Ann. Bangladesh Agric. (2014) **18** (1): 115-124 ISSN 1025-482X

EFFECT OF SPACING ON YIELD AND YIELD CONTRIBUTING CHARACTERS OF STEM AMARANTH

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Abstract

An experiment on stem amaranth (CV. SA040) comprising nine levels of spacing was conducted at the experimental field laboratory, Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during March 2008 to July 2008 to find out an optimum plant and row spacing for higher yield of stem amaranth. Plant height, leaves/plant, leaf weight/plant, stem weight/plant, stem diameter, stem yield (t/ha), dry matter (%), days to first flowering and 50% flowering, seed yield/plant and seed yield (t/ha), and 1000-seed weight were significantly influenced by different spacing treatments. The maximum stem weight/plant was obtained from widest spacing i. e., S_9 (40cm x 20cm) whereas, minimum was found in the closer spacing S_1 (20cm x 10cm). However, the stem yield decreased significantly with the increase in plant spacing. The highest stem yield (138.53 t/ha) was obtained from plant spacing 20cm x 10cm and the lowest (46.73 t/ha) was obtained from plant spacing 40cm x 20cm. The maximum seed yield (3.01 t/ha) was obtained from 30cm x 20cm plant spacing followed by that of 30cm x 15cm spacing (2.79 t/ha) and the lowest (4.09 t/ha) was obtained from closer spacing 20cm x 10cm. A positive linear relationship was obtained between plant height and stem yield. A negative linear relationship was found between stem yield/plant and leaf: stem ratio with stem yield.

Keywords: Amaranth, plant population, stem production, seed production.

Introduction

Amaranth (*Amaranthus hypochondriacus*) is one of the main species of the large and taxonomically diverse group of tropical leafy vegetables. It is a fast growing crop with a high yield potential in a short period and suitable for crop rotation with any other vegetable crop. The nutritional value of amaranth is excellent because of its high content of essential micronutrients, amaranth leaves are a good source of β-carotene, iron, calcium, vitamin C, and folic acid.

The average yield of stem amaranth in Bangladesh is 5.83 t/ha (BBS, 2005), which is much lower as compared to other amaranth growing countries. The low yield is mainly attributed due to lack of proper cultural practices like optimum spacing, fertilization, irrigation, etc.

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Plant density plays an important role in vegetative as well as reproductive growth of plant and yield of crop (Bansal *et al.,* 1995; Misra *et al.,* 1985). The maximum green yield per plant was obtained from widest spacing at all stages of harvesting, while it was decreased significantly with increase in plant spacing. The highest green yield was obtained from closer spacing 30cm x 10cm (Talukder, 1999) and grain yield of amaranth obtained from closer spacing 30cm x 15cm (Ananda and Dhanapal, 2006). According to Jaishree *et al.* (1996) 30cm x 15cm plant spacing seems to be optimum for getting higher grain yield of grain amaranth under rainfed condition. But information as regard to the plant spacing for amaranth cultivars is scanty (Bansal *et al.,* 1995; Misra *et al.,* 1985). The research information regarding optimum spacing of sowing is lacking in this country. The present investigation was, therefore, undertaken to find out optimum spacing of sowing for the production of stem amaranth.

