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Yield maximization of potato (*Solanum tuberosum* L) through integrated nutrient management system

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ABSTRACT

The increasing food demands of a growing human population and the need for an environmentally friendly strategy for sustainable agricultural development require significant attention when addressing the issue of enhancing crop productivity. Here we discussed the role of integrated nutrient management (INM) in resolving these concerns, which has been proposed as a promising strategy for addressing such challenges. INM has multifaceted potential for the improvement of plant performance and resource efficiency while also enabling the protection of the environment and resource quality. 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 investigate nutrient dynamics, potato yields and soil fertility in response to balanced fertilization. A field experiment was conducted at the research station of the Tuber Crops Research Sub Centre (TCRSC), Munshiganj during 2012-2013 to evaluate Maximizing potato production through nutrient management. Six treatments viz. T_1= Control, T_2= 100% Recommended Dose, T_3=Poultry manure + Recommended chemical fertilizer, T_4=Cowdung manure + Recommended chemical fertilizer, T_5= Poultry manure + 70% Recommended chemical fertilizer and T_6= Cowdung manur+70% Recommended chemical fertilizer were evaluated for this purpose. The results indicated that the highest tuber yield (36.48 t/ha) was found from T_4= Cowdung manur+ Recommended chemical fertilizer treatment. The lowest tuber yield (7.33 t/ha) was obtained from T_1=Control treatment. Various approaches and perspectives for further development of INM in the near future are also proposed and discussed. Strong and convincing evidence indicates that INM practice could be an innovative and environmentally friendly strategy for sustainable agriculture for developing countries like Bangladesh.

INTRODUCTION

The rising population and consumption, and reduction in available land and other productive units are placing unprecedented pressure on the current agriculture and natural resources to meet the increasing food demand. Achieving food security under sustainable systems poses a significant challenge in the developing world and is highly critical for alleviating poverty. To circumvent this challenge, crop producers tended to overuse certain inputs such as chemical fertilizers and pesticides which in turn have already started deteriorating environment. To meet the world's future food security and sustainability needs, food production must grow substantially while agriculture's environmental impact must shrink dramatically at the same time (Foley et al., 2011).

Potato is most important vegetable crop in Bangladesh. It is also used as food and cash crop in cool countries. It can meet vegetable demand and provide necessary nutrients for the people of the low income group (Islam et al., 2009; Hossain and Miah, 2012). The average yield of potato in

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Bangladesh is 18.25 t ha^{-1}, which is much below the crop potential productivity (BBS, 2010). Potato crop has strict requirement for a balanced fertilization, without which growth and development of the crop are poor and both yield and quality of tubers are diminished. Yield can be increased by the improved production agro technologies, involves manure and fertilization. Current fertilization rates are insufficient to sustain high yields and to replenish nutrient removal by the crop (Imas and Bansal, 2012). Potato yield could be increased by 50% only by improved nutrient management (Zhang et al., 2012). Great opportunities exist to increase potato yield and quality by improving nutrient management. Growing healthy potatoes for maximum yield and quality requires that all the essential nutrients be supplied at the right rate, the right time, and the right place (Roberts, 2007). For potatoes, either deficient or excessive plant nutrition can reduce tuber bulking and quality. Nutrient deficiencies may limit the leaf canopy growth and its duration, resulting in reduced carbohydrate production and tuber growth. Maintaining healthy leaves is a key to producing high yields. However, excessive nutrient applications may cause nutrient imbalances or over-stimulate vegetative growth at the expense of tuber production. Some nutrients, such as S, may also have indirect yield benefits by reducing tuber disease. One of the major challenges in potato production is the efficient management of nitrogen (N) fertilizer. Excessive N fertilizer applied at or before tuber setting can extend the vegetative growth period and delay tuber development, resulting in a lower tuber yield. However, too much N applied later in the season can delay maturity of the tubers, reducing yield and adversely affecting tuber quality. Thus, it is a high time to search for innovative practices which can guarantee higher yields with minimal further deterioration of our environment, especially for developing countries. Nutrient overuse for tuber crops is particularly dramatic in some developing countries (Mueller et al., 2012). Decreasing chemical input by balanced fertilization and nutrient management options can significantly minimize its use and subsequently reduce GHG emissions (Zhang et al. 2012). Thus, promising strategies with less environmental impact to reduce the GHG emissions is in line with future needs. Although science-based agricultural research studies have made considerable contributions to crop genetics and thus boosted both the quantity and quality of the global food supply (Wu et al., 2014), the actual yields of farmers' fields are typically less than one-third of the potential yields found in many field studies (Mueller et al., 2012). In addition, in many regions of the world, agricultural production increases have been accompanied by a significant degradation of natural resources, including soil nutrient and organic carbon depletion. Following global change, other negative impacts on agricultural lands appear to be further increasing (Bruinsma, 2009).

