PRECISION NITROGEN MANAGEMENT IN WHEAT AT RAMPUR, CHITWAN, NEPAL

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ABSTRACT

The application of blanket recommendation of nitrogen fertilizer leads to over or under fertilization. There is need to synchronize the N fertilizer application with plant demand. Field experiment was conducted during 2019 -2020 in Chitwan to assess the yield, nitrogen use efficiencies and economics of wheat production under precision N management compared with fixed time N management. Experiment was laid out in split plot design with sixteen treatments and three replications. The main plot treatments were varieties Vijay and Banganga and subplot treatments were three SPAD readings (≤35, ≤40, ≤45), two LCC readings (≤4, ≤5), Nutrient expert tool, fixed time nitrogen management(FTNM) with national recommended dose and control (zero N). The research result showed that varieties did not differ in yield and economics. Precision nitrogen management with SPAD≤45 and LCC≤5 consumed higher nitrogen doses and produced better yield attributes and yield (5585 and 5385 kgha^{-1} respectively) compared with FTNM. The agronomic use efficiency of nitrogen (AEN), recovery efficiency (REN), partial factor productivity (PFP were highest at LCC≤4 which consumed less nitrogen. SPAD≤35, LCC≤4 and NE treatments saved 15, 35 and 20 kgha^{-1} N respectively without compromising the yield obtained in FTNM. But, the benefit: cost ratio was highest at LCC≤5.Therefore, in terms of yield and profitability of wheat production, LCC≤5 is better than other treatments. The present national recommended dose of nitrogen to wheat crop is insufficient to achieve higher yield in Chitwan condition.

Key words: Agronomic efficiency of nitrogen (AEN), fixed time nitrogen management (FTNM), leaf color chart (LCC), NE (Nutrient Expert tool), partial factor productivity (PFP), recovery efficiency of nitrogen (REN), soil plant analysis development (SPAD)

INTRODUCTION

Wheat is one of the most important cereal crops in Nepal after rice and maize. It is cultivated in 0.7 million ha land with production of 2.1 million mt (MoALD, 2021). It is consumed as staple food by 36 % of the world population (Mohanty *et al.*, 2015). It is predicted that 50-70% more cereal grains will be required to feed 9.3 billion people by 2050 (Ladha *et al.*, 2005).

Nitrogen Fertilizer is an important agricultural input that contributes to the final yield of crop. The improper and inadequate use of fertilizers is one of the reasons of

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low productivity of wheat in Nepal (Bhatta *et al., 2020)*. Nitrogen fertilizer is generally managed by following the blanket or standard recommendations in developing countries like Nepal (Ladha *et al.*, 2005). Blanket fertilizer recommendation does not consider the spatial and temporal variation of crop demand to fertilizer leading to low fertilizer use efficiency, environmental pollution and higher cost of cultivation (Ghosh *et al.,* 2018).

The synchronization of Nitrogen fertilizer application with plant demand is necessary to reduce the losses, optimize the nutrient use efficiency and minimize the environmental pollution (Dineshkumar *et al.,* 2013). This could be done with the help of precision N management practices.

Precision nitrogen management is based on the principle of 4 'R's applying the right rate, at right time, in the right place, using the right source and balance (Chaudhary *et al*., 2019). Precision nitrogen management uses various tools and technologies such as LCC, SPAD, green-seeker, nutrient expert model, crop simulation model etc. for gathering information about spatial and temporal differences within the field in order to match inputs according to site-specific field conditions (Diacono et al., 2013).

The LCC and SPAD meter can be used to monitor plant N status in the field and determine the right time of nitrogen top dressing in the crop (Doberman and Fairhurst, 2000) at right physiological stage of nutrient demand (Majumdar *et al.*, 2013). Nitrogen management with LCC and SPAD facilitates the saving of nitrogen without yield reduction and improves N use efficiency (Barad*et al.,* 2018). Research works on precision nitrogen management in wheat crops are very limited in Nepal as most of the works are concentrated towards rice. Therefore, the present study is conducted with the objectives to determine the growth and productivity of wheat at conventional and precision N management, to the N use efficiencies of wheat at conventional and precision N management and to work out the economics of conventional and precision N management.