Materials and Methods

The experiment was conducted at the experimental field laboratory, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during March 2008 to July 2008. Amaranth genotype SA040 was selected for summer and winter seasons and used as plant material for the study (Ahammed, 2009). The treatments consisted of nine levels of spacing viz., S_1- 20cm x 10cm, S_2- 20cm x 15cm, S_3- 20cm x 20cm, S_4- 30cm x 10cm, S_5- 30cm x 15cm, S_6- 30cm x 20cm, S_7- 40cm x 10cm, S_8- 40cm x 15cm and S_9- 40cm x 20cm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 2.40 m x 1.8m. The unit plot and blocks were separated by 0.5m and 1.0m, respectively. Seeds of genotype SA040 were continuously sown on 29 March 2008 between rows maintaining spacing according to treatments after 15 days of sowing. The crop fertilization and necessary intercultural operations were done following Rashid (1999). The crop was harvested when started flowering. The data were recorded on the basis of IBPGR descriptor (Grubbed and Soloten, 1982). The following parameters, such as plant height (cm), leaves/plant, stem diameter (mm), leaf weight/plant (g), stem weight/plant (g), leaf: stem ratio, stem yield (t/ha), fibre (%), dry matter (%), days to first flowering, days to 50% flowering, seed yield/plant, seed yield (t/ha) and 1000-seed weight (g), were taken for consideration. Recorded data on different parameters were analyzed statistically and the means were separated by DMRT (Gomez and Gomez, 1984) at 5% level of probability.

Results and Discussion

Plant height

The plant height differed significantly at different spacings of stem amaranth (Table 1). It was observed that plant height increased with decreased plant spacing. The higher the population density, taller the plants up to a certain limit. The tallest plant (112.55cm) was observed in S_1 (20cm x 10cm) spacing (Table 1), which was statically similar to the treatment S_4 (30cm x 10cm) and S_2 (20cm x 15cm) whereas, S_9 (40cm x 20cm) plant spacing produced the shortest plants (99.78cm). The variation in plant height as influenced by plant spacing might be due to the elongation of internodes for height in a crowded population (Mackenzie *et al.,* 1975). Plant competition due to crowding for space might have elongated the densely populated plant (Willey and Heath, 1969). Singh and White Head (1993) reported that tallest plants were produced in the closer spacing. The present finding was in agreement with the above findings.

Leaves per plant

Significant variation was observed among the treatments in respect of leaves per plant of stem amaranth (Table 1). It was observed that leaves per plant increased with increasing plant spacing. The highest number of leaves per plant (27.53) was observed in wider S_9 (40cm x 20cm) plant spacing which was identical to the treatments S_8 (40cm x 15cm), S_7 (40cm x 10cm), and S_6 (30cm x 20cm), whereas closer S_1 (20cm x 10cm) plant spacing produced the lowest number of leaves (21.68). The higher the population density, lower the number of leaves up to a certain limit. The higher number of leaves in wider spacing might be due to uptake of more available nitrogen and other growth resources from the soil and less competition for space. Singh and White Head (1993) reported that the highest leaf numbers and maximum leaf area were obtained with the widest spacing. Similar results were also obtained by Talukder (1999). The present investigation was in agreement with the above findings.

Leaf weight per plant

Significant variation was observed among the different treatments in respect of leaf weight per plant (Table 1). It was observed that leaf weight per plant increased with increased plant spacing. The highest leaf weight per plant (89.40 g) was recorded in wider S_9 (40cm x 20cm) plant spacing, which was similar to S_6 (30cm x 20cm), S_8 (40cm x 15cm) and S_7 (40cm x 10cm) whereas the lowest leaf weight (59.15 g) per plant was found in S_2 (20cm x 15cm) plant spacing, which was identical to S_7 (20cm x 15cm) and S_3 (20cm x 20cm) spacing. The highest population density contributed the higher leaf weight per plant up to a certain limit. The maximum leaf weight per plant might be due to the maximum increase of leaf area at wider spacing and less competition for space.

Stem weight per plant

The stem weight per plant varied significantly among the different spacing levels in stem amaranth (Table 1). It was observed that stem weight per plant increased gradually with the increasing of plant spacing. The highest stem weight per plant (330.59 g) was observed in wider S_9 (40cm x 20cm) plant spacing, which was closely followed by the treatments S_8, S_7, S_6, S_5, and S_4 whereas, lowest stem weight per plant (271.56 g) was found in the closer plant spacing S_1 (20cm x 10cm). The higher the population density, lower the stem weight per plant was found. Singh and White Head (1993) reported that the maximum stem, petiole, and leaf fresh weights were produced in wider spacing. Similar results were also obtained by Talukder (1999). The present finding was in agreement with the above findings.

