SCREENING FOR NON-BOLTING TYPE(S) OF AMARANTHS SUITED FOR YEAR-ROUND PLANTING

BY

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THESIS

Submitted in partial fulfilment of the requirement for the Degree

Master of Science in Horticulture

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Department of Olericulture
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I hereby declare that this thesis entitled "Screening for non-bolting type(s) of amaranths suited for year-round planting" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

(DEVADAS, V.S.)

Vellanikkara,
7-10-1982.

CERTIFICATE

Certified that this thesis entitled "Screening for non-bolting type(s) of amaranthus suited for year-round planting" is a record of research work done independently by Sri.V.S. Devadas under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Dr. P.K. GOPALAKRISHNAN,
Chairman of Advisory Committee

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CERTIFICATE

We, the undersigned members of the Advisory Committee of Mr. Devadas, V.S. a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Screening for non-bolting type(s) of amaranths suited for year-round planting" may be submitted by Mr. Devadas, V.S. in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

Amaranth is one of the large and taxonomically diverse groups of tropical leaf vegetables. They are excellent vegetables for their fast growing nature, with an extremely high yield potential, lower susceptibility to soil borne diseases than many other vegetables, suitability for crop rotation with any other vegetable crop and for its high mineral and nutrient content. "Easiness in cultivation, high suitability for both home gardening and commercial cultivation, high favourable response to added fertilizers and to organic manure, amaranth is unique" (Grubben and Vans Lotten, 1981). In warm humid tropical climate, so congenial for amaranth cultivation, fresh leaf yield as high as 30 tonnes/ha in four weeks 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.

Because of low production cost and high yield, amaranth is one of the cheapest, dark green leaf vegetables and is often described as a "poor man's vegetable". The nutritional value of this crop is excellent because of its high content of essential micronutrients. Tender amaranth (A. *gangeticus*) contains 4 g protein, 397 mg Ca, 83 mg P, 25.5 mg Fe, 5520 mg carotene, 0.3 mg thiamine, 0.3 mg riboflavin, 1.2 mg niacin and 99 mg vitamin C per 100 g (Devadas and Saroja, 1980).

Studies on the adverse nutritional effects due to higher intake of amaranth leaves havé indicated that a consumption of more than 200 g/day can cause the formation of calcium oxalate stones in the human urinary system. The statistics of consumption indicate 18.8 g/person/day in many of the developing countries. Still, there is definite need to evolve lines with negligible content of free nitrates and oxalates.

Amaranth is mainly considered as a day neutral plant. Short day types have also been identified (Grubben, 1978). Bolting - premature flowering is one of the serious handicaps in vegetable amaranth culture. The bolted amaranth tastes bitter and is not accepted for consumption as also in commercial marketing. The need for evolving non-bolting types or delayed bolting types after a substantial vegetative growth is an important need for the widespread cultivation of vegetable amaranth. The effects of various meteorological parameters, number of cuttings and height of cuttings, physical characteristics of the soil etc. on different phases of flowering need to be thoroughly investigated.

Conventionally six species - *A. tricolor*, *A. spinosus*, *A. dubius*, *A. viridis*, *A. blitum* and *A. cruentus* are considered as vegetable types. The species, *A. viridis* and *A. spinosus* are weeds in many parts of India, though they are used as a delicate and much relished leaf vegetable in rural Kerala. Association of these species with the phenomenon of bolting, content of nitrates and oxalates, etc. need to be studied in the context of improvement of amaranths through interspecific hybridisation. The present series of experiments are formulated with the following objectives:

1. To identify line(s) which are non-bolting or delayed bolting and to ascribe the morphological reasons for such behaviour.

2. To study the effect of cutting, if any, on bolting.

3. To identify line(s) suitable for year-round planting and line(s) which are phenotypically stable.

4. To identify line(s) with negligible content of free oxalates and nitrates.

5. To establish the relation, if any, between various meteorological parameters and bolting.

Review of Literature

REVIEW OF LITERATURE

Vegetable amaranth, described often as a poor man's vegetable, is unique in many ways. In warm humid tropic climate, amaranth grows so fast that a fresh matter yield of as high as 30 T/ha obtained in four weeks time, would be a record production among many of the economic crops. Amaranths are less susceptible to soil borne parasitic diseases than many other vegetables. Ease in cultivation, suitability to be fitted in crop rotations, in both homestead nutrition gardens and commercial cultivation, quick and favourable response to organic farming conditions etc. make amaranth a high potential crop for the tropics.

The nutritional value of the crop is excellent because of its high content of essential micronutrients. It is a good source of carotene, iron, calcium, vitamin C, folic acid and other micronutrients. Protein of amaranth would be a valuable contributor to human diet.

The adverse nutritional effects resulting from consumption of above 200 g of leaves per day, are attributed to the nitrate and oxalate contents in leaves. The studies on consumption pattern (Grubben, 1977) of leafy vegetables indicated a daily intake of 5 g/head in Latin America, 11 g in Central and South-West Asia and 21 g in Africa. This intake is definitely non-consequential as compared to

200 g/day required for causing nutritional defects due to higher nitrate and oxalate intakes. Still, there is need to evolve lines with negligible content of the above undesirable nutrient factors.

Early bolting has been one of the serious handicaps in the cultivation of vegetable amaranths. Bolting causes a slight bitterness of the product, making it unacceptable for consumption. Reduction in total vegetable yield is considerably higher in bolted types. Literature on bolting, specifically in amaranths is rather scarce.

1. Physiology of flowering

Lang (1952, 1965) reviewed all aspects of the flowering phenomenon in crops. He separated the phenomenon of flowering into four major stages - floral initiation (the differentiation of floral primordia); floral organisation (the differentiation of individual floral parts); floral maturation consisting of several processes, many of them overlapping (growth of floral parts, differentiation of the sporogeneous tissue, meiosis, pollen and embryosac development) and anthesis. Flower initiation marks the transition from the vegetative to the reproductive phase. Lang defined, "flowers are modified shoots, which are produced by modified shoot meristem - the flower primordia". Once a meristem has been determined as a flower primordium, it is usually unable to revert to vegetative growth. Obviously then, the cardinal problem of the physiology of flower initiation is to understand which factors cause a shoot meristem to become a flower primordium and how they consummate their action. The inductive effect of endogeneous and exogeneous control of floral initiation have been dealt in detail by Lang (1965). Flower initiation is ultimately determined by the genotype of a plant. It occurs once a plant has reached a certain developmental stage and the sole environmental requirement being conditions permitting the plant to attain this stage. 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.

Lang (1965) explained that flower initiation, in some plants depends on the interaction between genotypes and very specific environmental conditions like a period of low temperature, daylength or photoperiod. The control of flower formation by daylength has been called photoperiodism.

2. Photoperiodism as a factor in flower initiation in amaranths

Panigrahi (1951) investigated the photoperiodic responses of A. gangeticus var. oleraceus Roxb. and found that under a 6 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 a short-day response of the species A. gangeticus var. oleraceous.

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 behaviour of A. caudatus. Zabka (1961) concluded that A. caudatus became sensitive to daylength 30 days from germination after which two short days were sufficient to induce floral initiation. The same species started flowering in long days of about 18 hours, 60 days after germination. This indicated that A. caudatus is a quantitatively short day plant. Singh and Gopal (1973) studied the photoperiodic response of A. spinosus. The species behaved as a quantitatively short day plant. Seth (1963) observed that A. leucocarpus is a day neutral plant like A. cruentus. He confirmed the short day response of A. caudatus earlier reported by Zabka (1957). Samson (1972) working at Wageningen revealed that a Surinam cultivar showed no difference in flowering response to daylengths of 10.5 and

13.5 hours, while a reddish leaved Ethiopean cultivar showed considerable delay in daylengths above 12.5 hours. This indicates the short day response type of behaviour in the Ethiopean cultivar. Detailed investigations by Grubben (1976) revealed that A. cruentus and A. dubius are day neutral types and cultivars of cereal amaranths (A. caudatus, A. hypochondriacus) are quantitatively short day plants. The vegetable amaranth, A. tricolor behaved as a quantitative short day plant. The cereal amaranth (A. caudathus, A. hypochondriacus) 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. Mathai (1978) reported that amaranths are in general short day plants and when planted towards shorter days (winter season) they may bolt early.

3. Meteorological factors affecting floral initiation

Zabka (1957) stated that temperature is also an important factor in determining the time of inflorescence initiation and subsequent development of plants under both long days and short days, in amaranths. Grubben (1976) observed that shaded plants flowered late indicating the effect of quality of light and temperature on floral initiation.

Lang (1952) stated that floral initiation shows a high degree of development under certain environmental conditions - the two conditions which most frequently controlled floral initiation in a specific manner are daylength and low temperature. Lang (1952) further opined that the effect of thermo induction on floral initiation is the same as due to photo induction. Reports on the specific role of low temperature on flowering in amaranths are rather limited.

4. Soil factors affecting floral initiation

Early flowering in amaranth was observed on plots which are not well cared for and those suffering from drought (Grubben, 1976). Amaranths cultivated on poor soils bolted early. Enyi (1965) reported that periods of water stress stimulate early flowering. In his view, the principal cause for early flowering in tropical region is certainly no photoperiodic effect; waterstress seemed a much more probable reason.

5. Genetic factors

There is definite varietal difference in bolting. A few amaranth types, Alleppey and Vechoor types were found to flower in 3-3½ months, whereas, a local Kannara type did not flower even after six months (Kerala Agricultural University, 1978-79). Variability was observed among various types of amaranths for time to flowering.

6. Other factors

Kauffmann and Gilbert (1981) were of the opinion that proper management is important to prevent bolting in amaranths. The height of cutting was also found to influence flowering in amaranths. Enyi (1965), Grubben (1976) and Deutsch (1977) found that cuttings when made very near the soil surface retarded the development of inflorescence in sprouts. Enyi (1965) attributed this to the depletion of auxin responsible for flower initiation, when the stem cutting is done at considerable depth. According to Enyi (1965) planting distance might also influence flowering, where due to depletion of nitrogen, the C/N quotient may increase. The higher C/N quotient leads to floral initiation in many crop plants. But Grubben (1976) stated that a higher dose of either N or carbon seemed to have little influence on the number of inflorescences formed.

Another factor that seems to have affected flowering is the mode of planting. Mohideen and Rajagopal (1975) reported that transplanting delayed flowering and increased the total duration of the vegetative phase making it possible to have more number of cuttings. Sulekha (1980) found that the age of plantlets also influenced flowering because early flowering took place in older seedlings.

7. Studies on phenotypic stability in amaranths

Yield per plant was observed highly to be influenced by the environment (Prasad et al., 1980). The investigation of Sreeranga Swami et al. (1980) also brought out the existence of strong Genotype x Environment (G x E) interactions in the diverse genetic population of amaranths. Mohideen and Muthukrishnan (1981) found that mean yield of greens and component characters were comparatively high in most of the types during the summer season as compared to rainy season. They classified the amaranth genotypes into high yielders, moderate yielders and low yielders. The high yielding types were characterised by vigorous growth as evidenced by the high mean value for leaf weight, stem weight, leaf length, leaf breadth, stem diameter and plant height. But a systematic approach to identify stable types as proposed by Eberhart and Russel (1966) in crop plants is lacking in vegetable amaranth. Little information is available on these lines.

8. Screening amaranth types with negligible content of oxalates and nitrates

The presence of antinutrient or noxious substances, oxalates and nitrates in amaranth leaves has always been a negative factor in its large scale consumption. Der Marderosian et al. (1980) found that mean nitrate levels were 0.08% in leaves (on fresh weight basis) and 0.15% in stems. The oxalate levels were 0.75% and 0.06% in leaves and stems respectively. Deutsch (1977) indicated that oxalates were more of a problem, when plants were grown under stress conditions. Kauffmann and Gilbert (1981) also observed that vegetable amaranth when grown under stress condition, are found to have higher oxalate content. Grubben (1976) found considerable differences in oxalic acid content among 25 varieties of amaranths. A systematic approach to identify amaranth lines with negligible content of nitrates and oxalates is rather missing. Similarly, little information is available on the chlorophyll content of the amaranths also.

Materials And Methods

MATERIALS AND METHODS

The present series of experiments were conducted during 12* continuous plantings at monthly interval from April 1981 to March 1982. The location of the experimental plots were at the Instructional Farm of College of Horticulture, Vellanikkara, which is situated between 10° 32" N latitude and 76° 16" E longitude, at an altitude of 23 metres above mean sea level. The place enjoys a typical warm humid tropical climate. The physical characteristics of the soils, where cropping was done are furnished in Appendix I. The mechanical analysis of soil was done as suggested by Piper (1966).

A. Experimental materials

The experimental materials included 25 genotypes of amaranth. These genotypes consisted of released varieties and promising lines, which are members of four *Amaranthus* species, *A. tricolor*, *A. dubius*, *A. viridis* and *A. spinosus*. The species status of the 25 genotypes were determined using the keys described by Bailey (1973) and Feine (1981).

The source and morphological descriptions of the 25 genotypes are given in Table 3.1.

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* The May 1981 planting failed due to heavy rainfall and resultant water stagnation.

B. Experimental design

The 25 genotypes were selected from the amaranth germ plasm maintained at the Department of Olericulture, College of Horticulture, Vellanikkara. The experimental materials were sown in a randomised block design with two replications. There were 150 rows/replication keeping six rows/genotype/replication. Out of these 6 rows, two rows were kept as control, the middle two rows were used for recording vegetable yield and the remaining two rows, kept as such after one harvest. The length of each row was 1.50 m, row to row distance, 0.30 m and plant to plant distance, 0.15 m. The plantings (direct sowing method) were done at monthly intervals treating each month's planting as a separate trial. The experimental plots for monthly planting were selected in contrasting soil types for physical characteristics.

C. Plant characters studied

1. Days to 50% germination

2. Plant height on the 30th day of sowing

The observation on plant height was made on the 30th day of sowing in rows kept without harvest. Five plants were randomly selected for taking observations on plant height.

3. Girth of stem at cut end on the 30th day of sowing

Diameter of stem-end was taken at first harvest from five randomly selected plants using vernier callipers.

4. Length of the 5th leaf on the 30th day of sowing

The fifth leaf from terminal bud was harvested from five randomly selected plants and the above observation was made.

5. Width of the 5th leaf on the 30th day of sowing

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

6. Length of petiole of the 5th leaf on the 30th day of sowing

Petiole length of the 5th leaf, used for measuring length and width, was also recorded from the randomly selected 5 plants.

7. Branches/plant on the 30th day of sowing

The observation was made at the time of first harvest.

8. Days to 50% bolting in control

From the two rows kept unharvested, days to 50% bolting were observed.

9. Days to 50% bolting in unicut rows

Days to 50% bolting was also recorded from the 2 rows left after one harvest.

10. Nodes on bolting day

Nodes to bolting were counted from 5 randomly selected plants.

11. Leaves on bolting day

Leaves were counted from the same 5 plants, used for counting nodes.

12. Plant height on bolting day

Plant height was also measured from the 5 plants randomly selected on the day of bolting.

13. Frequency of harvests

Number of harvests made from the rows kept for taking yield, for each genotype was also recorded.

14. Total vegetable yield

Vegetable yield was recorded from two rows/genotype/replication, where harvesting was done first on the 30th day of sowing and then at biweekly intervals. Harvesting was stopped when the plants flowered.

D. Meteorological observations

1. Maximum temperature

Maximum daily temperature during the period of experimentation were recorded.

2. Minimum temperature

The minimum daily temperature during the period of investigation were recorded.

3. Rainfall

Daily rainfall received was also recorded during the period of investigation.

4. Number of rainy days/week

5. Relative humidity

The daily relative humidity was recorded.

6. Bright sunshine hours

Bright sunshine hours observed on each day during the period of experimentation.

The data observed for these parameters are presented in Appendix IIa and IIb as weekly means.

E. Chemical analysis of edible parts.

1. Oxalate content

Oxalate content of edible parts was estimated by using ferron reagent as suggested by Marderosian (1930).

2. Nitrate content

Nitrate content of the edible parts was estimated by Nesselers reagent as suggested by Snell and Snell (1977).

3. Chlorophyll content of leaves

Chlorophyll-a, chlorophyll-b and total chlorophyll content were estimated using three samples/genotype as the method suggested by Arnon (1949). The leaf used for estimating chlorophyll content was fixed as the 9th leaf from bottom after appropriate standardisation (Appendix III).

F. Statistical analysis

1. Analysis of variance

The data for each character were analysed separately for each crop as in a randomised block design (Ostle, 1966). The mathematical model of the experimental design is given by

$$Y_{ij} = \mu + t_i + b_j + e_{ij}$$

$(i = 1,2, \ldots\ldots\ldots t;\ j = 1,2 \ldots\ldots\ldots r)$

where

Y_{ij} = observation of the i^{th} genotype in j^{th} replication

μ = general mean

t_i = true effect of i^{th} genotype

b_j = true effect of j^{th} block and

e_{ij} = random error

The actual break up of the total variation into different components is as given in Table 3.2. Grand mean, standard error of mean, critical difference and coefficient of variation were estimated as follows.

Table 3.2. General analysis of variance

Sources of variation	df	M.S.	F
Replications	1	R	R/E
Genotypes	24	G	G/E
Error	24	E	

2

Grand mean = $\frac{\text{Grand total}}{50}$

Standard error of mean $= \sqrt{\frac{E}{2}}$

Where E = error mean square

Critical difference $= \sqrt{\frac{2E}{2}}$ x table value of 't' at 24 df

Coefficient of variation = $\frac{\sqrt{E}}{\text{Grand mean}}$ x 100

2. Estimation of variability, heritability and expected genetic advance

Variability existing in 25 genotypes was estimated at genotypic and phenotypic levels.

Genotypic coefficient of variation,

(gcv) = $\frac{\text{Genotypic standard deviation}}{\text{Grand mean}}$ x 100

Phenotypic coefficient of variation,

(pcv) = $\frac{\text{Phenotypic standard deviation}}{\text{Grand mean}}$ x 100

Estimates of genotypic and phenotypic standard deviations were obtained by solving the following equations from the respective ANOVA of different characters.

Estimate of error variance, ($\hat{\sigma}_e^2$) = E

Estimate of genotypic variance, ($\hat{\sigma}_g^2$) = $\frac{G-E}{r}$

Estimate of phenotypic variance, ($\hat{\sigma}_p^2$) = $\hat{\sigma}_g^2$ + E

where, r = number of replications;

E = error mean square

G = Mean square for varieties

Heritability in broad sense was estimated by the formula,

$$h^2 = \frac{\hat{\sigma}_g^2}{\hat{\sigma}_p^2}$$

3. Pooled analysis of variance

Analysis of variance of the pooled data for each character was performed as suggested by Panse and Sukhatme (1978) and the detailed analysis of variance are given in Table 3.3.

4. Stability analysis

The phenotypic stability analysis for vegetable yield and days to 50% bolting were conducted as suggested by Eberhart and Russell (1966). Three parameters were estimated so as to measure phenotypic stability of cultivars. They are (i) mean, (ii) regression of individual mean performance on environmental index and (iii) deviation from regression. The linear model is of the form

$$Y_{ij} = \mu + b_i I_j + \delta_{ij}$$

where,

i = 1,2 25

j = 1,2 11

Y_{ij} = mean performance of i^{th} genotype in the j^{th} environment

μ = mean of all the genotypes over all the environments.

Table 3.3. Pooled analysis of variance

Source	df	SS
Total	274	$\sum_i \sum_j Y_{ij}^2 - CF$
Genotypes (G)	24	$\sum_i Y_{i.}^2/\binom{10}{11} - CF$
Seasons (S)	10 (11)*	$\sum_j Y_{.j}^2/25 - CF$
G x S	240 (264)*	
Pooled error	264 (288)*	

*There are 12 seasons for days to 50% germination bi = the regression coefficient of i^{th} genotype on the environmental index which measures the response of the genotype to different environments.

Ij = the environmental index which is defined as the deviation of the mean of all the genotypes at a given location from the overall mean.

δij = the deviation from regression of i^{th} genotype at the j^{th} environment.

The environmental index can be expressed as

$$Ij = (\sum_i Yij/25) - (\sum_i \sum_j Yij/275), \text{ with } \sum_j Ij = 0$$

The first stability parameter (bi) was estimated using the formula,

$$bi = \sum_j Yij\ I_j / \sum_j I_j^2$$

The second stability parameter (S^2d_i) was estimated using the formula

$$S^2d_i = (\sum_j \delta_{ij}^2/9) - S^2_e/r$$

where, S^2e/r is the estimate of the pooled error and

$$\sum_j \delta_{ij}^2 = (\sum_j Y_{ij}^2 - Y_i^2/11) - (\sum_j Y_{ij} I_j)^2 / \sum_j I_j^2$$

The average of error mean squares over all the environment was taken as the estimate of pooled error variance. The detailed analysis of variance for the estimation of stability parameters is given in Table 3.4.

Table 3.4. Analysis of variance for stability

Source	df	S.S.	M.S.
Total	274	$\sum_i \sum_j Y_{ij}^2 - CF = T.S.S.$	
Genotypes (G)	24	$\sum_i Y_{i.}^2/11 - CF = G.S.S.$	MS_1
Seasons (S)	10	$\sum_j Y_{.j}^2/25 - CF = S.S.S.$	
G x S	240	T.S.S.-G.S.S.-S.S.S.	MS_2
S + (GxS)	250	$\sum_i \sum_j Y_{ij}^2 - \sum_i Y_{i.}^2/11$	
S (linear)	1	$1/25 \left(\sum_j Y_{.j} I_j\right)^2 / \sum_j I_j^2 = S.S.E(1)$	
G x S (linear)	24	$\sum_i \left[\left(\sum_j Y_{ij} I_j\right)^2 / \sum_j I_j^2\right] - S.S.E.(1)$	MS_3
Pooled deviation	225	$\sum_i \left(\sum_j \delta_{ij}^2\right)$	MS_4
Genotype 1	9	$\sum_j Y_{1j}^2 - \frac{(Y_{1.})^2}{11} - \left(\sum_j Y_{1j} I_j\right)^2 / \sum_j I_j^2$	
⋮	⋮	⋮	
Genotype 25	9	$\sum_j Y_{25j}^2 - \frac{Y_{25.}^2}{11} - \left(\sum_j Y_{25j} I_j\right)^2 / \sum_j I_j^2$	
Pooled error	264		MS_5

i) The significance of the difference among genotype means was tested using the F ratio,

$$F = \frac{MS_1}{MS_4} = \frac{\text{Mean square for varieties}}{\text{pooled deviation-mean square}}$$

ii) The significance of genotype x environment interaction was tested using the F ratio,

$$F = \frac{MS_2}{MS_5} = \frac{\text{Mean square for genotype x seasons}}{\text{pooled error mean square}}$$

iii) The genetic differences among genotypes for their regression on the environmental index were tested using the F ratio,

$$F = \frac{MS_3}{MS_4} = \frac{\text{Mean square for G x S (linear)}}{\text{pooled deviation mean square}}$$

iv) Deviation from regression for each genotype was tested using the F ratio,

$$F = \frac{(\sum_j \delta_{ij}^2)/9}{MS_5}$$

v) The significance of the difference between regression coefficients and unit was tested using the appropriate 't' test,

$$t = \frac{bi-1}{\sqrt{MS_4 / I_j^2 2}}$$

5. Correlation of meteorological parameters and physical components of soil with days to 50% bolting

Simple correlation coefficients between meteorological parameters and days to 50% bolting were worked out as suggested by Snedecor and Cochran (1967) for each genotype. The meteorological data were averaged out for each week. The correlation between days to 50% bolting and the weekly mean of the parameters from the week of sowing to bolting was worked out. In the case of rainfall, total rainfall per week was used for the correlation analysis.

G. Ascertaining the species status of the genotypes

All the genotypes used in the investigation were examined in detail to put them under the botanical species. The keys used for the identification were that of Bailey (1973) and Feine (1980).

Results

RESULTS

The results obtained in the present investigation are presented under the following heads.

A. Analysis of variance, estimation of variability and heritability for vegetable yield and its component characters and bolting.

B. Stability analysis for total vegetable yield and days to 50% bolting.

C. Correlation of various meteorological parameters and physical properties of soil with days to 50% bolting.

D. Chemical analysis of the edible parts

E. Ascertaining the correct species status of the genotypes.

A. Analysis of variance, estimation of variability and heritability for vegetable yield and its component characters and bolting.

1. Days to 50% germination

The 25 amaranth genotypes differed significantly in all the 12 sowings (Table 4.1a). It ranged from 4 (A 24, A 25, A 39) to 17 (A 18) days (Appendix IV and Table 4.2a). The earliest (4 days) germination of all the varieties was observed during April 1981 sowing and delayed (6 days) germination was observed during June 1981. The genotypic

Table 4.1. General analysis of variance for vegetable yield and component characters. in amaranths

a. Days to 50% germination

Sources	df	Mean sum of squares											
		E_1	E_1^+	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}
Replications	1	0.50	0.50	12.50	0.72	6.48	0.98	0.60	0.50	2.00	0.18	0.02	1.71
Genotypes	24	1.36**	1.26**	21.17**	1.78**	2.22**	3.04**	2.00**	3.17**	2.48**	0.88**	2.21**	4.67**
Error	24	0.17	0.21	0.58	0.60	0.69	0.65	0.50	0.38	0.46	0.22	0.40	0.29

b. Height of plants on 30th day after sowing

Sources	df	Mean sum of squares										
		E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}
1	2	3	4	5	6	7	8	9	10	11	12	13
Replications	1	320.05	17.93	163.44	23.27	121.77	0.46	11.79	47.18	140.28	10.82	45.60
Genotypes	24	94.72**	45.73**	21.51	46.30**	19.49*	47.50*	47.84**	26.58**	64.43**	68.64**	118.12**
Error	24	31.79	16.69	11.72	7.86	8.85	23.73	4.06	3.31	17.15	12.55	37.23

c. Girth of stem at cut-end on 30th day after sowing

Sources	df	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}
Replications	1	0.79	5.92	27.83	12.41	0.17	4.26	0.56	2.56	0.01	0.66	23.12
Genotypes	24	7.40	11.08**	6.36	3.86**	3.49**	2.30	1.84*	5.61**	3.57	8.63**	14.77**
Error	24	4.98	1.14	3.61	1.08	0.98	1.37	0.80	0.36	3.26	1.59	5.56

* (p=0.05) ** (p=0.01)

Times of sowing: E_1 = April 1981; E_1^+ = May 1981; E_2 = June 1981; E_3 = July 1981; E_4 = August 1981; E_5 = September 1981; E_6 = October 1981; E_7 = November 1981; E_8 = December 1981; E_9 = January 1982; E_{10} = February 1982; E_{11} = March 1982. (contd.)

