Identification of Non Bolting Genotypes and Planting Time in Amaranthus (*Amaranthus tricolor* L.)

by

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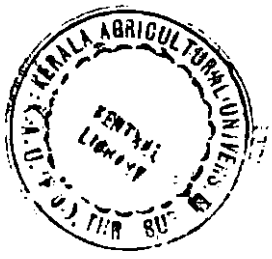
(2012-12-109)



THESIS

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DEPARTMENT OF OLERICULTURE
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DECLARATION

I, hereby declare that the thesis entitled **"Identification of Non Bolting Genotypes and Planting Time in Amaranthus (*Amaranthus tricolor* L.)"** is a bonafide record of research 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, fellowship or other similar title, of any other University or Society.

Vellayani, **Jacob Shemon**

Date: **(2012-12-109)**

CERTIFICATE

Certified that this thesis entitled "**Identification of Non Bolting Genotypes and Planting Time in Amaranthus (*Amaranthus tricolor* L.)**" is a record of research work done independently by **Mr. Jacob Shemon (2012-12-109)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the advisory committee of Mr. Jacob Shemon, a candidate for the degree of **Master of Science in Horticulture**, with major in Olericulture, agree that this thesis entitled **"Identification of Non Bolting Genotypes and Planting Time in Amaranthus (*Amaranthus tricolor* L.)"** may be submitted by Mr. Jacob Shemon, in partial fulfilment of the requirement for the degree.

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Jacob Shemon

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LIST OF ABBREVIATIONS

%	Percentage
µg	Microgram
µl	Microlitre
et al.	and Co-workers/ co-authors
g	gram
ha	Hectare
i.e.,	That is
kg	Kilogram
mg	Milligram
ml	Millilitre
m*M*	Millimolar
N	Normal
nm	Nanometre
°C	Degree celsius
sp.	Species
spp.	Species (plural)
t	Tone

INTRODUCTION

1. INTRODUCTION

Leafy vegetables are rich source of minerals and vitamins that play a major role in maintaining healthy life. Daily dietary intake of leafy vegetables would help reducing the malnutrition since they provide essential minerals, vitamins and amino acids that are absent in the rice based diet. They are less expensive and easily grown in any part of this country compared to other vegetables. Amaranthus is one of the popular leafy vegetable due to its easiness in culture, fast growth rate, adaptability to varying agro climate and high yield potential. It fits well into any crop rotation due to very short duration and high yield of edible matter per unit area (Malathy *et al.*, 2012).

Amaranthus also known as 'poor man's spinach' is popular among all communities of India particularly the poor. It serves as an alternative source of nutrition for people in developing countries since it is a rich and inexpensive source of protein, vitamins and dietary fibre. A considerable amount of vitamin C present in the leaves plays a significant role in maintaining the preferred oxidation reduction potential in human tissues. The leaves contain protein 4.0 g, fiber 1.0 g, vitamin A 9200 IU, riboflavin 0.1 mg, thiamine 0.01mg, vitamin C 99 mg, Fe 25.5 mg and Ca 397 mg per 100 g of edible portion (Choudhury, 2006).

Besides immense nutritional importance, it can also be successfully grown under varied soil and agro climatic conditions (Katiyar *et al.*, 2000; Shukla and Singh, 2000). It is extremely adaptable to adverse growing conditions, resists heat and drought, has no major disease problem and is among the easiest of plants to grow. A warm humid tropical climate is congenial for amaranthus cultivation. Fresh leaf yield as high as 30 t/ha in four weeks time from direct sowing has been reported. This may be the highest yield/ unit of land and per unit of time that can be obtained from any such leaf vegetable (Devadas, 1982). It is an annual C_4 plant that grows best at warm temperatures and high light intensities (El-Sharkawy *et al.*, 1968). Some amaranthus cultivars require short day for blooming (Grubben, 1977; Sawhney *et al.*, 1980).

Amaranthus belonging to the family Amaranthaceae, is a cosmopolitan genus of herbs. The genus is characterized by great diversity of species and forms, and green parts of some species are used as a vegetable. Amaranthus shows a wide range of morphological diversity among and even within a species. People around the world value amaranthus as leaf species, grain species and weed species. Conventionally four species – *Amaranthus tricolor*, *A. dubius*, *A. blitum* and *A.tristis* are considered as vegetable types. *A. caudatus, A. hypocondriacus, A. cruentus* are considered as grain types. *A. viridis* and *A. spinosus* are weeds in many parts of india, though they are used as delicate and much relished leaf vegetable in rural Kerala (Devadas, 1986). They are easily cross-bred, and even weedy types will cross with the intended crop if not rogued from the field (Brien and Price, 2008).

However, there are some potential drawbacks for amaranthus mainly due to genetic and environmental factors. These are premature bolting and presence of anti nutrient factors like oxalates and nitrates. Anti nutrient factors cause serious health problems. Premature flowering reduces yield especially in multi-cut types besides reducing quality of produce.

Amaranthus species which grow under varying climatic conditions differ in their day length requirements and respond differently to changes in photo and thermoperiodism. Screening of amaranth germplasm for non bolting types resulted in the identification of a high yielding, red leaved photosentive accession A-6 which was further progressed as 'Kannara Local' (Devadas, 1982). It is a short day cultivar which comes to flowering during November - December in Kerala. Another red variety 'Arun' (ACV-7) developed at the College of Agriculture, Vellayani for the southern districts of Kerala, by mass selection from 'Palapur local' is a photo insensitive variety with maroon coloured petiole and leaves (Gopalakrishnan, 2004).

The already existing varieties often show premature bolting tendencies. Few genotypes with delayed bolting have been observed in the seed production

programme of Department of Olericulture, College of Agriculture, Vellayani. So evaluation of these genotypes along with the released varieties of Kerala Agricultural University would result in the identification of delayed bolting genotype(s) with high yield and low anti nutrient factors. In this context, the present study was formulated with the following objectives.

1. To identify superior genotype(s) of amaranthus with respect to yield, non bolting and low anti-nutrient factors.
2. To arrive at best sowing time in amaranthus for better yield and quality.
3. To study the interaction effects of genotypes with planting dates.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Amaranthus is the most popular leafy vegetable among all communities of India particularly the poor. The preparations of amaranthus are used not only for consumption by human beings, but also as a component for pharmaceutical and cosmetic industry. The leaves and tender stems are rich in protein, minerals and vitamins. Because of its ability to adapt over a wide range of environments, amaranthus is widely spread throughout the country. Vegetable amaranthus can be grown round the year, but summer and rainy season's crop account more for total production. It is most suitable for growing in small kitchen garden as it requires least attention and minimum cultivation practices. It fits well in different systems of cropping like crop rotation because of its short duration and high yield of edible matter per unit area. Existence of wide variability in various traits was documented in amaranthus. Though, several improved varieties have been developed in India, bolting or early flowering is a serious problem in most of them. Yield and quality also vary with time of planting. The present study involves identification of non bolting genotypes and ideal planting time in amaranthus. The available literature on amaranthus relevant to the present study is reviewed under the following heads.

2.1 Seasonal influence on growth, yield, flowering and quality in amaranthus.
2.2 Influence of genotypes on growth, yield, flowering and quality in amaranthus.
2.3 Interaction between date of planting and genotypes
2.4 Genetic parameters.

2.1 SEASONAL INFLUENCE ON GROWTH, YIELD, FLOWERING AND QUALITY IN AMARANTHUS.

2.1.1 Photoperiodism

Photoperiod refers to the length of light and dark period for any 24 hour day in a specified location. It influences growth and development of the crop in various ways like induction of flowering, carbohydrate production, development

of storage organs and sex expression. Relative length of light and dark period determines the time of flowering in some vegetable crops while in others, photoperiod has no effect on flowering. Accordingly, the vegetable crops can be classified into three groups: long day, short day and day- neutral plants.

Panigrahi (1951) investigated the photoperiodic response of *A. gangeticus* var. *oleraceus* Roxb and found that under a six hour photoperiod flower buds were formed in 32 days after sowing compared to 39 days under normal illumination. Plants receiving 12, 18 and 24 hours respectively of illumination remained vegetative and under 18 hours illumination, they made the best vegetative growth. The studies indicated short day response of the species *A. gangeticus* var. *oleraceus* Roxb.

Zabka (1957) reported the photoperiodic response of *A.caudatus*. The species required short days for inflorescence development. The light intensity, light quality and the duration of light exposure affected the flowering behavior of *A. caudatus*.

Bleasdale (1973) opined that plants must attain a minimum amount of vegetative growth before flower buds can be produced. This period of vegetative growth may be only a few weeks in short lived annuals. He coined the term 'puberty' to describe the plant phase when plants are receptive to flowering stimuli.

Singh and Gopal (1973) studied the photoperiodic response of *A. spinosus.* The species behaved as a quantitatively short day plant.

In an experiment growth of *A. hybridus* under different daylight intensities in the dry season in Southern Nigeria, Eze (1987) observed that the percentage of flowering and number of branches were greatest and senescence was rapid, in full light.

Evaluation of four grain amaranth species during three sowing dates were done by Santos (1989) and the results revealed that as day length shortened the

yield decreased. Higher yields were obtained in the early sowing (August 25th) and the lowest yields recorded in the late sowing (September 14th) indicating that photoperiod is a determining factor for growth and production of amaranthus. As days shortened, flowering occurred at an earlier date.

Vireshwar *et al* (1991) reported that long days induced flowering in grain amaranth. Days to 50% bolting showed a variation from 47.80 days to 75.13 days Sindhu (2002).

2.1.2 Date of Sowing

Mugerwa and Bwabye (1974) investigated the productivity of a number of tropical grasses and legumes and commented that none of these yielded as much dry matter in a period of two months as amaranthus (9000 kg ha-^{1}). They suggested that because if its rapid growth, it would be possible to take two crops of amaranthus in a growing season.

Mohideen *et al.* (1982) evaluated seventy five types of amaranthus during summer (March) and monsoon (October) seasons and revealed that the summer season was conducive for the rapid growth and better expression of different characters.

Yield per plant was observed to be highly influenced by the environment Prasad *et al.* (1980).

Mohideen and Muthukrishnan (1981) classified the amaranthus genotypes into higher yielders, moderate yielders and low yielders and reported that the mean yield was higher in summer as compared to rainy season.

Two season trials in *A. tricolor* with nitrogen at 50-200 kg ha^{-1} and phosphorous at 50-100Kg ha^{-1} showed that the yields were the highest (11.6 t ha^{-1}) in the summer crop receiving the highest nitrogen rate as compared to the autumn crop which yielded 10.6 t ha-^{1} at the same nitrogen rate (Ramachandra and Thimmaraju, 1983)

An ideal season for producing amaranth in the temperate climate is during the hot months of the summer season. In addition, research has shown that green yields from amaranth produced at different locations in the United States are high enough to make commercial exploitation feasible (Campbell and Abbott, 1982; Makus, 1984; Sealy *et al.*, 1990; Singh and Whitehead, 1991).

The effect of date of planting on growth of amaranthus showed significant variations in days for maturity with time of sowing in grain amaranthus (Vireshwar *et al.*, 1991).

Field experiments to determine the suitable time period for planting amaranthus carried out during 1992 and 1993 revealed that seeds planted in mid-April failed to germinate. In all plantings from mid-May onwards, satisfactory germination was achieved. Mid-June planting produced tallest plants with highest green and dry matter yield, while these parameters were lowest for mid-September planted seeds. The range for green yield was 0.70-12.28 mg/ha and the dry matter yield varied from 0.15-1.24 mg/ha. The tallest and shortest plants measured 49.1 cm and 6.9 cm, respectively (Whitehead and Singh, 1996).

In an experiment Srinivasaiah *et al.* (2000) studied the effect of varieties and sowing dates on seed yield and quality in vegetable amaranthus at Gandhiji Krishi Vignana Kendra, Bangalore. Three varieties *viz.*, Arka Suguna, AG 114 and Local were sown on eight different dates with an interval of 30 days from July to February 1998. December sown crop took maximum days for flowering due to the prevalence of low temperature during November, December and January, while early flowering was obtained in August sown crop. The January sown crop resulted in delayed maturity (113.25 days) while early maturity (93.31 days) was observed in July sown crop.

In a study in amaranthus Krishnakumary (2000) reported that highest yield was realized in March planted crop and lowest in June planted crop.

Studies at Agricultural Research Station, Fortvalley Whitehead *et al.* (2002) revealed that the vegetative growth of June seeded amaranth took place during the

warmest part of the summer and as a result had maximum CO_2 exchange rate (CER), plant height, leafy fresh and dry yields. The relationship between planting date and CER, transpiration rate (E), stomatal conductance (g_s), plant height and leafy fresh and dry yields was quadratic, while a cubic equation provided best fit between the planting date and internal leaf CO_2 concentration (C_i). The results suggests that it is possible to stagger the planting of *A. tricolor* in Southeastern United States to assure availability of fresh leafy greens throughout the summer. However, the crop produces maximum leaf biomass when grown during the warmest part of summer.

Saha *et al.* (2003) reported that harvesting at 20 days after sowing was suitable for November sowing considering economic yield as well as palatability. December sowing had moderate palatability with leaf/stem ratio 1.38. On the other hand, in January sowing when harvested 30 DAS, expressed acceptable leaf-stem ratio (1.71). Therefore, harvesting of the crop should be done at 25 DAS in December sowing and 30 DAS in January sowing for getting economic yield and acceptable leaf/ stem ratio. He also reported that to obtain higher yields, time of sowing should be optimized during winter season. Plants of December sowing attained the maximum height (21.66 cm) compared to January sowing. This trend was also maintained in case of percent dry matter of stem, leaf and root.

Studies on amaranthus collections have been carried out by Svirskis (2003) at the Lithuanian Institute of Agriculture during the period of 1998-2001. Thirteen varieties of amaranthus was grown in the six – course perennial grass breeding crop rotation after ploughed in first year and sown fallow without additional fertilising and pesticides. The highest yield was produced when amaranth was sown in the middle of May at a seed rate of 2-4 kg ha^{-1}.

Barros *et al.* (2004) expressed that early planting date increased amaranth leaf area and water absorption during the critical period between flower bud appearance to flowering. Early planting also increased seed number per unit area without reducing its weight and improved yield.

The result of studies for two separate years revealed significant differences among the amaranthus strains for all the 10 characters in all the cuttings and on pooled basis, except for carotenoid and fibre in second cutting (2003) and fibre in fourth cutting (2004) (Shukla *et al.*, 2006).

An experiment was conducted by Yarnia (2010) at Islamic Azad University in North West of Iran to evaluate drought stress on production of amaranthus. Crop was raised under different planting density 5, 10, 20, 30 and 40 plants per m^2, and different sowing dates in 5-Apr, 20-Apr, 5-May, 20-May, 4-Jun, and 19-Jun in 2009-2010. The results showed that delay in sowing reduced plant height, number of inflorescence per plant, leaf area per plant, shoot dry weight, and grain yield per plant. This shows the importance of sowing date determination of this crop in the region. It was also observed that delay in sowing date resulted in a decrease in amaranth inflorescence. Delay in planting of 20-Apr to 5-May, 20-May, 3-Jun and 18-Jun reduced the number of inflorescence per plant as 23.35, 41.36, 54.95 and 56.69 %, respectively. Decreased plant growth with delay in sowing date decreases the number of flower.

In an investigation conducted at Soil and Water Management Research Farm Navsari, Kotadia *et al.* (2012) reported that the growing of leafy vegetables in shade net situation favoured plant growth attributes and gave higher production as compared to open field conditions during summer seasons.

2.1.3 Quality Parameters

The quality parameters also vary with environmental factors. George (1986) reported high level of oxalates in summer in all the 19 accessions studied (6.17 -12.63%) than in Kharif (4043-10.4%).

In a study at Lucknow, Bhargava *et al.* (2008) observed that the crop months of third year was warmer than the other two years. Higher temperature in 2004- 05 led to degradation of leaf pigments and Rubisco, which gave a higher leaf protein content in 2004-05.

highest (73.00) during the second fortnight of April 2004. Highest percentage of leaf damage was observed during the first fortnight of April 2005 (15.02). The population and extent of damage by *P. basalis* exhibited significant positive correlation with maximum and minimum temperature. The percentage of plants damaged by *H. recurvalis* ranged from 20.00 during second fortnight of September 2004 to 93.00 during second fortnight of November 2004. The percentage of leaves damaged by *H. recurvalis* was the highest during the second fortnight of June 2004 (25.47). The leaf damage showed significant negative correlation with maximum and minimum temperature with 'r' values being -0.4197 and 0.4339 respectively. She also observed that the percentage of plants infested by *Spodoptera litura* was maximum during the second fortnight of July 2004 (46.66). The percentage of leaves damaged by *S. litura* was low and ranged from 0.88 during the first fortnight of September 2004 to 1.74 during first fortnight of July 2004. The leaf damage caused by the pest showed significant positive correlation with rainfall (r=0.3656).

In a study Aderolu *et al.* (2013) evaluated three *Amaranthus* species: *A. cruentus, A. blitum* and *A. hybridus* for insect diversity and abundance during wet and dry seasons of two years following standard procedures. The *Hymenia recurvalis* F was the most damaging causing 69.4 ± 0.16% loss of foliage compared to control. The species abundance in both seasons was *Hymenia recurvalis* F. (2916.8 ± 138.83) > *Hypolixus truncatulus* (2262.7 ± 94.1) > *Lixus truncatulus* (2088.7 ± 36.4).

Sukumar and Ramalingham (1989) observed higher incidence of leaf spot during rainy season due to its dependence on rainy splash for the dispersal of its spores.

In a study Adebanjo (1994) the influence of the environment on the incidence of die back, stem and leaf blight in *Amaranthus cruentus* cv. NHAC 33, NHAC 30 and NHAC 100 was investigated in Nigeria, for six seasons during 1987-1988. The lowest incidence (0%) of dieback and stem blight (8%) was

Yarnia (2010) observed that protein rate in shoots decreased by delaying in sowing dates significantly. Shoot maximum protein equivalent to 12.35 % obtained by density of 10 plant. m^{-2} in 20 April and the minimum shoot protein was 4.22 % in 18 June with a density of 40 plant. m^{-2}. The reduction rate was 65-80 %.

2.1.4 Pest and Diseases

Genotypes and environmental factors influence the incidence of pests and diseases.

Lefroy (1909) observed that in India, cultivated amaranthus was infested by leaf webber in almost all the gardens during the warmer and early winter months. Fletcher (1914) recorded the occurrence of leaf webber *Hymenia recurvalis* (F) on various species of amaranthus in South India.

In India, leaf webber is found on all the species of amaranthus, but the cultivated species *Amaranthus cruentus* L. and *A. dubius* are more seriously infested. The moths were found in large numbers from July to October on various species of amaranthus. As the severity of winter increased, their numbers gradually dwindled. In January and February, they became very scarce and by the advent of summer, their numbers again increased (Bhattacherjee and Menon, 1964).

Being a leafy vegetable, it is advisable to use biological or herbal insecticides to control the amaranthus leaf webbers Unnikrishnan (1986). He 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.

Seasonal occurrence studies conducted by Asha (2005) revealed that the leaf webbers *Psara basalis* and *Hymenia recurvalis* were major pests of amaranthus. The leaf webber *Psara basalis* was present in the field throughout the year. The population and extent of damage caused by the pest was maximum during the summer months. The percentage of plants infested by *Psara basalis* was the

recorded during the first season for NHAC 33 and NHAC 30, whereas NHAC 100 gave 4% leaf blight in the third season (Dec-Feb). The lowest mean percentage of leaf blight was recorded for all cultivars by the third season. Conversely, the highest Incidence of symptoms caused by *Chaenephora cucurbitarum* in cultivars occurred in the second season (Aug- Oct).

Dang *et al.* (1995) reported that the development and progress of a disease under natural condition is influenced by prevailing environmental factors, the type of host cultivars and availability of pathogen inoculums.

Gokulapalan and Reghunath (1995) reported that the leaf spot disease in amaranthus is more pronounced in rainy season and in summer splash irrigation resulted in the spread of fungal spores to neighbouring plants.

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.

An investigation on genotypic and seasonal influence on leaf spot disease in amaranth revealed that the red leaved types were highly susceptible compared to green types. During rainy season, disease infection occurred within 15 days of planting and resulted in maximum percentage of disease severity. Experiments on seasonal influence of diseases recorded maximum disease severity in July crop and minimum in April crop. Low temperature, high relative humidity and high rainfall were the favourable weather conditions for disease development (Krishnakumary, 2000).

2.2 INFLUENCE OF GENOTYPES ON GROWTH, YIELD, FLOWERING AND QUALITY IN AMARANTHUS

Considerable variability has been reported in amaranthus genotypes with respect to growth, yield, flowering, quality and incidence of pest and diseases.

2.2.1 Growth and Yield

In the study to find out the clipping response of two species of amaranthus, Mohideen and Rajagopal (1974) reported that the cultivar 'Arakeerai' (*A. tricolor* var.*tristis*) responded favourably to cutting, registering an yield of 11,736 kg ha^{-1} as compared to 'Sirukeerai' (*A. blitum*) with an yield of 8680 kg ha^{-1}.

Olufolaji and Tayo (1980) studied the growth, development and mineral contents of three cultivars of amaranthus (*A. cruentus*) cv. Large Leaf, Light Red, Local Green were compared. There were small differences between the cultivars for the development per plant of leaf area, number of branches, number of nodes and dry weight production of stems, roots, inflorescences and most especially leaves at the edible stage.

Campbell and Abbott (1982) evaluated twenty species of Amaranthus, (three of *A. cruentus*, one of *A. dubius* and 16 of *A. tricolor*) in the field at Betsville, USA, during the summers of 1979 and 1980. Mean fresh yields (leaves and stems) for five trials sown on different dates ranged from 4.0 to 16.5 t/ha. Yields were highest for *A. dubius*. Entries with a high leaf: stem ratio probably have the greatest market potential and the highest ratios were found in *A. tricolor*.

Devadas (1982) reported that bolting is the major problem in the large scale cultivation of amaranthus. Screening of amaranthus germplasm for non bolting types at the college of Horticulture, Vellanikkara resulted in the identification of a high yielding, red leaved accession, A-6 which was further progressed as 'Kannara Local'. It is a short day cultivar which comes to flowering during November- December in Kerala. Days to flowering is a genetic character with much scope for improvement through simple selection.

Devadas *et al.* (1986) reported that in amaranthus bolting can be delayed by cutting and thus vegetative phase can be prolonged. This study also indicated that red amaranthus bolted late compared to green amaranthus.

Olufolaji and Tayo (1989) evaluated two determinate (early flowering) and two indeterminate (late flowering) varieties in two field trials at the National Horticultural Research Institute, Ibadan, Nigeria under two harvesting methods. He observed that pruning was superior to uprooting with respect to total number of leaves and branches developed, total fresh weight yield and the dry weight of the various plant parts. The later flowering indeterminate varieties performed better by 57% than the other varieties. Consequently, the prunned indeterminate varieties developed the highest green vegetative yield and the uprooted determinate varieties developed the least. It is suggested that planting the indeterminate, late flowering varieties at the start of the rains and continuously cutting back is a more profitable method of harvesting than uprooting at the optimum commercial stage. When time available for cultivation is low eg. towards the ends of the rains, the early flowering determinate varieties are thought to be better suited despite lower vegetable yields.

Rajan (1991) studied the response of red and green amaranthus varieties to different water management practices and nitrogen doses. Biometric characters were favourably influenced by frequent irrigations and higher nitrogen levels. Total yields were also higher in more frequently irrigated treatments and at higher nitrogen levels.

Bansal *et al.* (1993) studied the manipulation of source –sink in relation to productivity of amaranth through pruning treatments. Results indicated that pruning of 25 per cent leaves at pre- flowering remarkably suppressed grain yield. On the other hand, 25 per cent pruning of leaves at post flowering proved to be the best treatment from multiple use crop model in amaranth var. Annapoorna yielding 13.39 Q ha^{-1} of grain yield along 45.7 Q of fresh green leaves for vegetable yield.

Devadas *et al.* (1993) compared growth and yield parameters of 12 red and 11 green amaranthus and observed that red types have broader and longer leaves, fewer branches, took longer to bolt and were taller at bolting than green types.

Field studies to identify culivars with maximum yield potential were carried out during 1994 and 1995 summer seasons (Whitehead and Singh, 1996). *A. hybridus* and *A. cruentus* accessions were taller than other genotypes. *A. dubius* and *A. tricolor* accessions except PI 349553 were of similar height. *A. tricolor* accessions, RRC 389 and RRC 241 had maximum number of leaves and leaf area, respectively. RRC 241 also had the highest leaf fresh and dry weights. *A. hybridus* and *A. cruentus* accessions had the highest stem fresh and dry weights, and green and dry matter yields. RRC 241 produced maximum green yields among *A. tricolor* accessions.

Whitehead and Singh (1996) conducted field studies from 1992-1994 to determine the effect of different rates of N on the vegetative growth of amaranth. The genotype RRC 241 was used for seeding. There was a linear increase in plant height from N-fertilization. Leaf area increased with N-fertilization until 90 kg/ha. Stem and leaf fresh and dry weights increased linearly with N-fertilization. Quadratic equations provided the best fit for the green and dry matter yield. An R^2 for green yield of 0.70 as compared to 0.51 for the dry matter yield suggested that a higher percentage of the increases in green yield as compared to the dry matter yield could be attributed to N-fertilization probably as a result of an increase in succulence.

Priya (1998) conducted an initial screening using sixty diverse genotypes of amaranthus collected from different parts of the country. 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. In her evaluation of selected accessions found that genotypes showed significant difference for all the characters studied. 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.

In varietal evaluation trials at IIHR, Arka Arunima, a high yielding purple coloured multicut amaranth variety was released having broad leaves, with an yield of yields about 27 t ha^{-1} in three cuts (IIHR, 2000).

Sindhu (2002) reported that the accession AD 30 recorded the highest yield (464.80 g) and AD 34 the lowest (155.94 g). The highest leaf / stem ratio was obtained for AD 34 (2.48) and the least value for AD 11 (0.93). AD 34 was the late in bolting (75.13 days) and AD 3 was the earliest (47.80 days).

In an experiment with 13 genotypes of amaranthus, Svirskis (2003) reported the highest seed yield in 'Raudonukai' and green material in 'Rausukai'. It is likely that extra fertilisation especially nitrogen, would have increased amaranthus yield more, as this plant is a demanding one in terms of nutrients.

Forty six accessions of vegetable amaranth maintained at IIHR were characterized and evaluated during Kharif season by Varalakshmi (2004). Plant height, leaf width and petiole length were found to vary between 31 to 81.5 cm, 3 to 12 cm and 3 to 9 cm respectively. Days to flowering ranged from 29 to 69 days. This variation can be exploited for varietal improvement. Accessions AV- 8, AV-33 and AV- 39 had tall plants with more leaves while AV- 64 showed great height coupled with late flowering which is desirable. AV- 7 and AV- 45 were late bolters with large leaves.

In an experiment Vujačić (2005) evaluated ten genotypes of amaranthus for three years at the experimental field of "Zdravlje" Leskovac, without chemical control. Significant divergence was established in case of almost all morphological and productive traits: in plant height it varied from 93.18 cm (genotype 9 - *A. cruentus*) to 160.78 cm (genotype 1 – *A. mantegazzianus*); in foliage per plant it varied from 12.89 cm (genotype 10 - *A. cruentus*) to 23.46 cm (genotype 1 – *A. mantegazzianus*); average foliage length varied from 14.77 cm (genotype 9 – *A. cruentus*) to 26.72 cm (genotype 1 - *A mantegazzianus*); average foliage width ranged between 6.30 cm (genotype 9 – *A. cruentus*) and 14.46 cm (genotype 1 - *A mantegazzianus*); foliage mass per plant ranged between 94.05 g

(genotype 3 – *A. molleros*) and 246.81 g (genotype 1 – *A. mantegazzianus*); seed mass per plant varied from 45.56 g (genotype 3 – *A. molleros*) to 67.55 g (genotype 1 - *A mantegazzianus*), while the total seed yield ranged between 2.22 t/ha (genotype 3 – *A. molleros*) and 3.20 t/ha (genotype 1 – *A. mantegazzianus*).

Twenty nine strains of vegetable amaranth (*Amaranthus tricolor* L.) were grown for two successive seasons to study different selection parameters for foliage yield and its nine contributing morphological and quality traits by Shukla *et al.* (2006). The strains AV-38 (5.06 kg/plot) and AV-31 (5.04 kg/plot) recorded highest foliage yield, followed by AV-30 (4.78 kg/plot) and AV-23 (4.70 kg/plot).

Sujata (2006) evaluated 34 amaranthus accessions and observed that accession Am 37 had the highest number of branches (12.29) and Am 47, the lowest (7.18). Maximum stem girth was noted in Am 67 (5.0 cm) and minimum in Am 14 (2.58 cm). Am 37 took maximum days to 50 per cent bolting (72.67) whereas Am 72 was the earliest (45.27). The total leaf yield was maximum for Am 91 (235.56 g). In case of total stem weight, Am 71 (189.44 g) had the highest value and Am 13 (21.66 g) had the lowest. Highest total yield was recorded in Am 91 (387.22 g).

In an experiment conducted by Bindu (2007) to evaluate the seed yield and quality in amaranthus it was observed that among the different systems, transplanting 20 days after sowing was earliest to first and 50 % flowering.

Twenty four promising amaranthus accessions with respect to yield and disease resistance were evaluated during Sept- Dec 2005. The collections included 10 *A. tricolor*, 13 *A. dubius* and one *A.hypochondriacus*. Among *A. tricolor* accessions Am 44 (57.50 days) was latest and Am 52 and Am 76 (29.50 days) were the earliest. In *A. dubius* Am 8 recorded maximum number of days to flowering (39.00 days) and Am 83 and Am 85 (22.50 days) recorded minimum number of days to flowering. In *A. hypochondriacus* (Am 37) it was 112.50 days (Celine *et al.*, 2007).

Gopalakrishnan (2007) reported that premature flowering or bolting is a serious problem in amaranthus. Yield and quality deteriorate after flowering. Bolting is usually associated with genetic set up, day length, deficiency of nitrogen, extreme high temperature and poor soil aeration.

