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CALIBRATING LEAF COLOUR CHART FOR OPTIMAL FERTILIZER NITROGEN MANAGEMENT IN BASMATI RICE UNDER TEMPERATE CONDITIONS OF KASHMIR

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ABSTRACT

Field experiments were conducted in 2013 and 2014 with the aim to develop optimal nitrogen management for Basmati rice cv. 'Pusa Sugandh-3' using leaf colour chart (LCC). The treatments included no nitrogen (N_0) treatment, three fixed time (60, 90 and 120 kg N ha^{-1}) and four real time nitrogen management treatments. Grain and straw yield, total N uptake and various indices of N use efficiency were measured in both the years. The best response in all the parameters assessed was achieved with LCC treatments maintained at 20 kg N ha^{-1} (LCC 4_{20}) and 30 kg N ha^{-1} (LCC 4_{30}) . However, LCC 4_{20} treatment had significantly higher nitrogen use efficiency (NUE) as compared to LCC 4_{30} treatment because the nitrogen applied in former treatment was 20 kg ha^{-1} lesser than the later, while as yield in both the treatments was same. Based on the principle that threshold value is the one which simultaneously optimizes grain yield and NUE, LCC 4_{20} treatment was adjudged as threshold value for real time N management in Basmati rice variety 'Pusa Sugandh-3' under temperate conditions of Kashmir.

Key words: Basmati rice, LCC, nitrogen, N- use efficiency, yield

INTRODUCTION

Fertilizer nitrogen has become a key input in crop production. Globally cereals account for more than half of the total fertilizer N consumption (Varinderpal-Singh *et al*., 2011). Large variations in nitrogen supplying capacity of soil can exist across small distances within a landscape due to differences in historical fertilizer use, crop residue retention, input of organic materials and inherent soil fertility. The existing blanket fertilizer recommendations for irrigated rice involve application of fixed doses of fertilizer N at specified crop growth stages and do not take this variability into consideration (Bijay-Singh *et al*., 2012). This often leads to nutrient imbalances, inefficient fertilizer use and large losses to the environment (Ju *et al*., 2009). The commonly followed practice of applying excess nitrogen dose to keep N deficiency at bay further reduces this efficiency (Varinderpal-Singh *et al*., 2012). A substantial portion of applied N is lost due to poor synchronization of plant N demand with N supply (Varinderpal-Singh *et al.*, 2010). The need of the hour, therefore, is to synchronize N applications with crop demand. The improvement in synchronization between demand and supply of nitrogen is likely to be the most promising strategy to increase N use efficiency (NUE) in cereal crops (Bijay-Singh *et al.*, 2014). The leaf colour chart (LCC) provides an inexpensive and practically reliable option to guide need based fertilizer N application in cereals based on spectral properties of leaves. The present study was aimed to establish threshold LCC value for guiding crop demand-driven need-based fertilizer N applications in Basmati rice variety 'Pusa Sugandh-3' and to evaluate LCC based fertilizer N applications vis-à-vis blanket fixed time fertilizer N management to improve N use efficiency in rice.

MATERIALS AND METHODS

Field experiments were conducted for two consecutive years (2013-14) using Basmati rice cv. 'Pusa Sugandh-3' at University Farm, SKUAST-Kashmir, Srinagar (J&K). The site lies 34°10′ N and 74°79′ E at an altitude of 1,587 m masl. The soil (0-15 cm depth) of the experimental field was silty clay loam in texture with pH 6.7, electrical conductivity 0.24 dS m^{-1}, organic C 0.69% and available N, P and K of 136, 7.32 and 100 mg kg^{-1}, respectively. During 2013 and 2014, the mean monthly minimum and maximum temperature during growing seasons was 11 and 13°C and 26 and 27°C, respectively. The total rainfall during growing seasons in 2013 and 2014 was 512 and 567 mm.

Thirty-five days old rice seedlings were manually transplanted in the 1st week of June at hill spacing of 15×15 cm. Phosphorus (25 kg P ha^{-1}), potassium (25 K kg ha^{-1}) and zinc (10 kg $ZnSO_4.7H_2O$ ha^{-1}) were incorporated in all the plots a day before seedling transplantation. The experiment comprised of 8 treatments arranged in a randomized completely block design with each treatment replicated thrice. The treatments included a no-nitrogen (N_0), three fixed time N (60, 90 and 120 kg N ha^{-1}) and four real time N management treatments. In fixed time treatments, total N was applied in split doses at three predetermined stages i.e. 50% as basal dose and 25% each at mid-tillering and panicle initiation stages. In real time N management treatments, LCC threshold shades were maintained by applying N whenever the green colour of more than 5 out of 10 leaves were observed equal to or below the set critical limit of LCC score. The six-panel leaf colour chart used was manufactured by N Parameters Chennai (India) as per the specifications of IRRI (IRRI, 1996). LCC measurements were made from the top most fully expanded leaf at weekly interval, starting from 15 days after transplantation (DAT) upto 50% flowering. The leaf being measured was kept under shade of the body during measurements to avoid colour variance caused by direct sunlight. Unusually tall or short plants, wet and widely spaced leaves were avoided.

