International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 17, No. 4, p. 144-153, 2020

INNSPUB

RESEARCH PAPER OPEN ACCESS

Containerized soil-less vegetable seedlings production techniques and profitability for Bangladesh

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Key words: Containerized seedlings, Coco-dust, Mud-bed, Plastic cell tray, Profitability.

http://dx.doi.org/10.12692/ijb/17.4.144-153 Article published on October 10, 2020

Abstract

Owing to less quality and environmental limitations of traditionally cultivated mud-bed seedlings the present research aimed at identifying a suitable containerized vegetable seedling production system pertinent to Bangladesh and to assess the profitability of using containerized seedlings relative to traditional mud-bed seedlings. The experiments were conducted at Professor Purnendu Gain field laboratory of the Agrotechnology Discipline, Khulna University, Bangladesh from December 1, 2019, to March 15, 2020, using a completely randomized design (CRD) with five replications. The experiment consisted of tomato, eggplant, sweet gourd, cauliflower vegetables maintain various growing media viz. mud-bed (control), plastic cell tray, plastic cup (large), plastic cup (small). The plastic cell tray seedling production system had the plant growth significantly overweighing the mud-bed system. The cost-saving plus higher price of quality plastic cell tray vegetable seedlings contributed to net profitability of 66000 BDT (tomato), 86000 BDT (eggplant), 51000 BDT (sweet gourd), and 71000 BDT (cauliflower) for 50000 seedlings, respectively. Among the four vegetable plastic cell tray seedling production systems, the cost-effectiveness was higher with the eggplant seedlings production system. Thus, the plastic cell tray with coco-dust vegetable seedlings production system performed better than traditional mud-bed seedlings in Bangladesh that would confirm more profits with less sessional limitations.

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Introduction

Vegetable crops that are routinely transplanted, the availability of healthy seedlings is critical (Lin *et al.*, 2015; AHR, 2017; Bharathi and Ravishankar, 2018). Factors such as available space, the convenience of the production method, and adaptability can influence the methods used for transplant production. In a common method, vegetable seedlings are fields produced in raised beds. The roots of such transplants incur root injury when the seedlings are pulled from the beds for transplanting, adversely affecting transplant growth (Lin *et al.*, 2015). This is the method that Bangladeshi vegetable growers commonly use. Bare-root seedlings are produced in a mud-bed seedling production system for winter vegetable production. Removal from the soil, shipment and transplanting of bare-root seedlings cause injury and death of fine roots that compromise effective water uptake during the establishment of the crop (Lin *et al.*, 2015; Bharathi and Ravishankar, 2018).

Alternatively, seeds can be sown in either individual containers or the separate chambers or cells of seedling trays resulting in healthier and more vigorous seedlings than those grown in beds. In recent years, the commercial production of containerized seedlings has increased in countries that produce a large number of vegetables due to the many benefits during establishment. Usually, a soilless growing medium is used instead of soil to which nutrients are added for healthy root development and seedling growth. Containerized seedlings have a root ball that consists of the growing media and the root system, which holds moisture and ensures root integrity at transplanting. The intact root systems reduce the incidence of transplant shock (Lin *et al.*, 2015), facilitating more efficient absorption of water than bare-root seedlings. Containerized seedlings establish more quickly than bare-root seedlings under field conditions due to less early establishment stress. Besides, containerized seedlings have superior vigor (Lin *et al.*, 2015), which can result in better yield. The use of containerized transplants often results in better plant stands and earlier harvests, factors that can boost profits to offset extra production costs associated with seedling production and transplanting (Coolong and Boyhan, 2017). Therefore, containerized seedlings may have the potential to provide greater early crop yield and thus more profit to the producer.

Natural calamities are increasingly common phenomena due to climate change in Bangladesh. Bangladesh is regarded as the most vulnerable country due to climate change (The World Bank, 2018). Many vegetable seedlings are damaged in the field due to heavy rainfall, storms, flooding, etc. in recent years. Containerized vegetable seedlings grown under covered structures and on surfaces above the soil could be a suitable option to avoid these environmental hazards. Even without protected structures, with a containerized system, growers can easily move vegetable seedlings to a safer place during unfavorable weather.

