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Dry matter partitioning and yield performance of processing potato varieties across different growth stages

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ABSTRACT

An experiment was conducted at the research field of the Tuber Crops Research Sub-Center (TCRSC), Bangladesh Agricultural Institute, Munshiganj (BARI), during the potato growing season of 2021–22 with three processing potato varieties viz. BARI Alu-25, BARI Alu-28 and BARI Alu-29. The objective of this experiment was to evaluate three processing potato varieties for growth pattern, dry matter partitioning to the sink and yield performance of processing potato varieties at different days after planting (DAP). Five different harvests were conducted during the growing season to determine dry matter (DM) partitioning to various parts of the plant. The results indicated that 60 days after planting, BARI Alu-28 exhibited the highest tuber dry matter (DM) percentage at 65.98%, suggesting that this variety had reached the end of its vegetative growth phase and was transitioning into the tuber filling stage. In contrast, the other varieties were primarily allocating dry matter to the stems and leaves. A similar trend was observed at 70 and 80 days after planting (DAP). By 90 DAP, the translocation of assimilates to the leaves and stems decreased, with the highest tuber DM recorded at 89.05% in BARI Alu-25. At 100 DAP (the final harvest), BARI Alu-28 was in the senescing stage, while BARI Alu-25 exhibited the maximum total dry weight per plant (241 g). BARI Alu-25 also produced the highest tuber yield at 35.21 t/ha, whereas BARI Alu-28 had the lowest tuber yield at 25.34 t/ha.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a crucial crop globally, and in Bangladesh, it holds the position of the second largest food crop after rice. Over recent years, potatoes have become increasingly significant as both a food and cash crop, contributing to food security and the agricultural economy of the country (Ali and Haque, 2011). Potatoes are particularly valued for their high dry matter and protein content, producing more dry matter per unit area than any other major food crop (Ezekiel and Virma, 1999; Sukumaran et al., 1999). The crop's relatively short growing cycle also makes it an attractive option for farmers, allowing land to be used for other crops within the same year (Haque and Miah, 2012; Hossain et al., 2012).

Bangladesh has consistently produced around one crore metric tons of potatoes annually, positioning the country as the fourth largest potato producer in Asia and among the top 15 globally. Potatoes are cultivated across all agro-ecological zones in Bangladesh, with particularly high yields in districts such as Munsiganj, Bogra, Rangpur,

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Dinajpur, and parts of greater Cumilla (Rahim et al., 2023). The increasing area under potato cultivation and the rising production levels are driven by the crop's high market demand and profitability. However, despite this abundance, 4-5 million tons of potatoes remain unused each year, highlighting the need for improved utilization strategies.

The area under potato cultivation and its production are increasing daily due to the crop's high demand and profitability. Potatoes are grown in almost all districts of Bangladesh, with the highest production observed in Munsiganj, Bogra, Rangpur, Dinajpur, and parts of greater Cumilla (Anon., 2014). Over the past few decades, several high-yielding varieties (HYVs) of potatoes have been introduced to Bangladesh, tested under local conditions, and recommended for commercial cultivation (Khalil et al., 2013). The Tuber Crop Research Center of BARI has released about 104 varieties for cultivation, among which BARI Alu-25, BARI Alu-28, BARI Alu-29, BARI Alu-30, BARI Alu-33, BARI Alu-35, BARI Alu-36, BARI Alu-37, BARI Alu-41, BARI Alu-57, and BARI Alu-68 are notable for processing purposes. These varieties differ in growth characteristics, influencing their growing patterns, intercultural operations, and yields. Some are late-maturing, while others are early or medium-late (Haque et al., 1993).

Research on potato cultivars has typically focused on analyzing differences in tuber yield but has rarely examined the origins of these differences. Understanding the factors contributing to production differences is crucial for physiologists and agronomists to optimize natural resource use and obtain valuable information for selecting suitable genotypes and adopting appropriate agronomic practices (Borrego et al., 2000). Potato cultivars exhibit significant diversity in growth rates due to their genetic makeup and interaction with the environment. Notably, around 4-5 million tons of the one crore tons of potatoes produced in Bangladesh remain unused. Thus, research on processing potato varieties, particularly in terms of growth patterns and dry matter partitioning, could provide valuable insights for maximizing the use of this surplus.

Proper analysis of dry matter partitioning in potato varieties is essential for ensuring optimal yield by enabling timely intercultural operations and other management practices. The production of economic yield is heavily influenced by total dry matter production and its allocation to the reproductive organs (Singh et al., 1998). As Spitters (1987) noted, tuber yield is determined by the fraction of total biomass partitioned to the tubers. Variation in potato cultivar yield can therefore be analyzed based on differences in cumulative light absorption, the efficiency of converting absorbed light into dry matter (DM), and the fraction of DM allocated to the tubers (Van Delden, 2001).

