SCREENING AMARANTH GENOTYPES (*Amaranthus* spp.) FOR YIELD, QUALITY AND RESISTANCE TO BIOTIC STRESS

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By

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DECLARATION

I hereby declare that this thesis entitled **"Screening amaranth genotypes (*Amaranthus* spp.) for yield, quality and resistance to biotic stress"** is a *bónafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Priya. V.P.

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CERTIFICATE

Certified that this thesis entitled **"Screening amaranth genotypes (*Amaranthus* spp.) for yield, quality and resistance to biotic stress"** is a record of research work done independently by **Ms. Priya. V. P.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

1. INTRODUCTION

Amaranthus widely known as "poorman's spinach" is, perhaps, the most nutritious leafy vegetable of the tropics. It belongs to the family Amaranthaceae, comprising of 850 species spread over 65 genera. The genus *Amaranthus* includes vegetable types like *A. tricolor* L., *A. dubius* Mart. ex. Thell and *A. tristis* L., grain types like *A. hypochondriacus* L., *A. caudatus* L. and *A. cruentus* L. and wild types like *A. viridis* L. and *A. spinosus* L. Among these, *A. tricolor* is widely cultivated in Kerala throughout the year.

Being a C_4 plant, it is an exceptionally efficient photosynthesizer (Hauptli, 1977). Rapid growth, quick rejuvenation after each harvest, high yield per unit area, easiness in cultivation and low susceptibility to pests and diseases make it the most popular and loved leafy vegetable.

Apart from this, amaranthus is highly valued for its nutritive and medicinal properties. It is a good source of protein, carotene, vitamin C, folic acid and minerals like iron (Saunders and Becker, 1983). A few species are reported to have medicinal properties (Watt, 1972). All parts of this plant are used for culinary purposes. The tiny seeds of grain amaranthus are popped or parched and milled for flour or gruel.

But, the presence of antinutrient elements like oxalates and nitrates restricts its large scale consumption (Marderosian *et al.*, 1980). The free oxalates bind essential dietary divalent minerals, primarily calcium and make them nutritionally unavailable. Besides, the calcium oxalates formed, may accumulate and this may result in oxalurea or kidney stones. The nitrate level is of concern when it is converted to nitrite and nitrosamines. Therefore varieties with lower levels of anti nutrient elements are certainly desirable.

The crop is comparatively free from serious pests and diseases. But recently a new leaf blight disease caused by *Rhizoctonia solani* Kuhn was observed in severe intensity in many parts of the state (Kamala Nayar *et al.*, 1996). The disease causes considerable economic loss owing to reduction in marketability of the produce. Any attempt to locate a resistant source would be highly appreciated. Among the insect pests, leaf webber is the most important.

Despite its nutritive value and popularity, the crop still remains under-exploited. Very little attention has been paid to the genetic improvement of this crop. The aim of any crop improvement programme is to evolve superior genotypes with higher yield, better quality and resistance to pests and diseases. For this, a knowledge of the extent of genetic variability available in the population and the transmission of these characters from one generation to the next is important. An estimate of inter relationship between yield and other traits is of immense help to a breeder for selecting the best genotypes.

Path analysis studies would facilitate effective selection for simultaneous improvement of one or many yield contributing components. Genetic cataloguing of the available genotypes using descriptors will help in easy exchange of information about the germplasm available in different parts of the country as well as abroad.

Considering the above facts, the present investigation has been carried out with the following objectives.

i. To identify superior genotypes with high yield, quality and low oxalate content.

ii. To locate genotypes having resistance to leaf blight and leaf webber.

iii. To study the genetic variability of different quantitative and qualitative characters using genotypic and phenotypic co-efficients of variation and

iv. To find out the direct and indirect effects of each component on yield by path co-efficient analysis.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Amaranthus is one of the most popular leafy vegetables of South India. Despite its wide genetic variability, nutritional and economic importance, very little work has been done on its improvement. The available literature on amaranthus relevant to the present study is reviewed under the following heads.

1. Growth and Yield Characters
2. Quality Characters
   - 2.1. Nutrient factors
   - 2.2. Antinutrient factors
3. Biotic Stress
4. Genetic Variability and Correlation Studies

1. Growth and Yield Characters

The yield in any crop is a complex character determined by several components. Relationship between growth and yield contributing characters has been studied by many workers in amaranthus.

Kamalanathan *et al.* (1973) reported that the vegetable amaranthus type CO-1 belonging to *A. dubius* recorded an yield of 19,000 kg ha^{-1}.

Arakeerai (*A. tristis*) responded favourably to clipping with 11,736 kg of green yield per ha as compared to Sirukeerai (A. *blitum*) with 8,680 kg/ha. (Kader Mohideen and Rajagopal, 1974).

Rajagopal *et al.* (1977) evaluated several types of amaranthus and evolved a high yielding vareity CO-2 (*A. tricolor*) with an yield of 10,780 kg ha^{-1} at 25th day and 16,200 kg ha^{-1} at 30th day as compared to CO-1 with yields of 6578 and 12,789 kg ha^{-1} respectively.

Kader Mohideen (1978) reported that the optimum stage of harvest in amaranthus could be fixed at the 25th day after sowing. At this stage the performance of the types was found to be superior with increased leaf weight, stem weight, leaf length, leaf breadth, stem diameter and plant height. Subbiah (1979) stated that the green matter yield was found to increase from 27th to 42nd day after sowing in CO-1 and CO-2 amaranthus.

Olufolaji and Tayo (1980) studied the performance of four morphotypes of *A. cruentus* L. under two harvesting methods. They found that pruning was superior to uprooting with respect to total fresh and dry weight of various plant parts.

The effect of age of seedlings at transplanting and population density on total yield was studied by Sulekha (1980). The total vegetable yield per plant from all possible harvests was the highest in the low density planting. But the maximum yield m^{-2} for each harvest as well as total yield of all harvests were obtained from high density planting. It had an yield of 6.28 kg m^{-2} (62.80 t ha^{-1}).

The performance of 19 types of amaranthus belonging to *A. dubius, A. tricolor A. blitum, A. hypochondriacus, A. cruentus, A. tristis* and *A. edulis* was studied by Vijayakumar (1980). The yield of greens ranged from 0.920 kg m^{-2} to 4.7 kg m^{-2} on the 30th day of harvest.

Kader Mohideen and Muthukrishnan (1981) found that the mean yield of greens was high in most of the amaranthus types during summer season than in rainy season. They classified the amaranthus genotypes into high yielders, moderate yielders and low yielders.

Field evaluation of vegetable amaranthus (*Amaranthus* spp.) revealed that *A. dubius* was the highest yielder. Entries with a high leaf/stem ratio probably had the greatest market potential and the highest ratios were found in *A. tricolor* (Campbell and Abbott, 1982).

A high yielding clipping type of amaranthus CO-3 which recorded an yield of 10-12 t ha^{-1} was released by Tamil Nadu Agricultural University, Coimbatore through selection (Kader Mohideen *et al.*, 1985).

Kader Mohideen (1988) undertook mutation breeding studies with gamma rays on six genotypes of amaranthus. The study led to the selection of a number of promising mutant lines for earliness, dwarf stature, broad leaf characters, late flowering, basal branching and higher growth ability with higher green matter.

The grain and green yields were found to vary with seed colour. It was recorded that the highest vegetable yield in amaranthus was given by the black seeded cultivars while white seeded types recorded highest seed yield (Olufolaji and Dinakin, 1988).

Devadas *et al.* (1993) found that there were no significant differences between red and green amaranthus for plant height, stem girth and petiole length at 30 days after sowing, but the leaf length, leaf width and number of branches differed significantly. Higher yield and frequency of harvests were observed in red types as compared to green.

Influence of some cultural practices on the yield of amaranthus (*A. hybridus* L.) was studied by Norman and Shongwe (1993). They reported that the three cutting heights (10, 15 and 20 cm) did not influence the total shoot and stem yields. However, the total yields and leaf/stem ratios were greater with cutting heights of 15 and 20 cm than with 10 cm.

Norman and Sichone (1993) studied the vegetable yield of amaranthus as influenced by species and harvesting frequency. They reported that *A. hybridus*, A. *hypochondriacus* and A. *dubius* produced significantly higher yields than *A. flavus*. A. *hybridus* had the highest leaf/stem ratio (on a dry weight basis). Harvesting at three weeks interval significantly increased vegetable yield, compared with fortnightly harvesting, but the latter resulted in higher leaf/stem ratios.

A few improved varieties of amaranthus have been released from IARI, New Delhi. Pusa Kirti (*A. tricolor*) recorded an yield of 50 - 55 t ha^{-1}. Pusa Kiran was developed from a natural cross between *A. tricolor* and *A. tristis*. Its average yield was 35 t ha^{-1}. (Sirohi and Sivakami, 1995).

Evaluation of six amaranthus genotypes for productivity, taste and acceptability was carried out by Allemann *et al.* (1996). The highest yields were obtained from the first cutting and yield decreased progressively with each subsequent harvest. The highest total yield was obtained from *A. hypochondriacus* (43 t ha^{-1}) and the lowest from *A. tricolor* (13 t ha^{-1}).

Pusa Lal Chaulai, a red pigmented vegetable amaranthus suited for both spring-summer and kharif seasons has been released from IARI, New Delhi. It recorded an average yield of 49 and 45 t ha^{-1} in spring and kharif seasons (Sirohi and Sivakami, 1997).

A high yielding, double coloured and dual purpose amaranthus CO-5 has been released for commercial cultivation by TNAU, Coimbatore. This variety can be used as 'mulai keerai' in a crop duration of 30 days, and it can yield as much as 16.2 t ha^{-1}. When raised as `thandu keerai' with a duration of 50 days it can yield 33.17 t ha^{-1} (Anon., 1998).

Early bolting is one of the major problems in the large scale cultivation of amaranthus. There are day neutral and short day types of amaranthus. Apart from photoperiodism, flowering is affected by various factors like temperature, soil factors, height of cutting on harvest, nature of cutting, density of population, C/N ratio and age of plantlets.

Kader Mohideen and Rajagopal (1975) found that transplanting delayed flowering and prolonged the total duration of vegetative phase.

An attempt was made by Devadas (1982) to screen out non bolting types of amaranthus suited for year round planting in Kerala. The study showed that days to flowering is a genetic character.

2. Quality Characters

2.1. Nutrient factors

Amaranthus is a potential plant for combating the problems of under nutrition and malnutrition. It is a good source of protein, carotene, vitamin C, iron, calcium and a rare example of a vegetable where all the essential dietary components are combined in one.

Grubben (1976) found variation in different species of amaranthus for ascorbic acid content, which ranged from 325 to 1250 mg in 100 grams of dry matter. CO-2 amaranthus contains 3.5 g of protein, 1.3 g of crude fibre, 39.8 mg of phosphorus, 310 mg of calcium and 19 mg of iron in 100 g of edible matter (Rajagopal *et al.*, 1977).

Martin and Telek (1979) reported that amaranthus leaves are a good source of Vitamin A and C, calcium and iron. Relation between yield and some nutritive constituents in amaranthus was studied by Mathai *et al.* (1980). Protein content of the leaves on the dry matter basis ranged from 21 to 28 per cent in *A. caudatus* and 18.37 to 37.19 per cent in *A. tricolor*.

A study on the chemical composition of some green leafy vegetables revealed that *A. viridis*, a common weed had the highest fibre content of 21.3 g/100 g (Sreeramulu, 1982).

Ramanathan and Subbiah (1983) reported that the crude protein was highest in amaranthus at 27 days after sowing.

A comparative study of the nutrient composition of *A. viridis* L. and *A. caudatus* L. was made by Ezeala (1985). He observed that on dry weight basis *A. viridis* leaves contained 32.2 per cent crude protein and 11.2 per cent fibre whereas *A. caudatus* contained 27.2 per cent crude protein and 11.1 per cent fibre.

The nutrient content of CO-3 amaranthus was reported by Kader Mohideen *et al.* (1985). It contains 12.5 per cent protein and 17.4 per cent crude fibre on dry weight basis and 11.04 mg of carotene in 100 g of fresh matter.

Singh *et al.* (1985) reported that nitrogen application decreased the crude protein content of *A. tristis* cv. CO-3.

Vijayakumar and Shanmughavelu (1985) studied the nutritive values of seven types of amaranthus which ranged from 32.9 to 44.2 mg/100 g for ascorbic acid, 9.9 to 10.9 mg for carotene content, 16.5 to 21.9 per cent for crude fibre, 12.5 to 14.5 per cent for protein and 2.3 to 2.52 per cent for calcium content on dry weight basis.

Castanedac *et al.* (1986) reported that the protein content of amaranthus is similar to that of spinach.

A study conducted using 25 varieties of amaranthus (*A. caudatus*) revealed that the mean protein content was 12.66% (Imeri *et al.*, 1987).

George *et al.* (1989) studied the variability for nutritive aspects in 30 entries of amaranthus including *A. tricolor*, *A. dubius* and *A. cruentus*. *A. cruentus* Acc 14 had the highest dry matter content (17.2%) and a red entry Acc 59 had the highest crude protein content (29.3%). Acc 28 contained the highest quantity of beta carotene (36.1 mg/100 g of dry matter). Red and green-red entries had high protein and beta carotene contents.

Prakash and Pal (1991) after studying 61 accessions of amaranthus reported a variation for carotenoid content from 90 to 200 mg kg^{-1} in vegetable types and from 60 to 200 mg kg^{-1} in grain types. The variation in leaf protein was 14.0 to 30.0 g kg^{-1} and 15.0 to 43.0 g kg^{-1} for vegetable and grain types respectively.

Jijiamma and Prema (1993) studied the nutritional composition and organoleptic qualities of two cultivars of amaranthus (*Amaranthus tricolor* - red and green type) during the rainy and summer seasons. Leaf protein content was unaffected by seasons. The red cultivar, however, when grown in the summer season had better organoleptic quality.

2.2. Anti nutrient factors

Though amaranthus is a rich source of vitamins, minerals and protein, the presence of antinutrient factors like oxalates and nitrates has been a limiting factor in its large scale consumption. High oxalates may lead to kidney stones while high nitrates cause concern when it is converted to nitrites and nitrosamines.

Srivastava and Krishnan (1959) reported that the soluble oxalate content of *A. gangeticus* was 4.4 per cent and 7.44 per cent in the leaves and stems respectively on dry weight basis. Grubben (1976) observed considerable differences in the oxalic acid content among 25 varieties of amaranthus.

Deutsch (1977) indicated that healthy adults need not be concerned about the presence of these compounds as the leafy greens make up only a fraction of the daily food intake. One would need a daily intake of more than 100 g of fresh green to raise nitrate and oxalate levels. He also indicated that oxalates become more of a problem when plants are grown under stress. Martin and Telek (1979) suggested that the amount of amaranthus in the diet should be limited as it is high in oxalic acid content.

The presence of both these antinutritive factors in the leaves and stem was studied by Marderosian *et al.* (1980). Mean nitrate levels were 0.48 per cent, in leaves and 1.72 per cent in stems on dry weight basis. Oxalate levels were 4.5 per cent in leaves and 0.63 per cent in stems. They also reported that nitrates and oxatates in amaranthus are similar to those found in spinach and chard.

Amaranthus leaves have nitrate and oxalate levels similar to other green leafy vegetables, but adverse nutritional effects are not to be feared with consumption level of 100 to 200 g day^{-1} (Grubben and Vanslotten, 1981). The analysis of free oxalate and nitrate in the leaves and stem of eight *Amaranthus* species was done by Kauffmann and Gilbert (1981). *A dubius* widely accepted as a vegetable amaranthus was characterised by the lowest content of nitrates and oxalates among the different species.

Hill and Rawate (1982) studied the oxalic acid and nitrate content of *A. retroflexus* and found that these factors would be important only if large amounts were eaten raw. Telek and Graham (1983) reported amaranthus to contain nitrate levels upto 33.5 g kg^{-1}. Sanni (1983) reported that *A. hybridus* L. contained a nitrate level of 1675 ppm on dry weight basis which exceeded the safe limit of 500 ppm recommended by W.H.O.

In a study of eight accessions of *A. tricolor*, Makus (1984) reported that the amaranthus leaf blades contained 1.1 per cent nitrate nitrogen and 2.3 per cent soluble oxalates on dry weight basis.

The antinutrient factors were found to be influenced by various factors like nutrition, species and variety. The effect of added nitrogen on certain qualitative characters of *A. tristis* cv. CO-3 was studied by Singh *et al.* (1985). The results revealed that increasing levels of nitrogen increased the oxalic acid and hydrocyanic acid content of the edible matter.

Leaves of 30 entries of *A. tricolor*, *A. dubius* and *A. cruentus* were collected after 45 days growth in the field and analysed for total oxalate content. All green entries had low oxalate contents, while the red and green-red entries had high oxalate contents (George *et al.*, 1989). Vityakon and Standal (1989) also reported high levels of oxalate in *A. tricolor* L. (91 g kg^{-1}) on a dry weight basis.

Devadas and Mallika (1991) reported that the oxalate content varied from 3.60 to 5.10 per cent in the tender leaf and stem, in the different species of amaranthus. In general, the section Blitopsis had higher content of antinutrients than the section Amaranthus.

Prakash and Pal (1991) in their studies with 61 accessions comprising vegetable and grain amaranthus types, reported a variation in the content of nitrate from 1.8 to 9.2 g kg^{-1} and oxalate from 3.0 to 19.2 g kg^{-1} on fresh weight basis. The oxalate content increased with advance in growth period while the nitrate content remained constant.

Devadas *et al.* (1993) made a comparison of red and green amaranthus. It was seen that red pigmented lines had the highest content of oxalates.

In an investigation on screening of 41 amaranthus types for their oxalate content, it was found that oxalate content ranged from 0.82 to 0.92 per cent. The red types were observed to have higher content while the pale green types had lower oxalate contents (Thamburaj *et al.*, 1994).

3. Biotic Stress

Disease and pests form the major biotic stress faced by crops.

Disease - Leaf Blight

Diseases were not a severe problem in amaranthus till recently. Leaf blight caused by *Rhizoctonia solani* was found to be a major problem affecting amaranthus cultivation in South Kerala causing considerable economic loss.

Incidence of leaf blight caused by *Rhizoctonia solani* Kuhn has been recorded on several vegetables. Khatua and Maiti (1982) recorded severe aerial blight of radish in West Bengal. Bandyopadhyay and Khatua (1985) also reported the incidence of such disease in spinach, knolkhol, cabbage and cauliflower.

A similar disease caused by *Rhizoctonia solani* had been reported in flue cured tobacco (Shew and Main, 1985). There are also reports of *Rhizoctonia* leaf blight in ornamentals (Jana *et al.*, 1990).

Celine *et al.* (1995) observed field tolerance to leaf blight in CO-1 amaranthus.

Black *et al.* (1996) found out that smooth pig weed (*Amaranthus hybridus*) was a weed host for *Rhizoctonia solani*, causal agent for Rhizoctonia foliar blight of Soybean.

Kamala Nayar *et al.* (1996) found that *A. tricolor* was severely infected with *Rhizoctonia solani* during the post-monsoon period of 1994 (August - September) in Kerala. The pathogen produced cream coloured spots on leaves which spread rapidly and resulted in extensive damage and economic losses.

The green amaranthus variety CO-1 released from TNAU, Coimbatore was found to exhibit excellent field tolerance to leaf blight (Gokulapalan *et al.*, 1997). They also reported that raising of green and red amaranthus as a mixed crop can also help in reducing the spread and severity of this disease.

Pest - Leaf Webber

Though amaranthus is comparatively free from serious pests, leaf webber attacks the crop. This results in low vegetable yield and the affected crop becomes less acceptable in the market.

The leafy vegetable amaranthus (*Amaranthus viridis* L.) is badly damaged by leaf webbers, *Psara basalis* Fab. and *Hymenia recurvalis* (F.) which become severe at harvest stage (Bhattacharjee and Menon, 1964; Nair, 1980).

Johnson (1968) recorded that application of gamma B.H.C. (0.05%) or *Bacillus thuringiensis* (62.5 x 10^9 spores/100 ml) was superior to malathion sprays (0.05%) and hand picking in reducing larval population of *Hymenia recurvalis* infesting amaranthus.

