Effect of Commercial Organic Fertilizers on Potato (*Solanum tuberosum* L.) Tuber Production in Sandy Loam Soil

ABSTRACT

Potato crop has strict requirement for organic manure, without which growth and development are poor and yield is remarkably reduced, continuing with deterioration in soil health. The experiment was conducted under sub-tropical condition in order to evaluate the effect of four organic fertilizers on growth and yield of potato. The treatments were: two cultivars *viz*., Cardinal and Diamant and four organic fertilizers *viz*., cowdung at the rate of 8 t ha^{-1}, chicken manure at the rate of 8 t ha^{-1}, RDRS organic fertilizer at the rate of 740 kg ha^{-1} and Northern organic fertilizer at the rate of 500 kg ha^{-1} along with a control. The results revealed that the morphophysiological, yield attributes and yield were significantly higher in organic fertilizers than control. The highest plant height, leaf number, leaf fresh weight, total dry matter, absolute growth rate, tuber growth rate, tuber number plant^{-1} and larger tuber size were observed in chicken manure which resulted the highest tuber yield (29.71 t ha^{-1}) followed by cowdung (28.67 t ha^{-1}) with same statistical rank. The third highest tuber yield was recorded in RDRS organic fertilizer (26.42 t ha^{-1}) and Northern organic fertilizer (26.00 t ha^{-1})). In contrast, control produced the lowest tuber yield (16.60 t ha^{-1}) due to production of fewer numbers of tuber plant^{-1} and fewer number of large tuber. Among the organic fertilizers, chicken manure gave the highest net income as well as benefit-cost ratio and marginal rate of return whilst control gave the lowest. Cowdung organic fertilizer being second in performance of both yield and economic return can also be promoted as an alternate organic fertilizer if chicken manure is not readily available on commercial basis.

Key words Organic fertilizer, Growth, Tuber yield, Marginal rate of return and Potato

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important food crops of the world and holds the fourth position in production next to wheat, rice and maize (FAO 2015). In Bangladesh, potato is one of the major crops next to rice and wheat and covers an area of about 403.4 thousand hectare of land producing 5.95 million tons of potato with 24.74 tons of average yield per hectare (BBS 2015). It is considered as a vegetable crop and contributes as much 55 % of the total vegetable production in Bangladesh (BBS 2015). The area and production of potato in Bangladesh has been increasing during the last decades but the yield per unit area remains more or less static. Despite it important as a food crop, the productivity of these crops is becoming low mainly due to poor soil fertility of the most arable field (Islam et al. 2013). Most of the soils of Bangladesh have less than 2% and in some cases especially in the northern region of Bangladesh less than 1% organic matter (BARC 2012). This may be due to favourable climatic condition for microbial activities throughout the year, frequent tillage operations, huge use of chemical fertilizers and intensive crop cultivation. Again, the recycling of organic materials to soil through farmyard manures, composts and organic residues has been reduced considerably because rural people use a large portion of these organic residues as fuel. Continuous use of chemical fertilizers for long period of time may accelerate the depletion of soil organic matter in addition to causing micronutrient deficiencies. Urea depleted the organic matter content in soils as first discovered by Satter (1972). Organic fertilizers play important role in soil fertility, soil structure improvement, erosion control and supply of wide range of nutrients (Hossain et al. 2003; Jahiruddin et al. 2012; Haliru et al. 2015). Most recently, attention is focused on the global environmental problem to reduce the use of fertilizers and thus recycling of crop residues have become important issues. Organic farming is more sustainable to avoid environmental pollution and at the same time to obtain higher and sustained yield (Mondal et al*.* 2016). The problems including nutrient deficiencies as well as nutrient mining caused by intensive cropping with modern varieties and nutrient imbalance can be minimized by judicious application of nutrients through manure and or fertilizers. To obtain optimum yields and to maintain good soil health, an integrated organic-inorganic fertilizer approach for all crops is urgently needed for Bangladesh soils. It is, therefore, of paramount importance that our soils should be manured carefully so that they will be preserved in a healthy and fertile state for generation after generation. Islam et al. (2013) worked with different manures on potato and reported that application of chemical fertilizers along with manures improved soil health as well as increased yield of potato. Similar result was also reported by Adeyeye et al. (2016) in sweet potato and in potato (Djilani and Senoussi 2013). The favourable effect of organic matter is reducing erosion, increasing water holding capacity and physico-chemical conditions of the soil is well known. Now a day, there is growing awareness among the scientists in various parts of the world regarding the problems of environmental pollution through use of chemicals in crop production. As an alternative to chemicals, scientists in the world are trying to develop various manure-fertilizers for reducing environmental pollution and for obtaining pollution free crop products, especially vegetables. In this contest, some private farm already produced and marketing manure- fertilizers. In Bangladesh, two-company *viz*., RDRS and Northern Fertilizer declared that they have produced manure- fertilizer, which increases vegetable yield as well as increases soil quality. There is no information on the effect of the above two manure fertilizers on yield of potato in the northern region of Bangladesh. Hence there is a need to compare their effectiveness and usefulness in potatoes production. Thus, the present study was undertaken to study the growth and yield of potato as influenced by different organic fertilizers; and to select which organic fertilizer is more suitable for getting higher yield economically for potato production in the northern region of Bangladesh.

