**Evaluating precision nitrogen management strategies to improve wheat yield and soil fertility**

**Abstract**

Wheat (Triticum aestivum) is one of the most important staple food crops in India, ranking second after rice in terms of area and production. It plays a critical role in ensuring food security for millions of Indians. The experiment was conducted during 2022-23 at the soil research farm of CCS Haryana Agricultural University, Hisar. With the application of 130% of RDN, the yield of the wheat crop increased (52.09 q/ha), and a minimum (25 q/ha) was observed in the control. It also improved the available nitrogen in the soil. Wheat grain and straw yield were significantly increased with the increase of nitrogen doses, except at 145% high nitrogen doses the grain yield of wheat decreased. In all the treatments consisting of high doses of N and RDF (recommended dose of fertilizer), the soil pH and electrical conductivity were found statistically non-significant.

Keywords: Wheat, Nitrogen management strategies, Soil fertility, Yield, Green Revolution

**Introduction**

India has a long and rich tradition of wheat cultivation, which expanded rapidly after the Green Revolution of the 1960s. “Wheat (*Triticum aestivum* L.) is one of the most widely grown cereal crops in the world and serves as a staple food for billions, providing carbohydrates along with proteins, vitamins, and minerals” (Reddy et al., 2004). Today, India is the second-largest wheat producer globally, after China. The steady increase in production over the decades has been driven by improved farming techniques, high-yielding seed varieties, and supportive government measures such as minimum support prices (MSP) and procurement programs. These high-yielding varieties, however, demand higher fertilizer inputs, particularly nitrogen, to reach their full yield potential. Uttar Pradesh, Punjab, and Haryana are the leading wheat-producing states, with Uttar Pradesh at the top due to its fertile alluvial soils and extensive irrigation systems. Together, Punjab, Haryana, and western Uttar Pradesh are referred to as the “Granary of India.” Other important wheat-producing states include Bihar, Gujarat, West Bengal, Maharashtra, Uttarakhand, and Himachal Pradesh. India’s average wheat yield is about 3.37 tonnes per hectare, comparable to the global average but lower than countries like France (6.84 t/ha), Germany (6.67 t/ha), and China (5.42 t/ha). Globally, China leads wheat production, with key cultivation zones in the North China Plain and Yangtze River basin (Wang et al. 2019). The United States is also a major producer, particularly in states such as Kansas, North Dakota, and Washington, while Russia grows wheat extensively in the Volga region and Siberia. Despite favorable climatic and soil diversity, India faces challenges such as soil degradation and water scarcity in some regions. Addressing these issues through region-specific technologies, better seed distribution, and efficient resource use will be essential to boost yields and meet rising domestic demand. Nitrogen is one of the most critical nutrients for wheat production, and inadequate supply can sharply reduce yields. It plays a central role in almost all plant metabolic processes as a major component of proteins, enzymes, chlorophyll, nucleic acids, and other vital biomolecules (Kutman et al., 2011). Wheat varieties with high genetic yield potential require greater nitrogen inputs to fully express productivity (Behera et al., 2000). Proper nitrogen fertilization promotes vigorous growth and maximizes yield per hectare. While splitting nitrogen doses may not significantly affect economic yield, it can help reduce lodging, influence spike number, and increase the thousand-grain weight (Ayoub et al., 1994). Research suggests that applying about 120 kg N/ha often results in optimum yields (Lathwal and Singh, 1992; Das and Rao, 1993). Other studies (Geleto et al., 1995; Singh and Uttam, 1992) indicate that higher nitrogen application generally increases spike number, grain yield, and grain weight. However, “under favorable climatic and management conditions, increasing nitrogen from 90 to 225 kg/ha has sometimes shown no significant yield advantage” (Penckowski et al., 2009).