Table 4.2. Mean, standard error of mean (S.Em), range, genetic coefficient of variation (gcv), phenotypic coefficient of variation (pcv), coefficient of variation (cv), heritability (h^2), genetic advance (GA) and genetic advance as percentage of mean for vegetable yield and component characters

Seasons	Mean ± S.Em	Range	gcv	pcv	cv	h^2	GA	GA as percentage of mean
1	2	3	4	5	6	7	8	9
a. Days to 50% germination								
E_1	4.34±0.29	4.00-8.00	17.81	20.16	9.40	0.78	1.41	32.47
E_{1+}	4.60±0.32	4.00-7.50	15.78	18.63	9.91	0.72	1.27	27.52
E_2	6.06±0.54	4.00-17.00	52.94	54.42	12.61	0.95	6.43	106.10
E_3	4.92±0.55	4.00-8.50	15.63	22.13	15.67	0.50	1.12	22.74
E_4	5.44±0.59	4.00-8.50	16.10	22.17	15.26	0.53	1.31	24.07
E_5	5.18±0.57	4.00-10.50	21.10	26.20	15.52	0.65	1.81	35.02
E_6	5.54±0.50	4.00-6.00	15.65	20.20	12.76	0.60	1.38	24.98
E_7	4.74±0.43	4.00-10.00	24.94	28.10	12.91	0.79	2.16	45.64
E_8	5.48±0.48	4.00-8.00	18.34	22.12	12.35	0.69	1.72	31.33
E_9	4.62±0.33	4.00-6.50	12.42	16.00	10.07	0.60	0.92	19.87
E_{10}	4.70±0.44	4.00-9.00	20.26	24.28	13.36	0.70	1.64	34.83
E_{11}	4.76±0.38	4.00-8.00	15.36	19.10	11.35	0.65	1.21	25.47
b. Plant height on 30th day after sowing								
E_1	27.73±3.99	13.38-41.55	20.23	28.68	20.33	0.50	8.15	29.39
E_2	20.76±2.89	11.50-25.95	18.36	26.91	19.68	0.47	5.36	25.79
E_3	23.81± 2.42	20.05-29.63	9.30	17.12	14.38	0.29	2.47	10.39
E_4	14.26±1.98	7.17-25.25	30.71	36.49	19.65	0.71	7.61	53.35
E_5	19.08±2.10	12.50-23.95	12.09	19.73	15.60	0.38	2.91	15.26
E_6	18.52±3.44	10.50-31.70	18.59	32.21	26.30	0.33	4.10	22.11
E_7	15.51±1.42	9.13-29.63	30.18	32.85	13.00	0.84	8.85	57.09
E_8	16.30±1.29	9.20-25.13	20.93	23.71	11.15	0.78	6.20	38.05
E_9	23.09±2.93	14.65-35.20	21.06	27.66	17.93	0.58	7.63	33.02
E_{10}	24.50±2.50	14.75-35.00	114.49	21.64	14.45	0.69	9.07	37.02
E_{11}	44.17±4.31	23.50-60.80	14.40	19.95	13.81	0.52	9.45	21.40

(contd.)

coefficient of variation (gcv) ranged from 12.42 to 52.94. Heritability of the character varied from 0.50 to 0.95. Genetic advance (GA) as percentage of mean ranged from 19.87 to 106.10.

2. Plant height on the 30th day of sowing

All the genotypes were significantly different for plant height on the 30th day after sowing in 10 seasons (Table 4.1b) and in July 1981 sowing the genotypes were not significantly different. The plant height ranged from 23.50 cm (A 17) to 60.80 cm (A 28) during March 1982 (Appendix V and Table 4.2b). The highest average plant height (44.17 cm) was observed during March 1982 sowing and the lowest (14.26 cm) during August 1981 sowing. The gcv ranged from 9.30 in July 1981 to 114.49 in February 1982. Heritability ranged from 0.33 (October 1981 sowing) to 0.84 (November 1981 sowing). The GA as percentage of mean varied from 10.39 to 57.09.

3. Girth of stem at cut end on the 30th day of sowing

The genotypes were significantly different for girth of stem during 7 seasons and were not significantly different during 4 other seasons (Table 4.1c). The girth of stem ranged from 5.30 mm (A 43) to 15.60 mm (A 28) during March 1982 (Appendix VI and Table 4.2c). The maximum overall girth of stem was observed during March 1982 (10.04 mm) and

Table 4.2. continued

1	2	3	4	5	6	7	8	9
c. Girth of stem (mm) at cut-end on 30th day after sowing								
E_1	7.55±1.58	3.55-11.60	14.58	33.00	29.55	0.19	1.00	13.24
E_2	7.99±0.75	4.80-13.50	27.89	30.92	13.35	0.81	4.14	51.80
E_3	6.27±1.34	3.40- 9.40	18.72	35.64	30.32	0.28	1.27	20.28
E_4	4.51±0.74	2.70- 7.50	26.14	34.89	23.10	0.56	1.82	40.34
E_5	6.16±0.70	4.00- 9.25	18.15	34.30	16.08	0.28	1.22	19.79
E_6	5.76±0.83	3.80- 7.70	11.82	23.49	20.30	0.25	0.71	12.25
E_7	3.92±0.63	2.20- 6.25	18.38	29.33	22.89	0.39	0.93	23.62
E_8	3.39±0.42	1.48-10.00	47.87	51.00	17.63	0.88	3.13	9.54
E_9	5.70±1.28	3.20- 7.70	6.86	32.40	31.67	0.04	0.17	2.98
E_{10}	7.12±0.89	4.20-11.25	26.34	31.76	17.74	0.69	3.20	45.01
E_{11}	10.04±1.67	5.30-15.80	21.38	31.75	23.48	0.45	2.98	29.66
d. Length of 5th leaf (cm) on 30th day after sowing								
E_1	10.85±1.16	5.63-17.58	26.83	30.81	15.14	0.76	5.22	48.15
E_2	10.62±0.81	4.33-14.31	25.18	27.40	10.80	0.84	5.06	47.69
E_3	9.69±1.44	4.14-14.77	23.65	31.65	21.03	0.56	3.53	36.42
E_4	7.21±1.49	3.87-11.62	26.87	39.69	29.20	0.46	2.70	37.48
E_5	9.62±1.31	4.62-17.81	24.73	31.36	19.27	0.62	3.87	40.20
E_6	9.93±1.40	5.04-13.84	21.66	29.47	19.99	0.54	3.26	32.79
E_7	8.26±1.11	3.69-11.67	22.23	29.21	18.95	0.58	2.88	34.84
E_8	7.88±1.08	3.23-13.03	29.82	35.62	19.47	0.70	4.06	51.51
E_9	10.58±1.39	5.60-15.34	19.42	26.91	18.63	0.52	3.05	28.86
E_{10}	10.35±0.96	5.30-13.67	23.34	26.80	13.17	0.76	4.34	41.88
E_{11}	13.30±1.57	7.75-20.13	22.14	27.75	16.73	0.64	4.84	36.38

(contd.)

the minimum during December 1981 (3.39 mm). The gcv ranged from 11.82 to 27.89. Heritability varied from 0.04 to 0.81; and the GA as percentage of mean from 2.93 to 92.54.

4. Length of the 5th leaf, 30th day after sowing

All the 25 genotypes differed significantly for their leaf length during all the 11 seasons (Table 4.1d). It ranged from 7.75 cm (A 43) to 20.13 cm (A 13) during March 1982 (Appendix VII and Table 4.2d). The maximum overall mean for leaf length was also in March 1982 (13.30 cm) and the minimum in August 1981 (7.21 cm). The gcv ranged from 19.42 to 29.82, heritability from 0.46 to 0.84 and GA as percentage of mean from 28.88 to 48.15.

5. Width of the 5th leaf on the 30th day of sowing

The genotypes were significantly different in all the 11 seasons (Table 4.1e). It ranged from 5.09 cm (A 43) to 13.89 cm (A 13, A 28) in March 1982 sowing (Appendix VIII and Table 4.2e). The maximum mean width (8.65 cm) of all genotypes was observed in March 1982 sowing and the minimum (5.29 cm) in August 1981. The gcv ranged from 19.77 to 32.05, heritability from 0.52 to 0.86, and the GA as percentage of mean from 29.28 to 58.81.

6. Length of petiole of the 5th leaf on the 30th day of sowing

The genotypes differed significantly only in 7 seasons for length of petiole and in 4 seasons, they were not

Table 4.1 continued

1	2	3	4	5	6	7	8	9	10	11	12	13
d. Length of 5th leaf on 30th day after sowing												
Replications	1	51.65	1.28	0.47	0.76	1.03	11.25	4.79	4.09	0.25	1.20	8.10
Genotypes	24	19.64**	15.62**	14.66**	11.94**	14.75**	13.19**	9.18**	13.39**	12.32**	13.53**	22.28**
Error	24	2.70	1.32	4.15	4.43	3.43	3.94	2.45	2.35	3.88	1.86	4.95
e. Width of 5th leaf on 30th day after sowing												
Replications	1	39.18	2.61	0.14	0.00	0.10	1.57	0.29	1.09	0.06	1.55	0.00
Genotypes	24	6.32**	10.12**	5.71**	4.35**	5.71**	5.83**	5.69**	6.85**	7.07**	7.45**	12.47**
Error	24	1.31	0.74	1.36	1.36	1.38	1.85	0.73	0.79	1.53	0.90	3.26
f. Length of 5th leaf's petiole on 30th day after sowing												
Replications	1	12.67	0.06	0.69	0.13	0.44	0.51	0.18	0.00	4.74	0.27	1.07
Genotypes	24	1.31**	2.16*	3.69	1.44	2.48*	2.36**	2.41**	2.30**	1.57	3.45**	9.29
Error	24	0.46	0.92	1.91	1.11	1.05	0.59	0.73	0.36	1.08	0.59	5.13
g. Branches on 30th day after sowing												
Replications	1	4.68	0.50	0.36	0.02	3.77	0.01	0.14	4.32	0.15	0.13	3.04
Genotypes	24	15.74**	7.70**	5.03**	5.72**	4.51**	4.35**	4.38**	4.26**	5.07**	3.35**	6.13**
Error	24	3.07	2.22	0.55	0.25	1.24	1.61	0.27	0.48	0.89	0.54	3.06
h. Days to 50% bolting in control												
Replications	1	6.48	20.48	5.12	46.08	24.50	0.00	27.38	0.98	18.00	0.98	33.62
Genotypes	24	1315.41**	1190.35**	682.20**	352.46**	237.00**	221.44**	471.38**	596.72**	295.14**	297.96**	228.17**
Error	24	23.36	11.11	8.87	9.87	6.38	11.96	7.51	11.31	22.71	11.52	10.04

(contd.)

Table 4.2. continued

1	2	3	4	5	6	7	8	9
e. Width of 5th leaf (cm) on 30th day after sowing								
E_1	7.73±0.81	4.22-10.51	20.47	25.26	14.79	0.66	2.64	34.18
E_2	7.25±0.61	3.27-11.71	29.85	32.13	11.67	0.86	4.14	57.14
E_3	6.62±0.82	3.55-10.34	22.36	28.40	17.67	0.62	2.39	36.04
E_4	5.29±0.83	2.51- 8.87	23.08	31.97	22.13	0.52	1.82	34.48
E_5	6.51±0.83	3.05- 9.78	22.59	28.89	18.13	0.61	2.37	36.40
E_6	7.13±0.96	3.78-10.30	19.77	27.48	19.07	0.52	2.09	29.28
E_7	6.00±0.61	2.97- 9.64	26.15	29.82	14.33	0.77	2.85	47.44
E_8	5.43±0.63	2.38- 9.49	32.05	36.10	16.39	0.79	3.19	58.81
E_9	7.43±0.87	4.48-10.93	22.34	27.85	16.68	0.64	2.75	37.00
E_{10}	7.35±0.67	3.94-11.30	24.64	27.77	12.93	0.78	3.30	44.92
E_{11}	8.65±1.28	5.09-13.89	24.82	32.42	20.87	0.59	3.38	39.12
f. Length of petiole of 5th leaf (cm) on 30th day after sowing								
E_1	4.51±0.48	3.20- 5.85	14.47	20.86	15.02	0.48	0.93	20.68
E_2	4.81±0.68	2.15- 6.54	16.42	25.80	19.89	0.41	1.96	40.82
E_3	4.81±0.98	2.80- 8.28	19.64	34.77	28.71	0.32	1.10	22.84
E_4	3.65±0.74	1.90- 5.16	11.18	30.92	28.81	0.13	0.30	8.31
E_5	4.31±0.73	2.59- 6.89	19.61	30.84	23.81	0.40	1.11	25.66
E_6	4.76±0.54	2.58- 7.85	19.76	25.54	16.17	0.60	1.50	31.49
E_7	3.86±0.60	2.00- 5.87	23.76	32.43	22.05	0.54	1.39	35.84
E_8	3.80±0.42	2.43- 5.89	25.93	30.34	15.72	0.73	1.74	45.65
E_9	4.73±0.73	3.23- 6.87	10.46	24.30	21.93	0.19	0.44	9.25
E_{10}	5.03±0.54	2.80- 8.39	23.79	28.25	15.23	0.71	2.08	41.26
E_{11}	7.73±1.60	5.25-14.52	18.65	34.75	29.33	0.29	1.59	20.62

(contd.)

significantly different (Table 4.1f). It ranged from 5.25 cm (A 25) to 14.52 cm (A 28) in March 1981 sowing (Appendix IX and Table 4.2f). The maximum overall length of petiole was observed during March 1982 (7.73 cm) sowing and the minimum (3.65 cm) during August 1981 sowing. The range of gcv, heritability and GA as percentage of mean were 11.18 to 25.93, 0.13 to 0.73 and 8.31 to 45.65 respectively.

7. Branches/plant on the 30th day of sowing

All the 25 genotypes were significantly different in all the 11 seasons (Table 4.1g). The branches varied from 0.20 (A5) to 11.00 (A 34) in April 1981 crop (Appendix X and Table 4.2g). The maximum overall mean branches (4.50) were observed during March 1982 sowing and the minimum (2.63) during August 1981 sowing. The gcv ranged from 27.54 to 62.97, heritability from 0.33 to 0.91 and GA as percentage of mean from 32.79 to 124.04.

8. Days to 50% bolting in control

The genotypes were significantly different in all the 11 sowings (Table 4.1h). It ranged from 25 (A 12) to 124 (A 33) days during April 1981 sowing (Appendix XI and Table 4.2h). The maximum delay (55 days) in flowering was observed during June 1981 sowing and the earliest (40 days) flowering was during March 1982 sowing. The gcv, heritability and GA as percentage of mean varied from 24.61 to 49.45, 0.86 to 0.98 and 47.96 to 98.31 respectively.

Table 4.2. continued

1	2	3	4	5	6	7	8	9
g. Branches/plant on 30th day after sowing								
E_1	4.39±1.24	0.20-11.00	57.34	69.86	39.91	0.67	4.26	96.93
E_2	4.36±1.05	0.90- 8.70	38.00	51.12	34.19	0.55	2.54	58.19
E_3	4.12±0.52	1.75- 7.35	36.35	40.55	17.97	0.80	2.76	67.12
E_4	2.63±0.36	0.00- 6.00	62.97	65.83	19.24	0.91	3.26	124.04
E_5	3.29±0.79	1.17- 6.38	38.88	51.58	33.86	0.57	1.99	60.40
E_6	4.19±0.90	1.50- 7.40	27.97	41.22	30.28	0.46	1.64	39.10
E_7	2.94±0.37	0.17- 6.50	48.69	51.82	17.81	0.88	2.28	94.19
E_8	3.38±0.49	0.59- 5.38	40.71	45.56	20.47	0.80	2.53	74.91
E_9	4.07±0.67	0.88- 7.34	35.56	42.42	23.15	0.70	2.50	61.37
E_{10}	4.23±0.52	1.88- 7.67	28.04	33.00	17.40	0.72	2.08	49.10
E_{11}	4.50±0.24	1.59- 9.20	27.54	47.70	38.93	0.33	1.47	32.79
h. Days to 50% bolting in control								
E_1	52.32±3.42	24.00-124.00	48.58	49.54	9.24	0.97	51.44	98.31
E_2	55.10±2.36	25.00-124.00	44.07	44.48	6.03	0.98	49.56	89.94
E_3	54.68±2.11	24.00- 90.00	33.56	34.00	5.45	0.97	37.31	68.23
E_4	46.28±2.22	29.00- 62.00	28.28	29.08	6.79	0.95	26.22	56.65
E_5	44.82±1.79	28.00- 69.50	23.96	24.61	5.63	0.95	21.53	48.04
E_6	41.64±2.45	26.00- 60.50	24.58	25.94	8.31	0.90	19.97	47.96
E_7	47.10±1.94	22.00- 71.50	32.33	32.85	5.82	0.97	30.88	65.56
E_8	48.38±2.38	25.00- 76.50	35.36	36.04	6.95	0.96	34.58	71.48
E_9	42.56±3.37	21.00- 61.00	27.42	29.62	11.20	0.86	22.26	52.30
E_{10}	48.10±2.40	25.00- 74.50	24.88	25.86	7.06	0.93	23.72	49.31
E_{11}	39.90±2.24	22.00- 66.00	26.18	27.35	7.94	0.92	20.59	51.60

(contd.)

9. Days to 50% bolting in unicut rows

All genotypes differed significantly for the days to 50% bolting in the unicut rows in 10 sowings. They were not significantly different during February 1982 sowing (Table 4.1i). It ranged from 29 days (A 12) to 124 days (A 33) during April 1981 sowing (Appendix XII and Table 4.2i). The maximum overall mean days to bolting (66 days) was observed in the June 1981 sowing and the earliest (51 days) was in the August 1981 crop. The gcv, heritability and GA as percentage of mean ranged from 17.29 to 32.34, 0.81 to 0.99 and 27.30 to 66.81 respectively.

10. Nodes on bolting day

This was also significantly different in all genotypes during all the 11 seasons (Table 4.1j). It ranged from 10.10 (A 12) to 38.20 (A 6) during the June 1981 crop (Appendix XIII and Table 4.2j). The maximum overall mean number of nodes (22.17) was during the December 1981 crop and the minimum (17.33) was during the September 1981 sowing. The gcv, heritability and GA as percentage of mean varied from 16.14 to 36.50, 0.37 to 0.97 and 18.99 to 73.95 respectively.

11. Leaves on bolting day

All the 25 amaranth genotypes were significantly different in all the 11 sowings (Table 4.1k). It varied

Table 4.1. continued

1	2	3	4	5	6	7	8	9	10	11	12	13
i. Days to 50% bolting in unicut rows												
Replications	1	3.38	0.08	3.38	81.92	35.28	48.02	10.58	12.50	21.78	19.22	18.00
Genotypes	24	855.78**	927.46**	625.71**	380.13**	281.71**	280.73**	440.83**	638.03**	245.51**	275.22	196.61*
Error	24	10.01	5.91	6.09	10.80	4.41	72.73	18.16	39.92	7.66	29.18	8.13
j. Nodes on bolting day												
Replications	1	37.58	8.32	0.38	0.07	4.24	0.00	28.35	40.45	9.23	1.05	20.53
Genotypes	24	107.35**	110.07**	70.08**	45.75**	31.22**	57.77**	22.00**	97.47**	94.06**	51.13**	44.47
Error	24	5.19	1.84	4.49	0.80	1.96	4.98	4.55	5.98	9.09	4.12	22.67
k. Leaves on bolting day												
Replications	1	44.46	89.32	10.34	4.56	1.95	11.71	30.61	10.43	9.37	123.06	37.15
Genotypes	24	257.00**	469.51**	534.16**	227.87**	119.16**	228.93**	76.51*	105.49**	172.72**	153.25**	246.98**
Error	24	16.99	71.32	29.50	6.01	12.41	10.81	37.29	19.46	42.84	36.10	34.05
l. Plant height on bolting day												
Replications	1	185.40	2.45	3.56	23.19	235.31	953.80	87.17	23.32	29.38	0.18	167.23
Genotypes	24	2191.18**	2916.60**	991.04**	1097.47**	241.65**	372.85**	114.07**	408.66**	261.91	276.96**	946.17**
Error	24	70.75	100.50	26.76	17.94	55.36	77.63	14.50	24.15	163.30	60.95	69.30
m. Frequency of harvests												
Replications	1	0.50	0.98	0.18	0.00	0.02	2.00	0.00	0.00	0.18	0.00	0.02
Genotypes	24	0.26	2.14**	0.55**	0.35*	0.34**	1.94**	0.58**	1.98**	5.00**	3.78**	3.63**
Error	24	0.29	0.15	0.10	0.17	0.02	0.13	0.17	0.21	0.43	0.33	0.23

(contd.)

Table 4.2. continued

1	2	3	4	5	6	7	8	9
i. Days to 50% bolting in uni-cut rows								
E_1	63.58±2.24	29.50-124.00	32.34	32.72	4.98	0.98	41.87	65.85
E_2	65.76±1.72	32.00-124.00	32.65	32.85	3.70	0.99	43.93	66.81
E_3	64.46±1.74	24.00- 90.00	27.31	27.57	3.83	0.98	35.91	55.70
E_4	50.80±2.32	28.00- 68.00	26.75	27.52	6.47	0.94	27.21	53.56
E_5	54.20±1.48	34.00- 77.00	21.73	22.07	3.87	0.97	23.88	44.06
E_6	58.98±6.03	33.00- 78.00	17.29	22.54	14.46	0.59	16.11	27.30
E_7	62.50±3.01	36.00- 90.00	23.26	24.34	6.82	0.92	28.74	45.98
E_8	69.66±4.47	30.00- 96.00	24.83	26.43	9.07	0.88	33.46	48.03
E_9	54.26±1.96	27.50- 71.00	20.10	20.74	5.10	0.94	21.77	40.13
E_{10}	58.95±3.82	27.00- 78.00	18.82	20.93	9.16	0.81	20.54	34.85
E_{11}	53.64±2.02	40.00- 70.00	18.10	18.86	5.31	0.92	19.19	35.70
j. Nodes on bolting day								
E_1	21.25±1.61	11.50- 38.20	33.63	35.29	10.72	0.91	14.02	65.96
E_2	20.13±0.96	10.10- 38.20	36.50	37.15	6.70	0.97	14.89	73.95
E_3	20.71±1.50	11.00- 32.23	27.65	29.48	10.23	0.88	11.04	53.29
E_4	17.70±0.63	10.40- 29.67	26.79	27.26	5.06	0.97	9.57	57.07
E_5	17.33±0.99	13.35- 33.00	22.07	23.51	8.07	0.88	7.39	42.64
E_6	20.88±1.58	10.71- 28.88	24.61	26.83	10.70	0.84	9.69	46.41
E_7	18.30±1.51	1.01- 24.50	16.14	19.91	11.66	0.66	4.92	26.88
E_8	22.17±1.73	10.98- 35.88	30.16	32.45	1.03	0.88	13.09	59.05
E_9	21.65±2.13	10.60- 37.25	30.11	33.18	13.93	0.82	12.18	56.26
E_{10}	20.24±1.44	10.63- 34.00	23.95	25.97	10.03	0.85	9.19	45.40
E_{11}	20.38±3.37	11.34- 28.00	16.21	28.43	23.37	0.32	3.87	18.99

(contd.)

from 12.30 (A 3) to 83.88 (A 43) during July 1981 (Appendix XIV and Table 4.2k). The maximum overall mean (31.33) leaf was during the June 1981 crop and the minimum (17.77) was in September 1981. The gcv ranged from 26.96 to 54.30, heritability from 0.34 to 0.95 and the GA as percentage of mean from 27.21 to 108.83.

12. Plant height on bolting day

The genotypes differed significantly for plant height on bolting day in 10 sowings (Table 4.1l). It ranged from 13.84 cm (A 12) to 156.80 cm (A 33) during the April 1981 crop (Appendix XV and Table 4.2l). The maximum seasonal mean height was observed during the June 1981 crop and the minimum (30.22 cm) was in the November 1981 sowing. The range of gcv, heritability and GA as percentage of mean were 23.36, to 57.91, 0.23 to 0.97 and 16.00 to 105.53 respectively.

13. Frequency of harvest

The 25 amaranth genotypes differed significantly only in 10 sowings (Table 4.1m). The frequency ranged from 1 (A 12) to 6 cuttings (A 6, A 9, A 13, A 22) in January 1982 crop (Appendix XVI and Table 4.2m). The maximum overall mean number of harvests (3.50) were got in the January 1982 crop and the minimum (1.22) was in the September 1981 crop. The gcv, heritability and the GA as percentage of mean for the character ranged from 10.14 to 43.14, -0.07 to 0.89 and -5.43 to 81.49, respectively.