2. MATERIALS AND METHODS

2.1 Description of the study area

The experiment was carried out at the farmer's field of Rangpur district during the period from November 2015 to February 2016. Geographically the experimental area is located at 25^0 45 N latitude and $89^0$12 E longitudes. The soil was sandy loam. Some physical and chemical properties of the experimental soil collected from a depth of 0-15 cm prior to the application of fertilizer were analyzed. Chemical characteristics of the collected soil were determined by Hunter (1984) method. The soil was slightly acidic (pH 6.4), low in fertility status having organic matter 0.90%, available NH_4-N 65 µg g^{-1}, phosphorus 18 µg g^{-1}, potassium 0.15 meq100g^{-1}, available sulphur 10 µg g^{-1}, boron 0.16 µg $g^{-1}$and zinc 1.6 µg g^{-1}.

2.2 Planting material

Two popular potato varieties *viz.,* Cardinal and Diamant were used in the experiment. Cardinal and Diamant are high yielding varieties released in 1993 by BARI for commercial cultivation throughout the country (BARI 2014). The characteristics of Cardinal and Diamond are tuber oval shape, skin smooth with red colour, the tuber size of Cardinal is medium size whereas tuber size of Diamond is medium to large. The yield capacity of these two variety is 25-30 tons ha^{-1} (BARI 2014).

2.3 Experimental design and treatments

The experiment consists of two factors such as variety and different organic fertilizers. The experiment was laid out in a Split Plot Design with three replications where cultivars were placed in main plot and organic fertilizers placed in sub-plot. The size of the unit plot was 4.0 m $\times$ 4.0 m. The treatments were: Factor A: Varieties (Cardinal and Diamant) and Factor B: Organic fertilizers such as (i) No organic fertilizer (control), (ii) Cowdung at the rate of 8 t ha^{-1}, (iii) Poultry manure at the rate of 8 t ha^{-1} (iii) RDRS organic fertilzer at the rate of 750 kg ha^{-1} and (iv) Northern organic fertilizer at the rate of 500 kg ha^{-1}. The nutritive contents of different organic manures used are shown in Table 1.

2.4 Manure and fertilizer application

Cowdung, chicken manure, RDRS organic fertilizer and Northern organic fertilizer were applied at the rate of 10, 10, 0.75 and 0.50 t ha^{-1}, respectively. The rate of RDRS organic fertilizer and Northern organic fertilizer were recommended by the producing company. Urea, triple super phosphate (TSP), muriate of potash (MP), zypsum, zinc sulphate and borux were used as sources of nitrogen, phosphorus, potassium, sulphur, zinc and boron, respectively. The doses of fertilizers were: urea 320, TSP 232, MP 275, gypsum 120, $ZnSO_4$ 10 and boron 10 kg ha^{-1} (BARC 2012). Total amount of cowdung, poultry manure, RDRS organic fertilizer, Northern organic fertilizer, TSP, gypsum, $ZnSO_4$, borax and half of urea and MP were applied at basal doses during final land preparation. The remaining 50% urea and MP were side dressed in two equal splits at 25 and 45 days after planting (DAP) during first and second earthing up, respectively. The cost of fertilizer and gross return were calculated considering the following rates of fertilizer: Taka (Tk) 16.00 kg^{-1} urea, Tk. 22.00 kg^{-1} TSP, Tk. 15.00 kg^{-1} MP, Tk. 12.00 kg^{-1} gypsum, Tk. 300.00 kg^{-1} ZnSO4, Tk. 280.00 kg^{-1} borux, Tk. 0.80 kg^{-1} CD, Tk. 1.00 kg^{-1} PM, Tk. 25 kg^{-1} RDRS organic fertilizer and Tk. 30 kg^{-1} Northern organic fertilizer. The potato tuber rate was Tk. 12.00 kg^{-1}.