METHODOLOGY

The research was conducted in agronomy farm of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal starting from November 2019 to April 2020. It is located at $27^{0}40'$ North latitude and $84^{0}23'$ East longitude and 9.8 km South-west from Bharatpur Metropolitan city, the headquarter of Chitwan district. The soil of experimental site was sandy loam, acidic in pH (5.64), medium in organic matter (3.07%) and total Nitrogen (0.15%) and lower in P_20_5 (22.04 kgha^{-1}) and K_20 (80.04 kgha^{-1}). Average maximum temperature ranged from 25^{0}C to 27^{0}C and average minimum temperature ranged from 14.05^{0}C to 23.3^{0}C during the experimental period. The average relative humidity and rainfall was 84.94% and 5.30 mm respectively. These data were recorded by metrological station of NMRP, Rampur Chitwan.

The experiment was laid out in split plot design with the total of 16 treatments i.e., two varieties (Vijay and Banganga) as main factor and eight N management in subplot factor as follows.

T1 = Control (0 kgha^{-1} Nitrogen)
T2= 40 kgha^{-1} N basal + 30 kgha^{-1} N when SPAD reading showed 35 or less
T3 = 40 kgha^{-1} N basal + 30 kgha^{-1} N when SPAD reading showed 45 or less
T4= 40 kgha^{-1} N basal + 30 kgha^{-1} N when LCC reading showed 5 or less
T5 = Nutrient Expert Tool (Software used to calculate N requirement)
T6 = 40 kgha^{-1}N basal + 30 kgha^{-1} when SPAD reading showed 40 or less
T7 = 100 kgha^{-1}N, 40 kgha^{-1} N basal application+ top dressing at CRI and at Tillering
T8 = 40 kgha^{-1} N basal + 30 kgha^{-1} N when LCC reading showed 4 or less

The treatments were replicated thrice and there were total of 48 plots. Each individual plot had 12 rows with the spacing of 25cm apart with plot of 3m×2.5m (7.5m^2.) The spacing between plots was 0.5 m and the spacing between replications was 1.5 m. The line sowing was done with the spacing of 25 cm and continuous seed placement within rows.

The National Recommended Dose (NRD) of fertilizer i.e., 100:50:25 N, P_20_5 and K_20 kgha^{-1} (MoALD, 2019) was applied through the urea, Single Super Phosphate (SSP) and Muriate of Potash (MoP) respectively. Full dose of phosphorus (SSP) and potash was applied as basal dose at the time of sowing. 40 kg Nha^{-1} was applied as the basal dose and remaining Nitrogen fertilizer was applied as per the treatment guided by LCC and SPAD. However, on Nutrient Expert (NE) 26 kgha^{-1} N was applied as basal dose.
Both LCC and SPAD readings were taken at 21 days after sowing till flowering at the interval of 10 days during morning time 8-10 am. The reading was taken from topmost fully expanded leaf of 10 healthy plants.

Effective tillers per square meter

Before harvesting, effective tillers per square meter were determined by counting total number of tillers bearing spike from the row length of 2.5m.

Number of grains per spike

Twenty spikes from net plot area were randomly selected. The total no of grains per spike were calculated from each spike and mean were calculated.

Sterility percentage

$$\text{Sterility percentage} = \frac{\text{Total number of florets per spike} - \text{number of grain per spike}}{\text{Total number of grain per spike}} \times 100$$

Thousand grain weight

Thousand grain weight of wheat from each net plot was recorded and expressed in 12% moisture level.

Grain yield

$$\text{Grain yield kg ha}^{-1}\text{ at 12\% moisture} = \frac{(100 - \text{MC}) \times \text{plot yield(kg)} \times 10000}{(100 - 12) \times \text{net plot area}}$$

Agronomic Use Efficiency (AEN) (Dobermann, 2007)

$$\text{Agronomic Efficieny } = \frac{\text{Grain yield in N fertilized plot} - \text{Grain yield in no N plot}}{\text{Quantity of N applied in N fertilized plot}}$$

Recovery Efficiency (REN) (Dobermann, 2007)

$$\text{Recovery Efficieny} = \frac{\text{Total N uptake in N fertilized plot} - \text{Total N uptake in no N plot}}{\text{Quantity of N applied in N fertilized plot}}$$