Pande (1973) reported that *Hymenia recurvalis* has been an important defoliator of *Amaranthus viridis. H. recurvalis* is most active in July - October, when it completes 3-4 generations each lasting 22-34 days.

Being a leafy vegetable, it is advisable to use biological or herbal insecticides to control the amaranthus leaf webbers. It was in this connection that Unnikrishnan (1986) studied the effectiveness of some *Bacillus thuringiensis* strains on the control of amaranthus pests and reported that the strain HD 109 gave superior control of leaf webbers.

4. Genetic Variability and Correlation Studies

The improvement of any crop depends to a great extent upon the magnitude of genetic variability existing in the germplasm. Also, a knowledge of correlation between yield and its component characters is essential for a rational improvement in yield.

Considerable variability in growth, morphological and yield parameters was reported in amaranthus (Seth, 1963).

A correlation study with CO-1 amaranthus, suggested that leaf breadth, stem length and stem diameter are reliable characters for exercising selection (Kader Mohideen and Shanmugasubramanian, 1974).

Based on the results of a path coefficient analysis, Kader Mohideen (1978) reported that weight of leaves, weight of stem, height, stem diameter and breadth of leaf contributed the highest direct and indirect positive effects on yield of greens.

Vijayakumar (1980) found the plant height to have a positive and significant correlation with the green yield. According to him, the leaf/stem ratio exhibited a significant negative association with yield of greens.

Studies were undertaken with seventyfive genotypes of amaranthus (*A. tricolor* L.) to ascertain the extent of variability in yield of greens and its components by Kader Mohideen *et al.* (1982). At the optimum harvest stage of 25th day, the genotypic coefficient of variation was high for weight of stem, leaf/stem ratio, yield of greens and weight of leaves. High heritability estimates along with high genetic advance for the above characters, indicated that phenotypic selection for these traits will be more useful.

Fatokun (1985) examined forty accessions from 12 countries for 22 characters using cluster analysis and principal compound analysis. The latter suggested that leaf length and leaf dry weight per plant were the most important characters.

Wide variability was observed for height, number of leaves per plant, leaf length and width, inflorescence length, number of spikelets per plant, days to maturity, 1000 seed weight, seed protein content and seed yield per plant among 20 genotypes of *A. hypochondriacus* (Joshi, 1986).

Devadas *et al.* (1989) reported that leaf width, plant height on bolting day, days to 50% bolting and frequency of harvests are the most important factors favouring the total vegetable yield and further suggested the usefulness of these traits in the selection programme.

In amaranthus, the height and stem girth are positively correlated with yield (Hamid *et al.*, 1989). Das *et al.* (1991) studied the genetic variation for quantitative traits and yield components in grain amaranthus (A *hypochondriacus* L.). Panicle weight, which had the highest estimates of heritability and genetic advance and 100 grain weight contributed most to grain yield.

Pan *et al.* (1991) in their studies on vegetable amaranthus (*A. tricolor*), reported that among the characters studied, days to flowering, number of clippings, duration of harvest, diameter of stem and width of leaf had high GCV values indicating the presence of greater extent of genetic variability. High heritability estimates combined with high genetic advance as per cent of the mean were obtained for number of clippings, width of leaf, duration of harvest, total yield of greens, diameter of stem and leaf/stem ratio. The authors suggested that phenotypic selection for these traits would be most effective.

Agong and Ayiecho (1992) reported high correlation between the traits *viz.*, plant height, days to flowering and days to maturity in grain amaranthus.

Genetic divergence among 25 vegetable amaranthus accessions belonging to four botanical species were studied by Devadas *et al.* (1992). The 25 accessions were grouped into seven clusters. Study of intracluster differences revealed that the variability in *A. tricolor* was maximum when compared to other species.

Pandey (1993) indicated significant and positive association between yield and yield contributing traits. Path coefficient analysis suggested that harvest index had maximum direct effect on yield.

Varalakshmi and Pratap Reddy (1994) studied variability, heritability and correlation in vegetable amaranthus using twenty-five lines. High genotypic coefficient of variation was obtained for number of leaves, leaf weight, stem weight, leaf/stem ratio and yield of greens per plant. Heritability and genetic advance were also high for these five characters.

A set of 20 genetically diverse genotypes of grain amaranthus was analysed for genetic variability, correlation and path coefficient by Joshi and Rana (1995). Leaf length showed maximum direct effect on grain yield followed by number of leaves, plant height and 1000 grain weight.

Genetic variability, heritability and genetic advance for 11 characters in 144 genotypes of grain amaranthus were studied by Lohithaswa *et al.* (1996). High heritability coupled with moderate genetic advance was observed for plant height and days to 50 per cent flowering indicating that additive gene effects were operating for these characters and selection pressure could be applied on them for yield improvement.

Genetic variability studies in 40 genotypes of amaranthus revealed that the phenotypic coefficient of variability were higher than genotypic coefficients of variability for all the characters studied. PCV and GCV were maximum for leaf : stem ratio, number of leaves and fresh weight of leaves and minimum for stem girth (Revanappa and Mandalgeri, 1997).

Diversity for grain yield and other morpho-physiological characters has been reported in amaranthus germplasm (Bansal and Sharma, 1998).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was carried out at the Instructional Farm, College of Agriculture, Vellayani during 1997-'98. The experiments were undertaken under the following major heads.

3.1. Screening of amaranthus genotypes.

3.2. Evaluation of the selected promising accessions.

Experiment - 1

3.1 Screening of amaranthus genotypes

The basic material for the study consisted of 60 diverse genotypes of amaranthus collected from different parts of the country. The details of the accessions and their source are presented in Table 1.

The experiment was laid out in randomized block design with two replications. The seedlings were transplanted 25 days after sowing adopting a spacing of 50 x 30 cm. Ten plants were maintained per plot. The crop received timely management practices as per Package of Practices Recommendations of Kerala Agricultural University (KAU, 1996).

Table 1. List of amaranthus accessions used for the study and their source

Sl. No.	Genotype	Species/ Accesion number	Source
1	A 7	IC 95351	NBPGR, Akola
2	A 9	IC 95443	NBPGR, Akola
3	A 10	IC 95532	NBPGR, Akola
4	A 11	IC 66011	NBPGR, Akola
5	A 12	IC 66096	NBPGR, Akola
6	A 13	IC 66382	NBPGR, Akola
7	A 14	IC 66383	NBPGR, Akola
8	A 15	IC 95334	NBPGR, Akola
9	A 19	IC 65933	NBPGR, Akola
10	A 20	IC 65980	NBPGR, Akola
11	A 21	*A. tricolor* cv. Kannara local	KAU, Vellanikkara
12	A 22	—	Local green, Vellayani, Trivandrum
13	A 23	—	Local red, Vellayani, Trivandrum
14	A 24	—	Local red, Palakkad
15	A 25	—	Local red, Neyyattinkara, Trivandrum
16	A 26	—	Local green, Neyyattinkara, Trivandrum
17	A 27	—	Local red, Neyyattinkara, Trivandrum
18	A 28	—	Local red, Edaikode, Tamil Nadu
19	A 29	—	Local green, Edaikode, Tamil Nadu
20	A 30	—	Local red, Trivandrum District
21	A 31	—	Local red, Trivandrum District
22	A 32	—	Local red, Trivandrum District
23	A 33	*A. spinosus*	Uttukuzhi, Trivandrum
24	A 35	*A. tricolor*	Dept. of Olericulture, Vellanikkara
25	A 36	*A. tricolor*	Dept. of Olericulture, Vellanikkara
26	A 37	VKA 60	Dept. of Olericulture, Vellanikkara
27	A 38	VKA 69	Dept. of Olericulture, Vellanikkara
28	A 39	*A. tricolor*	Dept. of Olericulture, Vellanikkara
29	A 40	VKA 47	Dept. of Olericulture, Vellanikkara
30	A 41	*A. tricolor*	Dept. of Olericulture, Vellanikkara

Table 1. (Contd...)

Sl. No.	Genotype	Species/ Accesion number	Source
31	A 42	VKA 36	Dept. of Olericulture, Vellanikkara
32	A 43	*A. tricolor*	Dept. of Olericulture, Vellanikkara
33	A 45	*A. lividus*	KHDP, Vellanikkara
34	A 46	*A. lividus*	KHDP, Vellanikkara
35	A 47	*A. tricolor*	KHDP, Vellanikkara
36	A 48	*A. tricolor*	KHDP, Vellanikkara
37	A 49	*A. tricolor*	KHDP, Vellanikkara
38	A 50	*A. tricolor*	KHDP, Vellanikkara
39	A 51	*A. tricolor*	KHDP, Vellanikkara
40	A 52	*A. tricolor*	KHDP, Vellanikkara
41	A 53	Amt 194	KHDP, Vellanikkara
42	A 54	*A. tricolor*	KHDP, Vellanikkara
43	A 55	*A. tricolor*	KHDP, Vellanikkara
44	A 56	*A. tricolor*	KHDP, Vellanikkara
45	A 57	Amt 193	KHDP, Vellanikkara
46	A 58	*A. tricolor* cv. Pusa Lal Chaulai	IARI, New Delhi
47	A 59	-	Local, Trivandrum District
48	A 60	-	Local red, Trivandrum District
49	A 61	*A. dubius* cv. CO-1	TNAU,Coimbatore
50	A 62	*A. tricolor* cv. CO-2	TNAU, Coimbatore
51	A 63	*A. tristis* cv. CO-3	TNAU, Coimbatore
52	A 65	*A. spinosus*	KHDP, Vellayani
53	A 66	*A. tricolor*	KHDP, Vellayani
54	A 68	*A. tricolor*	KHDP, Vellayani
55	A 69	*A. tricolor*	KHDP, Vellayani
56	A 70	*A. viridis*	KHDP, Vellayani
57	A 75	*A. spinosus*	Neyveli, TamilNadu
58	A 78	-	Local Red, Trivandrum District
59	A 79	*A. viridis*	Trivandrum District
60	A 80	*A. tricolor* cv. Arun	AGC,Vellayani

3.1.1 Observations recorded

Five plants were randomly selected from each plot and tagged for recording the biometrical observations. The observations were taken 30 days after transplanting and the mean worked out for further analysis.

1. Plant height (cm)

The height of the plant was measured from ground level to the topmost leaf bud of all observational plants, average worked out and expressed in centimeters.

2. Stem girth (cm)

The girth of the main stem at the collar region was taken using a twine. The mean girth was worked out and expressed the centimeters.

3. Length of leaf lamina (cm)

The fifth leaf from top of the selected plants was used for making the above observation. The length was measured and expressed in centimeters.

4. Petiole length (cm)

The petiole length of the fifth leaf used for recording the length was measured and expressed in centimeters.

5. Leaf width (cm)

The width of the same leaf, used for recording the length was taken at the region of maximum width.

6. Number of branches

The total number of branches of each observational plant was counted and the average obtained.

7. Yield (g plant^{-1})

The vegetable yield was recorded from observational plants, when harvesting was done 30 days after transplanting. The yield was expressed as grams per plant.

8. Leaf / stem ratio

The leaf / stem ratio was obtained by dividing the weight of leaves by the weight of stem, recorded at the time of harvest.

9. Days to 50 per cent bolting

Days to 50 per cent bolting was recorded from the plants left unharvested.

10. Reaction to leaf blight

The performance of the accessions were closely monitored for the incidence and intensity of leaf blight disease caused by *Rhizoctonia solani*.

A scoring procedure (with a scale 0 - 7) was done depending on the extent of damage to the leaves (Plate 1).

0	→	no incidence
1	→	upto 25 per cent leaf area infected
3	→	26-50 per cent leaf area infected
5	→	51-75 per cent leaf area infected
7	→	> 75 per cent leaf area infected

11. Reaction to leaf webber

Hymenia recurvalis and *Psara basalis* are the important leaf webbers seen in amaranthus. Scoring was done for leaf webber attack by using the following score chart.

0	→	No
1	→	mild (25 per cent)
2	→	medium (50 per cent)
3	→	severe (75 per cent)
4	→	very severe (100 per cent)

3.1.2 Genetic cataloguing of the amaranthus accessions

The genotypes were described morphologically using descriptors developed from standard descriptor for amaranthus by IBPGR (Table 2).

Plate 1. Leaf blight intensity score

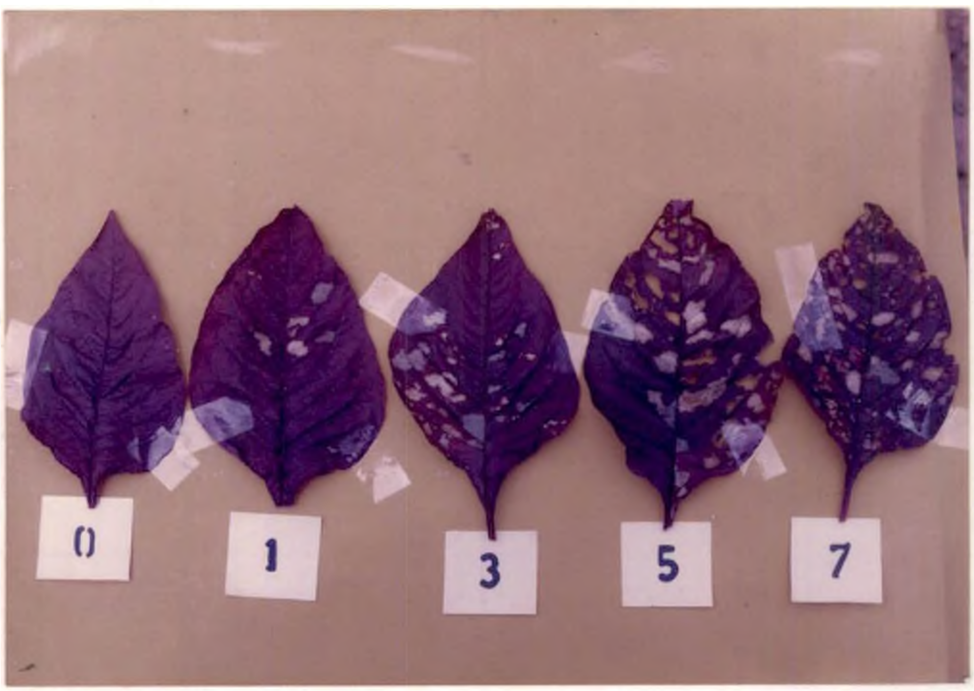

0
1
3
5
7

Table 2. Descriptor for Amaranthus

1. Growth Habit

   1 Erect
   2 Prostrate

2. Plant height (measured in cm)

   1 < 30
   2 30-45
   5 46-60
   7 > 60

3. Branching index

   1 No branches
   2 Few branches all near the base of the stem
   3 Many branches all near the base of the stem
   4 Branches all along the stem

4. Stem pubescence

   0 None
   3 Low
   5 Conspicious

5. Stem pigmentation

   1 Green
   2 Pale green
   3 Purplish green
   4 Pink / Purple
   5. Deep purple

6. Spines in leaf axils

   0 Absent
   1 Present

7. Leaf length (measured in cm on 5th leaf)

   1 < 5
   3 5-10
   5 11-16

8. Leaf width (measured in cm on 5th leaf)

   1 < 5
   3 5-10
   5 11-16

9. Leaf pubescence

   0 None
   3 Low
   5 Conspicious

10. Leaf pigmentation

   1 Entire lamina purple or red
   2 Basal area pigmented
   3 Green with deep purple centre
   4 Two stripes (V shaped)
   5 One stripe (V shaped)
   6 Green with margin and veins pigmented
   7 Purplish green
   8 Normal green
   9 Dark green

11. Leaf shape

   1 Lanceolate
   2 Elliptic
   3 Ovate
   4 Broad ovate
   5 Triangle ovate
   6 Rhombic ovate
   7 Rhombic

12. Leaf margin

   1 Entire
   2 Crenate
   3 Undulate

13. Prominence of leaf veins

   1 Smooth
   2 Slightly prominent
   3 Very prominent

14. Petiole pigmentation

1 Green
2 Dark green
3 Purple
4 Deep purple

15. Terminal inflorescence shape

1 Spike (dense)
2 Panicle with short branches
3 Panicle with long branches
4 Club shaped at tips

16. Terminal inflorescence attitude

1 Erect
2 Drooping

17. Axillary inflorescence

0 Absent
1 Present

18. Inflorescence clolour

1 Yellow
2 Green
3 Pink
4 Red

19. Days to 50 per cent bolting

1 30-45
2 46-60
3 61-75

20. Seed colour

1 Pale yellow
2 Pink
3 Red
4 Brown
5 Black

3.1.3 Statistical Analysis

The collected data were subjected to the following statistical analysis.

Analysis of Variance

Analysis of variance was done to test the significant difference among the genotypes for various traits.

Selection Index

The selection index developed by Smith (1937) using discriminant function of Fisher (1936) was used to discriminate the genotypes based on five characters viz. yield per plant, leaf / stem ratio, days to 50% bolting and scoring for leaf blight and leaf webber.

The selection index is described by the function $I = b_1 X_1 + b_2 X_2 + \ldots\ldots\ldots b_k X_k$ and the merit of a plant is described by the function $H = a_1G_1 + a_2G_2 + \ldots\ldots\ldots a_kG_k$, where $X_1, X_2 \ldots\ldots X_k$ are the phenotypic values and $G_1, G_2, \ldots\ldots\ldots G_k$ are genotypic values of the plant with respect to characters, $X_1, X_2 \ldots\ldots X_k$ and H is the genetic worth of the plant. It is assumed that the economic weight assigned to each character is equal to unity ie. $a_1, a_2 \ldots\ldots\ldots\ldots a_k = 1$. The b coefficients are determined such that the correlation between H and I is maximum.

Experiment - 2

3.2 Evaluation of the selected promising accessions

Based on the selection index score, disease and insect reaction and yield characters, fifteen promising accessions were selected (Table 3). Selfed seeds of these accessions were used for the second experiment.

Table 3. Selected Promising Accessions

1:	A 19	2.	A 21	3.	A 22
4.	A 24	5.	A 26	6.	A 29
7.	A 36	8.	A 39	9.	A 50
10.	A 56	11.	A 58	12.	A 61
13.	A 63	14.	A 66	15.	A 80

The experiment was laid out in randomised block design with three replications. The plants were grown at a spacing of 50 cm between rows and 30 cm between plants. There were forty plants per plot.

3.2.1 Observations recorded

Quantitative characters

Five plants each were marked at random for all the fifteen accessions in the three replications. Observations were recorded on the plant height (cm), stem girth (cm), length of leaf lamina (cm), petiole length (cm), leaf width (cm), number of branches and days to 50 per cent bolting as given in the first experiment.

The additional observations recorded were as follows :

1. Yield per cutting (g plant^{-1})

The vegetable yield was recorded from the observational plants, when harvesting was done first 30 days after transplanting and then at biweekly intervals. Three cuttings were made uniformly in all the accessions and the yield per cutting was recorded in grams per plant.

2. Total yield per plant (g plant^{-1})

Yield per plant from the three cuttings was added to get the total yield per plant and expressed in grams per plant.

3. Leaf / stem ratio

The leaf/stem ratio was obtained by dividing the weight of leaves by the weight of stem.

4. Total leaf weight (g plant^{-1})

The weight of leaves from the three cuttings was pooled and expressed as gram per plant.

5. Total stem weight (g plant^{-1})

The total weight of stem from the three cuttings were taken and expressed as gram per plant.

Qualitative characters

6. Crude protein (per cent)

The total nitrogen of the oven dried samples was estimated by the modified Microkjeldhal method (Jackson, 1967). The nitrogen values were multiplied by a factor, 6.25 to obtain the protein content expressed as percentage of dry weight of leaves (Simpson *et al.*, 1965).

7. Fibre (per cent)

The fibre content of the leaves was estimated by acid and alkali digestion method (Sadasivam and Manickam, 1992).

8. Oxalate content (per cent)

The oxalate content of the leaves was estimated (A.O.A.C, 1984) as percentage of dry weight of leaves.