Table 4.2. continued

1	2	3	4	5	6	7	8	9
k. Leaves on bolting day								
E_1	30.51±2.91	13.40-54.40	35.91	38.37	13.51	0.88	21.11	69.20
E_2	31.33±5.97	13.13-80.59	45.04	52.49	26.95	0.74	24.93	79.56
E_3	31.11±3.84	12.30-83.88	51.06	53.97	17.46	0.90	30.94	99.45
E_4	19.40±1.73	10.60-65.33	54.30	55.75	12.64	0.95	21.11	108.83
E_5	17.77±2.50	10.00-44.50	41.12	45.66	19.83	0.81	13.55	76.26
E_6	22.84±2.32	12.88-47.17	45.71	47.93	14.39	0.91	20.49	89.69
E_7	19.66±4.32	10.50-35.04	22.53	38.37	31.07	0.34	5.35	27.21
E_8	20.12±3.12	10.60-40.04	32.60	39.28	21.92	0.69	11.20	55.65
E_9	29.89±4.63	13.00-51.13	26.96	34.74	21.90	0.60	12.83	43.09
E_{10}	27.09±4.25	14.17-50.59	28.25	35.92	22.18	0.62	12.39	45.73
E_{11}	29.78±4.13	13.67-59.00	34.65	39.81	19.60	0.76	18.49	62.09
l. Plant height (cm) on bolting day								
E_1	68.44±5.95	13.84-156.80	47.58	49.14	12.29	0.94	64.91	94.84
E_2	70.77±7.09	14.35-156.80	53.03	54.89	14.17	0.93	74.68	105.53
E_3	47.59±3.66	16.10-106.40	46.14	47.41	10.87	0.95	44.00	92.46
E_4	40.12±3.00	12.50- 95.50	57.91	58.87	10.56	0.97	47.06	117.30
E_5	33.99±5.26	13.33- 59.84	28.39	35.85	21.89	0.63	15.73	46.27
E_6	48.54±6.23	21.75- 79.38	25.03	30.92	18.15	0.66	20.24	41.69
E_7	30.22±2.69	14.35- 45.34	23.36	26.54	12.60	0.77	12.77	42.26
E_8	43.22±3.47	15.03- 69.08	32.08	34.04	11.37	0.89	26.91	62.25
E_9	43.48±9.04	18.75- 61.25	16.15	33.54	29.39	0.23	6.96	16.00
E_{10}	44.25±5.52	17.50- 63.67	23.49	29.38	17.65	0.64	17.10	38.64
E_{11}	66.85±5.89	32.34-101.17	31.33	33.71	12.45	0.86	40.07	59.94

(contd.)

14. Total vegetable yield

The genotypes were significantly different only in 8 sowings (Table 4.1n). The total vegetable yield ranged from 625 g/0.45 m^2 (A 35) to 2,130 g/0.45 m^2 (A 3) during March 1982 crop (Appendix XVI and Table 4.2n). The maximum (1,233.60 g/0.45 m^2) overall mean yield was also during March 1982 crop and the lowest (128.80 g/0.45 m^2) during the November 1981 crop. The gcv for yield ranged from 29.84 to 67.67, heritability from 0.20 to 0.77 and GA as percentage of mean from 31.63 to 121.97.

15. Pooled analysis of variance for vegetable yield and its component characters

The data collected during 11 independent trials were analysed separately for each season (environment) and pooled analysis over all seasons was done to ascertain the extent of variations due to genotypes, seasons and genotypes x seasons interactions (Table 4.3). The genotypes x seasons interactions were highly significant (p=0.01) in all the seasons. The 11 seasons of plantings showed significant difference (p=0.01) with regard to most of the characters studied. The 25 genotypes were also significantly different for the 14 characters studied.

Table 4.1. continued

1	2	3	4	5	6	7	8	9	10	11	12	13
n. Total vegetable yield												
Replications	1	6.48	3698.00	233928.00	15488.00	29282.00	11552.00	3872.00	76050.00	12800.00	10658,00	672800.00
Genotypes	24	95292.41	241631.33*	63183.83	16307.00**	36393.83*	248852.17**	12642.83	65263.83**	372863.00**	276637.83*	416873.00**
Error	24	48421.48	116039.67	36448.83	4196.33	17377.83	67231.17	8476.17	8295.83	89175.00	136178.83	145866.67

Table 4.2. continued

1	2	3	4	5	6	7	8	9
m. Frequency of harvests								
E_1	1.38±0.38	1.00-2.00	10.14	37.68	39.14	-0.07	-0.08	-5.43
E_2	2.38±0.27	1.00-4.00	42.02	44.96	16.09	0.87	1.92	80.55
E_3	1.74±0.22	1.00-3.00	27.59	32.76	17.87	0.70	0.82	47.30
E_4	1.44±0.29	1.00-2.00	20.83	35.42	28.35	0.35	0.36	25.28
E_5	1.22±0.10	1.00-2.00	32.79	34.43	11.59	0.89	0.78	63.61
E_6	2.36±0.25	1.00-4.00	40.25	43.22	14.98	0.88	1.84	78.09
E_7	1.40±0.29	1.00-2.50	32.86	43.57	29.16	0.56	0.71	50.43
E_8	2.52±0.32	1.00-4.00	37.30	41.67	18.11	0.81	1.75	69.29
E_9	3.50±0.46	1.00-6.00	43.14	47.14	18.73	0.84	2.85	81.49
E_{10}	3.32±0.41	1.00-5.00	39.76	43.37	17.39	0.84	2.48	74.82
E_{11}	3.10±0.34	1.00-5.00	42.06	44.84	15.48	0.88	2.52	81.13
n. Total vegetable yield (g)								
E_1	576.04±155.60	220.00-1085.00	26.58	46.54	38.20	0.33	182.23	31.63
E_2	636.80±240.87	65.00-1090.00	39.35	66.41	53.49	0.35	304.90	47.88
E_3	282.40±135.00	80.00- 690.00	40.94	79.04	67.60	0.27	124.14	43.96
E_4	160.60± 45.81	55.00- 410.00	48.45	63.05	40.34	0.59	123.06	76.62
E_5	211.40± 93.21	65.00- 530.00	46.13	77.56	62.36	0.35	118.22	55.92
E_6	603.60±183.35	65.00-1245.00	43.93	65.86	42.96	0.57	466.80	77.34
E_7	128.80± 65.10	50.00- 350.00	35.43	79.78	71.48	0.20	42.34	32.87
E_8	249.40± 64.40	30.00- 490.00	67.67	76.90	36.52	0.77	304.20	121.97
E_9	677.60±211.10	170.00-1800.00	55.58	70.93	44.07	0.61	603.98	89.13
E_{10}	772.20±260.94	150.00-1375.00	34.32	58.83	47.79	0.34	318.39	41.23
E_{11}	1233.60±270.06	625.00-2130.00	29.84	43.00	30.96	0.48	526.25	42.66

Table 4.3. Pooled analysis of variance for vegetable yield and its components

Source	df	Mean sum of squares							
		Germination+	Plant height	Girth of stem	Leaf length	Leaf width	Petiole length	Branches	Days to bolting - control
Genotypes	24	9.82**	109.79**	14.28**	50.54**	27.31**	7.60**	17.72**	2051.57**
Seasons	10 (11)+	7.54**	1722.00**	92.63**	69.36**	25.47**	30.23**	10.48**	646.94**
Genotypes x Seasons	240 (264)+	1.05**	219767.45**	16774.95**	42567.88**	20797.38**	9671.58**	6193.16**	1004650.59**
Pooled error	264 (288)+	0.43	15.90	2.25	3.22	1.38	1.26	1.29	12.24

Source	Mean sum of squares					
	Days to bolting--unicut	Number of nodes	Number of leaves	Plant height (bolting day)	Frequency of harvest	Yield
Genotypes	1847.15**	243.69**	808.97**	2924.58**	5.80**	312160.80**
Seasons	895.87**	64.32**	744.14**	4788.91**	17.44**	2813397.63**
Genotypes x Seasons	1579995.38**	178598.31**	277923.97**	1077523.59**	2218.80**	114389186.00**
Pooled error	19.36	5.97	28.80	61.92	0.20	61609.80

+ There are 12 seasons for the character - days to germination.

** Significant at 1% level.

B. Stability analysis for total vegetable yield and days to 50% bolting

Phenotypic stability analysis as suggested by Eberhart and Russel (1966) was performed to estimate parameters of stability for each of the 25 genotypes (Table 4.4 and Table 4.5) with regard to the total vegetable yield and days to 50% bolting. Genotypes were significantly different for total vegetable yield and days to bolting. Effects of seasons were also significantly different. The genotypes x environment (seasons) interactions were highly significant (p=0.01). The equality of regression of individual mean performance on environmental index (bi) was tested for significance and was found to be highly significant for yield and bolting. The significance of difference between regression coefficient and unity was tested and were observed significant in A 3, A 5, A 12, A 28, A 33, A 34 and A 35 for yield and A 6, A 12, A 33 and A 39 for bolting. The deviation from regression (S^2di) of each of the genotypes was tested from 0 and was observed significant only for the genotype A 33 for bolting. In all other genotypes S^2di was not significantly different from zero. The genotype A 6 had the highest mean yield (769.09 g/0.45 m^2) followed by A 13 (740.46 g/0.45 m^2), A 22 (736.36 g/0.45 m^2) and A 33 (698.64 g/0.45 m^2).

Table 4.4. General analysis of variance of phenotypic stability for vegetable yield and days to bolting

Source	df	Mean sum of squares	
		Yield	Bolting
Genotypes	24	312160.80**	2051.57**
Seasons	10	2813397.63**	646.94**
Genotypes x Seasons	240	114389186.00**	1004650.59**
Season + (Genotype x Season)	250	109926155.10	964490.44
Season (linear)	1	10133796.77	6470.07
Genotypes x Season (linear)	24	884342.53**	364.34**
Pooled deviation	225	50430.12	57.62
Genotypes--			
A 2	9	31274.23	13.14
A 3	9	88235.53	13.44
A 4	9	73843.09	30.60
A 5	9	20343.27	46.45*
A 6	9	124428.70	280.39*
A 9	9	39903.29	20.50
A 12	9	20681.85	6.83
A 13	9	18413.04	28.51
A 14	9	78754.85	27.73
A 16	9	18706.52	45.57*
A 17	9	30574.14	7.72
A 18	9	77944.06	27.73
A 19	9	11416.06	24.52
A 22	9	124854.60	112.57*
A 24	9	31023.84	52.12*
A 25	9	75185.44	48.69*
A 27	9	25321.50	56.10*
A 28	9	68319.24	39.54*
A 33	9	42380.16	307.05*
A 34	9	24476.33	15.67
A 35	9	21985.06	12.81
A 39	9	21365.33	17.50
A 40	9	66100.95	90.65*
A 41	9	68133.98	51.61*
A 43	9	47087.94	62.97*
Pooled error	264	61609.80	12.24

* Significant at 5% level. ** Significant at 1% level.

Table 4.5. Parameters of phenotypic stability for vegetable yield and days to bolting

Genotypes	Mean		bi		S^2di	
	Yield	Bolting	Yield	Bolting	Yield	Bolting
A 2	385.46	33.23	0.93	0.60	469.33	7.02
A 3	662.27	39.86	1.49*	0.72	57430.63	7.32
A 4	576.82	43.05	0.96	0.31	43038.19	24.48
A 5	550.91	50.68	1.53*	0.62	-10461.63	40.33
A 6	769.09	75.05	1.30	4.16**	93623.80	274.27
A 9	473.64	54.59	0.62	0.59	9098.39	14.38
A 12	205.46	24.73	0.54*	0.05*	-10123.05	0.71
A 13	740.46	55.55	1.05	1.01	-2391.86	22.39
A 14	691.82	56.64	1.11	1.20	47949.95	21.61
A 16	484.55	61.64	1.11	1.38	-12098.38	39.45
A 17	355.91	30.50	0.90	-0.20	-230.76	1.60
A 18	404.55	33.77	1.21	0.90	47139.16	21.61
A 19	426.36	42.96	0.72	0.33	-19388.84	18.40
A 22	736.36	58.91	1.30	1.09	94049.70	106.45
A 24	646.00	64.36	1.24	1.20	218.94	46.00
A 25	594.09	61.68	0.66	1.60	44380.54	42.57
A 27	393.18	41.59	0.71	0.46	-5483.40	49.98
A 28	586.82	47.32	1.54*	1.45	37514.34	33.42
A 33	698.64	74.91	1.43*	4.50**	11575.26	300.93*
A 34	303.64	31.77	0.51*	0.21	-6328.57	9.55
A 38	233.64	34.68	0.37**	0.26	-8819.84	6.69
A 39	255.46	36.14	0.63	0.02*	-9439.57	11.38
A 40	589.55	46.68	1.41	1.92	35296.05	84.53
A 41	363.64	42.77	0.86	1.63	37329.08	45.49
A 43	445.46	40.77	0.86	0.17	16283.04	56.85

* Significant at 5% level
** Significant at 1% level

A two dimensional representation of stability parameters (μ and bi) is being made for the 25 amaranth genotypes for yield (Fig.1) and bolting (Fig.2). The line A 13 with higher mean yield (740.46 g/0.45 m^2) and regression coefficient tending to 1 appeared in the 4th quadrant. Line A 6 with the highest mean yield (769.09 g/0.45 m^2) had bi=1.30. The line A 25 with an average mean yield (594.09 g/0.45 m^2) had regression value 0.70 falling in the 3rd quadrant.

The line A 13 appeared stable for bolting. It took 56 days to bolt and had a bi value of 0.10. The lines A 33 and A 6 were highly unstable (bi=4.50 and 4.20 respectively) though they flowered only after 75 days of sowing on an average over 11 seasons. The line A 12 bolted 25 days after sowing and had a regression value less than 0.10.

C. Correlation of various meteorological parameters and physical properties of soil with days to 50% bolting

Correlation coefficients between days to 50% bolting and various meteorological parameters, mean maximum temperature, mean minimum temperature, total rainfall, number of rainy days, mean relative humidity and mean bright sunshine hours, recorded at weekly interval, from date of sowing to bolting for each of the 25 genotypes were worked out (Table 4.6). The genotypes started bolting from the 4th

FIG. 1 - SCATTER DIAGRAM INDICATING MEAN PERFORMANCE (μ) AND REGRESSION COEFFICIENT (b_i) FOR YIELD

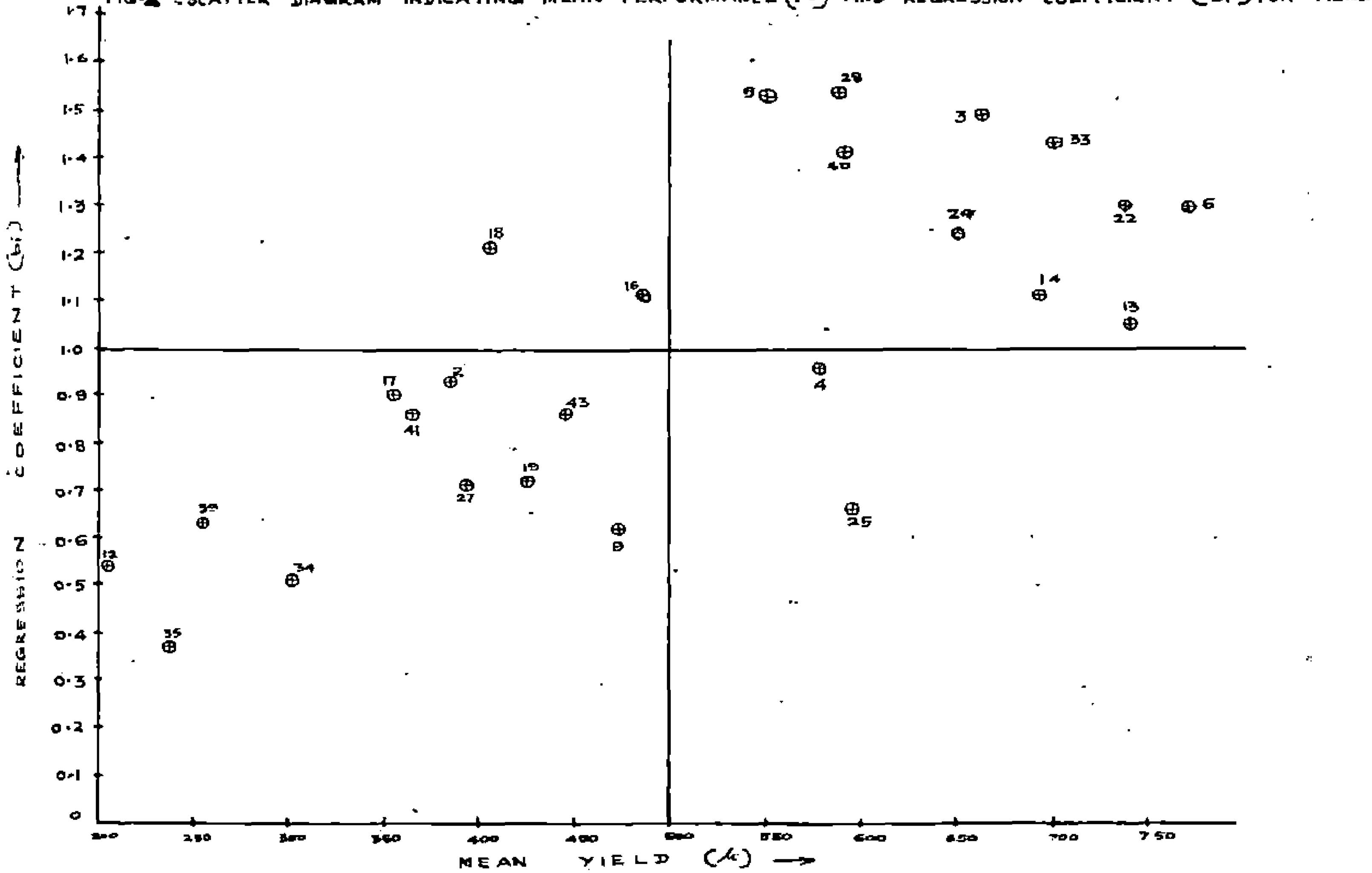


Fig 2 SCATTER DIAGRAM INDICATING MEAN PERFORMANCE (μ) AND REGRESSION COEFFICIENT (bi) FOR DAYS TO 50% BOLTING

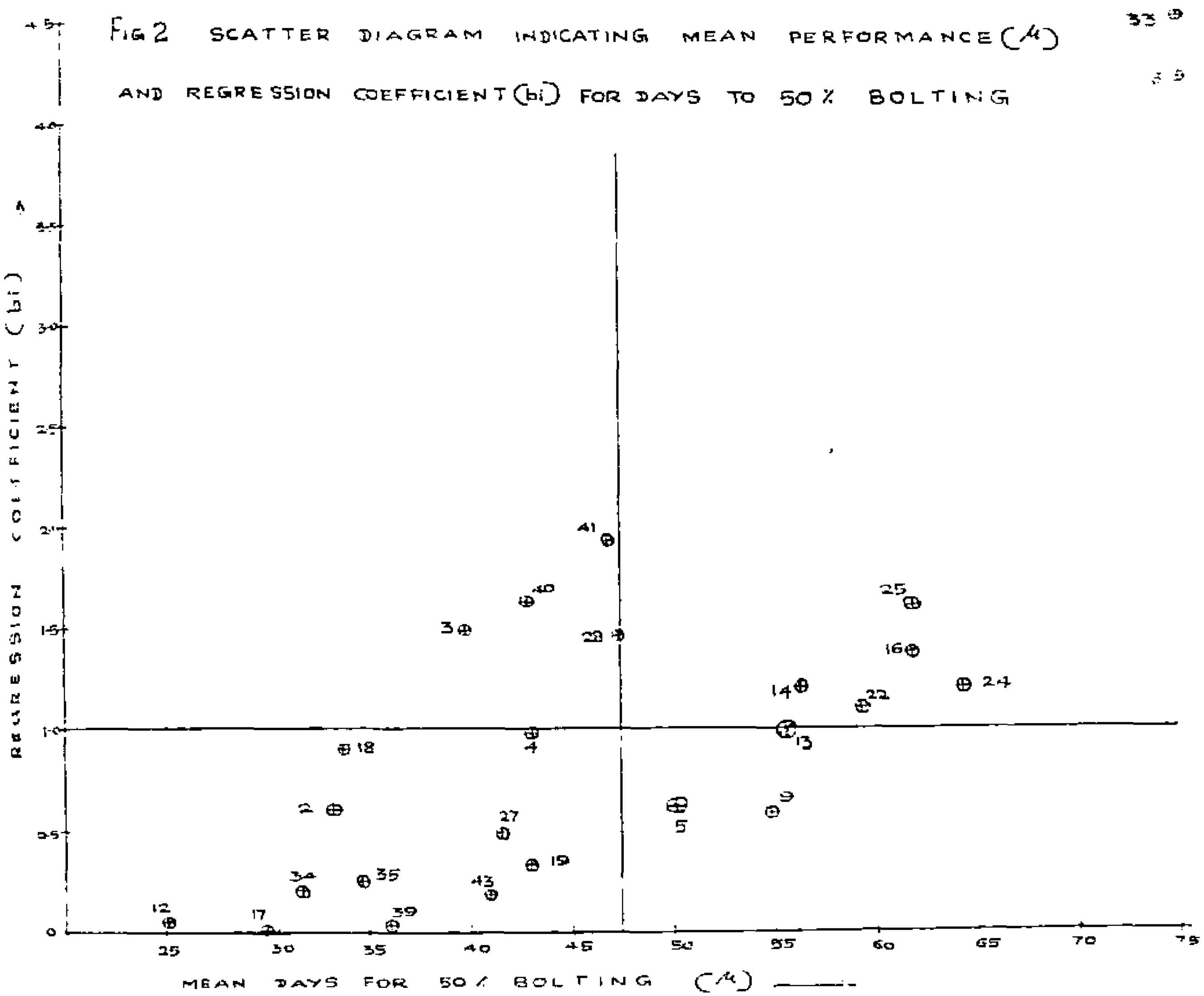


Table 4.6. Correlation coefficients between days to 50% bolting and various meteorological parameters for different amaranth genotypes during different growth periods

Genotypes	1st week of sowing						2nd week of sowing					
	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
A 2	-0.58	-0.34	0.72*	0.57	0.44	-0.52	-0.52	-0.29	0.50	0.65*	0.33	-0.44
A 3	-0.09	0.11	0.46	0.39	0.29	-0.24	-0.06	0.24	0.41	0.47	0.34	-0.31
A 4	-0.09	-0.57	0.30	0.20	-0.31	-0.14	-0.43	-0.66*	-0.11	0.09	0.02	-0.02
A 5	-0.61*	-0.57	0.75**	0.74**	0.30	-0.74**	-0.81**	-0.64*	0.46	0.69*	0.45	-0.63*
A 6	0.04	0.25	0.33	0.13	0.14	-0.05	0.08	0.30	0.66*	0.47	0.13	-0.18
A 9	-0.38	-0.64	0.38	0.24	-0.10	-0.45	-0.53	-0.58	0.37	0.34	-0.03	-0.19
A 12	-0.41	-0.24	0.21	0.45	0.22	-0.25	-0.51	-0.04	0.24	0.32	0.32	-0.37
A 13	-0.37	-0.69	0.10	0.24	-0.15	-0.50	-0.54	-0.64*	0.09	0.26	-0.11	-0.23
A 14	-0.21	0.08	0.49	0.28	0.24	0.01	-0.12	-0.03	0.62*	0.48	0.00	-0.20
A 16	-0.19	-0.48	0.31	0.10	-0.24	0.00	-0.30	-0.48	0.13	0.15	-0.26	0.11
A 17	0.65*	-0.27	-0.43	-0.62*	-0.62*	-0.65*	0.47	0.15	0.54	0.66*	0.33	0.68*
A 18	-0.37	0.31	0.74**	0.65*	0.68*	-0.51	-0.29	0.36	0.71*	0.74**	0.74**	-0.64*
A 19	-0.50	-0.45	0.55	0.55	0.24	-0.70*	-0.61	-0.51	0.54	0.57	0.21	-0.59
A 22	-0.70*	-0.54	0.50	0.48	0.16	-0.52	-0.78**	-0.54	0.26	0.48	0.12	-0.33
A 24	-0.25	-0.10	0.23	0.27	0.08	0.03	-0.22	-0.03	0.25	0.37	-0.05	-0.11
A 25	-0.34	-0.14	0.50	0.32	0.10	-0.24	-0.34	-0.30	0.29	0.49	-0.03	-0.18
A 27	-0.02	-0.26	0.30	0.29	0.07	0.23	-0.07	-0.38	0.05	0.09	0.00	-0.12
A 28	-0.38	-0.12	0.68*	0.57	0.37	-0.29	-0.45	0.03	0.69*	0.64*	0.51	-0.46
A 33	0.04	+0.22	0.30	0.08	0.12	0.01	0.11	0.28	0.63*	0.45	0.06	-0.12
A 34	-0.29	-0.68*	0.18	0.16	-0.22	-0.13	-0.53	-0.49	-0.02	0.10	0.02	0.01
A 35	0.15	-0.27	0.13	0.14	-0.30	-0.01	-0.16	-0.19	-0.06	0.04	0.10	-0.00
A 39	0.06	-0.74**	0.11	0.13	-0.26	-0.09	-0.23	-0.49	-0.08	-0.03	0.10	-0.00
A 40	-0.01	0.37	0.51	0.34	0.44	-0.15	0.11	0.38	0.65*	0.63*	0.37	-0.36
A 41	0.00	0.28	0.42	0.28	0.30	-0.01	0.14	0.27	0.58	0.51	0.12	-0.24
A 43	0.22	-0.21	-0.16	-0.19	-0.45	0.53	0.13	-0.31	-0.43	-0.37	-0.50	0.44

* Significant at 5% level. ** Significant at 1% level. (contd.)