**Material and methods**

A field experiment on wheat on aridisols was initiated in the rabi season at soil research farm CCS Haryana Agricultural University, Haryana (29.3024° N, 75.8069° 212 m above sea level). Soil of experimental site is sandy loam and the top (0-15 cm) soil low in available N (163.2 kg/ha), high in available P (21.50 kg/ha) and medium range of available K (337.82 kg/ha) shows in Table 1. The pH (1:2), EC (electrical conductivity) and organic carbon (%) were found 8.02, 0.37 dS/m and 0.51%, respectively in top soil of the experiment. The climate of the experimental site was semi arid type with a mean annual rainfall of 470 mm and potential evapotranspiration of 1654 mm. About 80 % of the rainfall occurs during the rainy season, i.e. June to September. The hottest months are May and June, with average highs reaching 42°C (108°F) and 42°C (106°F), respectively. January is the coldest month, with average lows around 6°C (43°F).

**Table 1. Initial soil chemical properties**

|  |  |  |
| --- | --- | --- |
| **Parameter**  | **Value** | **Method of Analysis** |
| pH (1:2) | 8.02 | Potentiometric Method (Jackson,1973) using 1:2 soil water suspension |
| EC (dS/m) | 0.37 | Conductometric method (Jackson, 1973) using 1:2 soil: water suspension)  |
| OC (%) | 0.51 | Walkey and Black Wet Oxidation Method, 1965 |
| Available N (kg/ha) | 163.03 | Kjeldahl -Distillation Method (Subbaiah and Asija, 1956) |
| Available P (kg/ha) | 21.50 | NaHCO3 Extraction and Colorimetry (Olsen et al*.*, 1954) |
| Available K (kg/ha) | 337.82 | 1N NH4OAC Extraction and Flame Photometry (Jackson,1973) |

Soil pH and EC was calculated by (Jackson, 1973) methods, taken 20 gram soil sample in 100 ml 100 ml beaker and 40 ml of distilled water was added in it to make a soil: water suspension of the ratio of 1:2. The suspension was mixes with glass road for 30 min and estimated pH and EC by pH meter and electrical conductivity meter. The OC of the soil was estimated using the Wet digestion method (WalkleyandBlack,1934). Further processing of samples and pass through 0.5 or 0.2 mm sieves. According to this method, one gram of soil sample was taken in a 500 ml conical flask and then 10 ml of potassium dichromate and 20 ml of conc.H2SO4 in it. Organic matter in the soil was oxidized with a mixture of potassium dichromate and concentrated sulphuric acid, utilizing the exothermic reaction of sulphuric acid. The excess of potassium dichromate that was not reduced by the organic matter of the soil was determined by titration using 0.5 N ferrous ammonium sulphate solution in the presence of sodium fluoride orphosphoric acid using diphenyl amine as an indicator. When the end point is reached, stop adding ferrous ammonium sulphate solution and note down the volume of ferrous ammonium sulphate used. And calculate the organic carbon content using a mathematical formula. Available N was determined using alkaline permanganate method (Subbiah and Asija, 1956). 5 g of soil was mixed with 25 ml alkaline KMnO4 solution and distilled. The organic matter present in the soil was oxidized by the nascent oxygen that is liberated by KMnO4, in the presence of 25 ml NaOH solution. The released ammonia was condensed and absorbed in a known volume of a standard acid H2SO4, and the excess of which was titrated against standard alkali by using methyl red as an indicator. Available P was determined by Olsen's method (Olsen et al.,1954). One gram of soil was extracted with10 ml 0.5M NaHCO3 at pH 8.5 in the presence of Darco G-60 (which adsorbs dispersed organic matter and helps in giving clear extract). Phosphorus in the extract was treated with ammonium molybdate, which results in the formation of heteropolycomplexes (phosphomolybdate). The phosphomolybdate was reduced by using of SnCl2 (a reducing agent). Due to this reduction,some of MO6+ was converted to Mo3+orMo5+, and the complex assumes the blue color. The intensity of blue color obtained was measured at a wavelength of 660nm using a red filter on a spectrophotometer. Available K was determined using neutral 1NNH4OAC solution using a flamephotometer (Jakson,1973). 5 g of soil was taken and mixed in 25ml of ammonium acetate in which NH4 replaces the potassium present in the soil by occupying its sites. At equilibrium, there was no replacement of ions, and the potassium obtained in the solution was estimated with a flame photometer.

Cost of Cultivation (Rs ha-1)

The cost of cultivation involves in each treatment was computed by adding the cost of all inputs used during the cultivation crop and the cost involved in each treatment varied due to different levels of nitrogen fertilizers and methods of planting.

