EFFECT OF SPLIT N FERTILIZER APPLICATION ON PHYSIO-AGRONOMIC TRAITS OF WHEAT (*TRITICUM AESTIVUM* L.) UNDER RAINFED CONDITIONS

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ABSTRACT:- Low soil fertility is one of the main wheat yield limiting factors under rainfed conditions. Farmers usually apply full N dose at seeding. However, winter showers during vegetative growth period provide an opportunity to apply N in split doses. Study was conducted to find out appropriate N rate and application method to enhance wheat productivity. Three N rates i.e., 60, 90, and 120 kg ha^{-1} and three application methods i.e. full basal N dose at planting and N application in two and three equal split doses at tiller formation and stem elongation stages. Maximum grain yield (5.20 t ha^{-1}) was achieved when N was applied @120 kg ha^{-1} in three equal split doses at planting, tiller formation and stem elongation stages. N application in 2 and 3 split doses resulted in 25 - 50% grain yield advantage at all N rates as compared to single basal N dose. Split N application was associated with significant increase ($P<0.05$) in spikes m^{-2}, 1000 grain weight and dry matter production. Split N application was also linked with better flag leaf chlorophyll retention and cooler crop canopies during grain filling stages which showed positive association with grain yield.

Key Words: Triticum aestivum; N fertilizer; Rainfed Conditions; Split N Application; Crop Yield; Yield Components; Pakistan.

INTRODUCTION

Rainfed agriculture covers about 80% of cultivable land and produces 60 – 70% of the world's food (Falkenmark and Rockstrom, 2004). Erratic rainfall and low soil fertility are two main factors limit wheat productivity under rainfed conditions (Lal, 1990; Fukai, 1999). N fertilizer application as single basal dose at the time of wheat sowing is a common farmer practice under rainfed conditions. Urea is the main source of N fertilizer through out the world and ammonia volatilization is the major pathway of N loss (Christianson et al., 1990; Agarwal and Praveen, 1994). Surface application of N in the form of urea may be lost by 30 - 50% as NH_3 in calcareous soils (Catchpoole, 1975; Fenn and Hossner, 1985; Zhang et al., 1992). Due to N loss through gaseous plant emission, soil denitrification, volatilization and leaching, N use efficiency for cereal production is low (33%) throughout the world. Crop usually suffers from nitrogen deficiency when it is most needed and appropriate N management involves timely application of N fertilizers when it is most demanded (Fageria

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and Baligar, 1999). At the same time, proper growth stage of the plants at the time of fertilizer application is equally important to influence N use efficiency (Ashraf and Azam, 1998). It is imperative to manage N application to minimize its loss and enhance N use efficiency. N fertilizer application in split doses may enhance N use efficiency through minimizing N losses (Vaughan et al., 1990).

Although, it is difficult to manage split N fertilizer application under rainfed conditions, however, regular winter showers during vegetative growth period in medium to high rainfall areas of the country provide opportunities to apply N in split doses to reduce N loss. The study was carried out to find out appropriate N rate and effect of N fertilizer application in split doses on wheat productivity under rainfed environment of Islamabad region.

MATERIALS AND METHOD

A two years (2004-05 and 2005-06) study was conducted at research area of Crop Sciences Institute, National Agricultural Research Centre (NARC), Islamabad, Pakistan situated at coordinates of latitude 33° 42' N and longitude 73° 10' E. Soil samples were taken and analyzed for physio-chemical properties before planting each year (Table 1). Data on mean monthly rainfall, temperature and relative humidity during growing seasons (November – April) for both years was noted (Table 2). The trial was laid out in split arrangement of Randomized Complete Block Design (RCBD) with three replications. The area of the main plot was 90 m^2 (9m x 10m) which was divided into three subplots measuring 30 m^2 (3m x 10m) each.

