ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 43(2): 267-280, June 2018

GROWTH ANALYSIS AND YIELD PERFORMANCE OF FOUR POTATO (*Solanum tuberosum* L.) VARIETIES

O. HOWLADER[1] AND M. A. HOQUE[2]

Abstract

An experiment with four potato varieties, namely Asterix, Cardinal, Diamant and Granola was conducted at the Horticulture Research Field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during November 2013 to February 2014 to observe the behaviour of growth parameters and yield potentiality of potato. Final harvest of tuber was done at 90 DAP. LAI, CGR, RGR and NAR were not significantly influenced by the varieties. Irrespective of varieties, LAI increased progressively with time reaching a peak at 60 DAP and thereafter declined. Granola maintained the lower LAI throughout all growth stages. Numerically, the maximum CGR (19.99 g m^{-2} day^{-1}) was found in Asterix at 50-60 DAP and the highest RGR (107.33 mg g^{-1} day^{-1}) as well as NAR (9.54 g m^{-2} day^{-1}) was recorded in Cardinal at 30-40 DAP. At 60-70 DAP, Cardinal recorded the highest TBR (84.35 g m^{-2} day^{-1}) while Asterix, the highest TGR (18.54 g m^{-2} day^{-1}) but Granola gave the lowest values of TBR (65.21 g m^{-2} day^{-1}) and TGR (14.92 g m^{-2} day^{-1}) at this growth stage. At all growth stages except 30 and 40 DAP, Diamant showed the best performance in SLA while Granola showed the lowest. The maximum yield was produced by Asterix (31.46 t/ha) closely followed by Diamant (29.91 t/ha) and Cardinal (27.27 t/ha) while the lowest yield was produced by Granola (24.82 t/ha). Granola showed the capacity of producing 95% or more of its final yield within 60 to 70 DAP. Therefore, Granola can be used as an early variety for potato cultivation.

Keywords: Potato, varieties, Leaf Area Index, Crop Growth Rate, Tuber Growth Rate. Tuber Bulking Rate and Yield.

Introduction

Potato (S*olanum tuberosum* L.) locally known as 'Alu' is a popular vegetables as well as cash crops in Bangladesh. It is the most important vegetable crop extensively grown all over the world and is called king of the vegetables (Mustafa, 1997). It is the second largest food crop in Bangladesh next to rice and has recently occupied an important place in the list of major food and cash crops of Bangladesh (Ali and Haque, 2011). The area and production of potatoes are increasing day by day due to its higher demand and profitability. Potato is grown more or less in all districts of Bangladesh but, better produced in the districts of Munsiganj, Bogra, Rangpur, Dinajpur and some parts of greater Comilla (Anon., 2014). More than 70 high yielding varieties (HYVs) of potato have been released for cultivation in our

[1&2] Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706, Bangladesh.

country by the Tuber Crop Research Centre of BARI. Yield of these released varieties varies from 25-35 t/ha. Some of these varieties are late or some are early or medium late or medium early (Haque *et al*., 2012). Moreover, these varieties differ in various growth characters that largely influence the growing pattern, intercultural operations or yield of a particular variety.

Plant growth analysis, a collective technique used to quantify the components of growth such as crop growth rate, relative growth rate, net assimilation rate, specific leaf area etc. which regulate the crop yield that is a function of total dry matter production and its effective distribution on to economically important plant parts (Mbah and Eke-Okoro, 2015). These growth parameters allow describing the growth of the plant or plant organ and the relationship between the assimilatory apparatus and dry matter production (Olivera, 2000).

Research on potato cultivars is usually limited to analyzing differences in tuber yield, yet rarely do such analyses seek to account for the origins of such differences. For an optimum use of natural resources, an explanation for the production differences is important both for physiologists and agronomists (Borrego *et al*., 2000) to obtain useful information for the choice of genotype and the most appropriate agronomic practices to adopt. Indeed, potato cultivars show considerable diversity in terms of growth rates, due to their genetic make-up and their interaction with the environment. Therefore, a study of dry matter production and distribution in the various plant organs during development is important to determine a cultivar's growth rate and production. For this purpose, growth analysis has been widely used to study the factors that affect the plant's production and development as the accumulation of photosynthates in time (Ascione *et al.,* 2013). Proper growth analysis of a potato variety ensures the yield by timely performing the intercultural operations and other activities. But study on growth analysis in our climatic condition is very limited. The present study was therefore, undertaken to analyze the growth pattern and yield potentiality of four potato varieties.

Materials and Methods

The experiment was conducted at the Horticultural Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during November 2013 to Februry 2014. Single-factor experiment was laid out in Randomized Complete Block Design with three replications. Apparently disease free, uniform sized (28-55mm) and well sprouted seed tubers of four potato varieties *viz*., Asterix, Cardinal, Diamant and Granola were used as planting material for the experiment. Unit plot size was 4.8 m × 2.5 m and tubers were planted at a depth of 3-5 cm adopting a spacing of 60 cm x 25 cm. Seed tubers were planted on 24 November 2013 and final harvesting was done on 22 February 2014. Fertilizers were applied @ 150-44-125-22-3.2-1 kg/ha of N-P-K-S-Zn-B, respectively (Abdullah *et al*., 2010). Urea, Triple Super Phospahte (TSP), Muriate of Potash (MoP), Gypsum, $ZnSO_4$ and Boric acid were used as

the sources of N, P, K. S. Zn and B, respectively. The land also received cowdung @ 10.0 t/ha. Half of urea and entire amount of cowdung, TSP, MoP, gupsum, $ZnSO_4$ and boric acid were applied during final land preparation and mixed in soil so that the tubers do not come in contact with fertilizers. The remaining half of N was top dressed at 30 days after planting (DAP). Irrigation, weeding, earthing up and other intercultural operations were done as and when necessary for raising a good crop. Furadan 5G @ 10 kg/ha was applied during the final land preparation to control cutworm and other soil borne insects. Malathion (0.2%) sprayed in two installments at 45 and 60 DAP to control insects. The crops were sprayed with Dithane-M 45 (0.2%) and Ridomil Gold (0.2%) alternately five times (at 30, 40, 50, 60 and 70 DAP) to prevent late blight infection and other diseases of potato.