2.5 Planting of seed tubers

The seed tubers after collection from storage room were kept in a ventilated room and allow to sprout in diffused light for obtaining healthy and good sprouts. Well sprouted whole seed tubers were cut into pieces maintaining 3-4 eyes per piece. The average weight of the cut seed piece was recorded at 35 g. The seed tubers were planted on 15 November 2015 in row furrows maintaining a spacing of 60 cm × 25 cm. The depth of the planting was approximately 5-7 cm. Immediate after planting the seed tubers were covered with soil.

2.6 Intercultural operations

At 25 DAP the crop was irrigated lightly so that uniform growth and development of the crop was occurred and also moisture status of soil retained as requirement of plants. The second irrigation was done at 45 DAP. Weeding was done manually twice at 25 and 45 days after planting to keep the crop free from weeds. The earthing up was done twice during the growing period of the potato tubers. The first earthing up was done at 25 days after planting and the second earthing up was done at 45 days after planting, which was proceeded by side dressing of the remaining urea and MP fertilizer. Furadan 5G a thev rate of 15 kg ha^{-1} was applied at final land preparation to prevent the crops from the soil insects especially cutworm. Ripcord and Diathan M-45 were applied 15 days interval from 30 DAP to 75 DAP as a preventive measure for controlling virus and fungal disease (early and late blight).

2.7 Parameters measured

The crops were periodically harvested to study growth and development rate from 45 DAP to 85 DAP at 10 days interval and the final harvest was taken at 90 days of planting. The second rows from the border of each plot were used for sampling. Five plants were randomly selected from each plot and uprooted for collecting leaf area, straw and tuber weight. The plants were separated into roots, stems, leaves and tubers, and the corresponding dry weight were recorded after oven drying at 80 ± 2 ^{0}C for 72 hours. Absolute growth rate and tuber growth rate were determined following the method of Hunt (1978). At harvest, ten plants from each plot were selected randomly for data recording on yield and yield related traits. Tuber yield was collected from each plot and converted into tonnes per hectare. The grading of tubers were done as Grade A = > 55 mm in diameter, Grade B = >40-<55 mm in diameter, Grade C = >25-<40 mm in diameter, Grade D = <25 mm in diameter (Tabatabaeefar 2002).

2.8 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences among treatments were compared by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell 1986). Partial budget analysis and marginal analysis of undominated fertilizer response to bulb yield on average of two years were done following Elias and Karim (1984).

3. RESULTS AND DISCUSSION

3.1 Morphological parameters

The effect of different sources of organic fertilizers on plant height, number of leaves and leaf fresh weight plant^{-1} was statistically significant in potato (Table 2). The highest plant height, number of leaves and leaf fresh weight plant^{-1} was observed in chicken manure (CM) followed by cowdung (CD) with same statistical rank. In contrast, the shortest plant, lowest number of leaves and leaf fresh weight plant^{-1} was recorded in control plot where no organic fertilizer was added. Increased number of leaves in CM and CD added plot was consequence of greater plant growth (Fig. 1) might be due to uptake greater nutrients than the other ones. Baniuniene and Zekaite (2008) reported that the effect of cowdung on leaf production was greater than other composts in potato, which supported the present results. Further, Adhikari et al. (1992) worked with three manures (cowdung, poultry manure and oil cake) and reported that poultry manure along with NPK produced the highest tuber yield. Between two varieties, Cardinal showed longer plant, produced higher number of leaves and leaf fresh weight plant^{-1} than Diamont (Table 2). Leaf number was higher in Cardinal than Diamant might be due to Cardinal plant was taller than Diamant which possessed higher number of nodes plant^{-1}.

3.2 Growth parameters

Total dry matter (TDM) production plant^{-1} and single tuber weight (STW) was significantly affected by different organic fertilizers at different growth stages except 35 days after planting (DAP) (Figs. 1A and 2A). Result showed that TDM plant^{-1} and STW increased with age. The highest TDM plant^{-1} and STW was observed in CM applied plot at all growth stages followed by CD applied plot with same statistical rank. There was no significant difference between RDRS and Northern organic fertilizers in TDM production plant^{-1} and STW at all growth stages which indicated that both RDRS and Northern fertilizers have equal influence on growth and development of potato plant. In contrast, control plot produced the lowest TDM and STW at all growth stages. Lower TDM plant^{-1} and STW under non-organic fertilizer might be due to less availability of nutrients by the plants that causes lesser photosynthates production which resulted slow plant growth (Fig. 1B) as well as shorter plant height, thereby produced lower TDM plant^{-1}. Similar result was also reported by Ifenkwe et al. (1987) in potato. They observed that stem weight, leaf weight as well as TDM plant^{-1} increased under organic manure condition in potato. Use of organic manure in crop production may have many advantages over chemical fertilizers. BINA (2005) mentioned that farmyard manure reducing erosion, increasing water holding capacity and physico-chemical conditions of the soil which resulted higher plant growth and development and TDM yield. In the present experiment, similar phenomenon may be happened in this experiment.