Seedbed was prepared using disc plow (primary tillage) followed by two cultivators and planking (secondary tillage). Wheat variety Wafaaq-2001 was sown in 1st week of November both years with self propelled wheat planter keeping seed rate of 120 kg ha^{-1}. Phosphate fertilizer was applied @85 kg P_2O_5 ha^{-1} in the form of DAP (46% P_2O_5 and 18% N). The entire P dose was incorporated in the soil at planting. The experiment comprised three N rates i.e. 60, 90, and 120 kg ha^{-1}(in the form of granular urea) which were assigned to the main plots and three application methods i.e. full basal N fertilizer dose at planting (1 - 0 - 0), N fertilizer application in two equal split doses (1/2 - 1/2 - 0) at planting and tiller formation (Feekes 3-4) and N fertilizer application in three equal split doses (1/3 - 1/3 -

Table 1. Physio-chemical soil properties of the experimental site

Parameters	Wheat Growing Seasons	
	2004 - 05	2005 - 06
Soil type (*ALFISOLS)		
pH	7.8	7.7
EC (dSm^{-1})	0.4	0.4
Organic matter (%)	0.7	0.8
Available P (mg kg^{-1})	6.8	7.2
Available K (mg kg^{-1})	62.0	61.0
Clay (%)	60.0	58.0
Silt (%)	32.0	31.0
Sand (%)	8.0	9.0
Texture	Clay	Clay

** Soils with a clayey B horizon and exchangeable cation saturation greater than 50% at pH7 (USDA, 1978)*

Table 2. Mean monthly rainfall, temperature and relative humidity at experimental site during wheat growing seasons 2004-05 and 2005-06

		Months						
Variable	Year	Nov	Dec	Jan	Feb	Mar	Apr	Total
Rainfall (mm)	2004-05	19.8	35.6	39.3	91.3	79.4	16.4	281
	2005-06	16.3	48.2	49.3	65.6	45.5	20.3	275
Temperature (˚C)	2004-05	16.2	12.1	10.4	10.6	16.8	21.5	-
	2005-06	16.3	11.5	11.1	17.4	18.8	24.0	-
Relative humidity (%)	2004-05	68.0	65.0	77.0	65.0	73.0	41.0	-
	2005-06	59.0	59.0	70.0	61.0	62.0	37.0	-

1/3) at planting, tiller formation (Feekes 3-4) and stem elongation (Feekes 7-8). Nitrogen rates were assigned to main plots and application methods to sub-plots. N fertilizer applied at planting was broadcasted and incorporated into the soil before seeding while N applied at tiller formation and stem elongation stages were top-dressed when the soil was moist immediately after rain showers. During growing season 2004-05, 1st split N dose was applied after 13 weeks of sowing at Feekes 4 stage, when experimental site received 33 mm rainfall. Second reasonable winter rainfall (17 mm) was received after 16 weeks of sowing at stem elongation (Feekes 7) and 2nd split N dose was top-dressed. During growing season 2005-06 crop received 1st split N dose after 14 weeks of sowing at Feekes 5 (29 mm rainfall occurrence) and 2nd dose was applied after 17 weeks of sowing (Feekes 7) when rainfall of 28 mm was received (Table 2). Chemical herbicide was used to control weeds. The crop was harvested in first week of May during both years.

Chlorophyll contents of 15 flag leaves per plot were measured after anthesis by using chlorophyll meter (FT Green LCC, 1000 N West St. Suite 1200 No. 638, Wilmington, DE19108 USA). The instrument had been used successfully to screen germplasm for drought and heat tolerance (Reynolds et al., 1998). Measurements with the chlorophyll meter produce relative SPAD meter values that are proportional to the amount of chlorophyll present in the leaf. SPAD values differ from photometric measurements of solvent-extracted chlorophyll by just ~ 6% on average (Ling et al., 2011). A hand-held Infrared Thermometer (Model AG- 42, Telatemp Crop, Fullerton, CA.) was used to measure canopy temperature at 100% canopy cover by holding the thermometer at an appropriate angle (30° from the horizontal and approximately 50 cm above the canopy) and 1 m distance from the edge of the plot to avoid the effect of soil temperature. One measurement per plot was taken between 1100 and 1400h under calm air conditions (Reynolds et al., 1998). Measurements of leaf chlorophyll and canopy temperature were taken for three successive weeks on March 15, 21 and 28, 2005 and March 13, 20 and 26, 2006, respectively.

Samples of 2 m^2 were harvested at the center of each plot at harvest maturity. Biomass, harvest index (HI), spikes m^{-2} grains per spike and 1000 grain weight were measured from this sample. Harvest index was calculated using the formula: [Harvest Index (%) = (Grain yield/Biological yield) x 100] (Reddy, 2004). Dry matter and seed weight were determined by drying the samples at 70 °C for 48h. Crop was harvested on May 07, 2005 and May 04, 2006.

