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Research Article

Precision nitrogen management in wheat using leaf color chart and its effect on grain yield & nitrogen use efficiencies

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Abstract:

A two-year study was executed at research farm of Department of Soil Science, Chaudhary Charan Singh Haryana Agriculture University, Hisar in *rabi* season during 2020-21 and 2021-22 to compare LCC as N management tool with other recommended practices for optimum yield and nitrogen use efficiency in wheat crop. The existing soil test based, soil test crop response (STCR) and recommended dose of fertilizer-N (Agronomic RDF) were selected for the study. LCC was used at two different timings, one is after the sowing of the crop while in another treatment, it was used after CRI (Crown root initiation) stage. Grain and straw yield (43.85 and 67.7 kg/ha, respectively) of wheat were found higher in LCC governed N management treatment which was statistically on par with that of STCR based N management and LCC based N management since sowing, however saving of fertilizer N from 8-68 kg/ha was observed under LCC based treatment, over above mentioned practices. It was found that the supply of nitrogen (46 kg/ha) at CRI stage is pre-requisite and cannot be ruled out to attain the maximum yield. The nitrogen use efficiencies as apparent recovery efficiency, agronomic efficiency supported the finding and higher value of these were found with N management *via* LCC (T5) and varied from 21.23-67.71 % among all treatments, in both the years. PAU based LCC nitrogen management can be used as economical viable and user friendly tool to govern the nitrogen requirement of wheat crop in western Haryana.

Keywords: Efficiency, Leaf color chart (LCC), N management, Nitrogen saving, Wheat yield

1. Introduction

Wheat crop has global significance for food security. Over 240 million ha area is under wheat cultivation along with its greatest world's trade compared to any other crops or for rest of the crop combined (Curtis *et al.*, 2002). It makes up around one-sixth of the world's total arable land. It is staple food for millions of people and have special significance in Indian context due to involvement in food, feed and fodder apart from various industrial uses (Ramdas *et al.* 2013). Wheat is grown predominantly as rabi crop, in India, however in certain part of country (Hilly area) it can even be grown in kharif season (Gupta and Kant, 2012). Due to its diversified climatic conditions, India produces the second-highest wheat grain in the world. At national level, area under cultivation of wheat was increased from 29.04 million ha to 30.54 million ha, with a pace of 1.5 million ha (5%) net gain in terms of area increase. Among the different states, largest share in area (9.75 million ha) was recorded in Uttar Pradesh (32 %), followed by Madhya Pradesh (18.75%), Punjab (11.48%), Rajasthan (9.74%), Haryana (8.36%) and Bihar (6.82%). Haryana although, have lesser area under cultivation compared to some other states but it has second largest productivity

(4738 kg/ha) of wheat after Punjab with total production of 11.24 million tonnes during 2013-14 to 2017-18 (Ramdas *et al.*, 2019). Economics of farming community, especially in northern India is highly influenced with wheat production and productivity. It is an exhaustive crop and contributes major share of fertilizers use in country.

Fertilizer is one of the essential but expensive input and along with framers, it also overburdened the government, through the subsidy provision. Fertilizers play leading role in increasing crop yield by almost 40% (Stewart *et al.*, 2005). There is direct and significant correlation of fertilizers use and crop production. (Bijay-Singh, 2016; FAI, 2020). Adequate quantity & timely application of fertilizers is important factors which need to be understood in deep and are of environmental concern too. Excessive fertilizers not only increase the inputs cost but also degrades soil and water in long run basis.

Even though it is a costly input, nitrogen is one of the essential fundamental nutrients since it is crucial to photosynthesis and directly affects the amount of dry matter produced. In India, nearly all of the soils are deficient for the nutrient nitrogen. Because the availability of N varies drastically from field to field, blanket fertiliser recommendations over large areas are inefficient. Differential amount of nitrogen is needed depending upon the demand of crop, growth stage of crop and native nitrogen content of the soil. If N inputs could be supplied in synchrony to real time crop demand and nutritional requirements, it would be more beneficial. Crop-demand based N application is one of the important management practice to save nitrogen fertilizer and to improve N use efficiency of the wheat crop (Majumdar *et al.*, 2013).

