Journal BiNET
Scientific Publication

Published with Open Access at Journal BiNET
Vol. 24, Issue 01: 1969-1976
Journal of Bioscience and Agriculture Research

Journal Home: www.journalbinet.com/jbar-journal.html

Impact of SPAD 502 meter based N fertilization on growth and yield attributes of wheat

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Article received: 08.03.2020; Revised: 09.04.2020; First published online: 15 April 2020.

ABSTRACT

A field experiment was undertaken at the Agronomic Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh to optimize nitrogen application in wheat field using SPAD-502 Chlorophyll Meter. Four nitrogen (N) rates from 0 to 120 kg ha^{-1} and different timing of N application were maintained in the experiment to test the usefulness of SPAD threshold values in decision making for supplemental nitrogen supply in wheat. A non-fertilized treatment was compared with three fertilized treatments getting 20 kg ha^{-1} of N at the time of crop emergence. After that supplementary nitrogen was applied to the three fertilized treatments @ 20, 40 or 60 kg N ha^{-1} when the SPAD values fell below the critical value of 45 SPAD (dynamic fertilization of nitrogen). Tillering of wheat plant was strongly influenced by N supply and spike bearing tillering enhanced when adequate N was applied. Application up to 120 kg N ha^{-1} significantly increased the plant height, total dry matter production, number of effective tillers, crop growth rate, yield contributing attributes and SPAD chlorophyll index in wheat. On the other hand, only culm reserve translocation to grain was observed higher in control and gradually decreased with increasing the levels of nitrogen. The ability of the SPAD meter to detect treatment differences due to various nitrogenous doses varied with the growth stage. The SPAD reading at all stages is positively correlated with wheat yield. Thus, the timing of nitrogen application should be closely coincided with the plant need-based to optimize the productivity of wheat.

Keywords*: Nitrogen, SPAD reading, Dry matter, Culm reserve and Yield.*

Cite Article: Rahman, M. Z., Akter, S., Hoque, M., Sadeque, A., Rahman, M. M. and Islam, M. R. (2020). Impact of SPAD 502 meter based N fertilization on growth and yield attributes of wheat. Journal of Bioscience and Agriculture Research, 24(01), 1969-1976.
Crossref: https://doi.org/10.18801/jbar.240120.241

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I. Introduction

Wheat (*Triticum aestivum* L.) is a crop under Poaceae family and the third most-cultivated cereal after corn and rice across the world (FAS, 2016). It is the second most important grain crop next to rice in Bangladesh and also serves the role of staple food for millions of people around the world (Timsina and Connor, 2001). Usually, naturally available plant nutrients in the soil may not be always sufficient to fulfill the crop demand. Plant unable to accomplish its normal growth and development in deficient nutrient condition. Application of fertilizers as a means of providing the essential plant nutrients to the soil is an important factor involved in crop production as well as in proper maintenance of soil fertility. The deficiency of essential plant nutrients in soil should be corrected by applying manure and inorganic fertilizers to facilitate adequate crop growth and optimum production.

Nitrogen (N) is one of the most decisive nutrients limiting yield of wheat and required comparatively a larger amount than other elements. Application of N has increased substantially in the last decades (Yahya, 2018). Accumulation N is closely associated with biomass accumulation in crop plants as radiation use efficiency is determined by the extent of leaf N per unit leaf area (Sinclair and Horie, 1989). Over application of N may offer vigorous growth of plants or a large volume of the applied N can escape soil-plant system to reach water bodies and the atmosphere thus creating pollution problems whereas deficiency of N may cause suffering from severe deficiency symptoms in the plants. However, judicious use of this nutrient requires its synchronized application with crop requirements. Hence, the stated experiment was laid out to investigate the SPAD meter based nitrogen application on yield and yield components of wheat.