M_1 - Mean maximum temperature
M_2 - Mean minimum temperature
M_3 - Total rainfall
M_4 - Number of rainy days
M_5 - Mean relative humidity
M_6 - Mean bright sunshine hours

Table 4.6. continued

Genotypes	3rd week of sowing						4th week of sowing					
	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
A 2	-0.63	-0.26	0.52	0.60	0.33	-0.68*	-0.75**	-0.06	0.59	0.56	0.49	-0.82**
A 3	-0.26	0.12	0.27	0.23	0.47	-0.30	-0.37	0.64*	0.24	0.31	0.60*	-0.51
A 4	-0.19	-0.37	-0.16	-0.01	0.04	-0.20	-0.29	-0.54	0.22	0.06	0.24	-0.12
A 5	-0.66	-0.28	0.38	0.59	0.36	-0.77**	-0.72*	-0.50	0.62*	0.47	0.50	-0.63*
A 6	-0.01	0.21	0.44	0.27	0.30	-0.13	-0.07	0.46	0.01	0.14	0.21	-0.15
A 9	-0.45	-0.70*	0.27	0.30	-0.07	-0.28	-0.57	-0.31	0.19	0.07	0.06	-0.34
A 12	-0.56	0.08	0.46	0.55	0.45	-0.56	-	-	-	-	-	-
A 13	-0.43	-0.63*	0.14	0.28	-0.15	-0.30	-0.55	-0.53	0.45	0.22	0.06	-0.31
A 14	-0.22	0.07	0.47	0.34	0.09	-0.29	-0.13	0.07	-0.02	0.04	0.03	-0.19
A 16	-0.29	-0.60*	0.08	0.06	-0.17	-0.10	-0.41	-0.17	0.04	-0.05	0.03	-0.25
A 17	0.66*	-0.08	-0.38	-0.43	-0.20	0.45	0.64*	-0.19	-0.45	-0.46	-0.12	0.52
A 18	-0.48	0.41	0.53	0.53	0.76**	-0.59	-0.48	0.54	0.37	0.53	0.67*	-0.64*
A 19	-0.45	-0.28	0.21	0.30	-0.03	-0.38	-0.42	-0.43	0.22	0.10	-0.07	-0.18
A 22	-0.77	-0.53	0.35	0.49	0.09	-0.57	-0.87**	-0.48	0.60*	0.47	0.23	-0.67*
A 24	-0.44	-0.04	0.40	0.38	0.23	0.37	-0.47	0.15	0.40	0.37	0.40	-0.52
A 25	-0.42	-0.26	0.18	0.22	0.20	-0.32	-0.56	-0.15	0.50	0.44	0.17	-0.49
A 27	0.07	-0.04	-0.03	0.02	-0.44	-0.20	0.10	-0.17	-0.13	-0.21	0.12	-0.01
A 28	-0.55	0.15	0.66*	0.64*	0.66*	-0.65*	-0.49	0.19	0.25	0.32	0.64*	-0.57
A 33	-0.09	0.17	0.47	0.29	0.25	-0.13	-0.07	0.42	0.06	0.18	0.19	-0.18
A 34	-0.45	-0.48	0.20	0.31	0.15	-0.35	-0.53	-0.43	0.30	0.18	0.33	-0.39
A 35	-0.06	-0.10	-0.15	-0.10	0.24	-0.05	-0.13	0.07	0.02	-0.05	0.42	-0.05
A 39	-0.04	-0.34	0.05	+0.15	0.19	-0.25	-0.13	-0.24	0.06	-0.08	0.45	-0.16
A 40	-0.11	0.47	0.48	0.38	0.53	-0.36	-0.12	0.56	0.29	0.42	0.51	-0.40
A 41	-0.07	0.29	0.40	0.27	0.28	-0.24	-0.07	0.51	0.11	0.20	0.31	-0.28
A 43	0.21	-0.26	-0.39	-0.40	-0.40	0.27	0.20	-0.17	-0.32	-0.42	-0.19	+0.26

(contd.)

Table 4.6. continued

Genotypes	5th week of sowing						6th week of sowing					
	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
A 2	-0.61*	-0.27	0.43	0.52	0.31	-0.38	-0.60*	-0.22	-0.02	0.31	0.22	-0.21
A 3	-0.54	0.23	0.45	0.45	0.50	-0.49	-0.65*	0.13	0.57	0.67*	0.48	-0.63*
A 4	-0.20	-0.01	-0.32	-0.17	0.17	0.04	0.24	0.15	-0.43	-0.33	-0.20	0.31
A 5	-0.60*	-0.40	0.09	0.28	0.30	-0.30	-0.26	-0.11	-0.39	-0.09	-0.02	0.13
A 6	-0.30	0.24	0.68*	0.42	0.47	-0.39	-0.40	-0.03	0.65*	0.79**	0.44	-0.61*
A 9	-0.42	-0.35	0.14	0.02	-0.05	0.03	-0.21	-0.40	-0.28	-0.06	-0.34	0.27
A 12	-	-	-	-	-	-	-	-	-	-	-	-
A 13	-0.23	-0.54	-0.24	-0.25	-0.26	0.36	0.07	-0.34	-0.48	-0.47	-0.56	0.55
A 14	-0.28	-0.19	0.70*	0.55	0.34	-0.56	-0.45	-0.39	0.56	0.76**	0.38	0.63*
A 16	-0.31	-0.15	0.16	0.08	0.07	-0.09	-0.23	-0.36	0.08	0.19	-0.17	-0.07
A 17	0.56	0.48	-0.33	-0.37	-0.08	0.29	-	-	-	-	-	-
A 18	-0.72*	0.24	0.66*	0.75**	0.73**	-0.76**	-0.79**	0.15	0.45	0.78**	0.66*	0.72*
A 19	-0.31	-0.66*	0.06	0.03	-0.12	-0.13	-0.15	-0.42	-0.15	0.02	-0.32	0.17
A 22	-0.61*	-0.44	0.10	0.22	0.13	-0.06	-0.34	-0.42	-0.31	-0.09	-0.30	0.16
A 24	-0.50	0.03	0.42	0.43	0.47	-0.31	-0.47	-0.23	0.48	0.48	0.24	-0.54
A 25	-0.34	-0.24	0.18	0.18	0.16	-0.06	-0.27	-0.22	0.21	0.34	-0.05	-0.17
A 27	0.02	-0.27	0.02	0.13	-0.01	-0.38	-0.07	-0.08	-0.05	0.09	0.22	-0.17
A 28	-0.79**	0.20	0.74**	0.79**	0.84**	-0.82**	-0.68*	-0.04	0.30	0.63*	0.59	-0.65*
A 33	-0.25	0.20	0.70*	0.42	0.44	-0.34	-0.39	-0.06	0.64*	0.78**	0.44	-0.60
A 34	-0.45	0.02	-0.02	0.09	0.29	-0.03	-0.05	-0.08	-0.45	-0.30	-0.16	0.23
A 35	-0.31	0.38	-0.14	-0.07	0.39	-0.15	0.02	0.31	0.04	0.00	0.06	-0.09
A 39	-0.19	0.12	-0.14	-0.04	0.18	-0.09	0.11	0.24	-0.49	-0.39	0.08	0.27
A 40	-0.31	0.25	0.69*	0.59	0.59	-0.55	-0.51	0.20	0.69*	0.87**	0.75**	-0.77**
A 41	-0.25	0.07	0.66*	0.51	0.41	-0.52	-0.52	-0.06	0.80**	0.89**	0.60	-0.78**
A 43	0.18	-0.03	-0.24	-0.20	-0.13	0.01	0.18	-0.15	0.16	-0.03	-0.14	-0.03

(contd.)

Table 4.6. continued

Genotypes	7th week of sowing						8th week of sowing					
	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
A 2	-	-	-	-	-	-	-	-	-	-	-	-
A 3	-0.77**	0.21	0.67*	0.69*	0.55	-0.67*	-0.68*	-	-	-	-	-
A 4	0.15	0.11	-0.25	-0.16	-0.15	0.18	-0.26	0.05	-0.24	-0.03	-0.37	0.28
A 5	-0.33	-0.14	-0.11	0.12	0.17	-0.22	-0.27	0.15	-0.02	0.23	0.08	-0.15
A 6	-0.56	0.17	0.68*	0.66*	0.53	-0.72*	-0.65*	-0.27	+0.87**	+0.87**	0.51	-0.77**
A 9	-0.24	-0.30	-0.13	-0.04	-0.13	-0.03	-0.21	-0.48	0.05	0.21	-0.19	-0.04
A 12	-	-	-	-	-	-	-	-	-	-	-	-
A 13	0.02	-0.48	-0.31	-0.33	-0.31	0.21	0.06	-0.12	-0.39	-0.23	-0.34	0.20
A 14	-0.49	-0.01	0.58	0.54	0.57	-0.74**	-0.52	-0.29	0.65	0.67*	0.54	-0.58
A 16	-0.24	-0.07	0.17	0.13	0.01	-0.23	-0.12	-0.70*	0.16	0.27	-0.21	-0.01
A 17	-	-	-	-	-	-	-	-	-	-	-	-
A 18	-0.88**	0.25	0.61*	0.85**	0.62*	-0.81**	-	-	-	-	-	-
A 19	-0.26	-0.58	0.05	0.12	-0.04	-0.17	-0.38	-0.03	0.17	0.25	0.11	-0.27
A 22	-0.31	-0.25	-0.09	0.08	-0.15	-0.18	-0.17	-0.51	-0.09	0.04	-0.23	0.00
A 24	-0.51	0.06	0.53	0.41	0.31	-0.59	-0.34	-0.48	0.30	0.33	0.06	-0.32
A 25	-0.40	-0.02	0.45	0.51	0.25	-0.50	-0.33	-0.53	0.45	0.50	0.19	-0.37
A 27	-0.04	-0.03	0.06	-0.02	0.39	-0.11	-0.01	0.35	-0.08	0.04	0.23	0.06
A 28	-0.70*	0.24	0.37	0.52	0.50	-0.69*	-0.61*	-0.15	0.51	0.65*	0.28	-0.53
A 33	-0.53	0.21	0.68*	0.65*	0.57	-0.73*	-0.60*	-0.30	0.85**	0.85**	0.56	-0.75**
A 34	-	-	-	-	-	-	-	-	-	-	-	-
A 35	-0.12	0.18	0.10	0.04	-0.04	0.01	-0.01	-	-	-	-	-
A 39	-	-	-	-	-	-	-	-	-	-	-	-
A 40	-0.69*	0.38	0.80**	0.86**	0.90**	-0.88**	-0.73*	0.07	0.93**	0.96**	0.86**	-0.89**
A 41	-0.65*	0.17	0.85**	0.76**	0.81**	-0.86**	-0.69*	-0.14	0.86**	0.85**	0.75*	-0.79**
A 43	0.22	-0.01	0.75**	-0.18	-0.09	0.11	-	-	-	-	-	-

(contd.)

Table 4.6. continued

Genotypes	9th week of sowing						10th week of sowing					
	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
A 2	-	-	-	-	-	-	-	-	-	-	-	-
A 3	-	-	-	-	-	-	-	-	-	-	-	-
A 4	-	-	-	-	-	-	-	-	-	-	-	-
A 5	-0.22	-0.12	0.01	0.39	-0.09	0.12	0.25	-0.42	-0.54	-0.46	-0.12	0.18
A 6	-0.45	-0.17	0.70*	0.60	0.46	-0.26	-0.15	-0.04	0.56	0.40	0.40	-0.36
A 9	0.01	-0.19	-0.05	0.16	-0.13	0.35	-	-	-	-	-	-
A 12	-	-	-	-	-	-	-	-	-	-	-	-
A 13	0.14	-0.05	-0.17	0.07	-0.36	0.36	-	-	-	-	-	-
A 14	-0.42	-0.28	0.56	0.52	0.29	-0.19	0.23	-0.28	0.22	-0.03	0.28	-0.05
A 16	0.08	-0.38	0.17	0.21	-0.14	0.29	0.56	-0.51	-0.28	-0.40	-0.21	0.33
A 17	-	-	-	-	-	-	-	-	-	-	-	-
A 18	-	-	-	-	-	-	-	-	-	-	-	-
A 19	-	-	-	-	-	-	-	-	-	-	-	-
A 22	-0.05	-0.47	0.00	0.30	-0.23	0.09	0.32	-0.58	-0.41	-0.42	-0.29	0.19
A 24	-0.31	-0.52	0.59	0.66*	0.04	-0.34	0.24	-0.59	0.19	-0.15	0.07	-0.11
A 25	-0.17	-0.27	0.50	0.50	0.18	0.03	0.24	-0.36	-0.03	-0.16	0.14	-0.01
A 27	-	-	-	-	-	-	-	-	-	-	-	-
A 28	-0.53	-0.46	0.40	0.67*	0.18	-0.38	-0.05	-0.33	0.15	0.07	0.09	-0.21
A 33	-0.44	-0.11	0.70*	0.63*	0.52	-0.31	-0.10	-0.20	0.56	0.39	0.47	-0.40
A 34	-	-	-	-	-	-	-	-	-	-	-	-
A 35	-	-	-	-	-	-	-	-	-	-	-	-
A 39	-	-	-	-	-	-	-	-	-	-	-	-
A 40	-0.74**	0.10	0.83**	0.80**	0.81**	-0.54	-0.29	0.10	0.60*	0.44	0.64*	-0.58
A 41	-0.66*	-0.04	0.84**	0.72*	0.62*	-0.38	-0.26	-0.14	0.50	0.21	0.47	-0.33
A 43	-	-	-	-	-	-	-	-	-	-	-	-

(contd.)

Table 4.6. continued

Genotypes	11th week of sowing						12th week of sowing					
	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
A 2	-	-	-	-	-	-	-	-	-	-	-	-
A 3	-	-	-	-	-	-	-	-	-	-	-	-
A 4	-	-	-	-	-	-	-	-	-	-	-	-
A 5	-	-	-	-	-	-	-	-	-	-	-	-
A 6	-0.31	0.06	0.69*	0.80**	0.56	-0.71*	-0.21	-0.07	0.32	0.42	0.50	-0.48
A 9	-	-	-	-	-	-	-	-	-	-	-	-
A 12	-	-	-	-	-	-	-	-	-	-	-	-
A 13	-	-	-	-	-	-	-	-	-	-	-	-
A 14	-	-	-	-	-	-	-	-	-	-	-	-
A 16	0.48	-0.43	-0.18	-0.05	-0.16	0.10	-	-	-	-	-	-
A 17	-	-	-	-	-	-	-	-	-	-	-	-
A 18	-	-	-	-	-	-	-	-	-	-	-	-
A 19	-	-	-	-	-	-	-	-	-	-	-	-
A 22	0.34	-0.45	-0.40	-0.32	-0.27	0.14	-	-	-	-	-	-
A 24	0.19	-0.55	0.34	0.14	-0.01	-0.10	-	-	-	-	-	-
A 25	0.19	-0.20	-0.01	0.06	0.18	0.20	0.27	-0.20	-0.28	-0.18	0.17	0.05
A 27	-	-	-	-	-	-	-	-	-	-	-	-
A 28	-	-	-	-	-	-	-	-	-	-	-	-
A 33	-0.27	0.09	0.68*	0.78**	0.60*	0.70*	-0.16	-0.04	0.30	0.43	0.51	-0.45
A 34	-	-	-	-	-	-	-	-	-	-	-	-
A 35	-	-	-	-	-	-	-	-	-	-	-	-
A 39	-	-	-	-	-	-	-	-	-	-	-	-
A 40	-	-	-	-	-	-	-	-	-	-	-	-
A 41	-	-	-	-	-	-	-	-	-	-	-	-
A 43	-	-	-	-	-	-	-	-	-	-	-	-

(contd.)

Table 4.6. continued

Genotypes	13th week of sowing					
	M_1	M_2	M_3	M_4	M_5	M_6
A 2	-	-	-	-	-	-
A 3	-	-	-	-	-	-
A 4	-	-	-	-	-	-
A 5	-	-	-	-	-	-
A 6	-0.33	-0.53	0.54	0.67*	0.59	0.55
A 9	-	-	-	-	-	-
A 12	-	-	-	-	-	-
A 13	-	-	-	-	-	-
A 14	-	-	-	-	-	-
A 16	-	-	-	-	-	-
A 17	-	-	-	-	-	-
A 18	-	-	-	-	-	-
A 19	-	-	-	-	-	-
A 22	-	-	-	-	-	-
A 24	-	-	-	-	-	-
A 25	-	-	-	-	-	-
A 27	-	-	-	-	-	-
A 28	-	-	-	-	-	-
A 33	-0.29	-0.53	0.52	0.67*	0.57	0.54
A 34	-	-	-	-	-	-
A 35	-	-	-	-	-	-
A 39	-	-	-	-	-	-
A 40	-	-	-	-	-	-
A 41	-	-	-	-	-	-
A 43	-	-	-	-	-	-

week onwards. Significant correlations were observed between days to bolting and mean maximum temperature in the first week of sowing in three genotypes (A 5, A 17, A 22). Significant correlations were observed in two genotypes (A 34 and A 39) for bolting and mean minimum temperature at first week. Six out of 25 genotypes exhibited significant correlation between days to bolting and total rainfall in the second week and number of rainy days in the second week. The lines A 6 and A 33 bolted only after the 13th week of sowing and significant correlation was observed between the days to bolting and the number of rainy days during the 13th week.

The physical properties of soil, percentage of sand, percentage of silt and percentage of clay were correlated with days to bolting for each genotype (Table 4.7) and collectively for all the genotypes (Table 4.8). The percentage of silt in the soil was observed highly correlated with days to bolting in A 5. Similarly percentage of clay in the soil had significant correlation with bolting in A 6. The genotypes as a whole had no significant correlation between the physical properties of soil and the days to bolting and the total vegetable yield.

D. Chemical analysis of the edible parts

Data on chemical analysis for free oxalates, free nitrates and chlorophyll content of amaranths are presented

Table 4.7. Correlation coefficients between days to 50% bolting and physical properties of soil

Genotypes	Percentage of		
	Sand	Silt	Clay
A 2	0.17	-0.40	0.07
A 3	0.13	-0.05	-0.10
A 4	-0.51	-0.40	0.56
A 5	-0.42	-0.67*	0.64*
A 6	-0.06	-0.11	0.10
A 9	-0.12	0.03	0.01
A 12	0.27	-0.41	0.07
A 13	0.23	-0.06	0.16
A 14	0.02	-0.40	0.22
A 16	0.06	-0.04	0.06
A 17	0.11	0.19	0.01
A 18	0.08	-0.39	0.15
A 19	0.60	-0.33	0.57
A 22	0.09	-0.39	0.12
A 24	0.36	-0.24	0.07
A 25	0.14	-0.40	0.28
A 27	0.24	-0.30	0.34
A 28	0.15	-0.52	0.19
A 33	0.82	-0.13	0.06
A 34	0.13	-0.24	0.03
A 35	0.30	0.10	0.26
A 39	0.15	-0.08	0.14
A 40	0.06	-0.37	0.25
A 41	0.01	-0.25	0.14
A 43	0.02	0.00	0.01

* Significant at 5% level

Table 4.8. Correlation coefficients between physical properties of soil and days to 50% bolting and total vegetable yield

Economic attribute	Percentage of		
	Sand	Silt	Clay
Days to bolting	-0.05	-0.59	0.25
Total vegetable yield	-0.29	0.14	0.15

in Table 4.9. The free oxalate content ranged from 0.94% (A 43) to 1.29% (A 41) on dry weight basis. The free nitrate content was maximum for A 2 (1.00%) and minimum in A 43 (0.58%).

Chlorophyll-a was minimum in A 14 (0.73 mg/g of fresh leaf sample). Chlorophyll-b content ranged from 0.59 mg/g of fresh leaf sample (A 41) to 1.80 mg/g of fresh leaf sample (A 34). The total chlorophyll content was minimum in A 14 (1.35 mg/g of fresh leaf sample) and maximum in A 34 (3.70 mg/g of fresh leaf sample).

E. Ascertaining the correct species status of the genotypes

The 25 genotypes were examined in detail to put them under distinct botanical species. The 24 genotypes fitted the key characteristics and description of four species - _A. tricolor_, _A. dubius_, _A. viridis_ and _A. spinosus_ (Fig. 3 to 27). The line A 17 fitted the key characteristics of _A. tricolor_ as per the keys of Bailey (1973) and Peino (1980), but had hollow stem, branched axillary inflorescence and (scorpioid cyme) and with leaf tips deeply lobed (Fig. 13). A typical _A. tricolor_ (A 16) and the line A 17 are described below for comparison.

A 16 (_A. tricolor_)

Annual herbaceous plant, smooth in appearance cultivated as vegetable; stem and petiole deep purple, stem