The field was kept flooded for 2 weeks before maturity. Pre-emergence herbicide 'Butachlor 5% G' was applied 3 days after transplantation. Weeding was also done manually at 30 and 60 DAT. Final harvest was done in 2nd week of October. The plants were sampled from 0.36 m^2 (16 hills) to determine tiller number, leaf area index, panicles m^{-2} and sterility percentage. Tiller number, including mother stem, was counted in each hill. Panicle number was counted in each hill at maturity. Leaf area was measured with a leaf area meter and expressed as leaf area index (LAI). Filled and unfilled spikelets were separated from each other by submerging them in clean water to assess sterility percentage. Grain weight was determined by oven drying the filled spikelets till constant weight. Average 1000-grains was taken as grain mass. Grain and straw yields were recorded from a net area of 2 m^2 from the centre of treatment plots. Grain yield was adjusted to 14% moisture content and dry straw yield noted. In order to calculate above ground total N uptake, N concentration in grain and straw was determined by digesting the samples in H_2SO_4, followed by analysis for total N using a Kjeltec-auto-analyzer.

The nitrogen use efficiency (NUE) measures; agronomic efficiency, recovery efficiency and partial factor productivity was calculated as follows:

$$\text{Agronomic efficiency} = \frac{\text{Grain yield in N-fertilized plots - Grain yield in } N_0 \text{ plot}}{\text{Quantity of N fertilizer applied in N-fertilized plot}}$$

$$\text{Recovery efficiency} = \frac{\text{Total N uptake in N-fertilized plot} - \text{Total N uptake in } N_0 \text{ plot}}{\text{Quantity of N fertilizer applied in N-fertilized plot}}$$

$$\text{Partial factor productivity} = \frac{\text{Grain yield (kg ha}^{-1}\text{) in N fertilized plot}}{\text{Quantity of fertilizer N applied N (kg N ha}^{-1}\text{)}}$$

Analysis of variance was performed on data using R software (version 3.2.0; Developer: R Core Team). Significantly different treatment means were separated using Fisher's protected least significant difference test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

The time of nitrogen application observed through use of LCC during the years 2013 and 2014 is presented in Table 1. A predetermined amount of fertilizer was used as basal dose in all the four LCC treatments. LCC was maintained upto 86th and 87th day after transplantation during 2013 and 2014, respectively, which corresponded to almost one week before flowering. The higher LCC values (LCC 4) required more number of splits and eventually higher amount of fertilizer N than lower LCC values (LCC 3).

Table 1: The quantity of nitrogen (kg ha^{-1}) applied to different LCC treatments

Treatments	Time of application (days after transplantation) during 2013													Number of splits	N applied (kg ha^{-1})
	Basal	26	29	35	40	42	57	64	65	80	86				
LCC 3_{20}	20			20				20						3	60
LCC 3_{30}	30				30				30					3	90
LCC 4_{20}	20	20				20	20			20				5	100
LCC 4_{30}	30		30				30				30			4	120
	Time of application (days after transplantation) during 2014														
	Basal	27	28	34	35	43	46	56	63	65	66	82	87		
LCC 3_{20}	20			20					20					3	60
LCC 3_{30}	30					30					30			3	90
LCC 4_{20}	20	20				20		20				20		5	100
LCC 4_{30}	30		30					30					30	4	120

The number of tiller produced per unit area and leaf area index (LAI) are two important growth parameters which depend upon the metabolic activities of plant and its corresponding growth. Application of nitrogen as per crop requirement at various growth stages eventually leads to better utilization of nitrogen for growth and development (Debtanu *et al*., 2004). In present study, the number of tillers m^{-2} and LAI varied significantly across the treatments during both the years (Table 2). The highest values were obtained in treatments N_{120}, LCC 4_{20} and LCC 4_{30}; and lowest in control (N_0) treatment. N_{60} and LCC 3_{20} treatments were at par with each other. Almost similar was the case with treatments LCC 3_{30} and N_{90}. Enhanced tillering at higher N application rates could attributed to more assured N supply to the plants at active tillering stage. Further, tiller number and leaf size are the two important factors which influence LAI (Tanaka *et al.,* 1964) and these, in turn, are greatly affected by soil N availability (Murata and Matsushima, 1978).