One of the potential & economical solution to synchronise crop need based N supply for efficient use of nitrogen, is LCC (Leaf colour chart) (Bijay-Singh *et al.*, 2002; Balasubramanian *et al.*, 2003; Yadvinder *et al.*, 2007). This concept is based on the results that showed a close relationship between chlorophyll content and N content of the leaves. The leaf N content varied with varying stages of crop. The direct link between leaf N content and LCC readings enables close monitoring of leaf N status at every growth stages using a single critical value for LCC. This makes LCC as one of the reliable and quick assessing tool for the above said purpose. Apart from the technical efficiency, LCC has low purchase value and has shown reliability in real time N management. The usage of LCC was initially restricted to rice cultivars but widened for many other crop varieties (Balasubramanian *et al.*, 1999, 2003; Bijay-Singh *et al.*, 2002). The leaf color chart (LCC) is an alternative to the chlorophyll meter or SPAD with a cost effective budget. The critical color shade on the LCC need to calculate and revised with changing crop cultivar and variety to guide realistic nitrogen application in the field.

This approach of N management is very limited in developing countries like India (Maiti and Das, 2006). The chlorophyll meter and LCC provide a simple, quick, and non-destructive way of determining leaf N content (Maiti et al., 2004). This type of study is very sparse in Haryana. Here, in this experiment we are evaluating the LCC developed by PAU (Punjab Agricultural University) in relation to popular wheat variety grown in Haryana. Therefore, the current investigation was conducted to evaluate need-based N management strategies for wheat crop using LCC with the objective to increase the wheat yield without enhancing the cost of cultivation, to reduce the losses of nitrogen fertilizers by precise and timely application and to find out the various fertilizer use efficiencies to correlate it with N economy as well as increasing yield.

2. Materials and methods

2.1 Experimental Site

A field study was conducted for consecutive two years (2020-2021 & 2021-22) at the research field of the department of Soil Science, CCS HAU, Hisar. The mean annual rainfall is 615.6 mm, 82% of which was received during June-August. Mean maximum and minimum temperatures were 30.5 & 17 ^{0}C. The soil has sandy loam texture and have slightly alkaline (8.55) pH with low EC (0.19 ds/m) and have low level of organic carbon content (0.37%). The initial status of soil available nitrogen, phosphorus and potassium content was 126, 12, 253 kg/ha.

2.2 Experimental Design and Treatments

The experiment was laid out in randomized block design (RBD) by growing wheat variety WH1105 after the harvesting of cotton crop in same field during *rabi* season of 2021-22 and 2022-23. The experiment consists of six nitrogen management practices which are replicated four times, T_1: Control; T_2: Recommended dose of Nitrogen (Blanket recommendation of 150 kg N /ha in two equal split at basal and at first irrigation); T_3: Soil test based nitrogen management (150 kg/ha); T_4: STCR based nitrogen management; T_5: LCC based nitrogen management (137.5 kg/ ha) DAP at the time of wheat sowing +100 kg urea/ha at the time of first irrigation (26 days after sowing (DOS)) + LCC based nitrogen application afterwards. T_6: LCC based nitrogen management (137.5 kg/ ha DAP at the time of sowing + LCC based nitrogen application from the first irrigation (26 DOS) itself. In the experiment, phosphorus was applied as basal dose of 60 kg/ha through DAP in all the treatments except T5 and T6 where it was applied as per the guidelines of PAU LCC and potassium was not applied in the soil due to high status of soil available potassium. The results were statistically analysed using OPSTAT software.

2.3 Measurement of LCC readings and N fertilizer application

LCC consisting of 6 panel with varying shades of green generated by PAU (Punjab Agricultural University) was used for taking readings. The readings of LCC were taken five days after the first irrigation and nitrogen was applied as per the guidelines of LCC. The LCC was used for measurements on five topmost fully expanded leaves. In each plot 10 plants were selected randomly for the reading. Mean of ten values of LCC taken for 10 plants in each plot was used to evaluate N status of plants. These value were taken to decide the rate of nitrogen application. The average value was 4.5-5.0 and thus applied 30 kg/ ha of nitrogen. In case of treatment 6 (T6), after the first irrigation, the LCC shades fallen between 4.5-5.0 while afterwards the LCC readings came between 4.0-4.5 thus nitrogen applied as 30 kg/ha and 67.2 kg/ha respectively. The LCC readings were noted at 15-day intervals at a specified time. Afterwards no requirement of nitrogen was indicated by LCC.

