Effect of Nitrogen Rate on Use Efficiency and Yield of Wheat in Inner Terai Condition of Nepal

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Research Article

Keywords: Agronomic Efficiency, Agro-physiological Efficiency, Nitrogen harvest Index, Biological Yield, Nitrogen Uptake

Posted Date: August 13th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-56824/v1>

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Version of Record: A version of this preprint was published at The Geographic Base on August 13th, 2020. See the published version at <https://doi.org/10.3126/tgb.v8i01.43477>.

Abstract

Unsuitable nitrogen management and low soil fertility are major constraints of wheat production in Nepal. Limited information is available on optimum nitrogen rates and use efficiencies. So a field experiment was conducted on the inner terai to determine the effect nitrogen on yield and improving the nitrogen use efficiency of wheat. Level of five doses of nitrogen, 0kg ha⁻¹ (Control), 60kg ha⁻¹, 80kg ha⁻¹, 100kg ha⁻¹ and 120kg ha⁻¹ were laid out in Randomized Completely Block Design (RCBD) with four replication. Observation on the various parameters of yield attributing characters like plant height(cm), tiller m⁻² thousand grain weight(Kg), spike length(cm), grain spike⁻¹ was found highest on Nitrogen dose 120 kg ha⁻¹. Similarly, nitrogen at 120kg ha⁻¹ increases the grain yield by increasing the biological yield and harvest index. Grain nitrogen concentration at 120 kg ha⁻¹ is statistically similar with 100 kg ha⁻¹ and 80 kg ha⁻¹ while nitrogen uptake is highest (114.833kg ha⁻¹) in 120kg ha⁻¹ and lowest in control. Agronomic use efficiency is highest observed in 100kg ha⁻¹ and lowest on 60 kg ha⁻¹. Apparent fertilizer N recovery ratio obtained high (49.62%) in 120 kg ha⁻¹ which is statistically similar to 100kg ha⁻¹ (46.97%) and lowest (31.76%) in 60 kg ha⁻¹. While observing agro physiological efficiency and Nitrogen harvest index did not show any significant difference among any treatments. The application of nitrogen at 120kg ha⁻¹ was required to produce the optimum yield and increasing the nitrogen use efficiency traits.

Introduction

Nitrogen is the major nutrient affecting the various physiological processes in plants. It is indispensable in a metabolic role like the synthesis of protein, nucleotides, nucleic acid, and chlorophyll. Nitrogen influences growth and development and promotes photosynthetic activities. Nitrogen is limiting factor in crop production and adequate and timely application is necessary for optimum crop production (Dobermann et al, 2003) while excess leads to loss which harms the environment like nitrate leaching, eutrophication, greenhouse gas emission, soil acidification and reduces crop yield (Huang et al., 2018). It is mobile in soil and only 40%-60% of applied is uptake by wheat which is due to the poor synchronization between the N application and crop demand (Erisman et al., 2018) and residual is lost to the environment through leaching, volatilization or indirectly through the activity and competition of soil microorganism (Guarda, Padovan, & Delogu, 2004). The risk for loss of N increases when there are low utilization efficiencies that occurs due to applied N exceeds the crop requirements (Ju et al, 2004). Effective and practical approaches are necessary for present conditions to increase the nitrogen uptake and use efficiency for a sustainable agriculture system and environment. (Reddy & Reddy, 1993)

Wheat (*Triticum aestivum* L.) is the leading cereals in the world, occupying 17% of the total cultivated land area of the world (CIMMYT, 2002). In Nepal, the national average yield of wheat is 2.3t ha⁻¹ (FAOSTAT, 2018.) While the experimental station yields of wheat are 5t ha⁻¹ (NARC, 2014). The gaps between potential wheat yields and actual yields are quite large, which are, amongst many factors, mainly due to improper nitrogen management, and low Nitrogen use efficiency is one of a major constraint to wheat production. It is necessary to improve the Nitrogen use efficiencies of the wheat to effectively capture and assimilate N to maximized yield per unit N applied (Sinebo et al, 2004). Nitrogen is considered as the major component for maximizing the wheat yield. Application of nitrogen at optimum rate has a positive impact on economic yield, spikes per plant, spike length, grains per spike, biomass yield and reduces the disease and pest infestation (Ghimire et al., 2019). Nitrogen doses vary with genotypes and management system but an average of 120kg ha⁻¹ are desirable for achieving the optimum yield without deteriorating the soil health (Chaudhari et al, 2019). Soil and climatic factor play a crucial role in mobilizing the nitrogen into a different form which has low accessibility to the plants and thus decreasing the use efficiency (Timsina et al, 2001). Nitrogen use efficiency depends upon the cultivars, optimizing the level of nitrogen should be high to responsive than none responsive otherwise application leads to toxicity, reduced yield, and environmental pollution (Guarda et al., 2004).