Law-ogbomo and Ajayi (2009) conducted field trials in 2007 and 2008 to determine the influence of planting density and poultry manure application on the growth and yield of *Amaranthus cruentus*. Results showed that planting density and poultry manure significantly affected the number of leaves, leaf area index, total dry matter and the crop growth rate positively in favour of increasing planting density and poultry manure application rate leading to higher herbage yield.

Varalakshmi *et al.* (2011) evaluated two varieties at Central Horticultural Experiment Stations of IIHR at Bhubaneswar, and at Hirehalli, for yield and quality during rainy season (June-July) of the year 2009. At CHES, Bhubaneswar, 'Arka Samraksha' recorded fresh greens yield of 13.9 t/ hectare by pulling, which was superior to the 'Arka Suguna' (8.54 t/ha) and 'Local' variety (8.75 t/ha). At CHES, Hirehalli, by pulling, it recorded 7.56 t/ha, which was significantly higher than in the Check, 'Arka Suguna' (4.31 t/ha) and 'Local' variety (4.11 t/ha). 'Arka Varna' at Bhubaneswar recorded fresh greens yield of 9.47 t/ha by pulling, which is superior to the checks ' Arka Suguna' (8.54 t/ha) and 'Local' variety (8.75 t/ha). At Hirehalli, by pulling it recorded 6.67 t/ha which was significantly higher than in the checks, 'Arka Suguna' (4.31 t/ha) and 'Local' variety (4.11 t/ha).

In another study they observed Arka Samraksha and Arka Varna at IIHR Experimental Farm, Hessaraghatta. Average fresh greens yield of Arka Samraksha was 10.91 t/ha by pulling, 30- 35 days after sowing and increase over the check variety, Arka Suguna, was 41.8% and over the Local Check 77.4%. Average fresh greens yield of Arka Varna was 10.58 t/ha by pulling in 30-35 days

after sowing, and the increase over check variety. Arka Suguna, was 37.6%, and over the Local Check 72.0%.

Thirteen, genotypes of amaranthus collected from the different agro-ecological zones of Pakistan were evaluated by Erum *et al.* (2012). The results showed highly significant differences for all the traits studied. Plant height ranged from 67cm to 116.7 cm. Highest plant height was recorded for 7033 (116.7 cm) followed by 7058 and 7065 (83.3 cm and 74.33cm, respectively. Greatest leaf area was observed for "7041" (150 cm^2). Similarly plant canopy ranged from 203 to 253 cm. The largest canopy was exhibited by 7030 (253 cm). The range for number of branches/plant and number of spikes/plant was 5-13 and 1-19, respectively. Highest numbers of branches (19) were observed for amaranthus variety obtained from China while 7065 secured second position for number of branches (10). Maximum average number of spikes/plant (19.6) produced by 7029. Perusal of the data revealed that highest yield 129.3 g/plant was produced by 7030.

An experiment conducted by Mandal and Dhangrah, (2012) to identify suitable genotypes of vegetable amaranthus for red and lateritic belt of West Bengal with 17 genotypes showed wide range of variation for yield/ha (55.8 to 303.9 q/ha). Among the genotypes, Bankura Collection 3 (303.9 q/ha) and Bolpur Collection 1 (287.0 q/ha) produced highest yield per hectare, followed by Pusa Kirti (283.5 q/ha). However, Bankura Collection 2, Kendrapara Collection 4, Arka Suguna, Kendrapara Collection 5 and Kendrapara Collection 3, which produced high leaf/stem ratio, were identified as promising foliage types.

Five accessions of the amaranthus species obtained from National Centre for Genetic Resources and Biotechnology, Ibadan, Nigeria, were evaluated in the field for variability in ten quantitative and nine qualitative traits by Akaneme and Ani (2013). The results revealed highly significant differences for leaf width, hypocotyl length, days to 50% flowering, 500 seed weight and leaf length.

Akaneme and Ani (2013) also observed significant variation among the five accessions for days to 50 % flowering which ranged from 41 days to 66 days, an interval of 25days from the earliest to the latest maturing accessions. Early and late flowering accessions were identified.

In an experiment Kumar and Yassin (2013) observed significant differential effects of density on genotypes for all characters, except plant height, leaf area at 50% flowering, weight of the inflorescence, number of rachis per inflorescence, rachis length per inflorescence, grain yield per plant, and grain yield per plot.

In 2008 - 2010, eight cultivars of vegetable amaranth were evaluated on a loamy upland soil (Mt. Carmel) and on a sandy terrace soil (Windsor) by Maynard (2013). The average yield of all cultivars at Mt. Carmel for years 2008, 2009, 2010 was 2.8 lb/plant. Trials were only conducted at Windsor in 2009 and 2010 where the yields were 1.5 lb/plant compared to 2.7 lb/plant for the same two years at Mt. Carmel. At Windsor, decreased yields were due to lower fertility of the sandy soils especially in 2009. Yields at Windsor increased in 2010 when the fertilizer was split between pre -plant and side - dress applications. All Red had the highest yields and Bayam the lowest, but the yields were statistically equivalent to the other cultivars.

Upadhyay and Maurya (2013) found that the inflorescence is very prominent, colorful, terminal and contain one male flower per glomerule (of nearly 100-250 flowers) in section amaranth while small, generally axillary with 10-25% male flowers per glomerule in section Blitopsis,vegetable amaranth fall in this section.

2.2.2 Quality Parameters

Considerable variability has been reported in amaranthus with respect to quality parameters also.

Grubben (1976) found variation in species for the ascorbic acid content which ranged from 32.5-125 mg in 100 g of dry matter. Variations in the content

of ascorbic acid (12-120 mg), potassium (0.41-0.58 %) and calcium (105-506 mg/100g) of fresh matter were reported by Joel Elias (1977) in different varieties of amaranthus.

Devadas (1982) reported variations from 0.94 – 1.29 per cent for oxalate in 25 accessions of vegetable amaranth and 0.55-0.94 per cent of nitrate. Hill and Rawatte (1982) recorded in *A. retroflexus* 5.36 per cent oxalic acid in the leaves and 2.66 per cent in the stems on dry weight basis.

Vijayakumar and Shanmughavelu (1985) reported the nutritive value of seven types of amaranthus which ranged from 32.9 - 44.2 mg/ 100g for ascorbic acid, 9.9 -10.9 mg for carotene content, 16.5-21.9% for crude fiber, 12.5-14.5% of protein and 2.3 -2.5% for calcium content.

Figueroa (1989) reported that red amaranthus types had a higher concentration of anti- nutritional substances and this could be the reason for lower protein quality in red type.

In an experiment George *et al.* (1989) collected Leaves of 30 entries of *A. tricolor, A. dubius* and *A. cruentus* after 45 days growth in the field and analysed for DM, crude protein, beta carotene and total oxalate contents. Results revealed highly significant differences among the entries for all the traits. *A. cruentus* ACC 14 had the highest DM content (17.2%) and red entry ACC 59, had the highest crude protein content (29.13%), ACC 28 contained highest quantity (36.1 mg/100 g DM) of beta carotene. All green entries had low oxalate contents, being lowest in CO 1 (3.04%). Red and green-red entries with high protein and beta carotene contents also had high oxalate contents.

Kononkov *et al.* (1995) studied the content of chlorophyll, carotenoids and beta-cyanine in leaves of different species of amaranthus and reported highest values in *A. tricolor* accessions (Chlorophyll a+b-14.61 mg/g, carotenoid content - 4.95 mg/g amaranthine 34.2 mg/g).

Priya (1998) evaluated quality parameters in selected accessions of amaranthus and reported that the *A. tricolor* accessions A 80 (Arun) and A 66 had highest protein content and vitamin A content.

Holubava (2002) evaluated the antinutrients in six amaranth genotypes and noted that the genotypes with highest amount of nitrate also contained the highest amount of oxalic acid.

In a study including 32 diverse accessions of *A. dubius*, Sindhu (2002) observed that the accession AD 16 had maximum protein (23.00 per cent) whereas, AD 8 had least protein (9.03 per cent). The vitamin A was maximum in AD 8 (8915.96 I.U) and was minimum in AD 2 (4331.50 I.U).

Nitrate and oxalate contents were found to range from 0.29 to 0.89 per cent and 0.8 to 1.9 per cent respectively in vegetable amaranthus (Tewari *et al.*, 2002).

In a study Sivirskis (2003) estimated chemical composition of green material and seeds of the varieties, 'Raudonukai' and that of 'Gelsukai'. Chemical composition of both varieties differed insignificantly and confirmed the high nutritional and feeding value of amaranth.

Shukla *et al.* (2006) evaluated twenty nine strains of vegetable amaranth (*Amaranthus tricolor* L.) and observed that the protein and carotenoid content averaged 1.24 ± 0.03 mg/100 mg and 0.83 ± 0.02 mg/g respectively.. The leaves of *A. tricolor* also have considerable quantities of ascorbic acid (112.33 ± 5.00 mg/100 g) and fibre (8.39 ± 0.10%).

In an experiment Sujata (2006) evaluated 34 amaranthus accessions and revealed that β carotene content was maximum in Am 5 (4655.54 µg/100 g) and minimum in Am 90 (1269.94 µg/100 g). Am 78 had the highest vitamin C content of 151.22 mg/100 g and Am 58 had the lowest (54.88 mg/100 g). Highest protein content was noticed in Am 91 (3.57%) and lowest in Am 27 (0.67 %). She also observed that the accession AD 23 had lowest (0.62 per cent) and AD 3 had

highest oxalate content (3.85 per cent). The nitrate level was minimum in AD 1 (0.25 per cent) and maximum in AD 30 (1.09 per cent).

Twenty six accessions of grain Amaranth (*Amaranthus hypochondriacus* L.) were evaluated for salient biochemical and quantitative traits particularly chlorophyll a and b, total chlorophyll, phenol content, leaf moisture, leaf protein content and yield plant^{-1} (Pandey and Singh, 2010). Leaf protein content was noted significant in four accessions, namely AG-67/1 (3.152 mg g-1), AG-21 (2.452 mg g-1), AG-306 (2.101 mg g^{-1}) and AG-1175 (2.101 mg g^{-1}). Accessions with more leaf protein have potential to increase nutritional value and can be utilized for vegetable purposes.

Shani *et al.* (2010) studied the nutritional and anti nutritional components of four amaranthus species namely *A. cruentus*, A. *spinosus*, *A. tricolor* and *A. viridis* collected from Thiruvananthapuram district.

Varalakshmi *et al.* (2011) evaluated two amaranthus lines (Arka Samraksha and Arka Varna) and observed that Arka Samraksha had maximum antioxidant activity of 499 mg (AEAC units) and minimum nitrate content of 27.3 mg, and 1.34 of oxalates per 100 fresh weight of leaves. It also recorded 4.0 % leaf protein. Arka Varna recorded antioxidant activity of 417 mg (AEAC units), nitrate content of 3.82 mg and 1.42 g of oxalates per 100 g fresh weight of leaves. Further, it has recorded 4.1 % of leaf protein.

In a study Erum *et al.* (2012) evaluated thirteen genotypes of amaranthus collected from different agro-ecological zones of Pakisthan. It was observed that nutritional profile of amaranthus seeds showed that highest amount of total carbohydrate, fats, protein and moisture contents in the samples 7033 (190 mg/ml), 7051(31.03%) and 7033 (100 µg/ml) and 7051 (13.75 %) respectively. Over all, the nutritional profile of the amaranthus seeds showed high nutritional contents with remarkable differences among the varieties.

2.2.3 Pest and Diseases

Sujatha (2006) evaluated 34 amaranthus accessions and revealed that leaf webber occurrence was most severe in Am 78 (2.07) and least in Am 42 (0.63).

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

In an experiment Sindhu (2002) observed that all the accessions of *Amaranthus dubius* were free of the natural infection of leaf blight. But 'Arun' was seriously damaged by the disease with a PDI of 68.10. On artificial inoculation, 14 accessions were categorised as immune and 15 accessions were highly resistant. The susceptible check 'Arun' was highly susceptible with a PDI of 70.03. The accessions AD 14, AD 16 and AD 28 were completely free from white rust infection under field conditions. Others showed disease severity in the range of 5.77 to 29.39. She also reported that mild attack of leaf webber was observed in all the 32 diverse accessions of *A. dubius*. The highest score was observed in AD 11 (3.00) and 16 accessions had minimum infestation with the score, 1.00.

In an experiment Sujata (2006) observed highest leaf blight intensity in Am 14 and Am 77 while the lowest score was observed in Am 89 and Am 91 both belonging to the species *A. dubius*.

Celine *et al.* (2013) reported that out of 89 accessions all *Amaranthus dubius* and *A. hypochondriacus* accessions were resistant to leaf blight under field conditions while the *A. tricolor* accessions exhibited various degrees of symptoms. The second experiment with 24 accessions that showed promise with respect to yield and disease resistance confirmed the field resistance of *A. dubius* and *A. hypochondriacus* accessions. Disease incidence in *A. tricolor* ranged between 0.55 and 2.12 on a 4 point scale. Screening against leaf blight under artificial epiphytotic conditions confirmed the resistance of *A. dubius* accessions, which were categorized as immune or highly resistant. The *A. dubius* accessions

'Am 78', 'Am 83', 'Am 84', 'Am 85', 'Am 86' and 'Am 87' which were immune.

2.3 INTERACTION BETWEEN DATE OF PLANTING AND GENOTYPES

2.3.1 G x E Interaction

Differential response of genotypes to varying environmental conditions have been observed in many crops. Such interaction effects of genotypes with environments are reviewed here under.

Samson (1972) working at Wageningen revealed that a Surinam cultivar of amaranthus showed no difference in flowering response to day length of 10.5 and 13.5 hours, while a reddish leaved Ethiopean cultivar showed considerable delay in daylength above 12.5 hours. This indicated the short day behaviour of the Ethiopean cultivar.

Detailed investigations by Grubben (1976) revealed that *A. cruentus* and *A. dubius* are day neutral types and cutivars of grain amaranthus (*A. caudatus*, *A. hypocondriacus*) are quantitatively short day plants. The grain amaranth (*A. caudatus, A. hypocondriacus*) flowered only by the end of September, when the days became sufficiently short.

Grubben (1976) also suggested that photoperiodic reaction alone, may not be the only factor responsible for flowering as a few varieties were practically indifferent to photoperiodicity and early flowering occurred irregularly and moreover in all seasons.

According to Deutsch (1977), genotype x environmental interactions appeared large for oxalates and calcium contents and also Oxalates became more of a problem when plants are grown under stress. He also opined 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 100g of fresh green to raise the nitrate and oxalate level.

The investigations of Sreerangaswami *et al.* (1980) brought out the existence of strong Genotype x Enviornment interactions in the diverse genetic populations of amaranth .

Five vegetable amaranth cultivars were evaluated during summer season by Sealy *et al.* (1990) and it is revealed that two cultivars, `Vleta' and 'Ibondwe', produced exceptionally well in central Texas as a summer greens crop, but only 'Ibondwe' performed well in all the criteria. Cultivar 'Ibondwe' was recommend for summer production of a fresh greens crop in the deep South, based on the plant's productivity in central Texas during even the hottest part of the year, high level of resistance to pythium damping-off, high beta carotene content (fresh weight basis), moderate oxalate content.

Sirohi and Sivakami (1995) compared the performance of different varieties of amaranth, viz. Pusa Keerthi, CO-2, Pusa kiran and Badichaulai and found that Pusa Keerthi was better for cultivation in summer season (51 t ha^{-1}) and Pusa kiran was the highest yielder in Kharif (35 t ha^{-1}).

Evaluations for six seasons resulted in the identification of two promising green amaranth cultures viz., Amt 105, Amt 237 (*A. tricolor*). Amt105 had a mean yield of 17.0 t/ha and Amt 237 yielded15.7 t/ha. They had comparatively high nutritive value and lower anti nutrient factors. Amt 105 was released for the state as 'Mohini' (Gopalakrishnan, 2004).

Anuja and Mohideen (2008) carried a study during two seasons viz., summer (March-May), 2002 and monsoon (July-September), 2003 with 100 vegetable amaranth genotypes collected from the diverse source and maintained at the Department of Horticulture, Tamil Nadu Agricultural University, Coimbatore belonging to the following species. *Amaranthus tricolor* - 78 accessions, *A. blitum*-11 accessions, A. *tristis·10* accessions, *A. dubius* - 1 accession. The mean yield of greens in summer was 24.02 g and 90.09 g which was comparatively higher than that of monsoon season with 14.91 g and 68.27 g respectively. During summer, the genotype A-50 showed best performance in yield of greens

per plant (179.5 g) followed by the accessions A-82 (172.40 g). During monsoon season, the accessions A-50 (160.30 g) and A-59 (16787 g), showed better performance in terms of greens yield per plant. It is of interest to note that the genotypes A50 and A 59 performed well in both summer and monsoon seasons.

It was also observed that the genotypes in general showed better performance for the yield and component traits in summer as compared to the monsoon seasons.

Experiments were conducted at HORDI in four growing seasons during 2010-2011 using four selected accessions, 'DOA red', 'Pure green', 'Diyapalagoda' and 'DOA green' (check variety). 'Pure green' exhibited higher growth and yield performance and wider adaptability, hence it could be recommended for commercial cultivation (Malathy *et al.*, 2012).

2.4 GENETIC PARAMETERS

2.4.1 Variability

The efficiency of selection in crop improvement programmes largely depends on the extent of genetic variability present in the population. Genetic variability for yield and yield contributing traits in the base population is essential for successful crop improvement. Larger the variability better the chances of identifying superior genotypes.

The variation present in the plant population is of three types viz., phenotypic, genotypic and environmental. Of these the genetic variance can be further partitioned to additive, dominance and epistatic variance components. The phenotypic, genotypic and environmental coefficient of variation (PCV, GCV and ECV respectively) gives an idea about the magnitude of variability present in the population.

Studies undertaken with seventy five genotypes of amaranthus (*A. tricolor* L.) to ascertain the extent of variability in yield of greens and its components by Mohideen *et al.* (1982) observed that at 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.

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).

A total of 25 accessions of *A. tricolor*, *A. dubius*, *A. spinosus* and *A. viridis* were evaluated for 13 biometric characters by Devadas *et al.* (1992). The accessions were grouped into 7 clusters. The study of inter and intra cluster differences revealed that variability was greatest in varieties of *A. tricolor*.

Varalakshmi and Pratap Reddy (1994) reported high genotypic coefficient of variation for number of leaves, leaf weight, stem weight, leaf/ stem ratio and yield of greens per plant.

In an experiment Priya (1998) evaluated selected amaranthus accessions and revealed high PCV and GCV 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.

Variability was noticed for growth characters, yield characters, quality characters and response to biotic stresses by Sindhu (2002). The PCV ranged from 12.82 to 61.88 and GCV from 12.75 to 57.17. Higher GCV and PCV for most of the characters revealed great extent of variability for these characters suggesting good scope for improvement through selection.

Rana *et al.* (2005) evaluated one hundred accessions (50 from India and 50 from exotic sources) of grain amaranth and reported a wide range of variation and significant differences for all the characters. The coefficients of variation at phenotypic and genotypic levels were high for seed yield, number of leaves, leaf length, inflorescence length and medium to low for other characters. The differences in the magnitude of PCV and GCV were more for quantitative

characters indicating more influence of environment in their governance, whereas it was less for qualitative characters viz., protein and oil content indicating consistency in the expression of these characters irrespective of growing conditions.

Shukla *et al.* (2006) observed that traits like fibre, branches/plant, leaves/plant, plant height and stem diameter had low values of coefficient of variation, which implies that chances of getting substantial gains under selection are likely to be less for these characters. On the other hand high values of coefficient of variation for ascorbic acid, foliage yield and leaf size indicated considerable scope for improvement in these traits through selection to enhance the potentiality of foliage yield. The relative amount of genetic variation is best expressed as genotypic coefficient of variation (GCV), since this variable takes into account the mean value as well as the unit of measurement into consideration. Genotypic coefficient of variation values ranged from 6.05 to 28.25% for pooled data. The PCV values showed similar trends as GCV and ranged from 6.41 to 28.60%. The values of PCV in all the cuttings and on pooled basis were higher than the corresponding GCV values for all the characters though the differences were low. The small differences between PCV and GCV for all the traits indicated that the variability was primarily due to genotypic differences.

Sujata (2006) reported high PCV and GCV values for yield characters.

Genetic variability and heritability studies involving 100 genotypes of amaranthus germplasm in summer and monsoon seasons indicated that there were highly significant differences between the genotypes for green yield and thirteen other characters (Anuja and Mohideen, 2007). Comparison of genotypic and phenotypic co-efficient variation for different traits indicated that the values of PCV were higher as compared to GCV due to the influence of environment. High genotypic co-efficient of variation was observed for number of leaves, yield of greens, root weight, leaf weight, stem weight and leaf area.

Five accessions of the species obtained from National Centre for Genetic Resources and Biotechnology, Ibadan, Nigeria, were evaluated in the field for variability in ten quantitative and nine qualitative traits (Akaneme and Ani, 2013). Analyses of variance revealed highly significant differences for leaf width, hypocotyls length, days to 50% flowering, 500 seed weight and leaf length. The range, coefficient of variability, phenotypic and genotypic coefficients of variability also revealed high variability for each of the quantitative traits.

Hasan *et al.* (2013) reported that differences between GCV and PCV were high for leaf length and stem diameter indicating the vulnerability of traits to environmental influences. High GCV and PCV were observed in leaf weight (77.54 and 80.14 % respectively) and dry weight without rind (74.42 and 74.47 % respectively).

2.4.2 Heritability and Genetic Advance (GA)

Heritability and genetic advance are important selection parameters. The ratio of genetic advance to phenotypic variance is known as heritability. Heritability (%) was categorized into low (0-30%), moderate (30-60%) and high (above 60%) as suggested by Robinson *et al.* (1949) and Johnson *et al.* (1955). Higher H^2 indicates the least environmental influence on the characters. The difference between the mean phenotypic value of the progeny of selected plants and the base or parental population is called as the genetic advance. The genetic advance was categorized into low (<20%) and high (>20%) as suggested by Robinson *et al.* (1949) and Johnson *et al.* (1955). High GA indicates that additive genes govern the character and low GA shows that non- additive gene action is involved. Heritability along with GA helps us in predicting the gene action and the method of breeding to be practiced.

Mohideen *et al.* (1982) revealed high heritability associated with high genetic advance for stem weight (90.65), leaf/stem ratio (73.79), yield of green (72.46), weight of leaves (64.94) and number of leaves (52.32) which further

suggested substantial additive gene effects governing these characters and phenotypic selection may be useful in improving these traits in amaranthus.

Pan *et al.* (1991) in their studies on vegetable amaranthus reported high heritability estimates combined with high genetic advance as per cent of the mean 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.

Heritability and genetic advance for 11 characters in 144 genotypes of grain amaranthus were reported 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 presuure could be applied on them for yield improvement.

In another study Priya (1998) observed that 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.

High heritability along with high genetic gain as per cent of mean was observed in all the characters studied (Sindhu, 2002). The range of heritability was 67.41 to 99.99 per cent.

In a study by Shukla *et al.* (2006) the values of heritability estimates were high for all the traits in all the cuttings as well as on pooled basis and ranged from 0.89 for branches/plant to 0.98 for foliage yield in pooled data. The values of expected genetic advance varied in different cuttings for different characters. The expected genetic advance as percent of mean varied from 11.76-57.48%. Branches/plant, fibre, plant height and stem diameter showed low expected genetic advance values which revealed the major role of non-additive gene action in the transmission of these characters from parents to offspring. Highest

expected genetic advance was noticed for ascorbic acid (57.48%) followed by foliage yield (48.30%) and leaf size (29.51%).

Heritability ranged from 38 to 97 per cent. High heritability with high genetic advance was seen for yield and quality characters (Sujata, 2006).

Heritability estimates in general were high for most of the characters studied Anuja and Mohideen (2007). High heritability coupled with high genetic advance (as per cent of mean) was observed for number of leaves, root length, root weight, leaf weight and stem weight. Hence, these characters need to be given more importance in selection as these are expected to be controlled by additive genes.

In a study conducted by Akaneme and Ani (2013) broad sense heritability estimate for days to 50 % flowering was quite high (79.92%) and that of plant height was low (23.75%). Other characters with moderate heritability estimates were hypocotyls length (57.38%), leaf width (56.62%) and 500 seed weight (54.55%). Two characters had negative but low heritability, petiole length (-6.69%) and internode length (-0.234%). Days to 50% flowering had the highest genetic advance.

Seventeen genotypes of stem amaranth were evaluated by Hasan *et al.* (2013) and high heritability estimates associated with fairly high estimates of genetic advance (GA) were observed for number of leaf, leaf weight and marketable yield which in fact demonstrated the presence of additive gene effects.

2.4.3 Correlation

Vijayakumar (1980) conducted studies on growth and development of certain types of amaranthus namely *A. tristis, A. tricolor, A. dubius* and *A. blitum* and observed that the plant height was significantly associated with the yield of greens (Stem and leaves) at all stages of growth.

In amaranthus, the height and stem girth are positively correlated with yield (Hamid *et al.*, 1989).

According to Priya (1998) 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.

Correlation studies conducted by Sindhu (2002) revealed that plant height, stem girth, length of leaf lamina, leaf width, number of branches and days to 50 per cent bolting had positive genotypic correlation with yield whereas leaf / stem ratio had negative correlation with total yield.

In an experiment undertaken by Shukla and Singh (2003) to analyse correlation in grain amaranth genotypes, the genotypic correlation for yield and yield components was higher than the corresponding phenotypic correlation. At the phenotypic level, positive correlation was seen between grain yield per plant and plant height and leaf size. At genotypic level, grain yield per plant was positively associated with other traits. Leaf size was positively associated with all characters except inflorescence length.

Twenty nine distinct strains of *A. tricolor* were evaluated to elucidate interrelationship among foliage yield and its seven contributing traits Shukla *et al.* (2004). Genotypic correlation values were generally higher than corresponding phenotypic correlation values in all cuttings for different traits. Foliage yield was positively correlated with plant height in all cuttings. Number of branches per plant was significantly correlated with number of leaves per plant and stem diameter in pooled as well as in all cuttings. Plant height, leaf size and stem diameter were important characters for increasing yield.

Sujata (2006) reported that all the morphological characters except days to 50 per cent bolting had positive correlation with yield. Leaf blight and leaf webber incidence exhibited negative correlation with yield.

Six genotypes of vegetable amaranthus and thirty F1 hybrids were used to estimate the correlation by Aruna (2009). The correlation coefficient between yield of greens with weight of leaves was highest both at genotypic level and at phenotypic level.

In an experiment Akaneme and Ani (2013) observed all the correlation coefficients. Eleven pairs of characters were positively and highly significantly correlated at 5% and 1% level, while one pair was negatively and significantly correlated at 5% level. The highest correlation was between 500 seed weight and leaf width. The 500 seed weight was also moderately correlated with hypocotyls length. Other moderate correlation coefficients were between canopy cover and plant height, stem diameter and leaf length, internode length and leaf length, days to 50% flowering and stem diameter, days to 50% flowering and leaf length. The only significant but negative correlation was between hypocotyls length and plant height.

In a study in stem amaranth Hasan *et al.* (2013) observed that Positive significant correlations for leaf length with leaf number, weight of leaf with leaf number and leaf length, stem diameter with leaf length, leaf weight and stem weight. Stem weight exhibited positive and significant correlation with dry weight both for rind and without rind. Length of leaf showed highly significant positive correlation with marketable yield both at phenotypic and genotypic levels.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Identification of non bolting genotypes and planting time in amaranthus (*Amaranthus tricolor* L.)" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period from March 2013 to May 2014.

3.1 EXPERIMENTAL SITE

The experimental site was located at 8° 5' N latitude and 77° 1' E longitude at 29 m above mean sea level. Soil type of the experimental site was red loam belonging to Vellayani series, texturally classified as sandy loam. The area enjoys a warm humid tropical climate.

3.2 MATERIALS

The material for the study comprised of eleven amaranthus genotypes which included the released variety of Kerala Agricultural University Arun, four local collections from Thiruvananthapuram district, three from Kollam district, two from Alapuzha district and one from the department of Olericulture, College of Agriculture, Vellayani. The test entries were assigned accessions numbers Amt 1 to Amt 11. The details of the genotypes and sources of genotypes were presented in Table 1. (Plate 1)

3.3 SEASON

Six crops were raised from March 2013 to January 2014 at bimonthly intervals. (Plate 2 to 7).

3.4 METHODS

3.4.1 Design and Layout

The experiment was laid out as six separate experiments in Randomized Block Design with 3 replications. There were six planting dates at alternate

Table 1. Details of eleven amaranthus genotypes used for the study.

Sl. No.	Genotypes	Source	Branching habit	Stem colour	Leaf colour
1.	Amt 1	Vellarada, Thiruvananthapuram	Medium	Light red	Light red
2.	Amt 2	Palapoor, Thiruvananthapuram	Low	Red	Greenish red
3.	Amt 3	Muhamma, Alappuzha	High	Pink	Pink
4.	Amt 4	Venganoor, Thiruvananthapuram	Medium	Red	Red
5.	Amt 5	Muhamma, Alappuzha	Medium	Red	Red
6.	Amt 6	Karunagapally, Kollam	Medium	Greenish red	Greenish red
7.	Amt 7	Department of Olericulture, College of Agriculture, Vellayani	Medium	Red	Red
8.	Amt 8	Department of Plant breeding and Genetics, College of Agriculture, Vellayani (Arun)	High	Deep red	Maroon
9.	Amt 9	Kottarakara, Kollam	Medium	Red	Dark red
10.	Amt 10	Neyyantinkara, Thiruvananthapuram	Medium	Red	Deep red
11.	Amt 11	Chathannur, Kollam	Low	Red	Red

Amt 1

Amt 2

Amt 3

Amt 4

Amt 5

Amt 6

Amt 7

Amt 8

Amt 9

Amt 10

Amt 11

Plate 1. Eleven genotypes used for the study

Plate 2. Field view of March planting

Plate 3. Field view of May planting

Plate 4. Field view of July planting

Plate 5. Field view of September planting

Plate 6. Field view of November planting

Plate 7. Field view of January planting

months starting from March 2013. Pre treatment soil fertility status was assessed in all experimental plots (Appendix I).