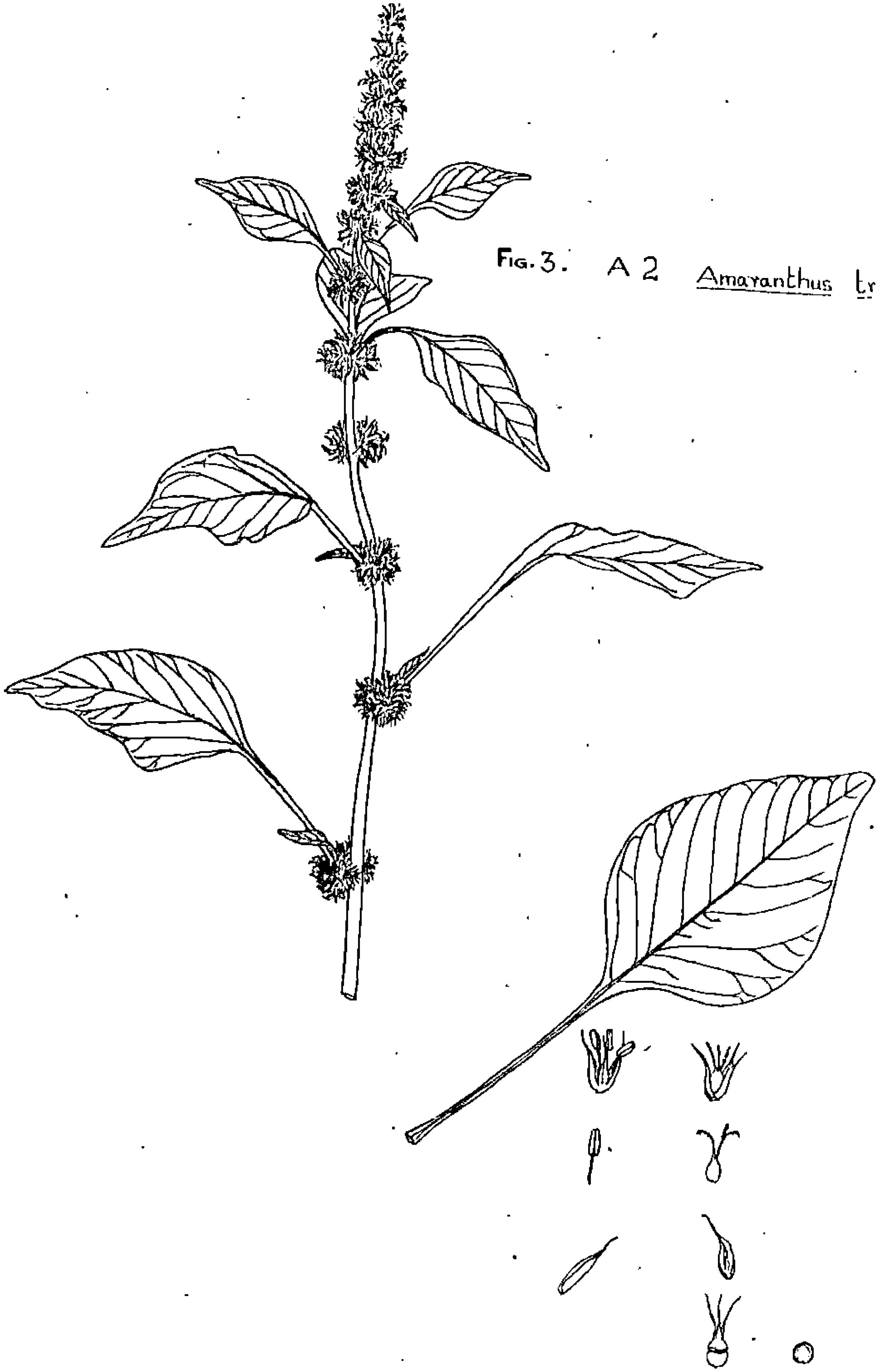


Fig. 3. A 2 *Amaranthus tricolor*

Fig. 4. A 3 A. dubius

Fig 5 A 4 A. tricolor

Fig. 6. A 5 A. tricolor

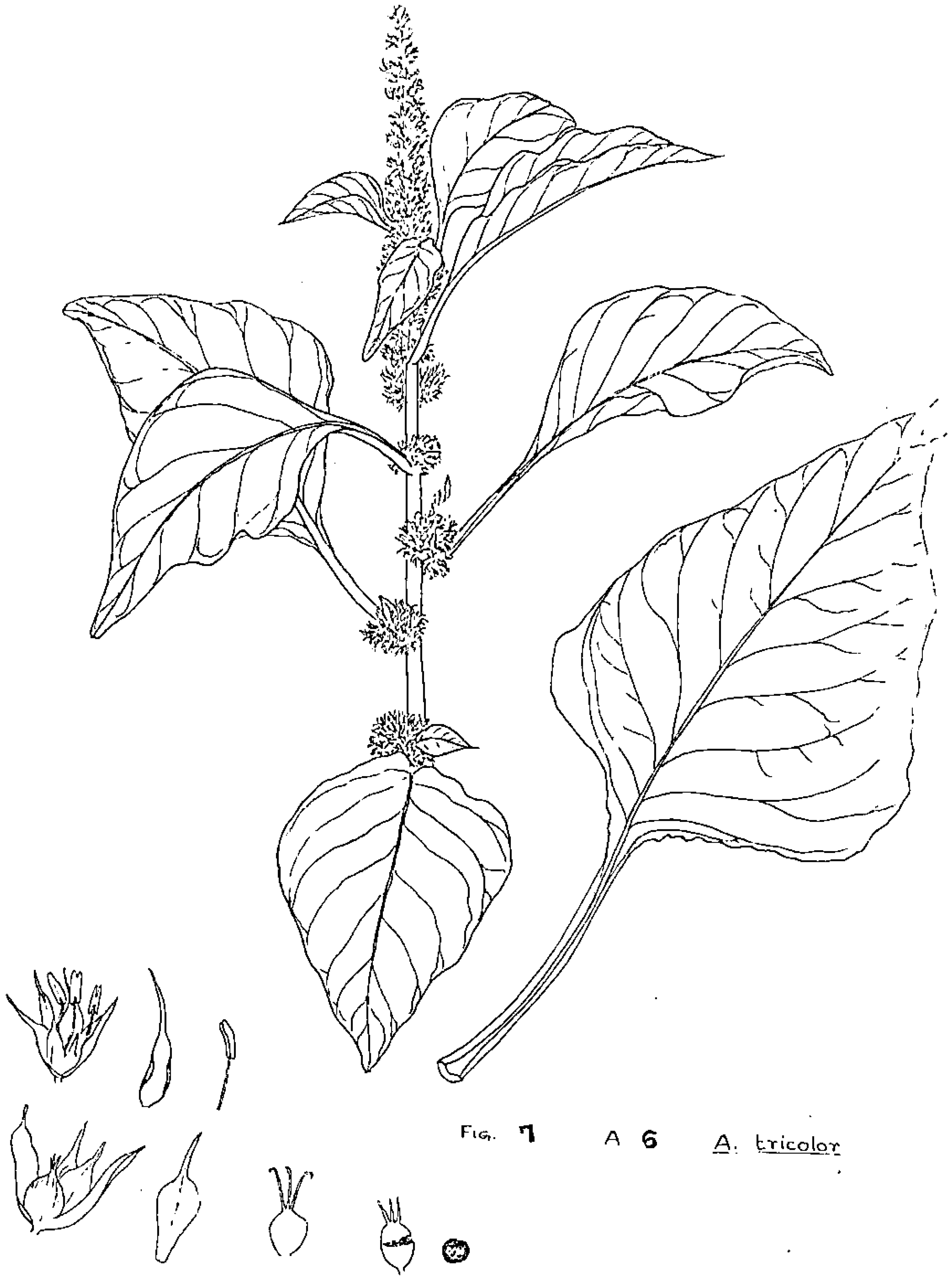


FIG. 7 A 6 A. tricolor

FIG. 8. A 9 A. tricolor

Fig. 9. A 12 *A. viridis*

Fig 10 A 13 A. tricolor

Fig. 11 A 14 A. tricolor

Fig. 12. A16 A. tricolor

Fig. 13 A 17 A. tricolor ssp. cavicaulis

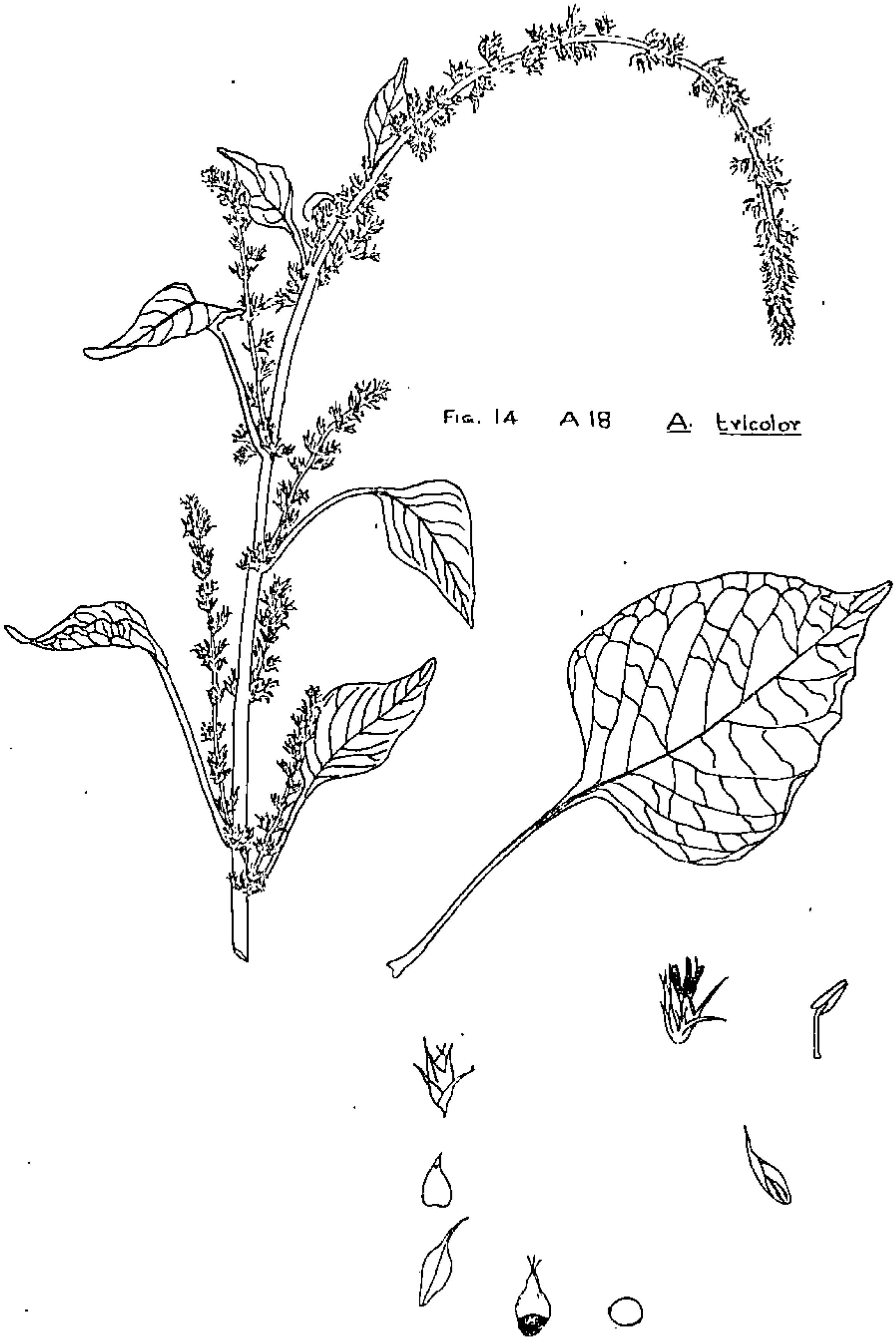


Fig. 14 A 18 *A. tricolor*

Fig 15 A 19 A. tricolor

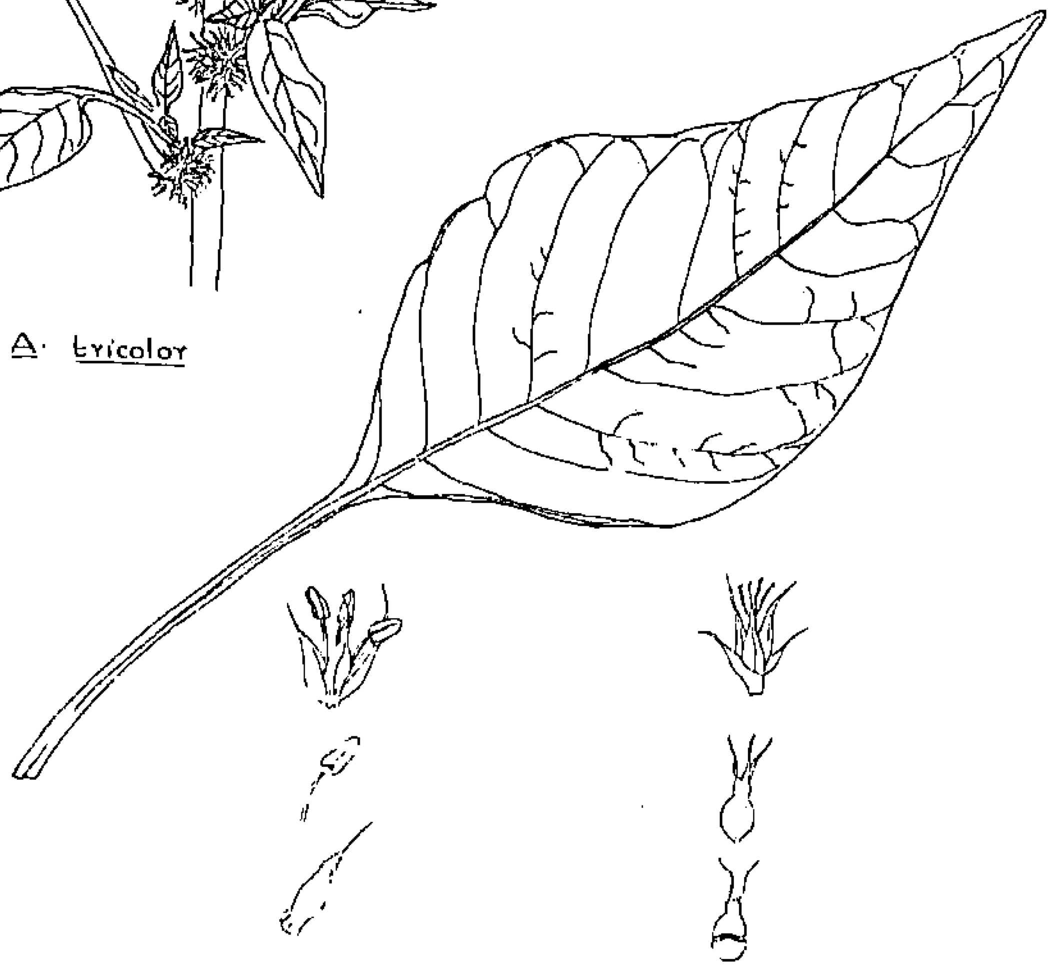


Fig. 16 A22 A. tricolor

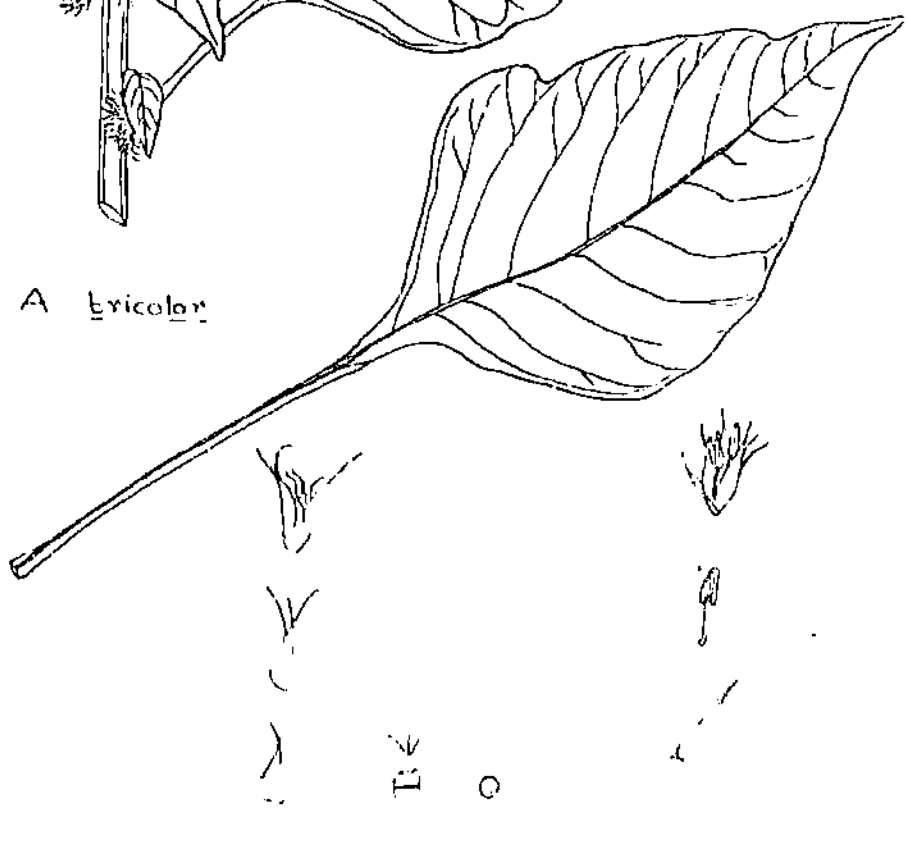


Fig 17 A 24 A tricolor

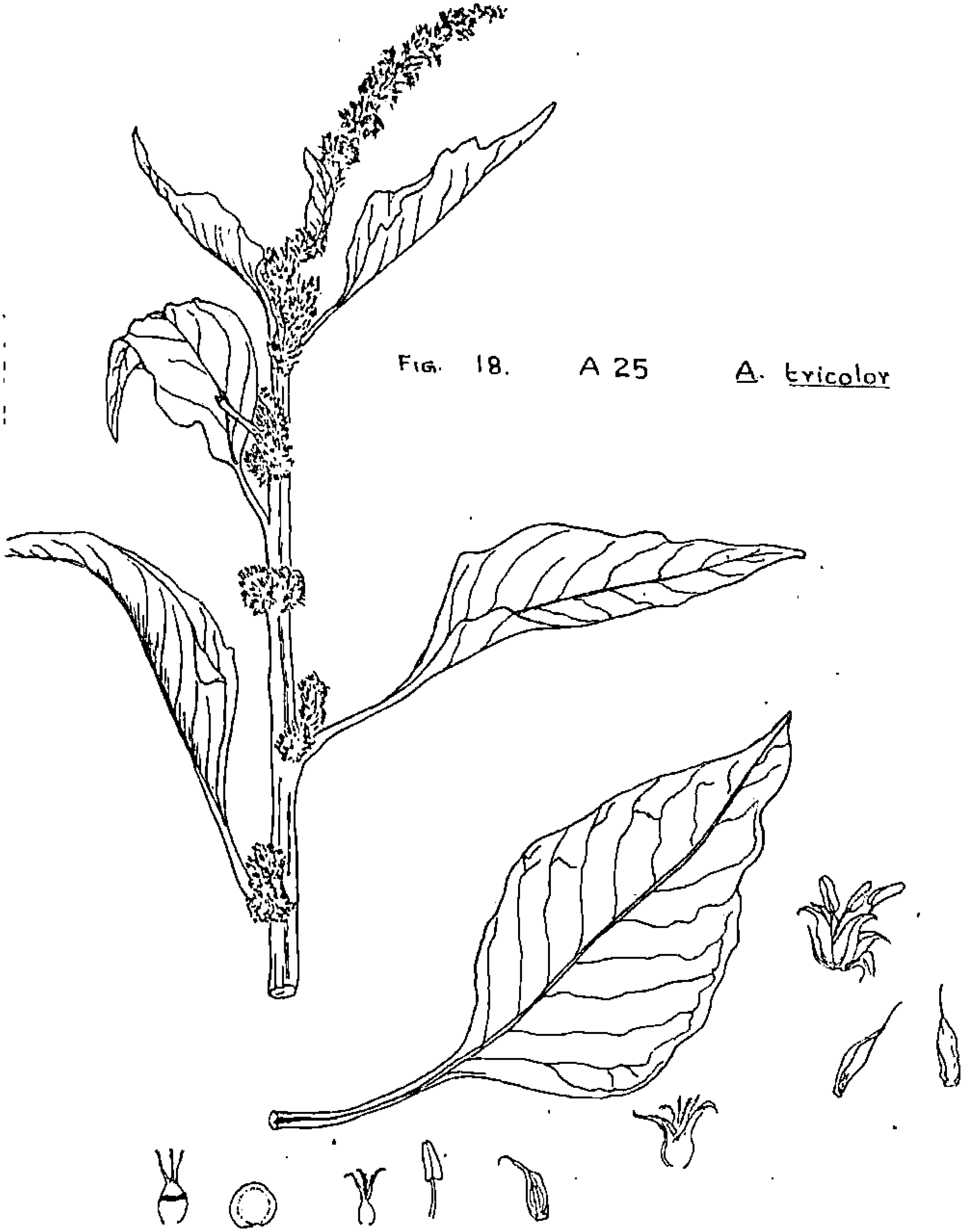
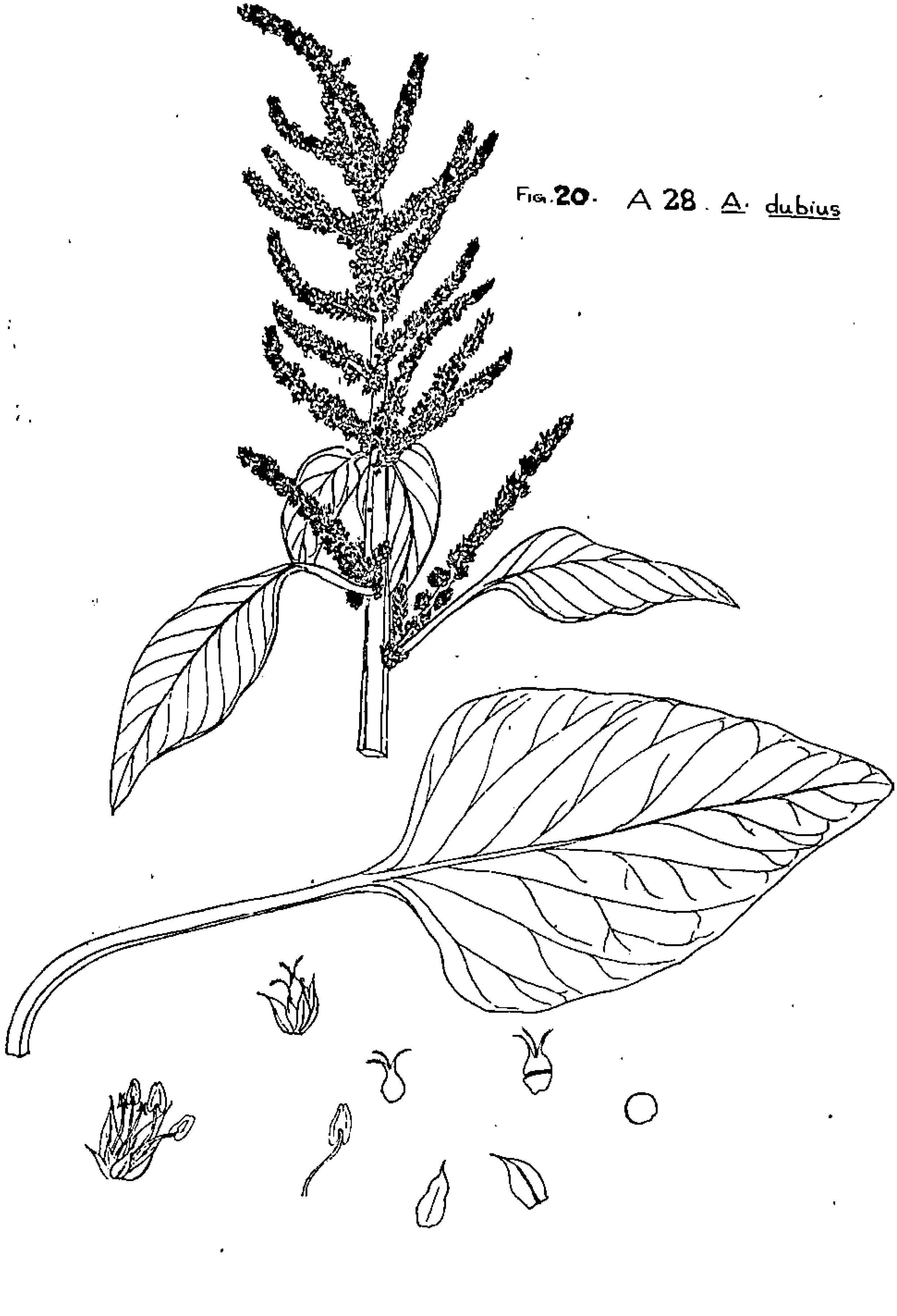


