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Nitrogen management of wheat cultivars for higher productivity - A review

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Abstract: The increased population pressure has led to the maximum use of chemical fertilizers especially in the major crops such as rice, wheat and maize production. India has an ever growing population needing food and also the growing urban middle class with higher standards of living is on the lookout for better quality product. The introduction of improved seeds increases the utility of traditional inputs and their consumption as well. Because of genetic variation, BVC 223, Qingnong 8, IPA99, CT 01217, Luomai 8, Seher 06, Sistan, Punjab 2011, Rasco 2005, PBW 343, Halna, HP 1744, VL Gehun 892, WH 1022, PBW 621, and PBW 550 cultivars of wheat crop differ in growth and development behaviour and respond higher to different nitrogen management practices. However, ever increasing prices of Nitrogen (N) fertilizers and possibilities of environmental pollution and groundwater contamination warn for their judicious and efficient use. The application of essential plant nutrients particularly N nutrient in optimum quantity (120-150 kg/ha) and right proportion (3-4 splits) through correct methods and time of application (LCC and green seeker based) is the key to increased and sustained crop production. The increase in quality due to nitrogen fertilization (120-330 kg/ha) may be due to its role in activation of cells division, metabolic and photosynthesis process and nutritive status of wheat plant. Keeping in view above all facts in mind, performance of wheat cultivars as influenced by different nitrogen rates will be discussed in this review.

Keywords: Cultivars, Grain quality, Grain yield, Nitrogen levels, Wheat

INTRODUCTION

Wheat has to play an important role in this direction considering the vast scope of increasing productivity of this crop through constructing management of nutrients and yield gaps by developing newly emerging high yielding cultivars (Majumdar *et al*., 2012) represented in Table 1.

Because of genetic variation, different cultivars of crop may differ in growth and development behavior and response to different management practices. Taller cultivars are generally less responsive to fertilizer application and give lesser yields than the dwarf cultivars. As cultivars vary widely, nitrogen has got differential response (Singh *et al.,* 2010). The cultivars have been found to differ in their efficiency to accumulate dry matter and yield attributing characters. The development of semi-dwarf wheat cultivars which resist lodging more than conventional taller cultivars have improved wheat yields by allowing greater efficient use of N fertilizer. In Punjab, Mahajan and Nagarajan, (2005) reported that two hybrids HM 9846 and HM 9837 were significantly superior in grain yield to the best check PBW 343.

Among various agronomic manipulations, application of nitrogen is one of the important factors which influence the grain yield and the quality of wheat. Plants take up most of their nitrogen as the ammonium (NH_4^+) or nitrate (NO_3^-) form. Nitrogen is necessary for chlorophyll synthesis as a part of the chlorophyll molecule, involved in photosynthesis and constituent of all amino acids and protein which are considered responsible for quality of wheat. Nitrogen application rate and timing are very important for yield and quality of wheat. The yield responses of different cultivars vary widely under different nitrogen management. But nitrogen is one of the most important and expensive input in wheat cultivation. However, ever increasing prices of N fertilizers and possibilities of environmental pollution and groundwater contamination, warn for their judicious and efficient use. Therefore, it is important to understand fertilizers use behaviour in the country over time as well as role of factors influencing fertilizer consumption at the national and regional/state level because intensity of fertilizer use varies from state to state and area to area. Technological factors such as high yielding cultivars, irrigation, cropping intensity and agricultural prices had positive impact on nitrogen fertilizer consumption. Availability of capital also caused nitrogen consumption positively. Price of fertilizer had a significant negative impact on nitrogen fertilizer use. Non-price factors namely, irrigation and cropping intensity, were more powerful in influencing N consumption compared with price factors. Price of N fertilizers was the third important determinant of fertilizer demand. Between, input price and price of

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Table 1. Importance of wheat in food grain production scenario.

Crops	Normal Area (million ha)	Normal Production (million tons)
Rice	44	107
Wheat	30	96
Total foodgrains	125	265

Source: *Fertilizer statistics,* (2013-14).

Table 2. Wheat Scenario, 2014-2015 (*www. Indiastat.com*).

Region	Area (mha)	Production (mt)	Productivity (t/ha)
India	31.19	95.76	3.2
Punjab	3.51	16.80	4.8

agricultural output, price of input (N fertilizer) was more powerful in influencing the consumption (Jaga and Patel, 2012).

This discrepancy regarding the fertilizer N requirement of wheat may be related to residual N in soil, differential cultivar response etc. Concerns about the N pollution of environment such as nitrate leaching into ground water and nitrous oxide emission into the atmosphere, have stimulated interest in low input strategies for N fertilization (Ramesh *et al.,* 2005). Based on the worldwide evaluation, the fertilizer N recovery efficiency has been found to be around 30% in wheat with current practices (Krupnik *et al.,* 2004). Recoveries of N from 70-80% are physically feasible in most situations with efficient N application through improvement in input level and timing. Efficient fertilizer management in terms of rate and application timing avoids crop N deficiency at critical periods of crop. Singh *et al.* (2010) reported from Jammu and Kashmir that cultivar Shalimar wheat 1 gave significantly higher grain yield at 150 kg N/ha whereas VL 738, HS 240 and HS 365 cultivars gave significantly higher yield only upto 100 kg N/ha.

