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Evaluation of Growth Performance and Economic Return Analysis of Bathua (*Chenopodium album*) Genotypes

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Abstract

Bathua (*Chenopodium album*), a fast-growing weedy annual plant under the genus Chenopodium, is valuable for its high nutritional, medicinal and economic values as a leafy vegetable. The present study was carried out to evaluate the growth performance and economic returns of bathua genotypes in acid soil at Sylhet, Bangladesh. The experiment was laid out in a randomized complete block design with three replications. Morphological and growth parameters were recorded at the final harvest. The maximum plant height, number of branches per plant, fresh weight of inflorescence and leaf length were recorded in local bathua 1(110.5 cm, 65.33, and 8.93 g, respectively). The maximum fresh weight of leaves per plant, the maximum dry weight of leaves per plant were recorded in local bathua 2 (39.92 g and 8.79 g respectively). Results revealed that the studied morphological parameters including plant height, fresh and dry weight of leaves per plant, fresh and dry weight of stem per plant, fresh and dry weight of inflorescence per plant, stem base diameter, number of leaves per plant, number of branches per plant and leaf length influences the foliage yield of bathua. The highest foliage yield (9.20 $t.ha^{-1}$), total gross return ($Tk.552000.ha^{-1}$), net return ($Tk.367000.ha^{-1}$) and BCR (2.98) were found in local bathua 1. From the findings of the present study, local bathua 1 could achieve higher productivity and profitability in acid soils of Sylhet, Bangladesh.

Keywords: bathua, evaluation, growth parameters, economic returns

Introduction

Bathua (*Chenopodium album*), a significant underused green vegetable with the chromosomal number 2n=36, is a member of the Chenopodiaceae family. It's originated native to Europe and widely distributed around the world, including the West Indies, North America, South America, Africa, Australia, Oceania, and South Asia (Pandey, 2008). In Bangladesh, bathua is known as weeds but it is very popular as leafy vegetable as of its highly nutritive, medicinal and economic values. It is a very good source of protein, carbohydrate, minerals, fibers, vitamin A, and vitamin C (Agrawal et al., 2014; Singh and Singh, 2017). Bathua also has certain therapeutic benefits, such as odontalgic, laxative, antirheumatic, antiphlogistic, anthelmintic for hookworms and roundworms, and blood purifying properties (Sanwal, 2008; Singh et al., 2018). Therefore, the identification of high yielding and stable germplasm of bathua is crucial for its further improvement.

The acreage and output of bathua in Bangladesh are quite small, and it is exclusively farmed locally and reportedly been observed growing naturally as a weed in fields of various crops, including wheat, barley, mustard, potato and gram (Bhattacharjee, 2001). Due to the lack of genotypes with high yields and insufficient or no systemic attention, the area and production of this crop have been constrained (Atikunnaher et al., 2017; Basavaraj et al., 2018; Yadav et al., 2013). Even the replacement of winter vegetable crop by irrigated rice cultivation is one of the major causes of the reduction of its production in the country (Hossain et al., 2017; Mainuddin et al., 2021; Sharmin et al., 2018). Although it has lots of benefits but it is one of the more resilient and

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aggressive weeds which can compete tremendously with the host crops, and can cause crop losses of up to 48% in sugar beets, 25% in soybeans and 13% in maize (Amini et al., 2011) which may loss the economic returns of the cultivated crops. Thus, one of the best options is to cultivate this crop as a sole leafy vegetable crop to boost up the national food supply.

As with other leafy vegetables crops, bathua yield also depicts the complicated nature and depends on a number of factors. The foundation of its successful breeding program is the research of yield and its components' direct and indirect effects, and as a result, yield increase can be better by evaluating the efficacy of yield components and making choices for traits that are closely related to yield (Bhuiyan et al., 2021; Tabassum et al., 2021; Yesmin et al., 2022). Few studies on bathua have been conducted to comprehend their performances, focusing mostly on the contribution of various yield components (Basavaraj et al., 2018; Basavaraj et al., 2019; Poonia and Upadhayay, 2015). It is crucial to quantify the growth factors and other pertinent variables that are important for crop improvement in order to comprehend the physiological underpinnings of yield variation (Hossain et al., 2009; Islam et al., 2022; Sarkar et al., 2021) between bathua genotypes.

