Evaluation of Six Amaranth Varieties

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Abstract

Six amaranth varieties from ARC were evaluated for shoot yield and other agronomic traits at ARC-AVRDC, Kasetsart University, Kamphaengsaen Campus, Nakhon Pathom, Thailand, from December 23, 1996 to January 31, 1997. These varieties produced fresh shoot yield from 4.10 to 10.04 t/ha. AS 007, AS 008, and AS 010 were outstanding varieties giving yield approaching 10 t/ha with desirable horticultural traits. AS 011 had the best appeal, better Calcium and Iron contents, but with a low yield of 4.10 t/ha. There were significant differences in the horticultural traits recorded.

Introduction

The edible amaranth is a member of the genus Amaranthus of the *Amaranthaceas* family. Amaranth has centers of diversity in central and south America, India, and southeast Asia. It has secondary diversity in east and west Africa. It is probably the most important leafy vegetable of the lowland tropics of Africa and Asia (2). Its cultivation for grain amaranth dates as far back as 5,000 to 7,000 years ago in south America and was used as a vegetable in the early civilization 2,000 years ago. Currently, it is consumed by humans in diverse geographical regions from southwest United States to China, India, Nepal, Africa, South Pacific Islands, Caribbean, Greece, Italy, Russia (7), and Asia (2). Its wide adaptability to diverse environments is attributed to its anatomical features and the C4 metabolism of this dicot plant (7).

Amaranth is a short-lived broad-leafed herbaceous annual with green to purplish-green leaves and grows as tall as 30-60 cm and up to 2.41 m. Young shoots are consumed as vegetables and the seeds are used as grain food. The crop is a highly nutritious green with a short growing duration of 3-6 weeks (6). Leaves of amaranth contain high levels of vitamins A and C and minerals such as Iron and Calcium. The grains have 12-18 % high lysine protein, high quality carbohydrate, and 5-9% high quality lipids (7). Vegetable amaranth also gives ratoon harvests. The young leaves of both vegetable and grain species are consumed as vegetables.

The vegetable amaranth is an underexploited plant. It is adaptable to hot, humid climate and is suitable for crop rotation as it is not susceptible to soil-borne diseases and pests such as nematodes, *Fusarium.* and *Sclerotium* (2). Vegetable amaranth received significantly less attention than grain amaranth. The vegetable amaranth species include *A. tricolor, A. dubius, A. lividus, A. creuntus* (7), *A. blitum* (4), *A. gangeticus, A. viridus* (1), and *A. hypochondiacus,* and *A. caudatus* as grain crops (7).

Vegetable yields of *A. cruentus* and *A. tricolor* are 10-40 t/ha for the growing periods of 20-80 days and 30-90 days, respectively (2). In Thailand, yield of 42.85 t/ha (8) and 14.93 t/ha (6) were reported while *A. tricolor* gave 7.4-9.4 t/ha in India (4) and 9.9-18.3 t/ha in the United States (3).

Since the crop is fast-growing, nutritious, and important in this part of the world, it is useful to study the crop more. It was therefore the objective of this experiment to evaluate six amaranth varieties from 'the ARC germplasm for shoot production and other agronomic traits.

Materials and Methods

This experiment was conducted from December 23, 1996 to January 31, 1997, at the ARC-AVRDC experimental field, Kasetsart University, Kamphaengsaen Campus, Nakhon Pathom, Thailand.

Six varieties of edible amaranth, namely, AS 004, AS 007, AS 008, AS 010, AS 017, and AS 011 from Thailand and Taiwan supplied by ARC-AVRDC were entered in a randomized complete block design with four replications. The seeds were directly sown on raised double beds measuring 0.75 x 33 m^2, each giving five rows of plants per bed spaced at 15 x 15 cm^2.

Granulated fertilizer 15:15:15 of NPK was applied at 62.5 kg/ha as basal at sowing. Urea at 1% solution was sprayed at 14 and 24 days after sowing (DAS). Urea was topdressed at 250 kg/ha at 28 DAS. Dried rice straws were used to mulch the beds. Furrow irrigation was carried out twice to thrice a week. Thinning to one plant per point was effected at 26 DAS. Insecticides Methamidophos and Cabaryl were sprayed two to three times per week and later reduced to once a week with pyrethroids as the crop was approaching harvests. Hand weeding was done once at 26 DAS.

The crop was harvested at 39 DAS by cutting the shoots at ground level and the fresh shoot yield were recorded. Ten plants were removed with roots from each treatment for recordings on plant weight and other horticultural characters. Plants (500 g) were dried in the oven for 48 hours at 50^{o}C and sent to the Central Laboratory for analyses of Calcium (Ca) and Iron (Fe) contents. The data were subjected to statistical analysis using the SAS program.

