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EFFECT OF SPLIT APPLICATION OF NITROGENON THE YIELD OF RICE CROP

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ABSTRACT

A three year field study was conducted at Adaptive Research Farm, Sheikhupura to find the most suitable nitrogen application schedule for rice (Super Basmati) during Kharif 2012, 2013 and 2014. Randomized complete block design with 3 replications was employed to investigate 4 different treatments of nitrogen split application @ 140 kg ha^{-1} viz: T_1= Puddling and tillering, T_2= Puddling, tillering and panicle initiation, T_3= Tillering, panicle initiation and flowering stage and T_4= Puddling, tillering, panicle initiation and flowering stage. Nursery of rice was transplanted in 2nd week of July each year. Paddy yield and all yield associated parameter of rice super basmati were significantly affected by treatments and highest of all of them were recorded when nitrogen was applied in 3 equal splits *i.e.* at puddling, tillering and panicle formation stage. In conclusion, nitrogen @ 140 kg ha^{-1} in 3 equal splits (puddling, tillering and panicle formation), is the most suitable combination of nitrogen splits to obtain higher paddy yields under agro-ecological conditions of Sheikhupura, Pakistan.
Keywords: puddling, rice, super basmati, flowering, tillering

INTRODUCTION

Rice (*Oryza sativa* L.) is among the most widely used cereals across the globe, grown under diverse range of climatic conditions, to feed the mankind. It is a very important source of foreign exchange earning giving about US $ 1.667 billion annually through its export by Pakistan. Moreover, Pakistan ranks 4th among world rice producing countries and provides about 30% of global rice supplies. During 2013-14, about 2.8 million hectare land was under rice in Pakistan. Efforts are being made to enhance the rice yield all at levels including research, government and farmers, but average yield of rice is far less than the genetic potential in Pakistan. Its production depends upon several agronomic factors including irrigation management, selection of suitable cultivar, optimum sowing time, effective control of insects, diseases and weeds and balanced fertilization (Angus et al., 1994; Jing et al., 2008). Any of these factors if not managed well can cause significant yield losses in rice crop.

Fertilizers play key role in crop production as they provide essential plant nutrients, critical for meeting the world food supplies. Among different types of fertilizers, nitrogenous fertilizers are the most important. It is the integral part of different compounds, like amino acids, DNA, RNA, phytohormones, and nzymes. Moreover, nitrogen is also involved in carbon and amino acid metabolism and synthesis of proteins (Cai et al., 2012). Vegetative growth of plant is primarily dependent upon adequate supply of nitrogen, if not managed properly, a stunted growth with pale yellow leaves is observed for cereals.

In cereal crops, nitrogen use efficiency is about 29% and 42% in developing and developed agricultural countries of the world, respectively (Pilbeam, 1996; Raun and Johnson, 1999; Beatty et al., 2010). Moreover, among yield limiting factors for rice, nitrogen is the most important (Ladha and Reddy, 2003; Samonte et al., 2006). During vegetative growth stage of rice, nitrogen is required for promoting growth and tillering, that determines number of panicles and during early panicle formation stage, development of spikelets is also dependent much on nitrogen supply. Moreover, nitrogen is also involved in sink size at late panicle formation stage. It is also actively involved in photosynthesis, carbohydrate accumulation and grain filling in rice (Mae, 1997). So, proper nitrogen management is key factor in narrowing the yield gap of rice. Application of nitrogenous fertilizer at proper time with a suitable rate according to the soil conditions can cause significant increase in paddy yield by increasing nitrogen use efficiency of crop (Ganga Devi et al., 2012;

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Shakouri et al., 2012). Researchers have reported different outcomes of their studies for deciding the best time of nitrogen fertilization. Ehsanullah et al. (2001), reported that nitrogen split application at three growth stages (transplanting, tillering and panicle emergence) should be followed to achieve higher paddy yield whereas Sathiya and Ramesh (2009) reported that application of nitrogen at critical growth stages like tillering can increase number of panicle and number of spikelets per spike in rice. In addition to this, application of nitrogen during critical growth stages of rice avoids its losses and facilitates its increased translocation into plant parts (Pushpanathan et al., 2005). If nitrogen is applied in splits rather than single time application with consideration of crop growth stages, it can increase yield of rice crop by increasing leaf area per plant, decreasing spikelet sterility and increasing the number of grains per panicle (Ehsanullah et al., 2001). It is obvious from all these studies that time of nitrogen application matters a lot in gaining higher rice yield, whereas sufficient experimental evidence is not available about the proper nitrogen fertilizer management in Sheikhupura region, thus the unwise use of nitrogenous fertilizer causes huge yield losses in rice, so the present study was planned with the objective to find the best suitable nitrogen split application schedule for rice crop in Sheikhupura region, Punjab, Pakistan.