Partial Factor Productivity (PFP) (Dobermann, 2007)

$$\text{PFP} = \frac{\text{Grain yield } (kg\ ha^{-1})}{\text{Total amount of Nitrogen applied (kg } ha^{-1})}$$

RESULTS AND DISCUSSIONS

TOTAL NITROGEN APPLIED

The amount of nitrogen applied in the variety Vijay was (108.75 kgha^{-1}) significantly higher than Banganga (Table 1). The highest amount of N (215 kgha^{-1}) was used with SPAD≤45 followed by LCC≤5 (165 kgha^{-1}) (Table1).There was saving of 15, 35 and 20 kgha^{-1} nitrogen respectively under SPAD≤35, LCC≤4 and NE compared with FTNM. Saving of Nitrogen under the LCC and SPAD guided nitrogen compared to FTNM in wheat was also observed by Reena *et al.* (2017) and Baral *et al.* (2019).

Table 1. Total nitrogen applied in wheat as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	Total N applied (kgha^{-1})	N saving/ excess
Varieties		
Vijay	108.75^{a}	-7.25
Banganga	100^{b}	0
SEm (±)	4.375	
LSD (0.05)	5.37	
CV (%)	4.1	

Treatments	Total N applied ($kgha^{-1}$)	N saving/ excess
Nitrogen management		
Control	0^{f}	
SPAD≤35	85^{de}	+15
SPAD≤40	125^{c}	-25
SPAD≤45	215^{a}	-115
LCC ≤4	65^{f}	+35
LCC ≤5	165^{b}	-65
NE	80^{ef}	+20
FTNM	100^{d}	0
SEm (±)	23.09	
LSD (0.05)	15.84	
CV (%)	12.9	
Grand mean	104	-4

Note: Figure(+) indicates the N saving and (-) indicates the excess of N in $kgha^{-1}$ as compared with fixed time N management RDF (100 kg Nha^{-1}). FTNM, fixed time splitting government recommended dose (100 kg N ha^{-1}); NE nutrient expert, (80 kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to Nha35 (85kg Nha-1); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45 (215 kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65 kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5 (165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart. Treatments means followed common letter(s) are not significantly different among each other based on DMRT at 5% level of significance.

The saving of N might be due to better synchronization of N fertilizer application with crop demand that led to increased nitrogen uptake, recovery efficiency and decreased volatilization and denitrification (Maiti and Das, 2006). However, there was no saving of N at SPAD and LCC at their higher threshold (40, 45 and 5). It indicated that the wheat was underfed in FTNM with national recommended dose, SPAD≤35, LCC≤4 and NE treatments.

YIELD ATTRIBUTES

Effective tillers

Higher number of effective tillers per meter square was recorded with SPAD≤45 and LCC≤5 and lower was observed with control (Table 2). The number of effective tillers m^{-2} found increasing with increasing nitrogen doses and number of splits. It might be due to higher availability of nitrogen at tiller forming stage of crop and reduction in tiller mortality (Rahman *et al.*, 2014). Yousaf *et al.* (2014) also reported higher number of effective tillers m^{-2} under the higher nitrogen doses. Increasing number of effective tiller m^{-2} with increasing number of split applications of N compared with single and double split was also reported by Bhardwaj *et al.* (2010).

Spike length

The higher spike length was recorded with SPAD≤45, LCC≤5 which were statistically at par with SPAD≤40. The smallest spike was on control plot. Length of spike found increasing with increasing nitrogen doses. Rai and Khadka (2009) also reported linear increase of spike length with nitrogen doses.

Grains per Spike

Banganga variety had significantly higher number of grains per spike (38.0) than Vijay (31). It might be due to differences in their genotypic character. Schwarte *et al*. (2006) reported that the number of grains per spike were strongly dependent on genetic factors rather than management factors. The number grains per spike were also found increasing with nitrogen doses and number of splits. Higher numbers of grains per spike were recorded on LCC≤5 which was statistically at par with SPAD≤45 and SPAD≤40 (Table 2). The lowest grains per spike were in control. Iqbal *et al*. (2012) also reported higher number grains per spike at higher N doses and lowest at control.

Sterility percentage

The sterility percent (46.4%) was found highest in control and it did not differ among all other nitrogen applied treatments (Table 2). Kataki *et al*. (2001) also reported that application of N did not have influence on wheat sterility with increasing doses of nitrogen from 16-160 kg Nha^{-1}.