Low fertilizer use and imbalanced nutrient application are partially responsible for low tuber yields and quality of potato. Potatoes are a shallow-rooted crop, generally growing on sandy, well-drained soils. These soil conditions frequently make water and N management difficult since nitrate is susceptible to leaching losses. On these sandy soils, it is recommended that potatoes receive split applications of N during the growing season. On the other hand, organic matter content of most of the Bangladesh soils is very low, the majority being below the critical level (<1.5%) (Anowar et al., 2015). Organic fertilizers such as animal manures and/or organic compost are alternative fertilizer sources. Several studies indicated that combined use of chemical fertilizer with manure could increase tuber yield and economic returns compared with fertilizer or manure alone (Parmar et al., 2007; Ferdous et al. 2011a,b; Rahman et al. 2011; Sarker et al. 2010).

Integrated management of nutrients (INM) may harness such discrepancies through maintenance or adjustment of soil fertility/productivity and of optimal plant nutrient supply for sustaining the desired level of crop productivity (FAO, 1995). Supplementation of fertilizers through manures and inorganic fertilizers were observed to augment yield and productivity (Mal et al.,2014; Ferdous et al. 2014;Anwar et al. 2012) of potato through improvement of soil health and fertility in a sustainable manner (Ferdous et al. 2011a,b; Rahman et al. 2011; Sarker et al. 2010; Manivannan et al., 2009; Hasan et al. 2006). INM can thus be considered an effective agricultural paradigm to ensure food

security (Ferdous et al. 2016) and improve environmental quality worldwide, especially in countries with rapidly developing economies. Balanced fertilization is a prerequisite for getting optimum yield potential of HYV potato. Sustainable production of potato cannot be retained by using chemical fertilizers alone because of deterioration in soil physical and biological environments (Khan et al., 2008). However, integrated use of both organic manure and chemical fertilizers are the best approach in providing greater stability in production and improving soil fertility status. Proper nutrient management for increasing productivity and sustaining fertility may be explored to face the crisis ahead. Keeping this in consideration, the present investigation has been undertaken to assess the efficiency of integrated nutrient management and improving the productivity of potato.

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 2012 to March 2013 cropping season to find out the nutrient management for potato production. The experiment was carried out in a randomized complete block design (RCBD) with 3 replications. Six treatments viz. T_1= Control, T_2= 100% Recommended Dose, T_3=Poultry manure + Recommended chemical fertilizer, T_4=Cowdung manure + Recommended chemical fertilizer, T_5= Poultry manure + 70% Recommended chemical fertilizer and T_6= Cowdung manure +70% Recommended chemical fertilizer were evaluated 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 29 November, 2012 with variety Diamant at the research field of the Tuber Crops Research Sub Centre, Munshigong during 2012-2013 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 29 November in 2012 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 fertilizer. 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 different nutrient management

All the plant characters of potato as affected by different nutrient management treatments are presented in Table 1. Number of stem per hill, days to start emergence and foliage coverage did not differ significantly by different combination of organic manure and chemical fertilizers but the Plant height was significantly differed from other treatments. The tallest plant was (64.63 cm) found from T_2 treatment followed by T_6 and the shorter plant was recorded from control treatment.

Table 1
Plant characters which influenced by the integrated nutrient combination during 2012- 13 at Munshigong, Bangladesh.