2.4 Nitrogen use efficiency

The content of N in grain and straw of wheat was determined from samples collected at the time of harvesting of the crop using lindar's (nessler's reagent) method (Reference). Total nitrogen uptake by the crop was used for determining nitrogen use efficiencies by using following expressions:

Formulae Used

$$AE = \Delta \text{ kg grain/kg yield N applied} \quad (1)$$

$$RE = (\Delta \text{ kg nitrogen uptake/fertilizer N applied}) \times 100 \quad (2)$$

$$PE = \Delta \text{ kg grain}/\Delta \text{ kg yield N uptake} \quad (3)$$

where AE = agronomic efficiency, RE = recovery efficiency, PE = physiological efficiency, Δ = difference between treatment plot and control plot.

3. Results and Discussion

3.1 Grain and straw yield

The various management practices for nitrogen application showed that LCC approach for nitrogen management outstand the other methods. The grain and straw yield increased significantly with the application of nitrogen fertilizers compared to the control treatment. On comparing the different approaches for supplying nitrogen to the crop, it was found that highest grain and straw yield was obtained under LCC based nitrogen management along with basal application of DAP and nitrogen at first irrigation. The grain yield varied from 22.7 to 40.3 q/ha in 2021-22 and 29.7 to 47.4 q/ha in 2022-23, highest being in the T5 (40.3 q/ha & 47.4 q/ha respectively) treatment in both years, which was on par with T6 (39.0 q/ha) and T4 (38.7 q/ha) and T3 in both the years (Table 1). The percent increase in the yield in treatment T5 over the absolute control (T1) was 77.5 % and 59.60 % respectively, in 2021-22 and 2022-23. In the treatment T4, nitrogen was applied according to soil test crop response (STCR) based equation and recorded higher yield than T2 &T3 but the input of fertilizer N was also higher in this treatment. The straw yield varied from 29.5 to 52.4 q/ha and 51.5 q/ha (T1) to 83.0 q/ha (T5) with highest being in treatment T5, respectively in both the years. The overall yield was lower than potential yield of the variety in both years due to the terminal heat stress (Fig. 1). The T5 treatment yielded the maximum grain and straw yield while using the least amount of nitrogen. With STCR management techniques, the maximum amount of nitrogen fertiliser was applied to the soil (208 kg/ha), and T5 treatment demonstrated savings of a total of 68 kg/ha as compared to that amount, without sacrificing yield. LCC saved a total of 30 kg/ha compared to RDN while producing a 12.7 % higher yield. The grain yield of treatments T5, T6, and T4 was comparable to one another, with treatment T5 acting as a nitrogen saviour relative to the other treatments. Several workers also found increase in yield with the usage of LCC in wheat and rice crop in different locations of India (Alam *et al.* (2006); Varinderpal *et al.*, 2012; Duttarganvi *et al.*, 2014 and Barad *et al.*, 2018). Grain and straw yield of soil test based nitrogen application was statistically at par with RDN practices.

Due to poorly designed N splitting, changes in crop N need, and indigenous N supply (INS), the recommendation of fixed-time split N applications at specific growth phases is insufficient to synchronise N supply with actual crop N demand (Dobermann *et al.*, 2003). The higher yield was obtained when the nitrogen was managed with the advanced diagnostic tool such as LCC which ensures the optimum application of nitrogen fertilizer in the soil as and when required by the crop (Ladha *et al.,* 2000; Maiti *et al.*, 2004). The leaf color and chlorophyll content of the leaves has direct indication of nitrogen present (Nachimuthu *et al.,* 2007) in the plant and accordingly ensures timely and adequate application of fertilizer (Delgado *et al.,* 1994). Maximum grain as well as straw yield obtained in T5 in both the years because of timely application of nitrogen in this treatment. The average value of LCC reading after first irrigation in this treatment was between 4.5-5.0 which leads to additional application nitrogen of 30 kg/ha according to the calculation. In treatment T6 the quantity of N was applied based on the readings of LCC since start of the experiment and no additional dose of nitrogen was given except for basal DAP. During initial stage the nitrogen requirement was high and incorporation of N at this time rendered higher yield in T5 as compared to T6. So, overall, the highest yield obtained with the use of LCC for nitrogen management but additional urea application at first irrigation seems to be crucial. The various nitrogen use efficiencies calculated from the data support the findings of the experiment.