Thousand grain weight

The thousand grain weight was observed higher in SPAD≤45 (58.81g) which was statistically at par with SPAD≤40, LCC≤5, LCC≤4 and NE (Table 2). All the treatments produced significantly higher thousand grain weight over control where no nitrogen was applied. It might be due to the better nutritional status of plant resulting in improvement on grain filling and development (Woyema *et al*. 2012). Similar results were also reported by Yousaf *et al*. (2014).

Table 2. Effective tiller, spike length, grains per spike, sterility percentage, thousand grain weight and grain yield as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	Effective tiller m^{-2}	Spike length (cm)	Sterility percentage	Grains per Spike	Thousand grains weight (g)	Grain yield ($kgha^{-1}$)
Varieties						
Vijay	238	15.15	36.1	31.9^{b}	56.58	4029.79
Banganga	247	15.93	36.0	38.0^{a}	55.94	4088.49

SEm (±)	4.33	0.39	0.04	3.04	0.32	29.00
LSD (0.05)	Ns	Ns	Ns	1.99	Ns	Ns
CV (%)	12.9	5.4	5	4.6	2.8	4.60
Nitrogen management						
Control	175^{c}	11.15^{d}	46.4^{a}	13.4^{d}	49.15^{c}	932.26^{d}
SPAD≤35	223^{b}	15.86^{bc}	34.8^{b}	35.5^{c}	56.34^{b}	3963.55^{c}
SPAD≤40	267^{ab}	16.60^{ab}	30.3^{b}	40.4^{ab}	56.74^{ab}	4807.67^{b}
SPAD≤45	283^{a}	16.83^{a}	37.5^{b}	40.0^{ab}	58.81^{a}	5585.00^{a}
LCC≤4	242^{ab}	15.43^{c}	32.3^{b}	35.8^{c}	57.81^{ab}	3869.12^{c}
LCC ≤5	275^{a}	16.83^{a}	34.0^{b}	43.0^{a}	57.10^{ab}	5385.00^{ab}
NE	225^{b}	15.80^{bc}	36.3^{b}	34.5^{c}	57.60^{ab}	3882.29^{c}
FTNM	251^{ab}	15.80^{bc}	36.6^{b}	37.3^{bc}	56.47^{b}	4047.67^{c}
SEm (±)	12.38	0.65	1.70	3.25	1.04	508
LSD (0.05)	41.33	0.79	7.36	3.22	1.52	405.87
CV (%)	14.4	4.3	17.3	7.8	3.1	12.7
Grand mean	243	15.54	36.0	35.0	56.26	4059

Note: FTNM, fixed time splitting government recommended dose (100kg Nha^{-1}); NE nutrient expert, (80kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to 35 (85kg Nha^{-1}); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45 (215kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5(165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart .Treatments means followed common letter (s) are not significantly different among each other based on DMRT at 5% level of significance.

GRAIN YIELD

The highest yield was observed with nitrogen application at SPAD≤45 (5585 kgha^{-1}) which was statistically at par with LCC≤5 but higher than SPAD≤40 (Table 2). The lowest yield was observed in control. Higher yield with SPAD≤45 and LCC≤5 was due to higher nitrogen doses (215 kgha^{-1} and 165 kgha^{-1}). This condition might have contributed to the availability of nitrogen at the later stages of the crop growth. Singh *et al.* (2013) reported that late season N supply contribute to the higher grain yield. Grain yield obtained in FTNM was statistically at par with LCC≤4, SPAD≤35 and NE respectively however, these treatments consumed less nitrogen compared with FTNM. This might be due to the better synchronization of N supply with crop N demand starting from vegetative growth to reproductive growth of crop. This led to increase in photosynthesis rate resulting to the higher growth and biomass production (Reena *et al.*, 2018). Higher yield under LCC≤5 compared with LCC≤4 was also reported by Dineshkumar *et al.* (2013), Maiti and Das (2006) and Singh *et al.* (2012). The increased grain yield with LCC<5 over other levels was associated with significant increase in yield components such as effective tillers m^{-2}, number of grains per spike and 1000-grain weight (Dineskhkumar *et al.*, 2013). Our results did not match with Ghosh *et al.* (2018) and Barad *et al.* (2018) who observed SPAD≤40 as better nitrogen management option for wheat in India.