Leaf: stem ratio

Significant variation was observed among the different spacing levels in respect of leaf: stem ratio (Table 3.2). The highest leaf: stem ratio (0.27) was observed in S_9 (40cm x 20cm) plant spacing, which was statistically similar to all the treatments except S_2 (20cm x 10cm) and S_3 (20cm x 20cm), whereas lowest leaf: stem ratio (0.19) was observed in S_3 (20cm x 20cm) plant spacing which was similar to S_2 (20cm x 10cm)

The leaf-stem ratio decreased with the decreasing plant density might be due to the stem portion which contributed more towards the plant weight than leaf portion. Talukder (1999) reported highest leaf: stem ratio in closer spacing.

Stem diameter

Significant variation was observed in respect of stem diameter among the different spacing levels (Table 1). It was observed that stem diameter increased with increasing plant spacing. The maximum stem diameter (24.22 mm) was observed in wider S_9 (40cm x 15cm), S_8 (40cm x 15cm) followed by that of S_6 (30cm x 20cm), S_7 (40cm x 10cm), S_5 (30cm x 15cm) and S_3 (20cm x 20cm) spacing whereas lowest stem diameter (20.53 mm) was found in the S_1 (20cm x 10cm) spacing. Talukder (1999) reported maximum stem girth was obtained from widest S_5 (30cm x 30cm) and minimum stem girth was obtained from the lowest S_1 (30cm x 10cm) plant spacing. The present finding was in agreement with the above findings.

Stem yield per hectare

Significant variation was observed among the different spacing treatments in respect of stem yield per hectare (Fig. 1). The highest stem yield per hectare (138.53 t/ha) was observed in closer S_1 (20cm x 10cm) plant spacing, which was statistically higher than any other treatments whereas, the lowest yield per hectare (46.73 t/ha) was found in the wider S_9 (40cm x 20cm) plant spacing, which was statistically similar to S_6 (30cm x 20cm) and S_8 (40cm x 15cm) plant spacing.

The highest stem yield per hectare in the closer spacing S_1 (20cm x 10cm) might be due to accommodation of higher number of plants per unit area. Though decrease in plant population due to increase in spacing resulted the highest stem yield per plant, it did not compensate the total yield recorded with higher plant population. Talukder (1999) reported highest green yield in closer spacing (30cm x 10cm) and lowest green yield in wider spacing (30cm x 25cm). Igbokwe (2000) reported plant

Table 1. Effect of spacing on plant height, leaves/plant, leaf weight, stem weight, leaf: stem ratio and stem diameter of stem amaranth genotype.

Treatment	Plant height (cm)	Leaves/plant	Leaf wt/plant (g)	Stem wet/plant (g)	Leaf: stem ratio	Stem diameter (mm)
S_1	112.55a	21.68d	61.54cd	271.56b	0.23ab	20.53d
S_2	108.22ab	22.53cd	59.15d	298.63ab	0.20b	20.62cd
S_3	100.44bc	25.32abc	59.61cd	307.65ab	0.19b	21.74a-d
S_4	108.44ab	23.79bcd	71.14b-d	315.24a	0.23ab	21.24b-d
S_5	103.67bc	24.33bcd	72.46b-d	320.88a	0.23ab	22.61a-d
S_6	99.89c	26.01ab	77.41ab	315.36a	0.25ab	23.10abc
S_7	102.66bc	25.89ab	74.43a-d	327.98a	0.23ab	22.72a-d
S_8	100.44bc	26.84ab	75.06a-c	327.62a	0.23ab	23.49ab
S_9	99.78c	27.53a	89.40a	330.59a	0.27a	24.22a
CV (%)	8.13	9.54	11.47	6.39	10.79	5.78

Means followed by same letter(s) in a column did not differ significantly from each other by DMRT at 5% level. NS indicates non-significant.

