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Effect of split application of nitrogen fertilizer on the yield and quality of potato (*Solanum tuberosum*)

Nizam Uddin Ahmed[1], Zannatul Ferdous[2,3]* Nashir Uddin Mahmud[4], Afzal Hossain[5], Md. Asad Uz Zaman[6]

[1]Scientific Officer, Tuber Crop Research Sub-station, Bangladesh Agricultural Research Institute, Munshigonj, Bangladesh
[2]Senior Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute, Agricultural Research Station, Alamnagar, Rangpur, Bangladesh
[3]Department of Food, Agriculture and Bioresources, School of Environment, Resources and Development, Asian Institute of Technology, Pathumthani 12120, Thailand
[4]Senior Scientific Officer, Soil Science Division, Regional Agricultural Research Station, Jessore, Bangladesh
[5]Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute, Agricultural Research Station, Alamnagar, Rangpur, Bangladesh
[6]Scientific Officer, Rice Farming Systems Division, Bangladesh Rice Research Institute Gazipur, Bangladesh

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***Corresponding Author**

Z. Ferdous
zferdous80@gmail.com

ABSTRACT

Unbalanced use of chemical fertilizer is a problem in the intensive cropping systems on the Central part of Bangladesh. Proper nutrient management is essential to maximize potato production and sustain agricultural production while minimizing negative impacts on the soil fertility. The aim of the present study was to effect of spilt application of N, potato yields and soil fertility in response to environmental impact. A field experiment was conducted at Tuber Crops Research Sub Centre (TCRSC), Munshiganj during rabi season 2014-2015 to evaluate the performance of maximizing potato production through split application of N fertilizer. Six treatments viz. T_1= control (no urea), T_2= Two splits (1/2 nitrogen at 10DAP and 1/2at the 30DAP), T3= Two splits (1/2 nitrogen at 15DAP and 1/2at the 45DAP) T_4=Three splits ($^1/_3$ nitrogen at 10 DAP , $^1/_3$ at the 30 DAP and $^1/_3$ at the 50 DAP), T_5=Four splits ($^1/_4$ nitrogen at 5 DAP , $^1/_4$ at the 20 DAP, $^1/_4$ at the 35 DAP and$^1/_4$ at the 50 DAP) along with T_6= existing practice (FRG, 2012 of two splits) were evaluated for this purpose . The result indicated that the highest tuber yield (35.75 t/ha) was found from T_5= Four splits ($^1/_4$ nitrogen at 5 DAP, $^1/_4$ at the 20 DAP, $^1/_4$ at the 35 DAP and$^1/_4$ at the 50 DAP) treatment. The lowest tuber yield was obtained from control treatment.

INTRODUCTION

Potato is used globally mainly as a staple food. In Asia, potatoes are mainly consumed as a vegetable. In Bangladesh, potatoes are by far the leading vegetable, with production about 7.9 million MT in 2010, compared to other fresh vegetables which total about 1.4 million MT. Per capita consumption is 23 kg in Bangladesh, 32 kg in China and 15 kg in India (Reardon et al., 2012). Bangladesh is a developing country of about 156.4 million people inhabiting in its 147,570 km^2 area and is primarily an agriculture-based economy (Ferdous et al., 2016). Potato is one of the most important crops in Bangladesh (Anowar et al. 2015). Nitrogen (N) is one of the nutrients that exerts the greatest influence on the growth and development of plants under different environmental conditions (Rens et al., 2015), it is also the key factor in the yield and quality of potatoes and it is not easy to control. Rational application of nitrogen fertilizer is one of the most important components of achieving a high yield (Gao, 1988; Ferdous et al., 2005).

Potato is the third largest food crop grown in Bangladesh and mainly consumed as vegetable. Potato is also the leading vegetable crop in the world. During last 30 years from 1981 -82 to 2010-11, the annual growth rate of area was