Results and Discussion

Shoot Yield

Significant differences on shoot yield were found among the varieties. Variety AS 008 gave almost two and a half times more than that of the lowest producer, AS 011. The top entries were AS 007, AS 008, and AS 010 giving shoot yield reaching 10 t/ha. Heavier leaf and stem weights resulted in heavier shoot productions (Table 1 and Fig. 1).

Shoot yield was significantly and positively correlated to plant height, (r = 0.86**), leaf length (r = 0.78**), stem width (r = 0.75 **), single plant weight (r = 0.73 **), single shoot weight (r = 0.73**), stem weight (r = 0.73**), root weight (r = 0.69**), leaf weight (r = 0.66**), and leaf width (r = -0.58) (Table 3).

The shoot yield obtained in this trial were in agreement with those recorded in India (7.4 -9.4 t/ha) (4), United States (9.9-18.3 t/ha) (3), and that of Grubben (10-40 t/ha) but lower than those grown in Thailand at 42..85 and 14.93 t/ha at the same location as the present trial (6.8 t/ha) where heavier nutrient inputs were used.

Single Plant Weight and Single Shoot Weight

AS 010 and AS 017 differed significantly from the other four varieties in single plant weights (Table 1). The larger four varieties averaged at 28.3 g compared with the lighter ones at 5.1 g. These plants were much smaller compared to an average of 69.4 g obtained by Makus (3) on *A. tricolor* in United States.

Single plant weight changes can be attributed to single shoot weight (r = 0.98 **), plant leaf weight (r = 0.96 **), root weight (r = 0.89**), and plant height (r = 0.89**). Lighter plants had lighter roots (Table 3).

As in single plant weights, the smaller plants of AS 017 and AS 011 were significantly lighter than the other four varieties (Table 1). Single shoot weight was more strongly correlated to leaf weight (r = 0.96**) than stem weight (r = 0.82**) and other agronomic characters (Table 3).

Leaf Weight and Stem Weight

Significantly different weights were observed for both leaf and stem weights among the varieties (Table 1 and Fig. 2). AS 007 and AS 008 had the heaviest leaf and stem, respectively. Both the leaf and stem weights recorded were lighter than that obtained by Makus (3) at 45.2 g and 16.6 g respectively. However, the leaf weight/stem weight (Leaf wt./stem wt.) ratio he recorded at 2.71 was within the range at 1.75 to 2.92 obtained in this experiment.

Leaf weight was highly correlated to leaf length, leaf width, and plant height as shown in Table 3. Stem weight had lower degree of association with the plant height (r = 0.76**) and stem width (r = 0.75**).

Root Weight and Length

There were similar trends in the root weights where the larger varieties had significantly higher root weights (Tables 1 and 2 and Fig. 2). On the average, the roots only accounted for 11.7 % of the plant weight. Table 3 showed that varieties differed significantly in root lengths. The shoots were 1.7 times longer than the roots. Root length was positively correlated to leaf length, leaf width, and plant height. Longer roots of AS 007, AS 008, and AS 010 are advantageous to extract water and nutrients in the soil at greater depths and would be useful for tolerance to drought.

Plant Height and Stem Width

The larger varieties were significantly taller than AS 011 and AS 017 as indicated in Table 2. Plant height was highly influenced by stem weight (r = 0.9588), leaf width, root size and shoot weights (Table 3). Stem width varied significantly among the varieties. As in other horticultural traits, the larger and taller plants, the wider the stems, were (Table 2). Stem width contributed highly to plant height and other agronomic traits except for root length (Table 3).

Leaf Length and Width

Table 3 indicates these parameters varied significantly among the varieties and was more homogenous than other characters recorded. They were strongly correlated with each other. Leaf, widths recorded were in agreement with that of Tisbe which gave 4 -10 cm (9).

Shoot-Plant and Shoot-Root Ratios

AS 011 and AS 017 had higher shoot weight yield percentage than the other varieties as indicated by the shoot/plant and shoot/root ratios (Table 3). Lower shoot weights led to lower shoot yield production. The amaranth had an average Harvest Index of 88% which was better than the other crops such as cabbage and fruit vegetables.

Days to Harvest

The varieties in this trial were harvested well before flowering at 39 DAS. AS 017 was probably harvested a day or two later. The amaranth could also be harvested earlier if a young and succulent crop was required with a lower yield.

Shoot Appearance

Table 4 provides the visual characteristics of the varieties. The dirty red leaves and red stripes on the stem of AS 004 would not be an appealing sight with most consumers compared to other light to yellowish or dark green varieties which they had been acquainted with. AS 011 with many wrinkled and light yellowish leaves had better appearance to buyers. Only AS 011 had the best visual appeal in terms of leaf and stem color, shape, and apparent succulent stem while the green-leafed varieties had more fibrous looking shoots.