FIG. 18. A 25 A. tricolor

FIG 19 A 27 A. tricolor

Fig. **20**. A 28. *A. dubius*



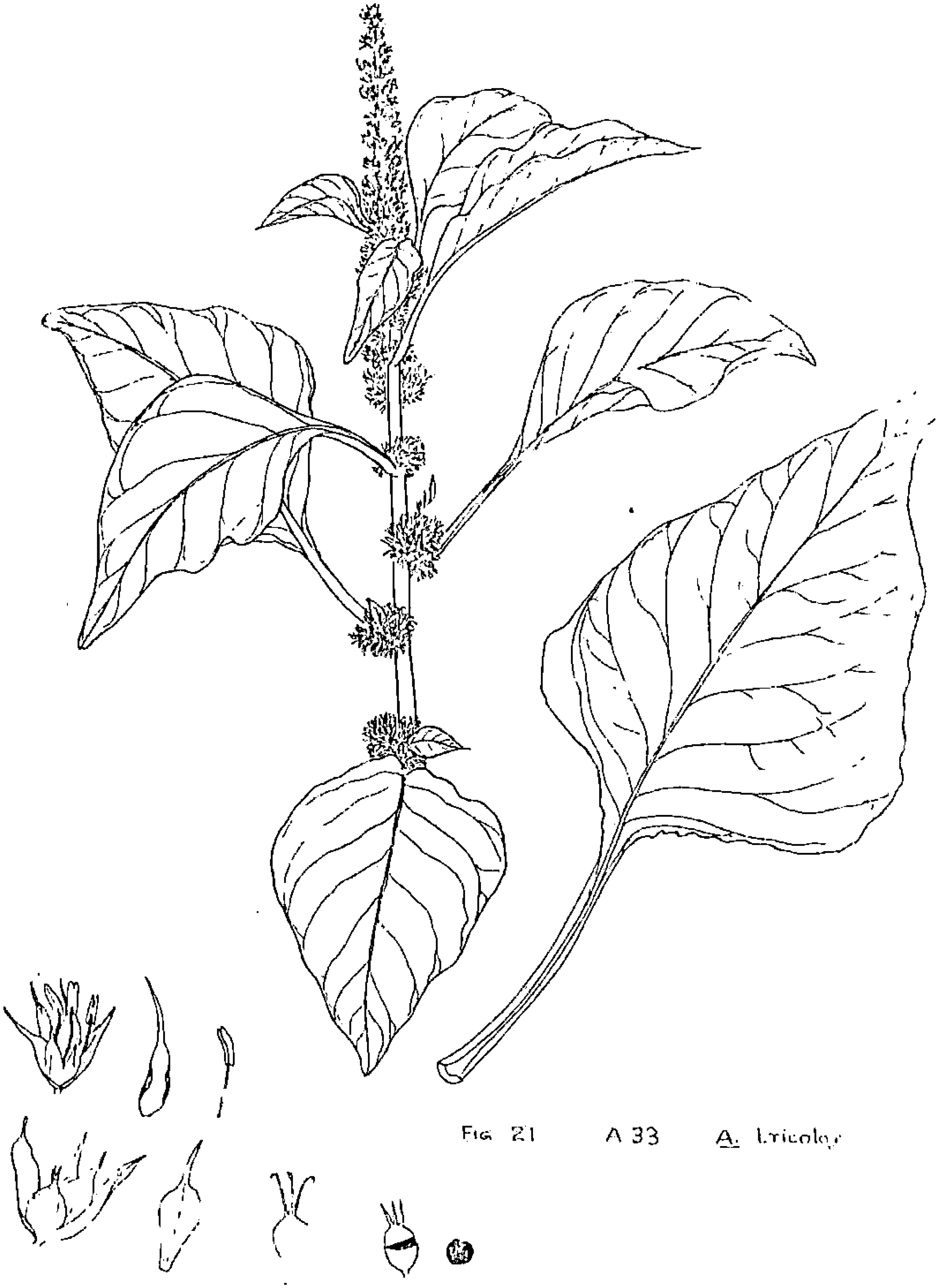


Fig 21 A 33 A. tricolor

FIG 22 , A 34 A. spinosus

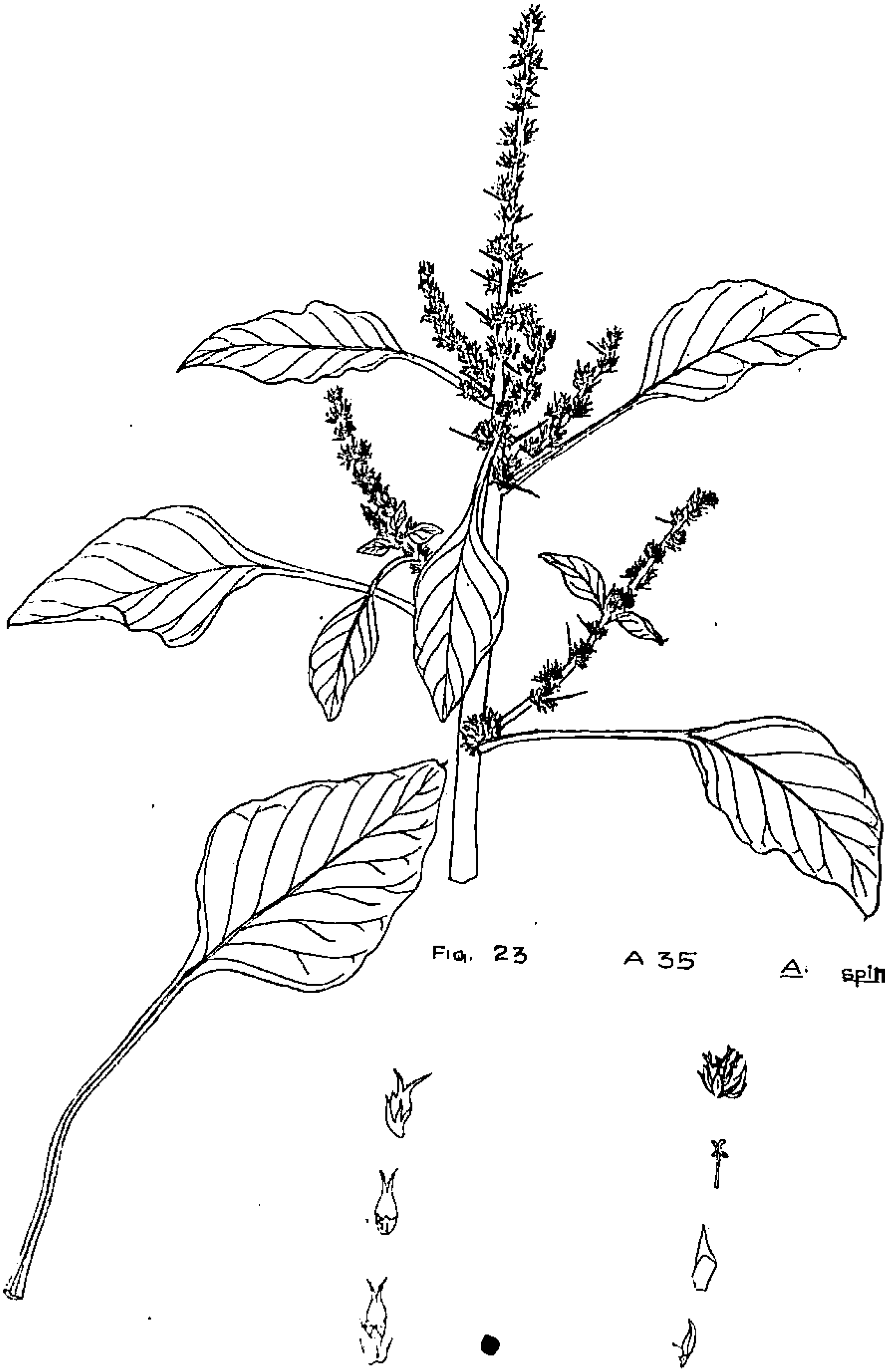


Fig. 23 A 35 A. spinosus

Fig 24 A 39 A. tricolor

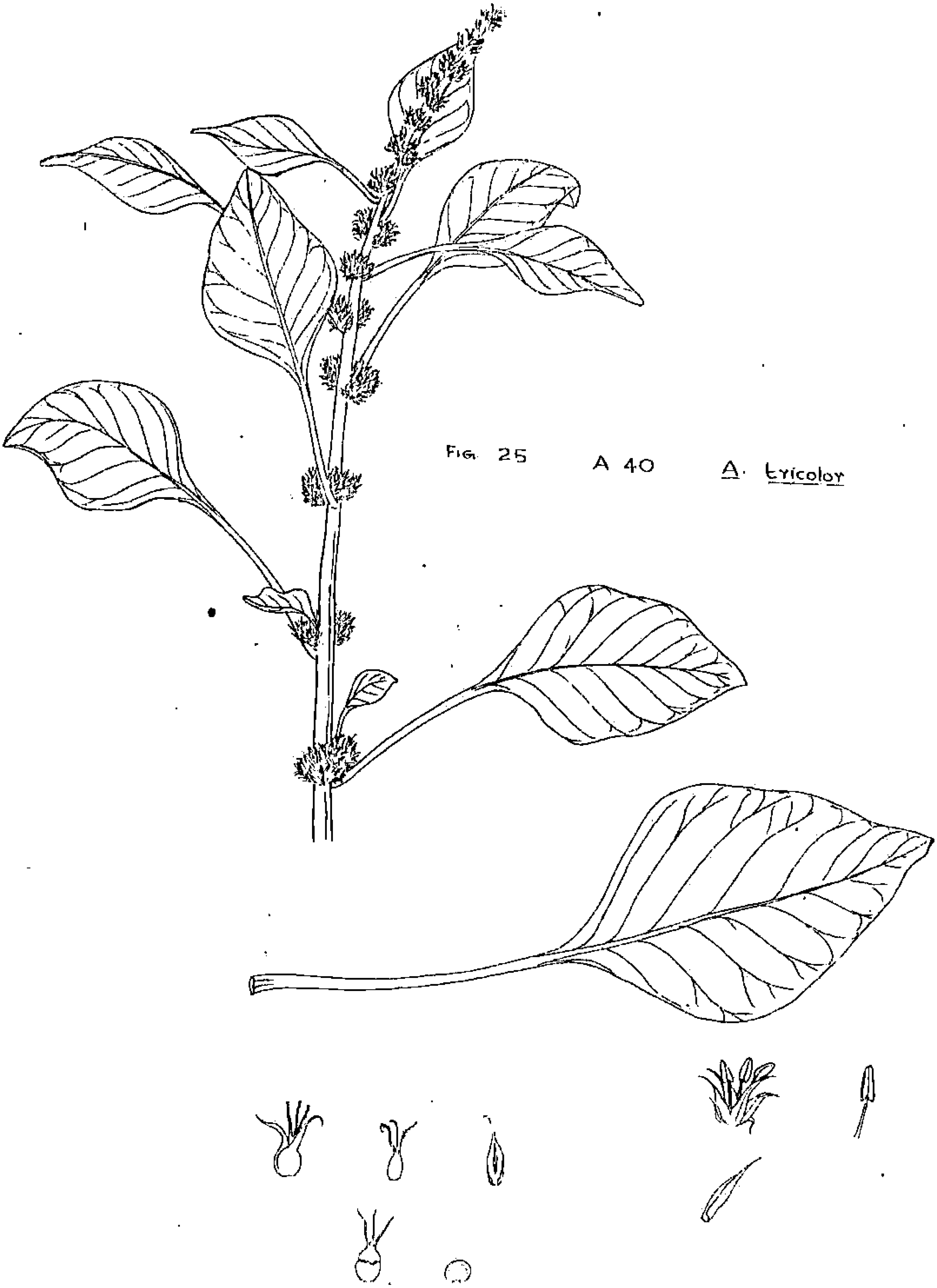


Fig. 25 A 40 A. tricolor

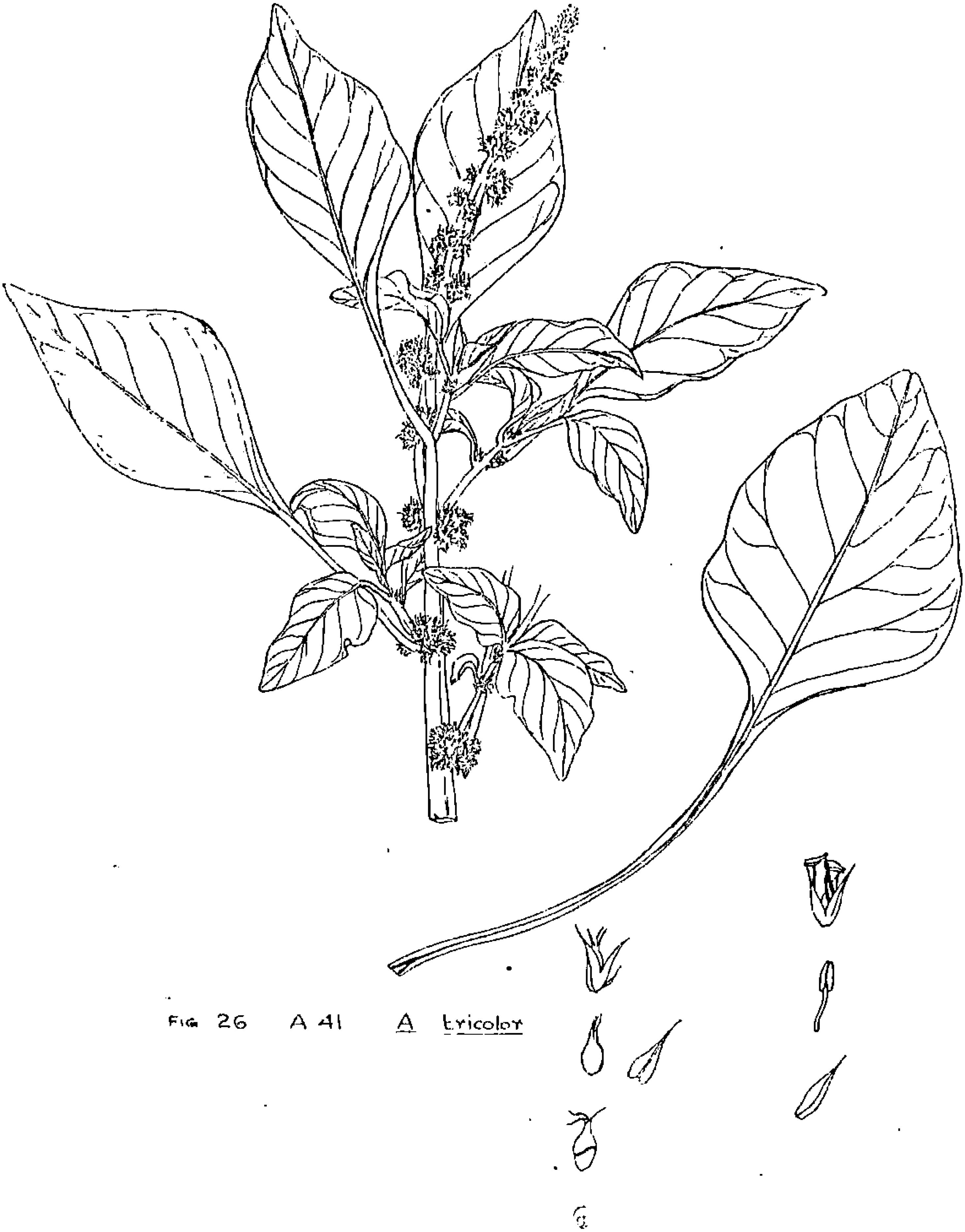


FIG 26 A 41 A tricolor

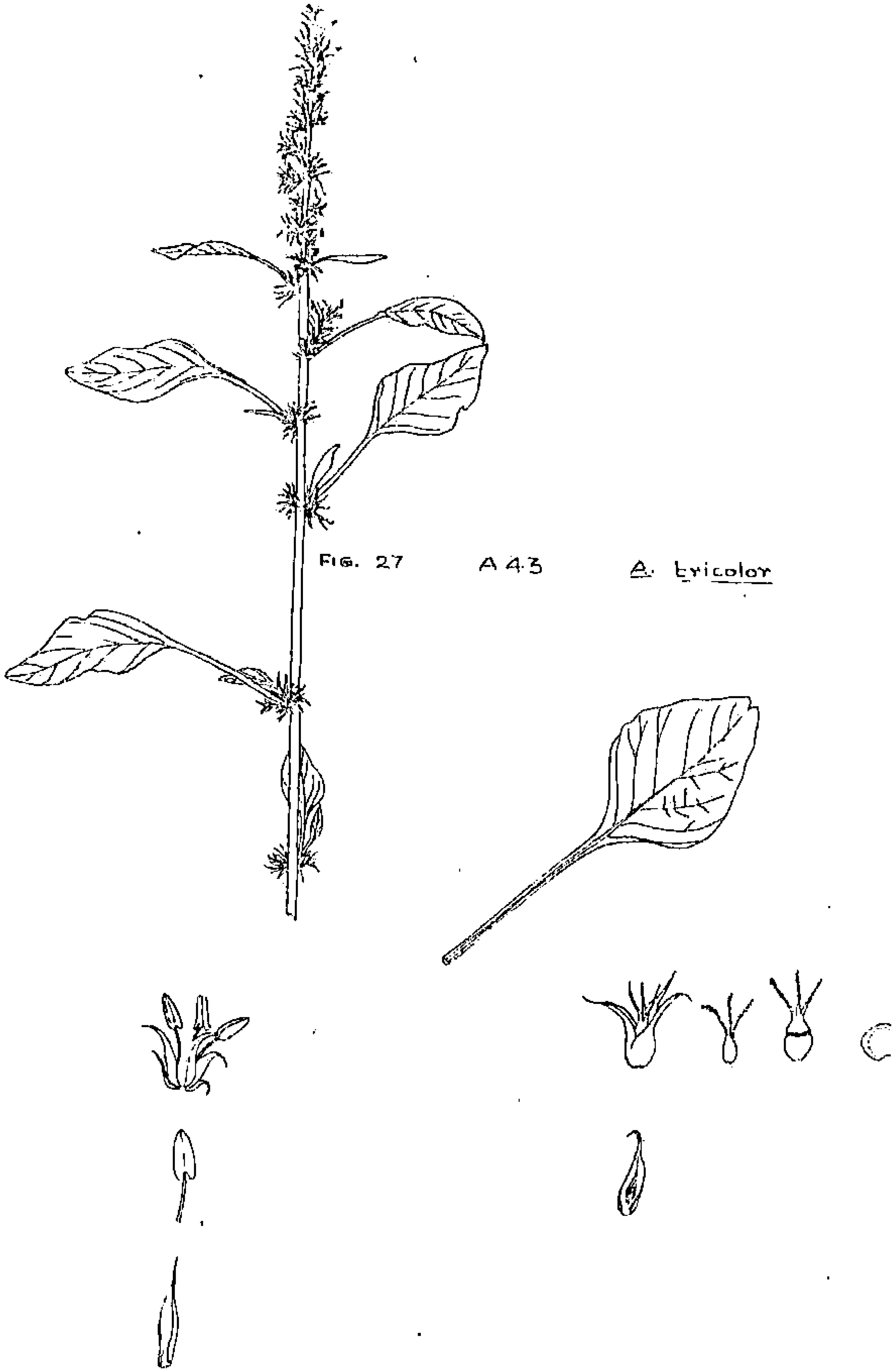


FIG. 27 A 43 A. tricolor

Table 4.9. Mean oxalate, nitrate and chlorophyll contents of 25 amaranth genotypes

Genotypes	Oxalate % (dry weight basis)	Nitrate % (dry weight basis)	Chlorophyll (mg/g of fresh leaf)		
			a	b	a+b
A 2	1.15	1.00	1.69	1.34	3.03
A 3	1.05	0.81	1.40	1.35	2.74
A 4	1.07	0.70	1.52	1.17	2.68
A 5	1.12	0.70	1.03	1.20	2.23
A 6	1.20	0.68	0.96	0.82	1.77
A 9	1.26	0.94	1.16	1.05	2.22
A 12	0.98	0.69	1.12	1.31	2.43
A 13	1.22	0.84	1.27	0.93	2.20
A 14	1.11	0.79	0.73	0.62	1.35
A 16	1.02	0.70	1.77	1.46	3.23
A 17	1.10	0.68	1.40	1.03	2.43
A 18	1.06	0.65	1.40	1.12	2.52
A 19	1.06	0.63	1.42	1.24	2.67
A 22	1.13	0.76	0.91	0.75	1.66
A 24	1.15	0.62	0.96	0.79	1.75
A 25	1.17	0.55	1.21	1.03	2.24
A 27	1.26	0.72	1.23	1.35	2.58
A 28	0.95	0.64	1.68	1.59	3.27
A 33	0.97	0.72	0.99	0.83	1.81
A 34	1.07	0.68	1.90	1.80	3.70
A 35	1.05	0.62	1.37	1.09	2.46
A 39	1.10	0.79	1.38	1.08	2.46
A 40	1.08	0.66	1.17	1.51	2.69
A 41	1.29	0.70	0.79	0.59	1.36
A 43	0.94	0.58	1.43	1.19	2.29

fibrous and solid; lamina purple, leaves alternate, petiole about as long as lamina; leaf broad ovate, margin entire, apex acute, inflorescence axillary and terminal; unisexual flowers clustered in axils, no distinct peduncle for axillary inflorescence; each flower is subtended by three bracts; perianth glabrous with purple streak along the margin; stamens 3, free; ovary-1, stigmas 3, fruit a one seeded dehiscent (circumscissile) utricle; persistent styles forming the beak; seeds deep black and shiny (Fig. 12).

A 17 (A. tricolor?)

Annual herbaceous plant smooth in appearance, cultivated as vegetable;main stem and petiole deep purple; stem hollow and fleshy; lamina greenish purple, leaves alternate, petiolate; petiole long about as long as the lamina; leaf triangular ovate, margin smooth, apex distinctly lobed; inflorescence axillary and terminal; axillary inflorescence scorpioid cyme with a distinct axis or peduncle; each flower subtended by three bracts; perianth glabrous. There is a prominent purple streak at the apex of the perianth; stamens 3, free, anthers 2 celled; stigmas 3; fruit a one seeded dehiscent (circumscissile) utricle; persistent styles forming a beak; seeds brown and shiny (Fig. 13).

Hence the line A 17 was quite distinct from other lines belonging to A. tricolor.

Discussion

DISCUSSION

Vegetable amaranth is an important leaf vegetable of the tropics. A fresh matter yield of as 30 tonnes/ha in a period of four weeks would be a record production among many of the economic crops. Being a "poor man's vegetable", its role in enriching the diet of an average Indian is considerable. Grubben (1977) reported a daily intake of 5 g/head/day in Latin America, 11 g in Central and South West Asia and 21 g in Africa. The presence of antinutrient or noxious substances, oxalates and nitrates in amaranth leaves has been a negative factor in large scale consumption of the crop (Diustech, 1977). Though the intake is definitely not of any concern as compared to 200 g/day for causing adverse nutritional effects, still there is definite need to identify line(s) with negligible content of the above undesirable nutrient factors.

Early bolting has been one of the limitations in the cultivation of vegetable types. There are day neutral and short day types of amaranths - short day types being obligatory in nature and day neutral types being affected by temperature (Zabka, 1957), soil factors (Enyi, 1965 and Grubben, 1976), genetic factors (Kerala Agricultural University 1978-79), other factors like height of cutting

(Kauffmann and Gilbert, 1981), nature of cutting (Grubben, 1976 and Deutsch, 1977), density of population (Enyi, 1965), C/N ratio (Grubben, 1976), mode of planting (Mohideen and Rajagopal, 1975) and age of plantlets (Sulekha, 1980). The role of genotype per se to decide early flowering requires further study.

Being a crop grown throughout the year, there is need to identify stable lines for total vegetable yield and days to bolting. The present investigation attempts to elucidate information on phenotypically stable line(s), line(s) with negligible contents of oxalates and nitrates and attemptes to pin point reasons - genetic, morphological, physical and meteorological, for early flowering.

The investigation was compartmentalised into four continuous aspects of study to arrive at useful information. The 25 amaranth genotypes differed significantly in all the 12 sowings. This indicates the inherent genetic differences among the 25 genotypes. The genotypes ranged from 4 (A 24, A 25, A 39) to 17 days (A 18) even for days to 50% germination. The very delayed germination in A 18 causing obvious anxiety to amaranth growers would be a matter for detailed investigation. The 25 genotypes exhibited significant variability for plant height, girth of stem at cut end, length of 5th leaf, width of 5th leaf, length of petiole, branches/plant, days to 50% bolting in control, days to 50% bolting in uni-cut rows, nodes on bolting day, plant height on bolting day, frequency of harvests and total vegetable yield. The expected GA for the above characters were very high indicating scope for simple selection methods to improve amaranth for the above characters. Ranjiprasad et al. (1980) also revealed that branches/plant has high heritability along with high GA. Leaves/plant and days to visible germination showed high heritability along with moderate GA. They observed a very low GA for yield/plant. This could be probably due to the different types of material under experimentation.

Phenotypically stable varieties are of great importance particularly in countries like India, where the environmental conditions differ from one climatic zone to another and even within one climatic zone itself. A breeding programme, aimed at developing phenotypically stable varieties, requires information on the extent of genotype x environment (G x E) interactions. No detailed information is available in amaranths regarding G x E interactions except that the report of Sreerangaswamy et al. (1980) that there existed a strong G x E interaction in the diverse genetic population of amaranths. In the present investigation, G x E interactions were highly significant as reported by Sreerangaswamy et al. (1980) for all the 14 characters studied. This indicates that the above characters are unstable and could fluctuate considerably with a change in the environment.

In practical plant breeding, it is necessary to identify genotypes suited for high, medium and low yielding environments. According to Eberhart and Russel (1966), an ideally adaptable variety would be one having higher mean, unit regression coefficient (b=1) and the deviation from regression as small as possible.

In the present investigation, stability parameters were worked out only for the characters, yield and bolting. The deviation from regression was not significant except for A 33, for bolting. Detailed analysis indicated that for yield, the genotypes A 6, A 22, A 33, A 3, A 40, A 28 and A 5 are suited for high yielding environments (Fig. 1). They have higher means, regression coefficient more than one and deviation from regression not significant. The stable varieties are A 13, A 14 and A 4. They have high means, regression coefficient one and lower deviation from regression. They are the adaptable lines, for medium yielding environments. Lines A 25 and A 9 can be recommended for low yielding environments, which have higher mean, regression coefficient less than one and deviation from regression smaller. These lines manifest their inherent potentialities fully well under low yielding environments. The stable lines for yield, suited for each environment are shown in the Table 5.1.

The stability parameters for bolting was also estimated. The lines A 24, A 25, A 16, A 14 and A 28 are suited for high yielding environments (Fig. 2). They have high mean, regression coefficient more than one and smaller deviation from regression, ie., they retain maximum vegetative phase under high-yielding environments or very good management practices. The lines A 22 and A 13 can be recommended for medium-yielding environments. They have higher mean, regression coefficient one and smaller deviation from regression also. The lines A 9 and A 5 are suited for low-yielding environments, they have higher mean, regression coefficient less than one and lesser deviation from regression. The details are given in Table 5.2.

The genotypes A 22 and A 13, being high yielders and stable for bolting can be recommended for seed production purpose also. They flower and seeds are obtained at all seasons of sowing. The lines A 6 and A 33 though high yielding, are not stable for days to bolting and hence not suited for seed production purpose. The lines bolt only under short day conditions available during October-November months. By all means, these two lines could be considered as short day types and the rest as day neutrals.

Table 5.1. Mean, regression coefficient and deviation from regression for yield in amaranths suited for high, medium and low-yielding environments

Environment	Genotype	Mean	bi	S^2di
High-yielding	A 6	769.09	1.30	93623.80
	A 22	736.36	1.30	94049.70
	A 33	698.64	1.43*	11575.26
	A 3	662.27	1.49*	57430.63
	A 40	589.55	1.41	35296.05
	A 28	586.82	1.54*	35514.34
	A 5	550.91	1.53*	-10461.63
Medium-yielding	A 13	740.46	1.05	-2391.96
	A 14	691.82	1.11	47949.95
	A 4	576.82	0.96	43038.19
Low-yielding	A 25	594.09	0.66	44380.54
	A 9	473.64	0.62	9098.39

* Significant at 5% level

Table 5.2. Mean days, regression coefficient and deviation from regression for bolting in amaranths suited for high, medium and low-yielding environments

Environment	Genotype	Mean	bi	S^2di
High-yielding	A 24	64.36	1.20	46.00
	A 25	61.68	1.60	42.57
	A 16	61.64	1.38	39.45
	A 14	56.64	1.20	21.61
	A 28	47.32	1.45	33.42
Medium-yielding	A 22	58.91	1.09	106.45
	A 13	55.55	1.01	22.39
Low-yielding	A 9	54.59	0.59	14.38
	A 5	50.58	0.62	40.33

The investigation reveals that the lines A 22 and A 14 can be recommended for high yielding environments as non-bolting types suited for year-round planting. Without considering the stability for bolting, A 6 and A 33 are also suited for high-yielding environments. These lines can be recommended for progressive farmers, or to highly fertile lands. The line A 13 is suited for medium (average) yielding environment as a non-bolting type, for year-round planting. This line performs better under average managemental practices. The non-bolting line A 9 is suited for low-yielding environments for year-round planting. This line is suited under poor soil conditions, or under poor managemental practices.

It was also seen that there is an influence of days to bolting on total vegetable yield (Fig. 28). As the bolting is delayed the vegetable yield is increased. The line A 12 bolted the earliest (25 days after sowing) and was the lowest yielder. Similarly the highest yielder (A 6) had the maximum delayed bolting (75 days) also.