3.6.2 Gross Return (Rs ha-1)

Total incomes generated by sales of entire produce from all the treatment are called gross returns. It was calculated by multiplying the yield of cane (t ha-1) as well as green top with the price of cane (Rs. t-1) and green top.

Gross returns (Rs ha-1) = cane yield (t ha-1) x cane price (Rs t-1) + green top yield (t ha-1) x prevailing price of top (Rs t-1)

3.5.3 Net Returns (Rs ha-1)

Net returns were calculated by subtracting variable costs from gross returns. Net returns = Gross returns - cost of cultivation

3.5.4 Benefit-Cost Ratio

The benefit-Cost ratio (B:C) use to find the gross returns per rupee of money invested. It was calculated by dividing the net returns by the total cost of cultivation under the respective treatment.

 Net Returns

B: C = x 100

 Cost of Cultivation

In this experiment, there were nine treatments with different levels of nitrogen, and each treatment was replicated three times. The statistical design was a randomized block design with 7 x 6 m plot size. The treatment details was as follows:

T1 : Control

T2 : 100% RDF (Recommended Dose of Fertilizer)

T3 : 115% N + PK

T4 : 130% N + PK

T5 : 145% N + PK

T6 : 115% NP + K

T7 : 130% NP + K

T8 : 145% NP + K

T9 : Soil test-based fertilizer application

Statistical Analysis

The data recorded for each parameter under different treatments was statistically analyzed in RBD. The critical difference (CD) was worked out for comparing the effect of treatments on soil, growth, yield and quality parameters at 5 % level of significance according to the protocol defined by Sheoran et al. (1998) using OPSTAT software.

**Results and discussion**

The initial soil chemical properties are shown in Table 1. The maximum grain yield (52.09 q/ha) of wheat was observed with the application of 130% high nitrogen doses (T4) and minimum (25 q/ha) was observed in control shown in Table 2. The increase in grain yield and its attributes supplied with higher doses of N. Results showed that yield was in the range of 0.306 to 0.563 Kg/m2. (Kaur et al 2015). With comparison to control, the wheat grain yield was increased by 51.61, 51.01, 48.55 and 50.63% in T4, T5, T7 and T8 treatment respectively. The T4 treatment was significantly higher wheat grain yield than T7 and at par with T5. With relation to grain yield, the straw yield was found higher in T5 followed by T8, T4, and T7. As reported earlier, grain yield is significantly influenced by N application (Singh et al., 2000; Sial et al., 2005 ). As compared to recommended dose (RDN), under low N levels viz. RDN- 50% and RDN-25%, the reduction in yield was 41 and 9%, respectively. Increased grain yield with increase in N application could be ascribed to increased biomass production with N fertilization.

Wheat grain and straw yield was significantly increased with the increase of nitrogen doses except at 145% high nitrogen doses; grain yield of wheat was decreased.

“The low N supply decreases grain weight due to less supply of the grain with carbohydrates and amino compounds during the lag phase when the number of storage cells and starch granules are being formed” as reported by Paponov et al. (2005). Overall, both grain and straw yields increased with higher nitrogen levels up to a certain point, highlighting the positive response of wheat to nitrogen fertilization. However, when nitrogen was applied at 145% of the recommended dose, the grain yield decreased, likely due to adverse effects such as lodging or imbalanced nutrient uptake. These results emphasize the importance of optimizing nitrogen application to maximize wheat yield while avoiding excessive doses that could negatively impact crop performance.

Abedi et al. (2011) observed from silty loam soils of Iran that “yield components were significantly increased with enhancing the level of nitrogen with no significant difference between 240 and 360 kg N/ha”.