Our test site's soil in Sylhet has a pH of 4.80, making it mildly acidic in nature. Usually, the acid soil with lowered pH (4.8 to 5.7) reduces the yield losses up to 30%, have been reported earlier in onion (Sarker et al., 2022), okra (Sumi et al., 2022) and sweet potato (Paul et al., 2021). The screening of cultivated crop genotypes for low pH tolerance would provide a better understanding of the crop adaptation and the management (Chy et al., 2022; Roy et al., 2016). In the meantime, growth performance of different crop plants has been conducted in the acid soil condition in Sylhet region (Monshi et al., 2015; Rahman et al., 2015; Tabassum et al., 2015). Therefore, the present study was conducted to analyze the morpho physiological variations of three genotypes of local bathua and evaluate their economic productivity in acid soil at Sylhet region.

Materials and Methods

Soil and Climate of the Experimental Site

The experiment was set up in the Department of Crop Botany and Tea Production Technology's experimental field in the acid soil at Sylhet Agricultural University, Sylhet, Bangladesh. The experimental area is situated at an elevation of 18 m above sea level, at latitudes of 24°54'34.07″ North and 91°54'5.43″ East. The soil at the test field is a member of the Khadimnagar soil series and is located in the Eastern-Surma-Kushiyara Floodplain Agro-Ecological Zone (AEZ-22). The selected plots of the land were high land. The soil had a pH of 6.80, was neutral, and was low to medium fertile and soil properties of the experimental sites are presented in the Table 1. It was also well drained. The experimental location is in a region with a subtropical climate, which is marked by high temperatures and frequent rainstorms from April to September and minimal rain from October to March. The atmosphere is often cool and sunny during the Rabi season. Starting February and continuing through the Kharif season, the air temperature starts to rise. The Sylhet Meteorological Station provided the detailed meteorological information regarding the monthly means of daily maximum, minimum, and average air temperature, relative humidity, total rainfall, and photoperiod hours (Table 2) at the experimental site during the experimentation period (November 2019 to April 2020).

Table 1. Nutrient status of the soil of experimental field

Elements	Amount
Soil pH	4.83
Organic matter (%)	1.39
Nitrogen (%)	0.07
Phosphorus (μg.g^{-1} of soil)	9.15
Potassium (me.100g^{-1} of soil)	0.38
Sulphur (μg.g^{-1} of soil)	37.98

Source: Regional Office of SRDI (Soil Resources Development Institute), Sylhet-3100, Bangladesh.

Experimental Materials and Design

Three bathua genotypes (local bathua 1, local bathua 2 and local bathua 3) were used as the planting materials for this experiment. Each of the bathua genotype was considered as individual treatment. All these genotypes used in this experiment were collected from the farmers field in the Sylhet region, Bangladesh. A randomized complete block design (RCBD) with three replications was used to set up the experiment. The initial division of the entire experimental area into three blocks. Then, each of the blocks was further divided into three plots and three different bathua genotypes were distributed among them at random. Consequently, there were 9 units in all. The treatments were assigned at random to each block's unit plots. The size of each plot was 2 m × 2.25 m. Co-efficient of variance of each of yield and yield contributing traits were also measured in percentage. Between the blocks and the plots, a 0.5

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Table 2. Monthly air temperature (ºC), relative humidity, rainfall and photoperiod per day of the experimental site during the period from November 2019 to April 2020