MATERIALS AND METHODS

Site description: The experiment was carried out at Adaptive Research Farm, Sheikhupura that lies between latitude 31^o – 42^o N and longitude 73^o – 59^o E on the globe at an altitude of 209.57 m. The climate is moist sub-humid with an annual rain fall of 250 – 500 mm. Rice-wheat cropping system is the major cropping system in this area. Composite soil sample to a depth of 30 cm was obtained from the experimental area with soil auger prior to sowing of crop. The sample was analyzed for its physio-chemical properties. Bouyoucos hydrometer method was employed to find the soil texture and 1% sodium hexametaphosphate was used as dispersing agent. The relative proportion of sand, silt and clay was 14%, 70% and 16%, respectively. The soil belongs to loamy type as described by the international textural triangle (Moodie et al., 1959). Moreover, a pH of 8.4 with 10.1% total soluble salts, 0.8% organic matter, 0.07% total nitrogen, 10.4 ppm available phosphorous and 204 ppm potash was recorded in chemical soil analysis for the soil of experimental site.

Crop husbandry: Nursery of rice cultivar, super basmati was raised in 2^{nd} week of June each year and was transplanted manually on puddled soil during 2^{nd} week of July at the age of about 30 days. Recommended dose of P and K, 80 and 62 kg ha^{-1}, respectively was applied to all plots at the time of puddling. The source of P and K was DAP and SOP for all the years in all treatments except in last treatment, where SSP was used at the time of puddling instead of DAP, as no nitrogen was required here at the time of puddling according to treatment structure. Zinc was applied @ 5 kg ha^{-1} in the form of zinc sulphate (33%) at active tillering stage. All other agronomic practices including weed management, irrigation scheduling and management of pests etc. were addressed uniformly for all the treatments. Each year, the crop was harvested and threshed manually from each plot at maturity.

Experimental Design and Treatments: Experiment was laid out in Randomized Complete Block Design (split plot arrangement) with 4 different combinations of nitrogenous fertilizer and years as the treatments and was replicated thrice. The source for nitrogenous fertilizer was Urea and DAP purchased from Fauji Fertilizer Limited, Pakistan. Nitrogen was applied at recommended rate (140 kg ha^{-1}) at different growth stages of rice in splits that are used as treatments and give below.

T_1= Puddling and tillering (2 equal splits)

T_2= Puddling, tillering and panicle initiation (3 equal splits)

T_3= Tillering, panicle initiation and flowering stage (3 equal splits)

T_4= Puddling, tillering, panicle initiation and flowering stage (4 equal splits)

The net plot size was 3.78 m × 3.12 m for each experimental unit.

Data Collection and Statistical analysis: Data regarding plant height at maturity, number of fertile tillers, number of grains per spike, 1000-grain weight and paddy yield were collected using the standard procedures. The collected data were analyzed statistically by employing the Fisher's analysis of variance technique. The significance of treatment means was tested using least significance difference (LSD) test at 5% probability level (Steel et al., 1997).

Table 1: Effect of different nitrogen split combinations on the yield and yield associated parameters of fine rice (Super basmati) during 2012, 2013 and 2014.