Design	:	RBD
Replication	:	3
Treatments	:	11 genotypes
Spacing	:	30 x 20 cm
Plants/ plot	:	30
Plot size	:	1.8 m^2

The crop was raised in garden land according to the Package of Practices recommendation of Kerala Agricultural University (KAU, 2011). The management practices were uniform for all the experiments.

3.5 OBSERVATIONS

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

3.5.1 Growth Characters

3.5.1.1 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.

3.5.1.2 Stem Girth (cm)

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

3.5.1.3 Leaf Length (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.

3.5.1.4 Leaf Width (cm)

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

3.5.1.5 Branches/ Plant

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

3.5.1.6 Days to First Flowering

Number of days from planting to the appearance of first flower was recorded from the plants left unharvested.

3.5.1.7 Days to 50 per cent Flowering

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

3.5.1.8 Days to Seed Maturity

Number of days taken from planting to seed maturity was recorded from the plants left unharvested.

3.5.2 Yield Characters

3.5.2.1. Yield per Cutting (g)

The vegetable yield from the observational plants was recorded at each cutting. The mean yield was recorded in grams per plant.

3.5.2.2 Yield per Plant (g)

Yield per plant from all cuttings was added in all observational plants to get the total yield per plant. Mean worked out and expressed in grams per plant.

3.5.2.3 Yield per Plot (kg)

Out of thirty plants, fifteen were left for vegetable harvest and the others for taking observations on flowering and seed characters. The weight of all cuttings in fifteen plants was taken and expressed in kilograms as yield per plot.

3.5.2.4 Yield per Hectare (t)

It is the yield calculated from the plot yield and expressed as tons/ha.

3.5.2.5 Total Leaf Weight (g)

The total weight of leaves from all cuttings was pooled and expressed as grams per plant.

3.5.2.6 Total Stem Weight (g)

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

3.5.2.7 Leaf / Stem Ratio

Leaf/stem ratio was obtained by dividing the total weight of leaves by the total weight of stem.

3.5.2.8 Seed Yield per Plant (g)

The seed yield from the observational plants was weighed, average worked out and was expressed in grams.

3.5.3 Quality Characters

3.5.3.1 β Carotene

Carotene content of fresh leaves at harvest (30 DAT) was estimated according to the method proposed by Srivastava and Kumar (1998).

5 g of fresh sample was taken and crushed in 10-15 ml acetone, adding a few crystals of anhydrous sodium sulphate, with the help of pestle and mortar. The supernatant was decanted into a beaker. Repeated the process twice and transferred the combined supernatant to a separator funnel. 10-15 ml of petroleum ether was added and mixed thoroughly. The two layers separated out on standing. The lower layer discarded and the upper layer was collected in a 100 ml volumetric flask. The volume was made up to 100 ml with petroleum ether and recorded the optical density using spectrophotometer at 452 nm using petroleum ether as blank.

3.5.3.2 Vitamin C

Vitamin C content of fruit was estimated by 2, 6-dichlorophenol indophenols dye method (Sadasivam and Manickam, 1996).

5 ml of the working standard solution was pipetted out into a 100 ml conical flask and 10 ml four per cent oxalic acid was added. It was titrated against the dye (V_1 ml). End point was the appearance of pink colour which persisted for at least five seconds. One gram of fresh leaf was extracted in an acid medium (4 % oxalic acid) and made up to a known volume (20 ml) and centrifuged. 5ml of the supernatent was taken and titrated against the dye until pink colour appeared (V_2 ml). Ascorbic acid content was calculated.

3.5.3.3 Oxalates

Estimated by the method suggested by A.O.A.C (1984).

One gram of dried powder was extracted twice with 0.25 N hydrochloric acid in a water bath for one hour each. The extract was centrifuged and the supernatant was collected in a conical flask. The extract was precipitated by adding 5 ml tungstophosphoric acid, kept overnight and centrifuged the next day. It was neutralized with 1:1 dilute ammonia solution and precipitated by adding 5 ml acetate buffer containing calcium chloride (pH 4.5). The precipitate was centrifuged and washed twice with wash liquid (6 ml each). The precipitate was then dissolved in 10-15 ml 2 N sulphuric acid and transferred into a 100 ml conical flask. It was titrated against 0.01 N potassium permanganate solution at 60°C.

3.5.3.4 Nitrate

Nitrate was estimated according to the procedure suggested by Middleton (1958).

0.1 g dried tissue was weighed in a beaker or flask. 9 ml silver sulphate was added and swirled quickly. One ml sodium phosphate was added immediately and it was allowed to stand for two hours. This solution was filtered. 2 ml of filtrate was measured into a 15 ml centrifuge tube, 2 ml copper sulphate solution was added and solution was mixed thoroughly followed by addition of water and made upto 6 ml. Approximately 0.5 g calcium hydroxide – magnesium carbonate mixture was added to this, mixed and allowed to stand for one hour and centrifuged at 3000 rpm for five minutes. 2 ml phenol-p- sulphonic acid was poured into a boiling tube, directly to the bottom. 2 ml supernatant was added drop by drop from above directly into the reagent, swirling carefully after the addition of each drop. This was cooled and 25 ml ammonium hydroxide was added with stirring. After proper cooling, the absorbance was read in a spectrophotometer at 475 nm with the instrument set at zero with water.

3.5.3.5 Protein

Protein was estimated following the method of Lowry *et al.* (1951). For extraction of protein, 500 mg fresh weight tissue of washed vegetable amaranth leaves was grind in 1 ml of 20% tri-chloro acetic acid and placed over night. Next day supernatant was discarded and the residue washed thoroughly 2–3 times with distilled water. The chlorophyll was removed from the residue by adding sufficient amount of 80% acetone solution and centrifugation. After the removal of chlorophyll, the sample was dried in vacuum to evaporate the acetone. Then the pellet was digested with 1 ml of 0.5N NaOH at 80 °C for 10 min in water bath. Further, 4 ml of distilled water was added and the sample was centrifuged at 7500 rpm. An aliquot of 0.5 ml was taken and 5 ml B.C. reagent (The B.C. reagent was prepared by adding 50 mg $CuSO_4.5H_2O$ in 10 ml of 2% sodium tartarate and 1 ml of this solution was added to 50 ml of 2% sodium carbonate prepared in 0.1N NaOH) was added. After 10 min the colour was developed by the addition of 0.5 ml 1N folin Ciocalteu's reagent in the sample. The absorbance values were taken at wavelength of 640 nm on spectrophotometer. The standard graph was plotted against concentration of protein and absorbance values, using bovine albumen serum protein of 0.2, 0.4, 0.6, 0.8 and 1μg/ml concentrations. The amount of protein in the sample can be calculated by comparing (interpolation) with the standard graph and expressed as mg/100 mg of fresh sample weight taken initially.

3.5.4 Pest and Disease Incidence

3.5.4.1 Reaction to Leaf Webber

Hymenia recurvalis and *Psara basalis* are the important leaf webbers seen in amaranthus. The total number of leaves and number of leaves infested was recorded from five observational plants at 30 days after transplanting and 10 days after spraying. The percentage of leaves infested was estimated in each treatment.

Percentage of leaf affected = Number of leaves affected x 100

Total number of leaves

3.5.4.2 Reaction to Leaf Blight

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

A scoring procedure (with a scale 0-4) was done depending on the extent of damage to the leaves.

0	No incidence
1	up to 25 per cent leaf area infected
2	26-50 per cent leaf area infected
3	51-75 per cent leaf area infected
4	> 75 per cent leaf area infected

Number of leaves affected was observed and scoring was done and from this leaf blight intensity was calculated.

Leaf blight intensity = Sum of individual rating X 100

Number of plants assessed 4

3.5.5 Weather Parameters

Following weather parameters during the course of investigation were recorded.

3.5.5.1 Maximum Temperature (^{O}c)

3.5.5.2 Minimum Temperature (^{O}c)

3.5.5.3 Sunshine Hours (H)

3.5.5.4 Relative Humidity (%)

3.6 STATISTICAL ANALYSIS

The data collected were subjected to the following statistical analysis.

3.6.1 Analysis of Variance

Analysis of variance was done according to Singh and Choudhary (1979) to test the significant difference among the genotypes with respect to various characters and to estimate variance components and other parameters like coefficient of variation, heritability and genetic advance (Table 2)

3.6.1.1 Variance:

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

3.6.1.2 Coefficient of Variation

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

$$GCV = \frac{\sigma_{px}}{X} \times 100$$

$$PCV = \frac{\sigma_{px}}{X} \times 100$$

Where,

σ_{gx} - genotypic standard deviation

σ_{px} - phenotypic standard deviation,

Table 2. Analysis of variance / covariance

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

3.6.1.3 Heritability

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

Where, H^2 is the heritability expressed in percentage (Jain, 1982). Heritability estimates were categorized as suggested by Jhonson *et al.* (1955).

0 – 30 per cent ⟶ Low

31 – 60 per cent ⟶ Moderate

>60 per cent ⟶ High

3.6.1.4 Genetic Advance as Percentage Mean

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

Where, k is the standard selection differential.

K = 2.06 at 5% selection intensity (Miller *et al.*, 1958)

The range of genetic advance as per cent of mean was classified according to Jhonson *et al.* (1995).

0- 10 per cent ⟶ Low

11- 20 per cent ⟶ Moderate

> 20 per cent ⟶ High

3.6.2 Correlation

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

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

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

3.6.3 Pooled Analysis

Pooled analysis of data over the planting time was done in a split plot fashion as suggested by Gomez and Gomez (1984), taking genotypes as the main plot treatment and planting times as the sub plot treatments to find out the best planting time in amaranthus.

RESULTS

4. RESULTS

The experiment entitled 'Identification of non bolting genotypes and planting time in amaranthus' was carried out in the Department of Olericulture, College of Agriculture, Vellayani during the period from March 2013 to May 2014.

The experiment was laid out as six separate experiments in randomized block design with three replications. The experimental data collected on growth characters, yield and yield attributes, pest and disease incidence, quality characters and genetic parameters were statistically analyzed and the results are presented below.

4.1 ANALYSIS OF VARIANCE

Analysis of variance revealed significant differences among genotypes for most of the characters in all the separate planting dates are given in Appendix I to VI. Pooled analysis also revealed significant differences for most of the characters studied. The mean performance of the genotypes over six planting dates for growth, yield and quality characters and pest and disease incidence are furnished in Tables 3 to 13.

4.1.1 Growth Characters

4.1.1.1 Plant Height

Significant variation was observed for plant height among the genotypes during all the planting dates. During March planting, tallest genotype was Amt 6 (84.14 cm) and the shortest was Amt 3 (29.24 cm). In May planting, Amt 6 (84.94 cm) recorded maximum height and the shortest plant was Amt 3 (27.22 cm). In July planting, Amt 6 (50.26 cm) recorded maximum height and least height was recorded for Amt 3 (18.19 cm). For September planting, maximum height was recorded in Amt 2 (77.09 cm) and the lowest value was recorded in Amt 3 (38.00 cm). Plant height during November planting was highest in Amt 6 (75.63 cm) and lowest in Amt 3 (31.20 cm). During January planting, genotype

Amt 2 (61.20 cm) recorded maximum plant height and Amt 3 (25.09 cm) the minimum.

Pooled analysis of eleven genotypes over the six planting dates showed significant G x E interaction for plant height (Table 3 and Figure 1). Among genotypes, tallest was Amt 6 (71.88 cm) followed by Amt 2 (65.19 cm). Amt 3 (28.16 cm) was the shortest followed by Amt 1 (35.70 cm).

Among planting dates, it was maximum for September planting (P4- 57.52 cm) which is on par with March planting (P1- 55.63 cm). It was minimum for July planting (P3-4.59 cm).

The interaction between genotypes and planting dates was significant for plant height at 30 days after planting. Amt 6 planted in May was the tallest (84.94 cm) which is on par with Amt 6 during March planting (84.14 cm) and Amt 2 during March planting (79.79 cm). The shortest plant was recorded in Amt 3 during July planting (18.19 cm).

4.1.1.2 Stem Girth

Significant difference was noticed for stem girth among the genotype for all the planting dates. During March planting, maximum stem girth was in Amt 5 (8.49 cm) and minimum in Amt 3 (4.71 cm). In May planting, stem girth was recorded maximum in Amt 6 (7.23 cm) and the minimum in Amt 11 (4.96 cm). When planted on July, genotype Amt 11 (5.28) obtained maximum stem girth and minimum in Amt 3 (3.51 cm). For September planting, stem girth was maximum in Amt 2 (5.00 cm) and minimum in Amt 3 (3.50 cm). Stem girth during November planting was maximum in Amt 6 (5.20 cm) and minimum in Amt 3 (3.86 cm). During January planting, stem girth was maximum in Amt 4 (5.18 cm) and minimum in Amt 10 (4.09 cm).

Pooled analysis for the six planting dates showed significant G x E interaction for stem girth (Table 3). Among genotypes, it was maximum for Amt 6 (5.70 cm) which is on par with Amt 5 (5.47 cm) and minimum for Amt 3 (4.23).

Among planting dates maximum stem girth was in March planting (P1) (6.68 cm) and minimum (4.30 cm) for July planting (P3).

Interaction between genotypes and planting dates showed significant difference for stem girth at 30 days after transplanting. Highest stem girth was recorded in Amt 5 during March planting (8.49 cm) and lowest for Amt 3 during September planting (3.50 cm).

4.1.1.3 Leaf Length

During March planting, leaf length differed significantly. Amt 9 (20.55 cm) recorded maximum leaf length whereas it was lowest in Amt 4 (15.28 cm). During May planting, significant variation was not observed for leaf length among the genotypes. In July planting, Amt 10 (17.54 cm) had maximum length of leaf lamina whereas it was lowest for Amt 4 (12.52 cm). Significant difference was observed for leaf length during September planting, Amt 7 (17.07 cm) recorded maximum leaf length and least was for Amt 5 (10.73). During November planting, maximum leaf length was obtained in Amt 9 (17.09 cm) and least in Amt 5 (12.89 cm). In January planting and it was maximum for Amt 8 (18.09) and minimum for Amt 5 (12.19 cm).

Pooled analysis for the six planting dates showed significant G x E interaction for leaf length (Table 4). Among genotypes, it was maximum in Amt 8 (17.04 cm) which is on par with Amt 9 (17.03 cm) and Amt 7 (16.77 cm). The lowest for Amt 5 (13.42). Among planting dates, March planting (P1) recorded maximum leaf length (17.35 cm) followed by May planting (P2) and lowest value (14.03 cm) was in September planting (P4).

The interaction among best genotypes and planting dates was also significant. The results showed that among treatment combinations, Amt 9 during March planting (20.55 cm) had maximum leaf length which is on par with Amt 7 during March planting (20.18 cm). Amt 5 during September planting (10.73 cm) was recorded the lowest value.

Table 3. Effect of genotypes, planting dates and their interaction on plant height and stem girth of amaranthus, cm

Genotypes	Plant height							Stem girth						
	P1	P2	P3	P4	P5	P6	Mean	P1	P2	P3	P4	P5	P6	Mean
Amt 1	39.03	31.78	24.09	47.13	35.30	36.85	35.70	6.46	5.10-	4.19	4.41	4.53	4.21	4.82
Amt 2	79.79	76.78	45.99	77.09	50.27	61.20	65.19	6.89	6.47	3.85	5.00	4.57	4.64	5.24
Amt 3	29.24	27.22	18.19	38.00	31.20	25.09	28.16	4.71	5.69	3.51	3.50	3.86	4.09	4.23
Amt 4	59.11	59.50	33.48	56.34	45.57	55.83	51.64	7.22	6.10	4.47	3.80	5.00	5.18	5.30
Amt 5	57.72	55.83	39.44	73.24	51.06	55.33	55.44	8.49	6.27	4.18	4.42	4.67	4.77	5.47
Amt 6	84.14	84.94	50.26	76.22	75.63	60.11	71.88	7.38	7.23	5.04	4.95	5.20	4.40	5.70
Amt 7	43.13	45.39	31.43	58.54	41.21	39.63	43.22	6.08	6.60	4.13	4.54	3.92	4.33	4.90
Amt 8	46.68	49.19	26.95	42.21	45.32	40.29	41.77	7.02	5.87	4.47	4.59	4.52	4.89	5.23
Amt 9	56.05	43.5	32.40	50.61	46.36	38.26	44.53	6.44	6.27	3.97	4.47	4.15	4.61	4.98
Amt 10	50.88	46.11	28.44	46.15	34.74	42.00	41.39	5.66	5.65	4.21	3.80	4.17	4.09	4.60
Amt 11	66.16	71.92	49.85	67.21	54.76	50.84	60.12	7.17	4.96	5.28	4.71	5.00	4.82	5.32
Mean	55.63	53.83	34.59	57.52	46.49	45.95		6.68	6.02	4.30	4.38	4.51	4.55	
CD (5%)	G						2.40	G						0.28
	P						2.56	P						0.43
	G x P						5.90	G x P						0.69

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

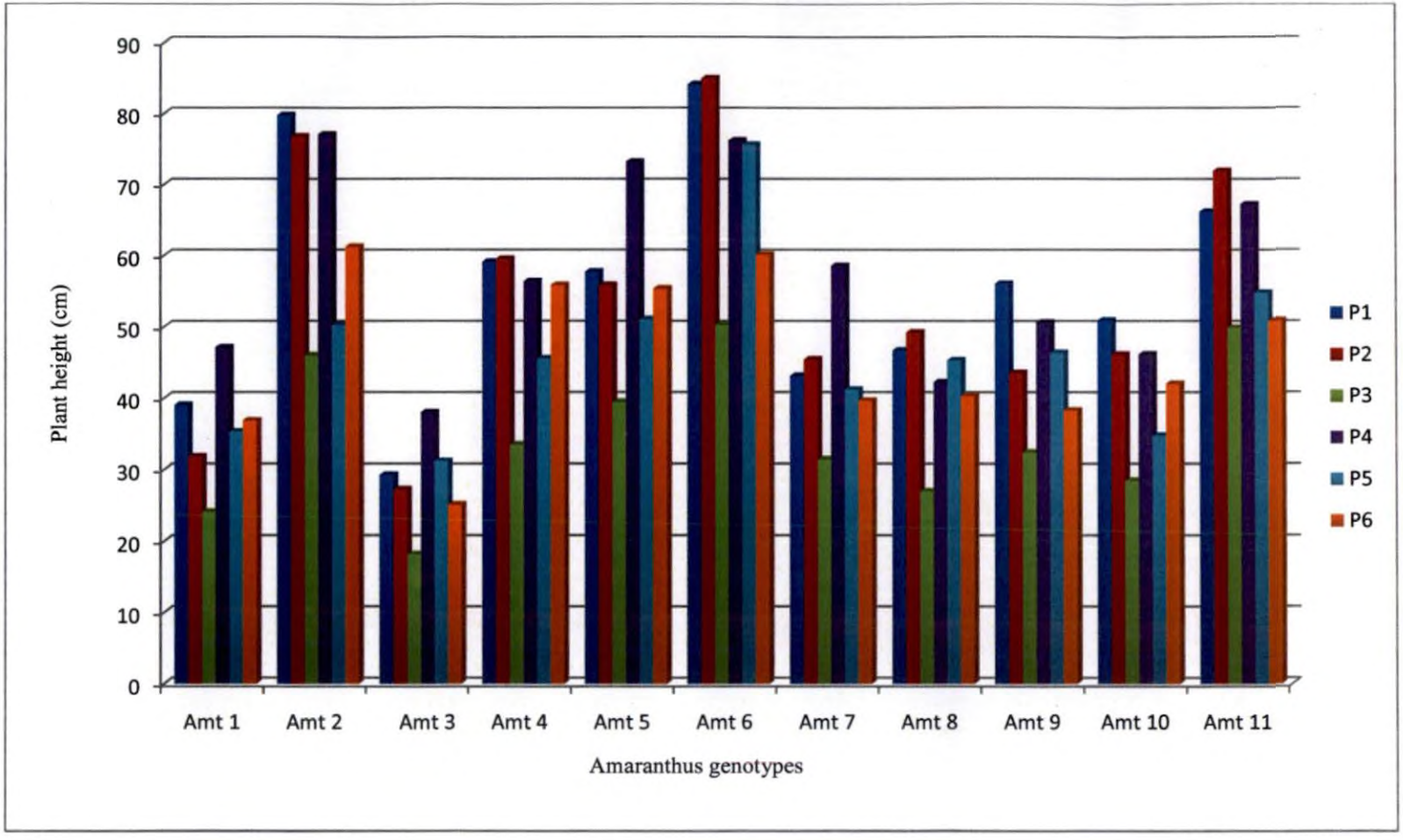

Fig. 1. Effect of genotypes, planting dates and their interactions on plant height of amaranthus

4.1.1.4 Leaf Width

Significant variation was observed for leaf width among the genotypes for all the seasons. During March planting, Amt 7 (13.24 cm) recorded maximum leaf width and lowest was for Amt 5 (8.44 cm). In May planting, maximum leaf width was obtained for Amt 7 (12.8 cm) and minimum was for Amt 1 (9.55 cm). When planted on July, genotype Amt 9 (11.48 cm) recorded maximum leaf width and least value was observed in Amt 5 (8.99 cm). For September planting, maximum leaf width was obtained for Amt 7 (9.49 cm) and minimum was for Amt 5 (6.00 cm). Leaf width was maximum for Amt 9 (11.22 cm) during November planting and minimum for Amt 3 (7.82 cm). During January planting maximum leaf width was recorded in Amt 8 (12.47 cm) and least value was recorded in Amt 5 (7.59 cm).

Pooled analysis for the six planting dates showed significant G x E interaction for leaf length at 30 days after transplanting (Table 4). Among genotypes, highest leaf width (11.56 cm) was obtained for Amt 7 which is on par with for Amt 8 (11.23 cm) and lowest for Amt 5 (8.25 cm)

Significant variation was obtained among planting dates also. Leaf width was highest (11.12 cm) for March planting (P1) followed by May planting (P2) (10.51 cm) and lowest for September planting (P4) (8.03 cm).

Interaction effect was also significant for leaf width. Maximum width (13.24 cm) observed for Amt 7 during March planting which is on par with Amt 1, Amt 8, Amt 11 during March planting and Amt 7 during May planting. Least value was obtained for Amt 5 during September planting (6.00 cm).

4.1.1.5 Branches per Plant

During all the planting times, significant variation was observed for branches per plant among the genotypes. During March planting, maximum branches per plant was in Amt 6 (11.76) and minimum for Amt 3 (8.00). In May planting, Amt 4 (14.89) recorded maximum branches per plant and least for Amt 1 (7.78). When planted on July, Amt 4 (9.33) recorded maximum branches per

Table 4. Effect genotypes, planting dates and their interaction on leaf length and leaf width of amaranthus, cm

Genotypes	Leaf length							Leaf width						
	P1	P2	P3	P4	P5	P6	Mean	P1	P2	P3	P4	P5	P6	Mean
Amt 1	17.07	14.15	14.81	14.43	14.37	16.12	15.16	13.18	9.56	11.24	9.28	11.04	11.27	10.93
Amt 2	15.54	14.24	14.00	12.45	13.07	16.14	14.24	9.08	9.81	9.04	7.06	7.87	9.84	8.78
Amt 3	16.15	14.48	14.03	13.24	13.31	15.52	14.46	9.40	9.83	9.14	6.75	7.82	8.89	8.64
Amt 4	15.28	15.32	12.52	11.27	13.53	12.89	13.47	10.09	10.49	9.28	6.48	9.06	8.42	8.97
Amt 5	15.59	15.40	13.74	10.73	12.89	12.19	13.42	8.44	10.21	8.99	6.00	8.27	7.59	8.25
Amt 6	18.57	16.38	16.99	14.58	16.80	14.86	16.36	11.06	10.74	11.05	8.42	9.32	8.91	9.92
Amt 7	20.18	17.14	15.36	17.07	14.38	16.500	16.77	13.24	12.80	11.20	9.49	11.12	11.48	11.56
Amt 8	18.23	16.17	17.46	15.48	16.80	18.09	17.04	12.82	10.36	11.32	9.41	11.01	12.47	11.23
Amt 9	20.55	15.58	15.41	16.19	17.09	17.33	17.03	12.01	10.63	11.48	7.92	11.22	9.33	10.43
Amt 10	17.58	16.25	17.54	15.20	15.57	15.43	16.26	10.08	10.71	11.32	8.17	9.41	10.70	10.07
Amt 11	16.12	15.90	17.41	13.66	14.90	14.50	15.41	12.92	10.43	10.04	9.40	10.66	10.56	10.67
Mean	17.35	15.55	15.39	14.03	14.79	15.42		11.12	10.51	10.38	8.03	9.71	9.95	
CP (5%)	G						0.60	G						0.45
	P						0.62	P						0.41
	G x P						1.46	G x P						1.11

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

plant and minimum for Amt 9 (6.11). For September planting, maximum branches per plant was observed for Amt 5 (15.22) and minimum for Amt 1 (7.94). In November planting maximum branches per plant was obtained for Amt 3 (10.19) and least value for Amt 4 (6.22). During January planting, branches per plant recorded maximum for Amt 8 (12.92) and minimum for Amt 6 (10.00).

Pooled analysis for the six planting dates showed significant G x E interaction for leaf length at 30 days after transplanting (Table 5). Among genotypes, it was observed that Amt 5 recorded maximum branches (11.13) which is on par with Amt 4 (10.54) and minimum number of branches (8.44) was recorded for Amt 1.

Significant differences were obtained for planting dates also. Maximum branches was recorded in January planting (P6- 11.37) which is on par with September planting (P4- 11.15) and May planting (P2- 10.86) whereas minimum branches (7.20) was recorded for November planting.

Interaction affect was also significant for branches per plant taken at 30 days after transplanting. Maximum branches per plant was obtained for Amt 5 during September planting (15.22) which is on par with Amt 4 during May planting (14.89) and Amt 5 during May planting (13.55). Lowest number of branches per plant was recorded in Amt 9 during July planting (6.11) (The genotypes depicting the leaf and stem characters given in Plate 8.).

4.1.1.6 Days to First Flowering

Significant variation was observed for days to first flowering among the genotype for all the planting times.

During March planting, flowering was latest in Amt 1 (124.33 days) followed by Amt 8 (71.67 days) and Amt 11 (65.67 days). The earliest flowering was observed in Amt 2 (13.00 days) followed by Amt 5 (19.67 days) and Amt 4 (23.67 days). In May planting, Amt 1 (112.56 days) exhibited latest flowering followed by Amt 8 (65.22 days) and Amt 11 (53.34 days). The earliest flowering was observed in Amt 2 (13.78 days) followed by Amt 4 (16.00 days) and Amt 5

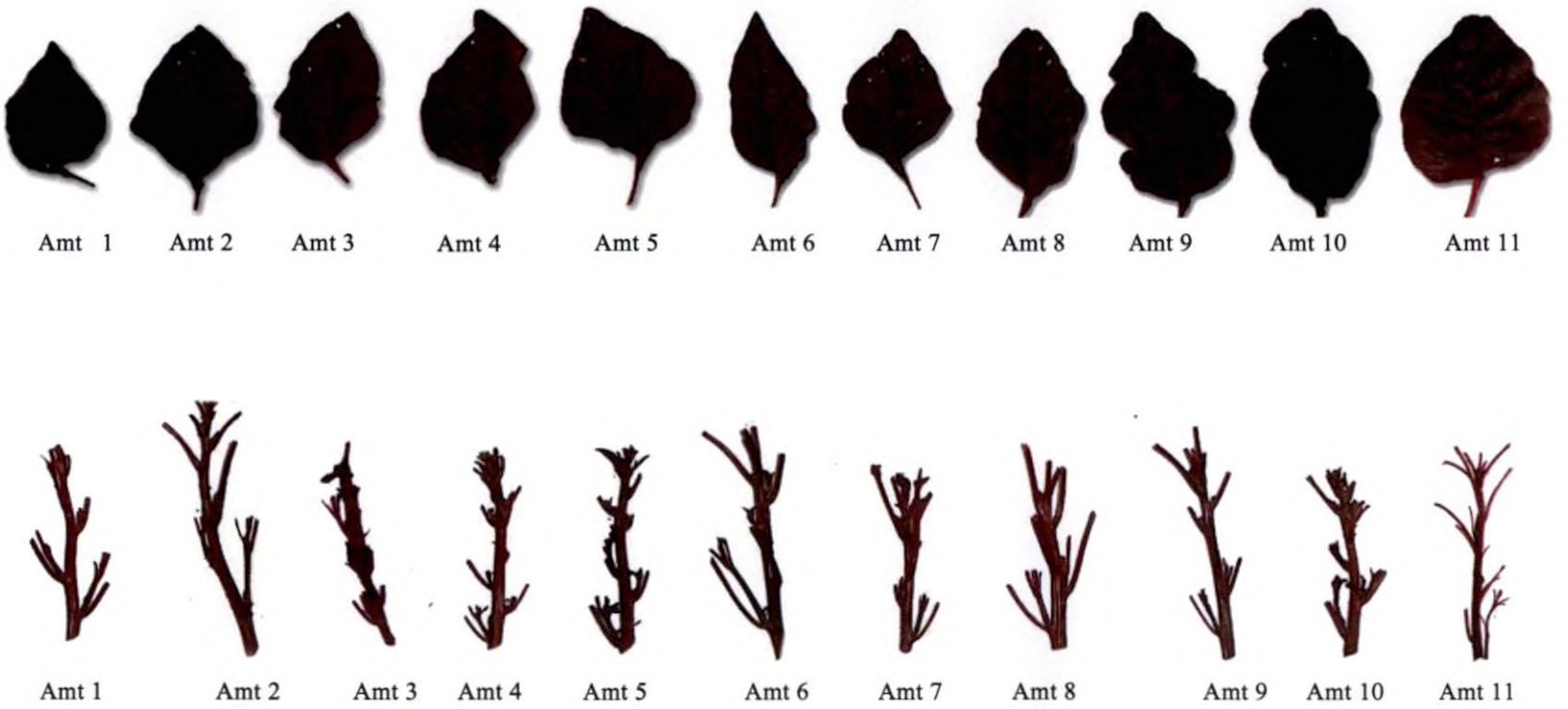

Plate 8. Variation in leaf and stem characters of eleven genotypes

(16.56 days). When planted on July, latest flowering was seen in Amt 1 (118.67 days) followed by Amt 8 (68.67 days) and Amt 11 (55.67 days). The earliest flowering was seen in Amt 2 (13.00 days) followed by Amt 4 (16.00 days) and Amt 3 (17.33 days). For September planting, latest flowering was noticed in Amt 1 (94.00 days) followed by Amt 11 (49.33 days) and Amt 8 (46.67 days). The earliest flowering was noticed in Amt 2 (13.67 days) followed by Amt 5 (16.00 days) and Amt 4 (22.67 days). When planting was done in November, Amt 1 (57.33 days) exhibited latest flowering followed by Amt 8 (48.67 days) and Amt 11 (44.67 days). The earliest flowering was noticed in Amt 2 (21.33 days) followed by Amt 3 (21.67 days) and Amt 4 (23.67 days). In January planting, latest flowering in Amt 1 (68.00 days) followed by Amt 8 (59.333 days) and Amt 11 (50.67 days). Earliest flowering was shown by Amt 2 (13.67 days) followed by Amt 5 (21.67 days) and Amt 3 (22.67 days).