The absolute growth rate (AGR) was determined from vegetative stage (45 DAP) to physiological maturity (85 DAP) and the results have been presented in Fig. 1B. Results revealed that AGR in all treatments was significantly different at all growth stages except at 35 DAP. The AGR increased untill 75 DAP and thereafter decreased with progress in maturity. The plants of chicken manure and cowdung application maintained the higher AGR value throughout the growth period. In contrast, the control plants maintained the lowest AGR over its growth period. Further, the maximum AGR was observed during tuber development stage in all the treatments. The AGR was higher in organic manure applied plant due to higher TDM (Fig. 1A). AGR is positively correlated with LAI because of TDM production depends on LAI (Mondal et al., 2011). The AGR increased along with increase in

LAI. The lower value of AGR at initial stages of growth was the result of lower LAI. This result is in agreement with the findings of Malek et al. (2012). At 65-75 DAP, the AGR value was found to be maximum which mean that plants expanded it's assimilate for the growth of leaf area and feeding of tubers. The declining of AGR after reaching the maximum in all treated plants was the result of abscission of leaves. These results are consistent with the results of Mondal et al. (2012). In case of tuber growth rate, similar result was also observed like AGR (Fig. 2B).

3.3 Yield attributes and tuber yield in potato

The number of tuber and tuber size significantly increased in organic manure added plot compared to control (Table 3). It means organic manures have effect for tuber production of potato. The highest number of tubers plant^{-1} and single tuber weight was observed in CM followed by CD with same statistical rank. The lowest number of tubers plant^{-1} and single tuber weight was recorded in control. The small size tuber in control plant might be due to lower tuber growth rate (Figs. 2A and 2B). Furthermore, the effect of RDRS and Northern organic fertilizer on tuber number and tuber size was statistically non-significant with each other and these two organic fertilizers influenced lesser on tuber production than CM and CD. The differential response among four organic fertilizers for tuber number and tuber size might be due to the fact that compost chicken and cowdung manure has capacity to release more nutrients (Table 1) than RDRS and Northern fertilizers, resulting higher tuber growth rate (Fig. 2B) occurred in CM and CD organic manure applied plant than RDRS and Northern fertilizers. Within organic manures, there was no significant difference with each other for single tuber weight. It means, these four organic manures *viz*. chicken manure, cowdung, RDRS and Northern organic fertilizer had equal influenced on tuber growth and development. Amara and Mourad (2013) reported that application of organic manures along with chemical fertilizers increased tuber size, which resulted increased tuber yield in potato. Further, Islam and Nahar (2012) reported that the effect of chicken manure on tuber production was greater than other composts in potato that supported the present results. Between two varieties, there was no significant variation regarding tuber production, tuber size and tuber yield hectare^{-1} (Table 3).

Tubers weight both plant^{-1} and hectare^{-1} was significantly affected by different organic fertilizers (Table 3). The tubers weight both plant^{-1} and hectare^{-1} was observed higher in organic fertilizer applied plot than control plot. The highest tubers weight both plant^{-1} and hectare^{-1} was observed in chicken manure followed by cowdung. In contrast, control produced the lowest tuber weight both plant^{-1} and hectare^{-1}. The commercial organic fertilizers, RDRS and Northern organic fertilizers stood third in tuber production plant^{-1}. Lower tuber weight both plant^{-1} and hectare^{-1} under non-organic fertilizer condition might be due to less availability of nutrients by the plants that causes lesser photosynthates production which resulted slow plant growth and produced fewer TDM plant^{-1} (Fig. 1A). Economic yield is strongly correlated with TDM production in field crops as reported by most of the workers (Mondal et al. 2012; Malek et al. 2012; Mondal et al. 2013; Fakir et al. 2014). Use of organic matter in crop production may have many advantages over chemical fertilizers. Carter et al. (2004) and Reeves et al. (2014) mentioned that farmyard manure reducing erosion, increasing water holding capacity and physico-chemical conditions of the soil which resulted higher plant growth and development, thereby tuber yield. In the present experiment, similar phenomenon may be happened.