S_1=20cm x10cm S_2=20cm x15cm S_3=20cm x20cm
S_4=30cm x10cm S_5=30cm x15cm S_6=30cm x20cm
S_7=40cm x10cm S_8=40cm x15cm S_9=40cm x 20cm

residue cover and marketable yield per hectare increased as plant spacing decreased. The present finding was in agreement with the above findings.

Fibre content (%)

Non-significant variation was observed among the different spacing levels in respect of fibre content (Table 2). However, highest fibre content was found in the spacing S_1 (20cm x10cm) and lowest was found in the spacing S_8 (40cm x 15cm).

Dry matter content

Significant variation was observed among the different spacing levels in respect of dry matter content (Table 2). It was observed that the dry matter content increased with the increase in population density. The highest dry matter content (9.20%) was observed in the closest spacing S_1 (20cm x 10cm) followed by that of S_3 (20cm x 20cm) and S_2 (20cm x 15cm) spacing. The lowest dry matter content (6.33%) was observed in the widest spacing S_9 (40cm x 20cm) followed by that of S_8 (40cm x 15cm) and S_7 (40cm x 10cm) plant spacing. Igbokwe (2000) reported that root and shoot fresh weight per plant, stem dry matter, leaf dry matter, shoot dry weight, and marketable yield per plant increased as plant spacing decreased. The present finding was in agreement with the above findings.

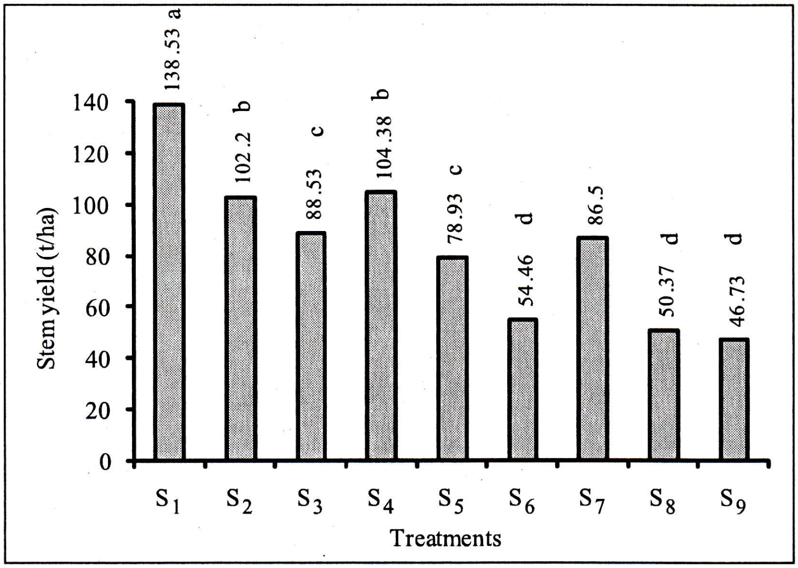

Fig. 1. Stem yield (t/ha) of stem amaranth as influenced by different spacing treatments.

Legend

S_1=20cm x10cm	S_2=20cm x15cm	S_3=20cm x20cm
S_4=30cm x10cm	S_5=30cm x15cm	S_6=30cm x20cm
S_7=40cm x10cm	S_8=40cm x15cm	S_9=40cm x20cm

Days to first flowering

Significant variation was found in respect of days to first flowering among the different plant spacing levels (Table 2). The maximum number of days (45.67 days) required for days to first flowering was observed in S_7 (40cm x 15cm) followed by that of S_9 (40cm x 20cm) whereas, the minimum time (43.00 days) required for days to first flowering was observed in S_1 (20cm x 10cm) plant spacing and was statistically similar to all the treatment except S_9 (40cm x 20cm) and S_7 (40cm x10cm) plant spacing. It was observed that early flowering was in closer spacing. Early flowering in closer spacing might be due to limited space for proper growth and tends to early flowering. Bansal *et al.* (1995) reported early flowering at closer spacing. The present finding was in agreement with the above findings.