9. Vitamin A (I.U.)

Carotene content of fresh leaves was estimated during the time of first harvest (30 DAT) by following the method of Srivastava and Kumar

(1994). The carotene values expressed in µg/100 g were divided by 0.6 to get the Vitamin A content in I.U (A.O.A.C, 1975).

10. Organoleptic qualities

The organoleptic qualities and acceptability trials were done using a scoring method (Jijiamma, 1989). The major quality attributes included in the score were colour, doneness, tenderness, odour and taste (Appendix I). Each of the above mentioned quality was assessed by a five point rating scale.

The panel members were selected from a group of healthy adults in the age group of 25 to 45. Simple triangle test was employed to select the panel members (Jellinek, 1985).

The judges were requested to taste one sample and score it. They were asked to taste the second sample, after washing their mouth. Each quality was assessed by the panel members after testing the same sample several times if needed. The panel members were permitted to take their own time to judge the samples.

The leaves were washed thoroughly in water to remove the adhering dirt and cut into small pieces. 125 g of chopped leaves were boiled with 50 ml of water and 1g of salt for ten minutes. The prepared sample was used for organoleptic quality scoring.

Biotic Stress

11. Reaction to leaf blight and leaf webber

Scording for the incidence of leaf blight and leaf webber was done as given.

3.2.2 Statistical Analysis

Data recorded from the 15 accessions on the following 24 characters were statistically analysed.

Quantitative characters

1. Plant height (cm)
2. Stem girth (cm)
3. Length of leaf lamina (cm)
4. Petiole length (cm)
5. Leaf width (cm)
6. Number of branches
7. Days to 50% bolting
8. Yield at first cutting (g $plant^{-1}$)
9. Leaf/stem ratio (first cutting)
10. Yield at second cutting (g $plant^{-1}$)
11. Leaf/stem ratio (second cutting)
12. Yield at third cutting (g $plant^{-1}$)
13. Leaf/stem ratio (third cutting)

14. Total yield (g plant^{-1})
15. Leaf/stem ratio (total)
16. Total leaf weight (g plant^{-1})
17. Total stem weight (g plant^{-1})

Qualitative characters

18. Crude protein (per cent)
19. Fibre (per cent)
20. Oxalate (per cent)
21. Vitamin A (I.U.)
22. Organoleptic qualities

Biotic stress

23. Reaction to leaf blight
24. Reaction to leaf webber

Analysis of variance and covariance

Analysis of variance and covariance were done,

(a) to test the significant difference among the genotypes, and

(b) to estimate variance components and other genetic parameters like correlation coefficients, heritability, genetic advance etc. (Singh and Choudhary, 1979).

Table 4 represents the analysis of variance/covariance. From this table other genetic parameters were estimated as follows

Variance

	X	Y
Environmental variance (σ^2_e)	$\sigma^2_{ex} = E_{xx}$	$\sigma^2_{ey} = E_{yy}$
Genotypic variance (σ^2_g)	$\sigma^2_{gx} = \dfrac{Gxx-Exx}{r}$	$\sigma^2 gy = \dfrac{G_{yy}-E_{yy}}{r}$
Phenotypic variance (σ^2_p)	$\sigma^2_{px} = \sigma^2_{gx} + \sigma^2_{ex}$	$\sigma^2_{py} = \sigma^2_{gy} + \sigma^2_{ey}$

Coefficient of variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated as

$$GCV = \frac{\sigma_{gx}}{\bar{x}} \times 100$$

$$PCV = \frac{\sigma_{px}}{\bar{x}} \times 100$$

where σ_{gx} - genotypic standard deviation,

σ_{px} - phenotypic standard deviation and

$\bar{x}$ is the mean of the character under study.

Table 4. Analysis of variance/covariance

Source	df	Observed mean square	Expected mean sum of products	Observed mean sum of products	Expected mean sum of products	Observed mean square	Expected mean square
		XX	XX	XY	XY	YY	YY
Block	(r - 1)	B_{xx}		B_{xy}		B_{yy}	-
Genotype	(v - 1)	G_{xx}	$\sigma^2_{ex} + r\sigma^2_{gx}$	G_{xy}	$\sigma_{exy} + r\sigma_{gxy}$	G_{yy}	$\sigma^2_{ex} + r\sigma^2_{gx}$
Error	(v-1) (r-1)	E_{xx}	σ^2_{ex}	E_{xy}	σ_{exy}	E_{yy}	σ^2_{ey}
Total	(rv-1)	T_{xx}		T_{xy}		T_{yy}	

Heritability (Broad sense)

$$H^2 = \frac{\sigma^2_{gx}}{\sigma^2_{px}} \times 100$$

where H^2 is the heritability (Jain, 1982) expressed in percentage.

Genetic advance as percentage of mean

$$GA = \frac{k\,H^2\sigma_p}{\bar{x}} \times 100$$

where k is the standardised selection differential. k=2.06 at 5% selection intensity (Miller *et al.*, 1958).

Correlation

$$\text{Genotypic correlation coefficient } (r_{gxy}) = \frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$$

$$\text{Phenotypic correlation coefficient } (r_{pxy}) = \frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$$

$$\text{Environmental correlation coefficient } (r_{exy}) = \frac{\sigma_{exy}}{\sigma_{ex} \times \sigma_{ey}}$$

Path analysis

The path coefficients were worked out by the method suggested by Wright (1921) using the characters which showed high correlation with yield. The simultaneous equations which give the estimates of path coefficients are as follows.

$$\begin{vmatrix} r_{1y} \\ r_{2y} \\ r_{iy} \\ r_{ky} \end{vmatrix} = \begin{vmatrix} 1 & r_{12} & r_{13} \cdots\cdots r_{1j} \cdots\cdots r_{1k} \\ & 1 & r_{23} \cdots\cdots\cdots\cdots r_{2k} \\ & & r_{ij} \cdots\cdots\cdots\cdots r_{ik} \\ & & \qquad\qquad\qquad 1 \end{vmatrix} \times \begin{vmatrix} P_1 \\ P_2 \\ P_i \\ P_k \end{vmatrix}$$

i.e. $\underline{Ry} = Rx \, . \, \underline{P}$ So that $\underline{P} = Rx^{-1}\underline{Ry}$

where r_{ij} is the genotypic correlation between x_i and x_j; i, j = 1, 2, ...k; r_{iy} is the genotypic correlation between x_i and y and P_i is the path coefficient of x_i The residual factor (R) which measures the contribution of other factors not defined in the casual scheme was estimated by the formula

$$R = \sqrt{(1 - \sum_{i=1}^{k} P_i \, r_{iy})}$$

Indirect effect of different characters on yield is obtained as $P_i \, r_{ij}$ for the i^{th} character *via* j^{th} character.

RESULTS

4. RESULTS

Experiment - 1

4.1. Screening of amaranthus genotypes

Sixty different genotypes of amaranthus were evaluated for field tolerance to biotic stress, yield and other morphological characters. The data on the observations recorded were statistically analysed and the results presented in this chapter.

4.1.1. Analysis of variance

The analysis of variance (Table 5) revealed significant differences among the sixty genotypes for all the characters studied.

4.1.2. Mean performance of the genotypes

The mean values of the sixty genotypes for the eleven characters studied are presented in Table 6.

Plant height

Significant variation was observed for plant height among the genotypes. The genotype A 57 recorded the maximum height (70.07 cm) and the least was for A 25 (21.53 cm).

Table 5. Analysis of variance for 11 characters in 60 genotypes of amaranthus (Mean squares are given)

Source	df	Plant height (cm)	Stem girth (cm)	Length of leaf lamina (cm)	Petiole length (cm)	Leaf width (cm)	No. of branches
Replication	1	5.625	0.1234	0.0752	0.0109	0.1226	0.001
Genotype	59	290.0636**	1.2861**	19.4663**	4.7101**	11.6984**	3.4983**
Error	59	5.4155	0.0202	0.2820	0.0275	0.0617	0.1819

Source	df	Yield (g plant^{-1})	Leaf / stem ratio	Days to 50% bolting	Leaf blight	Leaf webber
Replication	1	448.25	0.003	4.25	0.9399	2.7755
Genotype	59	3610.153**	0.0927**	163.7262**	8.338**	0.8667**
Error	59	77.2331	0.0028	0.8358	0.2204	0.0774

** Significant at 1% level

Table 6. Mean values for 11 biometric characters for 60 amaranthus genotypes

Genotypes	Plant height (cm)	Stem girth (cm)	Length of leaf lamina (cm)	Petiole length (cm)	Leaf width (cm)	Number of branches	Yield (g plant^{-1})	Leaf/ stem ratio	Days to 50% bolting	Leaf blight	Leaf webber
A 7	42.58	2.3	3.38	2.19	3.29	10	98.92	0.84	50.63	2	2.0
A 9	38.38	2.4	4.69	3.08	4.05	8.5	84.99	0.97	52.75	2.5	1.75
A 10	31.78	3.05	3.53	2.54	2.62	6.25	87.31	0.79	45.63	4.9	1.75
A 11	32.68	3.63	8.94	4.47	7.61	7.75	122.19	0.85	46.38	6.25	1.38
A 12	54.77	3.44	11.17	6.13	9.04	9.88	151.58	0.75	54.25	3.0	2.0
A 13	48.57	4.3	10.57	4.19	5.23	8.63	150.67	0.84	46.25	6.25	1.75
A 14	31.28	2.83	10.96	5.13	7.2	9.63	127.28	0.83	53.25	3.0	0.75
A 15	43.12	3.05	4.7	3.43	4.12	8.75	128.25	0.73	65.63	2.5	1.75
A 19	51.44	3.38	14.4	6.04	8.05	11.13	181.49	1.08	59.25	6.42	1.13
A 20	54.18	4.37	7.7	5.19	5.37	10.69	107.62	0.98	50.63	2.5	0.88
A 21	40.51	4.29	12.45	7.28	8.92	10.13	171.48	1.23	71.88	5.5	0
A 22	59.66	5.0	12.5	5.33	8.57	10.5	150.04	1.28	51.25	0	1.13
A 23	31.19	3.21	11.48	6.58	9.06	10.75	124.3	1.09	54.88	6.5	0.25
A 24	42.13	4.32	6.49	5.32	6.54	9.5	158.17	1.57	47.75	3.5	1.88

Contd...

Table 6. (Contd...)

Genotypes	Plant height (cm)	Stem girth (cm)	Length of leaf lamina (cm)	Petiole length (cm)	Leaf width (cm)	Number of branches	Yield (g plant^{-1})	Leaf/ stem ratio	Days to 50% bolting	Leaf blight	Leaf webber
A 25	21.53	4.34	10.32	4.45	6.09	9.75	164.63	1.18	64.13	4.25	0.50
A 26	54.05	5.22	12.93	6.62	8.64	10.5	156.9	1.18	59.25	0	0.63
A 27	22.94	4.28	10.31	3.79	6.3	9.13	115.32	1.2	66.75	3.25	1.0
A 28	32.39	3.16	6.26	3.21	3.14	10.13	116.02	1.05	46.88	7.0	1.13
A 29	59.03	5.06	14.49	6.76	8.64	11.88	162.29	1.02	50.63	0	0.75
A 30	34.18	3.69	12.14	6.23	8.12	9.88	158.32	1.21	50.0	6.25	0.5
A 31	48.22	4.29	12.16	7.38	8.18	11.13	199.5	0.91	50.13	6.25	1.0
A 32	41.93	3.3	12.18	5.79	6.29	10.5	207.69	0.91	52.13	0.75	2.0
A 33	52.91	3.87	4.72	3.01	3.24	7.75	223.79	0.46	36.88	0.75	0.25
A 35	44.37	3.29	11.78	6.18	5.73	9.5	152.73	0.81	61.13	2.5	1.13
A 36	54.53	3.24	11.04	5.13	5.12	11.13	184.2	0.92	49.63	2.75	0
A 37	50.12	4.46	4.56	4.56	5.18	8.75	136.26	1.19	61.5	3.5	1.25
A 38	47.77	3.15	10.34	4.42	6.49	11.25	158.17	1.09	54.38	2.75	1.25
A 39	53.71	3.32	12.46	5.98	6.26	9.75	158.67	1.35	62.25	3.25	1.38
A 40	54.77	4.02	10.19	5.90	6.15	11.13	137.43	0.95	61.88	6.25	2.25

Contd...

Table 6. (Contd...)

Genotypes	Plant height (cm)	Stem girth (cm)	Length of leaf lamina (cm)	Petiole length (cm)	Leaf width (cm)	Number of branches	Yield (g plant^{-1})	Leaf/ stem ratio	Days to 50% bolting	Leaf blight	Leaf webber
A 41	25.11	3.29	12.4	7.22	7.44	12.0	145.75	1.24	74.5	4.5	0.5
A 42	50.21	2.22	11.76	3.49	3.54	10.38	121.12	0.88	48.63	4.5	2.75
A 43	49.15	3.29	10.96	5.28	5.42	10.38	139.65	1.05	48.5	5.25	1.75
A 45	37.79	2.26	6.38	3.42	3.58	8.63	152.33	0.84	43.0	4.25	1.25
A 46	40.74	2.15	7.07	4.3	4.17	9.75	130.92	0.96	68.5	5.25	1.25
A 47	26.38	2.42	4.19	2.99	2.61	12.63	140.73	0.78	46.88	2.38	0.25
A 48	53.08	2.74	5.5	4.33	4.07	12.5	159.55	1.18	40.75	3.25	1.25
A 49	43.87	2.85	11.69	8.40	8.5	11.63	141.5	1.18	56.38	7.0	1.25
A 50	34.89	2.09	6.02	5.18	8.09	10.63	169.45	1.17	47.5	4.75	1.75
A 51	42.54	2.27	8.78	6.52	5.17	9.0	115.24	1.31	55.38	2.0	0.25
A 52	50.69	3.75	9.74	6.51	6.4	11.13	165.25	0.96	52.88	3.25	0.63
A 53	63.08	3.63	7.42	7.27	4.13	8.75	294.29	0.71	36.38	2.25	1.75
A 54	28.33	3.5	12.85	5.74	7.28	10.75	174.75	1.04	62.0	6.25	0.25
A 55	25.26	3.22	11.07	7.23	4.15	9.0	152.28	1.32	71.25	6.0	1.25
A 56	31.27	2.99	10.71	7.41	10.57	7.38	177.75	1.06	63.5	6.5	1.0

Contd...

Table 6. (Contd...)

Genotypes	Plant height (cm)	Stem girth (cm)	Length of leaf lamina (cm)	Petiole length (cm)	Leaf width (cm)	Number of branches	Yield (g plant^{-1})	Leaf/ stem ratio	Days to 50% bolting	Leaf blight	Leaf webber
A 57	70.07	3.52	8.12	6.89	4.65	7.25	304.5	0.72	40.88	1.75	1.75
A 58	40.7	1.88	5.15	2.52	3.5	11.13	248.75	0.86	58.13	3.25	1.25
A 59	61.83	4.53	10.72	6.19	6.18	8.75	123.83	0.92	64.88	5.0	0.75
A 60	27.83	4.7	11.21	4.44	4.44	10.75	159.17	1.17	55.25	7.0	0.25
A 61	66.73	4.29	13.55	6.43	11.66	10.5	172.55	1.09	52.0	0	0.75
A 62	42.8	3.3	10.02	6.63	10.32	9.13	147.68	1.24	57.5	2.25	1.00
A 63	44.56	3.44	11.35	7.35	6.44	9.88	184.01	1.08	58.0	3.25	0.25
A 65	63.59	3.7	13.55	5.48	5.5	11.0	159.83	0.47	68.38	3.50	0
A 66	30.26	3.46	10.75	7.34	10.13	9.0	164.17	1.14	66.75	5.75	1.25
A 68	39.53	3.65	10.83	6.12	8.97	10.38	167.04	0.89	64.0	7.00	0.50
A 69	36.78	3.16	10.29	4.19	6.64	9.5	144.23	0.88	67.5	5.0	1.25
A 70	34.62	3.67	11.13	5.23	10.49	8.63	120.42	1.12	63.88	6.25	1.50
A 75	30.89	2.18	4.98	6.59	4.59	11.63	223.3	0.86	64.13	5.25	0
A 78	27.32	3.54	11.59	3.98	10.41	8.63	142.58	1.27	63.50	2.25	0.63
A 79	26.94	2.29	4.16	3.35	2.28	8.13	139.39	0.65	46.88	2.75	0.25
A 80	33.15	3.87	13.39	7.51	11.48	9.13	167.7	1.08	67.25	6.75	1.25
CD(5%)	4.65	0.28	1.06	0.33	0.50	0.35	17.58	0.11	1.83	0.94	0.56

Stem girth

The maximum stem girth was obtained for A 26 (5.22 cm) and minimum for A 58 (1.88 cm). The general mean was 3.60 cm.

Length of leaf lamina

The genotype A 29 had the maximum length of leaf lamina (14.49 cm), whereas it was lowest for A 7 (3.38 cm).

Petiole length

It ranged from 2.19 cm (A 7) to 8.4 cm (A 49) with an overall mean of 4.76 cm.

Leaf width

Leaf width was maximum in A 61 (11.66 cm) and minimum in A 79 (2.28 cm). The general mean was 6.38 cm.

Number of branches

The maximum number of branches was observed in A 47 (12.63) and it was maximum for A 10 (6.25).

Yield (g/plant)

A 57 recorded the highest yield of 304.5 g followed by A 53 (294.29 g) and A 58 (248.75g). The lowest yield was observed for A9 (84.99g) followed by A 10 (87.31g) and A 7 (98.92g).

Leaf / stem ratio

The leaf / stem ratio was maximum in A 24 (1.57) and minimum in A 33 (0.46). The general mean was 1.0.

Days to 50 per cent bolting

The number of days to 50 per cent bolting was highest in A 41 (74.5) whereas it was lowest in A 53 (36.38).

Reaction to leaf blight

Leaf blight disease caused by *Rhizoctonia solani* was observed in varying intensities in the different genotypes. The symptoms appeared as small irregular whitish cream spots on the leaves. Later, these spots enlarged leading to severe blighting and defoliation.

The genotypes were scored for disease incidence on a 0-7 scale. Significant difference was observed among the genotypes (Plates 2 and 3). The maximum incidence was recorded in the accessions A 60, A 68, A 49 and A 28 (7.0). The genotypes A 22, A 26, A 29 and A 61 were completely free of the disease. The accessions A 7, A 32, A 33, A 51 and A 57 recorded a mild incidence.

Reaction to leaf webber

Low to medium incidence of leaf webber attack was noticed in the genotypes. The genotypes were scored on a 0-4 scale. The accession A 42 (2.75) recorded maximum damage by leaf webber followed by A 40 (2.25). The genotypes A 21, A 36, A 65 and A 75 were found to be free from any damage.

4.1.3. Selection index

Selection index was used to discriminate the varieties based on major components of yield. The following characters were used for constructing the index. Yield (X1), Leaf / stem ratio (X2), days to 50 per cent bolting (X3), reaction to leaf blight (X4) and leaf webber (X5).

The selection index worked out is given below.

$$I = 0.9370\ X1 + -9.4947\ X2 + 0.8902\ X3 + 0.3273\ X4 + 1.6854\ X5$$

The highest index score was obtained for the genotype A 57 (841.092) followed by A 53 (804.508), A 58 (689.008), A 50 (676.017) and A 75 (657.303). The genotypes A 79 (434.992), A 28 (410.787), A 7 (391.772), A 9 (365.208) and A 10 (339.017) recorded lower index value.

The selection index values were given in Table 7.

Table 7. Selection index values of amaranthus genotypes

Sl. No.	Genotype	Selection Index Values
1	A 57	841.092
2	A 53	804.508
3	A 58	689.008
4	A 50	676.017
5	A 75	657.303
6	A 31	649.918
7	A 32	647.296
8	A 19	631.902
9	A 61	627.876
10	A 65	625.330
11	A 33	624.498
12	A 21	612.353
13	A 63	611.645
14	A 36	603.552
15	A 29	598.967
16	A 80	596.966
17	A 56	590.659
18	A 68	586.946
19	A 26	584.874
20	A 39	580.149
21	A 54	574.856
22	A 52	573.677
23	A 66	572.094
24	A 12	570.397
25	A 22	558.664
26	A 35	558.103
27	A 40	550.837
28	A 38	550.483
29	A 49	544.095

Contd...