The interaction effect of cultivar and organic fertilizer for tuber number plant^{-1} and single tuber weight was non-significant (Table 3). It means that the effect of different organic manures on tuber number plant^{-1} and tuber size was almost similar in two cultivars. The apparent highest number of tubers plant^{-1} (14.13), single truber weight and tuber yield both per plant and per hectare was observed in Cardinal × chicken manure followed by Cardinal × cowdung and the lowest/lower was recorded in control plot with any cultivar.

3.4 Tubers size distribution (by number)

The harvested tubers were categorized into four grades according to size by number *viz*., Grade A-tuber greater than 55 mm size, Grade B-tubers in between > 40 mm and < 55 mm in size, Grade C-tubers in between >25 mm and <40 mm in size and Grade D- tubers less than 25 mm. It was observed that there was no significant variation between two cultivars regarding tuber size grade distribution of the potato varieties except Grade-D (Table 4).

The effect of organic fertilizers on tuber size grade distribution was significant (Table 4). The higher number of Grade-A and Grade-B tuber was recorded in organic fertilizers compared to control with being the highest in chicken manure (Grade-A 11.93% and Grade-B 50.98%). On the other hand, the highest number of Grade-C and Grade-D was recorded in control (Grade-C 36.96% and Grade-D 23.10%). Das (2006) reported that the genotypes which produced higher number of large tuber, Grade-A and Grade-B also produced higher yield in potato. In the experiment, organic fertilizer applied plot produced higher number of Grade-A and Grade-B tuber and also produced higher yield in potato.

The interaction effect of cultivar and organic fertilizer on tuber grade distribution was significant (Table 10). The highest number of Grade-A tuber was recorded in Cardinal × Northern organic fertilizer (13.59%) and Grade-B in Cardinal × cowdung (54.86%). On the other hand, the highest number of Grade-C and Grade-D was recorded in control plot with any variety.

3.5 Partial budget analysis

Application of manures with chemical fertilizers had positive effect on economic return over control (Table 5). In general, CM added plots showed the highest benefit followed by CD added plots. Two commercial manures, RDRS and Northern fertilizer added plots showed lower benefit than control with being the lowest in RDRS. CM added plots showed higher benefit as compared to CD added plots due to greater yield performance of potato tuber. Amongst manures added plot, CM added plot had the highest benefit over control (1,53,320.00 Tk. ha^{-1}) followed by CD added plot (1,42,360.00 Tk. ha^{-1}). The lowest benefit over control was observed in RDRS organic manure added plot (97,770.00 Tk. ha^{-1}). Marginal benefit-cost ratio was the highest in CD added plot (11.07) followed by CM added plot (10.71). The lowest marginal benefit-cost ratio was observed in RDRS organic manure added plot (7.01) followed by Northern organic fertilizer added plot (7.93).

Marginal analysis of undominated fertilizer response data recorded the highest marginal rate of return in CM added plots (5.48 %) followed by CD added plot (4.63 %) (Table 5). The lowest marginal rate of return was observed in RDRS organic fertilizer (1.09 %). Based on marginal rate of return, it may be concluded that for potato cultivation under sandy loam soil, the both marginal farmers and rich farmers may be advised to follow chicken manure along with chemical fertilizers. If there is not available of CM, the farmers may go to the treatment of CD with chemical fertilizers for maximum economic benefit and also sustainable soil health. However, the two commercial manure fertilizers, RDRS and Northern are not beneficial to potato cultivars.

4. CONCLUSION

Organic fertilizers have tremendous positive effect on growth, yield attributes and yield of potato. Among four organic fertilizers, chicken manure and cowdung have greater effect on potato tuber yield than RDRS and Northern organic fertilizers with being the highest in chicken manure fertilizer.

Chicken manure also showed the highest net income and marginal rate of return. In contrast, RDRS and Northern organic fertilizer showed lower net income as well as benefit-cost ratio and marginal rate of return with being the lowest in RDRS organic fertilizer.

COMPETING INTERESTS

Authors have no competing interests exist.