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16.34%. The expansion of production over the same period was 12.11% and yield was increasing at a very high rate of 42.53% annually (BBS, 2013). Urea is an ordinary fertilizer that is widely used across the whole world, and this compound can stimulate biomass and total nitrogen accumulation in potatoes (Silva et al., 2013). Potatoes require high nitrogen inputs to maximize yields, and yet fertilizer N recovery is often relatively low (<50%) because of the plant's shallow root system (Bundy and Andraski, 2005). Since nitrogen is highly mobile, its use and demand is continuously increasing as it is subjected to high loss from the soil plant system (Randal, 2000). Even under best management practices, approximately 30-50% of applied nitrogen is lost through different agencies and, hence, the farmer is compelled to apply more than what the crop needs to compensate for losses through leaching, volatilization, and denitrification making the nutrient unavailable during the critical stages of crop growth (Hyatt et al, 2010). Urea is the predominant form of N fertilizer used in Bangladesh and worldwide, mainly because of its high N content (46%) and lower cost per unit N compared to other N fertilizers. However, N recovery by plant from applied urea is always less (<50%) because of the heavy N losses of up to 30% of the applied N as ammonia (NH_3) volatilization (Sanz-Cobena et al., 2011). Such high NH_3 losses from applied urea lower the fertilizer use efficiency of applied urea, and thus represent both economic and agronomic losses. In addition NH_3 losses also pose a potential environmental hazard through eutrophication of lakes, rivers and other waterways when NH_3 is re-deposited in these ecosystems. Hence, improving fertilizer use efficiency of urea is therefore critical to minimize farm costs, increase crop productivity and improve livelihood of growers.

Effective synchronization between the rate and timing of N fertilizer applications versus potato N uptake is very challenging, considering the short potato crop cycle of 100–110 days combined with the vulnerability of sandy soils to nitrate leaching and irregular rainfall patterns (Stanley and Toor, 2010). Excessive levels of early season N can lead to delayed tuber initiation and reduced yield (Lauer, 1985), while increasing N rates at emergence or tuber initiation have not always increased yield (Rens et al., 2015). High N rate application concentrated at tuber initiation can cause rapid tuber growth, leading to a higher incidence of tuber defects such as growth crack, hollow heart and malformed tubers (Bussan, 2008). Nitrogen deficiency limits yields, and conversely, excessive N application can leach to the groundwater to some extent (Rens et al., 2015). Scientific data indicate that a significant improvement for N fertilizer used efficiency results from split N fertilizer applications according to potato growth needs (Rens et al., 2015; Datta et al., 2015), and a reduction in N fertilization rates may also have the undesirable effect on both reducing crop yield and nitrate leaching (Fandika et al. 2016; Westermann, 2005). There is a fundamental need to develop an N management strategy for potatoes that will not only improve N use efficiency but also reduce potential nitrate leaching (Rens et al., 2015; Fandika et al., 2016). Accordingly, spilt application of N fertilizer could be adopted as effective mitigation alternatives to control the environmental impacts of fertilization.

Many strategies have been developed to mitigate nutrient leaching and improve nutrient use efficiency. Timing of fertilizer application and manipulation of fertilizer rates are low cost strategies for reducing nutrient leaching so that nutrient supply is synchronized with plant nutrient demand (Worthington et al, 2007). Split application of nitrogen is one of the strategies of improving nitrogen use by the crops (Rens et al., 2015; Fandika et al., 2016). This research seeks to determine the effect of splitting varying levels nitrogen on the yield of potatoes. It is hypothesized in this research that splitting N fertilizer application increases fertilizer use by the crop, and increases tuber size, number and final yield.

MATERIALS AND METHOD

Site description and experimental design

The study was initiated at the research field Tuber crop sun-station Munsigonj, Bangladesh Agricultural Research Institute, Muunsigonj, Bangladesh during November 2014 to March 2015 cropping season to find out the proper urea application for potato production. The experiment was carried out in a randomized complete block design (RCBD) with 3 replications. Five different split application i.e: T_1=control (no urea),T_2=Two splits(1/2 nitrogen at 10DAP and 1/2at the 30DAP), T_3=Two splits(1/2 nitrogen at 15DAP and 1/2at the 45DAP) T_4=Three splits($^1/_3$ nitrogen at 10 DAP , $^1/_3$ at the 30 DAP and $^1/_3$ at the 50 DAP), T_5=Four splits ($^1/_4$ nitrogen at 5 DAP , $^1/_4$ at the 20 DAP, $^1/_4$ at the 35 DAP and$^1/_4$ at the 50 DAP) along with T_6= existing practice (FRG, 2012) of two splits (½ nitrogen as basal and ½ 30DAP) with 3 replications. The study area is located at 23°49' N latitude and 90°41' E longitude with 16 m above mean sea level. The soils of this region are moderately acidic, low in organic matter content. Overall, the fertility level is low to medium, but the status of K and CEC is medium in most of the places. The land was well prepared by tractor driven disc plough followed by laddering. The experiment was conducted on 28 November, 2014 with variety Diamant at the research field of the Tuber Crops Research Sub Centre, Munshigong during 2014-2015 potato growing season.