Table 7. (Contd...)

Sl. No.	Genotype	Selection Index Values
30	A 41	543.012
31	A 59	537.429
32	A 62	535.374
33	A 55	533.492
34	A 30	531.466
35	A 25	530.796
36	A 69	529.376
37	A 13	525.286
38	A 48	521.632
39	A 51	518.595
40	A 43	513.793
41	A 24	513.104
42	A 37	504.568
43	A 78	500.508
44	A 46	498.564
45	A 15	485.462
46	A 70	483.952
47	A 45	480.347
48	A 23	475.776
49	A 42	474.882
50	A 14	467.749
51	A 20	456.781
52	A 51	452.244
53	A 47	443.553
54	A 11	441.541
55	A 27	441.379
56	A 79	434.992
57	A 28	410.787
58	A 7	391.772
59	A 9	365.208
60	A 10	339.017

Fifteen promising accessions needed for the second experiment were selected based on the selection index values and other desirable characters. The characters taken into account along with yield were leaf stem / ratio, flowering nature and tolerance to leaf blight and leaf webbers.

The selected fifteen promising accessions with selection index ranks and the desirable characters were given in table 8.

4.1.4. Genetic cataloguing of the amaranthus accessions

The sixty genotypes used in the initial screening were described morphologically using the simplified descriptor developed from IBPGR descriptor for amaranthus.

The accessions were scored for twenty morphological characters on an appropriate scale ranging from 0-9 (Table 9).

All the accessions had erect growth habit. The plant height showed considerable variation among the genotypes. Majority of the genotypes had a height range of 30-60 cm. The genotypes A 25, A 27, A 41, A 47, A 54, A 55, A 60, A 78 and A 79 were having less than 30 cm height while A 53, A 57, A 59, A 61 and A 65 had more than 60cm height.

Regarding branching index, majority of the accessions had branches uniformly all along the stem. But A 9, A 33, A 47 and A 79 had a few branches all near the base of the stem. The genotypes A 12, A 15, A 38 and A 52 had many branches all near the base of the stem.

Table 8. Selected fifteen promising accessions with selection index ranks

Genotype	Yield	Leaf/stem ratio	Days to 50% bolting	Leaf blight	Leaf webber	Selection index rank
A 58	248.75	0.86	58.13	3.25	1.25	3
A 50	169.45	1.17	47.5	4.75	1.75	4
A 19	181.49	1.08	59.25	6.42	1.13	8
A 61	172.55	1.09	52.0	0	0.75	9
A 21	171.48	1.23	71.88	5.5	0	12
A 63	184.01	1.08	58.0	3.25	0.25	13
A 36	184.20	0.93	49.63	2.5	0	14
A 29	162.29	1.02	50.63	0	0.75	15
A 80	167.7	1.08	67.25	6.75	1.25	16
A 56	177.75	1.06	63.5	6.5	1.0	17
A 26	156.9	1.18	59.25	0	0.63	19
A 39	158.67	1.35	62.25	2.75	1.38	20
A 66	164.17	1.14	66.75	5.75	1.25	23
A 22	150.04	1.28	51.25	0	1.25	25
A 24	158.17	1.57	47.75	3.5	1.88	41

Table 9. Genetic cataloguing of amaranthus accessions

	Descriptor	A 7	A 9	A 10	A 11	A 12	A 13	A 14	A 15	A 19	A 20	A 21	A 22	A 23	A 24	A 25	A 26	A 27	A 28	A 29	A 30
1	Growth habit	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Plant height	3	3	3	3	5	5	3	3	5	5	3	5	3	3	1	5	1	3	5	3
3	Branching index	2	4	4	4	3	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4
4	Stem pubescence	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Stem pigmentation	2	1	1	3	3	1	2	3	3	3	5	1	4	5	2	1	2	3	1	4
6	Spines in leaf axils	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Leaf length	1	1	1	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3
8	Leaf width	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
9	Leaf pubescence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Leaf pigmentation	8	8	8	8	6	8	8	8	8	8	1	9	1	1	1	9	1	1	9	1
11	Leaf shape	3	3	2	3	3	2	3	2	2	2	5	5	4	5	4	5	4	4	5	4
12	Leaf margin	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	Prominence of leafveins	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	Petiole pigmentation	1	1	1	1	3	3	2	3	3	4	3	1	4	3	3	1	4	3	1	4
15	Terminal inflorescence shape	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	3	1	1	3	1
16	Terminal inflorescence attitude	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	Axillary inflorescence	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	Inflorescence colour	2	2	2	2	2	2	2	2	2	2	3	2	3	3	3	2	3	3	2	3
19	Days to 50% bolting	2	2	2	2	2	2	2	2	2	2	3	2	2	2	3	2	3	2	2	2
20	Seed colour	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Table 9. (Contd....)

	Descriptor	A 31	A 32	A 33	A 35	A 36	A 37	A 38	A 39	A 40	A 41	A 42	A 43	A 45	A 46	A 47	A 48	A 49	A 50	A 51	A 52
1	Growth habit	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Plant height	5	3	5	3	5	5	5	5	5	1	5	5	3	3	1	5	3	3	3	5
3	Branching index	4	4	2	4	4	4	3	4	4	4	4	4	4	4	2	4	4	4	4	3
4	Stem pubescence	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
5	Stem pigmentation	4	4	1	3	5	3	1	1	1	5	1	3	2	1	1	3	4	1	1	1
6	Spines in leaf axils	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Leaf length	5	5	1	5	5	1	5	5	5	5	5	5	3	3	1	3	5	3	5	5
8	Leaf width	3	3	1	3	3	3	3	3	3	3	1	3	1	1	1	1	3	3	3	3
9	Leaf pubescence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Leaf pigmentation	1	1	9	8	7	1	6	8	8	1	8	1	8	8	8	7	1	3	8	8
11	Leaf shape	4	1	3	5	1	3	2	4	2	5	2	3	3	5	2	2	4	6	3	2
12	Leaf margin	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	Prominence of leafveins	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	Petiole pigmentation	3	3	1	3	3	3	1	1	1	3	1	1	3	1	1	3	3	1	1	2
15	Terminal inflorescence shape	1	3	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
16	Terminal inflorescence attitude	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	Axillary inflorescence	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	Inflorescence colour	3	3	2	2	3	3	2	2	2	3	2	2	1	2	2	2	3	1	2	2
19	Days to 50% bolting	2	2	1	3	2	3	2	3	3	3	2	2	1	3	2	1	2	2	2	1
20	Seed colour	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Table 9. (Contd....)

	Descriptor	A 53	A 54	A 55	A 56	A 57	A 58	A 59	A 60	A 61	A 62	A 63	A 65	A 66	A 68	A 69	A 70	A 75	A 78	A 79	A 80
1	Growth habit	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Plant height	7	1	1	3	7	3	7	1	7	3	2	7	3	3	3	3	3	1	1	3
3	Branching index	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4
4	Stem pubescence	3	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0
5	Stem pigmentation	1	5	1	3	1	4	1	4	1	1	1	1	5	4	4	4	3	4	3	5
6	Spines in leaf axils	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0
7	Leaf length	3	5	5	5	3	3	5	5	5	5	5	5	5	5	5	5	1	5	1	5
8	Leaf width	1	3	1	5	1	1	3	1	5	3	3	3	5	3	3	5	1	5	1	5
9	Leaf pubescence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Leaf pigmentation	8	1	8	1	8	1	3	1	9	8	8	8	1	1	1	1	8	1	8	1
11	Leaf shape	5	5	4	2	2	5	5	4	5	3	3	2	4	5	4	5	5	4	5	4
12	Leaf margin	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	3	1	3	1
13	Prominence of leafveins	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
14	Petiole pigmentation	3	4	1	1	1	4	1	3	1	1	1	1	4	3	3	3	3	4	3	4
15	Terminal inflorescence shape	2	1	1	1	2	1	3	1	3	1	1	2	1	1	1	1	1	1	2	1
16	Terminal inflorescence attitude	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	Axillary inflorescence	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
18	Inflorescence colour	2	3	2	1	2	3	2	3	2	2	2	2	3	3	3	3	2	3	2	3
19	Days to 50% bolting	1	3	3	3	1	2	3	2	2	2	2	3	3	3	3	3	3	3	2	3
20	Seed colour	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

The accessions A 7, A 35, A 47, A 53, A 54, A 65 and A 79 had low stem pubescence , while in all other genotypes it was absent. Leaf pubescence was absent in all the genotypes.

Spines were present in the leaf axils of A 33, A 53, A 57, A 65, A 75 and A 79. The remaining genotypes were free of spines.

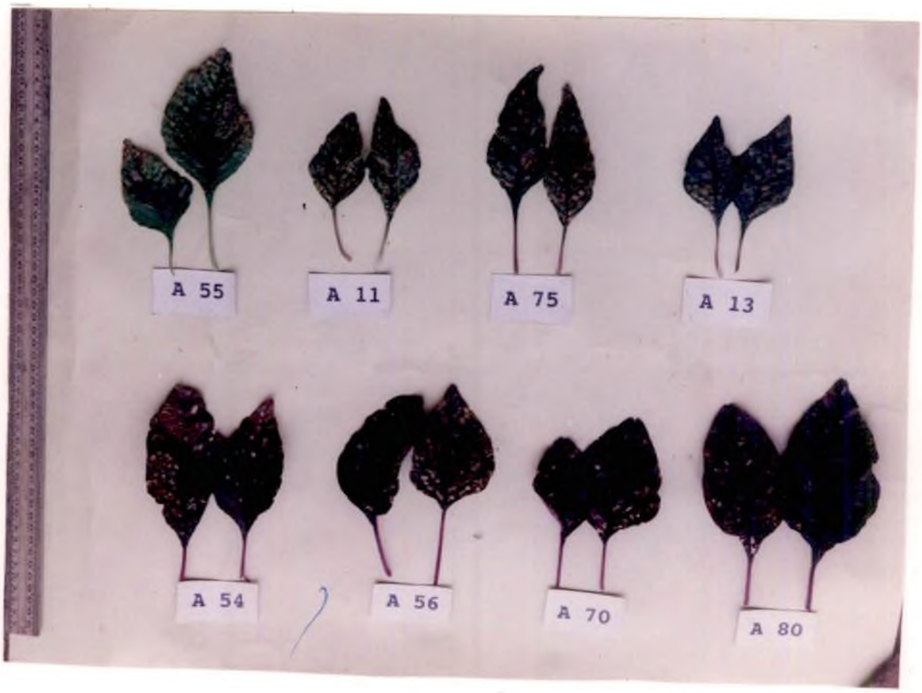
Considerable variation among the genotypes was observed for leaf characters like leaf size, leaf length, leaf width and leaf shape (Plates 4, 5). The leaf shape varied from lanceolate to rhombic. A 36 had lanceolate leaves. Elliptical leaves are seen in A 10, A 13, A 15, A 19, A 20, A 38, A 40, A 42, A 47, A 48, A 52, A 56, A 57 and A 65. The genotypes A 25, A 27, A 28, A 30, A 31, A 39, A 49, A 55, A 60, A 66, A 78 and A 80 had broad ovate shaped leaves. The genotype A 50 had rhombic ovate leaves. The remaining accessions had either ovate or triangular ovate leaves.

The stem, leaf and petiole pigmentation showed marked variation. The stem colour varied from green to purple / pink. The genotypes A 50 and A 59 had green leaves with deep purple central area. The accessions A 36 and A 48 had purplish green leaves. Green leaves with slight pigmentation of margins and veins were observed in A 12 and A 38. The rest of the accessions had either green, dark green or purple coloured leaves.

The leaf margins were entire and the leaves were having mostly slightly prominent veins. The petiole pigmentation showed variation. In

Plate 2. Variation in leaf blight incidence - High

Plate 3. Variation in leaf blight incidence - Moderate


A 55
A 11
A 75
A 13
A 54
A 56
A 70
A 80

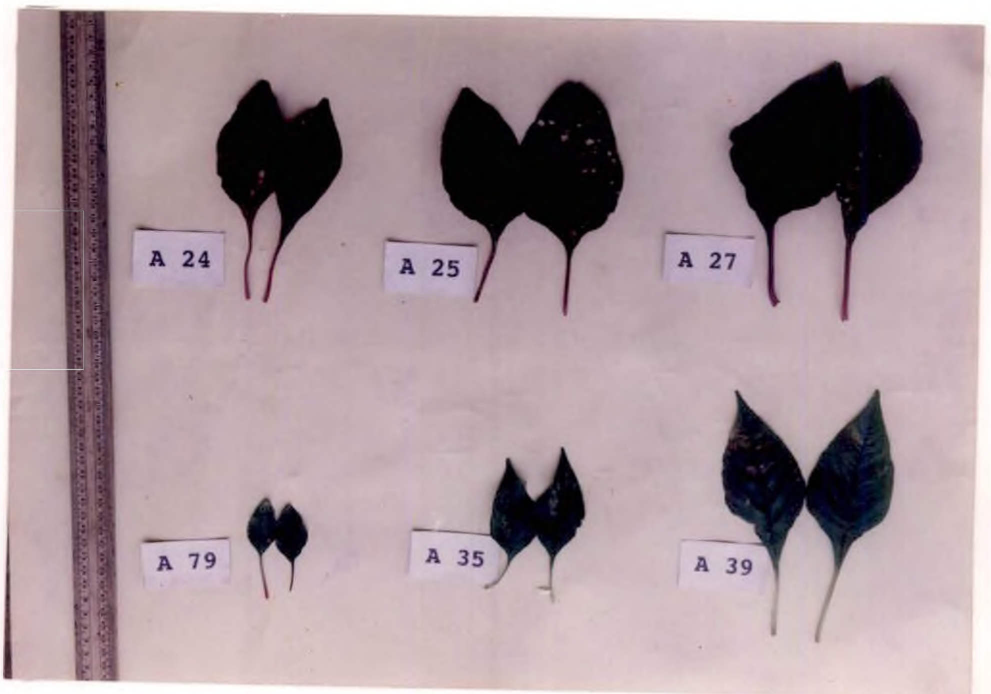
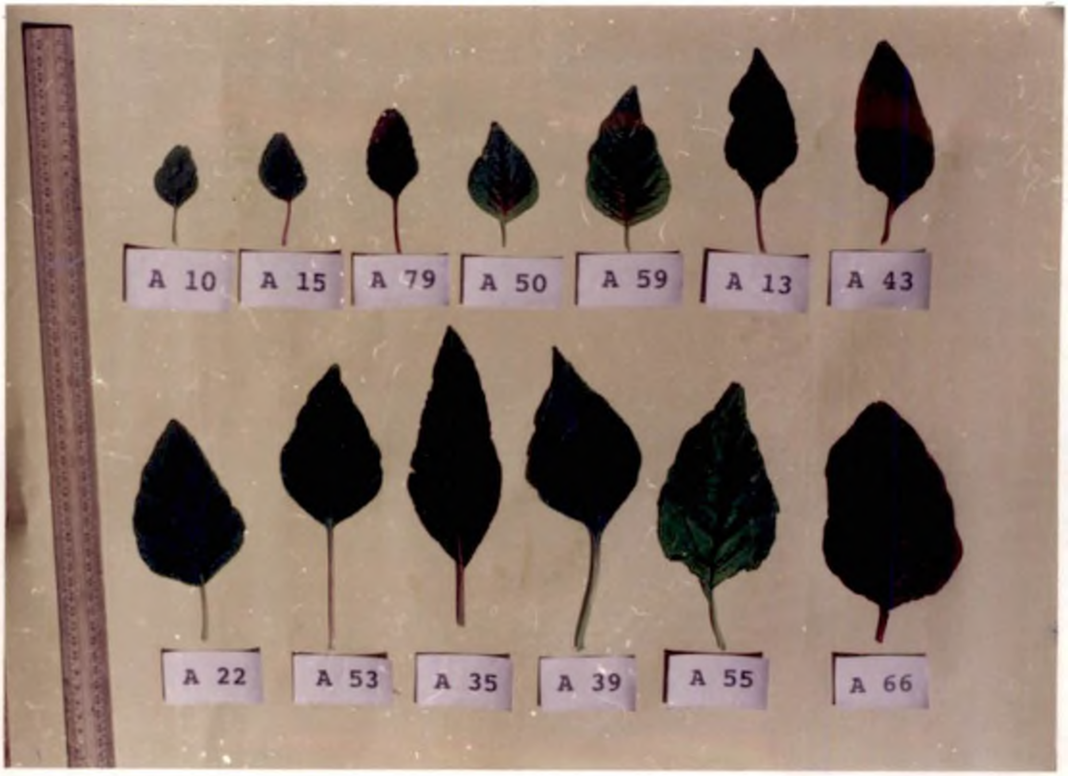
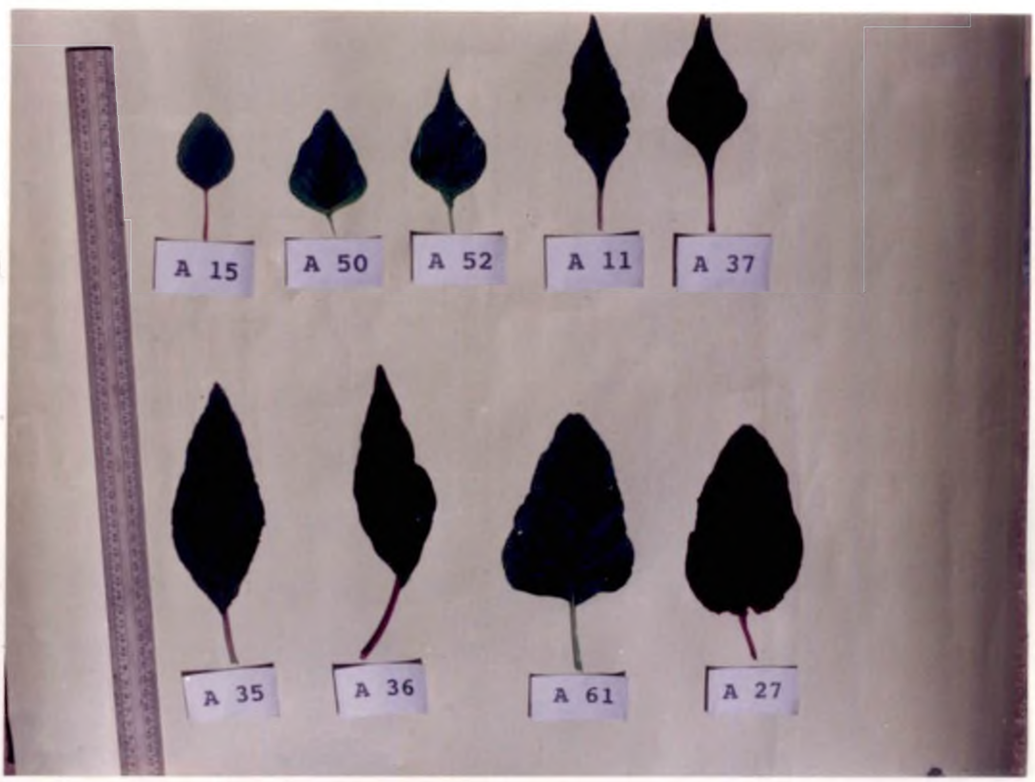

A 24
A 25
A 27
A 79
A 35
A 39

Plate 4. Variation in leaf size

Plate 5. Variation in leaf shape


A 10
A 15
A 79
A 50
A 59
A 13
A 43
A 22
A 53
A 35
A 39
A 55
A 66


A 15
A 50
A 52
A 11
A 37
A 35
A 36
A 61
A 27

general, green leaved varieties had green petiole colour while purple leaved varieties had purple coloured petioles. The accessions A 11, A 13, A 15, A 35 and A 53 had green leaves with slight purple coloured petiole.