Time and rate of N fertilization as top-dressing play a substantial role in ensuring higher crop productivity. Higher N fertilization as basal dose lessens the availability of nitrogen in the soil during peak growing period causing low crop yield. Innovative tools such as the SPAD (Soil plant analysis development) meter or Chlorophyll meter instantly provides a new strategy for estimating leaf N status as chlorophyll concentration by clamping the un-plucked leafy tissue and the SPAD readings are quite closely correlated with chlorophyll concentration per leaf area (Markwell et al., 1995). Moreover, the meter reading may monitor plant N status in the field and indicates the requirement of nitrogen topdressing, thus results in greater agronomic efficiency of nitrogenous fertilizer than the conventional application of nitrogen (Hassan et al., 2009). It is established that non-destructive assessment of N through chlorophyll meter and split topdressing of N fertilizer may improve N use efficiency and increase the wheat productivity (Debaeke et al., 2006). The challenges from high inconsistency in soil fertility status under subtropical climate and the hazard of under and overdoses of N could be checked by plant need-based N management through chlorophyll meter in the farmer's field. Scientists are focusing the potential of using SPAD meter in predicting fertilizer N requirements and to improve fertilizer use efficiency in wheat as this approach is gaining popularity among the farmers. However, its potentiality in optimizing the judicious N dose in wheat crop is not widely practiced across the subtropical areas of the world. Considering these above mentioned details, the field experiment was laid out to compare the performance of wheat under non fertilized treatment along with the SPAD meter-based N fertilization to establish the methods for maximizing the growth and development (yield) of wheat.

II. Materials and Methods

The experiment was carried out at the Field Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706 during November 2011 to March 2012. It is located in Madhupur Tract under AEZ-28 at geographic coordinate $24^0 05'$ North latitude and $90^0 16'$ East longitude with an elevation of 8.4 m above the mean sea level. The crop tested in the experiment was wheat (*Triticum aestivum* L.) variety BARI Gom-26 which was sown at a row-to-row spacing of 20 cm. Three fertilizer treatments were maintained in the 3 m × 2 m experimental plots in a Randomized Complete Block Design (RCBD) with four replications. A non-fertilized control (No) was compared with three treatments receiving 20 kg ha^{-1} of N in soil at crop emergence plus supplemental nitrogen application when the SPAD values fell below the critical value of 45 SPAD suggested by Barraclough and Kyte (2006) termed as dynamic fertilization of nitrogen (DN). Treatments were 1) DN_{60} = 20 kg ha^{-1} N in each time started from 36 days after sowing (DAS) and for three times total amount was 80 kg ha^{-1} N, (2) DN^{80} = 40 kg N ha^{-1} in each time started from 36 DAS and for two times total amount was

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80 kg ha^{-1} N, and (3) DN_{120} = 60 kg N ha^{-1} in each time started from 36 DAS and for two times total amount was 120 kg ha^{-1} N. A basal dose of 60 kg P_2O_5, 40 kg K_2O and 20 kg S ha^{-1} was added to every plot from triple super phosphate, muriate of potash and gypsum, respectively. The total amount of triple super phosphate, muriate of potash and gypsum fertilizers were applied plot wise during final land preparation. Plants were sampled periodically from a row length of 0.5 linear m per plot by harvesting at the base and these areas are converted to per meter square. The sampling was done at 50, 60, 70, 80 and 90 days after sowing. The above-ground plant parts were segmented into different components as leaf, stem and spike with the grain.

Besides this, a chlorophyll meter (SPAD-502, Minolta Camera Co. Ltd, Osaka, Japan) was used to record the chlorophyll content (SPAD value) from 36 DAS up to 89 DAS. A fully matured leaf from the top of the plant was selected for recording the SPAD values and the mean of five readings per plant was taken. Five plants were selected at random for mean SPAD value per treatment. The data refer to growth and physiological parameters as well as yield and yield attributes. Among the physiological parameters, SPAD value over time and corresponding leaf chlorophyll content, dry matter production, crop growth rate and culm reserve translocation were recorded. The yield data viz., the number of tillers per m^2, spike length, the number of spikelet per spike and the number of grains per spike, 1000-seed weight and the grain yield were recorded when the plant attained full maturity. Analysis of variance was done with the help of computer package MSTAT-C. The mean differences among the treatments were adjudged by Duncan's Multiple Range Test and LSD test at 0.05 level of probability.