Pooled analysis for the six planting dates showed significant G x E interaction for days to first flowering (Table 5). Among genotypes latest flowering was Amt 1 (95.82 days) and the earliest flowering was Amt 2 (14.74 days)

Days to first flowering varied significantly for planting dates of planting also. March planting (P1) resulted in latest flowering (45.70 days) followed by May planting (P2- 44.47 days) and earliest flowering was noticed in November planting (P5- 32.76 days).

Highly significant difference in days to first flowering was observed between genotypes and planting time interactions. The latest flowering was recorded in Amt 1 during March planting (124.33 days) and the earliest flowering was recorded in Amt 2 during March planting (13.00 days) which is on par with Amt 2 planted during May (13.78 days), July (13.01 days) September (13.66 days) and January(13.67 days).

Table 5. Effect of genotypes, planting dates and their interaction on branches/plant and days to first flowering of amaranthus.

Genotypes	Branches/plant							Days to first flowering						
	P1	P2	P3	P4	P5	P6	Mean	P1	P2	P3	P4	P5	P6	Mean
Amt 1	9.88	7.78	6.55	7.94	6.37	12.13	8.44	124.33	112.56	118.67	94.00	57.33	68.00	95.82
Amt 2	10.04	12.11	7.89	11.78	6.63	11.25	9.95	13.00	13.78	13.00	13.67	21.33	13.67	14.74
Amt 3	8.00	8.89	9.19	10.56	10.19	12.59	9.90	25.33	49.78	17.33	25.33	21.67	22.67	27.02
Amt 4	9.26	14.89	9.33	12.31	6.22	11.19	10.54	23.67	16.00	16.00	22.67	23.67	23.00	20.83
Amt 5	11.67	13.55	8.17	15.22	6.30	11.89	11.13	19.67	16.56	19.33	16.00	25.33	21.67	19.76
Amt 6	11.76	12.11	8.89	12.00	7.07	10.00	10.30	29.67	26.89	32.00	30.00	29.00	26.67	29.04
Amt 7	8.96	9.22	6.67	10.11	6.92	10.66	8.76	37.67	37.78	49.33	37.00	26.33	39.33	37.91
Amt 8	11.19	9.11	7.97	10.55	7.37	12.92	9.85	71.67	65.22	68.66	46.67	48.67	59.33	60.04
Amt 9	10.96	9.44	6.11	10.29	6.90	10.89	9.10	51.00	50.89	45.00	32.00	30.67	35.33	40.82
Amt 10	8.74	10.56	7.32	10.00	6.72	11.30	9.11	41.00	46.36	44.00	37.00	31.67	34.00	39.00
Amt 11	10.11	11.83	9.33	11.89	8.52	10.22	10.32	65.66	53.34	55.67	49.33	44.67	50.67	53.22
Mean	10.05	10.86	7.95	11.15	7.20	11.37		45.70	44.47	43.55	36.70	32.76	35.85	
CD (5%)	G						0.74	G						1.07
	P						0.63	P						0.74
	G x P						1.82	G x P						2.61

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

4.1.1.7 Days to 50 percent Flowering

Significant variation was observed for days to fifty per cent flowering among the genotype for all the planting times. During March planting, Amt 1 (146.67 days) was latest flowering followed by Amt 8 (96.33 days) and Amt 11 (81.33 days). The earliest flowering was Amt 2 (19.00 days) followed by Amt 4 (29.33 days) and Amt 5 (31.00 days). In May planting, latest flowering was Amt 1 (135.00 days) followed by Amt 8 (77.67 days) and Amt 9 (65.33 days). The earliest flowering was Amt 2 (20.69 days) followed by Amt 4 (24.00 days) and Amt 5 (31.00 days). When planted on July, latest flowering was Amt 1 (139.67 days) followed by Amt 8 (77.67 days) and Amt 11 (65.33 days). The earliest flowering was Amt 2 (17.33 days) followed by Amt 3 (19.33 days) and Amt 4 (20.00 days). For September planting, latest flowering was Amt 1 (112.00 days) followed by Amt 11 (52.67 days) and Amt 8 (52.33 days). Earliest flowering was Amt 2 (18.00 days) followed by Amt 5 (25.00 days) and Amt 4 (28.67 days). When planting was done in November, Amt 1 (69.00 days) was latest flowering followed by Amt 8 (61.33 days) and Amt 11 (59.3 days). The earliest flowering was Amt 2 (24.67 days) followed by Amt 3 (25.67 days) and Amt 4 (29.00 days). In January planting, latest flowering was Amt 1 (77.33 days) followed by Amt 8 (69.33 days) and Amt 11 (58.00 days). The earliest flowering was observed for Amt 2 (21.67 days) followed by Amt 4 (27.67 days) and Amt 5 (28.33 days).

Pooled analysis for the six planting dates showed significant G x E interaction for days to fifty per cent flowering (Table 6 and Figure 2). Among the genotypes, latest flowering was exhibited by Amt 1 (113.28 days) and earliest flowering by Amt 2 (20.22 days).

Planting dates showed significant difference on day to 50 percent flowering. Latest flowering was exhibited in March planting (P1- 58.49 days) and earliest flowering in November planting (P5- 41.91 days).

Interaction effects showed significant difference in days to 50 percent flowering. The latest flowering was exhibited by Amt 1 during March planting (146.67 days) which is followed by Amt 1 on July planting (139.6 days) and earliest flowering was exhibited by Amt 2 during July planting (17.33 days) which is on par with Amt 2 during March planting (19.00 days) and September planting (18.00 days).

4.1.1.8 Days to Seed Maturity

Effect of genotypes exerted significant variation for days to seed maturity in amaranthus for all the six planting dates. During March planting, Amt 1 (243.22 days) took maximum days for seed maturity whereas it was minimum for Amt 2 (56.00 days). In May planting, a maximum days for seed maturity was in for Amt 1 (221.67 days) and minimum in Amt 2 (63.89 days). When planted on July, genotype Amt 1 (210.11 days) took maximum days for seed maturity and the minimum was Amt 3 (54.67 days). For September planting, maximum days for seed maturity was observed in Amt 1 (186.00 days) and minimum in Amt 2 (54.00 days). Maximum days to seed maturity was taken by Amt 1 (172.00 days) during November planting and minimum by Amt 2 (57.33 days). During January planting, maximum days taken by Amt 1 (138.67 days) and minimum by Amt 2 (59.00 days).

Pooled analysis for the six planting dates showed significant G x E interaction for days to seed maturity (Table 6). Among genotypes, Amt 1 took maximum days for seed maturity (195.28 days) which is followed by Amt 8 (137.06 days) and Amt 11 (130.09 days). Amt 2 taken least days to seed maturity (60.07 days) followed by Amt 3 (72.43 days).

Difference in planting dates also influenced seed maturity in amaranthus. Planting in July month (P3) took maximum days for seed maturity (122.60 days), whereas September planting (P4- 93.55 days) was earliest for seed maturity.

Significant difference was observed between G x P interaction also. Maximum days for seed maturity was observed in Amt 1 during March planting

(243.22 days) followed by Amt 1 during May planting (221.67 days). It was earliest (54.00 days) in Amt 2 during September planting which is on par with Amt 2 during March (56.00 days) and November planting (57.33 days) and Amt 3 during July (54.67 days) and September planting (56.67 days).

4.1.2 Yield Characters

4.1.1.1 Yield per Cutting

Significant variation was observed for yield per cutting among genotypes for all the plantings. During March planting, it was observed that Amt 2 (221.54 g) obtained highest yield per cutting and lowest was Amt 3 (66.42 g). In May planting, maximum yield per cutting was obtained for Amt 5 (175.41 g) and least value was for Amt 1 (54.33 g). When planted on July genotype Amt 9 (82.32 g) recorded highest yield per cutting and lowest was recorded for Amt 3 (34.92 g). For September planting, yield per cutting was recorded maximum for Amt 6 (181.67 g) and minimum for Amt 3 (166.64 g). November planting observed maximum yield per cutting in Amt 6 (95.60 g) whereas, minimum in Amt 3 (38.74 g). During January planting, maximum yield per cutting was recorded in Amt 2 (130.10 g) and lowest value was for Amt 9 (54.07 g).

Pooled analysis of 11 genotypes over the six planting dates showed significant G x E interaction for yield per cutting in amaranthus (Table 7). Among genotypes, Amt 6 (128.37 g) obtained highest yield per cutting followed by Amt 2 (111.27 g). Lowest yield per cutting was for Amt 3 (58.66 g) followed by Amt 10 (72.45 g).

Among planting dates, maximum yield per cutting was recorded for March planting (P1- 142.81 g) followed by September planting (P4- 100.63g). Lowest yield per cutting was recorded for November planting (P5- 54.44 g).

Significant difference was observed between G X P interactions also. Highest yield per cutting was obtained for Amt 2 during March planting (221.54 g) followed by Amt 6 during March planting (202.24 g). Lowest yield per cutting was observed for Amt 3 during July planting (34.92 g).

Table 6. Effect of genotypes, planting dates and their interaction on days to fifty per cent flowering and days to seed maturity of amaranthus

Genotypes	Days to fifty per cent flowering							Days to seed maturity						
	P1	P2	P3	P4	P5	P6	Mean	P1	P2	P3	P4	P5	P6	Mean
Amt 1	146.67	135.00	139.67	112.00	69.00	77.33	113.28	243.22	221.67	210.11	186.00	172.00	138.67	195.28
Amt 2	19.00	20.67	17.33	18.00	24.67	21.67	20.22	56.00	63.89	70.22	54.00	57.33	59.00	60.07
Amt 3	35.00	62.00	19.33	32.00	25.67	29.33	34.00	65.22	130.33	54.67	56.67	65.00	62.67	72.43
Amt 4	29.33	24.00	20.00	28.67	29.00	27.67	26.44	70.87	74.33	92.67	66.33	63.00	69.33	72.76
Amt 5	31.00	31.00	21.33	25.00	32.67	28.33	28.22	71.55	75.33	95.67	68.33	65.33	72.33	74.76
Amt 6	36.00	35.67	43.00	38.33	39.00	34.00	37.67	91.66	129.89	112.22	108.00	100.67	95.00	106.24
Amt 7	54.33	48.67	55.33	47.67	34.33	45.67	47.67	91.67	95.55	128.44	82.00	110.33	111.33	103.22
Amt 8	96.33	77.67	77.67	52.33	61.33	69.33	72.44	154.00	156.33	142.67	111.00	135.33	123.00	137.06
Amt 9	65.67	65.33	52.00	37.00	46.00	44.00	51.67	130.56	126.78	138.78	98.00	125.00	107.00	121.02
Amt 10	48.67	54.33	50.00	42.33	40.00	40.00	45.89	108.00	100.13	134.78	93.00	121.00	112.00	111.49
Amt 11	81.33	60.67	65.33	52.67	59.33	58.00	62.89	136.56	123.33	168.34	105.67	95.00	118.67	130.09
Mean	58.49	55.91	51.00	44.24	41.91	43.21		110.85	117.96	122.6	93.55	100.91	106.90	
CD (5%)	G						1.21	G						1.43
	P						0.87	P						1.22
	G x P						2.97	G x P						3.50

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

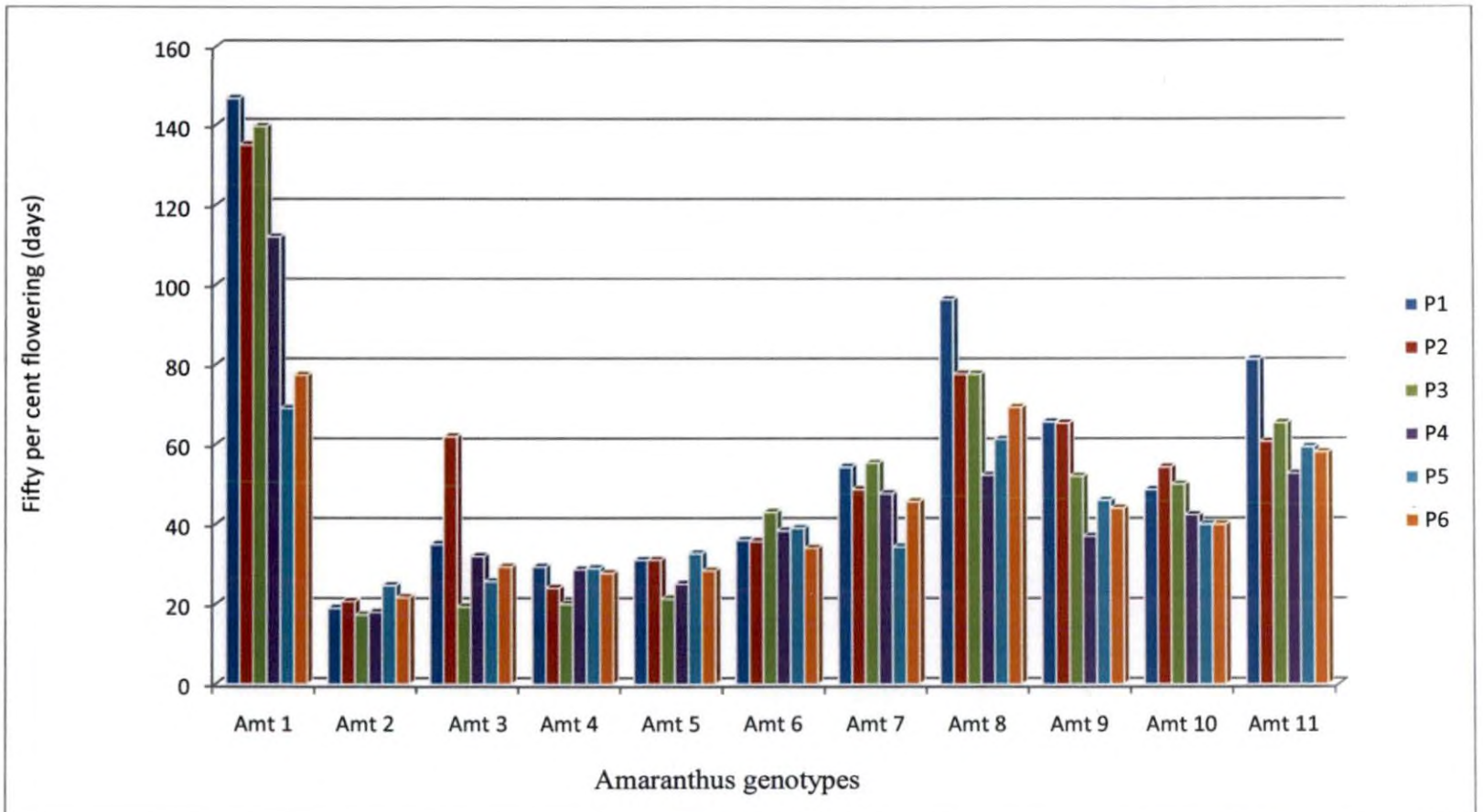

Fig. 2. Effect of genotypes, planting dates and their interactions on fifty per cent flowering of amaranthus

4.1.2.2 Yield per Plant

Significant variation was observed for yield per plant among genotypes for all the plantings. During March planting, Amt 1 (784.56 g) recorded highest yield per plant followed by Amt 8 (588.84 g) and Amt 11 (493.98 g). It was lowest for Amt 3 (132.83 g). In May planting, maximum yield per plant was obtained for Amt 1 (325.96 g) followed by Amt 6 (250.50 g) and Amt 8 (209.94 g). It was minimum for Amt 2 (138.52 g). When planted in July, Amt 1 (385.81 g) recorded highest yield per plant followed by Amt 8 (317.93 g) and Amt 9 (246.96 g). It was lowest for Amt 3(69.84 g). For September planting, yield per plant was maximum for Amt 1 (501.65 g) followed by Amt 6 (363.34 g) and Amt 11 (331.34 g). It was minimum for Amt 3 (66.64 g). Maximum yield per plant was observed during November planting for Amt 11 (237.34 g) followed by Amt 1 (220.14 g). It was minimum for Amt 3 (77.47 g). During January planting, maximum yield per plant was recorded in Amt 1 (419.93 g) followed by Amt 11 (385.26 g) and Amt 8 (365.62 g). It was minimum in Amt 3 (90.34 g).

Pooled analysis for the six planting times showed significant G x E interaction for yield per plant in amaranthus (Table 7 and Figure 3). Among genotypes, Amt 1 (439.67 g) had maximum yield followed by Amt 8 (320.88 g) and Amt 11 (313.05 g). Lowest yield per plant was recorded for Amt 3 (100.29 g).

Significant difference observed among different planting dates. Highest yield per plant was in March planting (P1- 346.77 g) followed by September planting (P4- 231.50 g). The lowest yield was recorded in November planting (P5- 152.01 g).

Interaction effects also varied significantly. Maximum yield per plant was obtained for Amt 1 during March planting (784.56 g) followed by Amt 8 during March planting (588.84 g) and Amt 1 (501.65 g) during September planting. Yield per plant was minimum for Amt 3 during September planting (66.64 g) which is on par with Amt 3 during July planting (69.84 g).

Table 7. Effect of genotypes, planting dates and their interaction on yield per cutting and yield per plant of amaranthus, g

Genotypes	Yield per cutting							Yield per plant						
	P1	P2	P3	P4	P5	P6	Mean	P1	P2	P3	P4	P5	P6	Mean
Amt 1	112.08	54.33	64.30	100.33	55.04	104.98	81.84	784.56	325.96	385.81	501.65	220.14	419.93	439.67
Amt 2	221.54	138.52	41.78	90.43	45.23	130.10	111.27	221.54	138.52	83.55	90.43	90.46	130.10	125.77
Amt 3	66.42	54.86	34.92	66.64	38.74	90.34	58.66	132.83	164.59	69.84	66.64	77.47	90.34	100.29
Amt 4	134.07	143.15	45.82	116.19	43.75	87.59	95.09	134.07	143.15	91.64	116.19	131.25	175.18	131.91
Amt 5	135.12	175.41	40.42	123.66	43.59	56.09	95.72	135.12	175.41	81.17	123.66	131.02	112.17	126.43
Amt 6	202.24	125.26	70.11	181.67	95.60	95.35	128.37	404.48	250.50	210.34	363.34	191.20	190.70	268.43
Amt 7	135.40	94.33	76.42	73.13	45.29	98.03	87.10	270.79	188.65	228.93	219.85	135.86	196.05	206.69
Amt 8	147.21	69.98	79.48	88.77	58.87	121.87	94.36	588.84	209.94	317.93	266.31	176.62	365.62	320.88
Amt 9	143.89	60.31	82.32	71.73	53.24	54.07	77.59	431.72	180.92	246.96	215.20	159.72	162.22	232.79
Amt 10	108.26	54.42	68.65	83.94	40.34	79.07	72.45	216.52	163.27	205.95	251.81	121.03	237.21	199.30
Amt 11	164.66	65.81	77.63	110.45	79.11	128.42	104.35	493.98	197.44	232.91	331.34	237.34	385.26	313.05
Mean	142.81	94.22	61.99	100.63	54.44	95.08		346.77	194.4	195.90	231.50	152.01	224.07	
CD (5%)	G						1.12	G						2.48
	P						1.06	P						2.53
	G x P						2.75	G x P						6.08

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

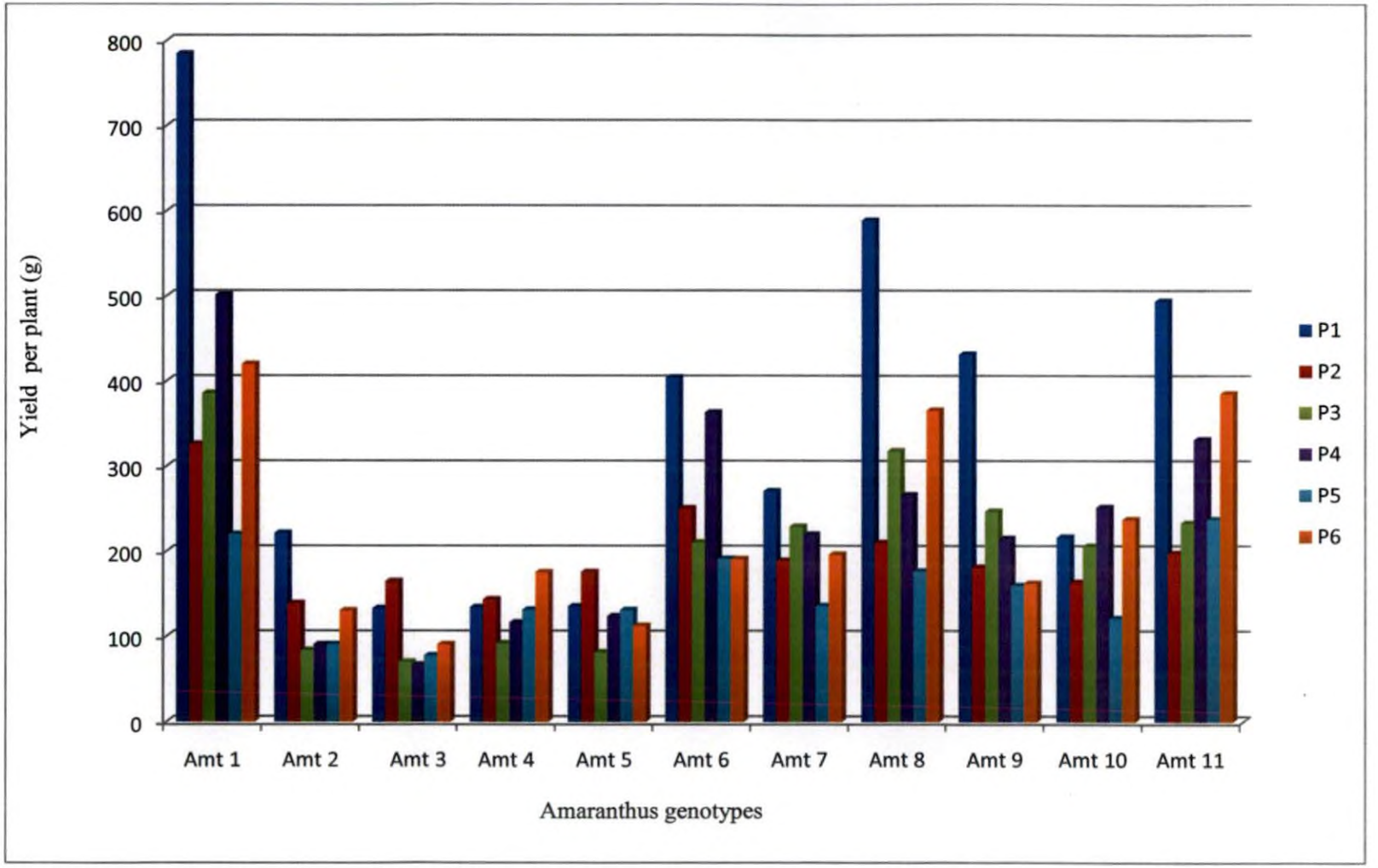

Fig. 3 Effect of genotypes, planting dates and their interaction on yield per plant of amaranthus

4.1.2.3 Yield per Plot

Significant variation was observed for yield per plot among genotypes for all the plantings. During March planting, maximum yield per plot was recorded for Amt 1 (8.83 kg) and minimum for Amt 2 (1.22 kg). In May planting, yield per plot was maximum for Amt 1 (4.89 kg) and minimum for Amt 2 (2.08 kg). When planted on July, it was observed that Amt 1 (5.79 kg) obtained maximum vegetable yield per plot and it was lowest for Amt 3 (1.05 kg). For September planting, Amt 1 (7.52 kg) obtained maximum yield per plot and lowest was for Amt 3 (1.00 kg). November planting observed highest yield per plot for Amt 11 (3.56) and lowest was for Amt 3 (1.16 kg). During January planting, yield per plot was obtained maximum for Amt 1 (6.30 kg) and minimum was for Amt 3 (1.35 kg).

Pooled analysis of 11 genotypes over six planting times showed significant G x E interaction for yield per plot in amaranthus (Table 8). Among genotypes, maximum yield per plot was recorded for Amt 1 (6.10 kg) followed by Amt 8 (4.45 kg) and Amt 11 (4.39 kg). Lowest yield was recorded for Amt 3 (1.42 kg).

Among planting dates, maximum yield per plot was obtained from March planting (P1- 3.76 kg) followed by September planting (P4- 3.47 kg) and minimum was obtained from November planting (P5- 2.28 kg).

Significant difference was obtained between G X P interaction also. Highest yield per plot was obtained for Amt 1 during March planting (8.83 kg) followed by Amt 1 during September planting (7.52 kg). Lowest yield per plant was observed for Amt 3 during September (1.00 kg) which is on par with Amt 2 planted July (1.05 kg), Amt 2 planted March (1.22 kg), Amt 2 planted September (1.36 kg), Amt 2 planted November (1.36 kg), Amt 5 planted July (1.22 kg), Amt 3 planted January (1.36 kg).

4.1.2.4 Leaf Weight

Significant variation was observed for leaf weight among genotypes for all the plantings.

During March planting, maximum leaf weight was recorded for Amt 1 (506.97 g) followed by Amt 8 (368.05 g) and Amt 11 (276.16 g). It was lowest for Amt 5 (61.55 g). In May planting, leaf weight was observed maximum for Amt 1 (183.17 g) followed by Amt 8 (106.48 g) and Amt 6 (97.18 g). It was recorded lowest for Amt 2 (38.39). When planted on July, it was observed that Amt 1 (274.79 g) obtained maximum leaf weight followed by Amt 8 (211.34 g) and Amt 9 (155.18 g). It was minimum for Amt 2 (37.72 g). For September planting, Amt 1 (236.53 g) obtained maximum leaf weight followed by Amt 11 (145.16 g) and Amt 8 (144.13 g). It was lowest for Amt 2 (27.23 g). When planting was done in November, highest value for leaf weight was recorded by Amt 1 (147.49 g) followed by Amt 11 (134.49 g) and Amt 8 (113.07 g). The lowest value was recorded for Amt 2 (42.18 g). January planting observed maximum leaf weight for Amt 1 (303.57 g) followed by Amt 8 (242.03 g) and Amt 11 (210.03 g). It was minimum for Amt 2 (41.76 g).

Pooled analysis of genotypes over six planting times showed significant G x E interaction for leaf weight in amaranthus (Table 8). Among genotypes, maximum leaf weight was for Amt 1 (275.42 g) followed by Amt 8 (197.51 g), Amt 11 (167.29 g) and lowest for Amt 2 (44.61 g) followed by Amt 5 (54.56).

Among planting dates, highest leaf weight was recorded for March planting (P1- 187.82 g) followed by January planting (P6- 129.42 g) and least weight was for May planting (P2- 86.41 g).

Interaction effects were significantly different for leaf weight between genotypes and planting time. Maximum leaf weight was observed for Amt 1 planted during March (506.97 g) followed by Amt 8 planted in March (368.05 g). Leaf weight was minimum in Amt 2 during September planting (27.23 g) followed by Amt 3 during September planting (34.87 g).

4.1.2.5 Stem Weight

Significant variation was observed for stem weight among genotypes for all the plantings. During March planting, maximum stem weight was for Amt 1

Table 8. Effect of genotypes, planting dates and their interaction on yield per plot and leaf weight of amaranthus

Genotypes	Yield per plot (kg)							Leaf weight (g)						
	P1	P2	P3	P4	P5	P6	Mean	P1	P2	P3	P4	P5	P6	Mean
Amt 1	8.83	4.89	5.79	7.52	3.30	6.30	6.10	506.97	183.173	274.79	236.53	147.49	303.57	275.42
Amt 2	1.22	2.08	1.25	1.36	1.36	1.95	1.49	80.35	38.39	37.72	27.23	42.18	41.76	44.61
Amt 3	1.49	2.47	1.05	1.00	1.16	1.36	1.42	95.61	80.93	42.97	34.87	53.86	55.80	60.67
Amt 4	1.51	2.15	1.37	1.74	1.97	2.63	1.89	65.42	50.48	55.17	40.58	64.57	83.44	59.94
Amt 5	1.52	2.63	1.22	1.85	1.97	1.68	1.81	61.55	61.64	44.90	43.33	63.24	52.68	54.56
Amt 6	4.55	3.76	3.16	5.45	2.87	2.86	3.77	148.38	97.18	125.87	130.57	92.70	103.36	116.34
Amt 7	3.05	2.83	3.43	3.30	2.04	2.94	2.93	150.68	85.64	143.48	94.02	81.16	110.16	110.86
Amt 8	6.62	3.15	4.77	3.99	2.65	5.48	4.45	368.05	106.48	211.34	144.11	113.07	242.03	197.51
Amt 9	4.86	2.71	3.70	3.23	2.40	2.43	3.22	196.49	75.60	155.18	107.21	95.74	97.29	121.25
Amt 10	2.44	2.45	3.09	3.78	1.82	3.56	2.85	116.29	77.45	140.74	105.43	77.18	123.48	106.76
Amt 11	5.56	2.96	3.49	4.97	3.56	5.78	4.39	276.16	93.55	144.37	145.16	134.49	210.03	167.29
Mean	3.76	2.92	2.94	3.47	2.28	3.36		187.82	86.41	125.14	100.82	87.79	129.42	
CD (5%)	G						0.15	G						1.63
	P						0.14	P						1.14
	G x P						0.37	G x P						3.98

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

(277.59 g) and minimum for Amt 3 (37.22 g). In May planting, stem weight was maximum for Amt 6 (153.32 g) and least value for Amt 3 (83.66 g). When planted on July, stem weight was maximum in Amt 1 (111.01 g) and Amt 3 (26.87 g) the least. For September planting, maximum stem weight was obtained for Amt 1 (265.78 g) and minimum for Amt 3 (31.78 g). Maximum stem weight during November planting was recorded in Amt 11 (102.85 g) and minimum was in Amt 3 (23.61 g). During January planting, Amt 11 (175.23 g) had maximum stem weight and Amt 3 (34.54 g) the least.