Crop management

Well-sprouted tubers were planted in the furrows as per treatment. The source of N, P, K, S and B was urea, triple super phosphate, murate of potash, gypsum and boric acid, respectively. Applied fertilizers and planted tubers were covered with soils properly making a ridge. Then two furrows at a depth of 5-6 cm were made 10-12 cm apart from furrow having planted tubers where except N and all other fertilizers applied. The crop was planted on 28 November in 2014 and maintaining 60 cm X 25 cm plant spacing. Weeding was required once to keep the plots weed free. Irrigations were provided at stolonization (22-23 days after planting (DAP), tuberization (33-35 DAP) and bulking (55-56 DAP) period, respectively. Earthing up was done once followed by top dressing of remaining N was applied as per treatment. Preventive measures were taken to control virus and blight diseases applying appropriate insecticides and fungicides. Carbofuran 5 G at the rate of 15 kg $ha^{-1}$was applied in furrows (depth 5-6 cm) to control cut worm. Mancozeb, Mancozeb+ Metaloxil and Malathion applied at the rate of 2 kg, 1.5 kg and 1 L, respectively. Mancozeb, Mancozeb+ Metaloxil was applied twice while malathion was applied four times. Plants were dehaulmed at 100 DAP and tubers were harvested at 7 days after dehaulming.

Data collection and statistical analysis

After maturing randomly 5 plants were harvested to record the yield and yield contributing characters of potato. Tuber yield was harvested from randomly pre-selected central areas (about 9 m^{-2}) of each plot and converted into tons per hectare (t ha^{-1}). Mean data was analyzed statistically and was carried out to analysis of variance (ANOVA) using the MSTAT-C (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of potato plant character under split application of N fertilizer

That plant height (cm) at 60 days after planting (DAP) and % foliage coverage differed significantly but days to start emergence, did not differ significantly by different split application of urea-N (Table 1). In case of plant height was significantly differed and the tallest plant (67.63cm) was produced by the treatment T_6 existing practice of two splits (½ nitrogen as basal and ½ 30 DAP) and the control T_1 gave the shortest plant 54.00 cm in the studied treatments. The maximum % foliage coverage at 60 DAP (98.33%) was found in treatment T_5 and the minimum (80%) was in the treatment T_1 and T_2.

Yield performance of potato under spilt application of N fertilizer

Effect of treatment of split application of urea-N on the yield and yield contributing characters were presented in the table 2. It was revealed that all of the parameters were significantly influenced by the treatment application except dry matter that were presented in the table-2. Number of stem per hill, number of tuber/hill and tuber yield t/ha were significantly varied, and the treatment T_4 gave the maximum (6.93) number of stem per hill which was statistically different from the other treatment.

Table 1
Plant characters of influenced by the split application of urea- N during 2014- 2015 at Munshigonj.

Treatment	Days to start emergence	Plant height (cm) at 60 DAP	Foliage coverage at 60 DAP (%)
T_1) control (no urea)	14.00	54d	80c
T_2) Two splits (1/2 Nitrogen at 10 DAP and ½ at the 30 DAP)	14.00	57.04bc	80c
T_3) Two splits(1/2 nitrogen at 15 DAP and ½ at the 45 DAP)	13.67	56.33cd	83.33c
T_4) Three splits ($^1/_3$ nitrogen at 10 DAP , $^1/_3$ at the 30 DAP and $^1/_3$ at the 50 DAP),	13.33	56.32cd	85bc
T_5) Four splits ($^1/_4$ nitrogen at 5 DAP , $^1/_4$ at the 20 DAP, $^1/_4$ at the 35 DAP and $^1/_4$ at the 50 DAP)	14.0	59.53b	98.33a
T_6) Existing practice (FRG, 2012) of two splits (½ nitrogen as basal and ½ 30 DAP)	14.00	67.73a	91.67ab
CV (%)	3.49	2.52	4.80
Level of significance	NS	**	*

Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT; DAP=Days after planting

Table 2
Effect of integrated nutrient combination on yield & yield contributing characters and dry matter (%) during 2014-2015 at Munshigonj.

Treatment	Number of Stem hill^{-1} at 60 DAP	Number of tuber hill^{-1}	Tuber Yield (t ha^{-1}) at 90 DAP	Dry matter percent at 90 DAP
T_1) control (no urea)	3.68c	7.69b	22.58c	19.08
T_2) Two splits (1/2 nitrogen at 10 DAP and ½ at the 30 DAP),	5.6b	8.41ab	28.27b	18.94
T_3) Two splits (1/2 nitrogen at 15 DAP and ½ at the 45 DAP)	4.57bc	8.73a	29.92b	19.19
T_4) Three splits ($^1/_3$ nitrogen at 10 DAP , $^1/_3$ at the 30 DAP and $^1/_3$ at the 50 DAP),	6.93a	8.92a	31.04b	18.76
T_5) Four splits ($^1/_4$ nitrogen at 5 DAP , $^1/_4$ at the 20 DAP, $^1/_4$ at the 35 DAP and $^1/_4$ at the 50 DAP)	4.61bc	9.06a	35.75a	19.8
T_6) Existing practice (FRG,2012) of two splits (½ nitrogen as basal and ½ 30 DAP)	5.13b	8.75a	32.43ab	19.16
CV (%)	14.31	4.99	7.34	3.22
Level of significance	*	*	**	NS

Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT.