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Table 1 Nutritive content of different organic fertilizers used in the experiment

Nutrients (%)	Cowdung	Poultry manure	RDRS organic fertilizer†	Northern organic fertilizer†
Organic matter	5.56	6.87	25.66	15.50
N	1.12	1.25	1.40	4.00
P	0.35	0.60	2.06	1.15
K	0.62	0.88	1.54	1.50
S	0.35	0.42	0.60	1.00
Zn	---	---	0.017	0.015
B	---	---	1.30	0.016
Ca	---		1.64	2.50
Mg	---		0.257	0.75
Mn	---		0.028	0.017
Fe	---		1.759	0.05
Cu	---		0.009	0.024

†: The nutrient content of RDRS and Nortern organic fertilizers were supplied by the producing company

Table 2 Effect of organic fertilizers on plant height, leaf production and leaf fresh weight at 85 days after planting of two potato cultivars conducted at Rangpur during 2015-16

Treatments	Plant height (cm)	Leaves plant^{-1} (no)	Leaves fresh weight plant^{-1} (g)
Variety			
Cardinal	61.8	76.6 a	131.3 a
Diamont	59.7	68.6 b	115.9 b
F-test	NS	*	*
Organic fertilizer			
Control	55.4 c	55.3 c	98.5 c
Cowdung	64.1 a	79.5 a	140.3 a
Chicken manure	65.8 a	81.7 a	147.5 a
RDRS organic fertilizer	60.0 b	73.5 b	117.4 b
Northern organic fertilizer	58.6 b	73.0 b	114.2 b
F-test	**	**	**
CV (%)	2.53	5.25	5.79

In a column, within treatments, common letter (s) indicates do not differ significantly at P ≤ 0.05 as per DMRT; Control = No organic fertilizer was applied; Cowdung = Cowdung applied @ 8 t/ha; Poultry manure = Poultry manure applied @ 8 t/ha; RDRS = RDRS organic fertilizer applied @ 750 kg/ha; Northern = Northern organic fertilizer applied @ 500 kg/ha as per the producer guideline

Table 3 Effect of organic fertilizers on yield contributing parameters and tuber yield of two potato cultivars conducted at Rangpur during 2015-16

Treatments	Tubers plant^{-1} (no)	Weight tuber^{-1} (g)	Tuber weight plant^{-1} (g)	Tuber yield (t ha^{-1})
Variety				
Cardinal	6.03	55.61	324.6 a	26.39
Diamont	5.94	57.50	295.5 b	24.57
F-test	NS	NS	*	NS
Organic fertilizer				
Control	5.10 c	50.54 b	251.1 c	16.60 c
Cowdung	6.48 ab	58.11 a	341.7 a	28.67 ab
Chicken manure	6.70 a	59.78 a	354.2 a	29.71 a
RDRS organic fertilizer	6.15 b	57.51 a	310.3 b	26.42 b
Northern organic fertilizer	5.98 b	57.03 a	312.9 b	26.00 b
F-test	**	*	**	**
Interaction between cultivar and organic fertilizer				
Variety: Cardinal				
Control	5.01	49.64	238.2 c	17.21 d
Cowdung	6.70	57.37	356.7 ab	29.74 a
Chicken manure	7.00	59.27	376.6 a	30.82 a
RDRS organic fertilizer	6.30	55.69	319.2 b	26.92 b
Northern organic fertilizer	5.16	56.19	332.2 ab	27.24 ab
Variety: Diamond				

Control	5.20	51.45	223.9 c	15.98 d
Cowdung	6.25	58.83	326.7 b	27.59 ab
Chicken manure	6.40	60.29	331.8 ab	28.60 ab
RDRS organic fertilizer	6.05	59.05	301.4 b	25.91 bc
Northern organic fertilizer	5.82	57.88	293.6 b	24.76 c
F-test	NS	NS	*	*
CV (%)	4.53	2.97	5.25	5.79

In a column, within treatments, common letter (s) indicate do not differ significantly at P ≤ 0.05 as per DMRT; Control = No organic fertilizer was applied; Cowdung = Cowdung applied @ 10 t/ha; RDRS = RDRS organic fertilizer applied @ 750 kg/ha; Northern = Northern organic fertilizer applied @ 500 kg/ha as per the producer guideline

Table 4. Effect of organic fertilizers on tuber size by number at harvest in two potato cultivars conducted at Rangpur during 2015-2016