Winter vegetables are widely cultivated in Bangladesh due to a wide range of adaptability in various soil and climate. Vegetable production has increased tremendously in recent years in Bangladesh, which helps to create employment opportunities, increase income and reduce poverty (Zaman, 2019). In the 2017-18 fiscal year, 26,230,927 tons of vegetables were produced from 1,169,326 hectares of land, while 19,396,755 tons in the 2013-2014 fiscal year from 9,68827 hectares according to the Department of Agricultural Extension (Hossain, 2019). Bangladesh is the third-largest vegetable producing country in the world after China and India. To enhance the sustainability and productivity of vegetable production, high-quality vegetable seedlings are necessary. Krishnan *et al.* (2014) identified insufficient availability of quality planting materials as an important factor that constrains horticultural industry development. The availability of affordable, good quality seedlings would facilitate an expansion in vegetable production.

To shift from a mud-bed based system to containerized seedling production, the new technology should be evaluated so that systems suitable for Bangladesh that can be readily adopted by local farmers can be identified. Thus, there is a need for relevant research and extension on containerized vegetable seedling production techniques in Bangladesh. A partial budget analysis is also appropriate to evaluate the costs and benefits related to containerized seedlings for vegetable production systems in Bangladesh.

It is hypothesized that the containerized seedling production methods will produce disease-free and vigorous seedlings than the mud-bed system at costs that are affordable for farmers. Therefore, the objective of this study is to identify a suitable containerized vegetable seedling production technique pertinent to Bangladesh and to assess the costs and benefits of using a containerized seedling system by partial budget analysis.

Materials and methods

Production of containerized vegetable seedlings

The experiments were conducted at Professor Purnendu Gain field laboratory (89°34' E Longitudes and 22°47' N Latitude) of the Agrotechnology Discipline from December 1, 2019 to March 15, 2020. The experiments were laid out in a completely randomized design (CRD) with five replications. Each replication consisted of 20 plants. Different vegetables seedlings were produced using several different plastic containers like plastic cell trays (100-cells/tray) and individual containers such as one-time plastic cups large (6.0 cm × 8.2 cm × 14.2 cm) and small (6.0 cm × 8.2 cm × 12.3 cm). Locally available coco-dust was used as a growing media and it was sterilized before use in containers. Containerized seedlings performance was evaluated and compared with conventional bare-root seedlings, which was grown in a mud-bed. The performance of tomato (*Solanum lycopersicum*) (BARI Tomato-19), eggplant (*Solanum melongena*) (BARI Begun-4), sweet gourd (*Cucurbita pepo*) (BARI Misti Kumra-2) and cauliflower (*Brassica oleracea var. botrytis*) (BARI Fulkopi-2) seedlings were evaluated. The vegetable seeds were collected from the Regional Agricultural Research Station (RARS), Jashore, Bangladesh. Irrigation was applied using a watering can (5 liters) as 7 days interval to maintain proper moisture of the growing media and in the mud-bed. The manures and fertilizers that were used in the growing media as per suggested by Azad *et al.* (2017). The growing medium was observed every day and the number of germinated seeds was recorded. The germination (%) was calculated using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of seed germinated}}{\text{Total number of seeds placed in growing medium}} \times 100$$

The number of surviving seedlings was assessed at 2 and 4 weeks after sowing and those data were used to calculate the percentage of vegetable seedlings survival. Plant vigor was assessed using a modification of the procedure reported in Monfort *et al.* (2007). A scale of 0 to 10 was used with 0 being dead plants and 10 being the most vigorous plants. The number of leaves per plant was counted at 4 weeks after transplanting. The plant height was measured using a measuring scale and stem diameter was measured using digital slide calipers, total biomass (root and shoot) were dried at 65°C for 72 hours and dry weights were determined at 4 weeks after sowing.

Partial budget analysis of containerized vegetable seedling production systems in Bangladesh

The cost of containers, coco-dust and intercultural operations (land preparation, watering, weeding uplifting and tying) according to market price were included for partial budgeting. A partial budget analysis was conducted summarizing the changes in revenue and expenses using the best-containerized seedling system in comparison with the mud-bed seedling production system.

Statistical analysis

Recorded data were analyzed statistically using the GLM procedure of SAS and mean separation was done with Tukey-Kramer adjustment at $p \leq 0.05$ (SAS software Version 9.4, SAS Institute Inc, Cary, NC). The graphs were illustrated using SigmaPlot 10.0 (SigmaPlot®10.0, Systat Software Inc.).