This study was carried out to evaluate the application rate of nitrogen on yield attributing character, nitrogen uptake, and use efficiencies of wheat.

Materials And Methods

2.1 Description of study site:

The study was carried from November 2017 to February 2018 in the Chitwan district of Nepal. Located at 27.6706° N latitude and 84.4385° E longitudes and 208 MASL.

Average annual temperature is 24° C and 1993 mm average annual rainfall. The soil type of the area experimental site is Dyschrochrept according to USDA taxonomy with sandy loam in texture. The soil was sampled from 0-20 cm depth and analyzed physio-chemical properties as given below.

Table 1: Initial Soil physiochemical characteristics.

Parameters	Result	Method
Texture	Sandy loam	Hydrometer (Bouyoucos, 1962)
pH	6.7	Potentiometric (Jackson, 1959)
Organic matter	0.92%	Walkely and Black (Walkely & Black, 1934)
Total Nitrogen	0.07%	Kjeldahl (Bremner & Mulvaney, 1982)
Available Phosphorous	5.44 ppm	Olsen's (Olsen et al, 1954)
Available Potassium	0.14 ppm	Ammonium acetate (Jackson, 1959)
Bulk density	1.132 g cm ⁻³	Core (Keen, 1921)

2.2 Treatments and experimental design:

Treatment consist of five nitrogen rates i.e 0, 60, 80, 100, 120 kg N ha⁻¹ which was layout in Randomized completely Block Design (RCBD) with four replication. The Gross plot size for planting was 2X3 =6 m² with 8 rows spaced 25 cm apart. Four central row with the net plot size 3 m² is used for biometrical observation the distance between plots and blocks is 0.5 cm and 1m respectively. Required doses of potassium (Murate of Potash 60% K₂O) and phosphorous (Single superphosphate 16%P₂O₅) was applied as basal i.e 25 and 50 Kg ha⁻¹ . Nitrogen (Urea,46%N) were applied in 50% at sowing and 25% at tillering and 25% at booting stage.

2.3 Data collection:

The plant was random sampled from each plot and data for plant height, grain per spikes, and spike length were observed. For the tiller area of 1 m² was marked inside the net plot and data was collected. Similarly, grain and straw yield are collected from the net plot area.

Plants from the net plot area were harvested in 120DAS and it was threshed and grain was sun-dried and 12% moisture was maintained and weighed, while after threshing straw weight was taken immediately. Grain and straw sample was taken to the laboratory for determination of Nitrogen content by Kjeldahl method (AACC, 1999). Total grain N uptake is determined by Total grain yield(kg ha⁻¹) multiplied by N content(%) in grain Total straw N uptake is determined by nitrogen content in straw multiplied by total weight of straw(kg ha⁻¹). Total N uptake is the addition of Total grain N uptake and Total straw N uptake (Fageria et al, 2010). The nitrogen use efficiency traits are:

2.3.1 Agronomic efficiency (kg kg⁻¹)

$$AE = \frac{GF(Kg) - G0(Kg)}{NA(Kg)}$$

2.3.2 Apparent fertilizer N recovery Efficiency (%)

$$ARE\% = \frac{NUf(Kg) - NU0(Kg)}{NA(Kg)} \times 100\%$$

2.3.3 Agrophysiological efficiency (kg kg⁻¹)

$$APE = \frac{GF(Kg) - G0(Kg)}{NUf(kg) - NU0(Kg)}$$

Where AE= Agronomic Efficiency. Kg kg⁻¹

Gf= Grain yield from N fertilized plots (60,80,100,120 kg/ha)

G0=grain yields from Unfertilized Plots

NA= Nitrogen Applied

NUf =Nitrogen uptake by fertilized plots.

NU0=Nitrogen uptake by unfertilized plots.