Treatments	Tuber size (%)			
	Grade A (> 55 mm)	Grade B (> 40 mm-< 55 mm)	Grade C (> 25 mm-< 40 mm)	Grade D (< 25 mm)
Variety				
Cardinal	10.86	45.44	31.99	11.91 b
Diamont	10.81	42.27	31.50	15.42 a
F-test	NS	NS	NS	*
Organic fertilizer				
Control	7.90 b	32.43 d	36.96 a	22.72 b
Cowdung	11.50 a	48.02 ab	30.44 bc	40.54 a
Chicken manure	11.93 a	50.95 a	28.55 c	8.57 d
RDRS organic fertilizer	10.98 a	45.31 bc	30.50 bc	13.22 c
Northern organic fertilizer	11.88 a	42.56 c	32.29 b	13.28 c
F-test	**	**	*	**
Interaction between cultivar and organic fertilizer				
Variety: Cardinal				
Control	7.70 d	28.08 g	40.66 a	23.56 a
Cowdung	11.01 bc	50.86 b	30.28 cd	8.85 g
Chicken manure	11.41 b	54.80 a	28.50 d	5.29 h
RDRS organic fertilizer	10.80 c	50.32 b	28.92 d	9.96 f
Northern organic fertilizer	13.39 a	43.12 d	31.60 c	11.89 ef
Variety: Diamond				
Control	8.09 d	36.68 f	33.25 b	21.88 ab
Cowdung	11.99 b	45.19 cd	30.59 cd	12.23 de
Chicken manure	12.44 ab	47.10 bc	28.61 d	11.85 ef
RDRS organic fertilizer	11.15 bc	40.29 e	32.07 bc	16.49 c
Northern organic fertilizer	10.36 c	42.00 de	32.98 bc	14.66 cd
F-test	**	**	**	**
CV (%)	4.33	8.14	6.55	8.91

In a column, within treatments, common letter (s) indicate do not differ significantly at P ≤ 0.05 as per DMRT; Control = No organic fertilizer was applied; Cowdung applied @ 8 t/ha; Poultry manure applied @ 8 t/ha; RDRS organic fertilizer applied @ 750 kg/ha; Northern organic fertilizer applied @ 500 kg/ha as per the producer guideline

Table 5. Partial budget analysis for fertilizers and manures of yield in potato (mean of two varieties)

Treatment	Economic yield ($t\ ha^{-1}$)	Gross margin profit ($Tk.\ ha^{-1}$)	Variable cost ($Tk.\ ha^{-1}$)	Net margin benefit ($Tk.\ ha^{-1}$)	Marginal net margin benefit ($Tk.\ ha^{-1}$)	Marginal benefit-cost ratio	Marginal rate of return (%)
Control	17.21	2,06,520.00	21,589.00	1,84,931.00	---	8.57	---
CD	29.74	3,56,880.00	29,589.00	3,27,291.00	1,42,360.00	11.07	4.63
CM	30.82	3,69,840.00	31,589.00	3,38,251.00	1,53,320.00	10.71	5.48
RDRS OM	26.92	3,23,040.00	40,339.00	2,82,701.00	97,770.00	7.01	1.09
Northern OM	27.24	3,26,880.00	36,589.00	2,90,291.00	1,05,360.00	7.93	1.52

CD = Cowdung; CM = Chicken manure; OM = Organic manure; The price rate of manures and fertilizers: Taka (Tk) 16.00 kg^{-1} urea, Tk. 22.00 kg^{-1} TSP, Tk. 15.00 kg^{-1} MP, Tk. 0.80/kg CD, Tk. 1.00/kg CM, Tk. 20 kg^{-1} RDRS organic fertilizer and Tk. 25 kg^{-1} Northern organic fertilizer. The potato tuber rate was Tk. 12.00 kg^{-1}.

