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Impact of Thickness of Floating Bed on the Performance of Select Summer Vegetables

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ABSTRACT

This research was conducted to evaluate the effect of thickness of floating beds on the growth and yield of okra, Indian spinach, cucumber and red amaranth, from 2013 to 2014, at Gopalganj district in Bangladesh. The single-factor experiment was conducted as a Randomized Complete Block Design (RCBD) with three replications. There were three treatments viz. 1.5 m, 2.0 m and 2.5 m thickness of floating bed, the raw material of which was solely comprised of water hyacinth biomass. The thickness of the floating bed was reduced each month due to a gradual decomposition of water hyacinth, and as the rotten material fell into the water and soil. The rate at which the floating bed became thinner accelerated through time. For okra, the maximum plant height (150.67 and 151.77 cm, respectively) was found in response to the 2.5 m thick bed which was significantly similar to the 2.0 m thick bed in both growing seasons. Bed thickness of 2.5 m led to more branches (6.67 and 6.67, respectively), leaves (47.00 and 49.67, respectively), fruits (25.00 and 26.00, respectively), fruit length (14.56 cm and 14.02 cm, respectively), fruit diameter (6.29 cm and 6.08 cm, respectively) and yield (7.99 and 8.09 t ha-1, respectively). Minimum values were observed in response to the 1.5 m thick bed in both years. A similar trend was also observed in the case of other three corps, i.e. Indian spinach, Cucumber and Red amaranth, regarding their growth and yield, as a function of bed thickness. From an economic viewpoint, the 2.0-meter thick bed was found suitable for the production of the said crops.

Introduction

Floating agriculture or floating bed vegetable production is a farmer's innovation that is being practiced in low-altitude areas of middle and southern districts of Bangladesh, as well as in the Haor region of Bangladesh. In some parts of the country, farmers practice floating cultivation in their submerged lands. Floating agriculture is an environmentally-friendly option for increasing land availability for agriculture. Since people are increasingly confronting adverse effects of climate change, it is simply a matter of changes in weather patterns that ultimately determines crop survival; too little water or too much can damage crops, and people could be left with not enough food to live, along with higher risks in food safety and security (Rahman and Alam, 2003; CARE, 2011). The procedure of floating agriculture can even contribute to the maintenance of healthy wetlands (Haq et al., 2004), some of which function as coastal defense lines and support a wide range of biodiversity.

In the floating bed method, mostly horticultural crops like vegetables are cultivated. Seedlings can

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also be raised on this type of bed (Irfanullah et al., 2011). In southern regions, as well as southwestern coastal areas and the Haor region of Bangladesh, the land is submerged under flood water for 7-8 months. This usually restricts the use of land for cultivation. The condition becomes very acute if flood is more and if it is persistent than usually expected (as in the floods of 1988, 1998 and 2007). Geographically, Bangladesh is a climate-induced vulnerable country (Dasgupta et al., 2016). In 2017, the Global Climate Risk Index ranked Bangladesh 6th among climate-affected countries (Kreft et al., 2016), due to the impacts of weather-related events like storms, floods, and heat waves.

Water hyacinths is locally available in many parts of Bangladesh and can be used for the preparation of floating beds. They tend to provide a platform on which seedlings, vegetables and crops can be raised. Dried and rotten water hyacinths can act as foundations for growing crops and for producing manure. The first few layers usually act as the base of the floating bed and maintain the stability and buoyancy, while the top layers are used by plants as compost. Due to water logged conditions in the southwest and northeastern regions of Bangladesh, the scope for vegetable production is decreasing day by day in field conditions. Meanwhile, floating beds can create revenues for increasing vegetable production in the water logged areas of the southwest and northeastern regions of Bangladesh.

Thicker floating beds are more likely to remain stable for more than 12 months. Thus, round-the-year cultivation becomes feasible on these beds. The thickness of a floating bed depends on the duration of water logging and life cycle of the crops, as it needs to float for the whole time of inundation and simultaneously supply essential nutrients for crop growth.