Wheat is an excellent source of nutrition in terms of carbohydrates, minerals, proteins and is unique among all the cereal grains as its flour makes a cohesive mass of dough when mixed with water which can be moulded to make innumberable products. There are large differences between grain quality requirements for the major food types such as bread, biscuits, *chapati*, pastries and cookies (Pal *et al.,* 2010). It has been estimated that only 33% of total N applied for cereal production in the world is actually accumulated in grain and 67% lost due to various reasons (Bellido and Bellido, 2001). About 75% of recommended calories intake from cereals, emphasize the need for enhancing its protein content. Though the protein content depends mainly on genetic characters, it may be possible to certain extent by the fertilizer management of crop (Krishnakumari *et al.,* 2000). Kaur *et al.* (2010) reported from Hisar, Haryana that quality of wheat grain in terms of increased protein fractions like albumin, globulin, prolamin and glutenin increased significantly with split application of nitrogen. Among agronomic practices, the rate and technique of nitrogen fertilization has been used successfully to improve grain quality and protein content (Mattas *et al.,* 2011).

In this review, an overview is related nitrogen management of wheat [*Triticum aestivum* (L.) emend. Fiori and Paol cultivars for higher productivity have been explored.

Present scenario of wheat in India: Wheat (*Triticum aestivum* L.) is amongst the three most important cereals worldwide symbolizing over a quarter of the total world's cereal production and a chief source of calories for more than 1.5 billion people as well around the globe In India, wheat is the second most important food crop after rice with a total production of 95.76 million tonnes (mt) which is 12% of the world food production from 31.19 million hectares (mha) of land with productivity of 3.2 t/ha (Anonymous, 2015). In India, the domestic consumption of wheat during 2014 was 37.60 mt . It has been projected that to feed 1.3 billion population and for diversified uses, India will have to produce at least 109 mt of wheat by 2020 A.D. which might be only possible through elevating the national productivity upto 4.0 t/ha (Nagarajan and Rana, 2002). It was grown on an area of 3.51 mha in Punjab with production of 16.80 mt and grain yield of 4.8 t/ha (Anonymous, 2015) represented in Table 2.

Cultivars: The continuous selection of high yielding cultivars with mid range of adaptability to edaphic and environmental conditions is very essential to increase productivity. Arzadun *et al.* (2006) concluded from Argentinean Pampus that cultivar BVC 223 produced higher grain yield than cultivar Charrua due to increased yield attributes. Zhang *et al.* (2006) observed from China that winter wheat cultivar Qingnong 8 had highest grain yield under proper fertilizer management. Al-noori and Khalaf, (2006) reported from Iran that IPA 99 gave highest grain yield at both locations at Telkaef and Mosul (4.6 and 4.3 t/ha respectively) while minimum yield was for cultivar Abu-Ghraib/3. Tayyar (2007) from North-Western Turkey reported that Romanian bread wheat cultivar Joseph gave higher yield and better quality characters than local cultivars. Khan *et al.* (2007) concluded from Peshawar, Pakistan that cultivars CT 01217, CT 01222 and CT

Table 3. Highest yielding cultivars of wheat in foreign regions.

Wheat Cultivars	Grain yield (t/ha)	Reference
IPA 99	4.6	Al-noori and Khalaf, (2006), Iran
CT 01217	4.7	Khan *et al.,*(2007), Peshawar, Pakistan
Joseph	5.1	Tayyar, (2007), Turkey
Punjab-2011	4.3	Khalid *et al*., (2014), Faisalabad, Pakistan

Table 4. Highest yielding cultivars of wheat in Indian regions.

Wheat Cultivars	Grain yield (t/ha)	Reference
PBW 343	4.5	Bhat and Mahal, (2006), Ludhiana, Punjab
VL Gehun 892	10.0	Kant *et al.,* (2010), Almora (Uttarakhand)
PBW 343	4.2	Kumar *et al.,* (2012), Hisar, Haryana
PBW 621	5.9	Ram *et al*., (2012), Ludhiana, Punjab
PBW 550	5.8	Ram *et al*., (2013), Ludhiana, Punjab
PBW 550	5.2	Kaur *et al*., (2016), Ludhiana, Punjab

Table 5. Highest yield (t/ha) obtained from different nitrogen schedule in foreign regions.

Nitrogen Scheduling	Soil status	Grain yield (t/ha)	Reference
N_{120}: 1/3 basal, 1/3 at CR1 and 1/3 at 1st node stage	Silty clay loam	4.1	Rahman *et al*.,(2011), Bangladesh
N_{150}: 4 splits of total N, 1/4 at sowing, 1/4 at the 1st irrigation, 1/4 at the 2nd irrigation (45 DAS), and 1/4 at the 3rd irrigation (70 DAS)	Sandy loam	6.2	Usman *et al*., (2014), Pakistan

Table 6. Highest yield (t/ha) obtained from different nitrogen schedule in Indian regions.