Pooled analysis for the six planting times showed significant G x E interaction for stem weight in amaranthus (Table 9). Among genotypes, Amt 1 (164.36 g) recorded maximum stem weight which is followed by Amt 6 (152.08 g) and Amt 11 (145.75 g). Amt 3 (39.61 g) recorded minimum stem weight.

Significant difference observed among planting dates also. Stem weight was maximum for crop planted during March (158.95 g) followed by crop planted during September (130.73 g) and lowest stem weight was recorded in November planting (64.22 g).

Interaction effects showed significant effects for stem weight in amaranthus. Amt 1 during March planting (277.59 g) recorded maximum followed by Amt 1 during September planting (265.78 g) and Amt 6 during March planting (256.10 g). The lowest stem weight was recorded for Amt 3 during November planting (23.61 g).

4.1.2.6 Leaf/ Stem Ratio

Significant variation was observed for leaf/stem ratio among genotypes for all the plantings. During March planting, maximum leaf/stem ratio was observed for Amt 3 (2.57) and minimum for Amt 2 (0.56). In May planting, leaf/stem ratio was maximum for Amt 1 (1.28) and least for Amt 2 (0.38). When planted on July, leaf/stem ratio was maximum in Amt 1 (2.47). The least value was recorded in Amt 2 (0.82). For September planting, maximum leaf/stem ratio was obtained for Amt 8 (1.18) and minimum for Amt 2 (0.43). Leaf/stem ratio recorded during

November planting was maximum in Amt 3 (1.51) and minimum in Amt 2 (0.58). During January planting, Amt 1 (2.60) obtained maximum leaf/stem ratio and Amt 2 (0.47) the least.

Pooled analysis showed significant G x E interaction for leaf/stem ratio in amaranthus (Table 9 and Figure 4). Among genotypes, leaf / Stem ratio was maximum for Amt 1 (1.74) followed by Amt 8 (1.50). Lowest leaf/ stem ratio (0.54) was observed for Amt 2.

Significant difference was not observed for leaf / stem ratio among different planting dates.

Interaction effects were highly significant for leaf/ stem ratio in amaranthus. Highest leaf/ stem ratio was recorded (2.60) in Amt 1 during January planting which is on par with Amt 3 during March planting (2.57) and Amt 1 during July planting (2.47). The lowest value was recorded for Amt 2 during May planting (0.38).

4.1.2.7 Seed Yield per Plant

Significant variation was observed for seed yield per plant among genotypes for all the plantings. During March planting, maximum seed yield per plant was observed for Amt 6 (21.32 g) and minimum for Amt 3 (4.21 g). In May planting, seed yield per plant was maximum for Amt 6 (9.54 g) and least for Amt 3 (4.48 g). When planted on July, seed yield per plant was maximum in Amt 1 (13.64 g) and the least in Amt 3 (4.52 g). For September planting, maximum seed yield per plant was for Amt 6 (12.12 g) and minimum for Amt 3 (5.45 g). Seed yield per plant for November planting, recorded maximum in Amt 6 (16.77 g) and minimum in Amt 3 (3.81 g). During January planting, Amt 6 (12.42 g) obtained maximum seed yield per plant and Amt 3 (4.12 g) the least.

Pooled analysis for the six planting dates showed significant G x E interaction for seed yield per plant in amaranthus (Table 10 and Figure 5). Among genotypes, Amt 6 (13.78 g) gave maximum seed yield per plant followed by

Table 9. Effect of genotypes, planting dates and their interaction on stem weight and leaf/stem ratio of amaranthus

Genotypes	Stem weight (g)							Leaf/stem ratio						
	P1	P2	P3	P4	P5	P6	Mean	P1	P2	P3	P4	P5	P6	Mean
Amt 1	277.59	142.79	111.01	265.78	72.65	116.36	164.36	1.82	1.28	2.47	0.89	1.35	2.60	1.74
Amt 2	141.19	100.14	45.83	63.20	48.28	88.33	81.16	0.567	0.38	0.82	0.43	0.58	0.47	0.54
Amt 3	37.22	83.66	26.87	31.78	23.61	34.54	39.61	2.57	0.97	1.60	1.10	1.51	1.62	1.56
Amt 4	68.64	92.67	36.47	75.61	66.68	91.74	71.97	0.96	0.55	1.51	0.54	0.65	0.91	0.85
Amt 5	73.57	113.77	36.27	80.33	67.77	59.49	71.87	0.84	0.54	1.24	0.54	0.62	0.89	0.78
Amt 6	256.10	153.32	84.46	232.77	98.50	87.34	152.08	0.58	0.64	1.49	0.56	0.63	1.18	0.85
Amt 7	120.10	103.01	85.45	125.83	54.70	85.89	95.83	1.26	0.83	1.68	0.75	0.98	1.28	1.13
Amt 8	220.79	103.46	106.59	122.20	63.55	123.59	123.36	1.67	1.03	2.02	1.18	1.16	1.96	1.50
Amt 9	235.23	105.32	91.78	107.99	63.97	64.93	111.54	0.83	0.72	1.69	1.00	1.02	1.50	1.13
Amt 10	100.23	85.82	65.21	146.38	43.85	113.74	92.54	1.16	0.90	2.16	0.72	1.18	1.09	1.20
Amt 11	217.82	103.89	88.54	186.18	102.85	175.23	145.75	1.27	0.90	1.63	0.78	0.88	1.20	1.11
Mean	158.95	107.99	70.77	130.73	64.22	94.65		1.23	0.79	1.67	0.77	0.96	1.34	
CD (5%)	G						1.30	G						0.07
	P						2.20	P						NS
	G x P						3.18	G x P						0.19

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

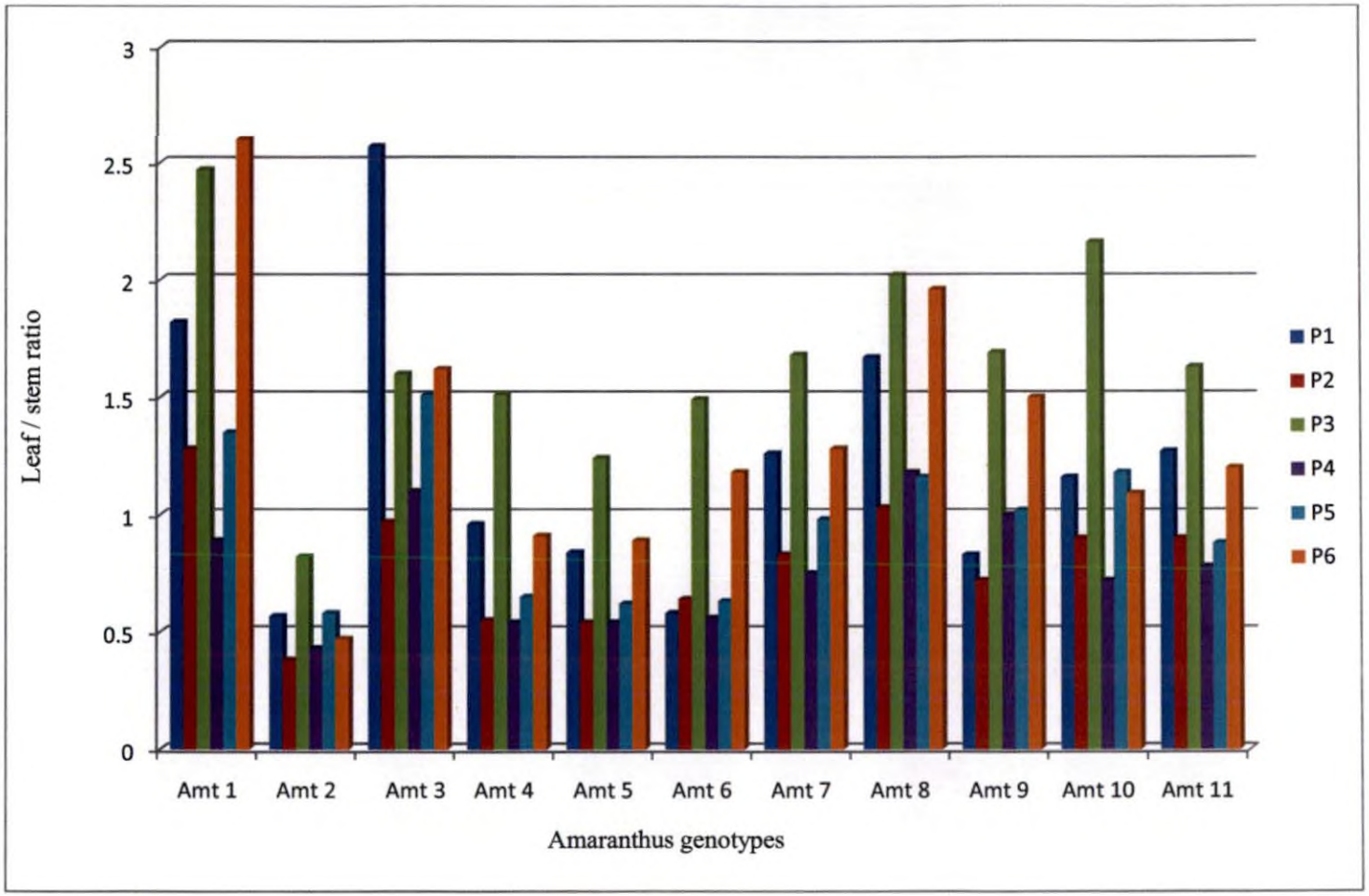

Fig. 4. Effect of genotypes, planting dates and their interactions on leaf / stem ratio of amaranthus

Amt 11 (11.76 g). Lowest seed yield per plant was obtained in Amt 3 (4.43 g) followed by Amt 4 (6.92 g).

Effect of planting dates exerted significant effects for seed yield per plant. Maximum seed yield per plant (11.00 g) was obtained in March planting (P1) followed by November planting (P5- 9.15 g). May planting (P2) recorded lowest seed yield per plant (7.40 g).

Significant difference was observed for G X P interactions also. Amt 6 during March planting results in maximum seed yield per plant (21.32 g) followed by Amt 11 during March planting (17.38 g). Lowest value was recorded for Amt 3 during November planting (3.81 g).

4.1.3 Incidence of Pest and Diseases

4.1.3.1 Leaf Blight Intensity

Significant variation was observed for leaf blight intensity among genotypes for all the plantings.

During March planting, no leaf blight incidence was noticed for Amt 1, Amt 4, Amt 9 and Amt 3. Maximum intensity was in Amt 5 (2.63). In May planting, leaf blight intensity was minimum for Amt 11 (2.34) and maximum for Amt 1 (4.23). When planted on July, leaf blight intensity was minimum for Amt 11 (3.40) and maximum for Amt 2 (5.08). For September planting, leaf blight intensity was nil for Amt 11, A 5, Amt 6, Amt 4 and maximum value Amt 10 (3.06). Leaf blight intensity was recorded for November planting and it was observed minimum for Amt 11 (2.27) and maximum value Amt 1 (3.38). During the January planting, leaf blight intensity was minimum for Amt 3 (1.80) and maximum value for Amt 1 (3.92).

Pooled analysis for the six planting dates showed significant G x E interaction for leaf blight intensity in amaranthus (Table 11 and Figure 6). Among genotypes, Amt 11 (2.28) showed least susceptible to leaf blight which is

Table 10. Effect of genotypes, planting dates and their interaction on seed yield of amaranthus, g

Genotypes	Seed yield /plant						
	P1	P2	P3	P4	P5	P6	Mean
Amt 1	9.26	8.30	13.64	9.08	8.74	8.15	9.53
Amt 2	7.25	7.76	7.59	7.84	7.08	6.97	7.42
Amt 3	4.21	4.48	4.52	5.45	3.81	4.12	4.43
Amt 4	7.14	6.82	6.50	7.18	6.60	7.26	6.92
Amt 5	12.17	9.21	7.47	8.32	9.22	8.25	9.11
Amt 6	21.32	9.54	10.51	12.12	16.77	12.42	13.78
Amt 7	8.69	7.62	9.94	10.14	8.48	9.26	9.02
Amt 8	9.46	5.17	8.37	9.71	8.81	8.16	8.28
Amt 9	9.49	8.05	8.47	9.25	9.96	7.68	8.82
Amt 10	14.55	6.97	11.05	9.23	8.86	8.59	9.87
Amt 11	17.38	7.46	11.08	10.97	12.30	11.33	11.76
Mean	10.99	7.4 0	9.01	9.03	9.15	8.38	
CD (5%)	G						0.14
	P						0.16
	G x P						0.34

*P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

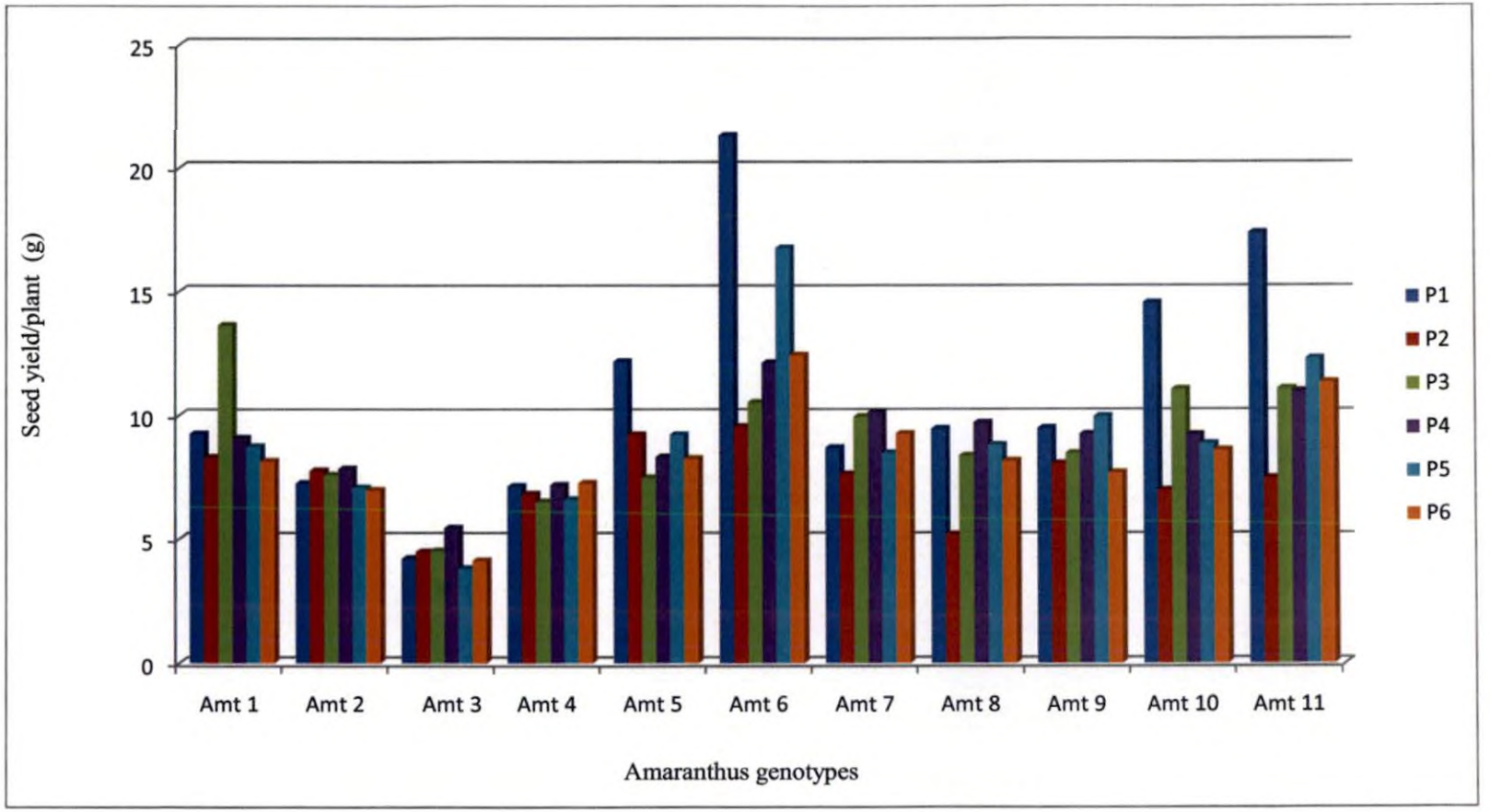

Fig. 5. Effect of genotypes, planting dates and their interactions on seed yield/ plant of amaranthus

on par with Amt 4 (2.57). The genotype Amt 8 (3.22) was highly susceptibile to leaf blight intensity.

High resistance to leaf blight disease was recorded during March planting (P1- 1.72) whereas, high susceptibility was noticed in July planting (P3- 4.35).

Interaction effects were significant for leaf blight intensity in amaranthus. No leaf blight incidence was noticed for Amt 1, Amt 3, Amt 4, Amt 9 planted during March and Amt 4, Amt 5, Amt 6, Amt 11 planted during September. It was high for Amt 2 planted July (5.08) which is on par with Amt 5, Amt 8, Amt 3, Amt 9, Amt 10, Amt 7, Amt 4 planted during July and Amt 8 planted during May.

4.1.3.2 Leaf Webber Incidence

There was no significant difference among genotypes for six separate experiments. The incidence was low i e, <25%.

Pooled analysis of 11 genotypes over six planting times showed no significant G x E interaction for leaf webber incidence in amaranthus (Table 12).

4.1.4 Quality Characters

The important nutrients and antinutrients in amaranthus were analysed. It was observed that nutrients like protene, β carotene, vitamin C and antinutrients like oxalates and nitrates were not influenced by genotypes (Table 13).

4.1.5 Weather Parameters

The weather parameters during the cropping period from March 2013 to May 2014 is given in Appendix VIII.

4.2 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The population means, range, genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV), heritability and genetic advance for 17 characters of amaranthus were studied and are presented in Table 14.

Table 11. Effect of genotypes, planting dates and their interaction on leaf blight intensity of amaranthus

Genotypes	Leaf blight intensity						
	P1	P2	P3	P4	P5	P6	Mean
Amt 1	0 .00(1.00)	16.93 (3.93)	13.53 (3.45)	6.71 (2.63)	10.41 (3.38)	14.37 (3.50)	2.92
Amt 2	2.79 (1.95)	9.11 (3.18)	24.77 (5.08)	3.49 (2.11)	9.54 (3.25)	10.55 (3.40)	3.16
Amt 3	0.00 (1.00)	7.62 (2.94)	20.44 (4.63)	8.31 (3.05)	5.25 (2.50)	2.23 (1.80)	2.65
Amt 4	0.00 (1.00)	7.28 (2.88)	16.86 (4.23)	0.00 (1.00)	9.34 (3.21)	8.67 (3.11)	2.57
Amt 5	5.94 (2.63)	5.42 (2.53)	24.7 (5.07)	0.00 (1.00)	5.64 (2.58)	8.47 (3.08)	2.81
Amt 6	3.14 (2.03)	8.44 (3.07)	12.8 (3.73)	0.00 (1.00)	7.93 (2.99)	6.41 (2.72)	2.59
Amt 7	4.67 (2.38)	4.86 (2.42)	17.87 (4.34)	8.03 (3.00)	8.64 (3.10)	5.58 (2.56)	2.97
Amt 8	3.32 (2.08)	15.05 (4.01)	22.13 (4.80)	7.12 (2.85)	6.21 (2.68)	7.34 (2.89)	3.22
Amt 9	0.00 (1.00)	10.41 (3.38)	20.4 (4.63)	5.87 (2.62)	7.35 (2.89)	8.93 (3.15)	2.94
Amt 10	2.25 (1.80)	8.58 (3.10)	18.74 (4.44)	8.37 (3.06)	8.11 (3.02)	12.81 (3.72)	3.19
Amt 11	3.00 (2.00)	4.49 (2.34)	10.59 (3.40)	0.00 (1.00)	4.17 (2.27)	6.00(2.65)	2.28
Mean	1.72	3.07	4.35	2.12	2.87	2.96	
CD (5%)	G						(0.32)
	P						(0.25)
	G x P						(0.78)

* Data in parenthesis are transformed values

**P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

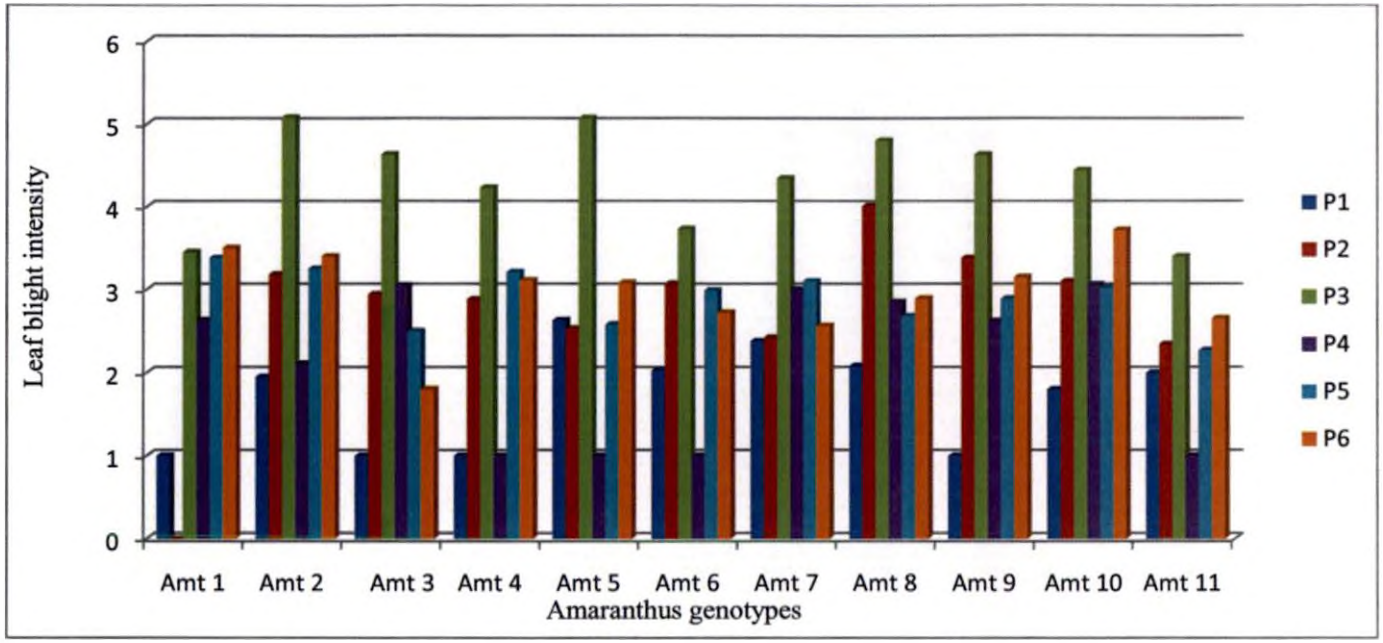

Fig. 6. Effect of genotypes, planting dates and their interactions on leaf blight intensity of amaranthus.

Table 12. Effect of genotypes, planting dates and their interaction on leaf webber incidence of amaranthus

Genotypes	Leaf webber incidence						
	P1	P2	P3	P4	P5	P6	Mean
Amt 1	0.00 (1.00)	0.11 (1.05)	0.00 (1.00)	0.00 (1.00)	0.38 (1.18)	0.2 (1.05)	1.04
Amt 2	0.24 (1.11)	0.2 (1.10)	0.16 (1.08)	0.08 (1.04)	0.24 (1.11)	1.99 (2.97)	1.24
Amt 3	0.16 (1.07)	0.10 (1.05)	0.24 (1.11)	0.00 (1.00)	0.16 (1.08)	0.31 (1.15)	1.08
Amt 4	0.16(1.07)	0.43 (1.19)	0.16 (1.07)	0.00 (1.00)	0.62 (1.27)	0.00 (1 .00)	1.1
Amt 5	0.57 (1.25)	0.21 (1.10)	0.00 (1.00)	0.23 (1.11)	0.74 (1.32)	0.16 (1.08)	1.14
Amt 6	0.16 (1.08)	0.32 (1.15)	0.32 (1.14)	0.16 (1.07)	0.41 (1.19)	0.08 (1.04)	1.11
Amt 7	0.57 (1.25)	0.21 (1.1)	0.00 (1.00)	0.24 (1.11)	0.08 (1.04)	0.55 (1.25)	1.13
Amt 8	0.13 (1.06)	0.10 (1.05)	0.00 (1.00)	0.00 (1.00)	0.89 (1.38)	0.25 (1.12)	1.1
Amt 9	0.00 (1.00)	0.00 (1.00)	0.16 (1.08)	0.08 (1.04)	0.06 (1.03)	0.00 (1.00)	1.03
Amt 10	0.16 (1.08)	0.00 (1.00)	0.16 (1.07)	0.00 (1.00)	0.16 (1.08)	0.08 (1.04)	1.05
Amt 11	0.16 (1.07)	0.00 (1 .00)	0.08 (1.04)	0.08 (1.04)	1.15 (1.47)	0.16 (1.08)	1.12
Mean	1.10	1.07	1.05	1.04	1.19	1.16	
CD (5%)	G						NS
	P						NS
	G x P						NS

* Data in parenthesis are transformed values

**P1- March planting, P2- May planting, P3- July planting, P4- September planting, P5- November planting, P6- January planting

Table 13. Mean performance of genotypes for quality characters

Genotypes	β carotene (µg/100g)	Vitamin C (mg/100g)	Oxalate (%)	Nitrate (%)	Protein (%)
Amt 1	2818.99	77.73	0.42	0.73	4.15
Amt 2	2868.53	78.80	0.48	0.72	4.26
Amt 3	2840.13	77.33	0.58	0.75	4.07
Amt 4	2831.85	76.33	0.62	0.63	4.09
Amt 5	2885.85	78.67	0.87	0.82	4.12
Amt 6	2825.74	76.33	0.41	0.65	4.31
Amt 7	2890.15	78.80	0.54	0.62	4.28
Amt 8	2855.63	77.67	0.74	0.74	4.44
Amt 9	2870.36	78.65	0.55	0.78	4.59
Amt 10	2873.06	79.13	0.61	0.69	4.45
Amt 11	2807.48	77.98	0.39	0.58	4.15
CD	NS	NS	NS	NS	NS

Plant height ranged from 18.19 cm to 84.94 cm with a mean of 49.00 cm. The GCV was 26.70 and PCV was 29.44. Heritability was as high as 82.78 per cent while genetic advance was 49.90.

Stem girth showed a range of 3.50-8.49 cm and the mean was 5.07 cm. GCV was 7.78 and PCV was 13.89. Heritability was 31.67 while genetic advance was 8.98

The leaf length had a general mean of 15.42 cm and the range was 10.73-20.55 cm. PCV was 8.68 and GCV was 11.90. It had a heritability of 53.54% and genetic gain of 13.05.

Leaf width ranged from 6.00 to 13.24 cm and 9.95 cm being the overall mean. PCV was 11.19 and GCV was 14.61. Heritability was low (59.45 percent). Genetic gain as percentage of mean was very low 17.64.

The branches per plant had a mean of 9.76 and the range was from 6.11 to 15.22. The PCV was 17.98 and GCV was 7.49. Heritability was very low (17.61 per cent). Genetic gain as percentage of mean was very low (6.42).

Days to first flowering ranged from 13.00 to 124.33 days. The general mean was 39.84 days. It recorded a PCV of 62.61 and a GCV of 58.08. Very high heritability of 86.43 per cent and genetic gain was 110.99 were noticed.

Days to fifty per cent flowering ranged from 17.33 to 146.67 days. The general mean was 49.13 days. It recorded PCV of 58.27 and GCV of 53.64. Very high heritability of 85.67 per cent and genetic gain 101.73 were recorded.

Days to seed maturity showed a range of 54.00 to 243.22 days and the mean was 109.52 days. It recorded a GCV of 38.41 and PCV of 40.98. It had a very high heritability of 88.78 per cent and genetic gain of 74.17.

Yield per cutting exhibited a mean of 91.53 g which ranged from 34.92 to 221.54 g. GCV was 19.90 and PCV was 34.96. Heritability was recorded as 32.86 per cent and genetic gain was 23.34.

Yield per plant ranged from 69.84 to 784.57 g with a general mean of 224.11 g. The GCV was 46.18 and PCV was 55.46. Heritability was 69.12% and genetic gain was 79.22.

Yield per plot ranged from 1.00 to 8.83 kg with a general mean of 3.36 kg. The GCV was 48.21 and PCV was 68.16. The heritability was 69.98 % and genetic gain was 79.82.

Leaf weight ranged from 27.23 to 506.97 g with a mean of 119.57 g. The GCV was 58.43 and PCV was 68.03. The heritability was 74.14 % and genetic gain was 103.37.

Stem weight exhibited a mean of 104.55 g with a range from 23.61 to 277.59 g. The GCV was 36.28 and PCV was 49.06. The heritability was 71.56 and genetic gain was 55.27.

Leaf / stem ratio ranged from 0.38 to 2.61 with a mean of 1.21. The GCV was 32.03 and PCV was 38.04. The heritability was 71.56 % and genetic gain was 55.54.

Seed yield per plant exhibited a mean of 8.99 g and ranged from 3.81 to 21.32. The GCV was 26.78 and PCV was 33.38. The heritability was 64.69 and genetic gain was 44.25.