Results

Tomato seedlings growth evaluation

The growing medium effect was not significant for the seed germination of tomato (Data not shown in the text). However, plant height was significantly affected by the growing medium. Plant height was higher with a plastic cell tray (8.80 cm) compared to mud-bed seedlings (6.55 cm) (Fig. 1A). But, mud-bed seedlings didn't differ from one-time plastic cup seedlings for plant height. A parallel trend was observed for plant vigor. At 2 and 4 weeks after sowing (WAS), the vigor with a plastic cell tray was higher than mud-bed seedlings (Fig. 1B). Alike seed germination, plant survival was not influenced by the growing medium.

Plastic cell tray containing seedlings were produced more leaves relative to mud-bed seedlings, although mud-bed seedlings didn't differ from one-time plastic cup seedlings for leaf number (Fig. 1C). Stem diameter was not significantly affected by the growing medium. Total biomass was higher in the plastic cell tray compared to mud-bed seedlings (Fig. 1D).

Table 1. Cost comparison between plastic cell tray and mud-bed tomato seedlings production.

Category	Cost items	Cost due to use of mud-bed seedlings (BDT[w]/50000 seedlings)	Cost due to use of plastic cell tray seedlings (BDT/50000 seedlings)	Cost changes due to the use of plastic cell tray seedlings (BDT/50000 seedlings)
Operating	Labor for land preparation and sowing[u]	7500	2500	-5000
	Plastic cell tray cost[v]	-	17500	17500
	Coco-dust cost[x]	-	1500	1500
	Labor for weeding[y]	2500	-	-2500
	Labor for uplifting and tying[z]	2500	-	-2500
Total		12500	21500	9000

[u]Labor cost for land preparation and sowing (50000 seedlings): at 500 BDT/labor- 15 labors for mud-bed and 5-labor for plastic cell tray, [v]Plastic cell tray cost: at 35 BDT/tray- total 500 trays, [w]BDT-Bangladeshi taka, [x]Coco-dust cost: 300/medium gunny bag-5 bags in total, [y]Labor cost for weeding: at 500 BDT/labor- 5 for mud-bed seedlings, [z]Labor cost for uplifting and tying: at 500 BDT/labor- 5 for mud-bed seedlings.

Table 2. The net effect of using plastic cell tray tomato seedlings relative to med-bed tomato seedlings.

Budget variable	Selling prices of mud-bed (BDT/50000 seedlings)[z]	Selling price of plastic cell tray (BDT/50000 seedlings)[z]	Value changes (BDT/50000 seedlings)
Revenue changes	25000	100000	75000
Cost changes	12500	21500	9000
Net effects	12500	78500	66000

[z] Selling price (50000 seedlings): at 0.5 BDT/seedling for mud-bed and 2.0 BDT/seedling for plastic cell tray.

Economic evaluation for tomato seedlings production

The plastic cell tray tomato seedlings production system was reduced significant operating cost required for labors (land preparation and sowing, weeding, seedlings uplifting and tying) but increased materials (cell tray, coo-dust) cost. The cost of production of plastic cell tray seedlings required about 72% more (9000 BDT) than that of mud-bed seedlings (Table 1). However, the cost increase in the plastic cell tray was 17500 and 1500 BDT for purchasing plastic cell tray and coco-dust, respectively. The selling price of plastic cell tray seedlings was increased by 75000 BDT over mud-bed seedlings for 50000 seedlings (Table 2). During vegetable production season the individual seedling price was varied from 0.5 to 2.0 BDT. The expected net profit from using the plastic cell tray was 66000 BDT/50000 seedlings.

Eggplant seedlings growth assessment

The growing medium effect was not significant for seed germination, plant height and survival of brinjal seedlings (Data not shown in the text). At 2 and 4 WAS, there was a significant effect of growing medium for plant vigor (Fig. 2A).

Table 3. The net effect of using plastic cell tray eggplant seedlings relative to med-bed eggplant seedlings.