Nutrient Contents

The whole plant samples analyzed for Ca and Fe contents indicated that varieties AS 008 and AS 017 had significantly the highest and the lowest concentrations of Ca, respectively compared with the others, which did not differ significantly from each other. There were no significant correlations for Ca in all the traits recorded (Table 2).

Fe content did not vary significantly among the varieties despite the large differences recorded due to high Coefficient of Variation reaching 54.46% (Table 2). No significant correlations were observed for this element and all the other plant traits, except for the root length (r = -0.42*).

There was a strongly significant negative correlation between Ca and Fe contents of the plant tissues (r + -0.67 **) (Table 2). High Fe content in the crop would be followed by low Ca in the same crop or vice versa.

Pests and Diseases Incidence

Flea beetle attacked the young seedlings but were soon controlled by insecticide sprays. No other serious pests or diseases were recorded.

Conclusion

This trial indicated that AS 007, AS 008, and AS 010 were high producers of amaranth shoots with desirable horticultural traits. AS 011 had the best appeal, better Ca and Fe contents, but a low yield at 4.10 t/ha.

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Table 1. Yield and yield component of six amaranth varieties.

Treatment	Shoot Yield (t/ha)	Plant Wt.(g)	Shoot Wt.(g)	Root Wt.(g)	Leaf Wt.(g)	Stem Wt.(g)	Shoot Wt./Plant Wt.	Shoot Wt./Root Wt.	Leaf Wt./Stem Wt.
AS 004	7.66ab[a]	25.9a	23.0a	2.9a	13.2bc	9.9ab	0.88ab	6.32b	1.8a
AS 007	9.35a	33.0a	29.2a	3.7a	19.8a	9.5ab	0.86b	7.19ab	2.40a
AS 008	10.04a	27.2a	23.7a	3.5a	14.9ab	12.6a	0.87b	7.44ab	2.47a
AS 010	9.69a	27.4a	23.8a	3.6a	14.5a-c	9.3ab	0.86b	6.65ab	1.75a
AS 011	4.10c	12.0b	10.9b	1.2b	6.9d	3.9c	0.90a	10.04a	2.92a
AS 017	6.10bc	14.9b	13.5b	1.4b	8.6cd	6.3bc	0.89a	9.82a	1.85a
Mean	7.82	23.4	20.6	2.7	13.0	8.6	0.88	7.91	2.20
CV(%)	21.46	28.53	29.9	23.7	29.67	35.3	1.72	26.50	36.79

[a]Means with the same letters are not significantly different from each other at 5% by DMRT.

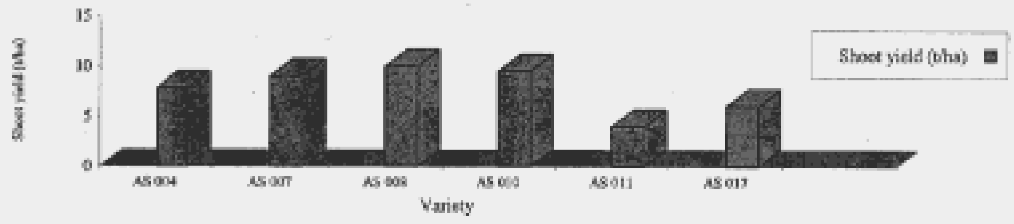

Fig.1 Shoot yield of six amaranth varieties (t/ha).

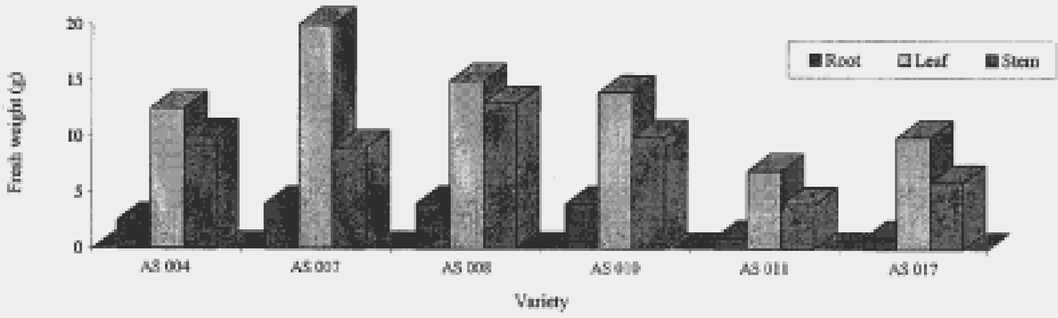

Fig. 2 Yield components of six amaranth varieties.