Growth analysis was carried out by destructive sampling of plants with sequential harvesting at ten days interval. Five potato plants of each variety were randomly uprooted from the inner rows of the plots at 30, 40, 50, 60, 70 and 80 DAP. Total plant biomass was separated into leaves, stems, roots and tubers and fresh weight of each biomass group was taken with an electric balance. For dry matter estimation of each biomass group except tuber, the samples were kept in an oven. The temperature of the oven was set to 65˚C and was dried until a constant weight was obtained. The final weight of the dried sample was taken by an electric balance. In case of tuber, about 100g of fresh tuber from each unit plot was measured and dry weight was taken at 30, 40, 50, 60, 70, 80 and 90 DAP following the procedure described above. This dry weight of 100 g tuber was used to calculate total dry weight per square meter. Leaf area per plant was measured with an automatic leaf area meter (Model AAM-8, HYYASHI, DENKOH, Japan) after harvest at different DAP. Growth parameters such as crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area index (LAI) and specific leaf area (SLA) were calculated by using the following formulae given by Gardner *et al.* (1985):

$$\text{CGR} = \frac{1}{\text{GA}} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2} \text{ day}^{-1}$$

Where, W_1 = dry weight (g) at time T_1, W_2 = dry weight (g) at time T_2 and GA = ground area or land area (m^2).

$$\text{RGR} = \frac{\text{Ln}W_2 - \text{Ln}\ W_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where, W_1 = dry weight (g) of plant at time T_1, W_2 = dry weight (g) of plant at time T_2 and Ln = natural logarithm.

$$\text{NAR} = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\text{Ln}L_2 - \text{Ln}L_1}{L_2 - L_1} \text{ gm}^{-1}\text{day}^{-1}$$

Where, W_1= dry weight (g) of plant at time T_1, W_2= dry weight (g) of plant at time T_2, L_1= leaf area (m^2) at time T_1, L_2= leaf area (m^2) at time T_2 and Ln= natural logarithm.

$$\text{LAL} = \frac{\text{Surface area of green leaves } (m^2)}{\text{Land area from where the leaves were collected } (m^2)}$$

$$\text{SLA} = \frac{\text{Surface area of green leaves } (cm^2)}{\text{Leaf dry weight (g)}} \text{ cm2 g-1}$$

Whereas, tuber bulk rate (TBR) and tuber growth rate (TGR) were calculated by using following formulae given by Sen *et al.*, (2014).

$$\text{TBR} = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \ gm^{-1}day^{-1}$$

Where, W_1 = fresh weight (g) of tuber at time T_1, W_2 = fresh weight (g) of tuber at time T_2 and GA = ground area or land area (m^2)

$$\text{TGR} = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \ gm^{-1}day^{-1}$$

Where, W_1 = dry weight (g) of tuber at time T_1, W_2 = dry weight (g) of tuber at time T_2 and GA = ground area or land area (m^2)

Besides, data on fresh and dry weight of tuber per plant was also recorded at 90 DAP and dry matter (%) was calculated following the standard formula. The collected data on various parameters were analyzed using MSTAT-C program. The means were separated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Results obtained from the present study are presented below:

Leaf area index

Leaf area index (LAI) was measured for four potato varieties at 30 to 80 DAP (Fig. 1). The pattern of LAI at different stages was almost similar for all the varieties. Regardless of varieties, LAI increased sharply upto 40 DAP and afterwards LAI increased gradually reaching a peak at 60 DAP and declined thereafter. The sharp increase in LAI at 40 DAP might be due to production of more leaves per ground area and faster rate of leaf emergence and leaf expansion. At 50 DAP, Diamant recorded the maximum LAI closely followed by Asterix and Cardinal while Granola recorded the lowest LAI. Among the varieties, the maximum LAI was found in Cardinal (4.13) at 60 DAP, while in Granola it was found the lowest (3.19). The highest values of LAI at 60 DAP indicated full

shooting of expanded leaves which increased the capacity factor for carbon assimilation. Higher LAI at 50 and 60 DAP was obtained which might be due to the higher number of leaves and branches per unit area. After 60 DAP, LAI for all the varieties showed declining trend but there was a marked variation among the values at 70 DAP stage. Significantly, the maximum LAI was found in Cardinal (3.37) closely followed by Diamant (3.21) and the lowest LAI was found in Granola (2.24) identical with Asterix (2.34). This might be due to the fact that Cardinal and Diamant had maximum number of leaves per ground area and less number senescent leaves compared to Asterix and Granola. These findings were in agreement with Ranjibar *et al.* (2012) and Sen *et al*. (2014), who reported the highest LAI at 60 DAP. According to findings of Ranjibar *et al.* (2012), LAI was the manifestation of the capacity factor of growth of the crop and it had a great effect on plant growth and the final yield of dried material.