There are no fixed rules about the size and shape of the floating beds, especially the thickness of the floating bed. So far, villagers have made floating beds by water hyacinth, and farmers are seen cultivating vegetables on these beds traditionally, although they do not follow any scientific method. Through original research, thus, it seemed necessary to arrive at a scientific method or model for this purpose. Considering the points in view, the current research was carried out with the objectives of measuring the capabilities and particularities of these floating beds. Also, the aim was to determine the impact of thickness of the floating bed on the performance of summer vegetables that are mostly consumed in Bangladesh.

Materials and Methods

Location of the experimental site and duration

The experiment was conducted in the sub district of Tungipara in Gopalganj, Bangladesh, from June to October, 2013, and also from June to October, 2014. The site was located between 23000` - 23050` north latitude and 89050` - 89059` east longitude.

Experimental design and planting materials

The single-factor experiment was conducted as a Randomized Complete Block Design (RCBD) with three replications and with three levels of bed thickness as treatments, i.e. 2.5 m, 2.0 m and 1.5 m. Water hyacinth was used as a raw material to construct the floating beds. Four crops were cultured on the beds by seed cultivation, i.e. red amaranth (*Amaranthus gangaticus* L.), Indian spinach (*Basella alba* L.), cucumber (*Cucumis sativus* L.) and okra (*Abelmoschus esculentus* L.). The three treatments were then prepared with desired values of width and length, and were distributed randomly among each block, so that all treatments occurred in each block. The size of each unit of floating bed was 5 m length x 1m width.

Floating bed preparation

Matured water hyacinths were collected from a nearby river and wetlands where they grow profusely. Then, a first layer was made with 1.7 m thickness, 1.0 m width and 5 m length; 1.4 m thickness, 1.0 m width, and 5 m length; 1.0 m thickness, 1.0 m width, and 5 m length, according to the respective treatments, i.e. 2.5 m, 2.0 m and 1.5 m. Water hyacinths were again dumped on the first layer after 10 days from the first dumping, although this time with 0.8 m thickness, 0.6 m thickness, and 0.5 m thickness, respectively, for the treatments of 2.5 m, 2.0 m and 1.5 m. When the required thickness was achieved for each treatment, the bed was left for decomposition before sowing the seeds or planting the seedlings.

Maintenance of floating bed

Bamboos were used as anchorage of the floating beds to keep them fixed in place, and to prevent them from floating away by wind or water currents. The decomposed parts of the floating bed, as well as roots of water hyacinth were cut and placed underneath the seedlings, or they were put on chopped materials on the floating bed, 30 cm away from the edge of the bed. Thus, the seedlings received nutrients and grew healthy. A small country-boat was used for monitoring and maintaining the floating beds.

Raising of seedlings

A small ball was made with decomposed water hyacinth. The ball is locally called "Tema". After two days, the seeds of okra, Indian spinach and cucumber germinated and were placed inside the Tema. Two sprouted seeds were put in each Tema which, in turn, was placed on the seedbed. The seedbed was shaded by polythene for protection against heavy rainfall.

Transplanting, seed sowing and other intercultural operations

Before transplanting, a hole or pit was made on the floating bed, while maintaining plant spacing as 50 cm x 50 cm, with okra and Indian spinach planted on two rows. Cucumber was planted at 80 cm spacing in the middle portion of the floating bed in one row. Before sowing Red amaranth seeds, a layer was made with decomposed water hyacinth on the floating bed. Then, after 2 days, excessive moisture was reduced and the seeds were mixed with ash, before being sown on the floating beds. Irrigation, weeding and plant protection were carried out as and when needed, especially at the primary stage of seedling establishment. Fungicide 'Thiovit' and insecticide 'Diazinon' were used to control powdery mildew in cucumber, and to control shoot/fruit borers in okra, respectively.