III. Results and Discussion

Plant height

Plant height was substantially influenced by nitrogen treatments recorded at different growth stages of wheat (Table 01). Plant height increased with the increase of N rate up to 120 kg per ha. However, the tallest plant (89.42 cm) was obtained with the treatment DN_{120} which was also identical to the treatment receiving DN_{120} and DN_{80} whereas the shortest plant (86.46 cm) was recorded from the treatment N_0 (control). It might be due to the addition of nitrogen led to enhanced vegetative growth of wheat, which resulted in increasing plant height. These results confirm with those of Hussain et al. (2002), who reported that the higher levels of N significantly increased the plant height.

Table 01. Effect of nitrogen top dress on plant height at different growth stages of wheat

Treatments	Plant height (cm)				
	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
N_0	60.16	74.40	79.60	81.13	85.5
Dynamic					
DN_{60}	62.25	79.31	84.07	86.87	89.20
DN_{80}	63.65	78.67	83.25	85.05	88.65
DN_{120}	64.90	78.90	85.82	86.10	89.42
$LSD_{0.05}$	4.66	4.74	3.60	3.92	3.40
CV	6.95	5.15	5.96	6.19	5.67

Total dry matter production

At the early stage of the crop growth, there were no marked differences in dry matter production among the different levels of N but the considerable difference was observed beyond 60 days after sowing (Figure 01). TDM increased slowly up to 60 DAS and rapidly thereafter that persisted till maturity for all the treatments. The highest rate of TDM production was observed from 70 to 90 DAS irrespective of nitrogen levels. Plants grown under the treatment N_0 produced significantly lower TDM than those treated with DN_{60}, DN_{80} and DN_{120} because of N application leads to proper formation and accumulation of photosynthates as well as normal growth and development of wheat. It might be due to increased photosynthetic rate and higher leaf areas that increased TDM production. This result is also in agreement with the findings of Lopez-Bellido et al. (2000), who reported that the amount of total dry matter was significantly greater at higher doses of N per unit area of land.

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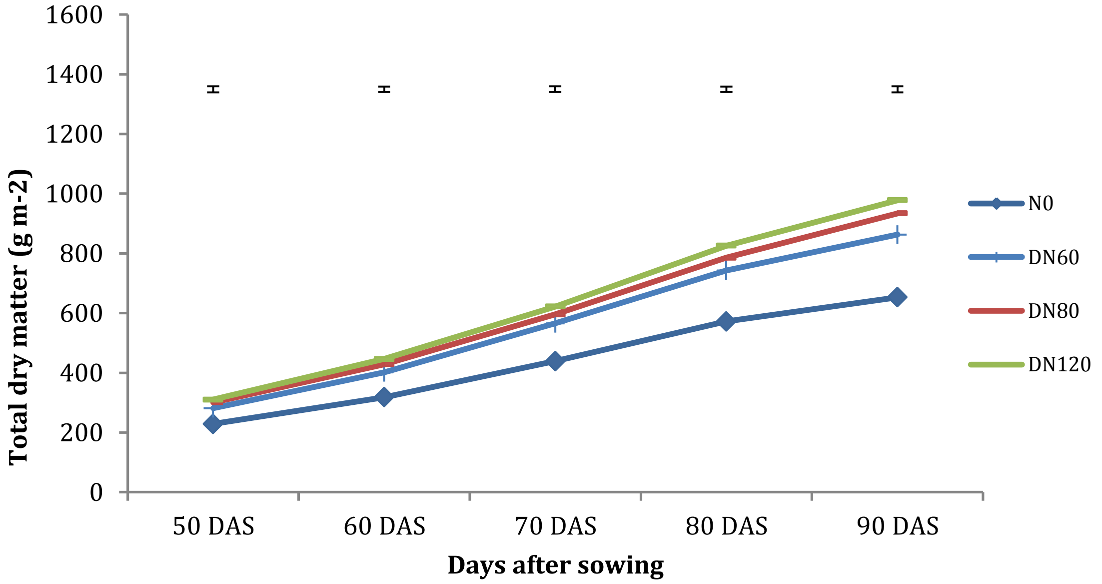

Figure 01. Effect of different nitrogen levels on total dry matter accumulation in wheat over time