Treatment	Days to start emergence	Plant height (cm) at 60 DAP	Foliage coverage at 60 DAP (%)	No. of stem/hill at 60 DAP
T_1(Control)	14.00	55.70 c	90	5.67
T_2 (100%RD)	14.00	64.63 a	100	5.43
T_3(PM+RCF)	13.67	57.02bc	100	4.37
T_4(CD+RCF)	13.33	59.25bc	100	4.60
T_5(PM+70%RDF)	14.00	56.87bc	100	5.40
T_6(CD+70%RDF)	14.00	60.1b	100	5.27
CV (%)	3.49	3.27	0.00	13.38
Level of significance	NS	**	NS	NS

DAP= Days after planting, RD=Recommended Dose, PM= Poultry Manure, CD=Cowdung, RCF= Recommended chemical fertilizer, Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT

Yield performance of potato under different nutrient management

The highest number of tuber hill^{-1} (9.9) was obtained from T_1= Control followed by T_2= 100% Recommended Dose, T_4=Cowdung manure + Recommended chemical fertilizer and T_6= Cowdung manur+70% Recommended chemical fertilizer and the lowest number of tuber hill^{-1} was recorded from T_5= Poultry manure + 70% Recommended chemical fertilizer treatment. The highest weight of tuber hill^{-1} (0.529 kg) was obtained from T_6= Cowdung manur+70% Recommended chemical fertilizer followed by T_4 and the lowest weight of tuber hill^{-1} (0.391 kg) was obtained from T_1= control treatment (Table 2). Agronomic management practices had significant effects on potato yield over the 2012-2013 study periods. The Treatment T_4=Cowdung manure + Recommended chemical fertilizer produced the heaviest tuber 0.557 kg/hill which is statistically similar with T_3=Poultry manure + Recommended chemical fertilizer (0.54 kg/hill), T_6= Cowdung manur+70% Recommended chemical fertilizer (0.53 kg/hill) and T_5= Poultry manure + 70% Recommended chemical fertilizer (0.48 kg/hill). The highest tuber yield (36.48 t ha^{-1}) was obtained from T_4=Cowdung manure + Recommended chemical fertilizer which is significantly differ from other treatment and the lowest tuber yield (25.68 t ha^{-1}) was recorded from T_1= Control treatment.

Effect of dry matter production of potato influenced by the different nutrient management

Dry matter production of potato influenced by the different nutrient management during 2012-13 presented in table 2. In case of dry matter percentage the highest dry matter percentage 20.57% was recorded in the treatment T_2= 100% Recommended Dose which was statistically similar with T_1= Control and T_6= Cowdung manur+70% Recommended chemical fertilizer. The lowest dry matter percentage 18.70% was recorded in the treatment combination T_4=Cowdung manure + Recommended chemical fertilizer.

Table 2
Effect of integrated nutrient management on yield & yield contributing characters and dry matter (%) during 2012-13 at Munshigong, Bangladesh.

Treatment	No. of tuber /hill	Weight of tuber / hill (kg)	Tuber Yield (t/ha) at 90 DAP	Dry matter percent at 90 DAP
T_1(Control)	9.90a	0.391b	25.68d	20.23a
T_2 (100%RD)	9.46ab	0.513a	33.43bc	20.57a
T_3(PM+RCF)	8.77b	0.537a	34.43b	20.24a
T_4(CD+RCF)	9.27ab	0.557a	36.48a	18.70b
T_5(PM+70%RDF)	7.47c	0.476a	31.58c	19.38ab
T_6(CD+70%RDF)	9.43ab	0.529a	34.31b	20.16a
CV (%)	5.89	8.29	8.50	3.13
Level of significance	**	**	*	*

DAP= Days after planting, RD=Recommended Dose, PM= Poultry Manure, CD=Cowdung, RCF= Recommended chemical fertilizer, 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 integrated nutrient management on the tuber grading of potato during 2012-13 at Munshigong, Bangladesh.