Data collection

Five plants were selected randomly from each unit of the plot and the parameters were recorded at 15-day intervals. The measurable factors included plant height (cm), number of leaves, branches and fruits per plant, length and diameter of fruit (cm), individual fruit weight (g), weight of harvested fruits per plant and fruit yield per hectare in case of okra. In the case of Indian spinach, the main stem length (cm), number of leaves and branches per plant, total leaf and stem weight (g), fresh yield per plant (kg) and yield (t ha-1) were measured. In the case of cucumber, main stem length (cm), number of leaves, branches and fruits per plant, length and diameter of fruit (cm), individual fruit weight (g), weight of harvested fruits per plant, fruit yield (t ha^{-1}) were measured. Meanwhile, plant height (cm), number of leaves per plant, fresh weight of 5 plants (g) and yield (t ha^{-1}) were measured in red amaranth. The collected data, with respect to various parameters, were statistically analyzed using MSTAT-C statistical package, and the difference between mean values were evaluated by Duncan's New Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Results

Okra growth

The values of parameters increased significantly with the increase in bed thickness (Table 1). The maximum plant height (150.67 and 151.77 cm, respectively) was found in the 2.5 m thick bed, followed by the 2.0 m thick bed (127.33 and 127.83 cm, respectively), whereas the minimum plant height (99.33 and 89.43 cm, respectively) was recorded in plants of the 1.5 m thick floating bed in 2013 and 2014. The maximum number of branches (6.67 and 6.67, respectively) and leaves (47.00 and 49.67, respectively) were found in plants of the 2.5 m thick bed, whereas the minimum number of branches (3.00 and 2.33, respectively) and leaves (21.00 and 25.33, respectively) were obtained in the 1.5 m thick bed in 2013 and 2014 (Table 1).

Okra yield and yield components

The maximum number of fruits (25.00 and 26.00, respectively) was found in the 2.5 m thick bed, and the minimum number (13.00 and 14.00, respectively) was found in the 1.5 m thick floating bed. The maximum fruit length (14.56 and 14.02 cm, respectively) was found in the 2.5 m thickness and the minimum (12.76 and 12.93 cm, respectively) was recorded in the 1.5 m thickness of floating bed in 2013 and 2014, respectively. The maximum fruit diameter (6.29 and 6.08 cm, respectively) was found in the 2.5 m thickness and the minimum (5.57 and 5.65 cm, respectively) was recorded in the 1.5 m thickness of floating bed in both years (2013 and 2014), respectively (Table 2).

Individual fruit weight, fruit weight per plant and yield per hectare showed significant improvements in relation to increased bed thickness (Table 2). The maximum individual fruit weight (20.21 and 20.55 g, respectively), fruit weight plant-1 (370.59 and 404.67 g, respectively) and yield (7.99 and 8.09 t ha-1, respectively) were found in the 2.5 m thick floating beds, whereas the minimum individual fruit weight (14.83 and 15.80 g, respectively), fruit weight plant-1 (213.08 and 240.67 g, respectively) and yield (4.77 and 4.83 t ha-1, respectively) were found in the 1.5 m thick floating beds in the two consecutive years (2013 and 2014, respectively).

Table 1. Growth contributing features of okra as influenced by thickness of the floating bed

Treatments	Plant height (cm)		Branches plant^{-1} (No.)		Leaves plant^{-1} (No.)	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	150.67 a	151.77 a	6.67 a	6.67 a	47.00 a	49.67 a
T_2	127.33 a	127.83 a	6.00 a	5.67 b	30.33 b	35.67 b
T_3	99.33 b	89.43 b	3.00 b	2.33 c	21.00 c	25.33 c
CV (%)	5.36	11.63	13.27	13.64	13.59	11.60

Figures in a column having common letter(s) do not differ significantly (P≤0.05). CV= Coefficient of variation. T_1 = 2.5 meter, T_2 = 2.0 meter, T_3 = 1.5 meter of floating bed thickness (water hyacinth as raw material).

Table 2. Yield and yield contributing features of okra as influenced by thickness of the floating bed

Treatments	Fruits plant^{-1} (No.)		Fruit length (cm)		Fruit diameter (cm)		Individual fruit weight (g)		Fruits weight plant^{-1} (g)		Yield (t ha^{-1})	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	25.00 a	26.00 a	14.56 a	14.02 a	6.29 a	6.08 a	20.21a	20.55a	370.59 a	404.67 a	7.99 a	8.09 a
T_2	24.23 a	23.33 a	14.65 a	14.30 a	6.15 a	6.02 a	19.56a	19.65a	315.73 a	341.33 a	6.91 a	6.83 a
T_3	13.00 b	14.00 b	12.76 b	12.93 b	5.57 b	5.65 b	14.83b	15.80b	213.08 b	240.67 b	4.77 b	4.83 b
CV (%)	7.25	8.44	5.33	6.00	4.57	4.33	11.34	10.11	13.24	12.36	10.33	12.34

Figures in a column having common letter(s) do not differ significantly (P≤0.05). CV= Coefficient of variation. T_1 = 2.5 meter, T_2 = 2.0 meter, T_3 = 1.5 meter of floating bed thickness (water hyacinth as raw material).