Nitrogen (Kg/ha)	Saren and Jana, (2001), Kalyani West Bengal	Verma *et al.,* (2005), Kanpur U.P.	Kachroo and Ravinder (2006), Kashmir	Kumar *et al* . (2007), Hisar Haryana	Singh *et al.* (2009), Ludhiana, Punjab	Singh *et al.* (2010), Kashmir
0					6.5	
40			3.5			
50	3.0					4.4
60		4.3				
80			5.1			
90		4.6		3.9	6.6	
100	4.1					4.7
120		4.8	5.3	4.2	6.8	
150				4.3	7.1	4.7
180				4.3		
C.D.	1.4	0.6	2.7	0.1	0.3	0.2

01085 with grain yield of 4.7, 4.3 and 4.3 t/ha respectively performed well with respect to harvest index (40.5, 31.0 and 36.5%) and medium plant height character (89, 92 and 91 cm) as compared to those of the best check line (Bakhtawar 92) which is an indication that some bread wheat cultivars among existing germplasm may have in built resistance/tolerance against terminal heat stress under late planting condition.. Zhou *et al.* (2008) reported from China that Luomai 8 wheat cultivar had the highest grain yield Khalid as compared to local wheat cultivars. Paik *et al.* (2008) observed from Korean Republic that Keumbang had highest yield than Jeokjoong wheat cultivar.

Mujahid *et al.* (2008) from Faisalabad, Pakistan reported that cultivar Seher 06 produced higher grain yield (10%) than Inqilab 91. Ranjbar *et al.* (2010) from Iran observed that cultivar Sistan produced highest grain yield than cultivar Verinak. *et al*. (2014) reported from Faisalabad, Pakistan that significantly highest yield (4.4 t/ha) was obtained by Punjab2011 which was followed by Millat (3.7 t/ha) and Sehar 2006 (3.5 t/ha). Longove *et al*. (2014) concluded from Balochistan that cultivar Rasco-2005 surpassed all the cultivars for growth and yield performance, followed by Zardana and Rakhshan 10. Rasco 2005 produced highest grain yield (5.3 t/ha), followed by Zardana (5.2 t/ha), Rakhshan 10 (5.0 t/ha), Tijaban-10 (4.6 t/ha) while lowest grain yield (4.3 t/ha) was recorded in Sariab-95. Hence, cultivar Rasco-2005, Zardana and Rakhshan-10 were the most promising cultivars, while Tijaban-10 also showed promising performance and could be a good addition to the pipeline wheat cultivars of Balochistan. Moghadam *et al*. (2014) resulted that cultivar 12 with 3.1 t/ha produced the higher grain yield and cultivar 9 had the lowest (1.7 t/ha) than other cultivars.

Bhat and Mahal, (2006) from Ludhiana, Punjab reported that bread wheat cultivar PBW 343 recorded the higher yield attributing characters resulting in significantly higher yield than *durum* wheat cultivar PDW 274. Singh *et al.* (2007) from Faizabad, Uttar Pradesh observed that cultivar Halna had highest grain yield followed by cultivar K 8962, DW B14, NW 1076 and NW 1014. Pandey *et al.* (2008) from Pusa, Bihar reported that cultivar HP 1744 recorded significantly higher yield attributes, grain yield, straw yield, N uptake, net returns and B:C than cultivar UP 262. Kant *et al.* (2010) reported from Almora,Uttarakhand that cultivar VL Gehun 892 produced higher grain yield and cultivar PBW 226 characterized for earliness and high grain weight which has early maturity (143 days) and higher average productivity/day (1.0 t/ha/day) making it a suitable for late sowing in northern hills of India.

Kumar *et al.* (2010) reported from Hisar, Haryana that cultivars WH 1022 and PBW 343 produced significant higher number of spikes/m^2 and biological yield than

Table 7. Highest yield (t/ha) obtained from different nitrogen schedule in Indian regions.

Nitrogen Scheduling	Soil status	Grain yield (t/ha)	Reference
N_{120}: 60 kg N at basal + 60 kg N at CRI as neem coated urea	Loamy sand	5.9	Behera *et al.,* (2008), Indore, M.P.
N_{120}: (1/4 N as basal +1/2 at CRI + 1/4 at jointing)	Sandy loam	4.9	Sharma and Kaur, (2013), Ludhiana
N_{150}: 1/4 basal +1/2 at tillering +1/4 at floral initiation	Sandy loam	4.4	Kharub and Chander, (2010), Haryana
N_{150}: 1/3 after 1st irrigation + 1/3 at boot stage + 1/3 at anthesis	Sandy loam	4.7	Kumar *et al.,* (2010), Hisar, Haryana
N_{180}: 1/3 at sowing +1/3 at CRI + 1/3 at anthesis Stage	Sandy loam	5.6	Mattas *et al., (*2011), Ludhiana, Punjab

Table 8. Highest yield obtained by LCC based nitrogen levels in foreign regions.

Nitrogen rate	Soil status	Grain yield (t/ha)	Reference
59.8 kg/fad using SPAD as nitrogen sufficiency index (NSI)	Clay	3.0	Habbal *et al*., (2010) Giza, Egypt
Recommended practice (RP):80 kg/fad		3.1	

Table 9. Highest yield obtained by Greenseeker based nitrogen levels in foreign regions.