NITROGEN USE EFFICIENCIES

The highest AEN found with nitrogen application at LCC≤4 (37.39 $kgkg^{-1}$) which was statistically at par with other treatments except SPAD≤45 and LCC≤5 in which higher nitrogen was applied (Table 3). AEN found decreasing with increasing nitrogen doses. The lower AEN with SPAD≤45 and LCC≤5might be due to the application of N at later stages of crop growth. Singh *et al.* (2012) reported that N applied after maximum tillering growth stages might not improve the AEN. Higher AEN under LCC and SPAD at their lower threshold (4, 35 and 40) and NE might be due to timely availability of N for their better utilization by the plant (Reena *et al.*, 2018). It might also be due to increased uptake and reduced loss of Nitrogen (Frageria and Balighar, 2005). Ghosh *et al.* (2018) reported that SPAD based nitrogen management increased AEN by 58.5% over FTNM. Shukla *et al.* (2004) observed higher AEN under LCC≤4 than LCC≤5.The AEN value ranged from 18.57-37.39 $kgkg^{-1}$ in this research. Doberman (2005) stated AEN range for cereal crops lies between 10-30 $kgkg^{-1}$. More than 30 $kgkg^{-1}$AEN indicates the well managed systems or low level of N use or low soil N supply.

The higher REN was found with nitrogen application at LCC≤4 (79.54%) which was statistically at par with all other nitrogen applied treatments except SPAD≤45 (Table 3). The lowest recovery efficiency was with SPAD≤45. It might be due to the application of higher doses of N exceeding the crop demand (Baral *et al.*, 2021). The recovery efficiency ranged from 61.17-79.54 %. According to Dobermann (2005), the recovery efficiency values for wheat in a well-managed system ranged between 50-80%. The recovery efficiency of LCC≤4 was 79%. It might be due to low levels of nitrogen use. The increase in AEN and REN with lower amount of nitrogen was associated with increase in grain yield with less nitrogen compared with that of high amount of nitrogen application (Ghosh *et al.*, 2018). The PFP was found highest with nitrogen application at LCC≤4 which was statistically at par with SPAD≤35. The PFP was also found decreasing with increasing nitrogen doses. It might be due to higher values of nitrogen dose on denominator compared with numerator and also due to diminishing law of marginal utility. Similar trend was also observed by Rawal *et al.* (2022).

Table 3. Agronomic use efficiency, recovery efficiency and partial factor productivity as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	AEN ($kgkg^{-1}$)	REN (%)	PFP($kgkg^{-1}$)
Varieties			
Vijay	25.66	68.28	34
Banganga	31.91	65.39	39
SEm (±)	2.42	0.01	2.79
LSD (0.05)	Ns	Ns	Ns
CV (%)	56.4	29.8	21.3

Treatments	AEN ($kgkg^{-1}$)	REN (%)	PFP($kgkg^{-1}$)
Nitrogen management			
Control	0.00	0.00	0.00
SPAD≤35	32.27^{ab}	62.95^{ab}	48.00^{ab}
SPAD≤40	26.44^{abc}	65.08^{ab}	41.63^{bc}
SPAD≤45	18.57^{c}	61.17^{b}	24.58^{d}
LCC≤4	37.39^{a}	79.54^{a}	62.74^{a}
LCC ≤5	23.74^{bc}	69.16^{ab}	31.38^{cd}
NE	32.45^{ab}	67.31^{ab}	46.22^{bc}
FTNM	27.42^{abc}	62.47^{b}	39.39^{bc}
SEm (±)	2.361	0.017	6.60
LSD (0.05)	10.44	15.20	13.67
CV (%)	33.91	18.9	31.4
Grand mean	29.88	67.2	36.79

Note: FTNM, fixed time splitting government recommended dose (100 kg Nha^{-1}); NE nutrient expert, (80 kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to 35(85kg Nha^{-1}); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45(215 kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5(165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart .Treatments means followed common letter (s) are not significantly different among each other based on DMRT at 5% level of significance.