Month	Temperature (ºC)			Rainfall (mm)		Relative Humidity (%)	Photoperiod (hours)
	Max.	Min.	Average	Total	Average	Average	Average
November 2019	35.0	23.0	31.17	31	30.4	64.27	8.59
December 2019	31.0	24.0	27.90	13	9.4	67.88	10.53
January 2020	31.0	19.0	26.19	12	9.4	56.48	8.62
February 2020	34.0	25.0	28.9	51	36.2	50.2	8.55
March 2020	39.0	30.0	34.32	204	155.3	49.06	10.87
April 2020	40.0	27.0	36.00	588	375.6	59.78	12.26

Source: Sylhet Meteorological Station, Shahi Eidgah, Sylhet, Bangladesh.

m space was kept to allow for various multicultural operations and good drainage. Bathua seeds directly sown in the soil with the spacing of 2-3 cm apart and later the plant-to-plant distance were maintained with 12 cm of each. Data for yield contributing traits were collected as randomly selected ten plants from each plot.

Crop Husbandry

Using a power tiller to prepare the trial plot, it was then laddered to get a good tilth. Spading was used to level the terrain, and laddering was used to break up the clods. Dolomite (1.50 $t.ha^{-1}$) and well decomposed cow manure (10 $t.ha^{-1}$) was applied to improve soil fertility and characteristics (Ferdous et al., 2018); raising the pH and addition of organic matter to acidic soil increased crop production. The land was cleared of all weeds and brambles. After leveling the land's surface, the plots' perimeter was prepared with irrigation and drainage channels. In order to provide the plot with supplies of nitrogen, phosphorus, potassium, and sulfur, a general dose of urea, triple superphosphate (TSP), muriate of potash (MOP), and gypsum were treated at 60, 110, 85, and 125 $kg.ha^{-1}$, respectively and fertilizer dosages were applied according to the Fertilizer Recommendation Guide (BARC, 2012). At the time of the last land preparation, one third of urea and full of other fertilizers were applied and later the final two thirds of the urea were applied in two stages: 35 DAS (days after sowing) and 65 DAS. All intercultural operations were used in accordance with their requirements.

Harvesting

There are two very simple ways to determine whether a plant is young or old, and the greens are considerably superior on younger plants. On immature plants, all of the leaves have coarse sawtooth edges or borders and are rhomboid (diamond-shaped). On older plants, the upper leaves have smooth edges throughout and are shaped like lanceolate to elliptical, which are long, narrow, and come to a point at both ends (in this case, not a sharp pointed tip). Another sign of a plant's maturity is the stem of older plants is pinkish-mauve in hue, the stem of younger plants is green.

Collection of Experimental Data

Ten plants were randomly chosen from each plot, and their heights were measured from the ground level (stem base) to the tip of upper most landar region of the plant by a meter scale at 20 days interval from 20 DAS up to 80 DAS. The mean plant height was calculated and expressed in centimeter (cm). The number of leaves, base diameter, branches, leaf length of each plant was counted from 25 DAS, 50 DAS and 80 DAS. Fully expanded leaves were considered as leaves. The length of the leaf which subtends the uppermost inflorescence was measured from ligule to apex after flowering by a meter scale. Fresh and dry weight of leaves, stem and inflorescences per plant were measured. Firstly, each of the individual plant parameters were measured as fresh weight (g) and then sun dried for 7 days along with 30ºC in oven dryer then again measured their dry weight (g).

The foliage yield in unit plat was converted in $t.ha^{-1}$. Total labor costs as well as the price of variable inputs required for various procedures were gathered in order to calculate the variable cost of various genotypes, which in turn allowed for the determination of the cost of production as a whole, gross return, and net return. Foliage yield was transformed into a gross return and then multiplied by the market price. Net return was the sum of gross return and total production costs. Benefit cost ratio (BCR) was determined using the formula below in order to compare treatments' superior performance.

$$\text{Benefit-cost Ratio} = \frac{Gross\ return\ \ (Tk/ha)}{Total\ cost\ of\ production\ \ (Tk/ha}$$

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Statistical Analysis

The data were examined using the statistical program R-Studio, which was created by J.J. Allaire and released by Chapman and Hall/CRC in its second edition. Duncan's New Multiple Range Test (Gomez and Gomez, 1984) was used to compare the differences between the treatment means.