The significant difference existing in the 25 genotypes for days to 50% bolting indicated that genotypes _per se_ has a significant role in bolting. The physical factors like cutting influenced bolting (Table 5.3). In all the 11 sowings, significant delay in bolting was observed in one cut rows

Fig.28. DIAGRAM INDICATING DAYS TO 50% BOLTING AND VEGETABLE YIELD OF 25 AMARANTH GENOTYPES

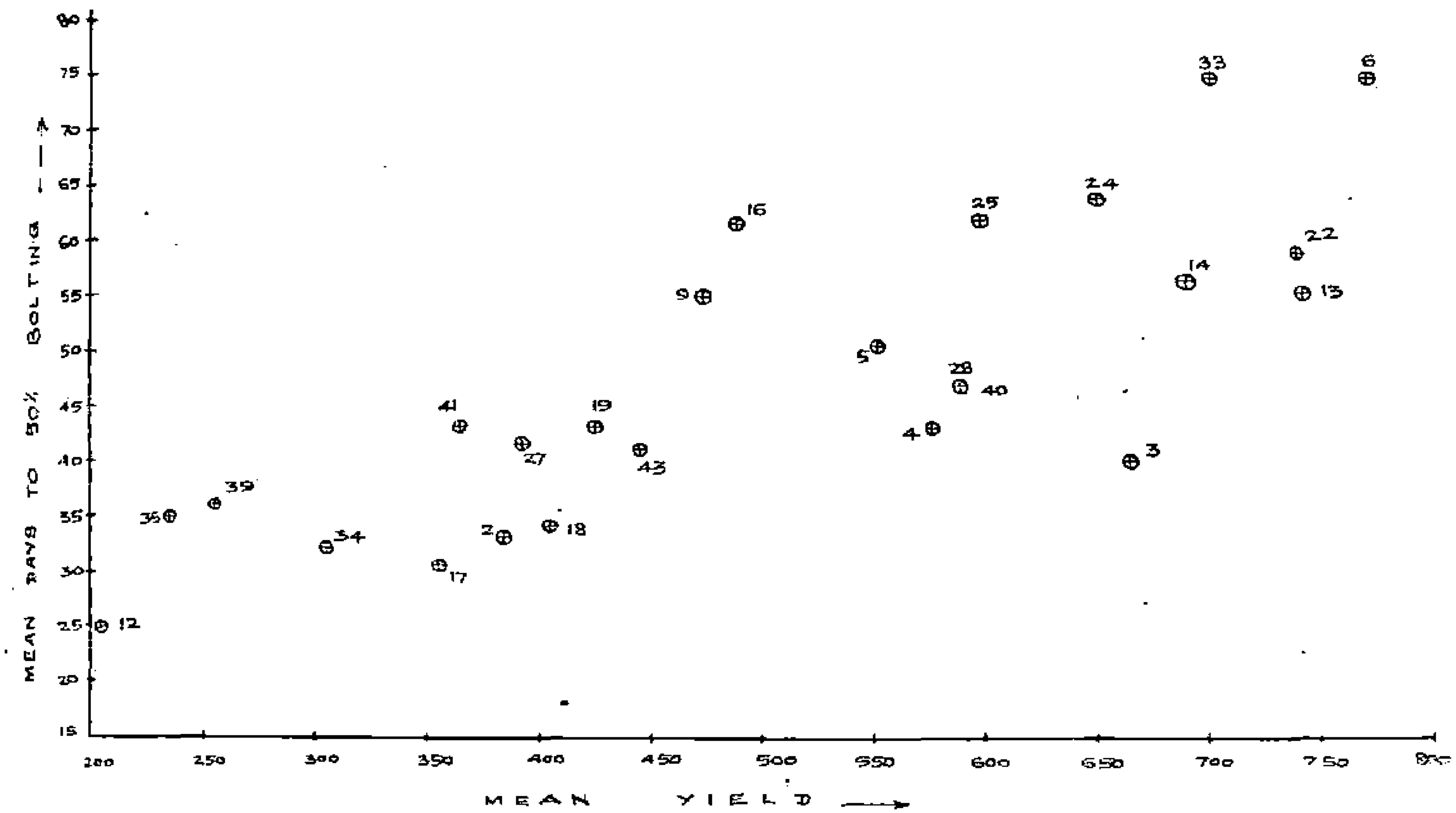


Table 5.3. Effect of cutting on bolting in amaranth genotypes

Seasons	Seasonal means		Percentage of delay
	Days to bolt in unicut rows	Days to bolt in control	
E_1	64	52	21.52
E_2	66	55	19.35
E_3	64	55	17.89
E_4	51	46	9.77
E_5	54	45	20.93
E_6	59	42	41.64
E_7	63	47	32.70
E_8	70	48	43.99
E_9	54	43	27.49
E_{10}	59	48	22.54
E_{11}	54	40	34.44

't' value = 9.14**

** Significant at 1% level

as compared to uncut, control. The study confirms in unambiguous terms the effect of cutting the cause delayed bolting.

The role of colour variance--red and green--in bolting was examined in detail (Table 5.4). The observation of delayed bolting in all the red types as compared to green types was an interesting observation in the present study. In 5 out of the 11 sowings, the χ^2 value measuring the significance of the difference between expected and observed frequencies were highly significant (p=0.05). Deviation χ^2 which measured the significance of difference between the two groups as a whole were also highly significant (p=0.001) thus confirming the role of colour variant to determine bolting. This is further observed from the delayed flowering habit in A 35 and early flowering in A 34. A 35 differed from A 34 mainly in the red coloured stem and the petiole of the former though both belonged to A. spinosus (Appendix VIII). The heterogenity χ^2 was not significant which indicated no significant interaction between seasonal effects and colour variation with regard to bolting.

The role of meteorological parameters, mean maximum temperature, mean minimum temperature, total rainfall, number of rainy days, mean relative humidity and mean bright sunshine hours was examined in detail (Table 5.5). The weeks

Table 5.4. Comparison of red amaranths (12)+ and green amaranths (11) with regard to days to 50% bolting

Seasons	Location Means		χ^2
	Red	Green	
E_1	66	40	6.03*
E_2	69	43	5.88*
E_3	66	44	4.28*
E_4	55	39	2.71
E_5	48	43	0.24
E_6	46	36	1.16
E_7	58	37	4.44*
E_8	59	39	4.15*
E_9	50	35	2.61
E_{10}	55	42	1.54
E_{11}	47	33	2.52

+ The lines A 19 and A 35 were excluded for this comparison as they had mixed colour of red and green

Total χ^2 = 35.56** (p=0.01)

Deviation χ^2 = 32.62*** (p=0.001)

Heterogenity χ^2 = 2.94 (Not significant)

Table 5.5. Number of amaranth genotypes with significant correlation between days to bolting and meteorological parameters recorded at weekly intervals

Week	Mean maximum temperature	Mean minimum temperature	Total rainfall	Number of rainy days	Mean relative humidity	Mean bright sunshine hours
1st	3/25	2/25	4/25	2/25	2/25	3/25
2nd	2/25	3/25	6/25	6/25	1/25	3/25
3rd	1/25	3/25	1/25	1/25	2/25	3/25
4th	4/24	1/24	2/24	0/24	3/24	4/24
5th	5/24	1/24	7/24	2/24	2/24	2/24
6th	4/23	0/23	4/23	8/23	2/23	7/23
7th	5/20	0/20	7/20	6/20	3/20	8/20
8th	6/16	1/16	4/16	6/16	2/16	4/16
9th	2/13	0/13	4/13	5/13	2/13	0/13
10th	0/11	0/11	1/11	0/11	1/11	0/11
11th	0/7	0/7	2/7	2/7	1/7	2/7
12th	0/3	0/3	0/3	0/3	0/3	0/3
13th	0/2	0/2	0/2	2/2	0/2	0/2

from 4 to 8 appear to be critical for days to bolting. The various meteorological parameters in the first week itself determined bolting in three of the 25 genotypes. It was noted that the number of rainy days in the 13th week of sowing decided flowering in two of the genotypes (A 6 and A 33). Precisely these lines are short day types and obviously would flower under short day conditions only. The rest 23 genotypes are day neutral types and are affected by various meteorological parameters in the specific weeks after sowing.

The 25 genotypes were chemically analysed for free oxalate, free nitrate and total chlorophyll contents. The lines A 28 and A 43 had lower oxalates. The line A 43 also had the lowest content of free nitrate. The presence of variability for the content of free oxalates and nitrates lead us to think of scope for selection to develop low oxalate and low nitrate content.

Observation of a deviant fitting to the key characteristics of A. tricolor, but for its hollow stem, lobed leaf tips, branched axillary inflorescence, and brown coloured seeds, led the author to name it as a subspecies under A. tricolor, tentatively, A. tricolor ssp. cavicaulis meaning thereby hollow-stemmed A. tricolor. Based on these, a new key is prepared by combining the keys of Bailey (1973) and Feine (1980) with necessary modifications, as given below.

The present study could arrive at certain definite conclusions. Lines A 6 and A 33 are obligate short day types and suited for planting except during September. Cuttings invariably delay flowering in amaranths. The red colour variance had delayed bolting when compared to green coloured variance. Presence of high variability associated with high heritability give good scope for improvement of amaranth through selection. Lines with lower content of oxalates and nitrates are available.

Summary

SUMMARY

The present experiment, "Screening for non-bolting type(s) of amaranths suited for year-round planting" was planned to identify line(s), which are non-bolting or delayed bolting and to ascribe the morphological reasons for such behaviour. Effect of cutting, if any, on bolting, identification of line(s) suited for year-round planting and phenotypically stable line(s), selection of line(s) with negligible content of free oxalates and nitrates and establishment of relation, if any, between meteorological parameters and bolting were the other objectives of the study.

2. The experimental material consisted of 25 amaranth genotypes belonging to 4 botanical species planted at monthly interval in a randomised block design with two replications. Observations were recorded on total vegetable yield and its components, bolting and chemical properties of the leaves.

3. The 25 amaranth genotypes differed significantly for days to 50% germination, plant height, girth of stem at cut end, length of 5th leaf, width of 5th leaf, length of petiole, branches/plant, days to 50% bolting in control, days to 50% bolting in unicut rows, nodes on bolting day, leaves on bolting day, plant height on bolting day, frequency of harvests and total vegetable yield.

4. High heritability, associated with high phenotypic coefficient of variation resulting in high expected genetic advance was observed for all the 14 characters under study.

5. Genotypes x seasons interactions were highly significant for the 14 characters. The seasons were also significantly different.

6. Parameters of phenotypic stability (μ, bi, S^2di) were worked out for the 25 genotypes. The line A 13 had higher total vegetable yield (740.46 g/0.45 m^2) and regression value of 1.05. The line A 6 gave the maximum vegetable yield (769.09 g/0.45 m^2).

7. The stability parameters for days to bolting were worked out. The lines A 33 and A 6 though high yielding had very delayed bolting and was highly unstable (bi= >1.00).

8. It was found that A 22 and A 14 are suited for high-yielding environments with regard to yield and bolting (yield—736.36 g and 691.82 g/0.45 m^2 respectively; days to bolting—59 and 57 respectively). The genotype A 13 can be recommended as a non-bolting type suited for year-round planting, for medium yielding environments (yield—740.46 g/0.45 m^2; days to bolting—56) and the line A 9 can be recommended for low yielding environments (yield—473.64 g; days to bolting 55). Other promising lines for high-yielding environments with regard to yield are A 6 and A 33.

9. Relation between meteorological parameters and days to bolting was studied. The line A 6 and A 33 bolted 13th week after sowing and number of rainy days in the 13th week decided flowering in the above two lines. Mean maximum temperature during the first week determined days to bolting in A 5, A 17 and A 22. Mean bright sunshine hours during the first week of sowing influenced flowering in A 5, A 17 and A 19.

10. The correlation coefficients between physical properties of soil, where cropping was done and economic attributes, were not significant considering genotypes as a whole. Percentage of silt and percentage of clay in the soil influenced bolting in A 5.

11. Cutting was observed to delay bolting in all the amaranth genotypes. Percentage of delay over control (uncut) ranged from 9.77 (August 1981) to 43.99 (December 1981).

12. The edible parts were analysed for free oxalates, free nitrates, chlorophyll-a and chlorophyll-b content. Free oxalate content ranged from 0.94% (A 43) to 1.29% (A 41 on dry weight basis and nitrate content from 1.00% (A 2) to 0.58% (A 43). The total chlorophyll content ranged from 1.35 mg/g of fresh leaf (A 14) to 3.70 mg/g (A 34).

13. The line A 6 yielded the highest (769.09 g/0.45 m^2) and bolted 75 days after sowing. Other lines of promise are A 13 (740.46 g/0.45 m^2), A 22 (736.36 g/0.45 m^2) and A 33 (698.64 g/0.45 m^2).

14. The line A 17, a variant of *A. tricolor* is tentatively named as *A. tricolor* ssp. *cavicaulis*, meaning thereby "hollow stemmed *A. tricolor*".

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Appendices

Appendix I. Physical properties of the soil

Plot	Percentage of		
	Sand	Silt	Clay
E_1 (April 1981)	61.50	12.25	26.25
E_2 (June 1981)	62.00	8.50	29.50
E_3 (July 1981)	52.25	4.00	43.75
E_4 (August 1981)	65.75	8.25	26.00
E_5 (September 1981)	63.75	9.00	27.25
E_6 (October 1981)	54.50	12.25	33.25
E_7 (November 1981)	64.00	18.00	16.00
E_8 (December 1981)	58.00	10.25	31.75
E_9 (January 1982)	57.25	11.00	31.75
E_{10} (February 1982)	54.50	12.25	33.25
E_{11} (March 1982)	60.25	12.00	27.75

Appendix IIa. Meteorological data averaged over weekly intervals during April 1981 to June 1982

Month	Week	Meteorological parameters					
		Maximum temperature (M_1)	Minimum temperature (M_2)	Total rainfall (M_3)	Number of rainy days (M_4)	Relative humidity (M_5)	Bright sunshine hours (M_6)
April 1981	1	36.00	25.60	0.00	0	66.55	7.60
	2	36.90	25.70	1.90	2	66.80	8.00
	3	35.30	25.40	14.20	1	62.90	9.10
	4	34.30	26.00	13.00	2	77.60	9.80
May 1981	1	35.90	25.90	52.20	2	68.95	7.70
	2	34.30	24.70	48.40	1	78.10	9.40
	3	34.60	26.60	19.40	2	76.30	8.00
	4	32.30	24.50	105.80	4	81.85	5.00
June 1981	1	30.30	23.10	394.40	7	91.75	0.40
	2	28.20	22.50	283.30	7	92.15	1.60
	3	27.70	22.10	356.80	7	90.10	0.80
	4	28.80	22.10	143.80	5	86.75	4.40
July 1981	1	29.90	22.90	131.90	4	86.75	5.50
	2	29.00	22.00	170.60	7	87.75	3.70
	3	30.40	23.10	19.30	2	78.05	5.30
	4	28.30	22.80	191.10	8	90.10	1.20
August 1981	1	28.90	21.60	68.60	5	90.90	4.10
	2	28.40	22.40	50.00	4	86.85	2.80
	3	27.50	22.30	257.10	7	88.60	2.70
	4	29.20	21.90	32.20	4	82.85	5.10
September 1981	1.	30.70	23.60	48.10	3	79.15	6.30
	2	28.40	22.50	138.70	7	88.20	3.20
	3	28.50	22.90	252.60	7	88.75	2.60
	4	29.60	22.90	82.40	5	84.25	7.30
October 1981	1	30.80	22.80	11.00	1	81.45	6.90
	2	30.70	22.60	25.20	2	78.75	5.90
	3	31.50	23.00	10.20	1	77.55	6.20
	4	30.20	22.80	40.00	5	79.30	2.50
November 1981	1	30.20	22.50	50.60	2	81.90	4.80
	2	31.20	22.10	27.40	2	73.45	7.30
	3	32.30	22.60	0.00	0	68.10	9.10
	4	31.30	21.10	22.00	1	65.60	6.60

(...2)

Appendix IIa. continued

Month	Week	M_1	M_2	M_3	M_4	M_5	M_6
December 1981	1	32.20	22.00	0.00	0	60.75	9.90
	2	32.10	18.60	0.00	0	59.40	10.00
	3	30.70	23.50	0.00	0	65.45	7.10
	4	31.90	22.00	0.00	0	56.80	9.90
January 1982	1	31.50	21.50	0.00	0	55.15	9.90
	2	32.30	20.30	0.00	0	58.75	10.10
	3	32.70	20.70	0.00	0	57.20	10.00
	4	33.20	22.50	0.00	0	68.65	9.80
February 1982	1	34.60	21.70	0.00	0	54.95	9.50
	2	36.00	21.30	0.00	0	53.75	9.90
	3	35.90	21.30	0.00	0	55.50	10.10
	4	37.10	20.70	0.00	0	53.15	10.10
March 1982	1	34.90	22.10	0.00	0	67.60	9.80
	2	36.90	21.60	0.00	0	77.90	9.50
	3	35.70	23.50	0.00	0	85.15	9.30
	4	33.90	25.90	0.00	0	79.90	8.30
April 1982	1	35.00	25.60	0.00	0	84.65	8.50
	2	35.20	25.00	0.00	0	82.95	10.00
	3	35.30	24.30	32.20	3	71.90	9.10
	4	34.30	26.00	13.00	2	77.60	8.30
May 1982	1	33.70	25.50	6.00	1	83.45	7.70
	2	34.70	24.80	4.70	3	70.20	9.40
	3	33.70	23.60	128.50	2	79.00	6.80
	4	33.00	24.40	0.00	0	85.15	4.90
June 1982	1	23.10	30.30	92.00	7	87.05	4.00
	2	23.40	30.20	151.60	5	92.05	3.10
	3	22.70	28.10	291.60	7	93.00	0.90
	4	23.60	29.80	199.60	7	92.50	3.80

Appendix IIb. Meteorological observations averaged over weekly intervals from the date of sowing for each month's crop, used for correlation

1st week

Season	M_1	M_2	M_3	M_4	M_5	M_6
E_1	34.30	26.00	13.00	2	77.60	9.80
E_2	28.80	22.10	143.80	5	86.75	4.40
E_3	28.30	22.80	191.10	8	90.10	1.20
E_4	29.20	21.90	32.20	4	82.85	5.10
E_5	29.60	22.90	82.40	5	84.25	7.30
E_6	30.20	22.80	40.00	5	79.30	2.50
E_7	31.30	21.10	2.20	1	65.60	6.60
E_8	31.90	22.00	0.00	0	56.80	9.90
E_9	33.20	22.50	0.00	0	68.65	9.80
E_{10}	37.10	20.70	0.00	0	53.15	10.10
E_{11}	33.90	25.90	0.00	0	79.90	8.30

2nd week

Season	M_1	M_2	M_3	M_4	M_5	M_6
E_1	35.90	25.90	52.20	2	68.95	7.70
E_2	29.90	22.90	131.90	4	86.75	5.50
E_3	28.90	21.60	68.60	5	90.90	4.10
E_4	30.70	23.60	48.10	3	79.15	6.30
E_5	30.80	22.80	11.00	1	81.45	6.90
E_6	30.20	22.50	50.60	2	81.90	4.80
E_7	32.20	22.00	0.00	0	60.75	9.00
E_8	31.50	21.50	0.00	0	55.15	9.90
E_9	34.60	21.70	0.00	0	54.95	9.50
E_{10}	34.90	22.10	0.00	0	67.60	9.80
E_{11}	35.00	25.60	0.00	0	84.65	8.50

3rd week

Season	M_1	M_2	M_3	M_4	M_5	M_6
E_1	34.30	24.70	48.40	1	78.10	9.40
E_2	29.00	22.00	170.60	7	87.75	3.70
E_3	28.40	22.40	50.00	4	86.85	2.80
E_4	28.40	22.50	138.70	7	88.20	3.20
E_5	30.70	22.60	25.20	2	78.75	5.90
E_6	31.20	22.10	27.40	2	73.45	7.30
E_7	32.10	18.60	0.00	0	59.40	10.00
E_8	32.30	20.30	0.00	0	58.75	10.10
E_9	36.00	21.30	0.00	0	53.75	9.90
E_{10}	36.90	21.60	0.00	0	77.90	9.50
E_{11}	35.20	25.00	0.00	0	82.95	10.00

(contd.)

Appendix IIb. continued

Season	M_1	M_2	M_3	M_4	M_5	M_6
4th week						
E_1	34.60	26.60	19.40	2	76.30	8.00
E_2	30.40	23.10	19.30	2	78.05	5.30
E_3	27.50	22.30	257.10	7	88.60	2.70
E_4	28.50	22.90	252.60	7	88.75	2.60
E_5	31.50	23.00	10.20	1	77.55	6.20
E_6	32.30	22.60	0.00	0	68.10	9.10
E_7	30.70	23.50	0.00	0	65.45	7.10
E_8	32.70	20.70	0.00	0	57.20	10.00
E_9	35.90	21.30	0.00	0	55.50	10.10
E_{10}	35.70	23.50	0.00	0	85.15	9.30
E_{11}	35.30	24.30	32.20	3	71.90	9.10
5th week						
E_1	32.30	24.50	105.80	4	81.85	5.00
E_2	28.30	22.80	191.10	8	90.10	1.20
E_3	29.20	21.90	32.20	4	82.85	5.10
E_4	29.60	22.90	82.40	5	84.25	7.30
E_5	30.20	22.80	40.00	5	79.30	2.50
E_6	31.30	21.10	2.20	1	65.60	6.60
E_7	31.90	22.00	0.00	0	56.80	9.90
E_8	33.20	22.50	0.00	0	68.65	9.80
E_9	37.10	20.70	0.00	0	53.15	10.10
E_{10}	33.90	25.90	0.00	0	79.90	8.30
E_{11}	34.30	26.00	13.00	2	77.60	8.30
6th week						
E_1	30.30	23.10	394.40	7	91.75	0.40
E_2	28.90	21.60	68.60	5	90.90	4.10
E_3	30.70	23.60	48.10	3	79.15	6.30
E_4	30.80	22.80	11.00	1	81.45	6.90
E_5	30.20	22.50	50.60	2	81.90	4.80
E_6	32.20	22.00	0.00	0	60.75	9.00
E_7	31.50	21.50	0.00	0	55.15	9.90
E_8	34.60	21.70	0.00	0	54.95	9.50
E_9	34.90	22.10	0.00	0	67.60	9.80
E_{10}	35.00	25.60	0.00	0	84.65	8.50
E_{11}	33.70	25.50	6.00	1	83.45	7.70

(contd.)

Appendix IIb. continued

Season	M_1	M_2	M_3	M_4	M_5	M_6
7th week						
E_1	28.20	22.50	283.30	7	92.15	1.60
E_2	28.40	22.40	50.00	4	86.85	2.80
E_3	28.40	22.50	138.70	7	83.20	3.20
E_4	30.70	22.60	25.20	2	78.75	5.90
E_5	31.20	22.10	27.40	2	73.45	7.30
E_6	32.10	18.60	0.00	0	59.40	10.00
E_7	32.30	20.30	0.00	0	58.75	10.10
E_8	36.00	21.30	0.00	0	53.75	9.90
E_9	36.90	21.60	0.00	0	77.90	9.50
E_{10}	35.20	25.00	0.00	0	82.95	10.00
E_{11}	34.70	24.80	4.70	3	70.20	9.40
8th week						
E_1	27.70	22.10	356.80	7	90.10	0.80
E_2	27.50	22.30	257.10	7	88.60	2.70
E_3	28.50	22.90	252.60	7	88.75	2.60
E_4	31.50	23.00	10.20	1	77.55	6.20
E_5	32.30	22.60	0.00	0	68.10	9.10
E_6	30.70	23.50	0.00	0	65.45	7.10
E_7	32.70	20.70	0.00	0	57.20	10.00
E_8	35.90	21.30	0.00	0	55.50	10.10
E_9	35.70	23.50	0.00	0	85.15	9.30
E_{10}	35.30	24.30	32.20	3	71.90	9.10
E_{11}	33.70	23.60	128.50	2	79.00	6.80
9th week						
E_1	28.80	22.10	143.80	5	86.75	4.40
E_2	29.20	21.90	32.20	4	82.85	5.10
E_3	29.60	22.90	82.40	5	84.25	7.30
E_4	30.20	22.80	40.00	5	79.30	2.50
E_5	31.30	21.10	2.20	1	65.60	6.60
E_6	31.90	22.00	0.00	0	56.80	9.90
E_7	33.20	22.50	0.00	0	68.65	9.80
E_8	37.10	20.70	0.00	0	53.15	10.10
E_9	33.90	25.90	0.00	0	79.90	8.30
E_{10}	34.30	26.00	13.00	2	77.60	8.30
E_{11}	33.00	24.40	0.00	0	85.15	4.90

(contd.)

Appendix IIb. continued

Season	M_1	M_2	M_3	M_4	M_5	M_6
<u>10th week</u>						
E_1	29.90	22.90	131.90	4	86.75	5.50
E_2	30.70	23.60	48.10	3	79.15	6.30
E_3	30.80	22.80	11.00	1	81.45	6.90
E_4	30.20	22.50	50.60	2	81.90	4.80
E_5	32.20	22.00	0.00	0	60.75	9.00
E_6	31.50	21.50	0.00	0	55.15	9.90
E_7	34.60	21.70	0.00	0	54.95	9.50
E_8	34.90	22.10	0.00	0	67.60	9.80
E_9	35.00	25.60	0.00	0	84.65	8.50
E_{10}	33.70	25.50	6.00	1	83.45	7.70
E_{11}	23.10	30.30	92.00	7	87.05	4.00
<u>11th week</u>						
E_1	29.00	22.00	170.60	7	87.75	3.70
E_2	28.40	22.50	138.70	7	88.20	3.20
E_3	30.70	22.60	25.20	2	78.75	5.90
E_4	31.20	22.10	27.40	2	73.45	7.30
E_5	32.10	18.60	0.00	0	59.40	10.00
E_6	32.30	20.30	0.00	0	58.75	10.10
E_7	36.00	21.30	0.00	0	53.75	9.90
E_8	36.90	21.60	0.00	0	77.90	9.50
E_9	35.20	25.00	0.00	0	82.95	10.00
E_{10}	34.70	24.80	4.70	3	70.20	9.40
E_{11}	23.40	30.20	151.60	5	92.05	3.10
<u>12th week</u>						
E_1	30.40	23.10	19.30	2	78.05	5.30
E_2	28.50	22.90	256.60	7	88.75	2.60
E_3	31.50	23.00	10.20	1	77.55	6.20
E_4	32.30	22.60	0.00	0	68.10	9.10
E_5	30.70	23.50	0.00	0	65.45	7.10
E_6	32.70	20.70	0.00	0	57.20	10.00
E_7	35.90	21.30	0.00	0	55.50	10.10
E_8	35.70	23.50	0.00	0	85.15	9.30
E_9	35.30	24.30	32.20	3	71.90	9.10
E_{10}	33.70	23.60	128.50	2	79.00	6.80
E_{11}	22.70	28.10	291.60	7	93.00	0.90

(contd.)