Benefit Cost Ratio (BCR)

The BCR was found highest in LCC≤5(2.0) which was statistically at par with SPAD≤45 and SPAD≤40 (Table 4). The net return was highest with nitrogen application at LCC≤5, SPAD≤45 and SPAD≤40. Kharel et al (2021) reported the BCR of wheat was 1.78 in inner terai of Nepal. However, it was found higher at higher nitrogen doses in this study. The total cost of cultivation varied because Vijay variety consumed higher nitrogen dose compared to Banganga.

Table 4. Cost of cultivation (NRs ha^{-1}), gross return (NRs ha^{-1}), net return (NRs ha^{-1}) and BCR as influenced by precision N management and varieties at Rampur, Chitwan, 2019-2020

Treatments	Total cost of cultivation (NRs ha^{-1})	Gross return (NRs ha^{-1})	Net return (NRs ha^{-1})	B:C R
Varieties				
Vijay	78562.36	128977.3	50414.84	1.64
Banganga	77344.21	131055.4	53710.66	1.69
SEm (±)	608	1039.03	647.91	0.03
LSD (0.05)	667.38	Ns	Ns	Ns
CV (%)	0.7	3.9	10.5	4.6
Nitrogen management				

Treatments	Total cost of cultivation (NRs ha^{-1})	Gross return (NRs ha^{-1})	Net return (NRs ha^{-1})	B:C R
Control	64708.50	30141.52[d]	-34566.00[c]	0.46[c]
SPAD≤35	75147.63	127428.09[c]	52280.20[b]	1.69[b]
SPAD≤40	80428.79	153531.57 [b]	73102.78[a]	1.91[ab]
SPAD≤45	92744.73	178436.71[a]	85691.98[a]	1.92[ab]
LCC≤4	72573.72	124165.09[c]	51591.38[b]	1.70[b]
LCC ≤5	85976.62	172434.98[a]	86458.3[a]	2.00[a]
NE	74870.82	123941.65[c]	49070.83[b]	1.65[b]
FTNM	77178.07	130051.26[c]	52873.20[b]	1.68[b]
SEm (±)	3022.61	16229.19	13543.09	0.17
LSD (0.05)	3139.32	18820.88	18598.76	0.24
CV (%)	2.7	12.2	30.2	12.9
Grand mean	77953.28	130016.4	52062.75	1.63

Note: FTNM, fixed time splitting government recommended dose (100kg Nha^{-1}); NE nutrient expert, (80kg Nha^{-1}); SPAD ≤35, 30 kg Nha^{-1} when SPAD reading less than or equal to 35 (85kg Nha^{-1}); SPAD≤ 40, 30 kg Nha^{-1} when SPAD reading less than or equal to 40 (125kg Nha^{-1}); SPAD≤45 30 kg Nha^{-1} when SPAD reading less than or equal to 45(215kg Nha^{-1}); LCC ≤ 4 , 30 kg Nha^{-1} when LCC reading less than or equal to 4 (65kg Nha^{-1}); LCC ≤5, 30 kg Nha^{-1} when LCC reading less than or equal to 5(165 kg Nha^{-1}); SPAD, soil plant analysis development ; LCC, leaf color chart .Treatments means followed common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

CONCLUSIONS

Higher yield of wheat with higher BCR and economic net return were recorded with the higher nitrogen application at LCC≤5. So, the present fixed time N application with national recommended dose is insufficient to achieve the high yield of wheat. There is need for revision of blanket recommendation of N fertilizer application in wheat as the crops are underfed. The nitrogen saving, AEN, REN, partial factor productivity found highest with a nitrogen application at LCC≤4 without compromising the yield loss as compared with FTNM.

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REFERENCES

Barad, B. B. Mathukia, R. K. Der, H. N. and Bodar, K. H., 2018. Validation of LCC and SPAD meter for nitrogen management in wheat and their effect on yield, nutrients uptake and post-harvest soil fertility, International Journal of Chemical Studies, 6(3): 1456-1459.

Baral, B. R. Pande, K. R. Gaihre, Y. K. Baral, K. R. Sah, S. K. Thapa, Y. B. and Singh, U. 2021. Real-time nitrogen management using decision support-tools increases nitrogen use efficiency of rice. Nutrient Cycling in Agroecosystems, 119(3): 355-368.https://doi.org/10.1007/s10705-021-10129-6

Baral, B. R. Sah, S. K. Pande, K. R. Gaihre, Y. K. and Baral, K. R., 2019. In-season nitrogen fertilizer managment in irrigated wheat based on available decision support tools: International (SAARC) Youth Scientific Conference (pp. 2-8). Ministry of Industry, Tourism, Forest and Environment ,Hetauda, Makwanpur.