Leaf blight intensity ranged from 1.00 to 5.08 with a mean of 2.54. The GCV was 12.61 and PCV was 26.36. The heritability was 23.68 and genetic gain was 12.42.

Leaf webber incidence ranged from 1.00 to 1.99 with a mean of 0.99. The GCV was 1.27 and PCV was 19.50. The heritability was -0.40 and genetic gain was -0.17.

4.3 CORRELATION STUDIES

The phenotypic, genotypic and environmental correlation among 16 characters were worked out and presented in Tables 15 and Table 16.

Table 14. GCV, PCV, Heritability and Genetic Advance in amaranthus

Characters	Range	Mean	GCV (%)	PCV (%)	Heritability (%)	Genetic Advance (%)	Genetic Advance as percentage of mean
Plant height (cm)	18.19- 84.94	49.00	26.70	29.44	82.78	24.45	49.90
Stem girth (cm)	3.50- 8.49	5.07	7.78	13.89	31.67	0.46	8.98
Leaf length (cm)	10.73-20.55	15.42	8.68	11.90	53.54	2.01	13.05
Leaf width (cm)	6.00-13.24	9.95	11.19	14.61	59.45	1.75	17.64
Branches /plant	6.11-15.22	9.76	7.49	17.98	17.61	0.63	6.42
Days for first flowering	13.00-124.33	39.84	58.08	62.61	86.43	44.21	110.99
Days for 50% flowering	17.33-146.67	49.13	53.64	58.27	85.67	49.98	101.73
Days for seed maturity	54.00-243.22	109.52	38.41	40.98	88.78	81.23	74.17
Yield/ cutting (g)	34.92-221.54	91.53	19.90	34.96	32.86	21.36	23.34
Yield/ plant (g)	69.84-784.56	224.11	46.18	55.46	69.12	177.54	79.22
Yield/ plot (kg)	1.00-8.83	3.36	48.21	68.16	69.98	142.12	79.82
Leaf weight (g)	27.23- 506.97	119.57	58.43	68.03	74.14	123.60	103.37
Stem weight (g)	23.61-277.59	104.55	36.28	49.06	55.43	57.79	55.27
Leaf/stem ratio	0.38-2.61	1.21	32.03	38.04	71.56	0.67	55.54
Seed yield/ plant(g)	3.81-21.32	8.99	26.78	33.38	64.69	3.98	44.25
Leaf blight intensity	1.00-5.08	2.54	12.61	26.36	23.68	0.70	12.42
Leaf webber incidence	1.00-1.99	0.99	1.27	19.50	-0.40	-0.07	-0.17

4.3.1 Phenotypic Correlation Coefficients

4.3.1.1 *Correlation Between Yield and Other Characters*

Yield per plant showed significant positive correlation with leaf length (0.3321), leaf width (0.6416), days to first flowering (0.8257), days to 50% flowering (0.8273), days to seed maturity (0.8296), yield per cutting (0.2225), leaf weight (0.9611), stem weight (0.3472).

4.3.1.2 *Correlation Among the Yield Component*

Plant height had high significant positive correlation with stem girth (0.5357), branches per plant (0.3460), yield per cutting (0.5963), yield per plant (0.6990), stem weight (0.2078). It exhibited significant negative correlation with leaf width (-0.1432), days to first flowering (-0.3870), days to fifty per cent flowering (-0.3845), days to seed maturity (-0.2829), leaf/stem ratio (-0.6613).

Stem girth showed significant positive correlation with plant height (0.5357), branches per plant (0.2307), yield per cutting (0.4418), stem weight (0.2541). It was negatively correlated with leaf/ stem ratio (-0.3848).

Leaf length has strong positive correlation with leaf width (0.6616), days to first flowering (0.2444), days to fifty per cent flowering (0.2515), days to seed maturity (0.3132), yield per plant (0.3321), leaf weight (0.3088), stem weight (0.3149), leaf/ stem ratio (0.2173).

Leaf width exhibited positive correlation with leaf length (0.6616), days to first flowering (0.5085), days to fifty per cent flowering (0.5118), days to seed maturity (0.5616), yield per cutting (0.1622), yield per plant (0.6416), leaf weight (0.6372), stem weight (0.5413), leaf/ stem ratio (0.3273). It was negatively correlated with plant height (-0.1432) and branches per plant (-0.1430).

Branches per plant had significant positive correlation with plant height (0.3460), stem girth (0.2307), yield per cutting (0.3870). It was negatively correlated with leaf width (-0.1430), days to first flowering (-0.3537), days to

fifty per cent flowering (-0.3327), days to seed maturity (-0.2855), leaf weight (-0.1496), leaf/ stem ratio (-0.1586).

Days to first flowering showed significant positive correlation with leaf length (0.2444), leaf width (0.5085), days to fifty per cent flowering (0.9921), days to seed maturity (0.9123), yield per plant (0.8257), leaf/ stem ratio (0.5691) and showed negative correlation with plant height (-0.3870), branches per plant (-0.3537) and yield per cutting (-0.1659).

Days to fifty per cent flowering was positively correlated with leaf length (0.2515), leaf width (0.5118), days to first flowering (0.9921), days to seed maturity (0.9099), yield per plant (0.8273), leaf weight (0.8861), stem weight (0.6001), leaf / stem ratio (0.5601). It was negatively correlated with plant height (-0.3845), branches per plant (-0.3327), yield per cutting (-0.1462).

Days to seed maturity exhibited significant positive correlation with leaf length (0.3132), leaf width (0.5616), days to first flowering (0.9123), days to fifty per cent flowering (0.9099), yield per plant (0.8296), leaf weight (0.8689), stem weight (0.6328), leaf / stem ratio (0.5491). It was negatively correlated with plant height (-0.2829) and branches per plant (-0.2855).

Yield per cutting showed positive correlation with plant height (0.5963), stem girth (0.4418), leaf width (0.1622), branches per plant (0.3870), stem weight (0.4330). It was negatively correlated with days to first flowering (-0.1659), days to fifty per cent flowering (-0.1462), leaf / stem ratio (-0.3526).

Leaf weight was positively correlated with leaf length (0.3088), leaf width (0.6372), days to first flowering (0.8844), days to fifty per cent flowering (0.8861), days to seed maturity (0.8689), stem weight (0.7435), leaf / stem ratio (0.5365) and negatively correlated with plant height (-0.2386), branches per plant (-0.1496).

Stem weight had high significant positive correlation with plant height (0.2078), stem girth (0.2541), leaf length (0.3149), leaf width (0.5413), days to

first flowering (0.5985), days to fifty per cent flowering (0.6001), days to seed maturity (0.6328), yield per cutting (0.4330), leaf weight (0.7435).

Leaf / stem ratio exhibited significant positive correlation with leaf length (0.2173), leaf width (0.3273), days to first flowering (0.5691), days to fifty per cent flowering (0.5601), days to seed maturity (0.5491), leaf weight (0.5365) and significant negative correlation with plant height (-0.6613), stem girth (-0.3848).

4.3.2 Genotypic Correlation Coefficients

Genotypic correlation coefficients were in general higher than phenotypic correlation for the characters under study (Table 16)

4.3.2.1 Correlation Between Yield and Other Characters

Yield per plant showed significant positive correlation with leaf length (0.5189), leaf width (0.7719), days to first flowering (0.9349), days to fifty per cent flowering (0.9372), days to seed maturity (0.9742), leaf weight (0.9788), stem weight (0.9264), leaf/ stem ratio (0.5664).

4.3.2.2 Correlation Among the Yield Components

Plant height had significant correlation with stem girth (0.9153), branches per plant (0.6127), yield per cutting (0.9842), stem weight (0.2812), and negative correlation with leaf length (-0.1463), leaf width (-0.2241), days to first flowering (-0.4256), days to fifty per cent flowering (-0.4201), days to seed maturity (-0.3236), leaf weight (-0.2833), leaf / stem ratio (-0.8456).

Stem girth observed significant positive correlation with plant height (0.9153), branches per plant (0.6623), yield per cutting (1.0040), stem weight (0.4241) and negatively correlated with days to first flowering (-0.2142), days to fifty per cent flowering (-0.1963), leaf/ stem ratio (-0.6975).

Leaf length had strong positive correlation with leaf width (0.8379), days to first flowering (0.4064), days to fifty per cent flowering (0.4102), days to seed maturity (0.4919), leaf weight (0.4843), stem weight (0.5239) and leaf / stem ratio

Table 15. Phenotypic correlation coefficients for growth, yield and yield components.

Character	X 1	X2	X 3	X 4	X 5	X 6	X 7	X 8	X 9	X 10	X 11	X 12	X 13	X 14	X 15	X 16
X 1	1.0000															
X 2	0.5357**	1.0000														
X 3	-0.0563	0.0772	1.0000													
X 4	-0.1432*	0.0886	0.6616**	1.0000												
X 5	0.3460**	0.2307**	-0.0973	-0.1430*	1.0000											
X 6	-0.3870**	-0.1035	0.2444**	0.5085**	-0.3537**	1.0000										
X 7	-0.3845**	-0.0903	0.2515**	0.5118**	-0.3327**	0.9921**	1.0000									
X 8	-0.2829**	-0.0247	0.3132**	0.5616**	-0.2855**	0.9123**	0.9099**	1.0000								
X 9	0.5963**	0.4418**	0.0924	0.1622*	0.3870**	-0.1659*	-0.1462*	-0.0503	1.0000							
X 10	-0.2386**	0.0170	0.3088**	0.6372**	-0.1496*	0.8844**	0.8861**	0.8689**	0.0662	1.0000						
X 11	0.2078**	0.2541**	0.3149**	0.5413**	-0.0598	0.5985**	0.6001**	0.6328**	0.4330**	0.7435**	1.0000					
X 12	-0.6613**	-0.3848	0.2173**	0.3273**	-0.1586*	0.5691**	0.5601**	0.5491**	-0.3526**	0.5365**	-0.0092	1.0000				
X 13	0.4836**	0.3807**	0.2678**	0.2769**	0.0280	0.2124**	0.2162**	0.2741**	0.4315**	0.2589**	0.5315**	-0.2070	1.0000			
X 14	-0.3152**	-0.1461*	-0.0212	-0.0058	-0.1700*	0.1926**	0.1904**	0.1265	-0.1791*	0.0855	-0.0215	0.1326*	-0.1017	1.0000		
X 15	0.0722	0.0217	0.0889	0.0414	0.1078	-0.0725	-0.0545	-0.1138	0.1752*	-0.0567	0.0091	-0.1221	-0.0224	-0.0533	1.0000	
X 16	-0.0699	0.1174	0.3321**	0.6416**	-0.1228	0.8257**	0.8273**	0.8296**	0.2225**	0.9611**	0.8989**	0.3472**	0.3884**	0.0478	-0.0331	1.0000

X 1. Plant height (cm)
X 2. Stem girth (cm)
X 3. Leaf length (cm)
X 4. Leaf width (cm)
X 5. Branches per plant
X 6. Days to first flowering
X 7. Days to 50% flowering
X 8. Days to seed maturity
X 9. Yield per cutting (g)
X 10. Leaf weight (g)
X 11. Stem weight (g)
X 12. Leaf/ stem ratio
X 13. Seed yield per plant
X 14. Leaf blight intensity
X 15. Leaf webber incidence
X 16. Yield per plant

(0.3636). It was negatively correlated with plant height (-0.1463), branches per plant (-0.6923).

Leaf width exhibited positive correlation with leaf length (0.8379), days to first flowering (0.7258), days to fifty per cent flowering (0.7253), days to seed maturity (0.7537), leaf weight (0.7680), stem weight (0.6924), leaf / stem ratio (0.5074) and negative correlation with branches per plant (-0.7258).

Branches per plant had significant positive correlation with plant height (0.6127), stem girth (0.6623), yield per cutting (0.4915) and significant negative correlation with leaf length (-0.6923), leaf width (-0.7929), days to first flowering (-0.6809), days to fifty per cent flowering (-0.6798), leaf weight (-0.6295), stem weight (-0.3708), leaf / stem ration (-0.6724).

Days to first flowering showed significant positive correlation with leaf length (0.4064), leaf width (0.7258), days to fifty per cent flowering (0.9993), days to seed maturity (0.9872), leaf weight (0.9879), stem weight (0.7323), leaf / stem ratio (0.7822). It was negatively correlated with plant height (-0.4256), stem girth (-0.2142), branches per plant (-0.6089), yield per cutting (-0.2142).

Days to fifty per cent flowering was positively correlated with leaf length (0.4102), leaf width (0.7253), days to first flowering (0.9993), days to seed maturity (0.9896), leaf weight (0.9887), stem weight (0.7370), leaf / stem ratio (0.7770). It was negatively correlated with plant height (-0.4201), stem girth (-0.1963), branches per plant (-0.6798), yield per cutting (-0.2063).

Days to seed maturity exhibited significant positive correlation with leaf length (0.4919), leaf width (0.7537), days to first flowering (0.9872), leaf weight (0.9963), stem weight (0.8238), leaf/ stem ratio (0.7068) and negatively correlated with plant height (-0.3236), branches per plant (-0.6776) and yield per cutting (-0.2063).

Yield per cutting showed significant positive correlation with plant height (0.9842), stem girth (1.0040), branches per plant (0.4915), stem weight (4520). It

was negatively correlated with days to first flowering (-0.2142), days to fifty per cent flowering (-0.2063) and leaf / stem ratio (0.6980).

Leaf weight was positively correlated with leaf length (0.4843), leaf width (0.7680), days to first flowering (0.9879), days to fifty per cent flowering (0.9887), stem weight (0.8297), leaf / stem ratio (0.7036) and negatively correlated with plant height (-0.2833), branches per plant (-0.6295).

Stem weight observed positive correlation with plant height (0.6924), days to first flowering (0.7323), days to fifty per cent flowering (0.7370), days to seed maturity (0.8238), yield per cutting (0.4520), leaf weight (0.8297), leaf / stem ratio (0.2500).

Leaf / stem ratio exhibited significant positive correlation with leaf length (0.3636), leaf width (0.5074), days to first flowering (0.7822), days to fifty per cent flowering (0.7770), days to seed maturity (0.7068), leaf weight (0.7036), stem weight (0.2500) and negatively correlated with plant height (-0.8456), stem girth (-0.6975), branches per plant (-0.6724) and yield per cutting (-0.6980).

Table 16. Genotypic correlation coefficients for growth, yield and yield components.

Character	X 1	X2	X 3	X 4	X 5	X 6	X 7	X 8	X 9	X 10	X 11	X 12	X 13	X 14	X 15	X 16
X 1	1.0000															
X 2	0.9153**	1.0000														
X 3	-0.1463*	-0.0940	1.0000													
X 4	-0.2241**	-0.0565	0.8379**	1.0000												
X 5	0.6127**	0.6623**	-0.6923**	-0.7929	1.0000											
X 6	-0.4256**	-0.2142**	0.4064**	0.7258**	-0.6809	1.0000										
X 7	-0.4201**	-0.1963**	0.4102**	0.7253**	-0.6798	0.9993**	1.0000									
X 8	-0.3236**	-0.0997	0.4919**	0.7537**	-0.6776	0.9872**	0.9896**	1.0000								
X 9	0.9842**	1.0040**	-0.0540	-0.0454	0.4915**	-0.2142	-0.2063	-0.1195	1.0000							
X 10	-0.2833**	-0.0486	0.4843**	0.7680**	-0.6295	0.9879**	0.9887**	0.9963**	-0.0549	1.0000						
X 11	0.2812**	0.4241**	0.5239**	0.6924**	-0.3708	0.7323**	0.7370**	0.8238**	0.4520**	0.8297**	1.0000					
X 12	-0.8456**	-0.6975	0.3636**	0.5074**	-0.6724	0.7822**	0.7770**	0.7068**	-0.6980	0.7036**	0.2500**	1.0000				
X 13	0.6228**	0.6441*	0.4260**	0.4146**	0.0239	0.2402**	0.2446**	0.3832**	0.6734**	0.3782**	0.8109**	-0.2150	1.0000			
X 14	-0.6051**	-0.7012	-0.0146	-0.0077	-0.7069	0.3160**	0.3057**	0.2758**	-0.5571	0.2089**	-0.1491	0.4826**	-0.4284	1.0000		
X 15	-1.3117	-0.7502	1.2827**	1.3262	-1.1056	1.1431**	1.1789	1.3142	-1.3918	0.9737**	0.6972**	1.1181**	1.0717**	0.0144	1.0000	
X 16	-0.0881	0.1225	0.5189**	0.7719**	-0.5606	0.9349**	0.9372**	0.9742**	0.1286	0.9788**	0.9264**	0.5664**	0.5525**	0.0861	0.9128**	1.0000

X 1. Plant height (cm)
X 2. Stem girth (cm)
X 3. Leaf length (cm)
X 4. Leaf width (cm)
X 5. Branches per plant
X 6. Days to first flowering
X 7. Days to 50% flowering
X 8. Days to seed maturity
X 9. Yield per cutting (g)
X 10. Leaf weight (g)
X 11. Stem weight (g)
X 12. Leaf/ stem ratio
X 13. Seed yield per plant
X 14. Leaf blight intensity
X 15. Leaf webber incidence
X 16. Yield per plant

DISCUSSION

5. DISCUSSION

Amaranthus is the most popular leafy vegetable of the tropics. Being highly rich and inexpensive source of nutrients it is also known as poor man's spinach. The leaves contain protein 4.0 g, fiber 1.0 g, vitamin A 9200 IU, riboflavin 0.1 mg, thiamine 0.01mg, vitamin C 99 mg, Fe 25.5 mg and Ca 397 mg per 100 g of edible portion (Choudhury, 2006).

However, there are some potential drawbacks mainly due to genetic and environmental factors. These are premature flowering or bolting and presence anti nutrient factors like oxalates and nitrates. Premature flowering reduces yield especially in multi-cut types besides reducing quality of produce. Anti nutrient factors causes serious health problems.

Amaranthus species which grow under varying climatic conditions differ in their day length requirements and respond differently to changes in photo and thermoperiodism. Screening of amaranth germplasm for non bolting types resulted in the identification of a high yielding, red leaved photosentive accession A-6 which was further progressed as 'Kannara Local'. It is a short day cultivar which comes to flowering during November - December in Kerala. Another red variety 'Arun' developed at the College of Agriculture, Vellayani for the southern districts of Kerala, by mass selection from 'Palapur local' is a photo insensitive variety with maroon coloured petiole and leaves. Two more high yielding variety viz. Krishnasree and Renusree have also been released by Kerala Agricultural University.

The already released varieties often show premature bolting tendencies. Few genotypes with delayed bolting have been observed in the seed production plot of Department of Olericulture, College of Agriculture, vellayani. So evaluation of these genotype(s) along with the released varieties of Kerala Agricultural University would result in the identification of delayed bolting genotype(s) with high yield and low anti nutrient factors. The present experiment was therefore carried out with the objective of identifying better genotypes in

respect of yield non bolting nature and low anti nutrient factors and to arrive at best planting time in amaranthus.

The project was laid out as six separate experiments in randomized block design with three replications. The experimental data collected on growth characters, yield and yield attributes, pest and disease incidence, quality characters and genetic parameters were statistically analyzed and the results presented in tables 3 to 16 are discussed here under.

5.1 GROWTH CHARACTERS

Significant genotypic variation for growth characters was observed in the present study. Among eleven genotypes, Amt 6 ranked first in overall performance with respect to all growth characters like plant height, stem girth, leaf length, leaf width, branches per plant. This being a locally adapted genotype, the better growth performance is quite natural. Similar genotypic variation for growth characters of amaranthus was reported by Olufolaji and Tayo (1980); Vijayakumar (1980); Whitehead and Singh (1996); Priya (1998) and Sujatha (2006).

Among planting dates, March planting resulted in maximum plant height, stem girth, leaf length, leaf width and branches per plant. Under Kerala conditions the climatic conditions prevailing during March- August are congenial for vegetative growth, which is particularly good for leafy vegetables. These findings are in agreement with the findings of Campbell and Abbott (1982) and Anuja and Mohideen (2007). The better growth of March planting might be due to conducive climatic conditions which in turn resulted in high dry matter accumulation. Similar, influence of planting dates on different vegetative characters like plant height, stem girth, leaf length, leaf width and branches per plant were also reported by Makus (1984); Sealy *et al.* (1990); Singh and Whitehead (1991); Krishnakumary (2000) and Saha *et al.* (2003).

Interaction effects of genotypes with planting dates were also significant for all growth characters. Maximum plant height and stem girth were recorded for

March planting of Amt 6. Leaf length and leaf width was maximum for March planting of Amt 7. Findings of Mohideen and Muthukrishnan (1981); Sealy *et al.* (1990); Sirohi and Sivakami (1995) and Anuja and Mohideen (2008) were in line with the present results.

5.2 PRE MATURE FLOWERING OR BOLTING

Premature flowering or bolting is a serious problem in amaranthus. Genotypes with late bolting tendencies are preferred character in amaranthus, especially in multicut types.

In the present study, the days to first flowering, 50 per cent flowering and days to seed maturity were significantly altered by genotypes, planting dates and their interaction. Among the genotypes, Amt 1 was the latest followed by Amt 8 and the early ones were Amt 2 and Amt 4. It is well known that premature flowering is a genetic character as reported by Devadas (1982); Devadas (1986); Vireshwar *et al.* (1991); Devadas (1993); Priya (1998); Sindhu (2002) and Akaneme and Ani (2013).

Among the planting dates, March planting resulted in latest flowering followed by May planting whereas maximum delay in seed maturity was observed in July planting followed by May planting. Minimum days for first flowering and fifty per cent flowering was in November planting and least days for seed maturation was in September planting. This is attributed to the short day conditions prevailed during these months. Impact of short days on flowering in amaranthus has been reported by Santos (1989) and Barros *et al.* (2004) which is in conformity with the findings.

Interaction effects showed significant difference for first flowering, 50 per cent flowering and days to seed maturity. March planting of Amt 1 observed latest in first flowering (124.33 days), fifty per cent flowering (146.67 days) and took maximum days for seed maturation (243.22 days).

During November planting Amt 1 resulted in early flowering (69.00 days). From this, it can be concluded that Amt 1 is a short day responsive genotype. Also it took minimum days for seed maturation. So the planting during these months can be used for seed production of Amt 1. Interaction between genotypes and planting dates for days to fifty per cent flowering and days to seed maturity were earlier reported by Mohideen *et al.* (1981); Sealy *et al.* (1990); Sirohi and Sivakami (1995) and Varalakshmi (2004).

5.3 YIELD AND YIELD ATTRIBUTES

Yield is the important character for any crop production. In amaranthus, yield per plant was found to be influenced by different genotypes. The best performer with respect to yield was Amt 1 (439.67 g) followed by Amt 8 (320.88 g) and Amt 11, whereas Amt 2 and Amt 3 were poor yielders. Yield and yield related characters are governed by genotypes and environments. Similar genetic variation has been reported by Celine *et al.* (2007). In her study, it was reported that in *A. tricolor* total yield was maximum for Am 76 (244.16 g/ plant) and among *A. dubius* accessions total yield was maximum for Am 85 (703.33 g/ plant). Similar findings were reported by Whitehead and Singh (1996); Priya (1998) and Shukla and Singh (2000).

Among planting dates, maximum yield per plant was observed in March planting (346.77 g) followed by January planting (224.07 g) and lowest yield per plant was obtained in September planting. Seasonal influence on yield of leafy vegetables is well known especially in amaranthus. As far as Kerala is concerned the ideal season for maximum biomass production in amaranthus is March- July.

Interaction effects revealed significant effects for yield per plant. During March planting Amt 1 recorded maximum yield per plant, which is followed by Amt 8 planted in the same month.

Yield attributes like leaf weight, stem weight and leaf/ stem ratio were highest for Amt 1 followed by Amt 8 and lowest for Amt 2 followed by Amt 4. According to Mohanalakshmi (1995), the optimum leaf/ stem ratio in amaranthus

is 1.0 to 1.5 and is to be aimed at in selection. Among the genotypes, the leaf/ stem ratio was found to range from 1.74 in Amt 1 to 0.54 in Amt 2. Variability among genotypes for yield attributes were reported by Whitehead and Singh (1996); Priya (1998); IIHR (2000); Sindhu (2002) and Sujatha (2006).

Among the different planting dates, March planting recorded better leaf weight (187.82 g), stem weight (158.95 g) and leaf / stem ratio (1.23). Such result may be attributed to the fact that plants in March planting got better opportunity to develop vegetatively, since they received long day condition. Amaranthus being a C 4 plant, summer season might have been conducive for better photosynthetic activity resulting in better assimilatory functions associated with better expression of characters (Anuja and Mohideen, 2008). Significant differences among planting dates and yield attributes were earlier reported by Berberich (1980); Campbell and Abbott (1982); Ramachandra and Thimmaraju (1983); Makus (1984); Sealy *et al.* (1990); Singh and Whitehead (1991) and Krishnakumary (2000).

Among interaction effects, maximum leaf weight, stem weight, leaf/ stem ratio were observed in March planting of Amt 1 and March planting of Amt 8. Studies by Mohideen and Muthukrishnan (1981); Sealy *et al.* (1990); Sirohi and Sivakami (1995); Anuja and Mohideen (2008) and Mandal and Dhangrah (2012) support the present findings.

5.4 QUALITY CHARACTERS

Quality characters are as important as yield in food crops especially vegetables. The important nutrients in amaranthus are protein, β carotene, vitamin C. The anti nutrients include oxalates and nitrates. An ideal variety should contain more nutrients and lower anti nutrients. Most of the cases quality is negatively correlated with yield. In the present study, it was observed that nutrients like protein, β carotene, vitamin C and anti nutrients like oxalates and nitrates were not influenced by genotypes. Similar results were obtained by Svirskis (2003). Svirskis (2003) who reported that chemical composition of green

material of the amaranthus varieties 'Randonukai' and 'Gelsukai' was differed insignificantly. Contrary to the present findings variation was observed in quality characters among genotypes as reported by various workers (Grubben, 1976; Devadas, 1982; Vijayakumar and Shanmugavelu, 1985; Shukla *et al.*, 2004; Sujatha, 2006; Pandey and Singh, 2010; Varalakshmi *et al.*, 2011 and Erum *et al.*, 2012). In these cases large numbers of diverse genotypes were included as against eleven genotypes in the present study.

5.5 PEST AND DISEASES

Temperature, rainfall and relative humidity are the critical climatic factors that have profound effect on incidence of pests and diseases. The climatic conditions influences the activity and seasonal population dynamics of insects (Huffaker *et al.* (1999); Huey and Berrigan (2001); Roy *et al.* (2002)) and it provides a congenial condition for fungal pathogens causing diseases.

In the present study, the important biotic stress factors noticed were leaf webber (*Psara basalis, Hymenia recurvalis*) and leaf blight (*Rhizoctonia solani*).

Significance difference was not observed in the present study among genotypes for leaf webber incidence. This could be due to limited number of genotypes used in the present study. However, genotypic differences with respect to leaf webber incidence were reported by earlier workers (Bhattacherjee and Menon (1964); Sindhu (2002) and Sujatha (2006)) which could be due to inclusion of more number of lines in their studies.

Leaf blight intensity was least in Amt 11. Genotypic variation were noticed by Adebanjo (1994); Celine *et al.* (1995); Sujatha (2006) and Celine *et al.* (2013) for leaf blight incidence.

Leaf webber incidence was meager and significant difference was not observed among planting dates. Contrary to the present results seasonal influence for leaf webber incidence was also noticed by Lefroy (1909); Bhattacherjee and Menon (1964); Asha (2005) and Aderolu *et al.* (2013). Disease intensity was

least in March planting. Similar results of less intensity in summer were also noticed by Sukumar and Ramalingham (1989); Gokulapalan and Reghunath (1995); Kamala Nayar *et al.* (1996) and Krishnakumary (2000).

G x P interactions was not significant for pest incidence which may be due to less number of lines used in the study. The significant differences reported earlier for leaf webber incidence could be due to more numbers of genotypes considered in their study.

Interaction effects showed significant difference for leaf blight intensity. No leaf blight incidence was observed in Amt 1, Amt 3, Amt 4, Amt 9 in March planting. Similar findings were reported by Krishnakumary (2000) and Adebanjo (1994).

5.6 VARIABILITY STUDIES

The magnitude of variability present in a population is of utmost importance as it provides the basis for effective selection. Since the observed variability in a population is the sum of variation arising due to the genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are the components used to measure the variability present in a population.

In the present study, the PCV was greater than GCV for all the traits, which indicates that the genotypic expression was super imposed by the environmental influence. Such environmental interference in the manifestation of these characters was earlier reported by Sindhu (2002) in amaranthus.

The PCV and GCV were highest for days to first flowering, days to fifty per cent flowering, yield per plant, yield per plot, leaf weight, stem weight and leaf/ stem ratio.

Maximum range was observed in yield per plant (69.84- 784.56 g) followed by leaf weight (27.23- 506.97 g) and stem weight (23.61- 277.59 g). Similar findings were reported by Abhay *et al.* (2002) and Hasan *et al.* (2013).

High and closer estimates of phenotypic and genotypic coefficients of variability were observed for plant height, days to first flowering, leaf width, yield per plant and yield attributes, suggesting greater contribution of genotype rather than environment. These results were in line with Bhargava *et al.* (2003) and Hasan *et al.* (2013).

The higher values of PCV and GCV for most of the characters revealed great extent of variability for these characters, there by suggesting good scope for improvement through selection.

5.7 HERITABILITY AND GENETIC ADVANCE

The variability existing in a population is the sum total of heritable and non-heritable components. A high value of heritability indicates that the phenotype of that trait strongly reflects its genotype. The magnitude of heritability indicates the effectiveness with which selection of the genotypes can be made based on the phenotype.

In the present investigation, the heritability estimates were moderate and high for all the characters except for leaf blight and leaf webber incidence which have least heritability. The high heritability estimates suggested that the traits might be generally affected by additive gene action and the phenotype of the trait would strongly reflect the genotype, and selection could be based on the phenotypic performance. Mohideen *et al.* (1982) observed high heritability (96.80%) for yield of greens, (92.30%) number of leaves, (93.50%) weight of leaves, (93.13%) weight of stem and (97.90%) leaf/ stem ratio which supports the present findings.