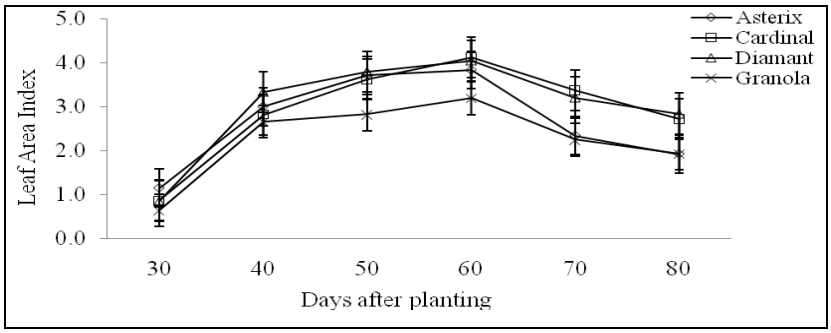

Fig. 1. Leaf area index of four potato varieties at different days after planting. Vertical bars indicate ±SE

Crop growth rate (g m^{-2} day^{-1})

The crop growth rate (CGR) of the four potato varieties were studied at different growth stages (Fig. 2). No significant variation in CGR value was observed among the varieties at all the growth stages. However, the CGR values increased progressively with time reaching peak at 50-60 DAP stage in Diamant, Cardinal and Asterix except Granola which recorded the maximum value of CGR at 40-50 DAP and thereafter declined till 70-80 DAP regardless of varieties. CGR values were found higher because of maximum leaf area index (LAI) between 50 and 60 DAP (Fig. 1). At 50-60 DAP stage the highest CGR was found in Asterix (19.99 g m^{-2} day^{-1}) followed by Diamant (18.45 g m^{-2} day^{-1}) and Granola (17.41 g m^{-2} day^{-1}), while the lowest was found in Cardinal (17.29 g m^{-2} day^{-1}). At 60-70 DAP and 70-80 DAP stages, Granola gave the lowest CGR values, 10.83 g m^{-2} day^{-1} and 8.98 g m^{-2} day^{-1}, respectively. At 70-80 DAP stage, the highest CGR was obtained in Asterix (11.28 g m^{-2} day^{-1}) followed by Cardinal (10.66 g m^{-2} day^{-1}) and Diamant (10.27 g m^{-2} day^{-1}). The decrease in CGR at the early of growing season indicates that the crop had an early maturing tendency. From this it may be interpreted that variety Granola had early maturing tendency, but the rest three

varieties *viz*., Asterix, Cardinal and Diamant had late maturing tendency as they maintained higher CGR values till the last stage of sample harvest. Similar results were reported by Mahmud (2012) and Esfahai *et al*. (2012). At later stages, CGR value slowed down because of reduction in absorption of solar radiation and leaf falling (Borrego *et al.*, 2000). According to research findings of Esfahai *et al*. (2012), early maturing varieties reached maximum CGR during the early stage compared to the late maturing ones.

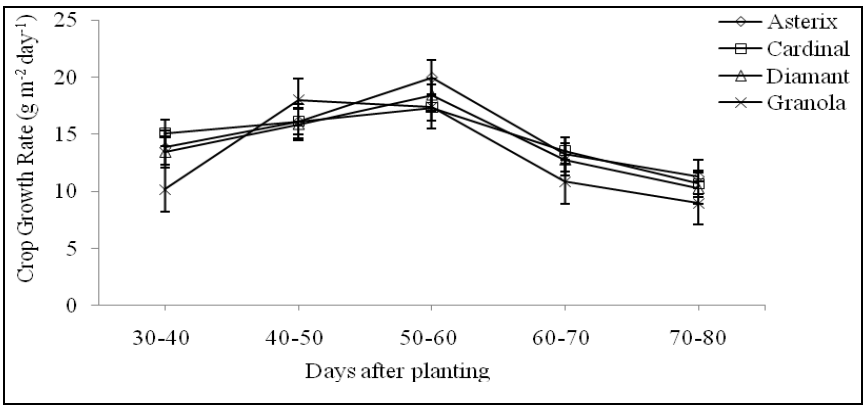

Fig. 2. Crop growth rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Relative growth rate (mg g^{-} day^{-1})

The relative growth rate (RGR) of four potato varieties were studied from 30 to 80 DAP growth stages (Fig. 3). No marked variation was observed in RGR value among the varieties at all the growth stages from 30-40 DAP to 70-80 DAP. Irrespective of varieties, the RGR values were earlier in the season and showed a decreasing trend as the crop advanced in age. The values of RGR were attained maximum at 30-40 DAP stage for each of the varieties. At this stage the highest RGR value was obtained from Cardinal (107.33 mg g^{-1} day^{-1}) followed by Asterix (93.18 mg g^{-1} day^{-1}) and Granola (91.73 mg g^{-1} day^{-1}), while the lowest from Diamant (89.37 mg g^{-1} day^{-1}). This may be interpreted as Cardinal is the most efficient variety in utilization of dry mass for further growth as relative growth rate expresses growth in terms of a rate of increase in size per unit of dry mass basis (Hunt, 2003). The greatest difference in RGR value among the varieties occurred at the time of tuber initiation (30 DAP) and development (40-50 DAP). For varieties Asterix, Cardinal and Diamant the RGR values declined very sharply after 30-40 DAP except Granola, which showed the highest RGR value (73.18mg g^{-1} day^{-1}) at 40-50 DAP stage. The RGR value decreased with plant age due to the fact that an increasing of the plant is structural rather than metabolically active tissue and as such does not contribute to growth. The decline in RGR value was also due to the decrease in net assimilation rate (NAR) (Fig. 4.). Our present findings were in agreement with Mahmud (2012) and Begum *et*

al. (2011), who reported similar decreasing trend of RGR in potato varieties and the highest RGR value was calculated at 30-40 DAP. According to Abbas (2011), the variation in the RGR in the respective varieties might be due to difference in temperature or weather during the crop seasons.