Bhardwaj, V. Yadav, V. and Chauhan, B. S., 2010. Effect of nitrogen application timings and varieties on growth and yield of wheat on raised beds. Archives of Agronomy and Soil Science , 56(2): 211-222.https://doi.org/10.1080/03650340903092218

Bhatta, R. D. Amgain, L. P. Subedi, R. and Kandel, B. P., 2020. Assessment of productivity and profitability of wheat using Nutrient Expert®-Wheat model in Jhapa district of Nepal. Heliyon, 6(6): e04144.https://doi.org/10. 1016/j.heliyon.2020

Chaudhary, M. M. Chaudhari, H. L. Patel, J. A. Patel, C. K. and Patel, H. K., 2019. Precision Nitrogen Management in Cereal Crops. International Journal of Agriculture Sciences, 11(8): 8317–8321.

Diacono, M. Rubino, P. and Montemurro, F., 2013. Precision N management of Wheat. A Review. Agronomy for Sustainable Development, 33(1): 219-241. DOI 10.1007/s13593-012-0111-z

Dineshkumar, S. P. Patil, B. N. Hiremath, S. M. Koti, R. V. Angadi, V. V. and Basavaraj, B., 2013. Performance of leaf color chart based nitrogen management on yield, quality and economics of emmer wheat (Triticum dicoccum) (Schrank.) Schulb var. DDK-1029 under irrigated conditions. Karnataka Journal of Agriculture Sciences, 26(3):360-367.

Doberman, A. and Fairhurst, T., 2000. Rice: nutrient disorders and nutrient management. Potash and Phosphate Institute: Potash and Phosphate Institute of Canada and International Rice Research Institute

Dobermann, A. R., 2005. Nitrogen Use Efficiency - State of the Art, University of Nebraska, Lincoln: Agronomy and Horticulture Faculty Publication

Dobermann, A., 2007. Nutrient use efficiency–measurement and management. Retrieved 3/3/2022. https://digitalcommons.unl.edu/ag_agron/

Fageria, N. K. and Baligar, V. C., 2005. Enhancing Nitrogen Use Efficiency in Crop Plants. Advances in Agronomy, 88(5): 97–185. https://doi.org/10.1016/S0065-2113(05)88004-6

Ghosh, M. Swain, D. K. Jha, M. K. and Tewari, V. K., 2018. Chlorophyll meter-based nitrogen management of wheat in Eastern India. Experimental Agriculture, 54(3):349–362. https://doi.org/10.1017/S0014479717000035

Iqbal, J. Hayat, K. Hussain, S. Ali, A. and Bakhsh, M. A. A. H. A., (2012). Effect of seeding rates and nitrogen levels on yield and yield components of wheat (Triticum aestivum L.). Pakistan Journal of Nutrition, 11(7): 531-541.https://dx.doi.org/10.3923/pjn.2012.629.634

Kataki, P. K. Upreti, H. K. and Bhatta, M. R., 2001. Soil boron deficiency induced wheat sterility in Nepal: response to boron and nitrogen application. Journal of New Seeds, 3(4): 23-39.https://doi.org/10.1300/J153v03n04_03

Kharel, M. Ghimire, Y.N. Timsina, K.P. Adhikari, S.P. Subedi, S. and Poudel, H.K., 2021. Economics of production and marketing of wheat in Rupandehi district of Nepal. Journal of Agriculture and Natural Resources, 4(), pp.238-245.

Ladha, J. K. Pathak, H. Krupnik, T. J. Six, J. and Kessel, C. V., 2005. Efficiency of fertilizer nitrogen in cereal production: Retrospects and Prospects. Advances in Agronomy, 87(05): 85-156.https://doi.org/10.1016/s0065-2113(05)87003-8.