Results and Discussion

Various techniques of growth analysis have been widely used in recent years for better understanding of morpho-physiological basis of yield variation in crop plants. Growth analysis is a physiological inquiry on the development of crop in chronological sequence to explain and account the causes for variations in yield through the events that have happened at different stages of growth. The study was conducted to characterize three local bathua genotypes (Figure 1) at morphological level and their economic return to evaluate the field performance of these genotypes. Phenologically the local bathua 1 shows red in colour while local bothua 2 greens' in colour and local 3 in greenish white color (Figure 1), which makes attractive as leafy vegetable to ensure better nutrition for human diet.

Local bathua 1 Local bathua 2 Local bathua 3

Figure 1. Leaf morphology of three bathua genotypes used in the experiment

Plant Height (cm)

The data on plant height presented in Table 3 indicated the significant variation among the different genotypes at 20, 40, 60, and 80 DAS. Plant height of the genotypes increased slowly until 40 DAS, then it increased rapidly to 80 DAS. The local bathua 1 showed the highest plant height (110.5 cm) at 80 DAS followed by local bathua 2 (87 cm). The shortest plant height was recorded in the genotype local bathua 3 (70.70 cm). Yadav et al. (2017) reported that plant height of forty bathua landraces varies from 100 to 135 cm. These results were in agreement with the findings of Basavaraj et al. (2019) who reported that the plant height had minimal diversity between the studied landraces. Plant height can vary from 70 to 110 cm, depending on the variety and growing conditions (Yadav et al., 2017).

Leaf Fresh and Dry Weight (g)

The fresh and dry weight of leaves of different genotypes revealed significant variations at all growth stages (Figure 2). Maximum amount of leaf fresh weight was produced by the genotype local bathua 2 (39.92 g) at harvesting which was statistically identical to local bathua 1 (37.5 g), while minimum amount of leaf fresh weight was produced by local bathua 3 (11.43 g). The variation among the genotypes for leaf fresh weight was due to the difference among the genotypes for number and size of leaves (Islam et al., 2022). On the other hand, maximum amount of leaf dry weight was produced by the genotype local bathua 2 (8.79 g) at harvesting which was statistically identical to local bathua 1 (8.36 g) and it was significantly different with local bathua 3 (5.37 g), while minimum amount of leaf dry weight was produced by local bathua 3 (5.37 g). The present findings are corroborated with the findings of Sarkar et al. (2021) and Toppo et al. (2017).

Stem Fresh and Dry Weight

Stem fresh and dry weight of different genotypes revealed significant variations at all growth stages (Figure 3). Maximum amount of stem fresh weight was produced by the genotype Local bathua 1 (34.34 g) at harvesting which was statistically identical to Local bathua 2 (18.66 g), while minimum amount of leaf fresh weight was produced by local bathua 3 (15.66 g). The result was similar to Poonia and Upadhayay (2015) and stated that such variation among the genotypes for stem fresh weight was due to the difference among the genotypes for number and size of stem. Moreover, maximum amount of stem dry weight was produced by the genotype local bathua 1 (15.95 g) at harvesting which was statistically identical to local bathua 2 (6.60 g), while minimum amount of stem dry weight was produced by local bathua 3 (1.39 g). Ahammed et al. (2013) reported that the plant dry weight depends on the dry matter present on the stem.