Treatment	% of Grading by Number			% of Grading by Weight		
	<28mm	28-55mm	>55 mm	<28mm	28-55mm	>55mm
T_1(Control)	11.22	88.29	0.67c	2.153a	95.88a	2.01c
T_2 (100%RD)	6.38	91.42	2.19b	0.82bc	91.26bc	7.91b
T_3(PM+RCF)	9.47	88.17	2.34b	0.77bc	91.51bc	7.69b
T_4(CD+RCF)	7.66	90.33	1.99b	1.59ab	91.96b	6.32b
T_5(PM+70%RDF)	6.27	90.21	3.51a	0.62c	87.99c	11.38a
T_6(CD+70%RDF)	5.99	91.09	2.71ab	0.58c	94.49ab	4.92bc
CV (%)	31.87	3.23	27.42	45.04	2.13	25.01
Level of significance	ns	ns	**	*	**	**

RD=Recommended Dose, PM= Poultry Manure, CD=Cowdung, RCF= Recommended chemical fertilizer, Means followed by the same or no letter in the same column do not differ significantly each other at the 5% level by DMRT.

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Effect of tuber grading under different nutrient management

Tuber grading of potato influenced by the different nutrient management during 2012-13 presented in table 3. The highest number of tuber size was (3.51 mm) found in T_5= Poultry manure + 70% Recommended chemical fertilizer at the >55mmsize of tuber followed by T_6= Cowdung manur+70% Recommended chemical fertilizer treatment and the lowest was obtained from control treatment at the >55mmsize of tuber.

Grading of tuber by weight percentage for all sized tuber was varied significantly. The heaviest tuber was found in T_5= Poultry manure + 70% Recommended chemical fertilizer at the >55mmsize of tuber followed by T_2, T_3, T_4 treatment and the lowest was obtained from control treatment. In case of size of <28mm the control T_1 gave the maximum weight % (2.2%) which was significantly differed from other treatments. The treatment T_6 shown the minimum weight % (0.58%). In case of tuber size 28-55mm the treatment T_5 shown the maximum weight % (95.88%) which is statistically similar with treatment T_6 (94.49%) followed by the treatment T_4 (91.96%) and the control produced the minimum weight % (87.99%) of same sized tubers.

Balanced nutrient management application significantly increased potato yield compared to the unbalanced treatment (Table 1, 2 & 3). Agronomic management practices had significant effects on potato yield over the 2012-2013 study periods. The authors attributed the yield decline to imbalanced and inadequate nutrient application by farmers. Besides, the current nutrient use in the high input crop systems indicates imbalance plant nutrition with very high use of N and less use of P and negligible use of K fertilisers and micro nutrients. This has led to nutrient imbalances in soils and lower nutrient use efficiency and economic profitability (Datta et al. 2015; Detchinli and Sogbedji, 2015). This warrants adequate and balanced use of plant nutrients not only for specific farm and ecology but also in production systems using fertilizer best management practices adapted to local situations and farm typologies to achieve better efficiency and nutrient stewardship. Achieng et al. (2010) found that the used of balanced fertilization increased crop yields 108 to 103% higher 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. (2005, 2011a,b, 2014) concluded that application of combined nutrient management is the best combination for sustainable crop yield. Ferdous et al. (2011a, b) who reported highest gross margin was found with combination of organic and inorganic fertilizer application at Rnagpur region in Bangladesh. Similar result was reported by Sarker et al. (2010) and Rahman et al. (2011) who report highest gross margin with combination of poultry bio slurry and inorganic fertilizer application.

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 simultaneous use of chemical fertilizer and organic manure approach resulted in higher potato productivity well as higher rates of economic return under farmers field condition. Among these treatments with Cowdung manure + Recommended chemical fertilizer gave the highest yield and economic return. Organic manure played a significant role in increasing the productivity of potato as well as increases the farmers' income. This study also indicates that the use of chemical fertilizers alone in potato cultivation in the AEZ-9 of Bangladesh could not maintain soil fertility and crop productivity, but can be improved and sustained through the combined use of fertilizers and manure (i.e., the integrated nutrient management system approach).

CONCLUSION

Results from this research indicate that there is considerable opportunity to modify fertilizer rates for potato production in Bangladesh. The higher yield of potato was obtained from T_4= Cowdung manure + Recommended chemical fertilizer at Munsiganj in 2012-2013. Balanced nutrient management compensated N, P and K requirement of the crops and showed its higher economic performance hence, it may be concluded that proper nutrient management may be the good alternatives for maximizing potato yield and management of soil health at AEZ-9 in Bangladesh.

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