The characters of the inflorescence were also studied. The genotypes A 22, A 26, A 29, A 33, A 59 and A 61 had panicles with long branches whereas A 36, A 51, A 52, A 53, A 57, A 65 and A 79 had panicles with short branches. The terminal inflorescence remained erect in all genotypes. Small axillary inflorescence was present in all genotypes except A 36 and A 75. The purple leaved types had purple inflorescence while green leaved types had green.

The days to 50 per cent bolting also showed wide variation among the genotypes. All the accessions had black seed colour except A 36 which had brown coloured seeds.

Experiment - 2

4.2. Evaluation of the selected promising accessions

In the second experiment the selected fifteen promising accessions were studied in detail. They showed considerable variation in morphological characters (Plate 6, 7 and 8). The data on the observations recorded for the fifteen accessions of amaranthus were statistically analysed and results presented.

4.2.1. Analysis of variance

The analysis of variance showed significant difference among the fifteen genotypes of amaranthus for all the characters studied except leaf webber attack (Table 10)

4.2.2. Mean performance of the genotypes

The mean values of the fifteen genotypes for the 24 characters studied were presented in table 11.

Quantitative characters

The genotype A 22 recorded the maximum plant height (54.43 cm) and the least was for A 66 (31.75 cm). The maximum stem girth was observed for A 29 (4.8 cm) and minimum for A 50 (2.19 cm). The length of leaf lamina was maximum in A 19 (15.33 cm) and minimum in A 63 (6.37 cm). The character petiole length was maximum for A 80 (7.75 cm) and minimum for A 58 (3.49 cm). The genotype A 80 also recorded the maximum leaf width (12.3 cm) while it was minimum for A 36 (7.1 cm).

The maximum number of branches was found is A 36 (10.67) and minimum in A 56 (6.6). The genotype A 24 was the earliest to flower (47.97 days) and A 21 the latest (72.77 days).

The yield from first cutting was maximum in A 22 (169.91 g) followed by A 29 (169.63 g). The minimum yield was for A 50 (92.46 g).

Table 10. Analysis of variance for 24 characters in 15 amaranthus genotypes (mean squares are given)

Source	df	1	2	3	4	5	6	7	8
Replications	2	3.4375	0.0052	0.0400	0.0871	0.6648	0.3512	12.9375	128.0313
Genotype	14	185.6189**	1.8174**	28.0369**	4.3041**	14.1648**	3.376**	158.3147**	2935.4780**
Error	28	5.6582	0.0348	0.2873	0.0829	0.3527	0.6947	8.3264	24.2545

Source	df	9	10	11	12	13	14	15	16
Replication	2	0.0029	55.3594	0.01556	73.5156	0.0073	408.625	0.0034	153.1875
Genotype	14	0.0907**	1132.5149**	0.8129**	913.9487**	1.0893**	10784.88**	0.3422**	6640.95**
Error	28	0.0056	48.8069	0.0181	11.1417	0.02136	91.0804	0.0041	41.3661

Source	df	17	18	19	20	21	22	23(+)	24(+)
Replication	2	43.5156	0.7542	0.4707	0.0006	3.3526	0.4179	0.0422	0.0923
Genotype	14	811.5715**	21.7011**	25.4221**	0.8784**	233.6156**	18.5685**	0.4102**	0.0286
Error	28	19.5658	0.3064	0.2540	0.0016	34418.29	0.8230	0.0120	0.0182

** Significant at 1% level
(+) transformed data

Table 11. Mean values for 24 biometric characters of 15 amaranthus genotypes

Genotypes	Plant height (cm)	Stem girth (cm)	Length of leaf lamina (cm)	Petiole length (cm)	Leaf width (cm)	No. of branches	Days to 50% flowering	Yield at first cutting (g plant^{-1})	Leaf/stem ratio (first cutting)	Yield at second cutting (g plant^{-1})	Leaf/stem ratio (second cutting)	Yield at third cutting (g plant^{-1})	Leaf stem ratio (third cutting)
	1	2	3	4	5	6	7	8	9	10	11	12	13
A 19	50.10	3.31	15.33	6.30	8.08	9.67	68.50	156.50	1.37	87.20	2.16	76.53	3.02
A 21	43.07	4.09	12.33	7.22	8.30	9.50	72.77	104.50	1.48	95.80	2.19	74.63	3.00
A 22	54.43	4.62	13.86	5.55	10.13	9.00	59.97	169.91	1.23	97.83	2.55	99.73	3.13
A 24	47.50	4.09	6.46	5.05	6.67	8.50	47.97	105.57	1.22	92.90	1.94	84.77	2.65
A 26	53.07	4.61	13.70	5.35	9.67	9.57	60.47	160.20	1.28	106.47	2.47	97.80	3.27
A 29	52.17	4.80	13.70	5.10	10.33	10.00	52.53	169.63	1.30	103.40	2.38	96.40	3.14
A 36	50.83	3.22	11.05	5.48	7.10	10.67	50.46	94.23	0.96	61.80	1.36	46.47	1.23
A 39	53.63	3.32	12.72	5.75	9.13	9.93	61.23	153.83	1.67	100.60	2.17	99.83	3.16
A 50	36.64	2.19	6.52	5.18	9.13	9.76	49.20	92.46	1.29	54.67	2.28	51.93	2.56
A 56	39.77	3.09	10.78	7.25	6.50	6.60	61.40	112.90	1.09	78.83	1.43	76.10	2.07
A 58	49.73	2.43	8.48	3.49	6.46	10.50	55.20	101.13	1.33	80.30	1.73	76.93	2.55
A 61	53.83	4.36	13.97	5.45	11.93	9.67	53.20	166.30	1.56	119.60	2.69	98.73	3.37
A 63	43.13	3.47	6.37	4.02	4.63	9.63	58.20	95.29	1.43	94.20	2.12	90.30	3.15
A 66	31.75	3.80	10.40	7.05	10.45	8.36	64.23	106.31	1.37	121.73	3.18	102.10	3.56
A 80	32.40	3.60	13.87	7.75	12.30	7.90	65.17	110.53	1.37	110.63	3.09	96.23	3.39
CD(5%)	3.98	0.31	0.90	0.48	0.99	1.39	4.83	8.24	0.13	11.68	0.22	5.58	0.24

Table 11. (Contd...)

Genotype	Total yield (g plant^{-1})	Leaf/stem ratio (total)	Total leaf weight (g plant^{-1})	Total stem weight (g plant^{-1})	Crude Protein (%)	Fibre (%)	Oxalate (%)	Vitamin A (I.U)	Organoleptic qualities	Leaf blight	Leaf webber
	14	15	16	17	18	19	20	21	22	23	24
A 19	320.23	1.84	207.53	112.7	11.1	10.13	0.91	5227.11	14.81	1.99 (1.73)	1.57 (1.60)
A 21	274.93	2.03	184.3	90.63	16.0	7.27	1.29	7529.16	17.0	2.66 (1.91)	1.07 (1.44)
A 22	367.61	1.87	239.7	127.91	10.43	11.43	0.92	6205.33	17.5	0 (1)	1.16 (1.47)
A 24	280.57	1.77	180.6	102.63	16.23	7.4	0.91	7336.10	15.26	2.3 (1.82)	1.66 (1.63)
A 26	364.47	1.94	240.67	123.8	10.3	11.15	0.91	6260.50	16.7	0 (1)	0.98 (1.41)
A 29	369.43	1.88	241	128.43	10.43	11.04	0.93	6232.9	17.39	0 (1)	1.4 (1.55)
A 36	202.5	1.12	107.3	95.19	12.43	14.45	1.39	6784.52	13.17	0.98 (1.41)	1.21 (1.49)
A 39	354.27	2.12	240.67	113.6	11.55	10.33	0.95	5598.61	19.16	1.98 (1.73)	1.48 (1.58)
A 50	197.06	1.78	127.4	71.59	13.03	5.42	2.09	6812.10	13.83	1.98 (1.73)	2.07 (1.75)
A 56	267.83	1.41	156.83	111.0	15.1	5.62	1.43	6039.85	15.17	1.98 (1.73)	1.40 (1.55)
A 58	258.36	1.73	163.87	94.33	15.53	5.98	1.42	7336.10	16.23	2.66 (1.91)	1.79 (1.68)
A 61	384.63	2.23	265.5	119.13	11.13	11.75	0.95	6205.33	18.88	0 (1)	1.25 (1.50)
A 63	279.79	2.08	189.0	90.82	11.93	13.37	0.82	5791.66	14.55	2.82 (1.96)	0.98 (1.41)
A 66	330.14	2.46	235.1	95.04	17.13	6.93	2.31	8025.57	21.44	1.98 (1.73)	1.48 (1.58)
A 80	317.40	2.32	222.0	95.4	17.96	7.33	2.40	8164.45	21.03	1.91 (1.71)	1.32 (1.52)
CD(5%)	15.96	0.11	10.75	7.40	0.93	0.84	0.06	310.24	1.52	0.18	0.23

Transformed values given in parenthesis

The genotype A 39 recorded the maximum leaf / stem ratio (1.67) whereas A 36 the least (0.96).

In the second and third cuttings, the maximum yield per plant was recorded in A 66 (121.73 g and 102.1 g respectively). The minimum yield in the 2nd cutting was for A 50 (54.67 g) and in the 3rd cutting for A 36 (46.47 g). The leaf / stem ratio for the 2nd and 3rd cuttings was maximum in A 66 (3.18; 3.56) whereas, it was minimum in A 36 (1.36; 1.23).

The total yield was maximum in A 61 (384.63g) (Plate 9), followed by A 29 (369.43 g) which were on par and minimum in A 50 (197.06g). The genotype A 66 recorded the maximum leaf/stem ratio (2.46) (Plate 10), whereas it was minimum in A 36 (1.12).

The genotype A 61 recorded the maximum leaf weight (265.5 g) and minimum in A 36 (107.3 g). The maximum total stem weight was observed in A 29 (128.43 g) followed by A 22 (127.91), whereas it was minimum in A 50 (71.599).

Qualitative characters

The quality characters like protein, fibre, vitamin A and oxalate content of the 15 accessions were analysed. The genotype A 80 recorded the maximum protein content (17.96%) which was on par with A 66 (17.13 %). It was minimum in A 26 (10.3 %) followed by A 22, A 29, A 19 and A 61 which were on par. The fibre content was maximum in A 36 (14.45%) and minimum in A 50 (5.42%).

The genotype A 80 recorded the maximum oxalate content (2.4%) and it was minimum for A 63 (0.82%). The maximum vitamin A content was present in A-80 (8164.45 I.U) followed by A 66 (8025.57 I.U.) which were on par and minimum in A 19 (5227.1 I.U).

Organoleptic qualities was maximum for A 66 (21.44) followed by A 80 (21.03) and minimum for A 36 (13.17).

Biotic stress

The fifteen accessions were scored for the incidence and intensity of leaf blight and leaf webber attack. The genotypes A 22, A 26, A 29 and A 61 were completely free from the leaf blight disease. Among the genotypes, the maximum incidence was recorded in A 63 followed by A 21 (2.66) and A 58 (2.66). The accessions A 36 (0.98) recorded a mild incidence.

The attack of leaf webber was very mild. Low incidence was observed in all the genotypes which did not differ significantly. However, among the genotypes, the lowest incidence was recorded by A 26 and A 63 (0.98).

4.2.3. Genetic variability, heritability and genetic advance

The population mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance and genetic gain (as percentage of mean) for all the twenty four characters studied are presented in Table 12.

Quantitative characters

Plant height

Plant height ranged from 31.75 to 54.43 cm with a mean of 46.14 cm. This characters had a GCV of 16.78 and PCV 17.56. The heritability was 91.38 per cent and genetic gain as percentage of mean was 33.05 (Fig. 1).

Stem girth

Significant variation was observed for this character among the genotypes. It ranged from 2.19 to 4.18cm with an overall mean of 3.67 cm. It recorded a PCV of 21.62 and a GCV of 21.01. Heritability was high (94.4%). Genetic gain as percentage of mean was 41.96.

Length of leaf lamina

The character had a general mean of 11.3 cm and the range was 6.36 to 15.33 cm. PCV was 27.32 and GCV 26.91. It had a high heritability of 96.9% and genetic gain of 54.6.

Table 12. Range, Mean, PCV, GCV, heritability, genetic advance and genetic gain as per cent of mean for 24 characters in amaranthus

Characters	Range	Mean ± SE	PCV	GCV	Herit-ability	Genetic advance	Genetic gain (as % of mean)
1. Plant height	31.75 - 54.43	46.14 ± 1.37	17.56	16.78	91.38	15.25	33.05
2. Stem girth	2.19 - 4.18	3.67 ± 0.11	21.62	21.01	94.4	1.54	41.96
3. Length of leaf lamina	6.36 - 15.33	11.30 ± 0.31	27.32	26.91	96.9	6.17	54.6
4. Petiole length	3.49 - 7.75	5.73 ± 0.17	21.30	20.69	94.4	2.37	41.36
5. Leaf width	4.63 - 12.3	8.72 ± 0.34	25.53	24.60	92.88	4.26	48.85
6. No.of branches	6.6 - 10.67	9.28 ±0.48	13.57	10.18	56.27	1.46	15.73
7. Days to 50% bolting	47.97 - 72.77	58.7 ± 1.67	13.01	12.65	85.72	13.49	22.98
8. Yield at first cutting	92.46 - 169.91	126.62 ± 2.84	24.91	24.60	97.56	63.69	50.06
9. Leaf stem ratio (1st cutting)	0.96 - 1.67	1.33 ± 0.04	13.85	12.65	83.37	0.32	24.06
10. Yield at second cutting	54.67 - 121.73	94.39 ± 4.03	21.45	20.13	88.09	36.75	38.93
11. Leaf/stem ratio (2nd cutting)	1.36 - 3.18	2.25 ± 0.07	23.63	22.87	93.62	1.03	45.78
12. Yield at third cutting	46.47 - 102.1	84.57 ± 1.93	20.89	20.51	96.78	35.09	41.50

Table 12. (Contd...)

Characters	Range	Mean ± SE	PCV	GCV	Herit-ability	Genetic advance	Genetic gain (as % of mean)
13. Leaf/stem ratio (3rd cutting)	1.23 - 3.56	2.88 ± 0.08	21.31	20.69	94.34	1.19	41.32
14. Total yield	197.06 - 384.63	305.28 ± 5.51	19.8	19.55	97.51	121.45	39.78
15. Leaf/stem ratio (total)	1.12 - 2.46	1.91 ± 0.04	17.93	17.61	96.47	0.68	35.60
16. Total leaf weight	107.3 - 265.5	184.5 ± 3.71	23.61	23.39	98.15	95.72	51.88
17. Total stem weight	71.59 - 128.43	105.01 ± 2.5	16.04	15.47	93.10	32.30	30.76
18. Crude protein	10.3 - 17.97	13.35 ± 0.32	20.42	19.99	95.88	5.39	40.37
19. Fibre	5.42 - 14.45	9.31 ± 0.29	31.58	31.12	97.06	5.88	63.16
20. Oxalate	0.81 - 2.40	1.31 ± 0.02	41.43	41.32	99.47	1.11	84.73
21. Vitamin A	5227.12 - 8164.46	6636.62 ± 107.11	13.49	13.20	95.71	1765.23	26.60
22. Organoleptic qualities	13.17 - 21.44	16.81 ± 0.52	15.44	14.47	87.79	4.69	27.90
23. Leaf blight	0 - 2.83	1.5 ± 0.22	70.89	66.62	88.32	2.01	134.0
24. Leaf webber	1 - 2.08	1.79 ± 0.24	32.46	13.43	17.11	0.16	8.94

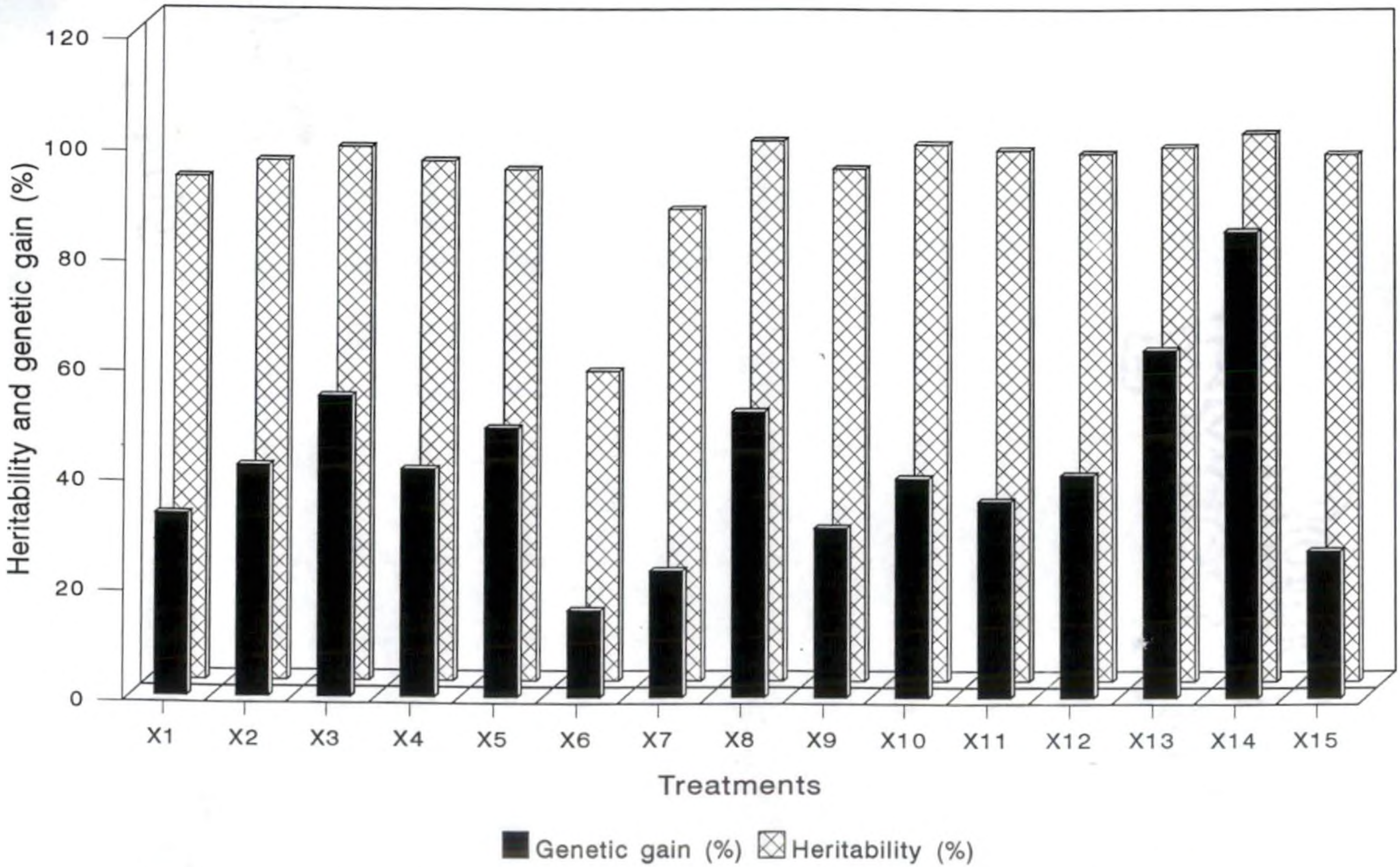


Fig. 1. Heritability and genetic gain (as percentage of mean) of 15 important characters in amaranthus

Petiole length

It ranged from 3.49 to 7.75 cm with a mean of 5.73 cm. PCV was 21.30 and GCV 20.69. Heritability of 94.4 per cent and genetic gain of 41.36 were recorded.

Leaf width

The range was 4.63 to 12.3 cm, 8.72cm being the overall mean. PCV was 25.53 and GCV was 24.60. It had a heritability of 92.88 and genetic gain of 48.85.

Number of branches

This character had a mean of 9.28 and the range was from 6.6 to 10.67. PCV was 13.57 and GCV 10.18. Heritability was low (56.27 per cent). Genetic gain as percentage of mean was very low (15.73).