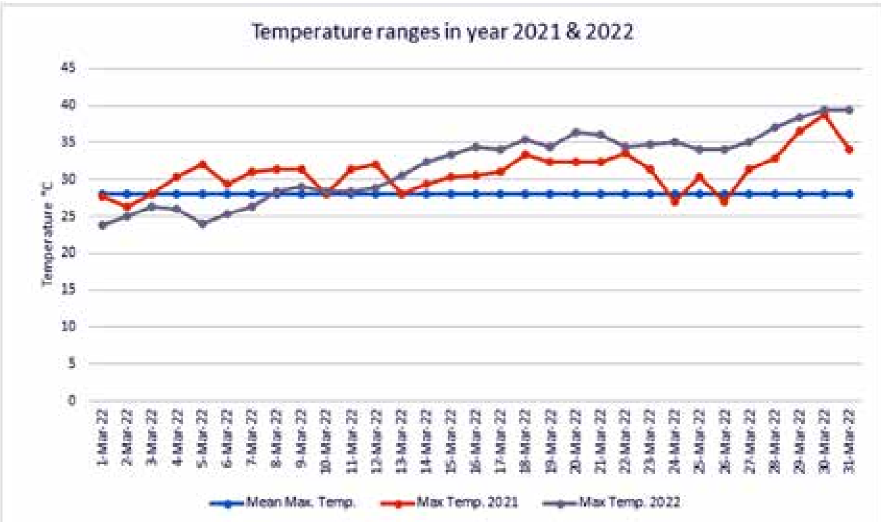

Figure 1: Temperature status depicting terminal heat during wheat cropping season
Source: Metrology Department, CCS HAU, Hisar

Table 1: Effect of different nitrogen management strategies on grain and straw yield of wheat crop (q/ha)

Treatments	Grain yield (q/ha)		Straw Yield q/ha	
	2021-22	2022-23	2021-22	2022-23
T1	22.7	29.7	29.5	51.5
T2	35.3	42.5	47.7	74.3
T3	37.0	46.0	46.6	80.0
T4	38.7	45.6	51.9	79.2
T5	40.3	47.4	52.4	83.0
T6	39.0	46.0	50.7	81.6
C.D (p=0.05)	**2.6**	**2.2**	**3.9**	**3.5**

Nutrient uptake & Nitrogen use efficiencies (NUE)

The average nitrogen uptake from grain varied from 31.96 to 81.13 kg/ha while the mean uptake of straw varied from 7.29 to 21.67 kg/ha (Table 3). The highest uptake was from T5 while the lowest being in the control treatment. The results emphasise the importance of the optimum timing of fertilizer application on the nutrient uptake (Varinderpal *et al.*, 2012). The total NPK content of grain varied from 1.22 to 1.85 %, 0.30 to 0.54 % and 0.24 to 0.41 % lowest in control and highest in the treatment T5 (Table 2). Similar trend was observed in straw. NPK content was higher recorded in LCC managed treatment due to synchronized and optimum nitrogen availability in soil using LCC. Apparent recovery efficiency and Agronomic efficiency varied from 21.23-48.60 % and 7.7 to 14.7 % respectively, among different treatment (Table 4). The nitrogen use efficiencies were found higher where the nitrogen was managed with LCC along with the nitrogen application at first irrigation (T5). Similar results were reported by Peng et al., 1996 and Maiti & Das, 2006. However, the highest (96.7 kg/kg) physiological efficiency was found in T2 as compared to other treatments. Such high physiological efficiency reflects either highly managed soil or it have low soil available nitrogen. In this treatment the lowest amount of N was applied and hence the later cause would be more reasonable. These results indicate that nitrogen applied based on crop need as determined by the LCC was used more efficient to optimize both grain yield and nitrogen use efficiencies. (Ladha *et al.*, 2000; Dobermann *et al.*, 2003; Shukla *et al.*, 2004). This also emphasise the importance of nitrogen fertilizer which along with the quantity also ensures the quality of grain and straw which lately used as animal fodder.