Budget variable	Selling prices of mud-bed (BDT/50000 seedlings)[z]	Selling price of plastic cell tray (BDT/50000 seedlings)[z]	Value changes (BDT/50000 seedlings)
Revenue changes	30000	125000	95000
Cost changes[x]	12500	21500	9000
Net effects	17500	103500	86000

[x] Cost of production (50000 seedlings) are alike to tomato (Table 1), [z]Selling price (50000 seedlings): at 0.6 BDT/seedling for mud-bed and 2.5 BDT/seedling for plastic cell tray.

Table 4. The net effect of using plastic cell tray sweet gourd seedlings relative to med-bed sweet gourd seedlings.

Budget variable	Selling prices of mud-bed (BDT/50000 seedlings)[z]	Selling price of plastic cell tray (BDT/50000 seedlings)[z]	Value changes (BDT/50000 seedlings)
Revenue changes	15000	75000	60000
Cost changes[x]	12500	21500	9000
Net effects	2500	53500	51000

[x] Cost of production (50000 seedlings) are alike to tomato (Table 1), [z]Selling price (50000 seedlings): at 0.3 BDT/seedling for mud-bed and 1.5 BDT/seedling for plastic cell tray.

Vigor was significantly higher with plastic cell tray than mud-bed seedlings. But, mud-bed seedlings didn't differ from small size one-time plastic cup seedlings for plant vigor. A similar trend was found for the leaf number of eggplants (Fig. 2B). However, the stem diameter was not significant throughout the research period. Like plant vigor, total biomass was higher with a plastic cell tray compared to mud-bed seedlings (Fig. 2C).

Table 5. The net effect of using plastic cell tray cauliflower seedlings relative to med-bed cauliflower seedlings.

Budget variable	Selling prices of mud-bed (BDT/50000 seedlings)[z]	Selling price of plastic cell tray (BDT/50000 seedlings)[z]	Value changes (BDT/50000 seedlings)
Revenue changes	20000	100000	80000
Cost changes[x]	12500	21500	9000
Net effects	7500	78500	71000

[x] Cost of production (50000 seedlings) are alike to tomato (Table 1).

[z] Selling price (50000 seedlings): at 0.4 BDT/seedling for mud-bed and 2.0 BDT/seedling for plastic cell tray.

Economic evaluation for eggplant seedlings production

The cost of production of plastic cell tray eggplant seedlings required about 72% more (9000 BDT) than that of mud-bed seedlings which were alike to tomato (Table 1). However, the selling price of 50000 plastic cell tray seedlings was increased by 95000 BDT over mud-bed seedlings (Table 3). During vegetable production season the individual seedling price was varied from 0.6 to 2.5 BDT. The expected net profit from using the plastic cell tray was 86000 BDT/50000 seedlings.

Sweet gourd seedlings growth assessment

The plant growth was not significantly affected by the growing medium except plant height and leaf number. Plant height was higher with a plastic cell tray (6.85 cm) compared to mud-bed seedlings (5.02 cm) (Fig. 3A). But, mud-bed seedlings didn't differ from one-time plastic cup seedlings for plant height. Similarly, leaf number was higher with a plastic cell tray compared to mud-bed seedlings (Fig. 3B). However, plastic cell tray seedlings didn't differ from large size plastic cups and mud-bed seedlings didn't vary from small size plastic cups.