The data were tested for analysis of variance using Statistics v. 7.0 (Analytical Software, 2000) package. Treatment means were compared using Tukey HSD test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Soil and Climatic Conditions

Experimental site comprised clay type soil with low organic matter (0.7 to 0.8%) and low amounts of N and P. The pH was 7.7 - 7.8 without any salinity problems (Table 1). The study was conducted under high rainfall conditions (>750 mm of annual average rainfall). Rainfall during wheat growing seasons (November – April) of 2004-05 and 2005-06 was 281 and 275 mm, respectively. Variation in precipitation between the two study years was relatively mild as total rainfall during 2004-05 growing season was only 3% higher than 2005-06 (Table 2). Despite mild drought stress during November, which usually occur in this particular area, crop growth was not severely affected by moisture deficiency during both wheat growing seasons. Distribution of rainfall was also more or less similar in the two years. Winter showers were well distributed in December and January which provided opportunity to apply N fertilizer in split doses at tiller formation (Feekes 3-4) and stem elongation growth stages (Feekes 7-8; Table 2). During both study years, 29-33 mm rainfall occurred during tiller formation and 17-28 mm during stem elongation stages. Long term average rainfall distribution (30 years average; data not shown) during wheat growing season showed more or less similar trend in this particular area.

Physiological Traits

N application in two and three split doses showed significantly higher flag leaf chlorophyll (SPAD values) at grain filling stages as compared to single basal N dose application. N application in three split doses at planting, tiller formation and stem elongation stages produced maximum mean flag leaf chlorophyll value (52) during grain filling stages followed by two split doses i.e. at planting and tiller

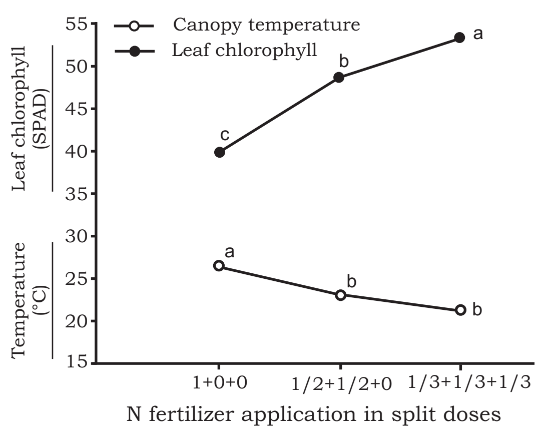

Figure 1. Effect of N fertilizer application in split doses on canopy temperature and leaf chlorophyll of wheat under rainfed conditions

formation (48) and single basal N dose (39 (Figure 1). N application in three split doses @120 kg ha^{-1} showed highest mean leaf chlorophyll value (52) and produced maximum grain yield (5.2 t ha^{-1}; Figure 1; Table 3). Split N application in two and three doses also lead to significantly cooler crop canopies at milky ripe (Feekes 11.1) and mealy ripe (Feekes 11.2) stages of grain filling as compared to plots applied with single basal N dose.

Table 3. Effect of N fertilizer rates and application methods on yield and yield components of wheat under rainfed conditions at NARC, Islamabad

Treatment		Dry matter (t ha^{-1})	Grain yield (t ha^{-1})	Harvest Index	Spikes m^{-2} (No.)	Grains $spike^{-1}$ (No.)	1000-grain weight (g)
Year							
2004 - 05		10.7	3.48	0.32	325	55	36
2005 - 06		10.6	3.43	0.32	324	55	36
N rates							
60		10.4	2.76	0.32	315	53	35
90		10.9	3.40	0.33	327	54	36
120		11.1	4.21	0.33	332	61	38
N application methods							
1- 0 - 0		10.3	2.49	0.32	310	47	33
1/2 - 1/2 - 0		10.9	3.59	0.32	326	57	36
1/3 - 1/3 - 1/3		11.3	4.29	0.33	338	60	39
N rates x N application methods							
60	1- 0 - 0	10.3	2.35	0.32	307	45	33
	1/2 - 1/2 - 0	10.5	2.82	0.31	314	51	35
	1/3 - 1/3 - 1/3	10.8	3.12	0.32	325	53	35
90	1- 0 - 0	10.4	2.53	0.32	310	44	33
	1/2 - 1/2 - 0	10.8	3.12	0.33	331	56	35
	1/3 - 1/3 - 1/3	11.3	4.56	0.34	342	61	41
120	1- 0 - 0	10.3	2.60	0.33	313	53	35
	1/2 - 1/2 - 0	11.7	4.83	0.33	351	64	39
	1/3 - 1/3 - 1/3	11.8	5.20	0.33	362	67	43
Critical difference at $P < 0.05$							
Year		0.2	0.1	6.9	1.3	0.3	0.6
N rates		0.2	0.1	3.3	2.3	1.4	0.6
N application methods		0.1	0.3	8.1	2.0	1.0	0.9
N rates x N application methods		0.3	0.3	2.8	2.3	1.5	0.6