Johnson *et al.* (1955) pointed out that high heritability along with high genetic advance would be more useful than heritability values alone in predicting

the resultant effect of selecting the genotype. In the present study, high values of genetic advance as percentage of mean (>20%) were obtained in the present study for plant height, days to first flowering, days to fifty per cent flowering, days to seed maturity, yield per cutting, yield per plant, yield per plot, leaf weight, stem weight, leaf / stem ratio, seed yield per plant. These results are also in line with the findings of Mohideen *et al.* (1982); Sindhu (2002); Bhargava (2003); Shukla *et al.* (2006); Sujatha (2006); Anuja and Mohideen (2007) and Akaneme and Ani (2013).

5.8 CORRELATION

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Correlation provides information on the nature and extent of relationship between all pairs of characters. So when the breeder applies selection for a particular character, not only it improves that trait, but also provides a reliable measure of genetic association between them, which is useful in the breeding programme. In the present study, high and positive phenotypic and genotypic correlation was obtained between yield per plant and leaf length, leaf width, days to first flowering, days to fifty per cent flowering, days to seed maturity, leaf weight, stem weight, leaf/ stem ratio and yield per cutting. Since, yield in amaranthus is decided by weight of greens, all vegetative characters like leaf weight, leaf length etc contributes to total weight. It is also well known that delay in flowering contributes to yield of greens especially in multicut types. This justify the present correlation of the yield with these characters.

The findings of Priya (1998); Sindhu (2002) and Sujatha (2006) which showed significant positive genotypic correlation between yield per plant and leaf length, leaf width, days to first flowering, days to fifty per cent flowering, days to seed maturity, leaf weight, stem weight and leaf/ stem ratio in amaranthus support the present results.

Hasan *et al.* (2013) who observed positive significant correlation for leaf length with leaf number and marketable yield both at phenotypic and genotypic levels was also in line with the results. In our studies also strong correlation were observed between yield and yield contributing factors in amaranthus (Elangovan *et al.*, 1980; Veeraragavathatham, 1989; Sivagamsundari, 1991; Aruna, 2009).

The inter association between the contributing characters were analysed, weight of leaf has significant association with weight of stem and leaf length and leaf width. Days to 50 % flowering have significant and positive correlation with leaf length and leaf width. Amaranthus being a leafy vegetable unlike other fruit vegetables, all traits which contributes to weight of greens may have high inter association values. Hence the present findings is quite rational in leafy vegetables. The results are in agreement with the findings of Veeraragavathatham (1989); Sivagamasundari (1991); Senthilkumar (1996) and Sathiyamoorthy (1997).

In general magnitude of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for the characters positively correlated with yield indicating low environmental influence on these characters.

Positive and high phenotypic and genotypic correlation of yield per plant with other characters implies that these characters can be taken into consideration for indirect selection for yield improvement in amaranthus. Similar findings of Hasan *et al,* (2013) are in corroboration with the present observations.

As a conclusion, in the present study, the best genotypes identified were Amt 1, Amt 8 and Amt 11 for maximum yield (Plate 9). The best planting season for maximum yield of green is March, where the plants continue in vegetative phase for 3 to 4 months. Considering genotype and season of planting, Amt 1 planted during March was late flowering and gave maximum yield of greens. For seed production point of view, the same high yielding genotype can be planted in January which gave earlier seed yield.

Amt 1

Amt 8

Amt 11

Plate 9. Best performers

SUMMARY

6. SUMMARY

The study entitled 'Identification of non bolting genotypes and planting time in amaranthus (*Amaranthus tricolor* L.)' was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period from March 2013 to May 2014. The main objective of the experiment was to find out non bolting genotype(s) of amaranthus with increased yield and acceptable quality and to arrive at best planting time in amaranthus for maximum green yield.

The experiment was laid out in randomized block design with eleven genotypes and six planting dates with three replications. The planting dates were 1 st March, 1 st May, 1 st July, 1 st September, 1 st November and 1st January.

Observations were recorded on growth, yield and yield characters. The data generated were analysed, presented in tables and discussed in previous chapters. Genetic analysis was also carried out. The findings of the study are summarized below.

Among genotypes, the tallest plant (71.88 cm) was Amt 6. Among planting dates, plants were tallest (57.52 cm) during September planting. Considering genotypes and planting time, the tallest genotype (84.94 cm) was Amt 6 when planted in May.

Stem girth was maximum (5.70 cm) for Amt 6. Among planting dates, March planting gave maximum girth (6.68 cm). Interaction of genotypes over planting dates showed highest stem girth value (8.49 cm) for Amt 5 planted in March.

Genotypes differed significantly for leaf length and leaf width. Amt 9 planted during March (20.55 cm) was superior for leaf length, whereas Amt 7 during March (12.80 cm) planting gave broader leaves.

Branches per plant was recorded maximum (11.13) in Amt 5 and among planting times, it was maximum (11.37) for January planting. G x P interactions

showed that Amt 5 during September planting (15.22) resulted in maximum branches/ plant.

Amt 1 was the latest flowering (95.82 days) followed by Amt 8 (60.04 days) and among planting dates, March planting (45.70 days) resulted in maximum delay in flowering. Interaction effect was significant and Amt 1 planted during March (124.33 days) was the latest.

Maximum delay in fifty per cent flowering was observed (113.28 days) in Amt 1 among genotypes and March (58.49 days) among planting dates. Interaction effects showed that Amt 1 during March planting showed maximum delay (146.67 days) in fifty per cent flowering.

Maximum days from planting to seed maturity was observed (195.28 days) in Amt 1 among genotypes and July planting (122.60 days) among planting dates. G x P interaction showed that Amt 1 during March planting requires maximum days (243.22 days) for seed maturity.

Yield per cutting was maximum (128.37 g) for Amt 6 and among planting dates, March planting (142.81 g).

Yield per plant was differed significantly among genotypes and planting dates. Amt 1 (439.67 g) was the highest yielder followed by Amt 8 (320.88 g) and Amt 11 (313.05 g). March planting (346.77 g) recorded highest yield per plant. The interaction effects also differed significantly. Highest yield per plant was in Amt 1 (784.56 g) planted on March 1 st followed by Amt 8 (588.84 g) planted in the same month.

Yield per plot was maximum for Amt 1 (6.10 kg) among genotypes and in March (3.76 kg) among planting dates. The interaction effects showed that Amt 1 planted in March (8.83 kg) resulted in highest yield.

Leaf weight and stem weight was influenced by genotypes and planting dates. Maximum was observed for Amt 1 (Leaf weight - 275.42 g), (Stem weight- 164.36 g) and among planting dates, it was maximum in March planting

(Leaf weight - 187.82 g), (Stem weight- 158.95 g). Interaction effects showed that the Amt 1 planted on March (Leaf weight - 506.97 g), (Stem weight- 277.59 g) gave maximum values.

Leaf/ stem ratio was influenced by genotypes and planting times. Amt 1 recorded maximum leaf/ stem ratio (1.74) and among planting times, it was maximum (1.67) in July planting. Interaction effects showed that, Amt 1 in January planting (2.60) recorded maximum leaf / stem ratio.

Maximum seed yield per plant was observed for Amt 6 (13.78 g) and among planting dates, March planting (10.99 g). Interaction effects showed that Amt 6 planted on March (21.32 g) obtained maximum seed yield.

No significant difference was noticed for quality characters like protein, β carotene, vitamin C and anti nutrients like oxalates and nitrates, among genotypes and planting dates.

Incidence of leaf webber (*Psara basalis* and *Hymenia recurvalis*) did not differ significantly among genotypes, planting dates and their interactions while leaf blight intensity (*Rhizoctonia solani*) differed significantly among genotypes, planting dates and their interactions. Among genotypes, Amt 11 (2.28) showed least susceptibility to leaf blight which is on par with Amt 4 (2.57). The genotype Amt 8 (3.22) was highly susceptibile to leaf blight incidence. Among planting dates, high resistance to leaf blight disease was recorded during March planting (P1- 1.72) whereas, high susceptibility was noticed in July planting (P3- 4.35). Interaction effects showed no leaf blight incidence for Amt 1, Amt 3, Amt 4, Amt 9 planted during March and Amt 4, Amt 5, Amt 6, Amt 11 planted during September. It was high for Amt 2 planted in July (5.08).

Phenotypic and genotypic coefficients of variation were high for 50 per cent flowering, yield per plant, yield per plot, leaf weight, stem weight and leaf/ stem ratio.

Heritability along with genetic advance was high for days to 50 per cent flowering, days to seed maturity, yield per plant, yield per plot, leaf weight, stem weight and leaf / stem ratio.

At genotypic level, yield per plant showed significant positive correlation with leaf length, leaf width, days to 50 per cent flowering, days to seed maturity, leaf weight, stem weight and leaf / stem ratio.

The study identified Amt 1, Amt 8 and Amt 11 as the best genotypes and March as the best planting time with respect to late flowering and yield in amaranthus. Interactions of genotypes with planting dates showed that Amt 1 planted during March was late flowering which gave maximum yield of greens.

REFERENCES

7. REFERENCES

A.O.A.C. [Association of Official Agricultural Chemists] 1984. Official and tentative methods of analysis. Washington D. C. p. 156.

Abhay, D., Nagda A. K. and Dashora A. 2002. Genetic variability and character association in Spanish bunch groundnut. *Res. on Crops*, 3(2): 416 – 420.

Adebanjo, A. 1994. Environmental influences on the incidence of shoot diseases and health of amaranthus seeds in humid tropics: Nigeria. *Ambio* 23(3): 206-9.

Aderolu, I. A., Omooloye, A. A. and Okelana, F. A. 2013. Occurrence, Abundance and Control of the Major Insect Pests Associated with Amaranths in Ibadan. *Entomol Ornithol Herpetol* 2(3): 112.

Akaneme, F.I. and Ani, G. O. 2013. Morphological Assessment of Genetic Variability among Accessions of *Amaranthus hybridus. World Appl. Sci. J.* 28 (4): 568-577.

Anuja, S. and Kader Mohideen, M. 2007. Variability, heritability and genetic advance studies in amaranthus (*Amaranthus* spp.). *The Asian J. Hort.* 2 (1): 63-66.

Anuja, S. and Kader Mohideen, M. 2008. Germplasm evaluation of four amaranthus species for green yield under coastal ecosystem. *Veg. Sci.* 35(1): 88-89.

Aruna, P. 2009. Correlation and path analysis in amaranthus. *The Asian J. Hort.* 4(2): 361-363.

Asha, J. S. 2005. Seasonal occurence and ecofriendly management of pest of amaranthus (*Amaranthus tricolor* L.). M.Sc. (Ag) thesis, College of Agriculture, Kerala Agricultural University, Vellayani. 117p.

Bansal, G. L., Rana, M.G. and Upadhyay, R.G.V. 1993. Manipulation of source sink in relation to productivity of Amaranthus through pruning treatments, *Amarath Newsl.* 3-4:5-6

Barros, J. F.C., M. Carvalho and G. Basch, 2004. Response of sunflower (*Helianthus annuus* L.) to sowing date and plant density under Mediterranean conditions. *Europ. J. Agron..*, 21: 347–356.

Berberich, S. 1980. Amaranth-a hot weather spinach substitute. *Agric. Res.* 29(1):15.

Bhargava, A., Shukla, S. and Ohri, D. 2003. Genetic variability and heritability of selected traits during different cuttings of vegetable *Chenopodium. Indian J. Genet.* 63(4): 359-360.

Bhargava, A., Shukla, S., Ohri, D. 2008. Genotype x environment interaction studies in *Chenopodium album* L.: an underutilized crop with promising potential. *Commun. Biometry Crop Sci.* 3 (1), 3–15.

Bhattacherjee, N. S. and Menon, M. G. R. 1964. Biology and control of Hymenia recurvalis (Fab). *Indian J. Ent.* 26: 179-183.

Bindu, L. S. 2007. Seed yield and quality in amaranthus as influenced by planting systems and harvest stages. M.Sc. (Hort.) thesis, College of Agriculture, Kerala Agricultural University, Vellayani. 103p.

Bleasdale, J. K. A. 1973. Plant physiology in relation to Horticulture. Momillan Publishing Co. Ltd., London. 1st edn. pp. 105-139.

Brien, O. G. K. and Price, M. L. 2008. Amaranth grain and vegetable types. www. Echonet.org.

Campbell, T. A and J. A Abbott. 1982. Field evaluation of vegetable amaranth (*Amaranthus spp.*). *HortScience.*17 (3): 407-9.

Celine, V. A., Girija, V. K., Sreelathakumary, I. and Abdul Vahab, M. 2013.Selection of amaranth genotypes for resistance to *Rhizoctonia solani*. *Int. J. Veg. Sci.* 19(2): 157-163.

Celine, V. A., Gokulapalan, C. and Reghunath, P. 1995. Amaranthus that resists foliar blight. *The Hindu dt.* 17 Oct., 1995.

Celine, V. A., Sujatha, S. S., Seema, S., Deepa, S. N., Sreelathakumary, I. and Abdul vahab, M. 2007. Characterisation and evaluation of vegetable amaranthus (*Amaranthus tricolor* L.) for high yield, quality and resistance to *Rhizoctonia solani*. *Acta Hort.* 752: 447-451.

Choudhury, B. 2006. *Vegetables*. National Book Trust, India. p209.

Dang, J. K., Kaushik, C. D. and Sangwan, M. S. 1995. Quantitative relationship between Alternaria leaf blight of Rape seed and Mustard and weather variables. *Indian J. Mycol.* 25 (3): 184-188.

Deutsch, J. A. 1977. Genetic variation of yield and nutritional value in several *Amaranthus species* used as a leafy vegetable. *Dissertation Abstracts International*, 38 (9): 3969p.

Devadas, V. S., Gopalakrishnan, P. K. and Peter, K. V. 1992. Genetic divergence in vegetable amaranthus. *S. Indian Hort.* 40: 16-20.

Devadas, V. S., Gopalakrishnan, P. K. and Peter, K. V. 1993. A comparison of red and green amaranth for growth and yield parameters. *S. Indian Hort.* 41(1): 43-46.

Devadas, V.S. 1982. Screening for non bolting type of amaranthus suited for year round planting. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur. 78p.

Devadas, V.S., Gopalakrishnan, P.K. and Peter, K.V. 1986. Effect of cutting and colour variation on bolting in vegetable amarathus. *Amarathus Newsl.* 2: 4-6

EI-Sharkawy, M. A., Loomis, R. S. and Williams, W.A. 1968. Photosynthetic and respiratory exchanges of carbon dioxide by leaves of the grain amaranth. *J. Appl. Ecol.* 15: 243-251.

Elangovan, M., Muthukrishnan, C. R. and Irulappan, I. 1980. A study of correlation analysis in bhendi (*Abelmoschus esculentus* (L.) Moench). *S. Indian J. Hort.* 29: 15-22

Erum, S., Naeemullah, M., Masood, S., Qayyum, A. and Rabbani, M. A. 2012. Genetic divergence in amaranthus collected from Pakistan. *The J. Anim. Plant Sci.* 22(3): 653-658.

Eze, J. M. O. 1987. Growth of *Amaranthus hybridus* (African spinach) under different daylight intensities in the dry season in Southern Nigeria. *Exp. Agric.* 23(2): 193-200.

Figueroa, M. M. S. 1989. Chemical composition of the vegetative part of different Amaranth crops in comparison with *Solanum spp.* and *Crotalaria spp. Amaranthus Newsl.* 1: 9-10

Fletcher, T. B. 1914. *Some South Indian insects*, M/S Bishen singh and Mahendra Pal Singh, Dehradun, 432p.

George, S. T. 1986. Studies on some important yield contributing and nutritive characters in leaf amaranth (*Amaranthus spp.*) Ph.D. Thesis, IARI, New Delhi.152p.

George, S. T., Barat, G. K., Sivakami, N. and Choudhury, B. 1989. Source and variability for nutritive aspects in amaranth (*Amaranthus species*). *Indian J. Agric. Sci.* 59(4): 274-5.

Gokulapalan, C. and Reghunath, P .1995. Leafspot in amaranthus. The Hindu Daily, July 27p.

Gomez, A. K. and Gomez, A. A. 1984. *Statistical Procedures for Agricultural Research.* An International Rice Research Institute Book, New York. pp. 34- 76.

Gopalakrishnan, T. R. 2004. *Three decades of vegetable research in Kerala Agricultural University.* Kerala Agricultural University, p 106.

Gopalakrishnan, T. R. 2007. *Vegetable crops.* New india publishing agency. NewDelhi, p 298.

Grubben, G. J. H. 1976. Cultivation of amaranth as a tropical leaf vegetable. Department of Agricultural Research, Royal Tropical Institute, Amsterdam. pp. 83, 92, 93, 101-103.

Grubben, G. J. H. 1977. Leaf vegetables, p. 91-110. In: H. D. Tindall and J.T. Williams (eds.). Tropical vegetables and their genetic resources. Intl. Board for Plant Genetics, Rome.

Hamid, M. M., Ahmed, N. and Hossain, S. M. 1989. Performance of same local and exotic germplasm of amaranth. *Agric. Sci. digest* 19: 200-204.

Hasan, M., Akther, C. A. and Raihan, M. S. 2013. Genetic Variability, Correlation and Path Analysis in Stem Amaranth *(Amaranthus tricolor* L.*)* Genotypes. *The Agriculturists. 11(1): 1-7*

Hill, R. M. and Rawate, D. 1982. Evaluation of food potential, some toxicological aspects and preparation of a protein isolates from the aerial part of amaranth. *J. Agric. Food Chem.* 30(30: 465-469.)

Holubava, K. 2002. Content of nitrate and oxalic acid in biomass of selected genotypes of amaranth (*Amaranthus spp.*). *Agricultura Tropica et Subtropica.* 35: 59-63.

Huey, R. B. and Berrigan, D. 2001. Temperature, demography, and ectotherm fitness. *Am. Nat.* 158: 204-210.

Huffaker, C., Berryman, A. and Turchin, P. 1999. Dynamics and regulation of insect populations. In: Huffaker, C. B., Gutierrez, A. P. (eds.). Ecological Entomology. Wiley, New York, pp. 269-305.

IIHR [Indian Institute of Horticultural Research]. 2000. Annual report- 1999-2000 Indian Institute of Horticultural Research, Bangalore, p181.

Jain, J. P. 1982. Statistical Techniques in Quantitative Genetics. Tata Mc Graw Hill Co., New Delhi, 281p.

Joel Elias. 1977. Food composition table for comparative nutrient composition of Amaranth greens and seeds. *Proceedings, of the first Amaranth Seminar*, Rodale Press, Inc. Pennsylvania, p.17

Johnson, H. W., Robinson, H. D. and Constock, R. E. 1955. Estimates of genetical and environmental variability in soyabeans. *Agron. J.* 47: 314-318.

Johnson, H. W., Robinson, H. E. and Comstock, R. F. 1995. Genotypic and phenotypic correlations in soyabeans and their implications in selection. *Agron. J.* 47: 447-483.

Joshi, B. D. 1986. Genetic variability in grain amaranth (*Amaranthus hypochondriacus* L.). *Indian J. Agric. Sci.* 56: 574-576.

Kamala Nayar., Gokulapalan, C. and Chandrasekharan Nair. 1996. A new foliar blight of Amaranthus caused by *Rhizoctonia solani. Indian Phytopath.* 49(4): 407

Katiyar, R. S., Shukla, S. and Rai, S. 2000. Varietal performance of grain amaranth (*Amaranthus hypochondriacus*) on sodic soil. *Proc. Nat. Acad. Sci.* 70: 185-187.

KAU (Kerala Agricultural University). 2011. Package of Practices Recommendations: Crops. 14 th Edition. Kerala Agricultural University, Thrissur, 214p.

Kononkov, P. F., Pivovarov, V. F. Girenko, M. M., Strukova, L. V. and Gins, M. S. 1995. Study of pigment content in leaves of vegetable forms of amaranth. *Russia Agric. Sci.* 9:30-32.

Kotadia, H. R., Patil, S. J., Bhalerao, P. P., Gaikwad, S. S. and Mahant, H. D. 2012. Influence of different growing conditions on yield of leafy vegetables during summer season. *The Asian J. of Hortic.* 7 (2): 300-302.

Krishnakumary, K. 2000. Genotypic and seasonal influence on leaf spot disease in amaranth. Ph.D thesis. Kerala Agricultural Universtiy, Thrissur.

Kumar, R. S. and Yassin, M. G. 2013. Prediction of adaptability and yield stability of elite grain amaranth genotypes under different population densities (*Amaranthus hypochondriacus* L.). 8(11): 995-1000.

Law-Ogbomo, K. E. and Ajayi, S. O. 2009. Growth and Yield Performance of *Amaranthus cruentus* Influenced by Planting Density and Poultry Manure Application. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca.* 37 (1): 195-199.

Lefroy, H. M. 1909. *Indian insect life.* Today and tomarrow's printers and publishers, New Delhi, 516p.

Lohithaswa, H. C., Nagaraj, T. E., Savithramma, D. L. and Hemaredy, H. B. 1996. Genetic variability studies in grain amaranth. *Mysore J. agric. Sci.* 30: 117-120.

Lowry, O. H., Rosebrough, N. J., Farr, A. L. and Randall, R. J. 1951. Protein measurement with the folin – phenol reagent. *J. Biol. Chem.* 193:265-275.

Makus, D. J. 1984. Evaluation of amaranth as a potential greens crop in the mid south. *HortScience* 19:81-883.

Malathy, P., Suraweera, D. D., Daundasekara, W. A. M., Nilanthi, W. D. G. P. and Wahundeniya, K. B. 2012. Yield, keeping quality, antioxidant content and some nutritional aspects of selected accessions of Amaranthus (*Amaranthus tricolor* L). *Int. J. Biosci. Bioinforma.* 2(5): 122-134.

Mandal, J. and Dhangrah, V. K. 2012. Screening Vegetable Amaranth under Summer Condition in Red and Lateritic Belt of West Bengal. *Environ. Ecol.* 30 (4A) : 1430—1433.

Maynard, A. A. 2013. Vegetable amaranth trials 2008-2010. The Connecticut Agricultural Experiment station, Newhaven, Bulletin 1038, 2p.

Middleton, K. R. 1958. A new procedure for rapid determination of nitrate and a study of the preparation of phenol- sulphonic acid reagent. *J. Appl. Chem.* 8: 505-508.

Miller, P. A., Williams, V. C., Robinson, H.P. and Comstock, R. E. 1958. Estimates of genotypic and environmental variances and covariance in upland cotton and their implications in selection. *Agron. J.* 5: 126-131.

Mohanalakshmi, M. 1995. Studies on variability in relation to stages of growth in Amaranthus. M.Sc. Thesis, TNAU, Coimbatore. 112p.

Mohideen, K. M. and Muthukrishnan, C. R. 1981. Studies on performance of amaranthus (*A. tricolor*) at different stages of harvest. *S. Indian Hort.* 29: 104-109.

Mohideen, K. M. and Rajagopal, A. 1974. Response of amaranthus to clipping. *Madras Agric. J.* 61: 885-886

Mohideen, K. M., Muthukrishnan, C. R. and Irulappan, I. 1982. Studies on variability in amaranthus (*Amarathus tricolor* L.) at different stages of harvest. *S. Indian Hort.* 30: 203-206.

Mugerwa, J. S and Bwabye, R. 1974. Yield, composition and in vitro digestibility of *Amaranthus hybrids* sub sp. incurvatus. *Trop. grasslands.* 8(1): 49-53

Olufolaji, A. O. and Tayo, A. O. 1989. Performance of four morphotypes of *Amaranthus cruentus* L. under two harvesting methods. *Trop. Agric.* 66(3): 273-6.

Olufolaji, A. O. and Tayo, T. O. 1980. Growth, development and mineral contents of three cultivars of amaranth. *Scientia Hortic.* 13(2): 181-9.

Pan, R. S., Sirohi, P. S. and Sivakami, N. 1991. Studies on variability in vegetable Amaranth (*Amaranthus tricolor* L.). *Amaranth Newsl.* 1: 10-11.

Pandey, R. M. and Singh, R. 2010. Genetic studies for biochemical and quantitative characters in grain amaranth (*Amaranthus hypochondriacus* L.). *Pl.Omics J.* 3(4):129-134.

Panigrahi, G. 1951. Photoperiodic studies in Indian vegetables (*Amaranthus gangeticus* var. *oleraceus* Roxb). *Curr. Sci.* 20:19.

Prasad, R., Bajpaye, N. K., Srivastava, S. P. 1980. Note on interrelationship and heritability in amaranth. *Indian J.Agric. Sci.* 50(2): 183-186.

Priya, V. P. 1998. Screening amaranthus genotypes for yield, quality and resistance to biotic stress. M.Sc. (Ag) thesis. Kerala Agricultural University. Thrissur. 86p.

Rajan, S. 1991. Production potential of amaranthus under irrigation and nitrogen levels. M.Sc. (Hort.) thesis, Kerala Agricultural university, Vellayani. 98p.

Ramachandra, H. A. and Thimmaraju, K. R. 1983. Effect of different levels of nitrogen and phosphorous on growth components and yield of amaranthus (*A. tricolor* L.) cv. A-25. *Mysore J. Agric. Sci.* 17 (2): 158-164.

Rana, J. C., Yadav, S. K., Mandal, S. and Sangeeta Yadav. 2005. Genetic divergence and interrelationship analysis in grain amaranth (*Amaranthus hypochondriacus*) germplasm. *Indian J. Genet.* 65(2): 99-102.

Robinson, H. F., Comstock, R. E and Harvery, V. H. 1949. Estimates of heritability and degrees of dominance in corn. *Agron. J.* 43: 281-282.

Roy, M., Brodeur, J. and Cloutier, C. 2002. Relationship between temperature and development rate of *Stethorus punctillum* (Coleoptera: Coccinellidae) and its prey *Tetranychus mcdanieli* (Acarina: Tetranychidae), *Environ. Ent.* 31: 177-187.

Sadasivam, S. and Manickam, A. 1996. *Biochemical Methods for Agricultural Sciences*. Wiley Eastern Ltd., New Delhi, 246p.

Saha, S. R., Uddin, M. N., Rahman, M. A., Sharifuzzaman, S. M. and Habib A. K. M. A. 2003. Growth and harvestable maturity of red amaranth at different sowing dates. *Asian J. Pl. Sci.* 2 : 431—433.

Samson, J. A. 1972. Tropical spinach from *Amarathus*, *Ipomoea* and *Xanthosoma. Surinaamee Landb.* 20: 15-21.

Santos, J. I. C. 1989. Evaluation of four Amarath species during three sowing times at the parceled plots of Caballo Blanco, Guatemala. *Amarath Newsl.* 1:5-6

Sathiyamurthy, V. A. 1997. Studies on gama ray induced mutation in bhendi. M. Sc. (Hort.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Sawhney, S., Kohli, R. K. and Sawhney, N. 1980. Photoperiodic studies on Amaranthus. *Indian J. Pl. Physiol.* 23: 103-111.

Sealy, K. L., Mc Williams, E. L., Novak, J., Fong, F. and Kenerly, C. M. 1990. Vegetable amaranth: Cultivar selection for summer production in the south, p. 396-398. In: Janick, J and Simon, J. E. (eds.). Advances in new crops. Timber Press, Portland, Ore.

Senthilkumar, M. 1996. Studies on induced mutagenesis in bhendi (*Abelmoschus esculentus* L.) M. Sc. (Hort.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Shani, M. S., Suhara, B. S., Bindu, R. N. 2010. A Comparitive study on the Nutritional and Anti-Nutritional Characters of Species of *Amaranthus*. (Amaranthaceae). *Indian J. Pl. Genet. Resour.* **23** (1): 73-76.

Shukla, S. and S. P. Singh, 2000. Studies on genetic parameters in vegetable amaranth. *J. Genet Breed* 54: 133-135.

Shukla, S. and Singh, S. P. 2003. Correlation and path analysis in grain amaranth (*Amaranthus spp.*). *Indian. J. Genet.* 63: 163-164.

Shukla, S., Bhargava, A., Chatterjee, A. and Singh, S. P. 2004. Estimates of genetic parameters to determine variability for foliage yield and its different quantitative and qualitative traits in vegetable amaranth (*A. tricolor*). *J. Genet. Breed.* 58: 169-176.

Shukla, S., Bhargava, A., Chatterjee, A., Srivastava, A., and Singh, S. P. 2006. Genotypic variability in vegetable amaranth (*Amaranthus tricolor* L.) for foliage yield and its contributing traits over successive cuttings and years. *Euphytica.* 151: 103-110.

Sindhu, L. 2002. Variability in vegetable amaranth (*Amaranthus dubius* Mart. ex. Thell.) for yield, quality and resistance to leaf blight. M.Sc. (Hort.) thesis, Kerala Agricultural university, Thrissur. 104p.

Singh, B. P. and Whitehead, W. F. 1991. Performance of amaranth at six in-row plant densities. *HortScience*, 26:708

Singh, K. P. and Gopal, B. 1973. The effect of photoperiodic and light intensity on the growth of some weeds of crop fields. *Proceedings of Uppsala Symposium*. 1970. pp. 77-84.

Singh, R. K. and Choudhary, B. D. 1979. Biometrical *Methods in Qualitative Genetic Analysis*. Kalyani Publishers, New Delhi, pp. 39-79.

Sirohi, P. S. and Sivakami, N. 1995. Vegetable amaranth varieties from IARI. *Indian Hort*. 39(1): 19-20

Sivagamasundari, S. 1991. Diallel analysis in okra (*Abelmoschus esculentus* (L.) Moench). M. Sc. (Hort.) Thesis, Tamil Nadu Agricultural University, Coimbatore. 92p.

Sreerangaswamy, S. R., Sambandamurthi, S. and Murugesan, M. 1980. Genetic evaluation and path analysis in Amarathus. *Madras Agric. J.* 67(1): 46-50

Srinivasaiah, K., Venkatareddy, D. M and Amarananjundeswara, H. 2000. Effect of varieties and sowing dates on seed yield and quality in vegetable amaranthus (*Amaranthus sp.*). *Seed Res*. 28: 131-135.