Table 2. Contents and other horticultural characters of six amaranth varieties.

Treatment	Fe (ppm)	Ca (%)	Plant Ht.(cm)	Root Length (cm)	Leaf length (cm)	Leaf width (cm)	Stem Width (mm)
AS 004	52.46	2.71ab[a]	31.9a	11.3b	14.5b	6.9ab	7.7a
AS 007	63.81	2.81ab	30.7a	17.8a	17.6a	7.8a	6.9ab
AS 008	36.71	3.72a	33.1a	18.8a	17.6a	7.8a	7.4a
AS 010	32.03	3.04ab	32.4a	17.2a	16.9ab	6.9ab	7.1ab
AS 011	57.27	3.11ab	16.3b	12.0b	11.4c	5.8bc	3.2c
AS 017	68.10	2.68b	20.9b	14.9b	11.0c	5.7c	5.5b
Mean	51.73	3.01	27.5	13.7	14.8	6.8	6.3
CV(%)	54.46	20.60	14.54	14.6	10.98	10.7	16.13

[a]Means with the same letters are not significantly different from each other at 5% by DMRT.

Table 3. Correlation coefficients of yield and horticultural characters of six amaranth varieties.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
Shoot Yield(X1)	1.00	0.73**	0.73**	0.69**	0.66**	0.73**	-0.31ns	-0.26ns	0.38ns	-0.33ns	0.78**	0.58**	0.75**	0.86**	0.10ns	-0.07ns
Plant Weight(X2)		1.00	0.99**	0.89**	0.96**	0.74**	-0.33ns	-0.37ns	0.28ns	-0.18ns	0.88**	0.82**	0.84**	0.89**	-0.01ns	-0.10ns
Shoot Weight(X3)			1.00	0.87**	0.96**	0.74**	0.28ns	-0.34ns	0.26ns	-0.19ns	0.86**	0.81**	0.82**	0.87**	0.06ns	-0.09ns
Root Weight(X4)				1.00	0.84**	0.69**	-0.66**	-0.56**	0.41*	-0.12ns	0.91**	0.85**	0.82**	0.86**	0.01ns	-0.31ns
Leaf Weight(X5)					1.00	0.61**	-0.36ns	-0.34ns	0.30ns	-0.01ns	0.84**	0.83**	0.73**	0.79**	0.06ns	-0.17ns
Stem Weight(X6)						1.00	-0.20ns	-0.22ns	-0.22ns	0.30ns	0.65**	0.63**	0.75**	0.76**	0.09ns	-0.11ns
Shoot Wt/Plant(X7)							1.00	0.61**	-0.43*	-0.23ns	-0.55**	-0.50**	-0.36ns	-0.37ns	0.04ns	0.29ns
Shoot Wt/Root(X8)								1.00	-0.23ns	-0.14ns	-0.49**	-0.33ns	-0.49**	-0.47*	-0.04ns	0.34ns
Root Length(X9)									1.00	0.06ns	0.47*	0.46*	0.18ns	0.24ns	0.36ns	-0.42*
Leaf Wt/Stem(X10)										1.00	-0.02ns	-0.03ns	-0.33ns	-0.29ns	-0.01ns	0.20ns
Leaf length(X11)											1.00	0.87**	0.78**	0.88**	-0.33ns	0.29ns
Leaf Width(X12)												1.00	0.70**	0.74**	0.21ns	-0.71ns
Stem Width(X13)													1.00	0.95**	-0.01ns	-0.21ns
Plant Height(X14)														1.00	0.11ns	-0.25ns
A(X15)															1.00	-0.67**
Fe(X16)																1.00

**=highly significant (P<0.01) *=significant ns=nonsignificant

Table 4. Plant characteristics of six amaranth varieties.

Varieties	Plant type	Stem	Leaf	Root	Branch
AS 004	Erect, Short	Red strips along stem, small	Dull red with green margins, oval	Slender, fibrous, short, tapering	Many short lateral on axil
AS 007	Erect, medium size	Dark to light green, red stem base	Dark green large ovate tapering to petiole	Fibrous, long tapering	Many short laterals on axil
AS 008	Erect, tall	Shiny smooth, dark green	Dark green large ovate tapering	Fibrous, long tapering	Many short laterals on axil
AS 010	Erect, tall	Shiny smooth, dark green	Dark green large ovate tapering	Fibrous, long tapering	Many short laterals on axil
AS 011	Erect, short	Light green, short	Wrinkled ovate with light yellow	Medium slender	Many, as long as main root
AS 017	Erect, short	Erect, short	Green leaf, light green petiole	Tap, many laterals	Many, as long as main root