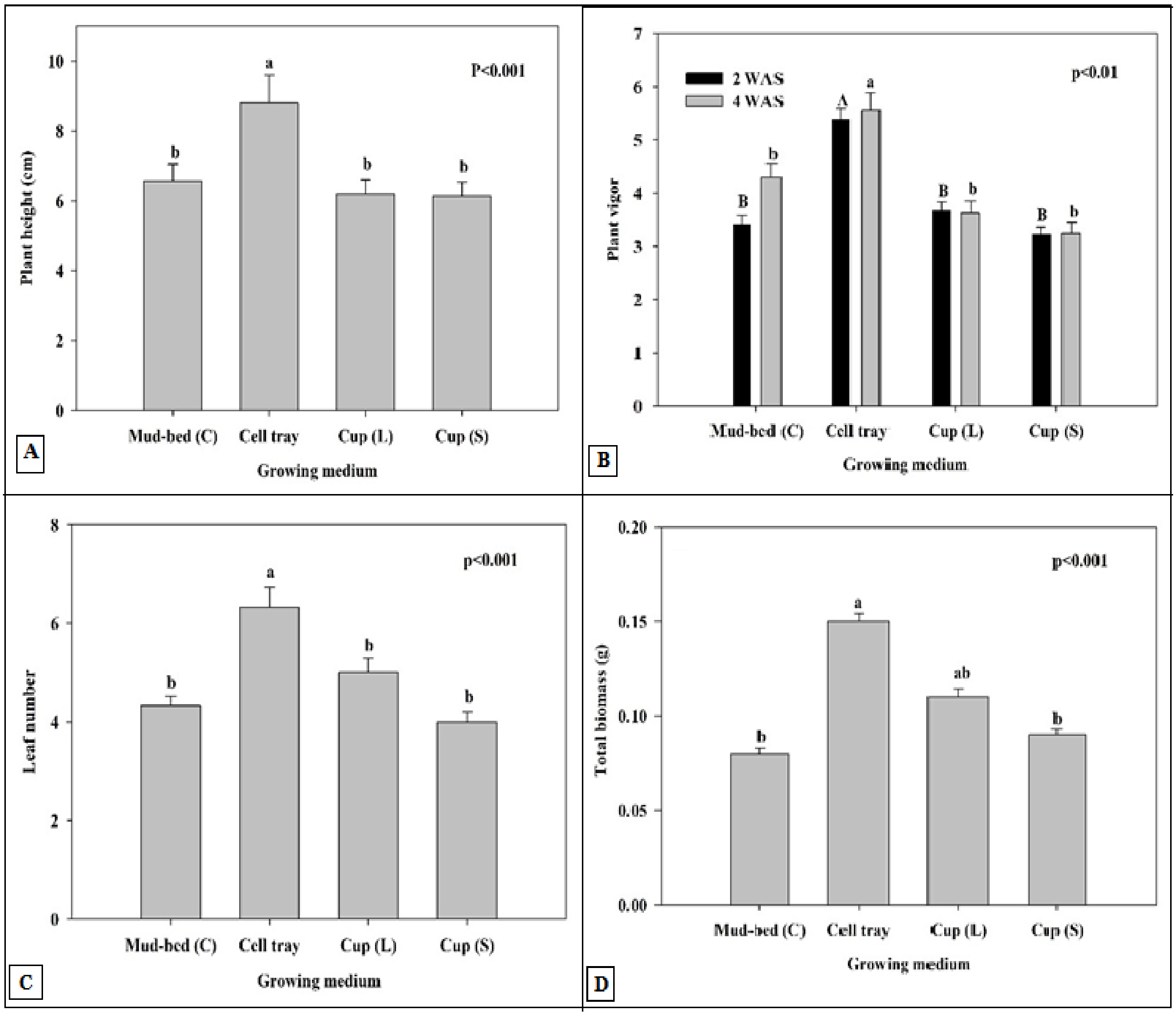

Fig. 1. Effect of mud-bed and containerized growing medium on A. plant height, B. plant vigor C. leaf number and D. total biomass of tomato seedlings, the vertical bar represents a standard error, p-value indicates significant level, means that do not share a letter are significantly different, C-control, L-large, S-small, WAS-week after sowing.

Economic evaluation for sweet gourd seedlings production

The selling price of 50000 plastic cell tray sweet gourd seedlings was increased by 60000 BDT over mud-bed seedlings (Table 4). During the vegetable production season, the individual seedling price was varied from 0.3 to 1.5 BDT. The expected net profit from using the plastic cell tray was 51000 BDT/50000 seedlings.

Cauliflower seedlings growth assessment

The growing medium was not significantly interacted with the growth of cauliflower except seed germination and plant vigor. The highest seed germination (100.0%) was recorded in a large size plastic cup similar to a plastic cell tray (98.7%). In contrast, the lowest was found in small size plastic cups (91.7%) which didn't differ from mud-bed seedlings (93.3%). At 2 and 4 WAS, plant vigor was higher with plastic cell tray compared to mud-bed seedlings which alike to plastic cups (Fig. 4).

Economic evaluation for cauliflower seedlings production

The total operating cost would be about the same for all crops. The selling price of 10000 plastic cell tray cauliflower seedlings was increased by 80000 BDT over mud-bed seedlings (Table 5). During the vegetable production season, the individual seedling price was varied from 0.4 to 2.0 BDT.