Maiti, D. and Das, D. K., 2006. Management of nitrogen through the use of Leaf Colour Chart (LCC) and Soil Plant Analysis Development (SPAD) in wheat under irrigated ecosystem. Archives of Agronomy and Soil Science, 52(1): 105–112. https://doi.org/10.1080/03650340500460875

Majumdar, K. Jat, M. L. Pampolino, M. Satyanarayana, T. Dutta, S. and Kumar, A., 2013. Nutrient management in wheat: current scenario, improved strategies and future research needs in India. Journal of Cereal Research, 4(1):1-10

MoALD, 2021. Statistical Information on Nepalese Agriculture. Singhdurbar, Kathmandu: Ministry of Agriculture and Livestock Development.

Mohanty, S. K. Singh, A. K. Jat, S. L. Parihar, C. M. Pooniya, V. Sharma, S. Chaudhary, V. and Singh, B., 2015. Precision nitrogen-management practices influences growth and yield of wheat (Triticum aestivum) under conservation agriculture. Indian Journal of Agronomy, 60(4): 617–621.

Rahman, M. A. R. Sarker, M. A. Z. Amin, M. F. Jahan, A. H. S. and Akhter, M. M., 2011. Yield response and nitrogen use efficiency of wheat under different doses and split application of Nitrogen fertilizer. Bangladesh Journal of Agricultural Research, 36(2): 231-240.https://doi.org/10.3329/bjar.v36i2.9249

Rai, S. K. and Khadka, Y. G., 2009. Wheat production long term application of inorganic and organic fertilizers in Rice-Wheat system under Rainfed Conditions. Nepal Agriculture Research Journal, 9: 40-48.

Rawal, N. Pande, K.R. Shrestha, R. and Vista S.P., 2022 Nutrient use efficiency (NUE) of wheat (Triticum aestivum L.) as affected by NPK fertilization. PLoS ONE 17(1): e0262771. https://doi.org/10.1371/journal.pone.0262771

Reena, V. C. Dhyani, S. C. Chaturvedi, S. and Gouda H.S., 2017. Growth, Yield and Nitrogen Use Efficiency in Wheat as Influenced by Leaf Colour Chart and Chlorophyll Meter Based Nitrogen Management. Int. J. Curr. Microbiol. App. Sci, 6(12): 1696-1704.https://doi.org/10.20546/ijcmas.2017.612.191

Schwarte, A. J. Gibson, L. R. Karlen, D. L. Dixon, P. M. Liebman, M. and Jannink, J. L., 2006. Planting date effects on winter triticale grain yield and yield components. Crop Sci. 46(3): 1218-1224.

Shukla, A. K. Ladha, J. K. Singh, V. K. Dwivedi, B. S. Balasubramanian, V. Gupta, R. K. Singh, S.Y. Pathak H.S. Pandey P.S. Padre, A.T. and Yadav, R. L., 2004. Calibrating the leaf color chart for nitrogen management in different genotypes of rice and wheat in a systems perspective. Agronomy Journal, 96(6): 1606-1621.https://doi.org/10.2134/agronj2004.1606

Singh, B. Singh, V. Singh, Y. Thind, H. S. Kumar, A. Singh, S. Choudhary, O.P. Gupta, R.K. and Vashistha, M.,2013. Supplementing fertilizer nitrogen application to irrigated wheat at maximum tillering stage using chlorophyll meter and optical sensor. Agricultural Research, 2(1): 81–89. http://dx.doi.org/10.1007/s40003-013-0053-y

Singh, V. Singh, B. Singh, Y. Thind, H. S. Singh, G. Kaur, S. Kumar A. and Vashistha, M., 2012. Establishment of threshold leaf colour greenness for need-based fertilizer nitrogen management in irrigated wheat (Triticum aestivum L.) using leaf colour chart. Field Crops Research, 130: 109–119.

Woyema, A. Bultosa, G. and Taa, A., 2012. Effect of different Nitrogen fertilizer rates on the yield and yield related traits for seven durum wheat cultivars grown in Siana, Southern Ethiopia. African Journal of Food, Agriculture, Nutrition and Development, 12(3):6079-6094.

Yousaf, M. Shaban, M. Ali, A. A. Fahad, S. Khan, J. and Wang, Y., 2014. Effect of Nitrogen application rates and timings of first irrigation on wheat growth and yield. International Journal of Agriculture innovations and Research, 2(4): 645-653.