2.3.4Nitrogen Harvest Index (%)

Estimated as the ratio of nitrogen uptake by grain and nitrogen uptake by grain plus straw yield (Fageria, 2014)

2.4 Data Analysis:

Analysis of Variance (ANOVA) was performed by using R agricloae v 1.3, and Mean comparison was done using Least Significant Difference (LSD) (Gomez & Gomez, 1984) at 5% level of significance.

Results And Discussion

3.1 Effect of Nitrogen doses on yield and yield attributes.

Table 2: Effect of nitrogen on growth and yield attributes.

Treatment	Plant height cm	Tillers m ⁻²	Spike length cm	Grains/Spikes	TGW gm	Grain Yield Kg ha ⁻¹	Straw yield Kg ha ⁻¹	Biological Yield Kg ha ⁻¹	Harvest index
No	68.433 c	226.766 d	7.767 b	26.60 b	24.966 c	2060.417e	3636.417 c	5696.833d	36.222 c
N60	72.567 b	304.667 c	8.400 b	29.833 b	31.400 b	2698.073 d	3997.623b	6851.590c	39.372 b
N80	81.333 a	338.033 b	9.300 a	37.233 a	34.333 b	3217.780 c	4153.517b	7215.403c	44.624 a
N100	82.767 a	384.600 a	9.833 a	39.067 a	41.233 a	3637.610 b	4286.17ab	7923.787b	45.891 a
N120	84.633 a	399.300 a	9.867 a	41.567 a	41.833 a	4133.227 a	4540.097 a	8673.323a	47.608 a
Mean	77.947	330.673	9.033	34.86	34.753	3149.421	4122.766	7272.17	42.744
CV%	2.4906	3.666	3.950	6.8745	5.1793	5.266	4.615254	3.65547	3.7563
SE	3.769	147	0.127	5.743	3.24	312.2798	36205	70667	2.578
LSD _{0.05}	3.655	22.828	0.671	4.513	3.38912	312.2798	358.26	500.525	3.0231

3.1.1 Plant height (cm)

Plant height (cm) has shown the significant effect of treatment, the highest plant height (84.633cm) was observed on 120 kg ha⁻¹ while the lowest (64.43cm) was observed on control. Nitrogen promotes cell division and differentiation so the application of nitrogen helps to increase the height of wheat. A similar result is observed by(Singh, 2001) increasing the nitrogen application increases the plant height.

3.1.2Tillers m⁻²

Tillers per square meter were found highest (399.3m⁻²) on 120 kg ha⁻¹ lowest (226.766 m⁻²) was observed on control (226.766 m⁻²). Optimizing the nitrogen application increases the number of tillers in wheat (Bly & Woodard, 2003; Erisman et al., 2018). Nitrogen application increases the number of tillers and reduces tiller mortality(Rahman et al, 1970).

3.1.3 Spike Length (cm)

Spike length(cm) is statistically similar over 120 kg ha⁻¹, 100 kg ha⁻¹, 80 kg ha⁻¹ however lowest was observed on control (7.76 cm)which is also statistically similar to 60 kg ha⁻¹ · Ali et al, (2011) reported that spike length was significantly increased by increasing nitrogen level over control.

3.1.4 Thousand Grain Weight (g)

Observation on Thousand-grain weight (TGW), highest was found to be in 120 kg ha⁻¹ (41.83 g) which is statistically at par with the 100 kg ha⁻¹ (41.23g), and lowest was found in control (24.966g). The result indicates Nitrogen is responsive to increase the grain size of wheat. Arduini et al, (2006) reported the application of N improves the grain size and grain N content. Zhang et al.,(2017)the observed influence of N fertilizer was highly significant on grain yield and TGW.

3.1.5 Grains spikes⁻¹

The highest observation of grains per spikes is on 120 kg ha⁻¹ (41.567) which is statistically similar to 100 kg ha⁻¹ and 80 kg ha⁻¹ while lowest in control (26.60). Generally, grain per spike could be a genetic factor but under managed system nitrogen has a significant effect on spike length. This observation also confirms by the result obtained by (Bielski et al, 2020).