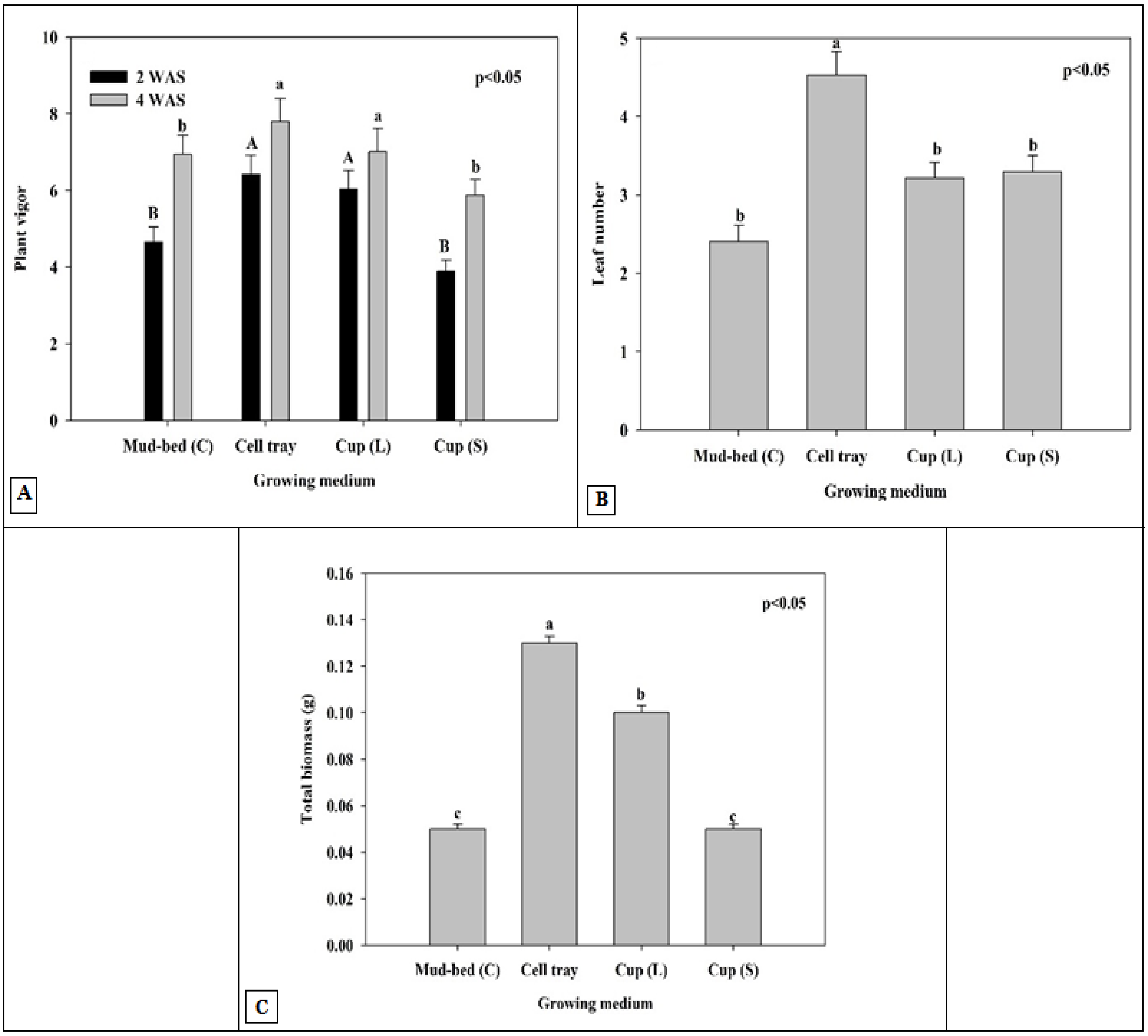

Fig. 2. Effect of mud-bed and containerized growing medium on A. plant vigor B. leaf number and D. total biomass of eggplant seedlings, the vertical bar represents a standard error, p-value indicates significant level, means that do not share a letter are significantly different, C-control, L-large, S-small, WAS-week after sowing.

The expected net profit from using the plastic cell tray was 71000 BDT/50000 seedlings.