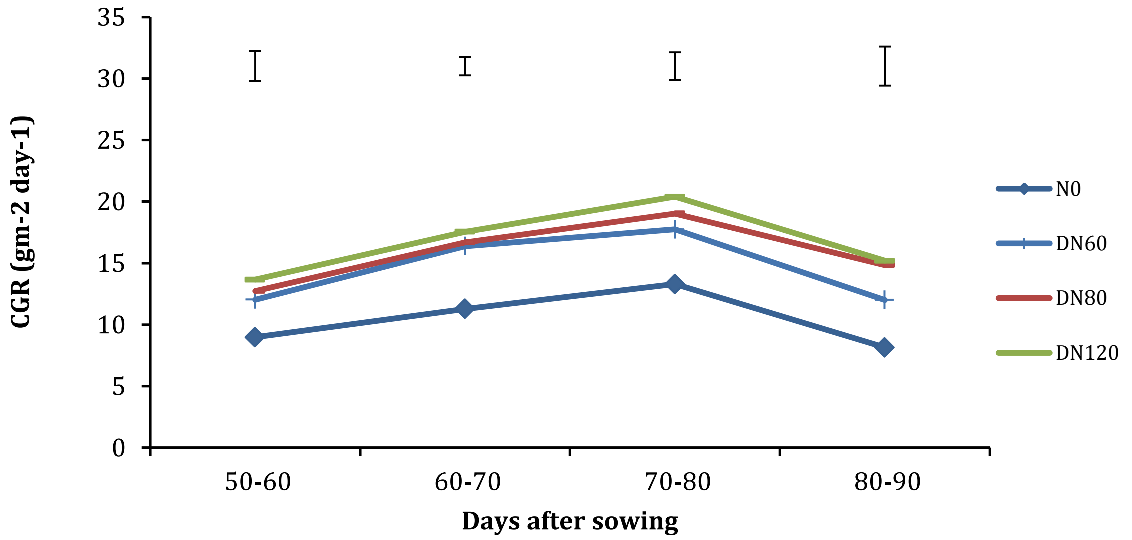

Figure 02. Crop growth rate (CGR) at different growth stages of wheat as influenced by different levels of nitrogen fertilizer

Crop growth rate (CGR)

Application of nitrogen fertilizer significantly contributed to crop growth from seedling to maturity and showed the conspicuous variation among the treatments (Figure 02). From 60 DAS crop growth rate increased almost linearly up to 70 DAS and thereafter a sharp increase was observed in all the treatments. After 80 DAS, a sharp decline was observed in all the treatments. This declining tendency may be due to cessation of vegetative growth and senescence of leaves as described by Ferdous (2001). Among the treatments, DN_{120} showed a maximum value of CGR during all the growth stages of wheat that were statistically similar to the treatments DN_{60} and DN_{80}. This result is close to the observation of Rahman (1998), who reported that CGR was high for using a high dose of N at all the growth stages.

Culm reserve translocation

All the carbon in the grain that is derived from photosynthesis prior to anthesis must have been present either as protein on stored carbohydrate in the vegetative organs and later translocated to the

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grains. Reserve translocation was reported to determine by net loss in dry weight of vegetative organs between anthesis and maturity (Bonnett and Incoll, 1992). The application of nitrogen significantly influenced the amount of culm reserve translocation from stem to spike (Figure 03). Plants grown without nitrogen application (control) translocated the highest photosynthate and it gradually decreased with increasing nitrogen rates up to 120 kg N ha^{-1}. At the treatment DN_{120}, the culm reserve translocation was the lowest. It might be due to the fact that in lower N rates plants produced lower amount of leaves, as well as poor or insufficient photosynthesis, resulted in the highest translocation of assimilates to the grain.