Days to 50% flowering

The number of days required for 50% flowering varied significantly among different spacing levels (Table 2). The maximum number of days required for days to 50% flowering (50.67 days) was observed in S_6 (30cm x 20cm) plant spacing, which was closely followed by S_8 (40cm x 15cm), S_7 (40cm x 10cm) and S_5 (30cm x 15cm) whereas, the minimum number of days (47.00 days) required for days to 50% flowering was observed in S_1 (20cm x 10cm) followed by that of S_2 (20cm x 15cm) plant spacing. It was observed that minimum days to 50% flowering were also observed in closer spacing.

Seed yield per plant

Significant variation was observed in respect of seed yield per plant among different spacing levels (Table 2). The highest seed yield (11.24 g) per plant was observed in wider S_9 (40cm x 20cm) plant spacing, which was closely followed by that of S_6 (30cm x 20cm) and S_8 (40cm x 20cm) plant spacing where as lowest seed yield per plant (5.61 g) was recorded in closer S_1 (20cm x 10cm) plant spacing and statistically different from other treatments.

The higher seed yield per plant at wider spacing might be due to that the plants of wider spacing produced larger canopy area of plants with long terminal inflorescences and more axillary inflorescences which bears more flowers and seeds. Talukder (1999) reported higher amount of seeds per plant from wider spacing (30cm x 30cm) and lower amount of seed per plant at closer spacing (30cm x 10cm). Peiretti and Gesumaria (1998) reported that seed yield per plant at harvest decrease with closer spacing. The present finding was in agreement with the above findings.

Seed yield (t/ha)

The seed yield per hectare varied significantly with different spacing levels (Table 2). The highest seed yield per hectare (3.01 t/ha) was observed in S_6 (30cm x 20cm) plant spacing, which was statiscally similar to that of S_5 (30cm x 15cm) plant spacing but different significantly with rest of the treatments whereas, the lowest seed yield per hectare (1.09 t/ha) was obtained from that of S_1 (20cm x 10cm) plant spacing, which was statistically similar with S_9 (40cm x 20cm) plant spacing. Talukder (1999) reported that highest seed yield (3.64 t/ha) was obtained from S_3 (30cm x 20cm) plant spacing and the lowest seed yield (2.69 t/ha) was obtained from S_5 (30cm x 30cm) plant spacing.

1000-seed weight

Significant effect of spacing on 1000-seed weight was found in stem amaranth (Table 2). The highest (0.87g) 1000-seed weight was observed in wider S_9 (40cm x 20cm) plant spacing, which was closely followed by that of S_8 (40cm x 15cm), S_6 (30cm x 20cm) and S_3 (20cm x 20cm) and S_5 (30cm x 15cm) plant spacing whereas, lowest 1000-seed weight (0.66 g) was observed in closer S_1 (20cm x 10cm) plant spacing closely followed by that of S_2 (20cm x 15cm) plant spacing. It was observed that seed size increased with increasing plant spacing. Talukder (1999) reported that highest 1000-seed weight (1.26 and 1.24 g) was obtained from S_4 (30cm x 25cm) and S_5 (30cm x 30cm) plant spacing, respectively, and the lowest 1000-seed weight (0.93 g) was obtained from S_3 (30cm x 15cm).

Table 2. Effect of spacing on fibre (%), dry matter (%), flowering, seed yield/plant, seed yield (t/ha) and 1000-seed weight of stem amaranth genotype.