Given the importance of understanding growth performance and dry matter partitioning in processing potato varieties, particularly across different growth stages, this study aims to analyze these factors in three processing potato varieties at various days after planting. Such detailed and organized growth analysis could be instrumental in achieving higher yields and promoting these varieties among farmers. However, little research has been conducted on the growth analysis of processing varieties under the climatic conditions of Bangladesh, making this study a timely and necessary contribution.

MATERIALS AND METHODS

Study location and experimental design

The experiment was conducted during the potato growing season of 2021–22 at the research field of the Tuber Crops Research Sub-Center (TCRSC), Bangladesh Agricultural Research Institute (BARI), located in Munshiganj. The research site is situated between 23°22′ N latitude and 90°28′–90°36′ E longitude. The TCRSC, Munshiganj, lies within Agro-ecological Zones (AEZ) 8, 9, 10, 12, and 16, with soil pH ranging from 5.2 to 7.5.

The experimental design was a randomized complete block design (RCBD) with three replications. The study focused on three processing potato varieties: BARI Alu-25, BARI Alu-28, and BARI Alu-29.

Planting Material and Plot Layout

Uniformly sized, disease-free, well-sprouted whole tubers (28–55 mm) of the selected potato varieties were planted on December 17, 2021, at a spacing of 60 cm × 25 cm. Each experimental plot measured 4.8 m × 3.0 m.

Fertilization and soil management

The following fertilizers were applied: urea at 265 kg/ha, TSP at 220 kg/ha, MoP at 280 kg/ha, gypsum at 85 kg/ha, zinc sulphate at 14 kg/ha, and boric acid at 12 kg/ha. Additionally, cow dung was applied at 10 t/ha during the final land preparation. A full dose of TSP, MoP, gypsum, zinc sulphate, and boric acid, along with half of the urea, was applied in furrows at planting. The remaining half of the urea was top-dressed 30 days after planting (DAP).

Crop management

Irrigation, weeding, earthing up, and other intercultural operations were carried out as needed to ensure optimal crop growth. To control soil-borne insects such as ants, mites, cutworms, and aphids, Eco-furan was applied at 15 kg/ha during the final land preparation. Admire (0.2%) was sprayed in three installments at 45, 60, and 70 DAP to manage insect pests. For disease prevention, particularly against late blight, the crops were alternately sprayed with Cleanzeb and Dithane-M-45 (0.2%) five times at 30, 40, 50, 60, and 70 DAP.

Harvest and sample collection

Final harvesting was conducted on March 26, 2022. To estimate dry matter partitioning, a single plant from each plot was randomly selected and harvested at 60, 70, 80, 90, and 100 DAP, excluding plants from the outer rows. The total plant biomass was separated into leaves, stems, roots, and tubers. The fresh weight of each biomass component was measured using an electric balance, followed by sun-drying to remove surface moisture. The dried samples were then placed in an electric oven set at 65°C and dried for at least 48 hours or until a constant weight was achieved. The final dry weight of each sample was recorded using an electric balance.

Dry matter partitioning

To estimate the proportion of total dry matter partitioned to different plant parts (leaf, stem, root, and tuber), the following formula was used:

Proportion of leaf /stem /root /tuber dry weight (%)= $\frac{\text{Leaf /stem /root /tuber dry weight (g)}}{\text{Total dry weight (leaf +stem +tuber +root) per plant (g)}} \times 100$

Statistical analysis

The collected data on various parameters were statistically analyzed using the Statistix 10 software program. Mean values were compared using the least significant difference (LSD) test at the 1% or 5% level of probability.

RESULTS AND DISCUSSION

Data on dry matter partitioning of different plant organs viz. stem, leaf, root, tuber and total dry matter per plant (g) was determined during the five consecutive harvests (60, 70, 80, 90 and 100 DAP) and are presented in (Tables1–6). At first harvest (Table 1), at 60 DAP, variation in the percentage of dry matter partitioning to stem, leaf, root, tuber and total dry matter accumulation was observed significant. The highest (25.33%) proportion of assimilates in stem was observed in BARI Alu-25 which was at par with BARI Alu-29 while the lowest (10.87%) in BARI Alu-28. Similar trend of dry matter partitioning variation was observed in case leaf and root.Similar findings were also reported by Praharaj et al., who stated that soon after emergence, almost all dry matter is partitioned to the leaves and stems. For tuber, the highest fraction of assimilates was diverted to tubers in case of BARI Alu-28 (65.98%) while the lowest (25.40%) was found from BARI Alu-25. At this harvest date, the total dry weight per plant was significantly different where the highest value was found in BARI Alu-29 (196 gm) and the lowest value (138 gm) in BARI Alu-25.At 60 DAP, tuber contributed higher fraction of total assimilates produced per plant for all the three processing varieties. It may be due to all the varieties were at active tuber bulking stage at 60DAP. Potato cultivars differed greatly in the proportion of dry matter allocation to different plant parts (tuber, leaf, stem, and root) over time opined by Geremew et al (2007).