Table 3. Cost and return analysis of okra production as a matter of the thickness of the floating bed (2013 and 2014)

Thickness of Bed (m)	Mean marketable yield of two years (t ha^{-1})	Mean total variable cost of two years (t ha^{-1})	Mean gross return of two years (t ha^{-1})	Mean net return of two years (t ha^{-1})	Mean benefit cost ratio of two years (BCR)
2.5	8.04 a	3092.13 a	3258.89 a	166.77 b	1.05 b
2.0	6.87 b	2513.08 b	2784.65 b	271.57 a	1.11 a
1.5	4.80 c	1934.08 c	1945.61 c	11.58 c	1.01 c
CV (%)	4.2	4.97	0.2829	8.57	2.6
Level of significance	*	*	*	*	*

*= Significant at 5% level. Mean values followed by common letter(s) in a column do not differ significantly by DMRT. CV= Coefficient of variation.

Sale of marketable okra @ US $ 405.34 per ton, Net return=Gross return – Total variable cost, Benefit cost ratio (BCR) = Gross return ÷ Total variable cost.

Okra economic consideration

In the context of economic consideration, the highest mean cost of production of okra was US $ 3092.13 in the 2.5 m thick bed, followed by the 2.0 m thick bed (US $ 2513.08) in both years. The floating bed of the 2.0 m thick bed led to the highest mean net return (US $ 271.57) and mean BCR value (1.11), followed by the 2.5-meter thick bed (US $166.77), (mean BCR 1.05), respectively (Table 3). Accordingly, the preparation of the floating bed in the 2.0-meter thick bed may be recommended for profitable okra production.

Indian spinach growth

Growth parameters of Indian spinach varied significantly (P≤0.05) as a function of the thickness of floating beds (Table 4). Main stem length increased in thicker beds as compared to other treatment groups. Stem length varied from 67.40 to 159.73 cm (in 2013) and from 106.83 to 168.03 cm (in 2014). The highest stem length (159.73 and 168.03 cm, respectively) was obtained in the 2.5 m thickness and the lowest (67.40 and 106.83 cm, respectively) was obtained in the 1.5 m thickness. The lowest number of leaves (94.33 and 109.00, respectively) was observed from the 1.5 m thickness while the highest number of leaves (134.00 and 133.67, respectively) was found in the 2.5 m thickness (in 2013 and 2014). The highest number of branches (7.33 and 7.33, respectively) was found in the 2.5 m thickness and the lowest (3.67 and 5.00, respectively) was found in the 1.5 m thickness (in 2013 and 2014). The highest stem length, maximum number of leaves and branches were found in the 2.5 m thickness because the decomposed biomass of water hyacinth is a rich source of plant nutrients which cause improvements in the main stem length and produce more leaves and branches in Indian spinach.

Indian spinach yield and yield components

Yield and yield components of Indian spinach varied significantly (P≤0.05) in response to differences in bed thickness (Table 5). The maximum leaf weight (658.33 and 696.00 g, respectively) and stem weight (661.00 and 667.00 g, respectively) were produced in the 2.5 m thick beds, whereas the minimum leaf weight (354.33 and 375.33 g, respectively) and stem weight (373.00 and 470.67 g, respectively) were produced from the 1.5 m thickness (in 2013 and 2014). The maximum fresh yield per plant (1.42 and 1.26 kg, respectively) and yield (36.90 and 35.95 t ha-1, respectively) were obtained from the 2.5 m thickness, whereas the minimum fresh yield per plant (0.73 and 0.85 kg, respectively) and yield (21.82 and 24.04 t ha-1, respectively) were obtained from the 1.5 m thickness (in 2013 and 2014).