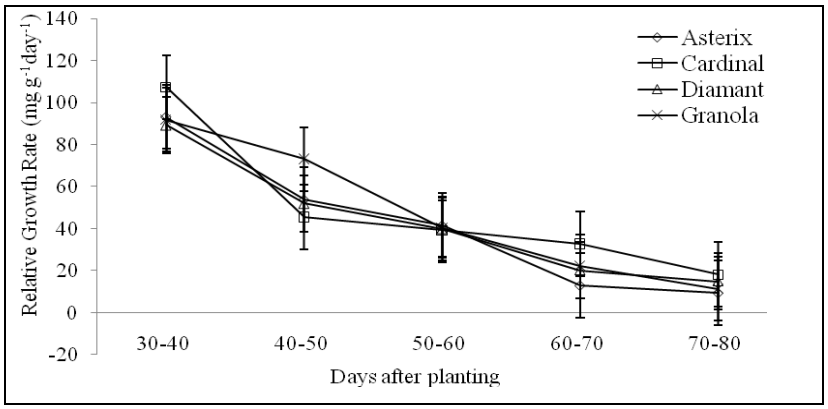

Fig. 3. Relative growth rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Net assimilation rate (g m^{-2} day^{-1})

Net assimilation rate (NAR) of four potato varieties were studied from 30-40 DAP to 70-80 DAP growth stages (Fig. 4). Among the varieties there were no significant variations found at these five growth stages. All the four varieties showed maximum level of NAR at the beginning of the growing season. The slight differences in NAR among the varieties were at the time of tuber initiation (30 DAP) and development (40 to 50 DAP). At 30-40 DAP, the highest NAR was found in Cardinal (9.54 g m^{-2} day^{-1}) followed by Diamant (7.74 g m^{-2} day^{-1}) and Granola (7.58 g m^{-2} day^{-1}), while the lowest in Asterix (7.52 g m^{-2} day^{-1}). NAR showed a decreasing trend with the advancement of crop upto maturity in case of four varieties. At the early of growing season, due to an underdeveloped canopy solar radiation can easily pass through the crop canopy. Thus underneath leaves can receive more solar radiation i.e. photosynthetic photon flux density (PPFD) for photosynthesis and consequently NAR was at the highest point at 30-40 DAP. As the crop develops, the underneath leaves receive lower amount of PPFD due to mutual shading of leaves and the aged leaves had lower photosynthetic efficiency. As a result, NAR was found lower compared to the preceding growth stage till 80 DAP. At 60-70 DAP and 70-80 DAP stages Granola maintained the highest NAR values of 4.83 g m^{-2} day^{-1} and 4.30 g m^{-2} day^{-1} and Asterix, the lowest NAR values of 3.79 g m^{-2} day^{-1} and 3.21 g m^{-2} day^{-1}, respectively. It might be interpreted as Granola had the capacity to manufacture higher photosynthates per unit leaf area and Asterix had the lowest capacity for this. The present findings were in agreement with Ranjibar *et al*. (2012) and Esfahai *et al*. (2012), who reported a decreasing pattern of NAR irrespective of potato genotypes. However, the differences of NAR in present findings might be

due to genetical difference. According to Tekalign and Hammes (2005), the enhanced NAR might be attributed to the increased photosynthetic efficiency of leaves. Solar radiation, active photosynthesis increased the efficiency of net gain of assimilates (NAR) and eventually yield.

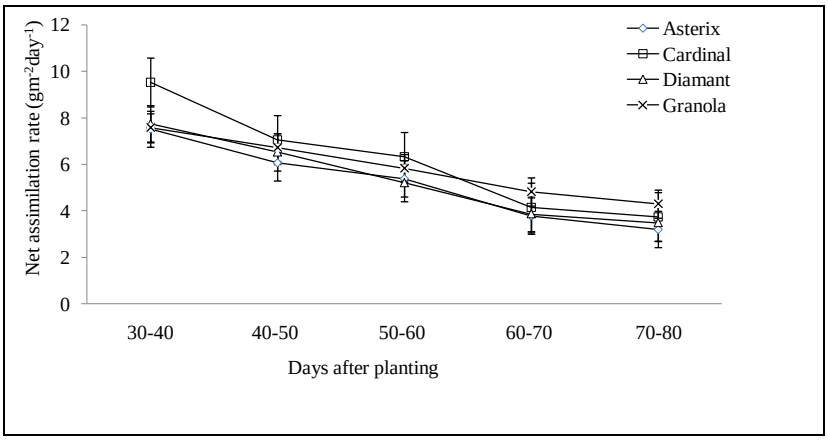

Fig. 4. Net assimilation rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Specific leaf area ($cm^2 g^{-1}$)