	2012	2013	2014	Mean
Plant height (cm)				
T_1= Puddling and tillering (2 equal splits)	100.0bc	99.0bcd	99.3bcd	99.4
T2= Puddling, tillering and panicle initiation (3 equal splits)	103.0a*	97.0d	100.3bc	100.1
T_3= Tillering, panicle initiation and flowering stage (3 equal splits)	98.0cd	102.0a	101.0ab	100.7
T_4= Puddling, tillering, panicle initiation and flowering stage (4 equal splits)	99.0bcd	101.3ab	99.0bcd	99.8
Mean	100.0	100.0	99.9	
LSD ($p \leq 0.05$) Year = Ns , Nitrogen splits= Ns , Year × Nitrogen splits= 2.39				
Number of Productive tillers (m^2)				
T_1= Puddling and tillering (2 equal splits)	116.7f	131.3bcd	135.0abc	127.7b
T2= Puddling, tillering and panicle initiation (3 equal splits)	131.0bcd	136.3ab	140.0a	135.8a
T_3= Tillering, panicle initiation and flowering stage (3 equal splits)	102.7g	127.3de	129.0cs	119.7c
T_4= Puddling, tillering, panicle initiation and flowering stage (4 equal splits)	121.0ef	135.0abc	137.0ab	131.0a
Mean	117.8b	132.5a	135.3a	
LSD ($p \leq 0.05$) Year = 4.28, Nitrogen splits= 3.45, Year × Nitrogen splits= 6.66				
Number of grains per spike				
T_1= Puddling and tillering (2 equal splits)	126.0	128.7	125.0	126.6c
T2= Puddling, tillering and panicle initiation (3 equal splits)	126.7	133.3	132.0	136.7a
T_3= Tillering, panicle initiation and flowering stage (3 equal splits)	124.7	126.7	122.3	124.6d
T_4= Puddling, tillering, panicle initiation and flowering stage (4 equal splits)	128.0	131.7	126.7	128.8b
Mean	127.1	130.1	126.5	
LSD ($p \leq 0.05$) Year = Ns , Nitrogen splits= 1.85, Year × Nitrogen splits= Ns				
1000-grain weight (g)				
T_1= Puddling and tillering (2 equal splits)	20.00ef	20.73cd	21.90b	20.88b
T2= Puddling, tillering and panicle initiation (3 equal splits)	21.10c	21.03cd	22.80a	21.64a
T_3= Tillering, panicle initiation and flowering stage (3 equal splits)	19.80f	20.60cde	20.40def	20.67c
T_4= Puddling, tillering, panicle initiation and flowering stage (4 equal splits)	20.90cd	20.97cd	20.90cd	20.92b
Mean	20.45b	20.83b	21.50a	
LSD ($p \leq 0.05$) Year = 0.540 , Nitrogen splits= 0.296, Year × Nitrogen splits= 0.692				
Paddy yield (t ha^{-1})				
T_1= Puddling and tillering (2 equal splits)	3.50fg	3.63f	4.62b	3.92c
T2= Puddling, tillering and panicle initiation (3 equal splits)	4.25c	3.73e	4.92a	4.30a
T_3= Tillering, panicle initiation and flowering stage (3 equal splits)	3.17h	3.33gh	4.03d	3.51d
T_4= Puddling, tillering, panicle initiation and flowering stage (4 equal splits)	3.63ef	3.70e	4.79ab	4.04b
Mean	3.64b	3.60b	4.59a	
LSD ($p \leq 0.05$) Year = 0.052 , Nitrogen splits= 0.108, Year × Nitrogen splits= 0.169				

*= Means not sharing the same letter for an individual factor or interaction for each parameter differ from each other at $p \leq 0.05$

RESULTS

Plant height (cm)

Results presented in Table 1 show that different nitrogen split combinations did not significantly affect the plant height in rice. Only the interaction of nitrogen splits and year was significant. Maximum plant height (103.0 cm) was recorded during 2013 with the application of nitrogen in 3 equal splits (puddling, tillering and panicle initiation) and minimum plant height (97.0 cm) was recorded in the same treatment during 2013 that may be the due to climatic effects. It is also obvious from the results that applying nitrogen at flowering stage does not cause significant increase in the plant height as in T_4 (puddling, tillering, panicle initiation and flowering stage) plant height (99.0 cm) was recorded which is statistically lesser than the maximum.

Number of fertile tillers (m^2)

Table-1 shows that different nitrogen split combinations significantly affected the number of fertile tillers in rice. Maximum number of fertile tillers (135.8) were recorded when nitrogen was applied at the time of puddling, tillering and panicle initiation (T_2) and minimum number of fertile tillers (119.7) was found when nitrogen was applied at the time of tillering, panicle initiation and flowering stage (T_3). Moreover, during 2013 and 2014, statistically higher numbers of productive tillers were recorded as given in Table 1. The interaction of nitrogen splits and year shows that maximum number of fertile tillers (140.0) were found during 2014 and the fertile tillers during 2013 (136.3) in the same treatment were statistically at par with it. Whereas, minimum number of fertile tillers (116.7) were found during 2012 in case of 2 splits of nitrogen (at the time of puddling and tillering).