Nitrogen rate	Soil status	Grain yield (t/ha)	Reference
66% Farmer practice (FP) at seeding and Green Seeker at 6-6.3 leaf stage Post-E. [(post emergent N application as a surface dribble on 12" centers using liquid UAN (28-00-00).]	Sandy loam	2.42	Lafond *et al*., (2008), Canada
FP: 90 kg N/ha		2.58	
$N_{51.1\ lb/ac}$ (Greenseeker at feekes 6)	Moderately well to well drained soils	97.4 bu/ac	Murdock *et al*., (2007), UK
$N_{52.3\ lb/ac}$ (FP)		92.5 bu/ac	

WH 711. The grain yield was significantly higher in cultivar WH 1022. Ram *et al*. (2012) from Ludhiana, Punjab reported that wheat cultivar PBW 621 recorded the highest grain yield which was statistically at par with PBW 550 but significantly higher than recorded in in PBW 590, PBW 343, DBW 17 and WH 542. The reported that higher grain yield in PBW 621 and PBW 550 due to higher yield attributing characters. Kumar *et al*. (2012) reported from HisarHaryana that PBW 343 produced significantly higher grain yield over all other cultivars viz. WH 147, WH 283, C 306, WH 896 except HD 2687. In another study at Ludhiana, Punjab, Ram *et al*. (2013) reported that cultivar PBW 550 recorded significantly higher grain yield than DBW 17 and WH 542. Kaur *et al*. (2013) concluded from Ludhiana, Punjab that dry matter accumulation was significantly higher in cultivar PBW 550 due to increased growth rate at vegetative stage but it was higher in cultivar PBW 621 at maturity stage with same nitrogen level of 150 kg N/ha. The highest nutrient uptake was recorded in cultivar PBW 550 at 150 kg N/ha. In another study, Kaur *et al*. (2016) also reported from Ludhiana, Punjab that leaf area index and photo synthetically active radiation interception was higher in variety PBW 621. The 1000-grain weight and grains per ear were significantly higher in variety PBW 550 than other varieties. The variety DBW 17 had significantly higher tiller density. The variety PBW 550 gave significantly higher grain yield but statistically on par with variety PBW 621.

Available literature indicates that that the varietal performance may vary as per their genetic makeup or the prevailing climatic conditions in different areas like China, Iran, Turkey and Pakistan. BVC 223, Qingnong 8, IPA99, CT 01217, Luomai 8, Seher 06, Sistan, Punjab 2011 and Rasco 2005 are the dominant cultivars of bread wheat in these regions. Bread wheat has 85% cultivated area in Indian states like Punjab, Uttar Pradesh, Haryana and Bihar having higher potential of growth and grain yield in cultivars PBW 343, Halna, HP 1744, VL Gehun 892, WH 1022, PBW 621, and PBW 550.

Nitrogen levels: Nitrogen is the most limiting nutrient for irrigated or high rainfall wheat production. Thus, such nitrogen fertilizer is almost always needed to achieve desired yield and protein content. Rahman *et al*. (2011) reported from silty clay loam soils of Dhaka, Bangladesh having low organic carbon (1.1%) and total N content (0.07%) that three split applications (1/3 basal, 1/3 at crown root initiation (CRI) and 1/3 at 1st node stage) of higher dose of nitrogen 120 kg/ha resulted in positive gain in apparent nitrogen use efficiency (ANUE). Haile *et al*. (2012) observed from

Table 10. Advantages of SSNM over existing practices in different regions of India.

Site	Yield (kg/ha)	
	SSNM based	State Average
R.S.Pura	4746	1825
Ludhiana	6548	4582
Modipuram	5940	2755
Kanpur	5685	2755
Ranchi	4057	2056

clayey soils of Ethopia having low organic carbon content (2.17%) and total N content (0.11%) that improved cultivar Madda Walabu provided significantly higher grain yield, N utilization efficiency (NUE) and N use efficiency (NUE) when N rate at 120 kg/ha was applied 1/4 at planting, 1/2 at mid-tillering, and 1/4 at anthesis. Shiraz *et al*. (2014) from Malaysia that maximum grain yield was obtained due to application of 120 kg N/ha followed by 100, 80 and 0 kg N/ha. Hossain *et al.* (2006) concluded from silty clay loam soils of Dhaka, Bangladesh having low organic carbon (0.8%) and N content (0.07%) that nitrogen dose at 150 kg/ha gave more number of plants, spikes per square meter, longer spike length and higher grain weight. Usman *et al*. (2014) concluded from from silty clay soils of Pakistanthat the more spikes/m^2, grains/ spike, 1000-grain weight, grain yield, and NUE were obtained at zero tillage, straw retained and 4 splits application of total N at 150 kg/ha (i.e., at sowing 20, 45 and 70 d after sowing). Liu and Shi, (2013) reported from sandy loam soils of China having organic carbon (1.16%) and available N (95.3 mg/kg) that winter wheat showed the best quality and grain yield at 225 kg N/ha. Abedi *et al*. (2011) observed from silty loam soils of Iran that yield components were significantly increased with enhancing the level of nitrogen with no significant difference between 240 and 360 kg N/ha.