Specific leaf area (SLA) of four potato varieties were measured at different growth stages (30 to 80 DAP) (Fig. 5). The pattern of SLA did not follow any definite pattern in this experiment. Marked variation was observed among the varieties at 30, 50 and 60 DAP. At 30 DAP the maximum SLA was observed in Cardinal (284.00 cm^2 g^{-1}) followed by Asterix (271.67 cm^2 g^{-1}) and Diamant (185.67 cm^2 g^{-1}), where the lowest was for Granola (154.33 cm^2 g^{-1}). At 40 DAP, SLA values did not show any significant variation, however it was highest in Granola (400.33cm^2 g^{-1}) and lowest in Cardinal (340.67 cm^2 g^{-1}). A different result was found at 50 DAP, when the highest SLA value was found in Diamant (370.67 cm^2 g^{-1}) followed by Asterix (320.00 cm^2 g^{-1}) and Cardinal (307.33 cm^2 g^{-1}). Granola showed the lowest value of SLA (281.00 cm^2 g^{-1}). Similar result was observed at 60 DAP, highest for Diamant (362.00 cm^2 g^{-1}) and lowest in Granola (294.67 cm^2 g^{-1}). Though at 70 and 80 DAP, no significant difference was found among the varieties with regard to SLA, Diamant showed the highest value, 320.67 cm^2 g^{-1} and 318.27 cm^2 g^{-1}, respectively and Granola had the lowest 279.67 cm^2 g^{-1} and 272.80 cm^2 g^{-1}, respectively. It is seen that after 40 DAP Diamant maintained the maximum SLA till 80 DAP compared to other varieties and Granola registered the lowest SLA till 80 DAP. So, Diamant had higher amount of leaf area available for light interception. Data revealed that all the varieties showed maximum specific leaf area at 40 DAP. It might be due to all the varieties had higher leaf area with lower leaf dry mass, as the plants were immature so ratio value was higher. Similar results were reported by Ranjibar *et al.* (2012), who obtained the higher specific leaf area were higher at the

beginning of the growth (40 DAP). But during the growing period, the total leaf weight of plant was increased, and it caused the reduction of SLA.

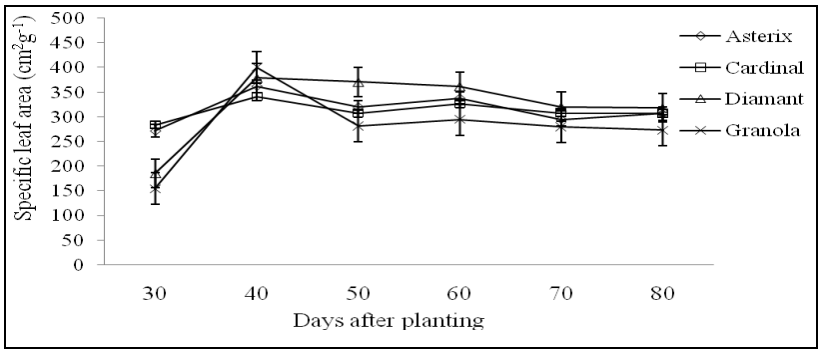

Fig. 5. Specific leaf area of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Tuber bulking rate (g m^{-2} day^{-1})

Tuber bulking rate of the four potato varieties were studied and data are represented in Fig. 6. Knowing the bulking profiles of varieties can be used to help determine when to harvest a crop for maximum yield. Knowing the bulking rate curves can also be useful in determining nutrient management practices, particularly nitrogen. Bulking profiles can be useful in determining when to apply nitrogen (Bohl and Love, 2004). Irrespective of varieties, tuber bulking rate (TBR) was found minimum at 30-40 DAP, where TBR values showed no significant variation among the varieties. But significant variation in TBR was found among the varieties at 40-50, 60-70 and 70-80 growth stages. After the initial stage (30-40 DAP), TBR in Diamant increased sharply upto 40-50 DAP and declined thereafter till 70-80 DAP. TBR in Asterix and Granola increased upto 50-60 DAP and then, in Granola TBR declined sharply while, in Asterix TBR decreased gradually till the sample harvest (70-80 DAP). From the initial stage (30-40 DAP), TBR in Cardinal increased progressively upto 70-80 DAP. At 50-60 DAP, the maximum TBR was found in Asterix (98.76 g m^{-2} day^{-1}) closely followed by Granola (98.67 g m^{-2} day^{-1}) and the lowest TBR was found in Cardinal (82.71 g m^{-2} day^{-1}). The highest bulking rate at 50-60 DAP was associated with greater leaf area index found between 50 and 60 DAP (Fig. 1). At 60-70 DAP, Cardinal showed the highest TBR (84.35 g m^{-2} day^{-1}) and Granola recorded the lowest value (65.21 g m^{-2} day^{-1}) and continued up to harvest. Almost similar pattern was found in the last stage (70-80 DAP), where, Cardinal had the highest TBR value (83.96 g m^{-2} day^{-1}), followed by Diamant (75.55 g m^{-2} day^{-1}) and Asterix (74.22 g m^{-2} day^{-1}), and Granola gave the lowest TBR (37.38 g m^{-2} day^{-1}). Sen *et al.* (2014) obtained peak tuber bulking rate at 45-60 DAP. The decrease in TBR value at earlier stages (after 50-60 DAP) may be due to the early bulking tendency of Granola. It may be concluded that Granola can be harvested slightly earlier than the other three varieties with an economic yield in our climatic condition, but Cradinal showed the highest TBR near harvest (70-80

DAP), it may take slightly more time to harvest and has potential to yield further in field followed by Diamant and Asterix. According to Kleinkopf *et al*. (2003), maximum bulking rates for any individual cultivar in the field can be determined by the physiological age of the seed and the environmental conditions during tuber initiation. To obtain adequate bulking rates for most commercial cultivars requires proper nutritional and production management. The growers have some control over the bulking rate through cultivar/seed lot selection and best management practices, but they have little control over annual environmental conditions during tuber initiation.