Days to 50 per cent bolting

It ranged from 47.97 to 72.77 days. The general mean was 58.7 days. It recorded a PCV of 13.01 and a GCV of 12.65. It had a heritability of 85.72 and genetic gain of 22.98.

Yield at first cutting

Yield exhibited a mean of 126.62 g and ranged from 92.46 g to 169.91 g. PCV was 24.91 and GCV was 24.60. Very high heritability was shown by this trait (97.56) and genetic gain was also high (50.06).

Leaf / stem ratio (1st cutting)

It ranged from 0.96 to 1.67 with a mean of 1.33. The heritability was 83.37 and genetic gain 24.06. The PCV was 13.85 and GCV 12.65.

Yield at second cutting

A very wide range of 54.67 to 121.73 was observed with a mean of 94.39 g. Moderately high heritability of 88.09 was recorded. The genetic gain was 38.93. The PCV and GCV were 21.45 and 20.13 respectively.

Leaf / stem ratio (2nd cutting)

It ranged from 1.36 to 3.18 with a mean of 2.25. The PCV was 23.63 and GCV was 22.87. This characters recorded high heritability (93.62) and the genetic gain was 45.78.

Yield at third cutting

The general mean was 84.57 g and the range was 46.47 to 102.1. The PCV was 20.89 and GCV was 20.51. Very high heritability of 96.78 was observed for this trait. The genetic gain was 41.50.

Leaf / stem ratio (3rd cutting)

This character exhibited a mean of 2.88 and ranged from 1.23 to 3.56. The PCV was 21.31 and GCV was 20.69. High heritability of 94.34 and a genetic gain of 41.32 were observed.

Total yield

This trait ranged considerably from 197.06 g to 384.63 g with a mean of 305.28 g. The PCV was 19.8 and GCV 19.55. Very high heritability was shown by this trait (97.51) and the genetic gain was 39.78.

Leaf / stem ratio (total)

It ranged from 1.12 to 2.46 with a mean of 1.91. The PCV and GCV were 17.93 and 17.61 respectively. Very high estimates of heritability was observed (96.47). The genetic gain as percentage of mean was 35.60.

Total leaf weight

The range was from 107.3 to 265.5 g with a mean of 184.5g. The PCV and GCV were 23.61 and 23.39 respectively. The heritability was very high (98.15). The genetic gain was 51.88.

Total stem weight

It ranged from 71.59 to 128.43 g with a mean of 105.01 g. The PCV was 16.04 and GCV 15.47. High heritability of 93.10 and moderate genetic gain of 30.76 were recorded.

Qualitative characters

Crude protein

This trait showed a range of 10.3 to 17.97 per cent, the mean being

13.32 per cent. The PCV was 20.42 and GCV 19.99. High heritability (95.88) and genetic gain (40.37) were observed.

Fibre

This character had an overall mean of 9.31 with a range of 5.42 to 14.45 per cent. PCV and GCV were 31.58 and 31.12 respectively. The heritability was very high (97.06). High genetic gain (63.16) was recorded.

Oxalate

The oxalate content ranged from 0.81 to 2.4 with a mean of 1.31. High PCV and GCV of 41.43 and 41.32 were recorded. Very high heritability of 99.47 was observed. The trait also recorded high genetic gain (84.73).

Vitamin A

The overall mean was 6636.62 (I.U) and the range 5227.12 to 8164.46 I.U. The PCV was 13.49 and GCV was 13.20. The heritability was high 95.71, but genetic gain was low.

Organoleptic qualities

This character showed a range of 13.17 to 21.44, mean being 16.81. PCV was 15.44 and GCV 14.47. Moderately high heritability was recorded (87.79). But the genetic gain was low (27.9).

Biotic stress

Reaction to leaf blight

This had an overall mean of 1.5, with a range of 0 to 2.83. The PCV and GCV were very high (70.89, 66.62). High heritability of 88.32 and very high genetic gain of 134.0 were recorded.

Reaction of leaf webber

It showed a range of 1 to 2.08, with a mean of 1.79. The PCV was 32.46 and GCV 13.43. The heritability was very low (17.11). The genetic gain as percentage of mean was also very low (8.94).

4.2.4. Correlation studies

The phenotypic, genotypic and environmental correlation among the 24 characters were worked out and presented in table 13, 14, 15.

Phenotypic correlation coefficients

Total yield per plant was positively and highly correlated with plant height (0.3773), stem girth (0.7258), leaf length (0.6593), leaf width (0.5809), leaf / stem ratio (total) (0.5815), total leaf weight (0.9783) and stem weight (0.8187).

Plant height was positively associated with number of branches

Table 13. Phenotypic correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1.0000																							
2	0.3735	1.0000																						
3	0.3491	0.5067	1.0000																					
4	-0.4827	0.1447	0.4595	1.0000																				
5	-0.0694	0.4002	0.6190	0.4225	1.0000																			
6	0.4691	-0.0561	-0.0245	-0.5026	-0.0382	1.0000																		
7	-0.2324	0.1029	0.4921	0.6005	0.1678	-0.1879	1.0000																	
8	0.6342	0.6318	0.7464	0.0038	0.5056	0.1231	0.1053	1.0000																
9	0.0757	0.0936	0.1834	0.0163	0.3168	0.2098	0.3594	0.2724	1.0000															
10	0.0417	0.6255	0.4454	0.2502	0.5430	-0.1726	0.3663	0.4866	0.5548	1.0000														
11	-0.3238	0.4175	0.3340	0.3302	0.7429	-0.1573	0.2635	0.2972	0.4380	0.6683	1.0000													
12	0.1079	0.6310	0.3834	0.0948	0.4512	-0.2153	0.2675	0.5743	0.5024	0.8884	0.6375	1.0000												
13	-0.0616	0.4615	0.3167	0.1415	0.5317	-0.0975	0.3801	0.4471	0.6844	0.7645	0.8118	0.8014	1.0000											
14	0.3773	0.7258	0.6593	0.1157	0.5809	-0.0560	0.2639	0.8571	0.4781	0.8531	0.5662	0.8939	0.7263	1.0000										
15	-0.2789	0.3094	0.1929	0.2248	0.5415	-0.1053	0.3864	0.2037	0.7631	0.7776	0.8643	0.7275	0.9150	0.5815	1.0000									
16	0.2554	0.6805	0.5949	0.1443	0.6257	-0.0613	0.3030	0.7685	0.5958	0.9042	0.6898	0.9221	0.8320	0.9783	0.7355	1.0000								
17	0.6329	0.6843	0.6639	0.0032	0.3145	0.0349	0.0686	0.8992	0.0302	0.5046	0.0900	0.6008	0.2584	0.8187	0.0129	0.6831	1.0000							
18	-0.7261	-0.2913	-0.3481	0.4260	-0.0453	-0.4370	0.1953	-0.6808	-0.0753	0.0321	0.1111	-0.0847	-0.0412	-0.3729	0.1728	-0.2747	-0.5531	1.0000						
19	0.5942	0.4293	0.3008	-0.3093	-0.0191	0.4182	-0.1623	0.4007	-0.0184	0.1220	-0.0713	0.1188	-0.0385	0.2894	-0.1125	0.2176	0.4112	-0.6900	1.0000					
20	-0.8334	-0.4223	-0.1656	0.4776	0.3277	-0.2909	0.1141	-0.5407	-0.1319	-0.0900	0.3715	-0.1969	-0.0034	-0.3708	0.2152	-0.2581	-0.6019	0.6907	-0.5812	1.0000				
21	-0.5978	-0.0572	-0.2472	0.2802	0.2338	-0.1886	0.0251	-0.5508	-0.1189	0.0812	0.3317	-0.0510	0.0456	-0.2772	0.2421	-0.1726	-0.5023	0.8030	-0.5063	0.7241	1.0000			
22	-0.2606	0.3616	0.4163	0.4164	0.7123	-0.1951	0.3841	0.2941	0.4901	0.8032	0.7547	0.7461	0.6632	0.6457	0.7631	0.7270	0.2557	0.2963	-0.1606	0.3461	0.3770	1.0000		
23	-0.5186	-0.6142	-0.5583	0.0703	-0.5641	-0.1165	0.2199	-0.7140	0.1494	-0.2639	-0.2266	-0.2823	-0.1456	-0.5478	0.0432	-0.4513	-0.6821	0.6182	-0.4833	0.2852	0.2549	-0.1203	1.0000	
24	-0.1612	-0.3967	-0.2953	-0.1198	-0.0495	0.1201	-0.1937	-0.1649	0.0485	-0.2442	-0.0837	-0.2718	-0.1308	-0.2494	-0.0630	-0.2171	-0.2796	0.1637	-0.4335	0.2503	0.0928	-0.0487	0.2000	1.0000

Table 14. Genotypic correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1.0000																							
2	0.3829	1.0000																						
3	0.3590	0.5276	1.0000																					
4	-0.5395	0.1418	0.4772	1.0000																				
5	0.0621	0.4556	0.6521	0.4581	1.0000																			
6	0.6394	0.0977	0.0171	0.7583	-0.1318	1.0000																		
7	0.2637	0.1369	0.5155	0.6724	0.1379	-0.3648	1.0000																	
8	0.6828	0.6501	0.7708	0.0101	0.5298	0.1298	0.1126	1.0000																
9	0.0644	0.1210	0.2053	0.0133	0.3108	0.1744	0.3722	0.3202	1.0000															
10	0.0526	0.6933	0.4881	0.2822	0.5786	-0.2319	0.3851	0.5235	0.6452	1.0000														
11	-0.3270	0.4314	0.3523	0.3496	0.8200	-0.1835	0.3326	0.3166	0.5147	0.7565	1.0000													
12	0.1333	0.6613	0.3954	0.1063	0.4716	-0.2938	0.2957	0.5960	0.5597	0.9517	0.6786	1.0000												
13	-0.1131	0.4895	0.3324	0.1534	0.5673	-0.1319	0.4401	0.4710	0.7676	0.8572	0.8839	0.8542	1.0000											
14	0.4150	0.7554	0.6813	0.1187	0.5998	-0.0898	0.2749	0.8667	0.5370	0.8734	0.6054	0.9090	0.7693	1.0000										
15	-0.3096	0.3263	0.1987	0.2387	0.5656	-0.1539	0.4250	0.2261	0.7863	0.8323	0.8997	0.7528	0.9510	0.6038	1.0000									
16	0.2766	0.7061	0.6123	0.1480	0.6453	-0.0983	0.3188	0.7794	0.6464	0.9291	0.7263	0.9377	0.8733	0.9801	0.7490	1.0000								
17	0.7138	0.7256	0.7033	-0.0009	0.3328	-0.0530	0.0639	0.9157	0.1000	0.5080	0.1205	0.6171	0.2970	0.8245	0.0491	0.6958	1.0000							
18	-0.7766	-0.3177	-0.3529	0.4430	-0.0465	-0.5727	0.2325	-0.7086	-0.0675	0.0260	0.1135	-0.0943	-0.0378	-0.3919	0.1887	-0.2865	-0.6014	1.0000						
19	0.6206	0.4370	0.3087	-0.3221	-0.0236	-0.5602	-0.1582	0.4089	-0.0274	0.1496	-0.0690	0.1237	-0.0543	0.3026	-0.1204	0.2257	0.4405	-0.7220	1.0000					
20	-0.8687	-0.4413	-0.1651	0.4921	0.3425	-0.3867	0.1321	-0.5510	-0.1326	-0.0893	0.3782	-0.1981	-0.0013	-0.3748	0.2252	-0.2580	-0.6277	0.7022	-0.5897	1.0000				
21	-0.6308	-0.0594	-0.2516	0.3055	0.2501	-0.2531	0.0432	-0.5685	0.1280	0.1076	0.3407	-0.0438	0.0464	-0.2786	0.2546	-0.1693	-0.5225	0.8523	-0.5200	0.7356	1.0000			
22	-0.2350	0.3993	0.4518	0.4786	0.7508	-0.3577	0.4093	0.3098	0.5650	0.8878	0.8324	0.7802	0.7632	0.6756	0.8324	0.7659	0.2549	0.3125	-0.1721	0.3699	0.4179	1.0000		
23	-0.5514	-0.6740	-0.6104	0.0391	-0.5965	-0.1870	0.2817	-0.7737	0.1725	-0.2694	-0.2695	-0.3134	-0.1175	-0.5835	0.0503	0.4799	-0.7470	0.6579	-0.5249	0.3024	0.2848	-0.1787	1.0000	
24	-0.3839	-1.1243	-0.6465	-0.2893	-0.0895	-0.0549	0.7068	-0.4791	-0.2052	-0.7817	-0.2307	-0.6099	-0.3447	-0.6932	-0.2886	-0.6359	-0.6516	0.4473	-1.0056	0.6291	0.2851	-0.3348	0.5936	1.0000

Table 15. Error correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1.0000																							
2	0.2574	1.0000																						
3	0.2166	0.0395	1.0000																					
4	0.2661	0.1943	0.0677	1.0000																				
5	-0.1556	-0.4223	0.0030	-0.1041	1.0000																			
6	0.0549	0.0972	-0.3239	0.3221	0.3255	1.0000																		
7	0.0091	-0.2285	0.3355	-0.0499	0.4439	0.2621	1.000																	
8	-0.2278	0.2100	-0.1250	0.3673	0.0313	0.2611	0.0382	1.0000																
9	0.1625	-0.1438	-0.0170	0.0462	0.3976	0.3349	0.2905	-0.2578	1.0000															
10	-0.0546	-0.0859	-0.0964	-0.0882	0.2132	-0.0410	0.2426	0.0233	0.0128	1.0000														
11	-0.2874	0.1990	-0.0386	0.0242	-0.3219	-0.1441	-0.3611	-0.1373	-0.1621	-0.2151	1.0000													
12	-0.3116	-0.0035	0.0304	-0.1495	0.0974	0.0090	-0.0197	-0.1289	0.0072	0.1715	-0.1516	1.0000												
13	0.6216	-0.0117	-0.0289	-0.0583	0.0097	-0.0093	-0.1748	-0.1296	0.0379	-0.2060	-0.3152	-0.2963	1.0000											
14	-0.3110	0.0225	-0.1183	0.0498	0.2392	0.1008	0.2104	0.4806	-0.0948	0.8017	-0.3068	0.4161	-0.3062	1.0000										
15	0.2139	-0.0482	0.0208	-0.0687	0.1222	0.0649	-0.0004	-0.5349	0.7564	0.1591	0.1963	0.0414	0.1735	-0.1381	1.0000									
16	-0.1652	0.0183	-0.1095	0.0568	0.2641	0.1307	0.2058	0.2744	0.2003	0.8588	-0.1873	0.3829+	-0.2579	0.9043	0.2627	1.0000								
17	-0.3306	0.0616	-0.0962	0.0651	0.0724	0.6196	0.1153	0.6451	-0.5412	0.4914	-0.3390	0.3244	-0.3177	0.7990	-0.6827	0.5035	1.0000							
18	0.0141	0.2318	-0.2224	0.0665	-0.0266	-0.1214	-0.2018	0.1433	-0.1806	0.1170	0.0694	0.1556	-0.1094	0.1910	-0.2276	0.1182	0.2828	1.0000						
19	0.1949	0.2692	0.0429	-0.0233	0.0718	0.0367	-0.2771	0.1021	0.0899	-0.2757	-0.1282	-0.0256	0.3291	-0.1817	0.1234	-0.1164	-0.1677	0.1878	1.0000					
20	-0.2416	0.3222	-0.2708	0.0401	-0.0765	-0.0336	-0.2877	0.1839	-0.3761	-0.2564	0.3557	-0.2077	-0.1256	-0.1449	-0.3978	-0.3271	0.1115	0.3285	-0.1445	1.0000				
21	-0.1292	-0.0135	-0.1349	-0.2084	-0.0362	-0.0210	-0.1798	-0.0463	-0.0535	-0.2461	0.1752	-0.2294	0.0303	-0.2472	-0.0656	-0.3034	-0.1664	-0.3206	-0.1444	0.4200	1.0000			
22	-0.4884	-0.0240	-0.0095	-0.2350	0.3682	0.2434	0.2204	0.1363	0.0473	0.1863	0.0011	0.4278	-0.3774	0.3740	-0.0450	0.3370	0.2755	0.1366	-0.0283	0.0153	-0.0830	1.0000		
23	-0.2318	0.0185	0.1120	0.4281	-0.2614	0.0680	-0.1949	0.0780	0.0100	-0.2224	0.2136	0.1075	-0.4719	-0.1168	-0.0496	-0.0971	-0.0522	0.1840	0.0454	0.0740	-0.0985	0.3102	1.0000	
24	-0.0349	0.2581	-0.2023	-0.0162	-0.0567	0.2278	0.2238	0.2168	0.3394	0.1888	0.0377	-0.1396	0.0357	0.2348	0.3171	0.3522	-0.0816	-0.0945	-0.1519	-0.1405	-0.1197	0.2547	-0.0988	1.0000

(0.4691), total stem weight (0.6329) and fibre content (0.5942). It had a high negative correlation with protein (-0.7261), oxalate (-0.8334) and vitamin A content (-0.5978). Stem girth was positively correlated to leaf length (0.5067), leaf weight (0.6805), stem weight (0.6843) and fibre content (0.4293). Length of leaf lamina was associated with petiole length (0.4595), leaf width (0.6190) and days to 50 per cent bolting (0.4921). High positive correlation was obtained between leaf width and total yield (0.5809), leaf / stem ratio (0.5415) and total leaf weight (0.6257).

The protein content had high positive correlation with oxalate (0.6907) and vitamin A (0.8030). A negative association was seen between protein and fibre content (-0.6900). Fibre content had negative correlation with oxalate (-0.5812) and vitamin A (-0.5063). The oxalate content was positively associated with vitamin A content (0.7241).

Leaf blight incidence was negatively correlated to fibre (-0.4833). It had a negative association with plant height (-0.5186), stem girth (-0.6142), leaf length (-0.5583), leaf width (-0.5641) and total yield (-0.5478). Protein content had a positive correlation with leaf blight (0.6182).