Srivastava, R. P. and Kumar, S. 1998. *Fruit and Vegetable Preservation-Principles and Practices*. 2nd edn. International Book Distributing Co., Lucknow, 444p.

Sujatha Sathy Sankaran. 2006. Characterization and evaluation of land races of amaranthus (*Amaranthus spp.)* Msc. (Hort.) thesis, Kerala Agricultural university, Thrissur. 114p.

Sukumar, J and Ramalingam, A. R. 1989. Epidemiology of *Cercospora moricola* leaf spot disease of mulberry 111, condial dispersal and disease incidence. *Sericologia* 29(4): 533-539.

Svirskis, A., 2003. Investigation of amaranth cultivation and utilisation in Lithunia. *Agron. Res.* 1(2): 253-264.

Tewari, S. K., Srivastava, A. and Prakash, D. 2002. Evaluation of nutraceutical composition of vegetable and grain *Amaranthus species. J. Med. Arom. Pl. Sci.* 24: 1050-1055.

Unnikrishnan, V. 1986. Control of pests of amaranthus using exotic and indigenous strains of *Bacillus thuringiensis* Berliner. M.Sc. (Ag) thesis, College of Agriculture, Kerala Agricultural University, Vellayani. 118p.

Upadhyay, K. K. and Maurya, K. 2013. Genetic association between foliage yield and its biochemical parameters in vegetable amaranthus (*Amaranthus tricolor* L.). *Int. J. Adv. Res. Technol.* 1(1): 56-74.

Varalakshmi, B. and Pratap Reddy, V. V. 1994. Variability, heritability and correlation studies in vegetable amaranthus. *S. Indian Hort.* 42: 361-364.

Varalakshmi, B., 2004. Characterization and preliminary evaluation of vegetable amaranth (*Amaranthus* sp.) germplasm. *Plant Genet. Resour. Newsl.* 137: 55-57.

Varalakshmi, B., Kesava Rao, V. and Naik, G. 2011. Antioxidant rich amaranth varieties, Arka Samraksha and Arka Varna. *J. Hort. Sci.* 6(2): 163-165.

Veeraragavathatham, D. 1989. Genetic analysis in okra (*Abelmoschus esculentus* (L.) Moench). Ph. D. Thesis, Tamil Nadu Agricultural University, Coimbatore. 108p.

Vijayakumar, M. 1980. Studies on growth and development of certain types of Amaranthus (*Amaranthus sp.* L.). M.Sc. (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore. 102p.

Vijayakumar, M. and Shanmugavelu, K. G. 1985. A comparison on the nutritive value of the greens of certain types of amaranthus. *Amaranth Newsl.* 1:8.

Vireshwar, S., Sharma, G. D.,Chabra, A. K. and Pauwar, K. S. 1991. Effect of date of planting on growth of amaranthus, an underutilized plant. *Haryana J. Agron.* 7: 164-165.

Vujačić, V. 2005. Variability and factor analysis of morphological and productive characteristics of species of the genus amaranthus. *Genetika.* 37(1): 1-13.

Whitehead, W. F. and Singh, B. P. 1996. Management methods for producing vegetable amaranth. In: *Progress in New crops*, pp. 511-515, Janick, J., Ed., ASHS Press, Alington, VA.

Whitehead, W. F., Carter, J. and Singh, B. P. 2002. Effect of planting date on vegetable amaranth leaf yield, plant height and gas exchange. *HortScience.* 37 (5): 773-777.

Yarnia, M. 2010. Sowing dates and density evaluation of amaranth (cv. koniz) as a new crop. *Adv. Environ. Biol.* 4(1): 41-46.

Zabka, . G. 1957. The effect of light conditions, temperature and Growth regulators on Photoperiodism of *Amaranthus caudatus* L. *Diss. Abstr.* 17 (2400). pp. 23, 246, 411.

ABSTRACT

Identification of Non Bolting Genotypes and Planting Time in Amaranthus (*Amaranthus tricolor* L.)

by

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Abstract of the thesis

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ABSTRACT

The present investigation on "Identification of non- bolting genotypes and planting time in amaranthus (*Amaranthus tricolor* L.)" was conducted at Department of Olericulture, College of Agriculture, Vellayani during 2013-14. The objectives were to find out non- bolting genotype(s) of amaranthus with increased yield and acceptable quality and to arrive at best planting time in amaranthus for maximum green yield.

Six separate experiments were laid out in randomized block design with 3 replications. Eleven genotypes were planted at bimonthly intervals starting from 1st March 2013 to January 2014. Analysis of variances revealed significant difference among genotypes, planting dates and their interactions for all the characters studied.

Among the genotypes, Amt 1 was the highest yielder (439.67 g/plant) followed by Amt 8 (320.88g/plant) and Amt 11 (313.05 g/plant). Maximum delay in fifty per cent flowering was in Amt 1 (113.28 days) followed by Amt 8 (72.44 days) and Amt 11 (62.89 days) whereas, earliest flowering was observed in Amt 2 (20.22 days). The lowest incidence of leaf blight was observed in Amt 11 (2.28) followed by Amt 4 (2.57) and leaf webber incidence was lowest for Amt 1 (1.04) followed by Amt 10 (1.05).

Among the planting dates, March planting recorded highest yield and yield attributes. It resulted in highest yield per plant (346.77 g) followed by September planting (231.49 g). The tallest plants were observed in September planting (57.52 cm) and maximum branches per plant in January planting (11.37). Fifty per cent flowering was latest in March planting (58.49 days) whereas it was earliest in November flowering (41.91 days). Lowest intensity of leaf blight was observed in March planting whereas leaf webber incidence was lowest in September planting.

The interaction effects between sowing dates and genotypes were significant for all the characters. Maximum yield per plant was in Amt 1 (784.56

g/plant) planted on March 1st followed by Amt 8 (588.83 g/plant) and Amt 11(493.98 g/plant) planted in the same month. Best leaf/stem ratio was observed in Amt 1 (2.61) in January 1st planting followed by Amt 3 (2.57) in March planting. Amt 1 in March planting (146.67 days) was latest in fifty per cent flowering followed by Amt 1 in July planting (139.67 days), whereas earliest days to flowering was in Amt 2 in July planting (17.33 days) followed by Amt 2 (18 days) in September planting.

The genotypes did not differ significantly for quality characters.

Variability among genotypes for all characters was studied using phenotypic and genotypic coefficient of variation, heritability and genetic advance. Correlation revealed high significant positive correlation to leaf length, leaf width, days to 50 per cent flowering, days to seed maturity, leaf weight, stem weight and leaf / stem ratio with yield per plant.

The study identified Amt 1 as the best genotype followed by Amt 8 and Amt 11 with respect to superiority in yield and late bolting nature and March as the best planting time followed by September. Considering season and varieties, the performance was best for the genotype Amt 1 when planted during March.

APPENDICES

Appendix I. Soil fertility status of the experimental plot before the experiment

Months	pH	EC ($d\ S\ m^{-1}$)	Oxidisable Organic C (%)	Available P ($Kg\ ha^{-1}$)	Available K ($Kg\ ha^{-1}$)
March	5.6	0.074	1.10	43.20	405
May	5.9	0.081	1.30	45.14	417
July	6.4	0.053	1.25	54.00	335
September	6.8	0.056	1.26	57.13	340
November	5.5	0.072	1.09	42.87	401
January	5.4	0.080	1.28	44.50	409

Appendix II. Mean performance of genotypes for biometric characters during March planting

Genotypes	Plant height (cm)	Stem girth (cm)	Leaf length (cm)	Leaf width (cm)	Branches /plant	Days to 1st flowering	Days to 50% flowering	Days to seed maturity	Yield/ cutting (g)	Yield/ plant (g)	Leaf weight (g)	Stem weight (g)	Leaf/ stem ratio	Yield/ plot (kg)	Yield (t/ha)	Seed yield/ plant (g)	Leaf blight intensity	Leaf webber incidence
Amt 1	39.03	6.46	17.07	13.18	9.88	124.33	146.67	243.22	112.08	784.56	506.97	277.59	1.82	8.83	98.07	9.26	1.00	1.00
Amt 2	79.79	6.89	15.54	9.08	10.04	13.00	19.00	56.00	221.54	221.54	80.35	141.19	0.567	1.22	10.16	7.25	1.95	1.11
Amt 3	29.24	4.71	16.15	9.40	8.00	25.33	35.00	65.22	66.42	132.83	95.61	37.22	2.57	1.49	16.60	4.21	1.00	1.07
Amt 4	59.11	7.22	15.28	10.09	9.26	23.67	29.33	70.87	134.07	134.07	65.42	68.64	0.96	1.51	16.75	7.14	1.00	1.07
Amt 5	57.72	8.49	15.59	8.44	11.67	19.67	31.00	71.55	135.12	135.12	61.55	73.57	0.84	1.52	16.89	12.17	2.63	1.25
Amt 6	84.14	7.38	18.57	11.06	11.76	29.67	36.00	91.66	202.24	404.48	148.38	256.10	0.58	4.55	50.56	21.32	2.03	1.08
Amt 7	43.13	6.08	20.18	13.24	8.96	37.67	54.33	91.67	135.4	270.79	150.68	120.10	1.26	3.05	33.85	8.69	2.38	1.25
Amt 8	46.68	7.02	18.23	12.82	11.19	71.67	96.33	154.00	147.21	588.84	368.05	220.79	1.67	6.62	73.60	9.46	2.08	1.06
Amt 9	56.05	6.44	20.55	12.01	10.96	51.00	65.66	130.56	143.89	431.72	196.49	235.23	0.83	4.86	53.97	9.49	1.00	1.00
Amt 10	50.88	5.66	17.58	10.08	8.74	41.00	48.66	108.00	108.26	216.52	116.29	100.23	1.16	2.44	27.06	14.55	1.80	1.08
Amt 11	66.16	7.17	16.12	12.92	10.11	65.66	81.33	136.56	164.66	493.98	276.16	217.82	1.27	5.56	61.75	17.38	2.00	1.07
Means	55.63	6.68	17.35	11.12	10.05	45.7	58.49	110.85	142.81	346.77	187.81	158.95	1.23	3.76	41.75	10.99	1.72	1.10
SE±	2.10	0.30	0.57	0.29	0.67	0.79	1.42	1.15	1.54	3.85	2.43	1.70	0.02	0.24	0.48	0.41	0.15	0.06
CD(0.05)	6.20	0.89	1.69	0.86	1.98	2.34	4.19	3.38	4.53	11.36	7.16	5.02	0.07	708.30	1.42	1.20	0.45	NS

Appendix III. Mean performance of genotypes for biometric characters during May planting

Genotypes	Plant height (cm)	Stem girth (cm)	Leaf length (cm)	Leaf width (cm)	Branches /plant	Days to 1st flowering	Days to 50% flowering	Days to seed maturity	Yield/ cutting (g)	Yield/ plant (g)	Leaf weight (g)	Stem weight (g)	Leaf/ stem ratio	Yield/ plot (kg)	Yield (t/ha)	Seed yield/ plant (g)	Leaf blight intensity	Leaf webber incidence
Amt 1	31.78	5.10	14.15	9.56	7.78	112.56	135.00	221.67	54.33	325.96	183.173	142.79	1.28	4.89	54.32	8.30	3.93	1.05
Amt 2	76.78	6.47	14.24	9.81	12.11	13.78	20.67	63.89	138.52	138.52	38.39	100.14	0.38	2.08	23.08	7.76	3.18	1.10
Amt 3	27.22	5.69	14.48	9.83	8.89	49.78	62.00	130.33	54.86	164.59	80.93	83.66	0.97	2.47	27.43	4.48	2.94	1.05
Amt 4	59.50	6.10	15.32	10.49	14.89	16.00	24.00	74.33	143.15	143.15	50.48	92.67	0.55	2.15	23.85	6.82	2.88	1.19
Amt 5	55.83	6.27	15.40	10.21	13.55	16.56	31.00	75.33	175.41	175.41	61.64	113.77	0.54	2.63	29.23	9.21	2.53	1.10
Amt 6	84.94	7.23	16.38	10.74	12.11	26.89	35.67	129.89	125.26	250.5	97.18	153.32	0.64	3.76	41.75	9.54	3.07	1.15
Amt 7	45.39	6.60	17.14	12.80	9.22	37.78	48.67	95.55	94.33	188.65	85.64	103.01	0.83	2.83	31.44	7.62	2.42	1.1
Amt 8	49.19	5.87	16.17	10.36	9.11	65.22	77.67	156.33	69.98	209.94	106.48	103.46	1.03	3.15	34.99	5.17	4.01	1.05
Amt 9	43.5	6.27	15.58	10.63	9.44	50.89	65.33	126.78	60.31	180.92	75.60	105.32	0.72	2.71	30.15	8.05	3.38	1.00
Amt 10	46.11	5.65	16.25	10.71	10.56	46.36	54.33	100.13	54.42	163.27	77.45	85.82	0.90	2.45	27.21	6.97	3.10	1.00
Amt 11	71.92	4.96	15.90	10.43	11.83	53.34	60.67	123.33	65.81	197.44	93.55	103.89	0.90	2.96	32.90	7.46	2.34	1 .00
Means	53.83	6.01	15.54	10.51	10.86	44.47	55.91	117.96	94.22	194.4	86.41	107.99	0.79	2.92	32.39	7.4 0	3.07	1.07
SE±	3.72	0.41	0.77	0.54	1.04	1.18	1.30	2.37	1.05	1.62	1.02	1.00	0.01	0.02	0.27	0.45	0.42	0.06
CD(0.05)	10.97	1.2	NS	1.60	3.07	3.47	3.85	6.99	3.11	4.79	3.02	2.97	0.03	0.07	0.79	1.34	1.23	NS

Appendix IV. Mean performance of genotypes for biometric characters during July planting

Genotypes	Plant height (cm)	Stem girth (cm)	Leaf length (cm)	Leaf width (cm)	Branches /plant	Days to 1st flowering	Days to 50% flowering	Days to seed maturity	Yield/ cutting (g)	Yield/ plant (g)	Leaf weight (g)	Stem weight (g)	Leaf/ stem ratio	Yield/ plot (kg)	Yield (t/ha)	Seed yield/ plant (g)	Leaf blight intensity	Leaf webber incidence
Amt 1	24.09	4.19	14.81	11.24	6.55	118.67	139.67	210.11	64.30	385.81	274.79	111.01	2.47	5.79	64.29	13.64	3.45	1.00
Amt 2	45.99	3.85	14.00	9.04	7.89	13.00	17.33	70.22	41.78	83.55	37.72	45.83	0.82	1.25	13.92	7.59	5.08	1.08
Amt 3	18.19	3.51	14.03	9.14	9.19	17.33	19.33	54.67	34.92	69.84	42.97	26.87	1.60	1.05	11.64	4.52	4.63	1.11
Amt 4	33.48	4.47	12.52	9.28	9.33	16.00	20.00	92.67	45.82	91.64	55.17	36.47	1.51	1.37	15.27	6.50	4.23	1.07
Amt 5	39.44	4.18	13.74	8.99	8.17	19.33	21.33	95.67	40.42	81.17	44.90	36.27	1.24	1.22	13.52	7.47	5.07	1.00
Amt 6	50.26	5.04	16.99	11.05	8.89	32.00	43.00	112.22	70.11	210.34	125.87	84.46	1.49	3.16	35.05	10.51	3.73	1.14
Amt 7	31.43	4.13	15.36	11.20	6.67	49.33	55.33	128.44	76.42	228.93	143.48	85.45	1.68	3.43	38.15	9.94	4.34	1.00
Amt 8	26.95	4.47	17.46	11.32	7.97	68.66	77.67	142.67	79.48	317.93	211.34	106.59	2.02	4.77	52.99	8.37	4.80	1.00
Amt 9	32.40	3.97	15.41	11.48	6.11	45.00	52.00	138.78	82.32	246.96	155.18	91.78	1.69	3.70	41.16	8.47	4.63	1.08
Amt 10	28.44	4.21	17.54	11.32	7.32	44.00	50.00	134.78	68.65	205.95	140.74	65.21	2.16	3.09	34.32	11.05	4.44	1.07
Amt 11	49.85	5.28	17.41	10.04	9.33	55.67	65.33	168.34	77.63	232.91	144.37	88.54	1.63	3.49	38.82	11.08	3.40	1.04
Means	34.59	4.30	15.40	10.38	7.95	43.55	51.00	122.60	61.99	195.91	125.14	70.77	1.67	2.94	32.65	9.01	4.35	1.05
SE±	1.20	0.18	0.28	0.38	0.42	0.89	0.93	0. 51	0.64	1.79	1.32	0.84	0.03	0.02	0.29	0.37	0.17	0.04
CD(0.05)	3.54	0.54	0.83	1.11	1.23	2.63	2.74	1.50	1.89	5.29	3.89	2.49	0.11	0.08	0.88	1.09	0.49	NS

Appendix V. Mean performance of genotypes for biometric characters during September planting

Genotypes	Plant height (cm)	Stem girth (cm)	Leaf length (cm)	Leaf width (cm)	Branches /plant	Days to 1st flowering	Days to 50% flowering	Days to seed maturity	Yield/ cutting (g)	Yield/ plant (g)	Leaf weight (g)	Stem weight (g)	Leaf/ stem ratio	Yield/ plot (kg)	Yield (t/ha)	Seed yield/ plant (g)	Leaf blight intensity	Leaf webber incidence
Amt 1	47.13	4.41	14.43	9.28	7.94	94.00	112.00	186.00	100.33	501.65	236.53	265.78	0.89	7.52	83.60	9.08	2.63	1.00
Amt 2	77.09	5.00	12.45	7.06	11.78	13.67	18.00	54.00	90.43	90.43	27.23	63.20	0.43	1.36	15.07	7.84	2.11	1.04
Amt 3	38.00	3.50	13.24	6.75	10.56	25.33	32.00	56.67	66.64	66.64	34.87	31.78	1.10	1.00	11.11	5.45	3.05	1.00
Amt 4	56.34	3.80	11.27	6.48	12.31	22.67	28.67	66.33	116.19	116.19	40.58	75.61	0.54	1.74	19.36	7.18	1.00	1.00
Amt 5	73.24	4.42	10.73	6.00	15.22	16.00	25.00	68.33	123.66	123.66	43.33	80.33	0.54	1.85	20.61	8.32	1.00	1.11
Amt 6	76.22	4.95	14.58	8.42	12.00	30.00	38.33	108.00	181.67	363.34	130.57	232.77	0.56	5.45	60.57	12.12	1.00	1.07
Amt 7	58.54	4.54	17.07	9.49	10.11	37.00	47.67	82.00	73.13	219.85	94.02	125.83	0.75	3.30	36.64	10.14	3.00	1.11
Amt 8	42.21	4.59	15.48	9.41	10.55	46.67	52.33	111	88.77	266.31	144.11	122.20	1.18	3.99	44.38	9.71	2.85	1.00
Amt 9	50.61	4.47	16.19	7.92	10.29	32.00	37.00	98.00	71.73	215.2	107.21	107.99	1.00	3.23	35.86	9.25	2.62	1.04
Amt 10	46.15	3.80	15.20	8.17	10.00	37.00	42.33	93.00	83.94	251.81	105.43	146.38	0.72	3.78	41.97	9.23	3.06	1.00
Amt 11	67.21	4.71	13.66	9.40	11.89	49.33	52.67	105.67	110.45	331.34	145.16	186.18	0.78	4.97	55.22	10.97	1.00	1.04
Means	57.52	4.38	14.03	8.03	11.15	36.70	44.24	93.55	100.63	231.49	100.82	130.73	0.772	3.47	38.58	9.03	2.12	1.04
SE±	1.46	0.17	0.60	0.39	0.50	0.83	0.97	0.57	0.79	1.71	1.24	1.04	0.01	0.02	0.28	0.30	0.06	0.04
CD(0.05)	4.29	0.51	1.76	1.15	1.48	2.45	2.87	1.67	2.33	5.05	3.65	3.08	0.06	0.08	0.84	0.90	0.21	NS

Appendix VI. Mean performance of genotypes for biometric characters during November planting

Genotypes	Plant height (cm)	Stem girth (cm)	Leaf length (cm)	Leaf width (cm)	Branches /plant	Days to 1st flowering	Days to 50% flowering	Days to seed maturity	Yield/ cutting (g)	Yield/ plant (g)	Leaf weight (g)	Stem weight (g)	Leaf/ stem ratio	Yield/ plot (kg)	Yield (t/ha)	Seed yield/ plant (g)	Leaf blight intensity	Leaf webber incidence
Amt 1	35.30	4.53	14.37	11.04	6.37	57.33	69.00	172.00	55.04	220.14	147.49	72.65	1.35	3.30	36.69	8.74	3.38	1.18
Amt 2	50.27	4.57	13.07	7.87	6.63	21.33	24.67	57.33	45.23	90.46	42.18	48.28	0.58	1.36	15.07	7.08	3.25	1.11
Amt 3	31.20	3.86	13.31	7.82	10.19	21.67	25.67	65.00	38.74	77.47	53.86	23.61	1.51	1.16	12.91	3.81	2.50	1.08
Amt 4	45.57	5.00	13.53	9.06	6.22	23.67	29.00	63.00	43.75	131.25	64.57	66.68	0.65	1.97	21.87	6.60	3.21	1.27
Amt 5	51.06	4.67	12.89	8.27	6.30	25.33	32.67	65.33	43.59	131.02	63.24	67.77	0.62	1.97	21.83	9.22	2.58	1.32
Amt 6	75.63	5.20	16.80	9.32	7.07	29.00	39.00	100.67	95.60	191.20	92.7	98.50	0.63	2.87	31.86	16.77	2.99	1.19
Amt 7	41.21	3.92	14.38	11.12	6.92	26.33	34.33	110.33	45.29	135.86	81.16	54.70	0.98	2.04	22.65	8.48	3.10	1.04
Amt 8	45.32	4.52	16.80	11.01	7.37	48.67	61.33	135.33	58.87	176.62	113.07	63.55	1.16	2.65	29.44	8.81	2.68	1.38
Amt 9	46.36	4.15	17.09	11.22	6.90	30.67	46.00	125.00	53.24	159.72	95.74	63.97	1.02	2.40	26.62	9.96	2.89	1.03
Amt 10	34.74	4.17	15.57	9.41	6.72	31.67	40.00	121.00	40.34	121.03	77.18	43.85	1.18	1.82	20.17	8.86	3.02	1.08
Amt 11	54.76	5.00	14.90	10.66	8.52	44.67	59.33	95.00	79.11	237.34	134.49	102.85	0.88	3.56	39.55	12.30	2.27	1.47
Means	46.49	4.50	14.79	9.71	7.20	32.75	41.91	100.91	54.44	152.01	87.79	64.22	0.96	2.28	25.33	9.15	2.87	1.19
SE±	1.77	0.15	0.43	0.29	0.51	0.97	0.92	0.94	0.58	1.52	0.79	0.97	0.16	0.02	0.25	0.21	0.19	0.06
CD(0.05)	5.22	0.45	1.26	0.86	1.51	2.86	2.70	2.76	1.70	4.48	2.32	2.86	0.47	0.07	0.74	0.61	0.56	0.21

Appendix VII. Mean performance of genotypes for biometric characters during January planting

Genotypes	Plant height (cm)	Stem girth (cm)	Leaf length (cm)	Leaf width (cm)	Branches /plant	Days to 1st flowering	Days to 50% flowering	Days to seed maturity	Yield/ cutting (g)	Yield/ plant (g)	Leaf weight (g)	Stem weight (g)	Leaf/ stem ratio	Yield/ plot (kg)	Yield (t/ha)	Seed yield/ plant (g)	Leaf blight intensity	Leaf webber incidence
Amt 1	36.85	4.21	16.12	11.27	12.13	68.00	77.333	138.67	104.98	419.93	303.57	116.36	2.60	6.30	69.99	8.15	3.50	1.05
Amt 2	61.20	4.64	16.14	9.84	11.25	13.67	21.67	59.00	130.10	130.10	41.76	88.33	0.47	1.95	21.68	6.97	3.40	2.97
Amt 3	25.09	4.09	15.52	8.89	12.59	22.67	29.33	62.67	90.34	90.34	55.80	34.54	1.62	1.36	15.05	4.12	1.80	1.15
Amt 4	55.83	5.18	12.89	8.42	11.19	23.00	27.67	69.33	87.59	175.18	83.44	91.74	0.91	2.63	29.19	7.26	3.11	1 .00
Amt 5	55.33	4.77	12.19	7.59	11.89	21.67	28.33	72.33	56.09	112.17	52.68	59.49	0.89	1.68	18.69	8.25	3.08	1.08
Amt 6	60.11	4.40	14.86	8.91	10.00	26.67	34.00	95.00	95.35	190.70	103.36	87.34	1.18	2.86	31.78	12.42	2.72	1.04
Amt 7	39.63	4.33	16.50	11.48	10.66	39.33	45.67	111.33	98.03	196.05	110.16	85.89	1.28	2.94	32.67	9.26	2.56	1.25
Amt 8	40.29	4.89	18.09	12.47	12.92	59.33	69.33	123.00	121.87	365.62	242.03	123.59	1.96	5.48	60.94	8.16	2.89	1.12
Amt 9	38.26	4.61	17.33	9.33	10.89	35.33	44.00	107.00	54.07	162.22	97.29	64.93	1.5	2.43	27.03	7.68	3.15	1.00
Amt 10	42.00	4.09	15.43	10.70	11.30	34.00	40.00	112.00	79.07	237.21	123.48	113.74	1.09	3.56	39.53	8.59	3.72	1.04
Amt 11	50.84	4.82	14.50	10.56	10.22	50.67	58.00	118.67	128.42	385.26	210.03	175.23	1.20	5.78	64.21	11.33	2.65	1.08
Means	45.95	4.54	15.42	9.95	11.37	35.85	43.21	106.90	95.08	224.07	129.42	94.65	1.34	3.36	37.34	8.38	2.96	1.16
SE±	1.30	0.15	0.31	0.43	0.56	0.89	0.61	1.00	0.98	1.55	1.15	1.06	0.01	0.02	0.25	0.19	0.09	0.05
CD(0.05)	3.83	0.45	0.92	1.27	1.65	2.62	1.77	2.98	2.89	4.56	3.39	3.12	0.06	0.07	0.75	0.56	0.28	0.15

APPENDIX – VIII

Weather data for the cropping period

(March 2013 to May 2014)

Standard weeks	Date	Temperature (°C) (maximum)	Temperature (°C) (minimum)	Sunshine (hours)	Relative Humidity (%)
9	26 Feb	32	21.4	9.5	91.3
10	5 Mar	32.1	24.3	9.3	94.7
11	12 Mar	32.3	23.9	9.3	93.4
12	19 Mar	32.3	23.7	9.8	91.4
13	26 Mar	33	25	9.9	92
14	2 Apr	32.9	26	9.9	92.7
15	9 Apr	32.8	25.6	9.7	89.9
16	16 Apr	33.2	25.1	10.2	84.8
17	23 Apr	33.3	25	9.6	87
18	30 Apr	32.7	25.8	9.2	90.6
19	7 May	32	26.1	9.1	90.7
20	14 May	32.4	25.7	10.0	90.6
21	21 May	32.1	24.2	9.0	91.7
22	28 May	30.1	22.3	8.3	95
23	4 Jun	29.2	22.8	8.7	93.6
24	11 Jun	29.1	23.2	7.0	95.1
25	18 Jun	28.3	22.5	7.6	95.4
26	25 Jun	29.9	23.3	9.3	90
27	2 Jul	29.3	23.4	9.0	93.9
28	9 Jul	28.5	23	8.4	93.7
29	16 Jul	28.3	23.5	8.1	94
30	23 Jul	29.4	21.9	9.0	92.3
31	30 Jul	29	21.6	8.4	93.1
32	6 Aug	28.8	23.9	9.4	96.7
33	13 Aug	28.6	23.7	9.6	93.3
34	20 Aug	29.8	24	9.9	92.7
35	27 Aug	30.2	24.4	9.3	86.6
36	3 Sep	28.8	23.7	9.3	97
37	10 Sep	28.7	23.4	7.9	98.6
38	17 Sep	28.8	24.3	8.2	96.3
39	24 Sep	30.2	24	8.7	93.7
40	1 Oct	30.5	22.6	10.3	94
41	8 Oct	30.6	23.3	9.7	91.4

APPENDIX – VIII

Weather data for the cropping period

(March 2013 to May 2014)

42	15 Oct	30.7	23.7	9.5	92.1
43	22 Oct	30.7	23	8.5	95
44	29 Oct	30.7	23.6	9.1	93.9
45	5 Nov	30.9	23.7	7.8	97
46	12 Nov	30.3	23.4	8.8	97.7
47	19 Nov	30.6	23.7	7.8	97.3
48	26 Nov	30.8	23	8.0	97.3
49	3 Dec	30.9	22.8	8.5	98.6
50	10 Dec	30.3	22.6	7.8	96.7
51	17 Dec	31.2	21.7	8.4	97.7
52	24 Dec	31	20.2	9.2	96.6
1	1 Jan	30.9	21.5	9.2	94.9
2	8 Jan	29	22.3	8.9	94.4
3	15 Jan	31	21.8	7.6	94.1
4	22 Jan	31.3	20.7	9.3	90.4
5	29 Jan	31.4	21.9	9.4	92.3
6	5 Feb	30.7	20.2	9.3	95.1
7	12 Feb	31.4	22.8	9.4	92.0
8	19 Feb	31.5	23.8	9.4	90.6
9	26 Feb	31.9	23.1	9.1	92.3
10	5 Mar	31.9	23.4	9.4	90.4
11	12 Mar	32.4	21.4	9.8	93.0
12	19 Mar	33	24.1	10.1	93.7
13	26 Mar	33	22.2	9.9	89.1
14	2 Apr	32.4	24.5	10.0	89.9
15	9 Apr	32	24.2	8.4	91.0
16	16 Apr	32	25	9.4	90.7
17	23 Apr	32.8	24.4	9.9	94.0
18	30 Apr	32.2	23.8	8.9	93.1
19	7 May	30.7	24.3	6.6	92.0
20	14 May	32.5	25.1	7.3	88.3
21	21 May	32.4	25.5	10.0	86.3