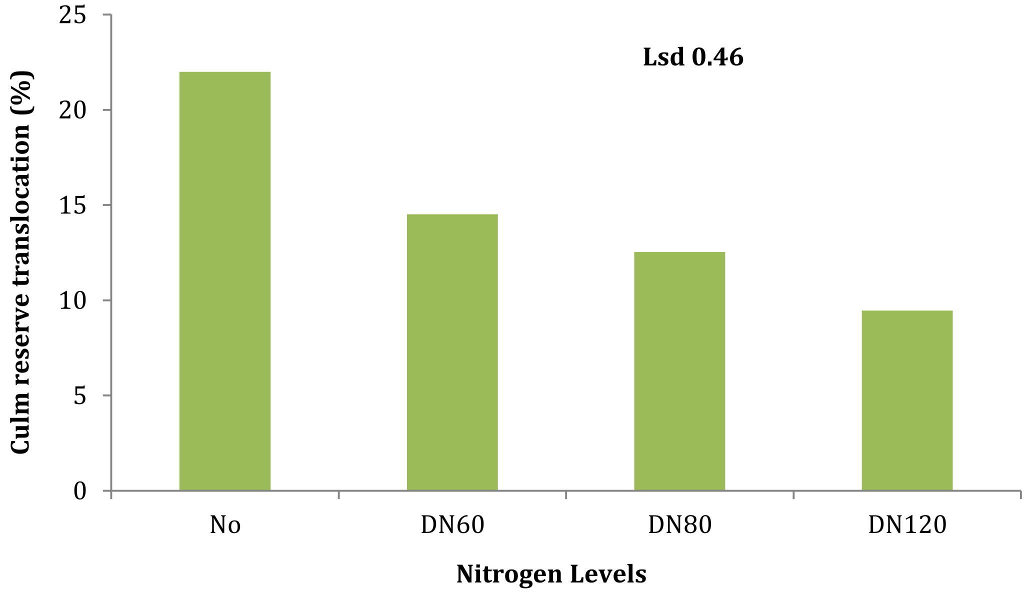

Figure 03. Effect of nitrogen levels on the culm reserve translocation to the reproductive organ.

Yield attributes and grain yield of wheat

Application of 120 kg N ha^{-1} (DN120) resulted in the maximum number of tillers m^{-2} than control. However, application of 120 kg N ha^{-1} (DN_{120}) resulted in a maximum number of tillers m^{-2} (300) which is statistically at par with DN_{80} (295.0), where nitrogen was applied @ of 80 kg N ha^{-1} (Table 02). A recent study revealed that increasing nitrogen application increases the number of tillers m^{-2} (Rahman et al., 2014). The maximum spike length was (9.96 cm) in case of DN_{120} treatment followed by (9.85 cm) in case of DN_{80} which is statistically at par with (9.52 cm) DN_{60} treatment (Table 02). Treatment N_0 where no nitrogen was applied produced a minimum spike length of 9.00 cm. These results are in conformity with those of Hasan et al. (2016). This tendency can be attributed to a higher dose of nitrogen, which greatly helps the plant parts to expose its potential to grow vigorously. The maximum number of spikelets per spike (17.95) was obtained with the treatment DN_{120} which was statistically at par with DN_{80} and DN_{60} whereas the lowest (15) number of spikelets was recorded in treatment N_0 (control). Similar results were also found by Nerson et al. (1980) who found maximum number of spikelets per spike with higher doses of N, as increasing N supply may facilitate the rate of spikelets initiation. The treatment DN_{120} produced the highest number of grains (49.50) spike^{-1} followed by DN_{80} which produced (48.20) grains spike^{-1} (Table 02). Minimum number of grains per spike was recorded in N_0 (control) treatment which produced 40.40 grains spike^{-1}. This result is also in agreement with the findings of Hasan et al. (2016) who observed that number of grains per spike in wheat increased significantly when the rate of N application increased.

The highest value of 1000-grain weight (47.42 g) was found in case of DN_{120} which was followed by DN_{80} and DN_{60}, respectively (Table 02). The 1000-grain weight value (39.69 g) for N_0 was significantly lower than the $DN_{60,}$ DN_{80} and DN_{120}. The results are in line with Abedin (1995), and who reported a significant increase in thousand grains weight of wheat with the higher doses of nitrogen. The highest value for grain yield (3.29 t ha^{-1}) was obtained from treatment DN_{120}, this value of grain yield is statistically similar to the grain yield of 3.27 t ha^{-1} from DN_{80} (Table 02). The lowest grain yield was produced from the control treatment (N_o) which was also statistically dissimilar from the treatment $DN_{60,}$ DN_{80} & DN_{120}. The results are in agreement with Rahman et al. (2014) and Hasan et al. (2016), who reported that N @ 120 kg ha^{-1} produced the highest wheat yield and the grain yield increased

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with increasing nitrogen rates up to a certain limit and the further increment in nitrogen rates has less or no contribution on the grain yield.