Genotypic correlation coefficients

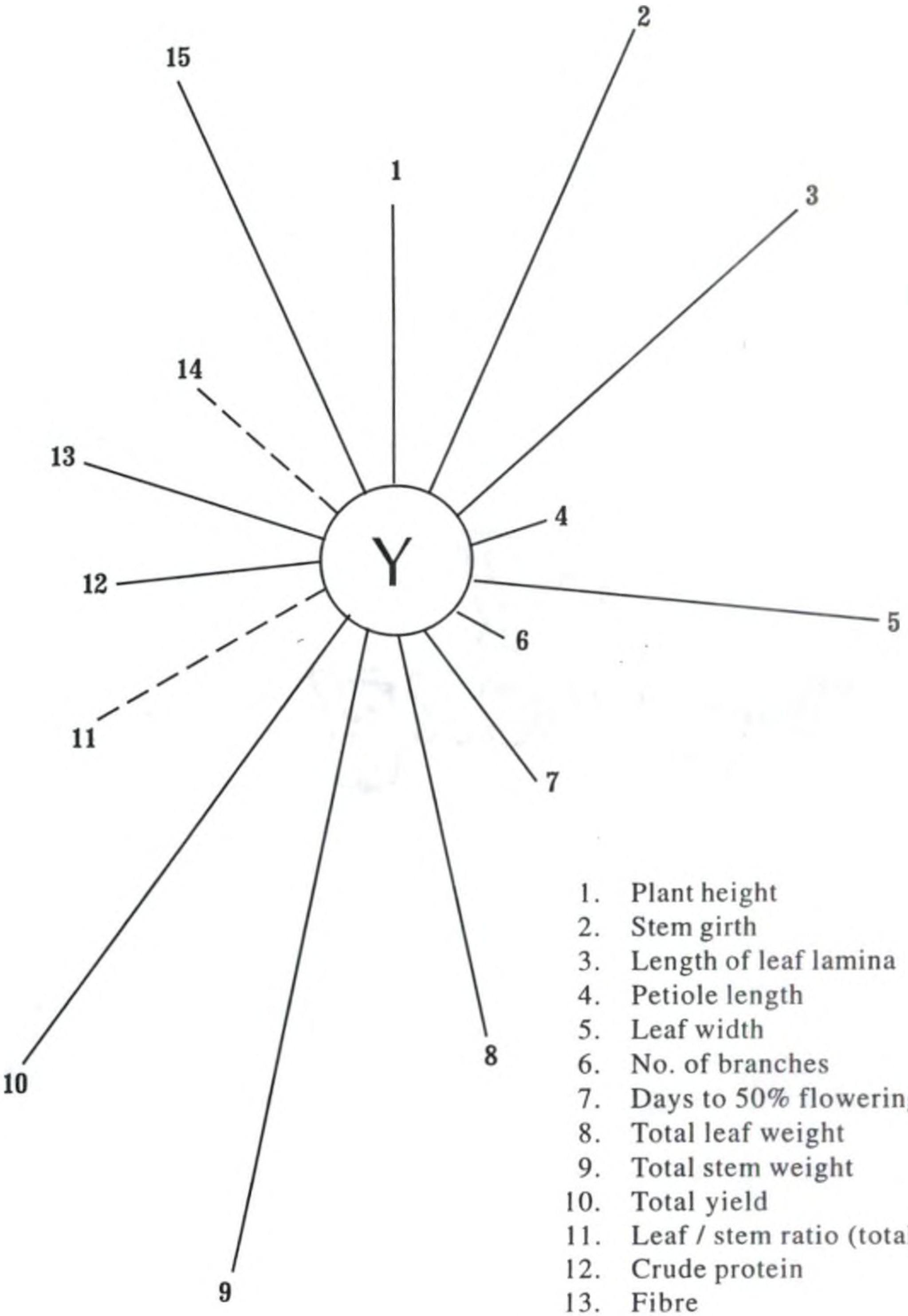
High positive correlation was obtained between yield and plant height (0.4150), stemgirth (0.7554), length of lamina (0.6813), leaf width

(0.5998), leaf / stem ratio (total) (0.6038), total leaf weight (0.9801) and stem weight (0.8245). Yield had a negative association with protein content (-0.3919) and oxalate content (-0.3748). Organoleptic qualities (0.6756) had a positive correlation with yield. Leaf blight (-0.5835) and leaf webber attack (-0.6932) had strong negative correlation with yield (Fig. 2).

Plant height was positively correlated with number of branches (0.6394), total stem weight (0.7138) and fibre content (0.6206). High negative correlation was obtained for plant height and protein content (-0.7766), oxalate (-0.8687) and vitamin A (-0.6308).

Stem girth had positive association with length of leaf lamina (0.5276), leaf width (0.4556), leaf weight (0.7061), stem weight (0.7256) and fibre content (0.4370). Length of leaf lamina was positively associated with petiole length (0.4772), leaf width (0.6521), days to 50 per cent bolting (0.5155). It had strong positive correlation with total leaf weight (0.6123) and stem weight (0.7033).

Leaf width had a positive correlation with yield (0.5998), leaf stem ratio (total) (0.5656) and total leaf weight (0.6453). Leaf width had a negative correlation with leaf blight incidence (-0.5965). Number of branches was positively associated with fibre content (0.5602). It was negatively associated with protein (-0.5727) and oxalate (-0.3867).



1. Plant height
2. Stem girth
3. Length of leaf lamina
4. Petiole length
5. Leaf width
6. No. of branches
7. Days to 50% flowering
8. Total leaf weight
9. Total stem weight
10. Total yield
11. Leaf / stem ratio (total)
12. Crude protein
13. Fibre
14. Oxalate
15. Vitamin A

Y. Yield

– – – – Negative correlation

——— Positive correlation

Fig. 2. Genotypic correlation of fifteen important characters with yield in amaranthus

The protein content had strong negative correlation with fibre content (-0.7220). It was positively associated with oxalate (0.7022) and vitamin A (0.8523).

Fibre content had negative association with oxalate content (-0.5897), vitamin A (-0.5200). The oxalate content had strong positive association with vitamin A (0.7356).

Organoleptic qualities had a positive association with vitamin A (0.4179).

Leaf blight incidence had strong negative association with plant height (-0.5514), stem girth (-0.6740), leaf length (-0.6104), leaf width (-0.5965), yield (-0.5835) and fibre content (-0.5249). Leaf blight had positive correlation with protein content (0.6579).

Error correlation coefficients

These were found to be generally very low indicating that the influence of environment is negligible in the expression of characters. But total yield had positive correlation with total leaf weight (0.9043) and stem weight (0.7990).

4.2.5. Path coefficient analysis

The genotypic correlations among yield and its component characters were partitioned into different components to find out the direct and indirect contribution of each character on yield (Table 16). The following characters which act independently on yield viz., plant height, stem girth, length of leaf lamina, leaf width. Days to 50 per cent bolting, leaf / stem ratio, crude protein, fibre and vitamin A content were selected for path coefficient analysis (Fig. 3). These components had comparatively high genotypic correlation with yield.

The direct effect of plant height on yield is high and positive (0.5555) and the total correlation is 0.4150. The positive and negative indirect effects through other traits got nullified.

The total correlation of stem girth on yield is 0.7554, but its direct effect is only 0.4377. Plant height (0.2127) and leaf width (0.2822) exerted an indirect effect on yield, through the stem girth.

The direct effect of length of leaf lamina on yield is low and negative (-0.1985). The total correlation of 0.6813 is contributed by the indirect effects via leaf width (0.4039), stem girth (0.2309) and protein content (0.2332).

Leaf width had a high and positive direct effect on yield (0.6194) and the total correlation is 0.5998. Stem girth (0.1944) and leaf / stem ratio (0.2098) had indirect positive effect on yield, but it is nullified by the negative effect of other components.

Table 16. Direct and indirect effects of yield components on total yield in amaranthus

Characters	Plant height	Stem girth	Length of leaf lamina	Leaf width	Days to 50% bottling	Leaf/ stem ratio	Crude Protein	Fibre	Vitamin A	Genotypic correlation with yield
Plant height	<u>0.5555</u>	0.1676	-0.0713	-0.0385	-0.0170	-0.1148	-0.6816	0.0305	0.5846	0.4150
Stem girth	0.2127	<u>0.4377</u>	-0.1047	0.2822	0.0089	0.1210	-0.2788	0.0214	0.0550	0.7554
Length of leaf lamina	0.1994	0.2309	<u>-0.1985</u>	0.4039	0.0332	0.0737	-0.3097	0.0152	0.2332	0.6813
Leaf width	-0.0345	0.1994	-0.1295	<u>0.6194</u>	0.0090	0.2098	-0.0408	-0.0012	-0.2318	0.5998
Days to 50% bolting	-0.1465	0.0600	-0.1023	0.0854	<u>0.0645</u>	0.1576	0.2640	-0.0078	-0.0400	0.2749
Leaf/stem ratio	-0.1720	0.1428	-0.0394	0.3503	0.0274	<u>0.3709</u>	0.1656	-0.0059	-0.2359	0.6038
Crude Protein	-0.4314	-0.1391	0.0701	-0.0288	0.0150	0.0700	<u>0.8776</u>	-0.0354	-0.7899	-0.3919
Fibre	0.3447	0.1913	-0.0613	-0.0146	-0.0120	-0.0447	-0.6336	<u>0.0491</u>	0.4819	0.3026
Vitamin A	-0.3504	-0.0260	0.0499	0.1549	0.0028	0.0944	0.7480	-0.02555	<u>-0.9267</u>	-0.2786

Residue = 0.1781

FIG.3. PATH DIAGRAM

X_1	-	Plant height
X_2	-	Stem girth
X_3	-	Length of leaf lamina
X_4	-	Leaf width
X_5	-	Days to 50% bolting
X_6	-	Leaf / stem ratio
X_7	-	Protein
X_8	-	Fibre
X_9	-	Vitamin A
Y	-	Genotypic correlation with yield

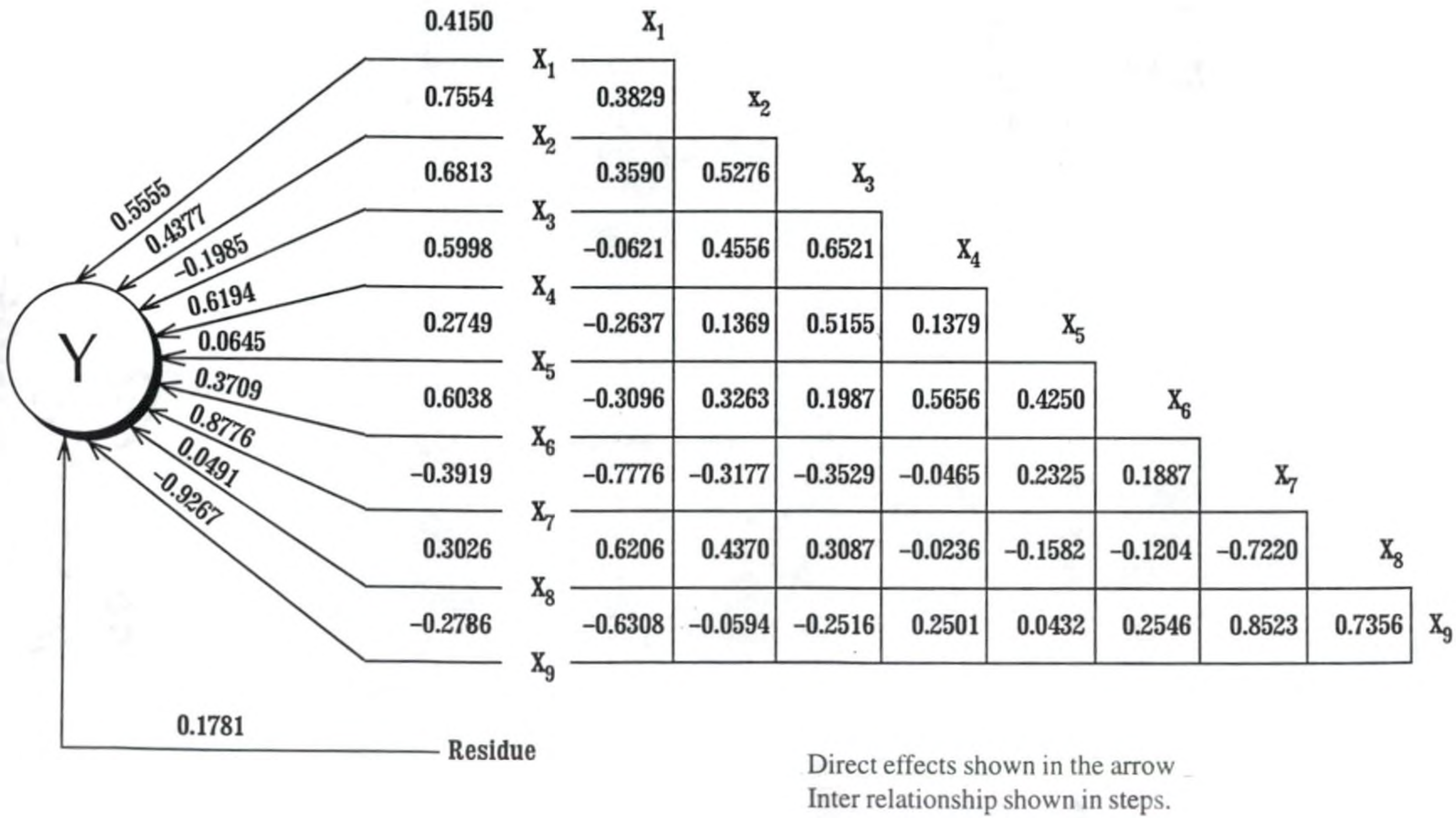


Fig. 3. Path diagram - Showing direct and indirect effects of the components on yield

The total correlation between yield and days to 50 per cent bolting is 0.2749, the direct effect being very low (0.0645). The total correlation is contributed by the indirect effects via leaf / stem ratio (0.1576) and protein content (0.2040).

Leaf / stem ratio exerted a positive direct effect on yield (0.3709). The indirect effects through leaf width (0.3503) also contributed to the total yield (0.6038). The negative and positive indirect effects through other traits got nullified.

The total correlation of yield with protein content is negative (-0.3919). The direct effect is positive (0.8776). The positive direct effect is nullified by the negative indirect effects through vitamin A (-0.7899) and plant height (-0.4314).

The direct effect of fibre content on yield is low (0.0491). But its indirect effect through plant height (0.3447) contribute to the total correlation of 0.3026.

The total correlation between yield and vitamin A content is negative (-0.2786), the direct effect being (-0.9267). The high negative direct effect is cancelled by the positive indirect effects of protein content (0.7480) and leaf width (0.1549).

The residue obtained was low (0.1781) indicating that the component characters taken for path analysis well explained the cause and effect system.

Plate 6. Leaf characters of the selected accessions


A 19
A 21
A 22
A 24
A 26
A 36
A 29
A 39
A 50
A 56
A 58
A 61
A 63
A 66
A 80

Plate 7. Inflorescence characters of the selected accessions

Plate 8. Inflorescence characters of the selected accessions


A 19
A 21
A 22
A 24
A 26
A 29
A 36
A 39


A 50
A 56
A 58
A 61
A 63
A 66
A 80

Plate 9. A 61 (*A. dubius* cv. CO-1), the genotype with highest yield

Plate 10. A 66, the genotype with highest leaf / stem ratio


A61


A66

DISCUSSION

5. DISCUSSION

Amaranthus is one of the most nutritious leafy vegetables of India. It is a potential plant for combating the problems of under nutrition and malnutrition. However, the crop still remains under exploited and the presence of antinutrient factors like oxalates limits its large scale consumption. The widespread occurrence of the new leaf blight disease caused by *Rhizoctonia solani* is assuming serious proportions in Kerala. Leaf webber, though not a serious pest, affects the crop to some extent. Hence, the present study was contemplated to identify high yielding lines with less oxalate and resistance to leaf blight and leaf webber.

The improvement of any crop depends on understanding the available variability, heritability and correlation among yield and yield contributing characters. In the case of amaranthus, very little attention has been paid to the genetic improvement of the crop. An attempt was made in the present investigation to study variability, heritability and correlations.

5.1. Screening of amaranthus genotypes

Evaluation of the available germplasm is the first step at priority to any resistance breeding programme. In the present study, the germplasm collected from various places within the state as well as from different parts of the country including cultivated and wild species of amaranthus were screened for the incidence of leaf blight and leaf webber. Observations were also recorded on yield and yield attributes.

The analysis of variance showed significant difference among the genotypes for all the characters studied *viz.* plant height, stem girth, length of leaf lamina, petiole length, leaf width, number of branches, yield, leaf/stem ratio, days to 50 % bolting, reaction to leaf blight and leaf webber.

In any crop, yield is the most important character which varies with genotypes and species. In the present study, the highest yield (304.5 g $plant^{-1}$) was obtained for the line A 57 followed by A 53 (294.27) which were on par. Similar results on genotypic differences in yield and yield attributes in amaranthus were reported by several research workers (Vijayakumar, 1980; Kader Mohideen and Muthukrishnan, 1981; Campbell and Abbott, 1982; Norman and Sichone, 1993).

A leaf/stem ratio of around 1 to 1.5 is considered optimum for a well balanced green matter production (Kader Mohideen and Muthukrishnan, 1981; Mohanalakshmi, 1995). Among the genotypes screened, the line A 24 belonging to *A. tricolor* recorded the highest leaf/stem ratio of 1.57. This result is in line with the findings of Campbell and Abbott (1982) who recorded highest leaf/stem ratio in *A. tricolor*, among different species of amaranthus studied.

Resistant varieties form a part of the integrated pest management system and is a boon to the farmers especially in the endemic areas. The present screening resulted in the identification of four accessions namely A 22, A 26, A 29 and A 61 which are completely resistant to leaf blight caused by *R. solani*. The incidence of leaf webber was mild. However, the genotypes A 21, A 36, A 65 and A 75 escaped the attack. Generally resistance/susceptibility is governed by the genetic constitution of genotype (s). The genotypic differences noticed in the present study indicates scope for selection against pests and diseases incidence in amaranthus. Variations in the incidence of damping off (Sealy *et al.*, 1988) and nematodes (Reddy *et al.*, 1980) were also reported in amaranthus.

Selection index is a linear function of different attributes having an appropriate weightage (Smith, 1937). It aids the breeder in indirect selection for genetic improvement in yield. Here, Selection Index was worked out using the characters *viz.* yield, leaf/stem ratio, days to 50 per cent bolting and reaction to leaf blight and leaf webber. Based on the selection indices and specific merit/demerit of each accession, fifteen genotypes were selected for further studies.

The genotypes A 57 and A 53 despite high selection index values were discarded due to their wild, fibrous nature, poor leaf/stem ratio and early flowering character. The accessions *viz.*, A 75, A 65 and A 33 had spines in the leaf axils with poor leaf/stem ratio. A 65 and A 75, though found free of leaf webber attack were rejected because of wild characters.

The accessions A 31, A 32, A 56 and A 68 were not selected because of their high susceptibility to leaf blight.

The selected accessions along with the index scores were given in results (table 5). The selected genotypes had various desirable characters like high leaf/stem ratio, delayed flowering, resistance to leaf blight and leaf webber, along with high yield. The accessions A 61, A 29, A 26 and A 22 were completely free of leaf blight and hence were selected. The leaf webber attack was mild to medium. The genotypes A 36 and A 21 were having no damage by leaf webber. The accessions A 80, A 56 and A 66 had high leaf/stem ratio and delayed flowering, though had serious incidence of leaf blight. The genotype A 24, though, with a low selection index, had the highest leaf/stem ratio. So it was selected.

5.1.1. Genetic cataloguing of amaranthus genotypes

Genetic cataloguing of germplasm based on standard descriptors helps international exchange of information about new accessions in a more scientific way. This also helps in locating some morphological characters linked with resistance/susceptibility which can be utilized for indirect selection.

A few wild types like *A. spinosus* had spines in the leaf axils, whereas, the cultivated types were free of spines. The leaf shape varied considerably among the genotypes.

Most of the genotypes had purple or green pigmentation on stem, branches and petioles. Association between leaf colour and inflorenscence pigmentation was noticed. Green leaved types had green inflorescence while purple leaved types had purple inflorescence. Inflorescence were either spikes or panicles with varying degrees of branching.

It was observed that all the four accessions *viz.,* A 22, A 26, A 29 and A 61, completely resistant to leaf blight were green types with terminal inflorescence.

5.2. Evaluation of the selected promising accessions

The fifteen selected accessions were subjected to detailed studies on various quantitative and qualitative characters. The reaction to leaf blight and leaf webber incidence were also assessed.

The extent of variability,heritability and genetic advance under selection for important traits were also studied with a view to bring about genetic improvement for yield and its components.

5.2.1. Mean performance of the genotypes

Analysis of variance revealed significant differences among the fifteen genotypes for all the characters studied except leaf webber attack.

The genotype A 61 (CO-1) was the top yielder followed by A 29, A 22 and A 26. These four genotypes belonged to *A. dubius*. This confirms the earlier findings of Campbell and Abbott (1982) and Norman and Sichone (1993) who recorded highest yield for *A. dubius*. These genotypes also has high leaf weight and stem weight which directly contributed to the total yield. These accessions also recorded high plant height and stem girth. The lowest yield was recorded in A 50 followed by A 36.

In most of the genotypes, the highest yield was obtained in the first cutting. Yield decreased progressively with each subsequent harvest. Allemann*et al.* (1996) had also made similar observation. In the accessions A 66 and A 80, the yield from the 2nd cutting was slightly higher than that from the first cutting. This may be due to the slow initial growth and further increased production of branches after the first cutting.

The leaf/stem ratio progressively increased with each harvest. It was the lowest for all genotypes in the first cutting and highest in the last cutting. Similar results were obtained by Norman and Sichone, 1993. The leaf/stem ratio (total) was maximum in A 66 followed by A 80 (Arun) both belonging to *A. tricolor* which confirms the findings of Campbell and Abbott (1982). The genotype A 36 recorded the lowest leaf/stem ratio, which was also a poor yielder.