3.1.6 Biological yield

Grain yield and straw yield ha⁻¹ is obtained highest from 120 kg ha⁻¹ (4133.27 kg ha⁻¹),(4540.097Kg ha⁻¹) followed by 100,80,60 kg ha⁻¹ ,lowest in control (2060.417kg ha⁻¹),(3636.417kg ha⁻¹).Rahman et al., (1970) reported gain and straw yield are highly significant over N application. Similarly, Belete, et al, (2018) reported the application of nitrogen is essential for obtaining optimum yield. (Guarda et al., 2004)also, obtain the highest grain and straw yield at 120kg ha⁻¹ of Nitrogen application. Biological yield is highest in 120 kg ha⁻¹ (4673.32 kg ha⁻¹) and the lowest is observed in control (5996.83 kg ha⁻¹). Application of nitrogen increases plant height, tillers, grain, and straw yield and dry matter production which have a positive impact on biological yield. (Ghobadi et al, 2010) reported that higher nitrogen increases the total dry matter production so that large canopy increases the surface area of solar energy interception and production of assimilates.

3.1.7 Harvest Index:

Harvest index is obtained highest (47.60) in 120 kg ha⁻¹ which was statistically at par with 100 kg ha⁻¹ and 80 kg ha⁻¹ while lowest in control (36.22). Harvest index means that there is a translocation of assimilated from the source to sink for the development of seeds. It is directly associated with the availability of nutrients for the production of dry matter and yield. The application of more nitrogen increases the biological yield up to a limit beyond that it causes toxicity(Ju et al., 2004).

3.2 Effect Nitrogen doses on grain and straw concentration and uptake:

Table 3: Effect of Nitrogen application on nitrogen content and uptake.

Treatments	Nitrogen Content (%)		Nitrogen Uptake Kg/ha		
	Grain	Straw	Grain	Straw	Total
N0		0.367 e	37.961 e	13.320 e	51.281 e
	1.843 c				
N60	1.970 b	0.413 d	53.172 d	17.165 d	70.337 d
N80	2.133 a	0.470 c	68.597 c	18.775 c	87.373 c
N100	2.170 a	0.490 b	78.916 b	21.003 b	99.919 b
N120	2.213 a	0.513 a	91.522 a	23.310 a	114.833 a
Mean	2.066	0.450	66.034		
				18.714	84.748
CV					
	2.535	1.619	7.338	4.244	5.784
SE		0.00053	23.48		
	0.00274			0.631	24.03
LSD _{0.05}		0.0137			
	0.0986		9.123	1.495	9.229

Analysis of Variance (ANOVA) shows there is a significant difference in doses of nitrogen on grain nitrogen concentration. Grain nitrogen concentration is increasing in increasing doses. The highest grain Nitrogen concentration is found in 120 kg ha⁻¹ (2.213%) while the lowest (1.843%) is found on control treatment. This is due to the optimum nitrogen availability increased the N mobilization in grain at the filling stage. While increasing the Nitrogen application from 60 to 120 kg ha⁻¹ Grain nitrogen concentration was found to increase from 1.52% to 2.28% in wheat (Arduini et al., 2006). Nitrogen rate 80,100,120 kg ha⁻¹ is statistically similar to grain nitrogen concentration. Application of Nitrogen higher than optimum requirement has little or no effect on grain nitrogen concentration and yield because it only prolongs the vegetative phase rather than the reproductive period with increasing the biomass and partly filled grains (Thenabadu, 1972).

Nitrogen content in the straw was significantly affected by the rate of nitrogen application, the highest concentration was observed in 120 kg ha⁻¹ (0.513%) while lowest (0.376%) in control (0 kg ha⁻¹). Increasing the Nitrogen concentration with N application is due to the availability of sufficient n for vegetative growth and development with profuse root system in wheat. a similar result is obtained while increasing the N application increases the N content in straw from 0 to 120 Kg/ha (Alemu et al, 2016).

Total N Uptake (Grain+Straw) is highest at 120kg ha⁻¹ (91.552kg ha⁻¹+23.310kg ha⁻¹) while lowest is obtained at 0 kg ha⁻¹ (37.961 kg ha⁻¹+13.32 kg ha⁻¹). There is a positive interaction between nitrogen applied and uptake could be due to the highest N within the plant which allows it to concentrate nitrogen as their yield increased. It has been reported that the highest N uptake of wheat has resulted from the highest N applied (Motzo et al, 2004). Total n uptake represents the biomass yield concerning applied Nitrogen and Thind et al., (2010) reported the highest biomass yield, and Uptake is obtained from the optimum application of the Nitrogen field.