Indian spinach economic consideration

In the context of economic consideration, the highest mean cost of production of Indian spinach was US $ 4111.26 in the 2.5 m thick bed, followed by the cost of the 2.0 m thick bed (US $ 2953.16) in both years. The 2.0 m thick floating bed resulted in the highest mean net return (US $ 2864.56) and mean BCR value (1.97), followed by the 2.5 m thick bed (US $ 2217.18) and BCR (1.54), respectively (Table 6). Using floating beds, 2.0 meters thick, may be recommended for profitable Indian spinach production.

Table 4. Growth contributing features of Indian spinach as influenced by thickness of the floating bed

Treatments	Main stem length (cm)		Leaves plant^{-1} (No.)		Branches plant^{-1} (No.)	
	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr
T_1	159.73 a	168.03 a	134.00 a	133.67 a	7.33 a	7.33 a
T_2	142.60 a	151.00 a	123.67 a	126.67 a	6.33 a	6.67a
T_3	67.40 b	106.83 b	94.33 b	109.00 b	3.67 b	5.00 b
CV (%)	8.22	10.67	12.25	11.11	16.82	9.62

Figures in a column having common letter(s) do not differ significantly (P≤0.05). CV= Coefficient of variation.
T_1 = 2.5 meter, T_2 = 2.0 meter, T_3 = 1.5 meter of floating bed thickness (water hyacinth as raw material).

Table 5. Yield and yield contributing features of Indian spinach as influenced by thickness of floating beds

Treatments	Total leaf weight (g)		Total stem weight (g)		Fresh yield plant^{-1} (kg)		Yield (t ha^{-1})	
	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr
T_1	658.33 a	696.00 a	661.00 a	667.00 a	1.42 a	1.26 a	36.90 a	35.95 a
T_2	524.33 a	517.67 a	625.67 a	620.33 a	1.28 a	1.09 a	33.86 a	33.12 a
T_3	354.33 b	375.33 b	373.00 b	470.67 b	0.73 b	0.85 b	21.82 b	24.04 b
CV (%)	17.11	11.07	14.15	11.12	12.43	8.70	9.02	8.07

Figures in a column having common letter(s) do not differ significantly ($P \leq 0.05$). CV= Coefficient of variation. T_1 = 2.5 meter, T_2 = 2.0 meter, T_3 = 1.5 meter of floating bed thickness (water hyacinth as raw material).

Table 6. Cost and return analysis of Indian spinach production due to thickness of floating beds (in 2013 and 2014)

Thickness of Bed (m)	Mean marketable yield of two years (t ha^{-1})	Mean total variable cost of two years (t ha^{-1})	Mean gross return of two years (t ha^{-1})	Mean net return of two years (t ha^{-1})	Mean benefit cost ratio of two years (BCR)
2.5	36.43 a	4111.26a	6328.44 a	2217.18 b	1.54 b
2.0	33.49 a	2953.16b	5817.72 b	2864.56 a	1.97 a
1.5	23.43 b	2760.22 c	4070.14 c	1309.93 c	1.47 c
CV (%)	2.4	0.9379	1.78	5.45	5.1
Level of significance	*	*	*	*	*

*= Significant at 5% level. Means followed by common letter(s) in a column do not differ significantly by DMRT. CV= Coefficient of variation.
Sale of marketable Indian spinach @ US $173.72 per ton, Net return=Gross return – Total variable cost, Benefit cost ratio (BCR) = Gross return ÷ Total variable cost.

Cucumber growth

Results on the impact of bed thickness on main vine length, number of branches per plant and number of leaves per plant of cucumber (Table 7) showed that the lowest vine length (161.10 and 160.80 cm, respectively), the minimum number (45.33 and 39.33, respectively) of leaves and the lowest number of branches (5.67 and 4.67, respectively) were observed in plants of the 1.5 m thickness, while the highest vine length (252.60 and 269.90 cm, respectively), the maximum number of leaves (91.33 and 89.00, respectively) and the highest number of branches (7.67 and 8.00, respectively) were observed in beds with 2.5 m thickness (in 2013 and 2014). However, there was no significant difference between the treatment group of 2.5 m thickness and 2.0 m thickness.