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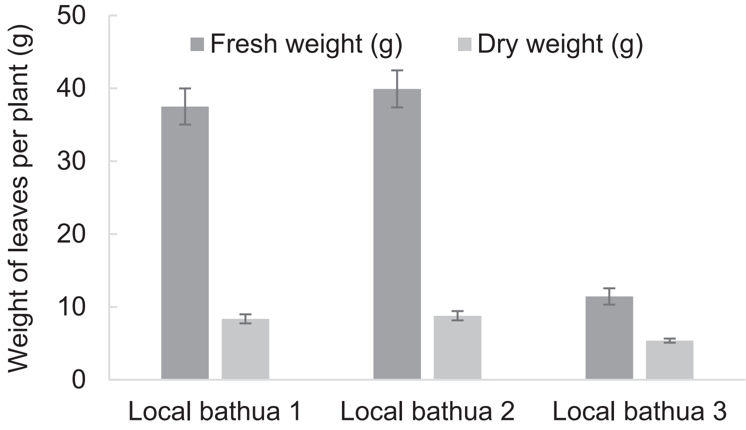

Figure 2. Leaf fresh and dry weight of three local bathua genotypes

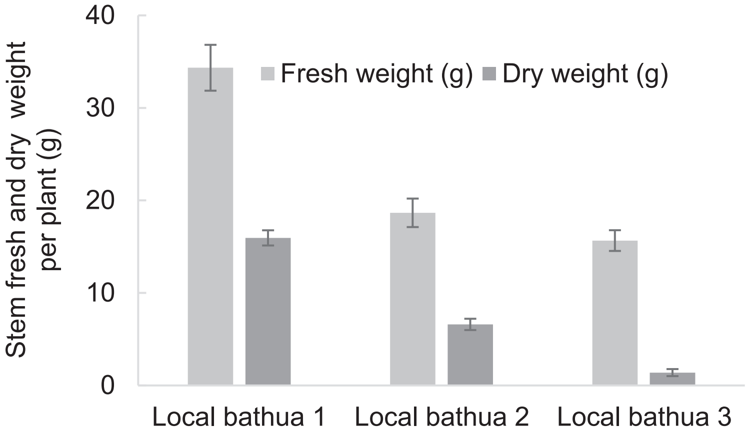

Figure 3. Stem fresh and dry weight of three bathua genotypes

Fresh and Dry Weight of Inflorescence (g)

The fresh and dry weight of inflorescence of different genotypes revealed significant variations at all growth stages (Figure 4). Maximum amount of inflorescence fresh weight was produced by the genotype local bathua 1 (40.13 g) at harvesting which was statistically identical to local bathua 2 (11.86 g), while minimum amount of inflorescence fresh weight was produced by local bathua 3 (9.30 g). The variation in inflorescence fresh weight among genotypes resulted from variations in inflorescence size and number per plant (Bhargava et al., 2007; Yadav et al., 2013). In addition, the highest amount of inflorescence fresh weight was produced by the genotype local bathua 1 (8.93 g) at harvesting which was statistically identical to local bathua 2 (3.20 g), while minimum amount of inflorescence fresh weight was produced by local bathua 3 (1.7 g). The present findings are corroborated with the findings of Ahammed et al. (2013) and Toppo et al. (2017).

Stem Base Diameter (cm)

Significant variations among the genotypes were observed in respect of stem base diameter (Table 4) Maximum stem base diameter was observed in local bathua 1 (9.10 cm) at 80 DAS, 50 DAS and 25 DAS whereas it was the smallest in local bathua 3 (2.90 cm and 1.40 cm, respectively). The variation in the stem base diameter was due to the variation in the genotypes. This result is in agreement with Poonia and Upadhayay (2015) and Basavaraj et al. (2018) who reported significant variations in yield among the bathua genotypes.