Tuber growth rate (g m^{-2} day^{-1})

The tuber growth (TGR) of the four potato varieties were studied from 30 to 80 DAP (Fig. 7). According to the results represented in the graph, the TGR in the plants followed a sigmoid pattern. In Asterix and Granola, TGR increased sharply upto 50-60 DAP beyond which it declined till 70-80 DAP. While in Diamant, TGR increased sharply upto 40-50 DAP, then increased gradually upto 50-60 DAP and thereafter declined. But TGR in Cardinal increased progressively upto 60-70 DAP and then decreased slightly.

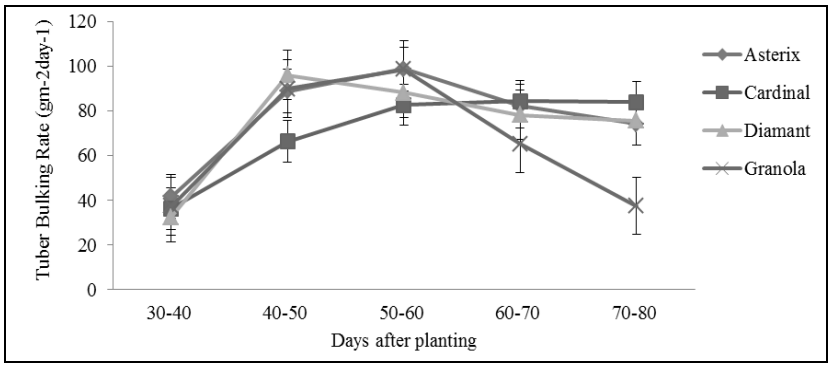

Fig. 6. Tuber bulking rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Minimum values of TGR were found at 30-40 DAP, where the varieties did not vary significantly. But marked variation was observed among the varieties at 40-50 DAP to 60-70 DAP stages. At 50-60 DAP, the highest TGR was attained by Asterix (20.72 g m^{-2} day^{-1}) followed by Granola (19.90 g m^{-2} day^{-1}), whereas, the lowest was for Cardinal (16.69 g m^{-2} day^{-1}) followed by Diamant (17.16 g m^{-2} day^{-1}). At 60-70 DAP a different scenario in TGR value was observed where Asterix (18.54 g m^{-2} day^{-1}) was the highest followed by Cardinal (18.18 g m^{-2} day^{-1}) and Diamant (16.59 g m^{-2} day^{-1}). At this stage Granola (14.92 g m^{-2} day^{-1}) showed the least TGR which indicates the earliness of this variety. On the other hand, Asterix and Diamant showed almost similar pattern of TGR at maturity (70-80 DAP). Though the TGR values at 70-80 DAP did not represent any marked variation, however, Cardinal showed the highest TGR (17.26 g m^{-2} day^{-1}) which might

indicate that it required slightly more time to reach the maturity stage. Similar finding was reported by Sen *et al.* (2014), who obtained the highest TGR at 45-60 DAP whereas Mahmud (2012) recorded the highest TGR in Asterix at 50-60 DAP.

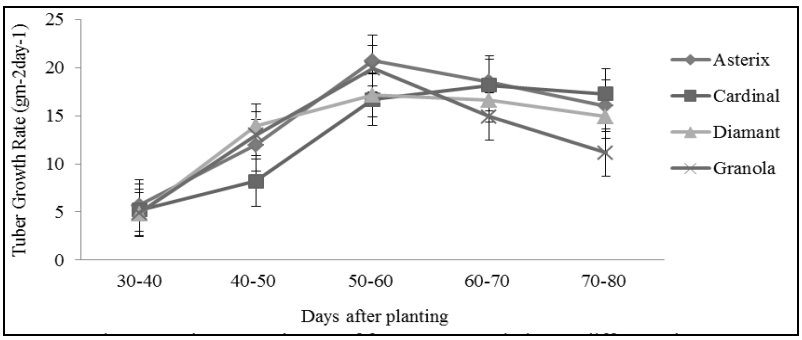

Fig. 7. Tuber growth rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Fresh tuber yield (t/ha) from 30-80 DAP

Data revealed that fresh weight of tubers increased with the advancement of time. At 30 and 40 DAP, tuber fresh weight did not vary significantly among the varieties (Table 1). At 50 DAP, the highest fresh weight was produced by Asterix (13.23 t/ha) and the lowest by Cardinal (10.39 t/ha). Cardinal produced the lowest tuber fresh weight at 60 DAP, while Granola the highest (23.56 t/ha). At 70 and 80 DAP, Asterix produced the maximum fresh yield of 27.62 t/ha and 31.11 t/ha, respectively. On the other hand, Cardinal produced minimum yield at 70 DAP (21.89 t/ha) and Granola at 80 DAP (24.66 t/ha). But from the percentage values, it was clearly evident that in Granola, 95% of final yield was obtained at 60 DAP, whereas, in Asterix and Cardinal, more than 98% yield was obtained at 80 DAP, while in Diamant, more than 95% yield was obtained at this stage.