Yadav and Kumar (2009) reported from clay loam soils of Faizabad, U.P. thatresponse to dose of 50 kg N/ha was less in wheat as compared to rice. Kumar *et al.* (2009) reported from sandy loam soils of Hisar, Haryana that 100% recommended dose of 60 kg N/ha, 30 kg P_2O_5/ha and 20 kg K_2O/ha significantly higher wheat grain yield. Yadav *et al.* (2010) from sandy loam soils of Kanpur, U.P. having low organic carbon (0.45%) and available N (225 kg/ha) that grain yield and plant height of wheat increased with increasing level of residual nitrogen and attained maximum at rate of 80 kg N/ha as compared to 60, 40 and 0 kg N/ha. Thind *et al.* (2010) from clay loam soils of Ludhiana, Punjab having organic carbon (0.41%) reported that performance of neem coated urea at rate of 90 kg N/ha of wheat was better than neem coated urea at rate of 120 kg N/ha in 2 split doses. Agarwal *et al.* (2007) from loamy soils of Ranchi, Bihar observed that application of recommended dose (RD) of 100 kg N/ha, 50 kg P_2O_5 /ha and 25 kg K_2O/ha increased the grain yield to an extent of 71.6% over 50 % NPK and was statistically on par with 75% NPK level. Kathuria *et al.* (2005) from sandy loam soils of Hisar, Haryana on sandy loam soils reported that application of 100% NPK on soil test basis, on par with application of 120 and 160 kg N/ha, produced significantly higher grain yield of wheat than control, 60 kg N/ha and 90 kg N/ha + *Azotobacter*.

Prasad *et al.* (2005a) from Kanpur, U.P. on sandy loam soils reported that recommended dose of 120 kg N/ha, 60 kg P/ha and 40 kg K/ha caused significantly maximum uptake of 126 kg N/ha which was reduced by 4.03 and 8.83% at 75 and 50% doses of fertilizers. Verma *et al.* (2005) also reported from Kanpur, U.P. on sandy loam soils that maximum equivalent yield of 8.0 t/ha was obtained at recommended dose of 120 kg N/ha, 60 kg P/ha and 40 kg K/ha which reduced to 7.5 and 7.0 t/ha at 75 and 50 % recommended doses of fertilizers. Prasad *et al.* (2005b) from Kanpur, U.P. on sandy loam soils reported that recommended dose of 120 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O/ha showed significantly higher values of N, P and K uptake in grain, stover and whole plant. Total uptake at recommended fertilizer was recorded by 87.12 kg N, 40.50 kg P_2O_5 and 142.86 K_2O/ha which reduced to 80.80 kg N, 34.55 kg P_2O_5 and 133.15 K_2O./ha at 75% recommended fertilizer and 71.91 kg N, 28.05 kg P_2O_5 and 122.24 K_2O/ha at 50% recommended fertilizer.

Choudhary *et al.* (2007) from Aligarh, U.P. on sandy loam soils reported that vermicompost at the rate of 10 t/ha and 120 kg N/ha gave highest N content in grain and straw of wheat. Pandey *et al.* (2008) from Pusa, Bihar with available 216 kg N/ha in soil, reported that tillers per metre row length, grain, straw yield, N-uptake and net returns increased significantly with successive increase in nitrogen level upto 120 kg N/ha. However, they reported that B:C was increased upto

Table 11. Highest yield obtained by LCC based nitrogen levels in Indian regions.

Nitrogen rate	Soil status	Grain yield (t/ha)	Reference
LCC (5), basal N @ 20 (kg/ha), 25 kg/ha at 21-42 DAS, 25 kg/ha at 43-63 DAS and 20 (kg/ha) at 64-84 DAS	Sandy loam	5.03	Maiti and Das (2006), West Bengal
RP:120 kg N/ha (Basal, CRI, MT)		4.33	
40 kg N/ha at LCC $_{\leq 4}$, no basal (21, 56, 77 DAS)	Sandy loam	5.6 Mg/ha	Shukla *et al.* (2004),
RP: 120 kg N/ha (basal, CRI, T)		4.9	Modipuram
RP: 120 kg N/ha (basal, 21, 62 DAS)	Sandy loam	4.9	Bhatia *et al.* (2011), New Delhi
30 kg N/ha at LCC$_{\leq 4}$, no basal N (21, 43, 56, 62, 77 DAS)		6.1	

Table 12. Highest yield obtained by green seeker based nitrogen levels in Indian regions.

Nitrogen rate	Soil status	Grain yield (t/ha)	Reference
N_{135} : 60 kg/ha at basal, 60 kg/ha at 1st irrigation and 15 (kg/ha) at 3rd irrigation (feekes 7 to 8)	Sandy loam	4.40	Singh *et al.* (2011), Ludhiana
FP: 120 kg N/ha (Basal, CRI)		4.35	

Table 13. Protein content (%) influenced by different nitrogen levels in foreign regions.