Leaf Number per Plant

The results showed that at 25, 50 and 80 DAS leaf number was comparatively low but leaf number increased rapidly at 80 DAS (Table 4). This is because the plants bear many branches with a number of leaves after 80 days. The highest number of leaves of 243 in local bathua 2, and the least average leaf number of 155.66 was recorded Local bathua3, and 156 per plant at 80 DAS. These results are in close conformity with the findings of Ahammed et al. (2013) and Basavaraj et al. (2019)

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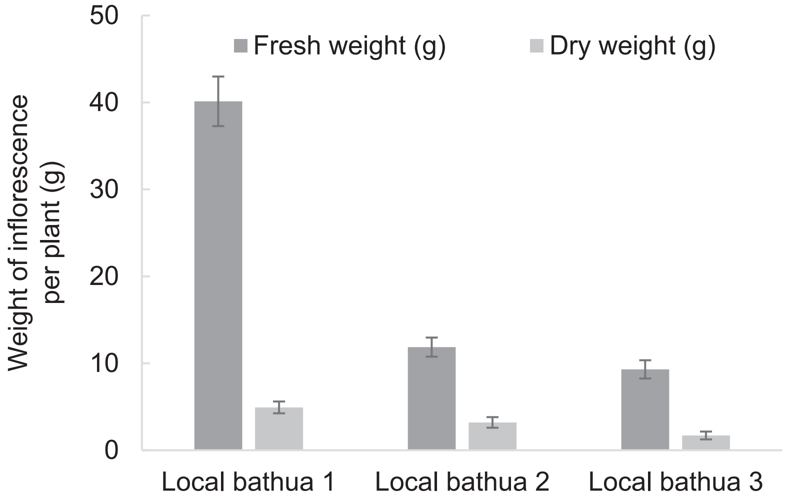

Figure 4. Fresh and dry weight of inflorescence of different bathua genotypes

Number of Branches per Plant

The results showed that at 25, 50 and 80 DAS branches number was low but branches number increased rapidly at 80 DAS (Table 4). This is because the plants bear many branches with a number of leaves after 80 days. The highest number of branches of 96.33 in Local bathua 1, and the least average leaf number of 65.33 in the local bathua 3 at 80 DAS. Toppo et al. (2017) stated that higher number of branches of a plant can increase the biomass as well as increase the biological yield.

Leaf Length per Plant (cm)

Significant variations among the bathua genotypes were observed in respect of leaf length (Table 4). The highest leaf length was observed in local bathua 1 (9.2 cm) at 80 DAS whereas local bathua 2 and local bathua 3 produced almost similar leaf length (5.5 cm and 4.8 cm, respectively). Typically, leaves have thin stems that are about half as long as the leaf blade, are triangular egg-shaped to lance-shaped, and are dull, pale gray green (Bhargava et al., 2007). Three primary veins that stretch from the base of lower leaves are often less than 1.5 times wider than the leaf's width. (Arif et al., 2013; Basavaraj et al., 2018; Singh et al., 2020). Kurashinge and Agarwal (2005) worked on characterization of bathua accessions and reported significant variation among different bathua accessions for leaf length and recorded longest leaf (19.18 cm) and shortest leaf (10.3 cm).

Foliage Yield

The studied genotypes foliage yield per plot was converted in $t.ha^{-1}$. Estimated foliage yield per hectare in bathua genotypes ranged from 6.45 to 9.20 ton (Table 5). The highest foliage yield was found in local bathua 1 followed by local bathua 2 whereas the lowest was found in local bathua 3. These differences happened maybe due to the number and weight of leaves. The results found from the present study were conformity with the findings of Basavaraj et al. (2018); Buragohain et al. (2013) and Hassan et al. (2013).

Economic Return Analysis

The gross return in different bathua genotypes is shown in Table 5. The highest gross return (Tk.552000 ha^{-1}) was obtained from the local bathua 1 while the lowest was obtained in Local bathua 3 (Tk.387000 ha^{-1}). The maximum gross income was noticed in local bathua 1 due to the deduction of labor cost and

Table 3. Plant height of different bathua genotype at different days after sowing

Genotypes	Plant height (cm)			
	Days after sowing			
	20	40	60	80
Local bathua 1	42.26a	93.20a	99.00a	110.50a
Local bathua 2	27.44b	41.33bc	71.18b	87.60b
Local bathua 3	20.36c	42.36b	57.97bc	70.70bc
Sig. level	**	**	*	**
CV (%)	38.92	30.18	28.84	20.62

Mean (s) within a column bearing similar letter (s) are statistically similar according to DMRT. ** = significant at 1% level of probability; * = significant at 5% level of probability.