Table 1. Fresh yield of tubers of four potato varieties at different days after planting

	Fresh yield of tuber (t/ha)					
Variety	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP
Asterix	0.17	4.35	13.23 a	23.11 a	27.62 a	31.11 a
	(0.55)	(13.81)	(42.07)	(73.46)	(87.80)	(98.89)
Cardinal	0.13	3.76	10.39 b	18.67 b	21.89 c	27.22 ab
	(0.48)	(13.79)	(38.12)	(68.45)	(80.27)	(99.82)
Diamant	0.11	3.35	12.97 a	21.78 a	23.11 bc	28.44 ab
	(0.37)	(11.21)	(43.35)	(72.81)	(77.27)	(95.10)
Granola	0.10	3.87	12.68 a	23.56 a	24.44 a	24.67 b
	(0.40)	(15.60)	(51.84)	(94.91)	(98.49)	(99.38)
Mean	0.13	3.83	12.36	21.78	24.27	27.86
CV%	14.26	10.61	7.80	7.00	3.33	8.9

In a column, means followed by same letter(s) are not significant at 5% level by DMRT. Figures in the parentheses indicate the percent of fresh yield compared to fresh yield at 90 DAP.

Fresh tuber yield at 90 DAP

Yield of four potato varieties showed statistically significant difference at different days after planting (Table 2). The highest fresh yield was found in Asterix (31.46 t/ha) and Granola showed the lowest (24.82 t/ha) (Table 2). Hoque *et al.* (2010) reported that, yield of Asterix, Cardinal, Diamant and Granola was 25-35 t/ha, 25-40 t/ha, 25-40 t/ha and 20-30 t/ha, respectively. The highest tuber yield per plant was obtained from Asterix (472.00 g) and the lowest from Granola (372.67 g). This was in agreement with the findings of Mahmud (2012), who recorded the highest yield per plant from Asterix (368.97 g). The variations in yield t/ha may be due to genetics, vegetative growth, crop duration/maturity and adaptability to prevailing environment. Yield was significantly influenced by variety and season of production (Sinha *et al*., 1992). Patel *et al.* (2008) provided that higher tuber yield may be due to better plant growth, genotype, adaptability in wide range of environment and combined effect of all other growth and yield attributes.

Dry matter (%)

The highest dry matter content was found in Asterix during harvest (21.33%) and lowest in Granola (18.92%) (Table 2). According to Hoque *et al.* (2010), Asterix had 19% and Granola had 19.1% dry matter during harvest.

Dry yield of tubers (t/ha)

The highest tuber dry weight per plant was in Asterix (101.62 g) closely followed by Diamant and the lowest in Granola (70.51 g) (Table 2). Barghi *et al.* (2012) reported that Agria and Satina varieties obtained tuber dry weight of 95.0 g and 90.0 g per plant, respectively. From this table it is evident that, the highest dry tuber yield was found in Asterix (6.77 t/ha) and the lowest in Granola (4.70 t/ha). This finding was in agreement with the results of Harahagazwe *et al.* (2012), who reported to have 5.7-6.8 t/ha dry yield of tubers in eight CIP potato genotypes.

Table 2. Tuber yield and dry matter of four potato varieties at harvest (90 DAP)

Variety	Fresh yield of tuber		Dry matter (%)	Dry yield of tuber	
	g/plant	t/ha		g/plant	t/ha
Asterix	472.00 a	31.46 a	21.53	101.62 a	6.77 a
Cardinal	409.00 a	27.27 a	20.90	85.48 a	5.70 a
Diamant	448.67 a	29.91 a	21.40	96.02 a	6.40 a
Granola	372.67 b	24.82 b	18.92	70.51 b	4.70 b
Mean	425.58	28.37	20.56	88.17	5.88
CV%	20.85	20.84	14.32	13.66	13.64

In a column, means followed by same letter(s) are not significant at 5% level by DMRT.

Conclusions

Potato varieties did not vary significantly with each other with regard to Leaf Area lndex (LAl), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR). Regardless of varieties, LAI increased progressively with time reaching a peak at 60 days after planting (DAP) and thereafter declined. In Asterix, Cardinal and Diamant the peak point in CGR was found at 60 DAP; while in Granola, the peak CGR found at 50 DAP. Tuber Bulking Rate (TBR) decreased sharply in Asterix, Cardinal and Granola up to 60 DAP and then decreased steadily in Cardinal but decreased in Asterix and Granola. While, in Diamant, TBR increased sharply up to 50 DAP and thereafter decreased steadily. On the other hand, in Asterix, Diamant and Granola Tuber Growth Rate (TGR) increased sharply up to 60 DAP beyond which it declined. But TGR increased up to 70 DAP in Cardinal. Granola produced tuber yield of 23.56 t/ha at 60 DAP and of 24.44 t/ha at 70 DAP, which were about 95% - 98.5% of final yield (24.82 t/ha obtained at 90 DAP). Therefore, Granola can be harvested within 60 to 70 DAP without significant yield reduction.

References

Abbas, G. 2011. Evaluation and selection of potato genotypes for better yield, storage and processing attributes. Ph. D. Dissertation. Department of Horticulture, Faculty of Crop and Food Sciences, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan.

Abdullah, S., M. A. Hoque, B. C. Kundu, A. T. M. T. Islam, M. H. Reza, M. S. Islam, M. H. Waliullah, Z. Islam, M. M. Rahman, J. A. Mahmud and T. K. Dey. 2010. Advanced yield trial of exotic potato varieties (3rd generation). Annual Report 2009-10. Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701. Pp: 26-29.