Cucumber yield and yield components

Results of fruit count, length, diameter, individual fruit weight and fresh yield of cucumber are shown in Table 8. All parameters showed a significant trend of increase in relation to bed thickness. While considering each year separately, i.e. 2013 and 2014, the number of fruits per plant varied from 5.67 to 13.67 and from 6.00 to 13.67, respectively, fruit length varied from 10.75 to 15.33 and from 11.78 to 14.33 cm, respectively, while fruit diameter varied from 13.25 to 15.67 and from 12.98 to 15.23 cm, respectively. Individual fruit weight varied from 162.20 to 210.14 g and from 125.04 to 188.86 g, respectively, during the two years. The minimum fresh fruit weight per plant (2.02 and 2.09 kg, respectively) and yield (12.12 and 12.52 t ha-1, respectively) were found in the 1.5 m thickness, whereas the maximum fresh fruit weight per plant (3.41 and 3.46 kg, respectively) and yield

(20.47 and 20.73 t ha-1, respectively) were found in the 2.5 m thickness. However, there was no significant difference between the effects of 2.5 m thickness and 2.0 m thickness in both years in this regard.

Table 7. Growth contributing features of cucumber as influenced by thickness of floating beds in 2013 and 2014

Treatments	Main vine length (cm)		Leaves plant^{-1} (No.)		Branches plant^{-1} (No.)	
	1styr	2ndyr	1styr	2ndyr	1styr	2ndyr
T_1	252.60 a	269.90 a	91.33 a	89.00 a	7.67 a	8.00 a
T_2	213.43 a	222.70 a	76.67 a	67.67 a	7.00 a	7.00 a
T_3	161.10 b	160.80 b	45.33 b	39.33 b	5.67 b	4.67 b
CV (%)	13.39	5.49	8.50	18.47	16.35	6.38

Figures in a column having common letter(s) do not differ significantly ($P \leq 0.05$). CV= Coefficient of variation. T_1 = 2.5 meter, T_2 = 2.0 meter, T_3 = 1.5 meter of floating bed thickness (water hyacinth as raw material).

Table 8. Yield and yield contributing features of cucumber as influenced by thickness of floating beds in 2013 and 2014

Treatments	Fruits plant^{-1} (No.)		Fruit length (cm)		Fruit diameter (cm)		Individual fruit weight (g)		Fruits weight plant^{-1} (g)		Yield (t ha^{-1})	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	13.67 a	13.67 a	15.33a	14.33a	15.67a	15.23a	210.14a	188.86a	3.41a	3.46a	20.47 a	20.73 a
T_2	12.33 a	12.00 a	14.81a	13.87a	15.34a	14.85a	206.29a	158.11a	3.04a	3.08a	18.24 a	18.51 a
T_3	5.67 b	6.00 b	10.75b	11.78b	13.25b	12.98b	162.20b	125.04b	2.02b	2.09b	12.12 b	12.52 b
CV (%)	15.31	9.99	3.63	2.66	6.23	3.78	6.79	8.94	6.31	6.26	10.25	10.23

Figures in a column having common letter(s) do not differ significantly ($P \leq 0.05$). CV= Coefficient of variation. T_1 = 2.5 meter, T_2 = 2.0 meter, T_3 = 1.5 meter of floating bed thickness (water hyacinth as raw material).

Cucumber economic consideration

Regarding economic considerations, the highest mean cost of production of cucumber was US $ 3590.11 in the 2.5 m thick bed, followed by the mean cost of the 2.0 m thick bed (US $. 2914.47) in both years. The floating bed of 2.0 m thick bed resulted in the highest mean net return (US $2406.10) and mean BCR value (1.83), followed by the 2.5-meter thick bed (US $ 2374.11) and (1.66 BCR), respectively in 2013 and 2014 (Table 9). Thus, the preparation of the 2.0-meter thick bed may be recommended for profitable cucumber production.