Table 02. Effect of nitrogen on yield contributing characters and grain yield of wheat

Treatments	Tillers m^{-2} (no.)	Spike length (cm)	Spikelets $spike^{-1}$ (no.)	Grains $spike^{-1}$ (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})
N_0	217.50	9.00	15.00	40.40	43.10	2.85
Dynamic						
DN_{60}	271.00	9.52	17.75	48.02	45.95	3.16
DN_{80}	295.00	9.85	17.36	48.20	46.27	3.27
DN_{120}	300.00	9.96	17.95	49.50	47.42	3.29
LSD	14.54	0.57	1.03	0.96	0.65	0.08
CV (%)	4.85	4.08	4.12	4.74	4.91	5.10

SPAD value and observed grain yield

The chlorophyll meter reading (SPAD) at different DAS and grain yield of wheat were showed an increasing trend with the increase of N dose (Table 03). Irrespective of fertilizer management options, the SPAD values showed an increasing trend with the advance of plant growth. The SPAD values varied from 22.75-50.54 among different fertilizer treatments. The values were higher (>36.58) in treatment receiving 120 kg N ha^{-1} as compared with reduced N fertilizer (DN_{60}) and control (N_0) treatment. However, the values remarkably decreased and varied from 38.96-22.75 in the control treatment. The grain yield had similar trends with the SPAD values estimated for different N fertilizer application. The SPAD chlorophyll meter reading gave the best indicator of photosynthetic activity as found by Sarkar et al. (1998), which may offer sufficient photosynthesis, growth and development of wheat. The highest grain yield was obtained in wheat from DN_{120}. Reducing fertilizers and control treatment also reduced wheat yield to some extent. However, a significantly greater grain yield reduction was occurred in the control treatment (N_o). This might be because zero supply of N generally restricted the plant growth as the native N from the soil is not sufficient to mitigate the crop N demand. Moreover, the increased SPAD chlorophyll meter reading may also be correlated with the increase in wheat yield (Sarkar et al., 1998).

Table 03. Leaf chlorophyll content (SPAD value) at different growth stages of wheat and observed grain yield

Treatments	Chlorophyll content (SPAD value)											Grain yield (t ha^{-1})
	36 DAS	42 DAS	48 DAS	53 DAS	59 DAS	65 DAS	71 DAS	77 DAS	83 DAS	89 DAS	95 DAS	
N_0	38.96^{a}	38.43^{a}	37.55^{c}	36.47^{b}	35.72^{d}	35.13^{c}	36.88^{d}	36.47^{d}	34.06^{d}	30.56^{d}	22.75^{d}	2.85^{d}
Dynamic												
DN_{60}	39.45^{a}	39.08^{a}	45.25^{ab}	43.17^{a}	45.60^{bc}	44.70^{b}	46.14^{c}	47.49^{c}	45.80^{bc}	38.11^{c}	34.75^{bc}	3.16^{c}
DN_{80}	39.70^{a}	39.60^{a}	45.75^{ab}	43.45^{a}	46.30^{ab}	46.75^{a}	47.04^{b}	49.15^{b}	46.80^{ab}	40.70^{ab}	36.95^{a}	3.28^{ab}
DN_{120}	39.10^{a}	39.53^{a}	46.47^{a}	43.58^{a}	47.05^{a}	47.15^{a}	49.97^{a}	50.54^{a}	47.78^{a}	41.22^{a}	36.58^{ab}	3.29^{a}

In a row, means followed by the same letter are not significantly different at the 5% level by DMRT

IV. Conclusion

Dose and time of N fertilization are decisive for the formation of a desirable number of tillers to optimize wheat yield. The response of wheat crop to the timing of N application is so prominent, which is also a determinant of the final yield. At early vegetative stage, SPAD chlorophyll meter reading should be maintained above the critical value of 45 to facilitate tiller formation, normal growth and development of spike bearing tiller. Otherwise, the yield of wheat reduces drastically. An application of 80 to 120 kg N ha^{-1} along with 20 Kg N ha^{-1} at emergence can meet up the N requirement of the crop and subsequently can ensure proper growth and development that leads to higher grain yield of wheat.

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EISSN: 2312-7945,

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EISSN: 2312-7945,

HOW TO CITE THIS ARTICLE?

Crossref: https://doi.org/10.18801/jbar.240120.241

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