The panicle number responded significantly to N application with treatments LCC 4_{20} and LCC 4_{30} producing highest number of panicles m^{-2} (Table 2). The panicle number in treatments $N_{90,}$ N_{120} and LCC 3_{30} was at par with one another. The higher panicle number in treatments LCC 4_{20} and LCC 4_{30} over other treatments could be attributed to better synchronization in supply and demand of nitrogen at all the critical growth stages. Besides, high leaf area coupled with high chlorophyll content at flowering has been reported to affect the amount of photosynthates available to the panicle (Avijit *et al*., 2011).

Table 2: The number of tiller m^{-2}, leaf area index and panicles m^{-2} in Basmati rice cv. 'Pusa Sugandh-3' grown in variable N fertilizer treatments during 2013 & 2014

Treatments	N rate (kg ha^{-1})	Number of tiller m^{-2} 2013	Number of tiller m^{-2} 2014	Leaf area index 2013	Leaf area index 2014	Number of panicles m^{-2} 2013	Number of panicles m^{-2} 2014
N_0	0	342.1^d	335.5^d	3.33^d	3.21^d	180.5^d	172.2^d
N_{60}	60	391.0^c	383.3^c	3.72^c	3.67^c	265.7^c	259.4^c
N_{90}	90	406.8^b	401.0^b	4.12^b	4.03^b	274.7^b	271.1^b
N_{120}	120	424.5^a	417.5^a	4.71^a	4.74^a	280.2^b	277.8^b
LCC 3_{20}	60	388.5^c	380.5^c	3.75^c	3.79^c	263.3^c	256.5^c
LCC 3_{30}	90	405.4^b	397.7^b	4.18^b	4.11^b	276.4^b	270.2^b
LCC 4_{20}	100	426.4^a	419.4^a	4.69^a	4.77^a	303.8^a	296.8^a
LCC 4_{30}	120	429.2^a	421.8^a	4.76^a	4.65^a	301.0^a	294.9^a

The values within a column having different superscripted letters significantly differ from each other based on Fisher's LSD test at $\alpha = 0.05$ superscripted

Grain yield, straw yield and total N uptake exhibited similar pattern of changes with respect to various nitrogen treatments during both the years with highest yield in treatments LCC 4_{20} and LCC 4_{30} (Table 3). The yields in treatments N_{120}, N_{90} and LCC 3_{30} were at par with each other. In treatments LCC 3_{20} and N_{60} as the nitrogen rate decreased, the yield also showed decrease. The lowest yield was obtained in treatment N_0. Higher grain yield in treatments LCC 4 might be due to more number of splits as compared to other treatments. Optimum availability and uptake of N at critical growth stages provides substrate for synthesis of organic compounds which constitute protoplasm (Bhat *et al*., 2015). This exhibits a favourable effect on yield characters and supports better assimilation of photosynthates towards grains (Ravi *et al*., 2007). A similar effect produced by N_{90} and N_{120} treatments on parameters like panicles m^{-2}, grain yield, straw yield and total N uptake indicates that the extra 30 kg N ha^{-1} nitrogen supplied in N_{120} treatment could not be utilized by the plants. It appears that the nitrogen applied at early vegetative stage perhaps exceeded the requirement of crop (Peng *et al*., 2010). Bijay-Singh *et al*. (2012) reported that the rice crop requires less N at early stages, more N during its grand growth period (panicle initiation to flowering) and a comparatively lower N during later stages of crop growth. In present study in the existing fixed time recommendation schedule the nitrogen was applied at basal, tillering and panicle initiation stages. Swain and Sandip (2010) and Bijay-Singh *et al*. (2012) have reported that flowering stage, in addition to tillering and panicle initiation stages, is a critical stage for nitrogen application. This amply clarifies that the existing recommendation approach of fixed time split nitrogen applications at specified growth stages is not adequate to synchronize nitrogen supply with actual crop nitrogen demand due to poorly designed nitrogen splitting and variations in crop N demand (Nachimuthu *et al*., 2007).