**Table 2: Effect of different N level on grain and straw yield of wheat**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Grain Yield (q/ha) | Straw Yield (q/ha) | B:C ratio |
| T1 (control) | 25.0 | 37.2 | 1.19 |
| T2 (RDF) | 48.0 | 64.4 | 2.28 |
| T3 (115%N) | 50.8 | 63.8 | 2.43 |
| T4 (130%N) | 52.1 | 68.9 | 2.51 |
| T5 (145%N) | 51.5 | 76.1 | 2.63 |
| T6 (115%NP) | 50.0 | 66.7 | 2.50 |
| T7 (130%NP) | 50.07 | 68.6 | 2.21 |
| T8 (145%NP) | 51.1 | 75.9 | 2.30 |
| T9 (STBF) | 49.9 | 57.7 | 2.10 |
| CD (=0.05) | 1.14 | 2.35 |  |

**Table 3: Effect of different N level on soil properties**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | Available nutrients (kg/ha) | pH | EC(dS/m) | OC (%) |
| **Nitrogen** | **Phosphorus** | **Potassium**  |
| T1 (control) | 104.9 | 21.78 | 344.4 | 8.00 | 0.30 | 0.51 |
| T2 (RDF) | 117.4 | 18.00 | 287.1 | 8.08 | 0.28 | 0.52 |
| T3 (115%N) | 175.8 | 22.22 | 325.0 | 7.94 | 0.33 | 0.50 |
| T4 (130%N) | 221.4 | 20.89 | 362.6 | 7.96 | 0.33 | 0.50 |
| T5 (145%N) | 204.7 | 22.67 | 325.0 | 8.08 | 0.28 | 0.49 |
| T6 (115%NP) | 215.3 | 24.00 | 353.7 | 8.25 | 0.38 | 0.51 |
| T7 (130%NP) | 155.1 | 21.78 | 275.0 | 8.00 | 0.32 | 0.51 |
| T8 (145%NP) | 199.0 | 22.67 | 298.4 | 8.00 | 0.32 | 0.52 |
| T9 (STBF) | 170.0 | 21.56 | 309.4 | 8.05 | 0.30 | 0.50 |
| CD (=0.05) | 3.1 | 1.6 | 4.2 | NS | NS | NS |

 The results revealed that in treatment T4 (130% N), available N was found significantly higher (221.45 kg/ha), compared to the control (104.95 kg/ha) (shown in Table 2). The T4 was significantly higher than all treatments. In all the treatments consisting of high doses of N and RDF (recommended dose of fertilizer), the soil pH and Electrical conductivity were found statistically non-significant. But the soil pH and EC werevaried in the range of 7.81-8.25 and 0.28-0.52% respectively. Available P and K varied from 18.0 to 24.0 kg/ha and 275 to 362.6 kg/ha. The net return was highest in T5 with 145% NP, the cost benefits ratio was highest in T5,i.e, 2.63, and minimum (1.19) was observed in T1(control). Continuous high nitrogen application can acidify the soil over time, especially when ammonium-based fertilizers are used. This can reduce soil pH, affecting nutrient availability. Nitrogen fertilization increases crop biomass and root growth, which can add more organic residues to the soil, potentially improving soil organic matter and stimulating microbial activity. Excessive nitrogen without balanced application of phosphorus, potassium, and micronutrients can lead to nutrient imbalances in the soil, affecting long-term soil health. Applying nitrogen beyond crop requirements can lead to residual nitrate accumulation in the soil. This not only poses environmental risks like leaching and groundwater contamination but can also affect subsequent crops. Kumar et al.(2009) revealed that “100% RDF (recommended dose of fertilizer) 60 kg N/ha, 30 kg P2O5/ha, and 20 kg K2O/ha increased the wheat yield”. “In the sandy loam soils of Kanpur, U.P. having low organic carbon (0.45%) and available N (225 kg/ha) that grain yield and plant height of wheat increased with increasing level of residual nitrogen and attained maximum at rate of 80 kg N/ha as compared to 60, 40 and 0 kg N/ha” Yadav et al.(2010). Thind et al. 2010 reported that “application of slow-release fertilizer i.e neem coated urea at a rate of 90 kg/N/ha was significantly higher the yield of wheat than the 120 kg N/ha in 2 split doses”.

**Conclusion**

From the above study, it may be concluded that the application of higher doses of Nitrogen in the soil it enhances the wheat yield. The application of higher doses of nitrogen increased the biomass of the wheat and increased the soil available nutrients. The modern wheat cultivars respond well to the highest N applications as compared to older taller cultivars. The availability of nitrogen to wheat during various phases of its growth and development is an important factor influencing the quality of grain.

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