Table-3
Effect of treatment combinations on the tuber grading.

Treatment	% of Grading by Number			% of Grading by Weight		
	<28mm	28-55mm	>55 mm	<28mm	28-55mm	>55mm
T_1	16.92	80.15	2.67	2.34	88.35a	9.91
T_2	14.86	82.98	2.15	2.36	86.64a	10.98
T_3	13.96	83.43	3.61	2.59	84.53a	12.88
T_4	17.1	80.94	1.95	2.7	86.78a	10.41
T_5	15.38	82.17	2.33	2.75	79.33b	17.93
T_6)	15	80.06	4.93	2.61	84.72a	12.66
CV (%)	14.18	2.50	41.37	15.20	3.17	22.97
Level of significance	ns	ns	ns	ns	*	ns

Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT.

The Treatment T_5 produce the highest number of tuber (9.06) per hill which is statistically same with T_4 & T_3 and the lowest was found in T_1. The highest tuber yield was obtained from T_5 treatment (35.75 t/ha) which was similar with treatment T_6. The lowest was recorded from T_1 (22.58t/ha) treatment. In case of dry matter percentage the highest dry matter percentage 19.8% was recorded in the treatment T_5 and the lowest dry matter percentage18.76% was recorded in the treatment T_4 three splits ($^1/_3$ nitrogen at 10 DAP , $^1/_3$ at the 30 DAP and $^1/_3$ at the 50 DAP).

Effect of tuber grading under split application of N fertilizer

From the table 3 it was revealed that grading of tuber by number and weight percentage affected by the treatment combinations. In case of grading of tuber by weight percentage for 28-55 mm sized tuber was varied significantly. The treatment T_1 (control) shown the maximum weight percentage i.e. 88.35% which was statistically similar with treatment T_4 86.78%, followed by T_2 (86.64%), T_3 (84.53%) and treatment T_5 four splits ($^1/_4$ nitrogen at 5 DAP, $^1/_4$ at the 20 DAP, $^1/_4$ at the 35 DAP and$^1/_4$ at the 50 DAP) produced the minimum weight percentage i.e.79.33% from the same sized tubers. In case of size >55mm the highest weight percentage (17.93) was produced by the Treatment T_5 and the lowest was found in control T_1 treatment (9.91%) from the same grade.

Balanced nutrient management application significantly increased potato yield compared to the unbalanced treatment (Ferdous et al. 2011a, b; Ferdous et al. 2014; Ferdous et al., 2017). Achieng et al. (2010) and Rahman et al. (2011) found that the used of balanced fertilization increased yields as compared with control treatments. Abebe et al. (2013) and Detchinli and Sogbedji (2015) documented similar performance of the mineral fertilizer, and Ferdous et al. (2011a,b) concluded that application of combined nutrient management is the best combination for sustainable potato yield. Both, limited or excessive N can lead to decreased tuber size (Ojala et al., 1990). Ferdous et al. (2005) and Hasan et al. (2006) found that split application of N fertilizer gave higher yield in wheat cultivation of Bangladesh. Anowar *et al.* (2012) who reported highest gross margin was found with combination of organic and inorganic fertilizer application at Rangpur region in Bangladesh.

The results of our study indicate that there is the potential to increase the productivity of potato in the Agro-Ecological Zone-9 of Bangladesh. The split application of N fertilizer approach resulted in higher potato productivity well as higher rates of economic return under farmers field condition. Split application of N fertilizer played a significant role in increasing the productivity of potato as well as reduced the loss of N fertilizer. This study also indicates that without proper application of N fertilizers for potato cultivation in the AEZ-9 of Bangladesh could not maintain soil fertility and crop productivity.

CONCLUSION

By considering different plant characters and yield contributing characters the treatment $T_5 =$ Four splits ($^1/_4$ nitrogen at 5 DAP, $^1/_4$ at the 20 DAP, $^1/_4$ at the 35 DAP and $^1/_4$ at the 50 DAP) could be the most useful combination for potato cultivation . From this result, it was evident that split application of N management has a great potentiality for maximizing potato production and economic return of the farmer.

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