3.3 Effect of Nitrogen doses on Nitrogen use efficiency traits.

Table 4: Effect of Nitrogen doses on Use Efficiencies.

Treatments	Agronomic Efficiency Kg Kg ⁻¹	Apparent fertilizer N recovery efficiency%	Agro physiological efficiency Kg Kg ⁻¹	Nitrogen Harvest Index
N0	-	-	-	79.644 a
N60	13.629 b	31.76033 c	33.254 a	78.951 a
N80	14.464 b	43.45517 b	32.652 a	78.467 a
N100	18.420 a	46.97133 ab	32.423 a	77.524 a
N120	16.945 ab	49.62600 a	31.892 a	77.049 a
Mean	11.89199	34.36257	26.04484	78.32755
CV	14.1836	9.08692	4.360871	2.97665
SE	2.845	9.75	1.29	2.3363
LSD _{0.05}	3.175818	5.87918	2.1385	2.87792

3.3.1 Agronomic Efficiency

The highest agronomic efficiency is obtained from 100kg ha⁻¹ (18.42) which is statistically similar to 120 kg ha⁻¹ and the lowest is obtained from 60 kg ha⁻¹. But the result shows that AE is in decreasing trend while increasing the nitrogen rates. a similar result was also reported by Arduini et al.,(2006) describes the trend of decreasing the AE while increasing the N fertilizer application.

3.3.2 Agrophysiological Use Efficiency:

There is no significant difference among the treatment against Agro physiological use efficiency but found highest (33.25) in 60kg ha⁻¹ while lowest in (31.89) in 120 kg ha⁻¹. The result obtained is that too similar to the (Gauer et al., 1992.) Concluded that APE depends upon genotypes and the highest value is obtained at low N applied and vice versa. Tana et al,(2015) also reported that NUE in wheat is reduced by high N application.

3.3.3 Apparent Fertilizers N recovery efficiency:

A significant difference is observed among treatments against fertilizer N recovery efficiency. Highest N recovery is observed in 120kg ha⁻¹ (49.626) which is statistically similar to 100kg ha⁻¹ (46.971) and lowest is observed at 60 kg ha⁻¹ (33.257). The difference in NUE depends upon climate, genotypes, and nitrogen rates and there will be a decline in apparent nitrogen recovery efficiency beyond 120kg ha⁻¹ (Gauer et al., 1992). Kidanu et al (2000) reported that recovery of N efficiency is high at 110 kg ha⁻¹ as compared to 60 and 85 kg ha⁻¹ in wheat. Value ranging from 30-50% is generally considered as a well-managed system for apparent fertilizer N recovery (Gauer et al., 1992).

3.3.4 Nitrogen harvest index:

Nitrogen Harvest index seems to be highest at control 0 kg ha⁻¹ (79.644%) and lowest at 120 kg ha⁻¹ (77.049%) but all the treatments are statistically similar. The efficiency of utilization of N however it is affected by N rate, genotype, and Other environmental factors(Fageria, 2014). The present result is supported by the result obtained from (Kidanu et al., 2000) lowest NHI is obtained from 110kg/ha while highest from the control plot. The average value of NHI under the managed system is 73%(Sinebo et al., 2004). Treatments that produce the least above-ground biomass and grain yield have a high nitrogen harvest index (López-Bellido & Redondo, 2005)

Conclusion

The application of different nitrogen rates affected the yield and yield attributing the character of wheat significantly. The application of Nitrogen 120Kg ha⁻¹ produces a high yield in comparison to other treatments. But observation on plant height, tiller m⁻², Spike length grain per spike 120 kg ha⁻¹ is statistically at par with 100 Kg ha⁻¹. Similarly, the higher N content and uptake in grain and spike is observed in 120 kg ha⁻¹ and lowest on control. However grain N content on 120 kg ha⁻¹ is statistically at par with 100 kg ha⁻¹ and 80 kg ha⁻¹. High agronomic use efficiency is obtained in 100 kg ha⁻¹ in comparison to other and apparent N recovery is obtained in 120kg ha⁻¹. However agro physiological use efficiency and Nitrogen Harvest index are observed maximum in control. Thus the application of nitrogen at a range of 100-120 Kg ha⁻¹ is essential for obtaining the optimum yield. Nitrogen Use efficiency traits are best obtained at the rate of 120kg ha⁻¹.

Declarations

Conflict of Interest: The authors declare no competing interest exists.

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