Nitrogen (Kg/ha)	Iqtidar *et al.* (2006), Pakistan	Shu-Ping *et al.* (2014), China	Sun *et al.* (2014), China	Szmigiel *et al.* (2014), Poland	Massoudifar *et al.* (2014), Iran
0	8.6a	10.68c	13.46c	12.43e	10.40d
50	11.5d				
60				13.06d	
70					12.23c
90				13.81c	
100	12.5c				
120		12.16b		14.59b	
150	13.4b		14.74Cb	15.18a	
160					13.86b
200	14.5a				
210			16.11ab		14.07a
225		13.52a			
270			16.85a		
330		13.34a			

80 kg N/ha only. Singh and Agarwal (2005) reported from sandy loam soils of Hisar, Haryana that yield attributes and grain yield increased with increasing nitrogen levels upto 150 kg/ha. Singh *et al.* (2007) reported from Agra, U.P. that application of 150 kg N/ha may be replaced by various combination of biofertilizers, FYM and chemical fertilizers which will be remunerative in terms of low input cost and sustainable productivity and soil health for longer period. Kumar *et al*. (2007) from sandy loam soils of Hisar, Haryana concluded that grain yield of wheat improved significantly with each successive levels of nitrogen 90, 120 and up to 150 kg N/ha but there was no further increase in yield beyond 150 kg N/ha. Mankotia and Kumar (2010) reported from Hisar, Haryana on sandy loam soils that application of 150 kg N/ha in 3 splits (1/3 at sowing + 1/3 after 1st irrigation + 1/3 at spike initiation) resulted in significantly taller plants, more dry matter accumulation, higher leaf area index and finally grain yield.

Nitrogen is the key input and therefore strongly impacts the plant growth from germination to maturity, yield and even quality of seed and stover. Ample literature is available about response of *Triticum aestivum* to applied N. The response varies with soil fertility status. Highest response of N from 120-150 kg/ha has been reported in Bangladesh, Ludhiana and Pakistan which are scheduled in 3-4 splits.

LCC and Greenseeker based nitrogen level: Site-specific nutrient management (SSNM) provides an approach to “feeding” crops with nutrients as and when they are needed. It ensures that all the required nutrients are applied at the proper rate and in proper ratio based on the crop’s nutrient needs. Win, (2003) reported that wheat cultivars resulted in the highest grain yield increase of 0.2 to 0.9 t grain/ha at 120 kg N/ha over yield of recommended N rate in *rabi* season with use of leaf chlorophyll chart. Alam *et al.* (2006) conducted an experiment at Bangladesh and reported that mean wheat grain yield increased by 8 q/ha at application of 20 kg N/ha at maximum tillering with use of LCC when combined with recommended N, P, K, S and Zn fertilizer use. Murdock and Schwab (2007) concluded from Oklahoma that spring nitrogen application is generally split with about 30% applied at Feekes 3 and 70% applied at Feekes 5 with a total application of 110-120 lbs/a in the more productive areas (well-drained soils) of the state. Murdock *et al*. (2007) resulted from Lexingston that the yield increases were due to both a better overall N recommendation for the field made by the sensor and the algorithm as well as better N distribu-tion in the field. Lafond *et al*. (2008) studied the evaluation of different N management strategies based on Greenseeker scale in Canada and observed that bread wheat have the highest grain yield at 64 kg N/ha.

Habbal *et al*. (2010) concluded from Giza, Egypt that the use of SPAD meter and NSI was very important to detect the nitrogen physiological rate for growth, yield and grain quality of wheat plant. Major research efforts in this line on wheat (Sharma and Tiwari, 2004) from Karnataka showed the advantage of SSNM over the existing practices (Table 10). Application of SSNM on rice-wheat cropping system in the above study locations increased the system yield to 14-16 t/ha with subsequent increase in economic return. The extra system net economic return of the SSNM treatments over state recommended practice was between Rs. 1578/ha in Ranchi to Rs. 26,224/ha in Modipuram. Far higher economic return was obtained through improved nutrient management as compared to the existing farmers’ practices that varied between Rs. 5783/ha and Rs. 28791/ha across the sites.

Shukla *et al.* (2004) conducted an experiment in Modipuram and results showed that maintenance of LCC value of 4 required 120 kg N/ha which produced higher grain yield, N uptake and NUE than that 80 kg N/ha and 150 kg N/ha. Maiti and Das (2005) conducted an experiment through LCC in West Bengal, and results showed that LCC value of 5 are better than LCC value of 4 for the best management of N dose with basal at rate of 20 kg/ha in wheat in an inceptisol.

Table 14. Protein content (%) influenced by different nitrogen schedule in Indian regions.