Table 2: Effect of different nitrogen management strategies on total NPK content of grain and straw

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T1	1.22	0.18	0.30	0.12	0.24	1.17
T2	1.46	0.22	0.40	0.14	0.27	1.20
T3	1.53	0.24	0.42	0.15	0.28	1.21
T4	1.71	0.26	0.45	0.17	0.35	1.24
T5	**1.85**	**0.32**	**0.54**	**0.20**	**0.41**	**1.28**
T6	1.73	0.28	0.48	0.18	0.37	1.26
C.D (5%)	0.061	0.019	0.027	0.018	0.020	0.028

Table 3: Effect of different nitrogen management strategies on nitrogen uptake of grain and straw

Treatments	Grain uptake (kg/ha)			Straw uptake (kg/ha)		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean
T1	27.69	36.23	31.96	5.31	9.27	7.29
T2	54.36	65.45	59.95	10.49	16.35	13.42
T3	56.61	70.38	63.49	11.18	19.20	15.19
T4	66.18	77.98	72.08	13.49	20.59	17.04
T5	**74.56**	**87.69**	**81.13**	**16.77**	**26.56**	**21.67**
T6	67.47	79.58	73.53	14.20	22.85	18.53
CD (5%)	**3.82**	**4.45**		2.80	3.10	

Table 4: Effect of different nitrogen management strategies on various nitrogen use efficiencies

Treatments	Apparent Recovery Efficiency (%)		Agronomic Efficiency (kg kg^{-1})		Physiological Efficiency (kg kg^{-1})	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T1	N.A	N.A	N.A	N.A	N.A	N.A
T2	21.23	24.19	8.4	13.2	**96.7**	**84.9**
T3	23.20	37.72	9.5	15.5	90.2	55.5
T4	22.44	31.52	7.7	11.0	82.3	58.6
T5	**48.60**	**67.71**	**14.7**	**20.6**	69.4	49.8
T6	38.02	54.24	12.7	18.2	77.1	51.0

Post-harvest nutrient status

The initial status of soil revealed that the soil has low initial nitrogen status and medium range of phosphorus and potassium. After the harvesting of wheat crop the available nitrogen content, after two years of experiment, varied from 114.0 kg/ha to 127.0 kg/ha and the highest amount was found treatment T4 where maximum nitrogen was applied. The post-harvest available nitrogen status of soil was found decreased over initial value in all the treatments (except T4) due to volatilization and leaching loss of nitrogen in addition to removal by the crop. The initial \status of soil available nitrogen was almost maintained in T4 in spite of above losses due to application of higher amount of nitrogen based on STCR equations. The available phosphorus and potassium varied from 10-15.2 kg/ha and 245.1-250.0 kg/ha, respectively and slight build-up of phosphorus was observed in soil compared to initial soil status, however there is depletion of available potassium content.

Conclusion

Nitrogen management through the use of LCC leads to efficient utilization of the N fertilizer. The grain and straw yield along with the nutrient use efficiencies were significantly influenced by managing N through the LCC and recorded saving of nitrogen from 8-68 kg/ha under treatment T5 in comparison to T6 and T4 treatments. LCC based nitrogen management after application of 46 kg N/ha at CRI stage (T5) produced about 12.7 % higher yield as compared to recommended dose of nitrogen (RDN) with a saving of 30 kg N /ha. Thus, blanket recommendation and soil test based nitrogen causes excessive application of nitrogen fertilizer results in over financial burden on the farmers as well as country. However, the role of crucial stage application of fertilizer cannot be ignored and application at CRI stage was found important and can't be omitted. Hence, LCC could be an effective and cheaper alternative for precision nitrogen management for the farmers of northern belt of India.

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Ethical standards: NA

Authors contribution:

Concept of research proposal (UK, DR & MKS); experiments planning and designing (UK and DR); Execution of field experiments and data collection (UK, DR & KKB); Analysis of data and interpretation (UK, PJ); Preparation of the manuscript (UK, DR, KKB, PJ).

Conflict of interest: No

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