Table 3: Grain yield, straw yield and N uptake in Basmati rice (cv. Pusa Sugandh-3) grown under different nitrogen fertilizer treatments during 2013 & 2014

Treatments	N rate (kg ha^{-1})	Grain yield (t ha^{-1}) 2013	Grain yield (t ha^{-1}) 2014	Straw yield (t ha^{-1}) 2013	Straw yield (t ha^{-1}) 2014	N uptake (kg ha^{-1}) 2013	N uptake (kg ha^{-1}) 2014
N_0	0	30.60^d	28.60^d	55.76^d	53.13^d	65.21^d	61.75^d
N_{60}	60	50.60^c	48.40^c	63.30^c	60.10^c	94.52^c	90.67^c
N_{90}	90	53.90^b	51.83^b	65.86^b	63.56^b	99.23^b	96.19^b
N_{120}	120	55.26^b	53.23^b	68.10^b	65.60^b	102.7^b	97.74^b
LCC 3_{20}	60	50.86^c	48.60^c	62.40^c	60.06^c	93.38^c	89.32^c
LCC 3_{30}	90	53.86^b	51.71^b	65.40^{bc}	63.76^b	99.08^b	94.47^b
LCC 4_{20}	100	58.76^a	56.73^a	72.26^a	69.36^a	109.12^a	104.58^a
LCC 4_{30}	120	58.63^a	56.53^a	71.83^a	69.56^a	108.74^a	104.88^a

The values within a column having different superscripted letters are significantly different from each other based on Fisher's LSD test at $\alpha = 0.05$

Table 4: The agronomic efficiency, recovery efficiency and partial factor productivity of Basmati rice cv. 'Pusa Sugandh-3' grown in different N fertilizer treatments during 2013 & 2014

Treatments	N rate (kg ha^{-1})	Agronomic efficiency (AE_N)		Recovery efficiency (RE_N)		Partial factor productivity (PFP_N)	
		2013	2014	2013	2014	2013	2014
N_0	0	-	-	-	-	-	-
N_{60}	60	33.33^a	33.00^a	0.49^a	0.48^a	84.33^a	80.67^a
N_{90}	90	25.89^c	25.81^c	0.38^c	0.38^c	59.89^b	57.59^b
N_{120}	120	20.55^e	20.53^e	0.31^d	0.30^d	46.05^c	44.36^c
LCC 3_{20}	60	33.77^a	33.33^a	0.47^a	0.46^a	84.77^a	81.00^a
LCC 3_{30}	90	25.84^c	25.68^c	0.38^c	0.37^c	59.84^b	57.46^b
LCC 4_{20}	100	28.16^b	28.13^b	0.44^b	0.43^b	58.76^b	56.73^b
LCC 4_{30}	120	23.36^d	23.28^d	0.36^c	0.36^c	48.86^c	47.11^c

Within a column the values having different superscripted letters are significantly different based on Fisher's LSD test at $\alpha = 0.05$

All the three nitrogen use efficiency (NUE) indices revealed change in a similar fashion with respect to the various nitrogen treatments. With increase in nitrogen application the NUE showed a decrease with highest NUE observed in treatments N_{60}, LCC 3_{20} and LCC 4_{20} (Table 4). The treatments N_{90} and LCC 3_{30} were at par with each other. Because of higher N application, NUE in treatment LCC 4_{30} was relatively low and that of treatment N_{120} was the lowest. The highest NUE in N_{60} and LCC 3_{20} treatments could be expected in rice wherein a linear response at low fertilizer input and a quadratic response thereafter has been normally reported (Debaeke *et al*. 2006., Esfahani *et al*. 2008). Treatment LCC 4_{20} had significantly higher NUE as compared to treatment LCC 4_{30} because the nitrogen applied in former treatment was comparatively (20 kg ha^{-1}) low than the later whileas the yield in both treatments was same. This shows that the N supply in treatment LCC 4_{20} matched more effectively with the crop N demand. Improving the synchronization between crop N demand and the available N supply is an important key to improve NUE (Muneshwar, Singh *et al*. 2002). Nitrogen losses from soil-plant system are large thereby leading to low fertilizer NUE when N application is not synchronized with crop demand (Peng *et al*., 1996).

Conclusion: The threshold LCC value is known as the one that simultaneously optimizes grain yield as well as NUE. After taking into account the overall results of all the observed parameters, the treatment LCC 4_{20} was adjudged as the best treatment. Therefore, it is recommended that the threshold leaf colour value LCC 4 established in this study by applying 20 kg N ha^{-1} when leaf greenness falls below the threshold greenness may be used for real time nitrogen management in Basmati rice cv. 'Pusa Sugandh-3' under temperate conditions of Kashmir valley.

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