Red amaranth growth

In the case of red amaranth, the results showed that the lowest plant height (14.93 and 16.90 cm, respectively) and the minimum number of leaves (10.67 and 9.33, respectively) were found in the 1.5 m thick bed, whereas the tallest plants (24. 87 and 22.93 cm, respectively) and the maximum number of leaves (14.67 and 12.00, respectively) were observed in the 2.5 m thick floating bed in 2013 and 2014, respectively.

The maximum fresh weight (45.00 and 43.00 g, respectively) and yield (10.81 and 10.68 t ha-1, respectively) were observed in the 2.5 m thick bed, whereas the minimum fresh weight (23.67 and 24.33 g, respectively) and yield (5.44 and 5.86 t ha-1, respectively) were observed in the 1.5 m thick bed in 2013 and 2014 (Table 10), respectively. However, there was no significant difference between the 2.5 m thickness and the 2.0 m thickness in the two years.

Table 9. Cost and return of cucumber production, depending on the thickness of the floating bed (2013 and 2014)

Thickness of Bed (m)	Mean marketable yield of two years (t ha^{-1})	Mean total variable cost of two years (t ha^{-1})	Mean gross return of two years (t ha^{-1})	Mean net return of two years (t ha^{-1})	Mean benefit cost ratio of two years (BCR)
2.5	20.60 a	3590.11a	5964.22 a	2374.11 a	1.66 b
2.0	18.38 b	2914.47 b	5321.47 b	2406.10 a	1.83 a
1.5	12.32 c	2335.42 c	3566.95 c	1231.52 b	1.53 c
CV (%)	2.10	1.91	2.04	7.77	2.08
Level of significance	*	*	*	*	*

*= Significant at 5% level. Mean values followed by common letter(s) in a column do not differ significantly by DMRT. CV= Coefficient of variation.
Sale of marketable cucumber @ US $ 289.53 per ton, Net return=Gross return – Total variable cost, Benefit cost ratio (BCR) = Gross return ÷ Total variable cost

Table 10. Growth, yield and yield contributing features of red amaranth as influenced by thickness of floating bed in 2013 and 2014

Treatments	Plant height (cm)		No. of leaves plant^{-1}		Fresh Wt. of 5 plants (g)		Yield (t ha^{-1})	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	24.87 a	22.93 a	14.67 a	12.00 a	45.00 a	43.00 a	10.81 a	10.68 a
T_2	21.50 a	21.57 a	13.67 a	11.00 a	41.00 a	39.67 a	9.70 a	9.83 a
T_3	14.93 b	16.90 b	10.67 b	9.33 b	23.67 b	24.33 b	5.44 b	5.86 b
CV (%)	14.32	8.80	8.88	7.25	11.30	12.36	10.32	6.85

Figures in a column having common letter(s) do not differ significantly ($P \leq 0.05$). CV= Coefficient of Variation. T_1 = 2.5 meter, T_2 = 2.0 meter, T_3 = 1.5 meter of floating bed thickness (water hyacinth as raw material).

Red amaranth economic consideration

Regarding economic considerations, the highest mean cost of production of red amaranth (US $ 3377.71) was recorded in the 2.5 m thick bed, followed by the 2.0 m thick bed (US $ 2702.31) in the two years. The floating bed of the 2.0 m thick floating bed resulted in the highest mean net return (US $ 1257.82) and mean BCR value (1.47), followed by the 2.5-meter thick bed (US $ 979.64), (1.29 BCR), respectively (Table 11). Thus, the preparation of the 2.0-meter thick floating bed may be recommended for profitable red amaranth production.

Discussion

From the results of the current experiment, it was found that almost all measurable parameters were significantly influenced by the thickness of the floating bed. Almost all features acquired the highest values when the floating bed had a thickness of 2.5 m. Nonetheless, there was no significant difference between the 2.5 m-thick and the 2.0 m-thick floating beds in both years. The 1.5 m-thick floating bed resulted in the lowest values in all the measured characteristics. A similar trend was observed in the three corps, i.e. Indian spinach, cucumber and red amaranth, regarding plant growth and yield, as a function of bed thickness.