Plots supplied with three split N doses showed lower mean canopy temperature (21.2 °C) at grain filling stages which was statistically at par with that of two split doses (23.1 °C) but significantly lower than that of single basal N dose (26.4 °C; Figure 1). N fertilizer application in split doses lead to better leaf chlorophyll retention, low canopy temperatures during grain filling stages and ultimately enhanced wheat productivity which might be linked with efficient photosynthetic activity and net assimilation rate (Amani et al., 1996; Reynolds et al., 1998). Association between better leaf N status and increased photosynthetic efficiency was also reported by Mae, (1997). López-Bellido et al. (2005) also found enhanced N use efficiency and increased wheat yield by split N fertilizer application during vegetative growth periods under well distributed rainfall conditions. While Alcoz et al. (1993) found inconsistent results of grain yield with split N application.

Agronomic Traits

Split N fertilizer application in two (1/2 - 1/2 - 0) and three doses (1/3 - 1/3 - 1/3) during vegetative growth periods significantly increased ($P<0.05$) dry matter production, spikes m^{-2}, 1000 grain weight and ultimately grain yield as compared to single basal N dose at planting (1 - 0 - 0; Table 3). Maximum average grain yield (4.29 t ha^{-1}) was obtained when N fertilizer was applied in three equal split doses at planting, tiller formation and stem elongation crop growth stages of the crop which was 17% and 42% higher when N was applied in two equal split doses at planting and tiller formation and single basal N dose at planting, respectively (Table 3). When N rates of 120 and 90 kg ha^{-1} were applied in three equal split doses produced maximum spikes m^{-2} (349 and 342, respectively; Table 3). No significant effect of N rates and application methods was observed on grains $spike^{-1}$. Significant increase ($P<0.05$) in 1000 grain weight was also noticed when N was applied in split doses as compared to single basal N dose. N application in three split doses @120 and 90 kg ha^{-1} produced significantly heavier grains (43g and 41g, respectively) as compared to rest of the combinations (Table 3). N application in split doses also increased ($P<0.05$) dry matter (DM) production as compared to single basal N dose at planting. Split N application in three split doses produced 11.8 and 11.5 t ha^{-1} dry matter, respectively at 120 and 90 kg N ha^{-1} which were significantly higher ($P<0.05$) as compared to single basal N doses of these applied N rates (Table 3). Significant increase in productive tillers production, when N was applied in split doses at tiller formation and stem elongation growth stages, can be attributed to adequate N availability at tiller formation and stem elongation growth stages as compared to single basal N dose at seeding (Moreno-Sevilla et al., 1995). Jan and Khan (2000) also reported increased productive tillers when N fertilizer was applied at tiller formation and node formation growth stages which ultimately resulted to produce more spikes per unit area (a very basic yield component). Number of grains $spike^{-1}$ is productive efficiency of a grain crop and no significant effect of split N application on number of grains per spike might be explained on the basis that it is purely genetic trait of the genotypes (Borner et al., 2002). Seed weight is also an important yield component and comparatively higher seed weight with split N application during vegetative growth period may be attributed to better leaf chlorophyll retention, comparatively cooler canopies and ultimately efficient photosynthetic activity during grain filling period (Reynolds et al., 1994).

It is thus concluded that In-season N fertilizer application management i.e. N fertilizer application in split doses from tiller formation to stem elongation growth stages instead of single basal N dose at planting may significantly enhance wheat yield under rainfed conditions, similar to agro-climatic conditions of study area where rainfall incidence provide opportunities to apply N fertilizer in split doses during vegetative growth.

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