as compared to 75% RDN whereas straw K concentration increased by 20.8 and 27.4%. When N was applied in three split doses up to the flowering stage (T_4 treatment) at Bathinda, the K content of the grain and straw was significantly higher (38.5 and 29.8%, respectively), compared to when N was applied in a single dose (T_1 treatment), whereas at Ludhiana, K concentration under T_2, T_3 and T_4 treatments increased by 16.2, 24.3 and 29.7% in grains and 15.1, 23.6 and 26.4% in barley straw, respectively over T_1 treatment.

Conclusion

The maximum N content in plants at the tillering stage indicated that barley crop needs most of their N demand at the tillering stage. High N application at tillering is also required to support the grand growth period of development. The N content from vegetative parts decreased towards the harvesting of crop, with more distribution into developing grains.

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