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Table 4. Yield contributing traits of Bathua genotypes at different days after sowing

Genotypes	Stem base diameter (cm)			Leaf number per plant			Number of branches per plant			Leaf length (cm)		
	Days after sowing (DAS)			Days after sowing (DAS)			Days after sowing (DAS)			Days after sowing (DAS)		
	25	50	80	25	50	80	25	50	80	25	50	80
Local bathua 1	2.67a	6.33a	9.10a	32.33 ab	65.66 ab	156.00 a	17.66ab	38.66a	55.66a	5.5a	8.2a	9.2a
Local bathua 2	0.473b	2.10b	3.96b	24.00 c	68.33 a	243.33 ab	20.33a	35.33ab	48.46b	3.3b	4.2b	5.5b
Local bathua 3	0.553b	1.40b	2.90b	38.00 a	43.00 c	155.66 b	13.00c	29.33c	38.77c	3.2bc	3.9bc	4.8bc
Sig. level	**	**	**	**	**	*	**	**	**	**	**	**
CV (%)	54.74	14.67	13.71	15.99	14.06	17.22	19.34	22.08	23.32	19.34	22.08	23.32

Note: Mean (s) within a column bearing similar letter (s) are statistically similar according to DMRT. ** = significant at 1% level of probability; * = significant at 5% level of probability

Table 5. Economic return analysis of different bathua genotypes

Genotypes	Foliage yield ($t.ha^{-1}$)	Gross return ($Tk.ha^{-1}$)	Total cost of Production ($Tk.ha^{-1}$)	Net return	BCR
Local bathua 1	9.20	552000	185000	367000	2.98
Local bathua 2	7.63	457800	185000	272800	2.47
Local bathua 3	6.45	387000	185000	202000	2.09

Note: Price of foliage yield of bathua @ 60 $Tk.kg^{-1}$; BCR= benefit cost ratio.

higher yield (Basavaraj et al., 2019). Moreover, net return over variable cost was found encouraging in the bathua genotypes. Out of the three genotypes, the highest net return (Tk.367000 ha^{-1}) was found in the local bathua 1. These were mainly due to higher yield of foliage yield and higher market price of bathua (Table 5). Another point is that, when benefit-cost ratio of each genotype was examined, it is found that the local bathua 1 gave the highest benefit-cost ratio (2.98). The lowest benefit-cost ratio (2.09) was obtained from the local bathua 3 which also gave the lowest net return (Table 5). Local bathua 1 had higher output compared to the other genotypes due to the effective usage of growth resources by the component crops (Ahammed et al., 2013; Basavaraj et al., 2018; Toppo et al., 2017).

Conclusion

Significant variability exists among the three genotypes, and it can be inferred that both local bathua 1 and local bathua 2 outperform others in terms of morpho-physiological characteristics and yield attributes, ultimately resulting in a higher foliage yield. Notably, the growth of genotype bathua 1 surpassed that of local bathua 3. While local 1 displays a distinct red hue, local bathua 2 and 3 exhibit a vibrant green color. This divergence in coloration provides an opportunity to diversify food offerings, enhancing nutritional value in an economical manner. Additionally, incorporating bathua into diets can markedly enrich the nutritional quality of meals, given its high nutrient content. Among the genotypes investigated, the preeminent foliage yield (9.20 $t.ha^{-1}$), total gross return (Tk. 552,000.ha^{-1}), net return (Tk. 367,000.ha^{-1}), and Benefit-Cost Ratio (BCR) of 2.98 were attained with local bathua 1. Consequently, local bathua 1 stands out as the most productive and financially viable option and holds the potential for increased productivity and profitability. Further studies are needed to examine the growth performance of bathua genotypes at different agro-ecological zones.

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