Treatment	Fibre (%) NS	Dry matter content (%)	Days to first flowering	Days to 50% flowering	Seed yield/plant (g)	Seed yield (t/ha)	1000 seed wt (g)
S_1	0.28	9.20a	43.00c	47.00c	5.61 d	1.09e	0.66 b
S_2	0.28	8.60ab	43.00c	48.00bc	7.51 b	1.85c	0.68 b
S_3	0.25	8.75ab	43.00c	49.33ab	8.03 b	1.87c	0.83 a
S_4	0.25	8.15bc	43.00c	49.33ab	6.57 c	1.78cd	0.76 ab
S_5	0.27	7.92bc	44.00bc	50.00ab	8.11 b	2.79ab	0.82 a
S_6	0.24	7.45cd	43.00c	50.67a	11.19 a	3.01a	0.84 a
S_7	0.25	6.90de	45.67a	50.33a	8.05 b	2.01c	0.78 ab
S_8	0.22	6.80de	43.00c	50.67a	10.98 a	2.48b	0.85 a
S_9	0.23	6.33e	44.67ab	50.00ab	11.24 a	1.37de	0.87 a
CV (%)	8.80	6.60	1.72	2.23	5.43	11.80	8.59

Means followed by same letter(s) in a column did not differ significantly from each other by DMRT at 5% level. **NS** indicates non-significant.

S_1=20cm x10cm S_2=20cm x15cm S_3=20cm x20cm
S_4=30cm x10cm S_5=30cm x15cm S_6=30cm x20cm
S_7=40cm x10cm S_8=40cm x15cm S_9=40cm x 20cm

Relationship between plant height and stem yield of stem amaranth

A positive linear relationship was observed between plant height and stem yield (Fig. 2). It was evident from Fig. 2 that the equation y= 5.8767 x -527.84 gave a good fit to the data and the value of co-efficient of determination (R^2= 0. 8322) showed that the fitted regression line had a significant regression coefficient. So, it indicated that the stem yield (t/ha) increased with the increasing of plant height.

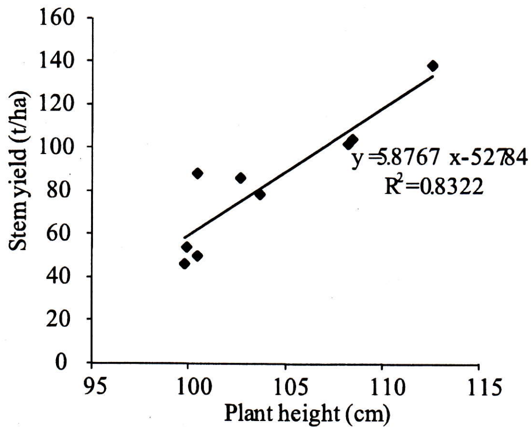

Fig. 2. Relationship between plant height and stem yield (t/ha) of stem amaranth.

Relationship between leaf: stem ratio and stem yield (t/ha) of stem amaranth

A negative linear relationship was observed between leaf: stem ratio and stem yield (t/ha) when the data was regressed (Fig. 3). The negative linerar relationship (Y= -627.05x+226.93) between leaf: stem ratio and stem yield (t/ha) was best explained for its value of coefficient of determination (R^2= 0.2464). It can be concluded from the Figure 4 that stem yield (t/ha) decreased with the increasing of leaf: stem ratio.

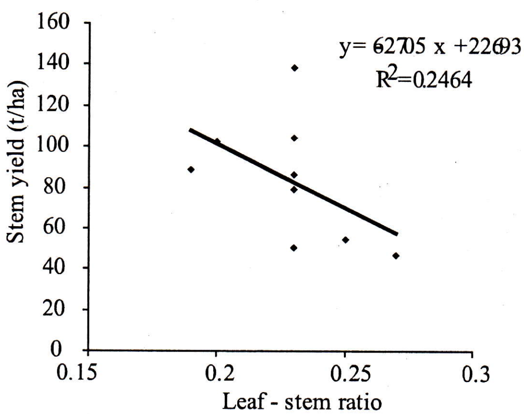

Fig. 3. Relationship between leaf: stem ratio and stem yield (t/ha) of stem amaranth.

From the study, it may be concluded that different spacing treatments had considerable effect on growth, stem yield, and seed yield of amaranth. Spacing of 20cm x 10cm was found better for stem production and spacing of 30cm x 20cm found for seed production.

A positive linear relationship was obtained between plant height and stem yield. A negative linear relationship was found between stem yield/ plant and leaf: stem ratio with stem yield.

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