Table1: Dry matter partitioning of different parts and total dry weight per plant of three processing potato varieties at 60DAP

Variety	Dry Matter (%)				Total Dry Weight per Plant (g)
	Stem	Leaf	Root	Tuber	
BARI Alu-25	25.33a	45.19a	4.08a	25.40c	138b
BARI Alu-28	10.87b	16.91b	2.21b	65.98a	196a
BARI Alu-29	22.04a	42.18a	3.82a	31.96b	142b
CV%	9.25	7.56	16.53	4.5	3.21
Level of significance	**	**	*	**	**

In a Column, Means Followed by Same Letter(s) are not Statistically Different by LSD.

At harvesting after 70days of planting (Table 2), the highest (21.36%) proportion of dry matter partitioned to stems was found in the variety BARI Alu-29, followed by BARI Alu-29 (21.36%) and the lowest (7.02%) proportion was observed in BARI Alu-28 variety. The percentage of dry matter partitioned to leaf, root, tuber andtotal dry weight per plant varied significantly among the cultivars. The highest (32.35%) proportion of dry matter in the leaf was found in BARI Alu-29 and the lowest (15.57%) was observed in BARI Alu-28. The maximum (74.92%) proportion of dry matter in the tuber and the highest (216 gm) total dry weight per plant was found in BARI Alu-28. Tubers had contributed the highest fraction of assimilates during this harvest date (70DAP) for all cultivars and the roots contributed the minimum share of assimilates, followed by stems. Geremew et al. (2007) found varietal differences in dry matter allocation to different plant parts of different potato varieties.

Table 2: Dry matter partitioning of different parts and total dry weight per plant of three processing potato varieties at 70 DAP

Variety	Dry Matter (%)				Total Dry Weight per Plant (g)
	Stem	Leaf	Root	Tuber	
BARI Alu-25	18.79	25.71b	4.25a	51.27ab	143b
BARI Alu-28	7.02	15.57c	1.66b	74.92a	216a
BARI Alu-29	21.36	32.35a	2.91ab	43.38b	194a
CV%	22.70	12.59	35.73	11.31	6.62
Level of significance	NS	**	*	*	**

In a Column, Means Followed by Same Letter(s) are not Statistically Different by LSD.

Table 3: Dry matter partitioning of different parts and total dry weight per plant of three processing potato varieties at 80 DAP

Variety	Dry Matter (%)				Total Dry Weight per Plant (g)
	Stem	Leaf	Root	Tuber	
BARI Alu-25	22.05	13.20b	2.30	62.45ab	187
BARI Alu-28	11.28	11.09b	1.78	75.86a	226
BARI Alu-29	17.86	25.10a	1.91	55.13b	192
CV%	12.05	18.12	28.47	7.44	9.37
Level of significance	NS	**	NS	*	NS

In a Column, Means Followed by Same Letter(s) are not Statistically Different by LSD.

Table 4: Dry matter partitioning of different parts and total dry weight per plant of three processing potato varieties at 90 DAP

Variety	Dry Matter (%)				Total Dry Weight per Plant (g)
	Stem	Leaf	Root	Tuber	
BARI Alu-25	5.04b	5.80c	1.11b	89.05a	239a
BARI Alu-28	6.67b	9.10b	2.05a	82.18c	195b
BARI Alu-29	8.84a	10.37a	1.47ab	79.34c	181b
CV%	16.13	7.06	18.70	2.03	8.30
Level of significance	*	**	*	**	*

In a Column, Means Followed by Same Letter(s) are not Statistically Different by LSD.

There was no significant variation among the varieties was found during the third harvest (at 80 DAP) for stem, root and total dry weight per plant but dry matter accumulation in leaf and tuber was varied significantly where BARI Alu-28 got its highest (226 gm) total DM accumulation and had the highest (75.86%) DM translocation towards tuber and the least towards root (Table 3). At this harvest date, the highest (22.05%) DM accumulation in the stem was observed for BARI Alu-25, compared with BARI Alu-28, which had the least (11.28%) accumulation. During this growth period, the proportion of DM translocated to leaf was higher (25.10%) for BARI Alu-29 and the least (11.09%) for BARI Alu-28. Tubers had accumulated the highest proportion of assimilates during this time for all varieties.