Number of grains per spike

Different nitrogen split combinations significantly affected the number of grain per spike in rice. Maximum number of grains per spike (136.7) were found by the application of nitrogen @ 140 kg ha^{-1} at the time of puddling, tillering and panicle initiation (3 equal splits) and minimum number of grains per spike (124.6) were recorded for the treatment where nitrogen was not applied at the time of puddling (T_3). There was no significant effect of year and interaction was also non-significant (Table 1).

1000-grain weight (g)

Grain weight index or 1000-grain weight of rice was also significantly affected by the different treatments of nitrogen applications (Table 1). Application of nitrogen @ 140 kg ha^{-1} in 3 equal splits at the time of puddling, tillering and panicle initiation gave highest 1000-grain weight of rice (21.64 g) and minimum 1000-grain weight (20.67 g) was recorded when nitrogen was applied in 3 equal splits (tillering, panicle initiation an flowering stage). As for as interaction of nitrogen splits and year is concerned, maximum 1000-grain weigh (22.80 g) was found during 2014 with the application of nitrogen in 3 equal splits (puddling, tillering and panicle initiation) and minimum 1000-grain weight (19.80 g) was found by applying nitrogen in 3 equal splits (tillering, panicle initiation and flowering). A significant year effect was also observed.

Paddy yield (t ha^{-1})

Paddy yield of rice was also significantly affected by different nitrogen split combinations as maximum paddy yield (4.30 t ha^{-1}) was recorded with the application of nitrogen in 3 equal splits (puddling, tillering and panicle initiation) and minimum paddy yield (3.51 t ha^{-1}) was recorded in case of application of nitrogen in 3 equal splits (tillering, panicle initiation and flowering stage). The interaction of nitrogen splits and year shows that during all years, paddy yield was statistically better with the application of nitrogen in 3 equal splits (puddling, tillering and panicle initiation) than all other treatments, however, highest paddy yield (4.92 t ha^{-1}) was recorded during 2014 by applying nitrogen in 3 equal splits (puddling, tillering and panicle initiation) and minimum was recorded during 2012 when nitrogen was applied in 3 equal splits (tillering, panicle initiation and flowering stage). Year also had a significant effect on paddy yield.

DISCUSSION

A balanced and sufficient supply of nitrogen is quite necessary for proper vegetative growth and green colour of rice crop. Moreover, proper nitrogen balance in crop also promotes the proper utilization of other essential elements like P and K. Ha and Suh (1993), reported that if nitrogen is supplied in proper splits, it can make plant more responsive towards better utilization of other inputs and gives better plant height than that of applying all the nitrogen at the time of sowing. If nitrogen is applied in splits, it remains available to plant for the entire growth season as in case of 2^{nd} treatment, higher plant height, more number of fertile tillers and more number of grains per spike were found in 2^{nd} treatment as compared to other treatments and results also showed that omitting nitrogen at the time of puddling can cause severe reduction in all yield related parameters and subsequently lower paddy yield was observed, when no nitrogen was applied at the time of puddling. Maske et al (1997) also reported similar findings that proper management of nitrogenous fertilizer can affect the yield related parameters and if nitrogen application is not managed well, a declined yield will be observed. Increase in the number of grains per panicle was also observed, when nitrogen was applied in splits rather than applying whole nitrogen in single dose. The increased number of grains per spike in T_2 might be due to availability of nitrogen to crop at all critical growth stages. These results are in line with those of Ha and Suh (1993) who reported that when nitrogen is applied in splits, it increases number of grains per panicle in rice. Mathew et al (1990) also reported the similar findings that applying whole nitrogen at the time of puddling, decreased 1000-grain weight in rice. In conclusion, applying nitrogen in 3 splits @ 140 kg ha^{-1} at the time of puddling, tillering and panicle formation is the most suitable split combination of nitrogenous fertilizer for obtaining high yields of fine rice in agro-ecological conditions of Sheikhupura, Pakistan due to its availability at all critical growth stages.

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