In the case of okra, the parameters showed significant improvements in response to thicker beds. The maximum plant height, maximum number of branches, maximum number of leaves, maximum number of fruits, maximum fruit length, maximum fruit diameter, individual fruit weight, fruit weight per plant and yield per hectare were found in the 2.5 m-thick bed, followed by the 2.0 m-thick bed, whereas minimum values were recorded in the 1.5 m-thick floating bed in both years.

Table 11. Cost and return of red amaranth production as a function of the thickness of floating beds (2013 and 2014)

Thickness of Bed (m)	Mean marketable yield of two years (t ha^{-1})	Mean total variable cost of two years (t ha^{-1})	Mean gross return of two years (t ha^{-1})	Mean net return of two years (t ha^{-1})	Mean benefit cost ratio of two years (BCR)
2.5	10.75 a	3377.71 a	4357.35 a	979.64 b	1.29 b
2.0	9.77 b	2702.31 b	3960.12 b	1257.82 a	1.47 a
1.5	5.65 c	1930.09 c	2290.14 c	360.05 c	1.19 c
CV (%)	3.3	3.86	4.05	7.13	2.3
Level of significance	*	*	*	*	*

*= Significant at 5% level. Means followed by common letter(s) in a column do not differ significantly by DMRT.
CV= Coefficient of variation.
Sale of marketable red amaranth @ US $ 405.34 per ton, Net return=Gross return – Total variable cost, Benefit cost ratio (BCR) = Gross return ÷ Total variable cost.

These results emanate from the fact that thicker beds tend to supply more plant nutrients for growth and yield. The floating bed is the only source of plant nutrients and growth media in this cultivation technique. The thickness of the floating bed, with decomposed water hyacinth, decreased gradually due to the ongoing process of decomposition, which led to the ultimate disintegration of bed compartments and their release into the water and soil. It was revealed that the decrease in bed thickness was accelerated through time. Decomposed water hyacinths were rich in a variety of organic debris and decomposing materials that released large amounts of essential nutrients. The nutrients in the compost usually do not leach out by rainwater and almost all of the nutrients remain available for the plants (Vidya and Girish, 2014).

It was observed that the thickness of the floating bed, i.e. decomposed water hyacinth, was the only source of plant nutrients because the 2.5 m-thick bed resulted in the best results among all other experimental data. Decomposed water hyacinth contained higher levels of relatively available nutrient elements which are essential for plant growth (Ntanos and Koutroubas, 2002). In this respect, Chatto et al. (2011) reported that a combination of individual organic sources with inorganic fertilizer in an equal proportion (50:50) caused a beneficial outcome in plant growth and yield-contributing parameters. Furthermore, using foliar application of mineral fertilizers can lead to improvements in plant growth, yield and productivity in this cultivation system (Souri and Yaghoubi Sooraki, 2019; Aghaye Noroozlo et al., 2019)

In the context of economic consideration, the highest mean cost of production of okra was observed in the 2.5 m-thick bed, followed by the 2.0 m-thick bed in both years. The floating bed of 2.0 m thickness resulted in the highest mean net return and mean BCR value, followed by the 2.5-m thick bed. Therefore, the preparation of floating beds with 2.0 m thickness may be profitable for okra production. Similar results were also obtained in the case of Indian spinach, cucumber and red amaranth in terms of growth and yield, as well as cost effectiveness in production. Generally, it can be said that the 2.0-m thick bed was suitable for okra, Indian spinach, cucumber and red amaranth production.

Conclusion

This experiment was conducted to evaluate how the thickness of floating beds can affect the performance of growth and yield in okra, Indian spinach, cucumber and red amaranth. It was found that almost all measurable parameters were significantly influenced by the thickness of the floating bed. Almost all features acquired the highest values when the floating bed was prepared by the 2.5 m thickness. Nonetheless, there was no significant difference between the 2.5 m and 2.0 m thickness of the floating beds in both years. In the case of economic consideration, the 2.0-m thick bed was found suitable for okra, Indian spinach, cucumber and red amaranth production. This thickness can be considered as suitable and cost-effective for okra, Indian spinach, cucumber and red amaranth cultivations under the climatic conditions in Gopalganj district in Bangladesh.

Conflict of interest

The authors indicate no conflict of interest in this work.

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