Ali, M. S. and A. Haque. 2011. Potato for food security in SAARC countries, SAARC Seed Congress and Fair 2011, Dhaka, Bangladesh.

Anonymous. 2014. Estimates of Potato, 2012-2013. Agriculture Wing, Bangladesh Bureau of Statistics, Government of the People's Republic of Bangladesh, Agargaon, Dhaka-1207.

Ascione, S., C. Ruggiero and C. Vitale. 2013. Contribution of growth components on relative, plant, crop and tuber growth rate of nine potato cultivars in southern Italy. *Intl. J. Sci*. **2:**1-11.

Barghi, A., A. Tobeh and N. Hassanzadeh. 2012. Effect of nitrogen fertilizer levels on tuber filling rate and protein assimilation in early and late maturing potato. *Annals Biol. Res.* **3**(9): 4264-4275.

Begum, F., B. C. Kundu, M. I. Hossain, S. Akter and M. M. Hossain. 2011. Physiological analysis of growth and yield of potato in relation to planting date. Annual Report 2010-11. Tuber Crops Research Center. Bangladesh Agriculture Research Institute, Gazipur, Bangladesh. Pp: 139-143.

Bohl, W. H. and S. L. Love. 2004. Bulking rate of six potato varieties in eastern Idaho. Idaho Potato Conference. January 22, 2004.

Borrego, F., J. M. Fernández, A. López, V. M. Parga, M. Murillo and A. Carvajal. 2000. Growth analysis in seven varieties of potato (*Solanum tuberosum* L.). *Agronomía Mesoamericana*. **11**(1):145-149.

Esfahai, M. N., M. R. Pour and A. Pazoki. 2012. Analysis of genetical diversity of some of the tetraploides potato cultivars grown in Iran. *Amer. J. Plant Sci*. **3:** 1770-1778.

Gardener, F. P., R. B. Pearce and R. L. Mitcheel. 1985. Growth and Development. *In*: Physiology of Crop Plants. Iowa State Univ. Press. Pp. 187-208.

Gomez, K. A. and A. A. Gomez. 1984. Statistical procedure for agricultural research. John Wily and Sons. N. Y. Pp. 20-215.

Haque, M. A., M. A. M. Miah, S. Hossain, and M. M. Rahman. 2012. Profitability of BARI released potato (*Solanum tuberosum* L.) varieties in some selected locations of Bangladesh. *Bangladesh J. Agril. Res.* **37**(1): 149-158.

Harahagazwe1, D., J. F. Ledent and G. Rusuku. 2012. Growth analysis and modelling of CIP potato genotypes for their characterization in two contrasting environments of Burundi. *African J. Agril. Res.* **7**(46): 6173-6185.

Hoque, M. A., S. Abdullah, M. Hossain and M. A. J. Bhuiyan. 2010. Processing characteristics of different potato varieties (*In Bengali*). Tuber Crops Research Sub Center, BARI, Munshiganj and KGF, Dhaka. Pp: 1-16.

Hunt, R. 2003. Growth analysis, individual plants. *In*. Encyclopedia of applied plant sciences. B. Thomas, D. J. Murphy, D. Murray. [eds.]. Academic Press, London. Pp: 588-596.

Kleinkopf, G. E., T. L. Brandt and N. Olsen. 2003. Physiology of tuber bulking. Idaho Potato Conference. January 23, 2003.

Mahmud, A. A. 2012. Improvement of drought tolerant potato varieties. An unpublished Ph. D. Dissertation. Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricutural University, Salna, Gazipur.

Mbah, E.U. and O. Eke-Okoro. 2015. Relationship between some growth parameters, dry matter content and yield of some sweet potato genotypes grown under rainfed weathered ultisol in the humid tropics. *J. Agron.* **14**(3): 121-129.

Mustafa, G. 1997. Input management of potato crop in Northern areas of Pakistan. An unpublished M.Sc. Thesis, Department of Agricultural Farm Management Unit, University of Reading. UK. P:14.

Olivera, C. A. D. S. 2000. Potato crop growth as affected by nitrogen and plant density. *Pesquisa Agropecuária Brasileira*. 35(5): 939-950 [Cited from https://pakjas.com.pk/ papers/2194.pdf].

Patel, C. K., P. T. Patel and S. M. Chaudhari. 2008. Effect of physiological age and seed size on seed production of potato in North Gujarat. *J. Indian Potato Assoc.* **27**(3-4): 87-90.

Ranjbar, M., M. N. Esfahani and S. Salehi. 2012. Phenology and morphological diversity of the main potato cultivars in Iran. *J. Orna. Hort. Plants.* **2** (3): 201-212.

Sen, D., A. Rakshit and D.C. Ghosh. 2014. Effect of transplanting dates and plant population on growth parameters of potato (*Solanum tuberosum* L.) raised from true potato seed (TPS). *Cercetări agronomice în moldova*. **XLVII** (1): 97-106.

Sinha, N. K., J. N. Cash and R. W. Chase. 1992. Differences in sugars chip color, specific gravity and yield of selected potato cultivars grown in Michigan. *Amer. Potato J.* **69:** 385-389.

Tekalign, T. and P. S. Hammes. 2005. Growth responses of potato (*Solanum tuberosum* L.) grown in a hot tropical lowland to applied paclobutrazol: 1. Shoot attributes, assimilate production and allocation. *New Zealand J. Crop Hort. Sci.* **33**(1): 35-42.