Discussion

Improved plant height, vigor, leaf number and biomass of plastic cell tray of different vegetables seedlings are consistent with previous reports that plastic cell tray containing seedlings can protect plants from adverse weather and soilless growing medium is used instead of soil to which nutrients are added for healthy root development and seedling growth. Also, plastic cell tray seedlings have a root ball that holds moisture and ensures root integrity and enhances seedlings growth and have superior vigor (Lin *et al.* 2015; Coolong, and Boyhan, 2017). Dimsey (2009) reported that seedlings can easily detach from the cell tray and the intact root systems reduce the incidence of transplant shock and improved crop uniformity which matched this finding. In contrast, the roots of mud-bed seedlings incur root injury when the seedlings are pulled from the beds for transplanting, adversely affecting transplant growth (Lin *et al.*, 2015). Several plant growth parameters (germination, survival, stem diameter) were not varied significantly among the containerized seedlings.

It may be all containerized seedlings were grown in coco-dust media that facilitated alike environments for roots development and seedlings growth.

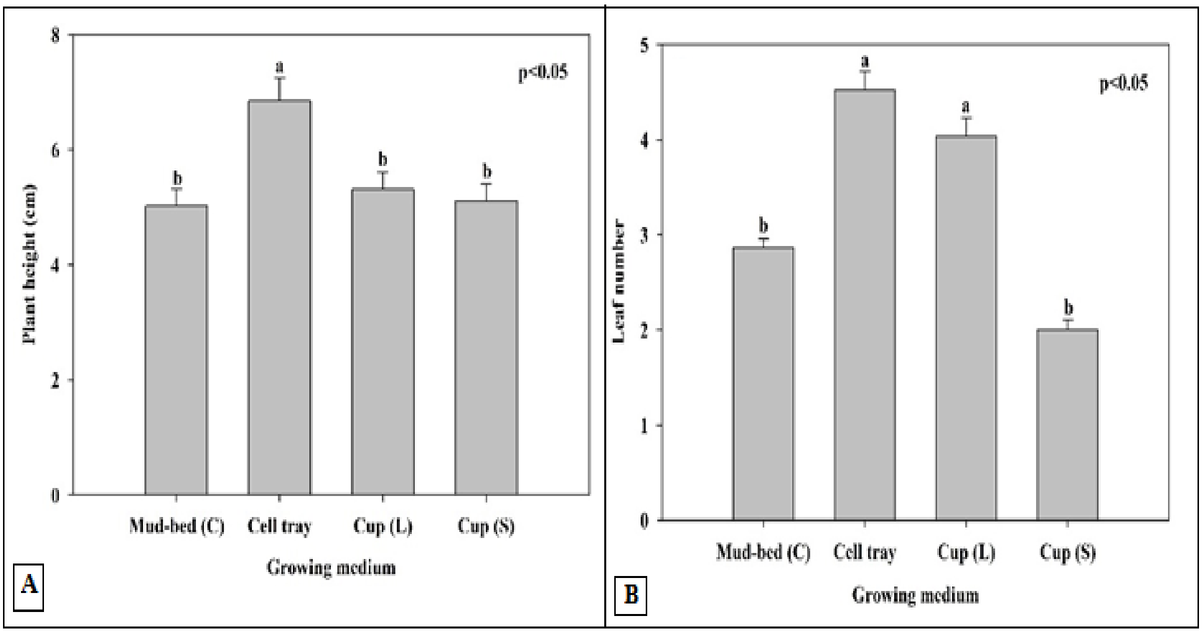

Fig. 3. Effect of mud-bed and containerized growing medium on A. plant vigor and B. leaf number of sweet gourd seedlings, the vertical bar represents a standard error, p-value indicates significant level, means that do not share a letter are significantly different, C-control, L-large, S-small.

There must be a revenue reward for the current vegetable seedlings grower in addition to the less operating costs for the plastic cell tray. That revenue reward was provided by price premiums from more individual seedling price. The savings in operating costs (labors) would add more to this cost-effectiveness.