A 21 (Kannara local) took maximum days for flowering (72.77). This variety is a season bound type identified at KAU Vellanikkara suited for year round planting (Devadas, 1982).

High protein and vitamin A content, less fibre and oxalates are desirable quality attributes of a leafy vegetable. The genotype A 80 (Arun) recorded the maximum protein and vitamin A content followed by A 66. In general, the red and green red accessions had high protein and vitamin A content. This result is in line with the findings of George *et al.* (1989). With respect to fibre content, the genotype A 36 had the highest value. The same line was poor in yield and leaf/stem ratio also.

The antinutrient factor, oxalate was highest (2.45) in A 80 (Arun) followed by A 66 while the green leaved genotype A 63 (*A. tristis* cv. CO-3) recorded the lowest oxalate content (0.82 %). In general, the purple/red coloured varieties had high oxalates while the green types had comparatively less oxalates, which is in agreement with the earlier findings (Kauffmann and Gilbert, 1981; George *et al.*, 1989; Devadas *et al.*, 1993 and Thamburaj *et al.*, 1994).

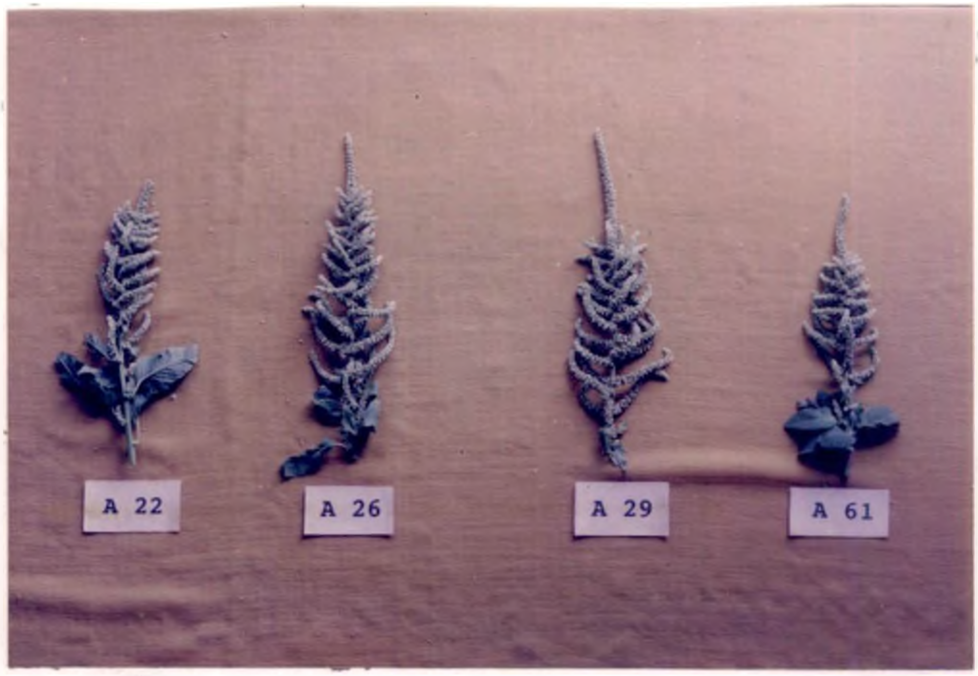
Considerable variation was observed in the organoleptic qualities of amaranthus. The genotypes A 80 and A 66 recorded the highest values for organoleptic qualities which were purple/red types. Greenish purple line A 36 had the poorest organoleptic qualities. Here, the particular leaf colour, high fibre content and low leaf/stem ratio might have contributed to the low quality of the cooked product. It can be concluded that, varieties with high leaf/stem ratio and bright purple/red colour are more acceptable to the consumers of Kerala.

The detailed study on the selected genotypes in the second experiment conclusively proved the leaf blight resistance of the four accessions *viz.* A 22, A 26, A 29 and A 61 (*A. dubius* cv CO-1) which were resistant in the first experiment also. This confirms the preliminary observations by Celine *et al.* (1995) who reported field tolerance of CO-1 to leaf blight disease. Critical observations on the vegetative and floral characters of A 22, A 26 and A 29, the local collections from Trivandrum district and neighbouring state of TamilNadu, confirmed that they belong to *A. dubius* (Plate 11, Fig. 4). The complete freedom, from disease incidence in *A. dubius* may be due to the polyploid nature of the species.

Besides, these four accessions were the top yielders. They were low in oxalate content too. Hence, *A. dubius* a species with high yield and leaf blight resistance may be recommended for large scale cultivation especially in endemic areas. Detailed studies on the biochemical and genetic mechanism of disease resistance/susceptibility are to be generated in future for incorporating the resistance to *A. tricolor* which has high consumer preference in Kerala.

The genotypes did not differ for leaf webber attack. However, incidence of leaf webber was observed in all the fifteen genotypes. The damage was negligible and did not affect the yield.

Plate 11. Inflorescence of the four *A. dubius* accessions


A 22
A 26
A 29
A 61

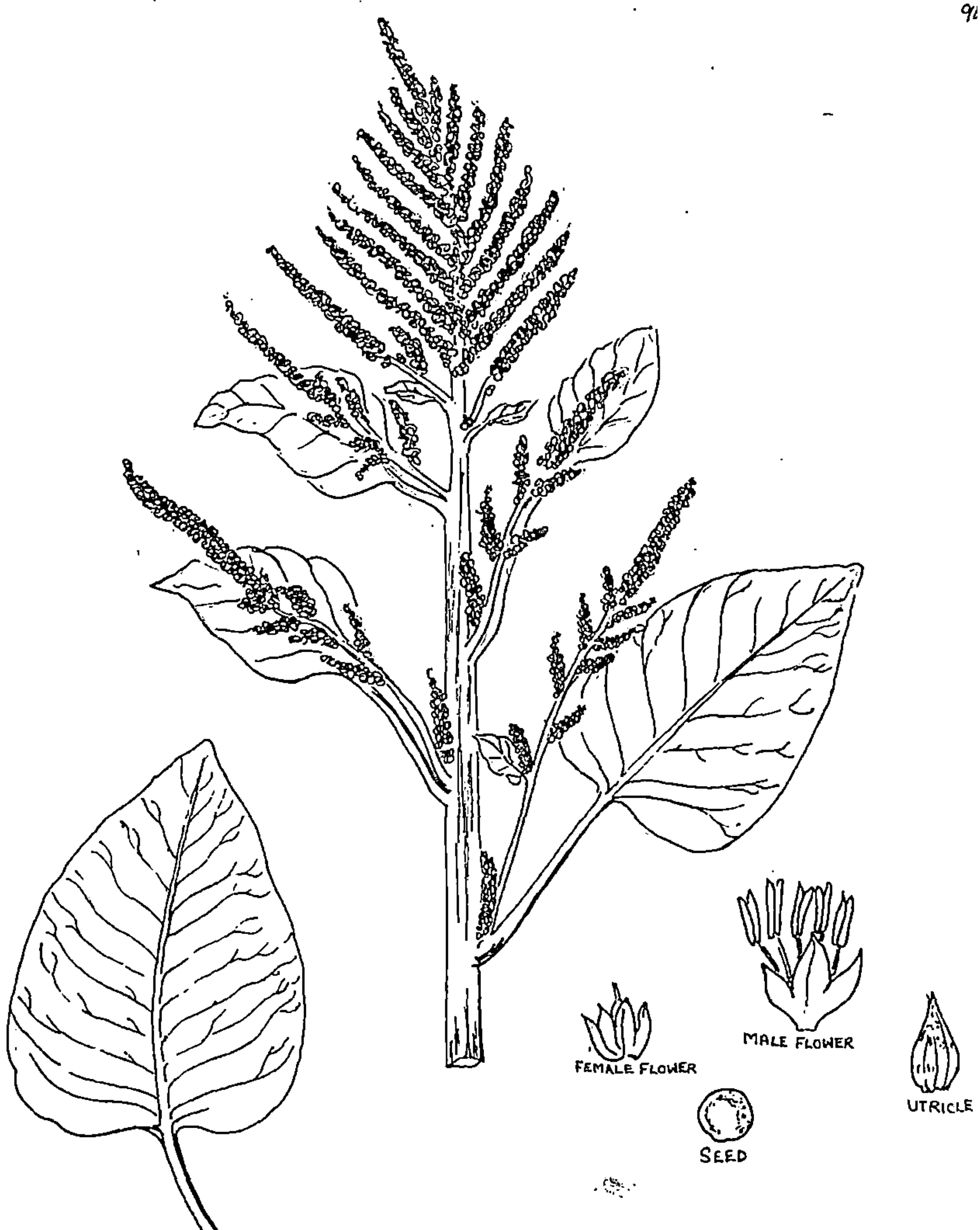


Fig. 4. Floral biology of *Amaranthus dubius* Mart. ex. Thell

5.2.2. Genetic variability, heritability and genetic advance

An insight into the magnitude of variability present in a crop species is of utmost importance in any successful crop improvement programme. The observed variability in the population is the total variation that arise due to genotypic and environmental effects. Heritability in conjunction with genetic advance would provide better information on the criteria of selection (Johnson *et al.*, 1955).

Existence of high variability for yield and its attributes in amaranthus was reported by many workers (Kader Mohideen *et al.*, 1982; Joshi, 1986; Pan *et al.*, 1991; Devadas *et al.*, 1992; and Varalakshmi and Pratap Reddy, 1994). In the present study also variability was seen for characters like plant height, stem girth, length of leaf lamina, petiole length, leaf width, number of branches, days to 50 % bolting, yield , leaf/stem ratio, stem weight and leaf weight.

Coefficients of variation-phenotypic (PCV) and genotypic (GCV) are better indices for comparison of characters with different units of measurement, than estimates of quantitative variation like range and variation around mean.

In the present investigation, PCV ranged from 13.01 to 70.89, whereas, GCV, from 10.18 to 66.62. High PCV and GCV were obtained for stem girth, length of leaf lamina, petiole length, leaf width, yield, leaf/stem ratio and leaf weight. The quality characters like crude protein, fibre and oxalates also had high PCV and GCV. These observations are in confirmation with the results of Pan *et al.* (1991) and Revanappa and Madalgeri (1997) for quantitative characters. The highest PCV and GCV were obtained for leaf blight.

The higher values of PCV and GCV for most of the characters revealed the great extent of variability for these characters, there by suggesting good scope for improvement through selection. Further more, the coefficients of variability revealed that the magnitude of genetic variation nearly approached the phenotypic variation in all the characters indicating that the selection on phenotypic basis will hold good for genotypic basis too.

Eventhough, high heritability estimates give indication of effectiveness of selection based on the phenotypic performance, it does not necessarily mean a high genetic advance for a particular character (Allard, 1960). Heritability along with genetic advance was more useful than heritability alone in predicting the resultant effect of selecting the best individuals (Johnson *et al.*, 1955).

High heritability along with high genetic gain was observed for length of leaf lamina, leaf width, leaf weight, fibre, oxalate content and reaction to leaf blight, indicating scope for improvement through selection for these characters. This is in line with the earlier works of Varalakshmi and Pratap Reddy (1994) for quantitative characters.

High heritability with moderate genetic gain was observed for plant height, stem girth, petiole length, yield,leaf / stem ratio, stem weight and crude protein.

Characters like days to 50 per cent bolting, vitamin A and organoleptic qualities had high heritability with low genetic gain, indicating the action of non additive genes for the expression of these traits.

5.2.3. Correlation studies

Correlation provides information on the nature and extent of relationship between all pairs of characters. So when the breeder applies selection, it not only improves that particular trait, but also for the characters associated with it.

In the present investigation, plant height, stem girth, length of leaf lamina, leaf width, leaf / stem ratio, total leaf weight and stem weight were the characters which exerted the highest positive and significant association with yield. Kader Mohideen and Muthukrishnan (1979) observed similar results for stem diameter, leaf length, leaf breadth, leaf weight and stem weight. But, they observed a negative association for leaf/stem ratio with yield which is contradictory to the findings of the present study.

Among the qualitative characters, fibre content and organoleptic qualities had a positive association with yield, while crude protein, oxalate and vitamin A had negative association with yield. The negative association of the antinutrient factor, oxalate, with yield is useful for the selection of high yielding with low oxalate content. Fibre content had a negative correlation with leaf blight incidence.

In general, magnitude of genotypic correlation coefficients were higher than the corresponding phenotypic correlations which indicated that environment had small and similar effects on these characters.

5.2.4. Path coefficient analysis

Selection based on yield alone is not very efficient but that based on its components as well could be more efficient (Evans, 1978). Path coefficient analysis provides a knowledge of the paths through which a component character influences the expression of economic character like yield. It helps in partitioning the genotypic correlation coefficients into direct and indirect effects of the component characters on yield.

In the present study, plant height, stem girth, leaf width and leaf/stem ratio exerted strong and positive direct effect on yield. Similar results were obtained by Kader Mohideen and Muthukrishnan (1979) for plant height, stem diameter and leaf breadth.

The residual effect noticed was only 0.1781 indicating that the variation in yield was highly attributable to factors selected in the study.

A perusal of the results of genetic variability, correlation and path analysis indicated that the characters such as plant height, stem girth, leaf width, leaf stem ratio, leaf weight and stem weight are to be considered in developing high yielding genotypes in amaranthus.

SUMMARY

6. SUMMARY

The present study entitled "Screening amaranth genotypes (*Amaranthus* spp.) for yield, quality and resistance to biotic stress" was conducted at the College of Agriculture, Vellayani during the period 1997-'98. The objective of the study was to identify superior genotypes with high yield, better quality, lesser oxalate content and resistance to leaf blight and leaf webber. The study also envisaged the assessment of variability existing in the available germplasm of amaranthus.

An initial screening was carried out using sixty diverse genotypes of amaranthus collected from different parts of the country. These genotypes were evaluated for biotic stress tolerance, viz. leaf blight and leaf webber, and yield characters. The morphological characters were scored using a standard descriptor of IBPGR.

Significant difference was observed among the genotypes for all the characters studied. The highest yield was obtained for A 57 (304.5 g plant^{-1}) followed by A 53 and A 58. The genotype A 24 belonging to *A. tricolor* recorded the highest leaf/stem ratio of 1.57. Four accessions namely A 22, A 26, A 29 and A 61 were found to be completely free of leaf blight caused by *Rhizoctonia solani*. The genotypes A 21, A 36, A 65 and A 75 escaped the attack of leaf webbers.

Selection index was worked out using the characters *viz.* yield, leaf/ stem ratio, days to 50 per cent bolting and reaction to leaf blight and leaf webber. Based on the index values and specific merit / demerit of each accession fifteen genotypes were selected for further detailed studies.

In the second experiment, the selected accessions were evaluated in a randomised block design with three replications. The genotypes showed significant difference for all the characters studied except reaction to leaf webber.

The genotypes A 61, A 29, A 22 and A 26 were the top yielders and all belonging to *A. dubius*. The leaf / stem ratio was maximum in A 66 (2.46) followed by A 80 (Arun). The line A 21 (Kannara local) took the maximum number of days for bolting (72.77).

A 80 (Arun) and A 66 had high protein content of 17.96 and 17.13 per cent respectively. The same genotypes had the highest vitamin A content. The antinutrient factor oxalate was lowest in A 63, *A. tristis* cv Co-3 (0.82%).

The genotypes A 22, A 26, A 29 and A 61 (Co-1) were completely resistant to leaf blight caused by *Rhizoctonia solani* in the second experiment also. The damage by leaf webber was mild and did not affect the yield.

High PCV and GCV were recorded for stem girth, length of leaf lamina, leaf width, yield during different cuttings, leaf / stem ratio, total leaf weight, fibre, oxalate and reaction to leaf blight. Heritability estimates ranged from 17.11 (reaction to leaf webber) to 99.47 (oxalate). High heritability along with high genetic gain was observed for length of leaf lamina, leaf width, leaf weight fibre, oxalate and reaction to leaf blight, indicating scope for improvement of these characters through selection.

The correlation studies revealed that the characters like plant height, stem girth, length of leaf lamina, leaf width, leaf / stem ratio, total leaf weight and stem weight were highly correlated with yield.

Path co-efficient analysis indicated that plant height (0.5555), stem girth (0.4377), leaf width (0.6194) and leaf / stem ratio (0.3709) exerted strong and positive direct effect on yield.

The genotypes A 22, A 26, A 29 and A 61 all belonging to *A. dubius* were identified as elite based on their superiority in yield, low oxalate content and resistance to leaf blight. Though the preference of Keralites is for red types, these green types can be recommended for cultivation and consumption in the present scenario.

APPENDIX

Appendix I

Score Card for the Organoleptic Evaluation of Cooked Amaranthus

Quality Attributes	Subdivisions of attributes	Score for each attribute	Score for samples Code No. 1	2	3	4	5	6
Appearance - Colour	Natural colour well preserved	5						
	Colour fairly preserved	4						
	Moderately preserved	3						
	Slightly discoloured	2						
	Highly discoloured	1						
Doneness	Well cooked	5						
	Fairly cooked	4						
	Just cooked	3						
	Slightly cooked	2						
	Slightly over cooked	1						
Tenderness	Very soft	5						
	Soft	4						
	Fairly soft	3						
	Fibrous	2						
	Very fibrous	1						
Odour	Very pleasant	5						
	Fairly pleasant	4						
	No odour	3						
	Fairly unpleasant	2						
	Unpleasant	1						
Taste	Very good	5						
	Good	4						
	Bland	3						
	Bad	2						
	Very bad	1						

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SCREENING AMARANTH GENOTYPES (*Amaranthus* spp.) FOR YIELD, QUALITY AND RESISTANCE TO BIOTIC STRESS

By

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ABSTRACT OF THE THESIS
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ABSTRACT

The present investigation on "Screening amaranth genotypes (*Amaranthus* spp.) for yield, quality and resistance to biotic stress" was carried out at the College of Agriculture, Vellayani during 1997-98. Sixty diverse genotypes of amaranthus collected from different parts of the country were initially evaluated for biotic stress tolerance viz., leaf blight caused by *Rhizoctonia solani* and leaf webber, yield and yield attributes. Selection index was worked out using five important characters *viz.,* yield, leaf / stem ratio, days to 50 per cent bolting, reaction to leaf blight and leaf webber. Based on the selection index values and specific merit / demerit of the accession, 15 genotypes were selected and were evaluated in a randomised block design with three replications for yield, yield attributes, quality characters, antinutrient factor - oxalate, and reaction to leaf blight and leaf webber. The GCV, PCV heritability and genetic gain were also worked out for different characters.

The accessions A 22, A 26, A 29 and A 61 (Co-1) were found to be free of leaf blight incidence in the initial evaluation trial. The attack of leaf webber was mild. The highest yield was recorded by A 57 followed by A 53 and A 58. The genotypes were catalogued morphologically using a standard descriptor.

The results of the second experiment showed significant difference among the fifteen genotypes for all the 24 characters studied except leaf webber incidence. The genotypes A 22, A 26, A 29 and A 61 (Co-1), all belonging to *Amaranthus dubius* were found ~~to~~ completely resistant to leaf blight in this experiment also. The same genotypes A 61, A 29, A 22 and A 26 were the top yielders in order of merit. The leaf / stem ratio was maximum for the accession A 66 followed by A 80 (Arun). These acessions also recorded high protein and vitamin A content. The antinutrient factor, oxalate was lowest for A 63 (*A. tristis* cv. CO-3). Leaf webber incidence was mild and did not cause any economic loss.

High values of PCV and GCV were obtained for most of the characters studied. High heritability coupled with high genetic gain was observed for length of leaf lamina, leaf width, leaf weight, fibre, oxalate and reaction to leaf blight, indicating scope for improvement through selection.

Plant height, stem girth, length of leaf lamina, leaf width, leaf / stem ratio, total leaf weight and stem weight were found to be highly correlated with yield. Path analysis study revealed strong and positive direct effect of plant height, stem girth and leaf / stem ratio on yield.

The genotypes A 22, A 26, A 29 and A 61 all belonging to *A. dubius* which were found elite due to their superiority in yield, low oxalate content and resistance to leaf blight, can be recommended for commercial cultivation in the endemic areas of the state.