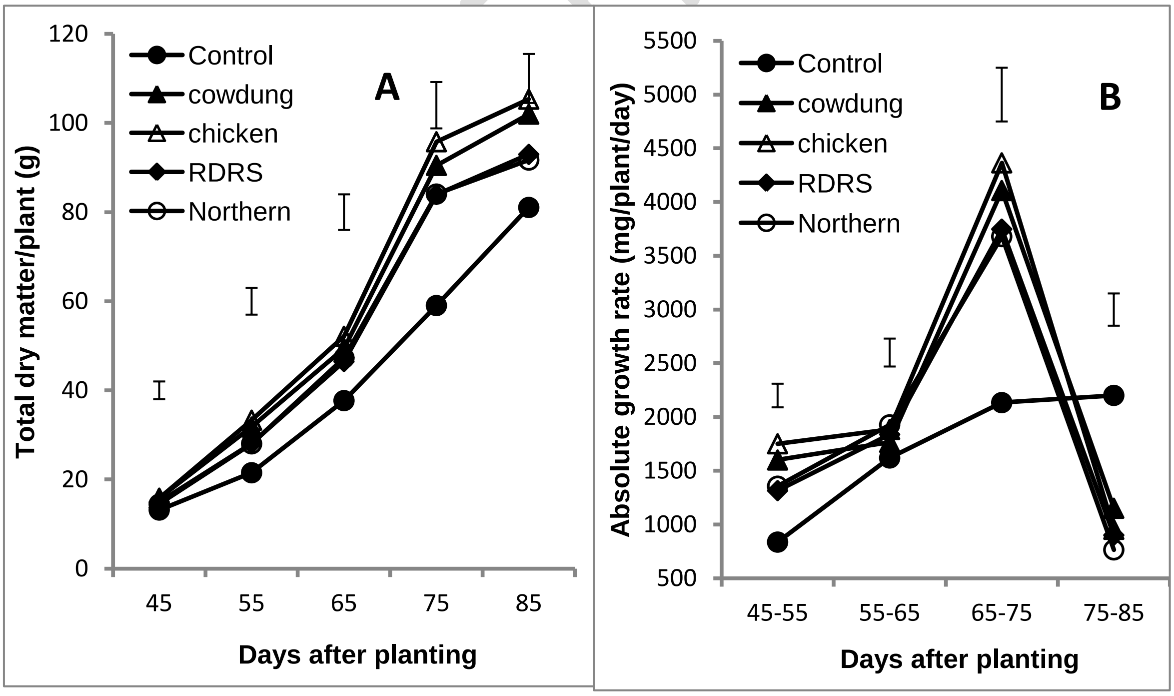

Fig. 1 Variation in (A) total dry matter production and (B) absolute growth rate at different growth stages due to different sources of manure application on potato cultivars. Vertical bars represent SE.

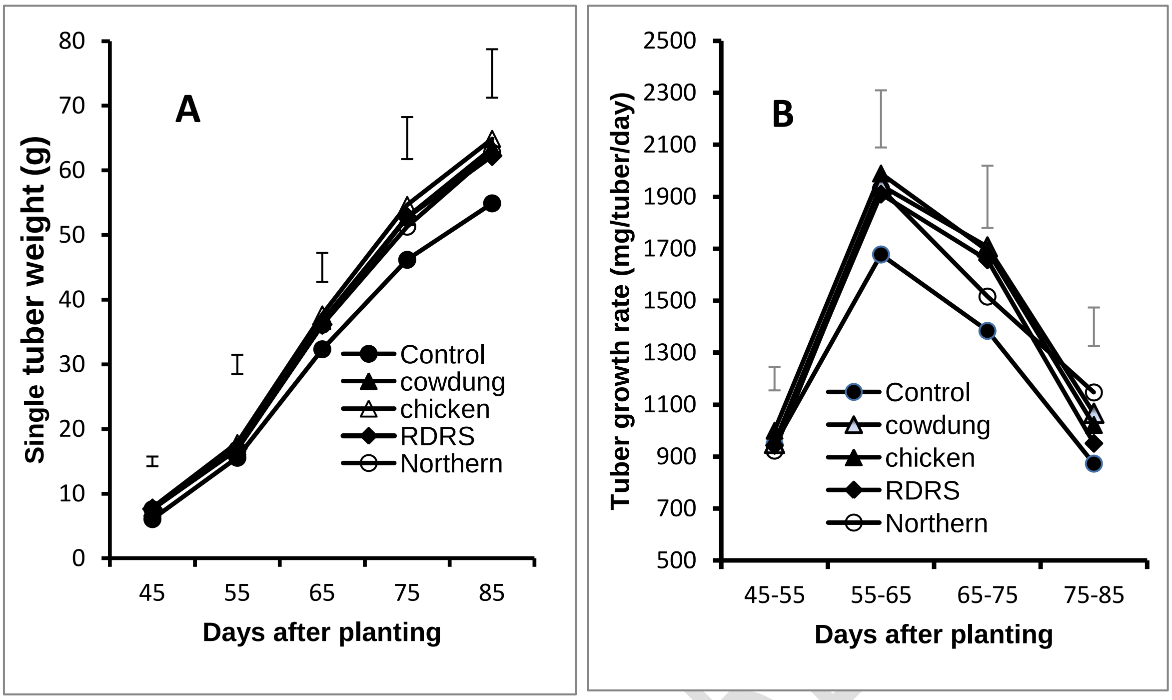

Fig. 2 Effect of different sources of organic fertilizers on (A) single tuber weight and (B) tuber growth rate at different growth stages in potato cultivars. Vertical bars represent SE.