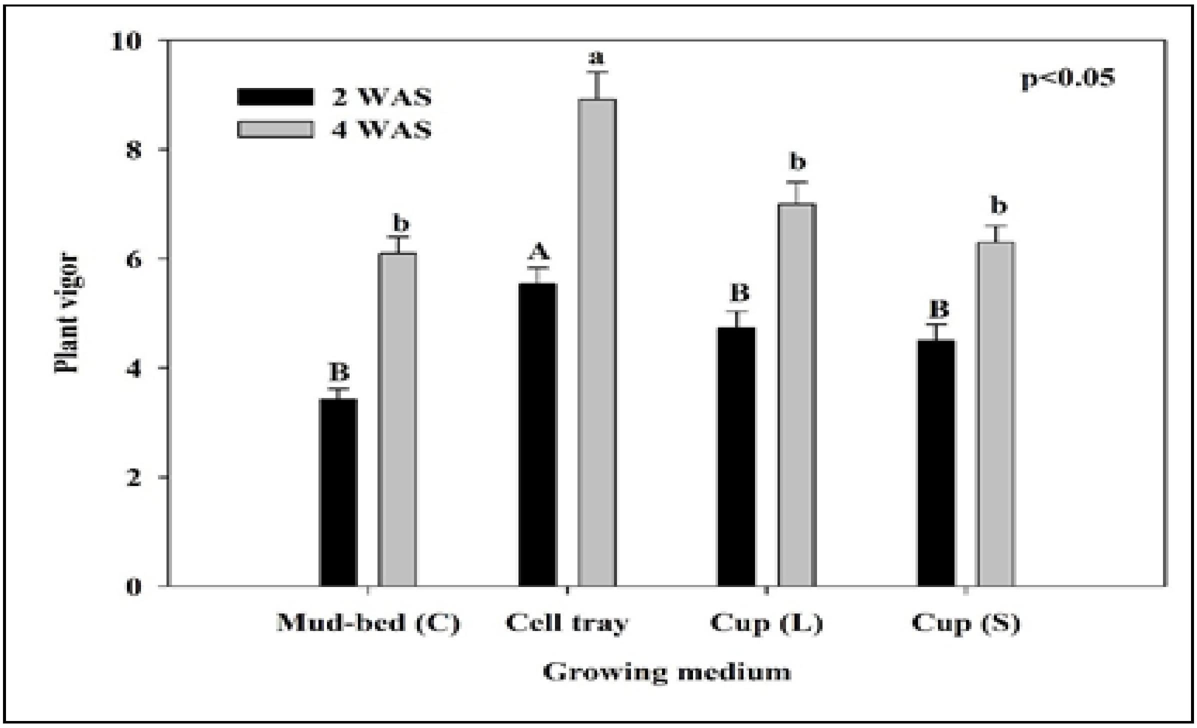

Fig. 4. Effect of mud-bed and containerized growing medium on plant vigor of cauliflower seedlings, the vertical bar represents a standard error, p-value indicates significant level, means that do not share a letter are significantly different, C-control, L-large, S-small, WAS- week after sowing.

The net profit was higher with containerized seedlings over field-grown seedlings reported by Coolong and Boyhan (2017). More profit can be made by containerized seedlings production system than filed grown seedlings that would ensure employment opportunities especially women and develop entrepreneurship. The capacity to establish plants without soil would be a special advantage of vegetable seedlings grower in making a profit from commercial or even small-scale vegetable cultivation in Bangladesh.

Conclusion

Growing media is important for vegetable seedlings production. Overall, the greater seedling growth was observed with a plastic cell tray compared to mud-bed seedlings. The total profitability of the plastic cell tray production system was elevated by 66000 BDT (tomato), 86000 BDT (eggplant), 51000 BDT (sweet gourd), and 71000 BDT (cauliflower), respectively for 50000 seedlings each compared to traditional mud-bed seedlings. Among the four vegetable seedling production system, the cost-effectiveness was higher with the eggplant seedlings production system. Thus, the plastic cell tray with a coco-dust seedling production system came up with a new hope for vegetable growers in Bangladesh that would ensure maximum economic returns.

Acknowledgements

This research work was supported by the United States Agency for International Development (USAID) through the International Maize and Wheat Improvement Center (CIMMYT) and Michigan State University (MSU) under the Borlaug Higher Education for Agricultural Research and Development (BHEARD) program. The author glad to the University of Florida, USA and Khulna University, Bangladesh for providing supports to accomplish this research works.

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