Nitrogen Scheduling	Soil status	Protein content (%)	Reference
N_{120}: 30 kg N at basal + 60 kg N at 1st node + 30 kg N at late jointing	Sandy loam	11.1	Behera and Pradhan, (2007), Indore, M.P.
N_{150}: 1/4 basal +1/2 at tillering +1/4 at floral initiation	Sandy loam	12.6	Kharub and Chander, (2010), Hisar, Haryana
N_{150}: 68 kg N at sowing + 75 kg N at 1st irrigation + 7 kg N (3 % urea spray) at anthesis)	Sandy loam	12.6	Kaur *et al.,* (2010), Hisar, Haryana

The nitrogen dose can be reduced as per the requirement of the cultivars. In Northern Karnataka, (Biradar *et al.* 2006) revealed that nutrient application on the basis of SSNM principles resulted in significantly higher grain yields over farmer practice (FP) and RDF. Average wheat yield in SSNM practice was 3.7 t/ha, which was 23% more than the RDF and 39% higher than the FP, with SSNM recorded an additional net income of Rs. 3060/ha and Rs. 4545/ha over RDF and FP, respectively. Maiti *et al.* (2006), using the QUEFTS approach also showed that SSNM significantly improved wheat yield in Eastern India and suggested revision of fertilizer recommendation in West Bengal. Recent studies on SSNM in wheat have looked into the aspect of real time N management for optimizing the efficiency of N. NUE in wheat is low and a recent worldwide evaluation showed that N recovery efficiency is about 30% (Krupnik *et al.*, 2004). Shukla *et al.* (2009) later reported similar observations for a wide range of crops including wheat. This showed clearly that application of limiting secondary and micronutrients in a site- specific manner will be necessary to improve yield of wheat. Bhatia *et al.* (2011) conducted an experiment in New Delhi and reported that application of urea with LCC value of 4 at rate of 30 kg N/ha produced 14 % higher yield whereas LCC value of 5 was found to be superior with 25% in wheat yield at same rate. It is concluded from above studies that nitrogen can be well managed and applied in optimum rate with the use of value of leaf chlorophyll chart which lies between 4 and 5.

LCC- Leaf color chart, DAS-Days after sowing: Singh *et al*. (2011) reported from sandy loam soils of Ludhiana that 100 kg N/ha in three splits gave highest grain yield as compared to 84, 87, 90, 91, 100, 103, 105, 111, 113 kg N/ha based on Greenseeker. Honnali and Chittapur (2013) from Karnataka, resulted that application of higher fertilizer than recommended also failed to improve yield in comparison to recommended dose of fertilizers. Moreover, yields in the treatment involving top dressing using LCC 4 recorded comparable yields (2081 kg/ha) as that obtained with recommended N management.

Studies conducted on LCC (5 to 6 t/ha) and green seeker (4.40 t/ha) based N levels adopted in Egypt, Canada, U.K. and India to save excessive N for obtaining sustainable grain yield of *Triticum aestivum* scheduled in three splits of 100-120 kg N/ha as compared farmer practices.

Interaction effect of wheat cultivars and nitrogen levels: The appropriate amount of N fertilizer to apply may be a difficult question to answer without knowing how much N the soil will supply, the growth and N uptake dynamics of the crop, and the yield potential. Bannnori *et al.* (2005) reported from Peshawar, Pakistan that number of tiller/ m^2, plant height, spike length, grains per spike, days to maturity, 1000-grain weight, grain yield and harvest index was significantly affected by the various nitrogen levels. The days to flowering, spike length and days to maturity of the wheat cultivars were significantly affected. The interaction between nitrogen and cultivars was non-significant. Arduini *et al.* (2006) concluded from Italy that post heading N accumulation was by far higher in the cultivars Simeto and Svevo than in cultivar Creso, whereas remobilization was highest in cultivar Svevo and lowest in cultivar Simeto.The percentage contribution of N remobilization to grain N was by far higher in cultivar Creso than in other two cultivars. Bakht *et al.* (2010) reported from Peshawar, Pakistan that maximum nitrogen concentration in straw and grain was recorded in the cultivar Saleem 2000 when fertilized with 150 kg N/ha (2/3rd soil + 1/3rd foliar) compared with Uqab 2000 and Pirsabak 2004. Iqbal *et al.* (2010) reported from Faisalabad, Pakistan that the highest grain yield (5.9 t/ha) was recorded in Sehar 2006 with the application of 120 kg N/ha followed by Sehar 2006 with 180 kg N/ha (5.0 t/ha). Minimum grain yield (2.5 t/ha) was recorded in Shafaq 2006 without any dose of nitrogen. Aynehband *et al.* (2010) reported from Iran that modern wheat cultivar Dena had the best grain yield because of greatest dry matter translocation efficiency and contribution of pre-anthesis assimilates to grain with better nitrogen use and translocation in high N application. It is concluded that the modern wheat cultivars responds well to highest N applications as compared to old taller cultivars.

Hussain *et al.* (2007) reported that the cultivars Daman 98 and inqilab 91 recorded higher plant height, spike weight, grains/spike, 1000-grain weight, biological yield and grain yield. Grain yield and biological yield were statistically similar at the doses of 150 kg N/ha and 200 kg N/ha. Among cultivars, Daman 98 and Inqilab 91 proved to be the best cultivars as compared to Bakhtawar 92. However, the protein content of wheat grains increased with an increase in nitrogen. Singh *et al.* (2007) reported from Aligarh, U.P. on sandy loam soils that the cultivar PBW 343 produced higher grain yield at 160 kg N/ha whereas HD 2329 and HD 2687 had highest grain yield at 120 kg N/ha.