At the fourth harvest (90 DAP), percentage of stem, leaf, root, tuber and the total DM accumulation differed significantly among varieties (Table 4). At 90 DAP; BARI Alu-25 had the highest (89.05%) proportion of DM translocated to tubers whereas the least (79.34%) was observed in BARI Alu-29. BARI Alu-25 had the highest (239 gm) total DM accumulation and it was the lowest (181 gm) for BARI Alu-29.

During the fifth and final harvest (100 DAP), all the varieties were already at the stage of senescing where BARI Alu-28 had completely senesced (Table 5). In general, DM partitioning to different plant parts was uniformly consistent among varieties for all the parameters considered. Translocation of assimilates was lower for leaves, stems and roots whereas the highest for tubers. At final harvest, BARI Alu-25 had the highest (90.48%) proportion of DM translocated to tubers whereas BARI Alu-29 obtained the least (86.10%) tubers dry matter allocation. BARI Alu-25 had the highest (241 gm) total DM accumulation and the lowest (188 gm) was observed in BARI Alu-29. These findings are in agreement with the results of Spitters (1987), who stated that potato cultivars differed greatly in the proportion of DM allocation to the tuber over time. Spitters (1987) grouped potato varieties into three categories for the growth, development, and DM allocation to the tuber. One group was those varieties in which tuber filling started early and harvest index increased rapidly with time and after the onset of tuber filling, assimilates were largely used for tuber growth. The second group was those varieties in which tuber filling also started early, but harvest index increased less rapidly with time and a substantial fraction of current assimilates partitioned to the haulm growth. The third group was those varieties in which tuber filling started later and showed a gradual increase of harvest index, with a continuous diversion of a major fraction of current assimilates to the production of new leaves and stem growth. 73 to 85% dry matter partitioned to tubers at mature harvest in the Sierra (150 DAP) but 33 to 75% on the Coast (120 DAP) in nine cultivars of potato reported by Victorio et al. (1986). Whereas, 64.1, 77.3, 85.7 and 89.4% dry matter partitioned to tubers at 58, 83, 108 and 133 DAP, respectively in 23 potato genotypes in Brazil was reported by Silva and Pinto, 2005. These differences might be due to the variation in crop duration, growing environment and interaction of cultivars to environment. Praharaj et al. (2010) reported that the partitioning of dry matter led to an almost exponential increase in the case of tubers soon after initiation or decrease in the case of leaves and stems in the early stages after emergence and thereafter the rate of increase or decrease in allocation was marginal.

Table 5: Dry matter partitioning of different parts and total dry weight per plant of three processing potato varieties at 100 DAP

Variety	Dry Matter (%)				Total Dry Weight per Plant (g)
	Stem	Leaf	Root	Tuber	
BARI Alu-25	4.51	4.18b	0.84	90.48a	241a
BARI Alu-28	-	-	-	-	-
BARI Alu-29	6.18	6.30a	1.42	86.10b	188b
CV%	28.13	5.75	16.85	2.49	*
Level of significance	NS	**	NS	*	8.32

In a Column, Means Followed by Same Letter(s) are not Statistically Different by LSD.

Table 6: Tuber fresh yield of three processing potato varieties at 100 DAP (final harvest)

Variety	Tuber fresh yield at 100 DAP
BARI Alu-25	35.21a
BARI Alu-28	25.34c
BARI Alu-29	29.46b
CV%	6.34
Level of significance	*

In a Column, Means Followed by Same Letter(s) are not Statistically Different by LSD.

At final harvest, the tuber fresh yield (t/ha) varied significantly for all the varieties. The maximum (35.21 t/ha) fresh tuber yield was found from BARI Alu-25 whereas the minimum (25.34 t/ha) was obtained from BARI Alu-28 (Table 6).

CONCLUSION

Three processing potato varieties were compared for their final yield, DM production and partitioning to the different plant parts, including the tubers. This research finding revealed that BARI Alu-28 was found to be an early variety, performing all the growth activities and DM accumulation in a short period of time, compared with the remaining varieties whereas BARI Alu-25 was the highest producer of fresh tuber yield, followed by BARI Alu-29 and BARI Alu-28. BARI Alu-25 had effectively allocated the DM to the tuber relative to others, which is the ultimate goal of potato crop production. The slow-growing nature and its efficiency of partitioning DM to its tubers made BARI Alu-25 a high yielder with appropriate tuber characteristics. BARI Alu-28 may be harvested between 70 and 80 DAP; whereas, BARI Alu-25 (Asterix) and BARI Alu-29 (Courage) may be harvested after 80 days of planting.

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