Behera and Pradhan (2007) reported from Indore, M.P. that the performance of cultivar HI 977 was superior in all the N levels except at 120 kg N/ha, where maximum grain yield was recorded for HI 1418 followed by GW 173. The cultivar GW 173 produced the higher grain yield than HI 1418 and LOK 1 in all the N levels except at 30 kg N/ha, where it produced the lowest grain yield and at 120 kg N/ha. Khicharh and Niwas (2007) reported from Hisar, Haryana that increased application of nitrogen to early sown wheat cultivar WH 711 gave maximum yield and thermal consumption as compared to late sown wheat cultivars. Singh *et al.* (2008) conducted an experiment at Lucknow, U.P. on sandy loam soils and reported that salt tolerant cultivar KRL 19 gave 13% higher yield over KRL 14 with 150 kg N/ha. Maximum agronomic response was found in cultivar CBR 13 with 120 kg N/ha and it decreased with increase in nitrogen level. But in traditional cultivar Bejhari response to nitrogen reduced drastically with increasing levels of nitrogen.

Grain quality parameters: Grain quality is a complex trait resulting from the interactions between numerous protein components. The protein composition of wheat seeds is important in determining bread-making quality (Johansson *et al*., 2001). Gluten proteins, a large complex composed mainly of glutenins and gliadins, play a key role in baking quality because of their impact on water absorption capacity of the dough, dough elasticity and extensibility that can affect wheat flour quality (Torbica *et al*., 2007).

Ooro *et al.* (2011) reported from Kenya that wheat flour protein content and grain nitrogen increased significantly in response to N rate at 120 kg/ha. Szmigiel *et al.* (2014) concluded from Poland that applied nitrogen doses caused increased protein content in grain within the range from 13.06 to 15.18% when the highest dose of 150 kg N/ha of nitrogen was applied. Massoudifar *et al.* (2014) reported from silty clay loam soils of Iran increased nitrogen application from control to 210 kg N/ha improved grain protein content of wheat cultivars Mihan, C-87-6 and C-87-11. Sun *et al.* (2014) concluded from China that the grain protein contents of wheat cultivar, Jimai 22 on 120, 210 and 270 kgN/ha were 11.5, 22.5, and 25% higher than on control. Shu-Ping *et al.* (2014) concluded from China that protein content increased from 12.16 % to 13.34% with increasing nitrogen application rate from 120 to 330 kg N/ha.

Kumar and Ahlawat (2006) reported from sandy loam soils of New Delhi that application of 120 kg N/ha in wheat recorded higher N uptake in wheat-maize cropping system than 0 and 60 kg N/ha. Meena (2010) reported from Bundi, Rajasthan that split application of N (40:40:40) kg/ha produced significantly higher test weight over 2 splits (0:80:40) kg/ha but statistically on par with 3 splits (20:50:50) and (60:60:0) kg/ha. Kharub and Chander (2010) reported from sandy loam soils of Hisar, Haryana that three or four splits of nitrogen resulted in significantly higher total protein yield of wheat as compared to 2 splits of nitrogen. Mehta *et al.* (2006) from sandy loam soils of Ludhiana, Punjab on loamy sand soils reported that the highest protein content (12.0 %) was found at 180 kg N/ha which was on par with 150 kg N/ha (11.9 %) and significantly higher than 120 kg N/ha (11.5 %). Singh and Yadav (2006) reported from loamy soils of Faizabad, U.P. that application of 150 kg N/ha recorded maximum nitrogen uptake over control in wheat. Kaur *et al.* (2006) concluded from sandy loam soils of Ludhiana, Punjab on loamy sand soils that maximum protein content (12.3 %) was found at 180 kg N/ha and 150 kg N/ha which were significantly higher than 120 kg N/ha (11.4 %). The nitrogen dose may affect the quality of the bread wheat cultivars especially protein. Kaur *et al.* (2010b) reported from Bathinda Punjab that there was significant increase in nitrogen content in grain as well as in straw under nitrogen scheduling [68 kg N at sowing + 75 kg N at irrigation + 7 kg N (3% urea spray) at anthesis] as compared to control. Arora *et al.* (2010) reported from Ludhiana, Punjab on sandy loam soils that N uptake significantly higher at application of 150 kg N/ha over 120 kg N/ha. Mattas *et al.* (2011) reported from sandy loam soils of Ludhiana Punjab that the N uptake and N content increased significantly with increasing level of N application from 120 to 180 kg N/ha in *durum* wheat cultivars. It is concluded that the availability of nitrogen to wheat during various phases of its growth and development is an important factor influencing the quality of grain.

Nitrogen application in general increased protein content. Above studies have revealed increase in protein content upto 25% of bread wheat from 120 to 330 kg N/ha is reported in Kenya, Poland and China. Scheduling of 120 to 180 kg N/ha in three to four splits in Indian regions increased protein content of bread wheat upto 12.6%.

Conclusions

From review of above studies, it may be concluded that the varietal performance may vary as per their genetic makeup or the prevailing climatic conditions in the area. Nitrogen can be well managed and applied in optimum rate with the use of value of leaf chlorophyll chart which lies between 4 and 5. Modern wheat cultivars respond well to highest N applications as compared to old taller cultivars. The availability of nitrogen to wheat during various phases of its growth and development is an important factor influencing the quality of grain.

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