Appendix IIb. continued

Season	M_1	M_2	M_3	M_4	M_5	M_6
<u>13th week</u>						
E_1	28.30	22.80	191.10	8	90.10	1.20
E_2	29.60	22.90	82.40	5	84.25	7.30
E_3	30.20	22.80	40.00	5	79.30	2.50
E_4	31.30	21.10	2.20	1	65.60	6.60
E_5	31.90	22.00	0.00	0	56.80	9.90
E_6	33.20	22.50	0.00	0	68.65	9.80
E_7	37.10	20.70	0.00	0	53.15	10.10
E_8	33.90	25.90	0.00	0	79.90	8.30
E_9	34.30	26.00	13.00	2	77.60	8.30
E_{10}	33.00	24.40	0.00	0	85.15	4.90
E_{11}	23.60	29.80	199.60	7	92.50	3.80

Appendix III. Standardisation of the leaf for estimating chlorophyll content in the line A 3

Leaf position	Mean chlorophyll content as mg/g of fresh leaf		
	Chlorophyll-a	Chlorophyll-b	Total chlorophyll
1	7.12	5.33	12.45
2	6.93	5.34	12.27
3	7.25	5.58	12.83
4	8.35	5.51	13.86
5	9.12	6.71	15.83
6	9.12	6.69	15.71
7	9.68	7.34	17.02
8	9.48	6.18	15.66
9	10.73	7.72	18.45
10	10.13	7.78	17.91

Appendix IV. Mean days to 50% germination of 25 amaranth genotypes

Genotypes	E_1	E_1^+	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	4.00	4.00	4.50	5.00	5.00	4.50	5.50	4.00	5.50	4.00	4.00	4.00	4.50
A 3	4.00	5.00	5.50	5.50	6.50	6.00	4.00	4.00	4.00	5.00	5.50	4.50	4.96
A 4	4.50	5.00	6.00	4.50	6.00	6.00	4.00	5.50	4.00	4.00	4.50	4.50	4.88
A 5	4.00	5.50	7.00	5.00	6.50	6.00	5.00	4.00	4.50	4.00	5.50	5.00	5.17
A 6	4.50	5.00	5.00	5.00	5.00	4.50	6.00	4.50	6.50	4.00	5.50	5.00	5.04
A 9	4.00	4.00	5.00	5.50	5.00	5.00	4.00	4.00	4.00	4.50	4.50	4.00	4.46
A 12	8.00	7.50	16.00	8.50	8.50	10.50	8.00	10.00	8.00	4.50	9.00	8.00	8.88
A 13	4.00	4.00	5.00	5.00	6.00	4.50	5.50	4.50	5.50	4.00	4.00	4.50	4.71
A 14	5.00	4.00	5.00	5.00	5.00	5.00	7.00	5.00	7.00	6.00	4.50	4.50	5.25
A 16	4.00	4.00	4.50	4.00	4.50	5.50	5.50	4.00	5.50	4.50	4.00	4.00	4.50
A 17	4.50	4.50	4.50	4.00	5.00	5.00	6.00	4.50	5.00	4.00	4.50	4.00	4.63
A 18	4.00	4.50	17.00	5.00	6.00	5.00	6.00	4.50	5.00	5.00	4.00	4.50	5.83
A 19	4.00	4.00	5.00	5.00	5.00	5.00	5.00	4.50	4.50	5.00	4.50	4.50	4.67
A 22	4.00	4.00	5.00	4.00	4.50	4.00	6.00	4.00	5.50	4.00	4.00	4.50	4.46
A 24	4.00	4.00	4.00	4.50	4.00	4.50	6.00	4.00	4.00	4.00	5.00	4.00	4.33
A 25	4.00	4.00	4.00	4.00	4.50	4.50	6.00	4.50	5.50	4.50	4.00	4.00	4.46
A 27	4.00	4.00	4.50	4.00	4.50	5.00	5.50	4.00	5.00	5.00	4.00	4.00	4.46
A 28	5.00	5.50	6.50	6.00	6.00	5.00	7.00	5.00	7.50	5.00	5.50	5.50	5.79
A 33	4.00	4.50	6.00	5.00	6.00	4.50	6.50	5.00	6.50	5.00	4.50	4.50	5.17
A 34	4.50	5.00	5.50	5.00	5.50	5.50	7.00	5.50	6.50	5.00	4.00	5.00	5.33
A 35	4.00	5.00	5.50	5.00	5.50	5.00	6.00	6.50	6.50	5.00	4.00	4.00	5.17
A 39	4.00	4.00	4.00	4.00	4.00	4.50	7.00	4.00	6.00	5.50	5.00	4.50	4.71
A 40	4.00	5.00	5.00	5.00	5.00	4.50	5.00	4.00	4.50	4.50	4.00	4.00	4.54
A 41	4.00	5.00	5.00	4.00	5.00	4.50	6.00	4.50	5.00	4.50	4.50	4.50	4.71
A 43	4.50	4.50	7.50	5.50	7.50	5.50	5.00	4.50	5.50	5.00	5.00	5.00	5.42
Overall mean	4.34	4.60	6.06	4.92	5.44	5.18	5.54	4.74	5.48	4.62	4.70	4.76	
C.D. ($p=0.05$)	0.84	0.94	1.58	1.59	1.71	1.66	1.46	1.26	1.40	0.92	1.30	1.11	

Appendix V. Mean plant height (cm) on 30th day of 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	41.55	24.04	27.00	16.38	23.60	31.70	22.88	16.80	35.20	34.30	48.60	29.28
A 3	24.12	22.20	25.40	7.17	20.63	19.35	21.88	16.00	20.19	19.13	48.40	22.22
A 4	33.01	29.95	24.25	23.13	21.88	23.10	23.88	15.50	26.63	26.25	42.40	26.36
A 5	35.10	28.20	27.80	25.25	20.25	22.40	29.63	25.13	26.88	29.25	52.10	29.27
A 6	20.20	21.99	28.85	14.85	18.84	10.50	11.63	15.95	17.00	29.75	44.30	21.26
A 9	27.48	22.30	21.90	13.55	19.75	22.00	13.25	15.70	20.88	22.67	42.40	21.99
A 12	38.71	13.54	21.80	10.65	15.17	13.55	10.25	13.25	16.40	16.00	33.70	18.46
A 13	26.40	20.80	20.10	17.57	23.95	15.37	13.38	20.60	23.28	21.88	51.88	23.20
A 14	28.71	12.55	25.50	9.44	15.58	18.50	13.75	15.50	18.40	27.71	38.50	20.38
A 16	24.18	20.65	22.35	13.64	20.50	18.10	13.50	15.30	19.60	32.46	50.00	22.75
A 17	30.14	30.10	29.20	17.85	22.50	24.00	15.63	17.60	22.13	25.29	23.50	23.27
A 18	24.90	22.24	28.68	13.05	14.15	16.80	14.63	9.20	27.68	22.50	47.10	21.90
A 19	18.80	20.00	22.45	11.30	18.65	13.80	11.57	18.88	19.93	18.33	44.30	19.82
A 22	31.20	17.75	20.10	11.10	21.30	18.50	11.19	14.30	32.63	32.83	47.00	23.45
A 24	24.22	22.15	21.50	14.03	18.13	21.80	16.13	19.65	23.88	27.34	50.40	23.56
A 25	30.03	20.50	21.40	19.50	19.75	20.30	16.13	14.00	29.48	30.34	51.13	24.78
A 27	34.10	25.60	20.50	23.70	18.50	24.60	19.80	25.10	27.75	35.00	45.00	27.24
A 28	18.40	11.50	20.35	8.95	18.30	22.10	16.94	16.98	23.30	20.50	60.80	21.65
A 33	20.98	21.40	21.35	10.02	15.67	14.20	11.26	12.65	14.65	18.13	37.60	17.99
A 34	31.05	24.60	26.55	8.95	22.38	14.45	9.13	14.10	29.30	21.50	48.10	22.74
A 35	33.94	21.15	21.40	16.90	19.88	20.00	13.38	18.50	14.77	14.75	39.38	21.28
A 39	35.47	19.20	29.63	11.19	19.13	14.09	12.00	15.60	27.88	20.88	39.40	22.22
A 40	25.92	19.20	21.60	11.90	22.20	18.10	16.00	14.90	25.63	19.75	45.50	21.88
A 41	13.38	13.18	20.05	11.70	13.75	10.85	13.25	11.19	16.50	19.50	31.90	15.93
A 43	21.21	14.20	25.50	14.84	12.50	14.95	18.63	15.10	17.40	26.38	40.90	20.15
Overall mean	27.73	20.76	23.81	14.26	19.08	18.52	15.51	16.30	23.09	24.50	44.17	
C.D. ($p=0.05$)	11.64	8.43	7.07	5.79	6.14	10.05	4.16	3.75	8.55	7.31	12.59	

Appendix VI. Mean girth of stem (mm) at cut end of 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	9.10	8.20	6.70	4.90	5.88	7.70	5.00	3.00	7.40	9.30	9.00	6.93
A 3	8.50	7.50	9.00	2.70	8.60	6.50	3.63	2.80	5.40	6.90	14.70	6.93
A 4	11.60	13.50	8.30	6.50	9.25	7.70	3.80	3.60	9.00	10.30	11.60	8.65
A 5	9.70	12.40	9.40	7.50	6.20	7.00	5.40	3.50	5.00	10.38	13.60	8.19
A 6	6.10	7.50	6.10	5.60	7.25	5.60	2.20	2.30	8.80	7.60	12.00	6.46
A 9	7.10	8.80	6.90	4.00	5.70	5.10	4.60	2.70	5.50	7.38	5.50	5.75
A 12	6.60	6.10	3.60	3.30	4.63	5.10	3.55	3.80	4.40	4.63	6.30	4.73
A 13	8.70	8.50	6.30	2.80	8.20	5.70	4.00	4.10	5.90	7.20	11.00	6.58
A 14	9.60	7.70	7.00	4.08	7.00	7.00	3.30	4.35	6.00	8.25	9.60	6.72
A 16	5.20	7.60	7.30	3.60	6.70	5.90	3.40	2.05	5.50	8.00	13.50	6.25
A 17	7.50	13.20	9.40	6.10	6.75	7.40	3.40	5.20	6.10	11.25	10.90	7.93
A 18	7.30	5.50	6.60	5.60	4.00	5.30	5.50	2.50	4.90	5.63	9.90	5.70
A 19	6.00	5.90	4.60	3.60	6.90	5.00	3.80	3.00	4.60	6.13	10.00	5.41
A 22	8.00	6.20	5.20	2.90	6.70	5.80	3.28	2.60	7.70	6.70	10.90	6.00
A 24	6.10	8.80	6.60	3.80	7.00	6.10	2.70	2.20	6.00	8.80	10.80	6.26
A 25	10.20	8.20	5.50	4.60	5.60	5.80	4.43	3.70	5.80	7.90	7.70	6.31
A 27	10.90	9.40	5.65	6.90	5.88	6.70	6.25	10.00	6.50	10.00	8.70	7.90
A 28	7.30	9.40	8.90	4.20	5.50	6.40	4.30	2.30	5.10	6.40	15.80	6.87
A 33	7.00	9.80	6.60	2.80	6.50	4.70	4.10	2.90	5.18	4.70	12.10	6.03
A 34	7.20	6.50	5.90	3.94	5.63	5.10	5.00	2.40	5.00	4.20	7.50	5.31
A 35	7.60	5.40	3.40	5.90	5.34	3.80	3.30	3.27	5.10	4.20	7.70	5.00
A 39	6.90	6.50	4.80	5.24	4.83	5.20	3.20	3.00	3.20	6.40	10.40	5.42
A 40	6.30	7.00	5.30	3.40	5.38	4.80	2.70	2.40	4.70	6.63	8.50	5.19
A 41	4.60	5.40	3.90	3.20	4.43	4.40	3.50	5.50	5.20	4.63	8.00	4.80
A 43	3.55	4.80	3.70	5.50	4.30	4.30	3.63	1.48	4.60	4.50	5.30	4.15
Overall mean	7.55	7.99	6.26	4.51	6.16	5.76	3.92	3.39	5.70	7.12	10.04	
C.D. (p=0.05)	4.61	2.20	3.92	2.15	2.05	2.42	1.85	1.23	3.73	2.61	4.86	

Appendix VII. Mean length of 5th leaf (cm) of 25 amaranth genotypes

Geno-types	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	12.22	9.23	8.26	7.12	8.35	11.79	9.25	5.99	9.96	9.63	11.51	9.39
A 3	12.17	12.53	8.64	4.09	11.77	10.77	9.67	6.77	11.67	12.29	16.23	10.60
A 4	13.30	11.34	9.35	10.15	9.88	11.51	11.38	8.22	10.44	11.93	15.39	11.17
A 5	11.32	13.05	10.17	11.62	10.61	10.74	9.77	8.95	11.18	12.65	16.33	11.49
A 6	12.24	13.98	14.77	8.20	10.52	9.15	11.00	11.12	12.70	13.40	14.98	12.00
A 9	14.11	11.12	10.77	7.28	10.68	12.93	7.57	8.40	12.08	9.45	14.06	10.77
A 12	7.00	4.55	6.67	3.87	6.24	5.04	3.69	4.68	5.60	5.32	9.17	5.62
A 13	5.14	13.07	11.22	12.23	13.14	9.81	9.90	9.34	13.36	11.68	20.13	11.73
A 14	4.25	11.27	10.01	5.61	10.08	13.01	10.08	10.39	12.35	12.24	15.63	10.45
A 16	11.77	10.95	13.74	11.48	11.78	11.27	9.78	8.90	9.04	10.72	13.84	11.21
A 17	9.36	10.59	9.22	6.56	10.30	9.25	8.62	6.33	9.43	10.98	9.00	9.06
A 18	10.58	10.37	8.05	7.14	5.58	7.05	5.58	3.23	11.08	10.84	9.99	8.13
A 19	12.34	10.64	9.62	6.54	9.52	9.53	6.83	8.59	11.31	11.80	15.99	10.24
A 22	17.58	13.55	10.35	6.63	17.81	12.32	6.74	10.15	15.34	13.67	17.32	12.59
A 24	12.23	12.02	14.55	10.61	10.75	13.06	10.50	10.24	11.92	11.42	16.65	12.18
A 25	15.29	11.53	10.47	8.92	11.59	11.54	7.40	11.25	11.95	10.65	12.32	11.17
A 27	13.16	14.09	10.67	6.49	9.45	12.60	9.30	13.03	13.60	13.30	13.06	11.70
A 28	10.25	11.67	13.43	7.51	10.55	13.84	11.67	7.88	14.30	13.45	16.33	11.90
A 33	11.75	14.31	12.14	6.55	8.97	11.24	6.55	11.20	10.04	11.20	16.09	10.91
A 34	6.86	6.03	6.05	3.93	6.40	6.86	3.89	4.93	7.12	6.90	9.00	6.18
A 35	10.50	7.76	7.50	7.09	7.26	7.32	7.55	6.72	7.18	5.70	8.92	7.59
A 39	10.41	7.28	4.14	5.58	7.23	6.78	7.00	5.11	8.64	7.65	11.40	7.29
A 40	10.89	9.15	9.02	4.64	9.10	7.29	8.10	5.09	8.44	9.03	11.66	8.40
A 41	10.86	11.07	7.84	6.61	8.25	7.83	8.25	5.78	9.05	7.64	9.77	8.45
A 43	5.63	4.33	5.68	4.82	4.62	5.75	6.35	4.72	6.68	5.30	7.75	5.60
Overall mean	10.85	10.62	9.69	7.21	9.62	9.93	8.26	7.88	10.58	10.35	13.30	
C.D. (p=0.05)	3.39	2.37	4.21	4.35	3.82	4.10	3.23	3.17	4.07	2.81	4.59	

Appendix VIII. Mean width of 5th leaf (cm) of 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	8.10	6.86	5.73	5.52	5.97	8.58	6.75	4.09	6.62	6.87	6.67	6.50
A 3	9.52	9.91	6.95	3.94	8.44	8.21	9.64	5.58	9.00	9.45	12.29	7.63
A 4	7.64	7.03	5.92	6.02	6.40	6.83	6.62	5.65	6.25	8.42	8.88	6.88
A 5	8.71	9.64	7.85	8.87	8.36	7.27	7.22	5.72	8.65	9.33	10.31	8.36
A 6	9.56	11.47	10.34	6.81	7.90	7.90	8.55	8.23	10.49	11.30	10.10	9.33
A 9	10.13	8.39	8.00	5.87	7.33	9.28	6.02	6.99	8.85	7.55	6.96	7.76
A 12	5.27	3.82	4.94	3.12	4.70	5.83	2.97	3.30	4.50	3.97	7.07	4.50
A 13	10.61	9.36	7.38	8.45	9.20	8.33	6.82	6.70	9.75	8.29	13.89	8.98
A 14	9.85	9.36	7.99	4.94	7.29	9.39	7.29	7.84	9.20	8.67	9.73	8.32
A 16	8.39	7.76	7.80	6.13	6.77	7.21	5.92	5.44	6.18	7.20	8.22	7.00
A 17	6.98	6.44	5.79	5.00	6.84	7.04	6.65	4.29	6.22	7.04	5.94	6.20
A 18	6.95	7.61	6.33	5.69	4.24	5.54	4.25	2.38	7.30	7.72	7.08	5.92
A 19	8.37	7.63	6.70	4.98	6.22	6.85	5.05	6.05	8.24	8.35	11.24	7.24
A 22	10.13	8.59	6.47	4.67	9.78	7.77	4.71	5.52	9.21	8.30	7.10	7.48
A 24	8.62	8.61	8.29	6.66	7.68	8.54	7.47	6.29	7.79	8.30	9.75	8.00
A 25	10.51	8.14	6.45	5.93	7.26	7.83	5.10	6.90	7.78	6.52	7.77	6.38
A 27	9.02	8.51	7.24	5.14	6.84	7.70	6.51	9.49	8.55	8.02	8.21	7.73
A 28	8.60	8.86	9.22	5.50	7.30	10.30	8.86	5.62	10.93	9.88	13.87	8.99
A 33	9.10	11.71	8.56	5.67	6.90	8.67	5.67	8.03	8.12	8.35	11.86	8.42
A 34	4.38	3.29	3.55	2.51	3.99	4.19	2.57	2.89	4.37	4.18	5.97	3.81
A 35	6.15	4.35	3.99	4.40	3.98	4.35	4.80	3.61	4.48	4.37	5.57	4.55
A 39	7.27	5.60	4.68	3.74	5.35	6.22	5.02	3.95	6.25	5.78	8.11	5.63
A 40	8.24	7.04	6.15	3.82	5.70	5.44	5.90	3.70	6.11	7.04	8.13	6.11
A 41	7.01	7.31	5.04	5.13	5.24	5.25	5.24	4.06	6.02	5.05	6.47	5.62
A 43	4.22	3.27	4.19	3.70	3.05	3.78	4.53	3.43	4.98	3.94	5.09	4.02
Overall mean	7.73	7.25	6.62	5.29	6.51	7.13	6.00	5.43	7.43	7.35	8.65	
C.D. (p=0.05)	2.36	1.78	2.24	2.41	2.43	2.81	1.77	1.84	2.55	1.96	3.73	

Appendix IX. Mean length of petiole (cm) of 5th leaf of 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	3.78	4.14	3.53	2.86	4.24	4.46	3.38	2.52	3.23	4.59	5.43	3.87
A 3	5.85	6.06	6.19	3.25	6.22	5.51	5.56	3.09	6.00	5.52	12.81	6.00
A 4	5.45	4.90	3.97	4.32	4.49	5.42	4.75	4.64	4.49	5.25	8.50	5.11
A 5	3.80	6.54	3.42	4.12	5.00	5.07	3.07	4.32	4.77	8.27	6.22	4.96
A 6	4.11	5.22	6.14	4.14	3.83	3.95	4.47	4.30	5.28	4.25	7.12	4.80
A 9	3.73	3.31	3.85	3.29	3.20	4.34	3.27	3.80	3.45	3.94	7.28	3.95
A 12	4.25	2.15	2.80	1.90	2.90	2.58	2.00	2.78	3.75	2.80	5.67	3.05
A 13	4.42	4.42	4.14	4.19	4.95	3.58	3.74	3.43	4.43	3.70	9.32	4.57
A 14	4.74	5.94	5.24	3.06	4.32	5.62	4.32	5.74	5.44	5.40	8.94	5.34
A 16	3.74	5.38	4.28	4.57	5.23	5.31	4.12	4.36	4.44	5.55	7.56	4.96
A 17	4.81	6.19	6.03	4.09	5.32	5.71	5.87	4.27	5.52	5.97	6.14	5.45
A 18	4.21	5.70	4.78	3.77	2.89	3.98	2.59	1.88	5.12	5.97	5.73	4.21
A 19	3.30	5.52	3.61	2.45	3.49	3.58	2.23	2.83	3.59	4.39	8.03	3.91
A 22	5.73	5.82	4.47	3.94	6.89	5.21	3.86	3.92	5.08	5.82	7.94	5.33
A 24	4.20	4.94	6.68	4.94	4.97	5.02	5.07	4.46	4.30	4.90	7.29	5.16
A 25	5.87	5.05	4.57	4.24	4.97	5.24	3.64	5.89	5.22	4.52	5.25	4.95
A 27	4.69	4.71	4.17	3.58	4.17	5.97	4.20	5.00	5.14	6.20	7.70	5.05
A 28	5.30	4.43	8.28	4.27	5.34	7.85	4.43	4.23	6.87	8.39	14.52	6.72
A 33	3.75	4.93	5.18	3.14	2.66	4.09	3.14	4.50	4.31	4.07	8.20	4.36
A 34	4.94	3.80	4.48	2.42	4.52	5.51	2.27	2.65	4.59	4.97	9.18	4.39
A 35	5.73	5.33	6.88	5.16	5.20	5.25	5.88	4.94	5.32	4.99	7.95	5.69
A 39	3.67	3.70	2.94	2.63	3.23	3.55	3.00	2.46	3.29	4.00	6.75	3.56
A 40	4.59	3.76	5.02	2.66	3.44	4.41	3.40	2.43	5.04	3.69	7.18	4.15
A 41	3.20	4.78	3.56	3.77	2.99	3.35	2.99	2.84	4.09	3.60	5.37	3.68
A 43	4.82	3.55	6.14	4.49	3.65	5.37	5.00	3.84	5.64	5.10	7.16	4.98
Overall mean	4.51	4.61	4.81	3.65	4.31	4.76	3.87	3.80	4.73	5.03	7.73	
C.D. ($p=0.05$)	1.40	1.97	2.85	2.17	2.12	1.59	1.76	1.24	2.14	1.58	4.68	

Appendix X. Mean branches of 25 amaranth genotypes

Geno-types	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	5.00	3.10	4.75	0.20	2.40	4.30	3.70	1.50	3.63	3.63	3.25	3.22
A 3	3.30	4.60	4.50	0.50	1.50	4.20	4.88	2.85	3.79	4.75	6.88	4.20
A 4	4.70	5.50	4.88	4.50	4.00	4.70	5.25	4.13	4.63	2.13	1.59	4.18
A 5	0.20	3.20	2.38	3.17	1.20	2.60	0.88	1.30	1.83	4.13	4.50	2.31
A 6	2.00	3.20	3.00	2.08	2.34	3.20	1.50	3.38	3.00	3.88	4.96	2.96
A 9	0.80	2.80	3.63	1.00	2.50	3.20	1.13	3.88	2.84	4.13	3.88	2.71
A 12	5.30	4.30	3.84	2.85	4.00	3.60	1.75	2.88	5.17	3.13	3.23	3.64
A 13	3.60	3.90	3.38	3.50	4.17	1.50	3.00	1.38	4.38	2.88	3.75	3.22
A 14	4.10	4.20	6.50	0.50	3.34	4.50	2.84	4.34	3.64	4.38	3.50	3.80
A 16	0.50	1.70	2.27	2.50	2.67	2.50	2.67	2.35	1.00	1.88	3.53	2.18
A 17	3.60	0.90	2.25	0.00	1.17	2.80	0.17	0.63	0.88	4.25	2.17	1.71
A 18	5.90	8.50	7.33	4.70	2.67	4.50	2.00	0.59	5.63	5.13	5.50	4.77
A 19	4.80	3.50	3.33	2.29	2.50	3.30	1.88	3.13	3.84	4.84	3.83	3.38
A 22	5.60	4.00	4.00	0.00	4.54	4.00	1.88	3.90	5.50	3.50	5.75	3.88
A 24	2.40	2.10	4.13	2.17	2.00	3.90	2.34	3.75	2.84	4.67	3.13	3.04
A 25	5.60	3.80	1.75	1.55	2.67	3.60	2.17	3.75	2.83	2.50	2.67	2.99
A 27	3.30	2.60	3.67	0.00	2.25	3.40	3.09	4.00	3.21	4.34	2.33	2.93
A 28	0.30	3.60	3.25	1.67	2.50	4.80	3.00	2.30	5.00	3.84	6.50	3.34
A 33	1.90	3.80	3.88	3.00	2.17	3.90	3.00	4.25	3.64	3.50	4.75	3.43
A 34	11.00	8.70	6.88	3.73	4.00	7.00	4.17	4.88	7.34	6.00	9.20	6.63
A 35	10.70	7.20	0.38	3.33	6.38	7.30	3.00	5.50	5.04	7.67	6.50	5.73
A 39	6.20	5.25	5.33	4.67	4.00	3.77	3.84	4.25	4.75	4.50	4.00	4.60
A 40	7.20	5.90	7.00	3.35	6.50	6.30	4.34	5.30	5.84	5.67	5.83	5.75
A 41	5.10	6.10	4.13	3.90	5.67	4.40	4.67	4.96	5.00	4.33	5.40	4.88
A 43	6.65	6.50	6.17	6.00	5.17	7.40	6.50	5.38	6.54	6.17	5.80	6.21
Overall mean	4.39	4.36	4.12	2.63	3.29	4.19	2.94	3.38	4.07	4.23	4.50	
C.D. ($p=0.05$)	3.62	3.08	1.53	1.04	2.30	2.62	1.08	1.43	1.94	1.52	3.61	

Appendix XI. Mean days to 50% bolting in control rows for 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	31.00	38.50	41.50	36.00	33.50	27.00	37.50	29.00	32.00	31.00	28.50	33.23
A 3	47.00	43.00	46.00	38.00	40.50	35.00	44.50	34.00	32.00	41.50	37.00	39.86
A 4	35.50	41.00	50.50	41.50	45.00	42.00	40.50	51.00	38.00	50.50	38.00	43.05
A 5	40.00	55.00	65.50	55.00	50.50	54.00	47.00	50.00	47.00	53.00	40.50	50.68
A 6	121.00	121.00	90.00	57.00	38.00	58.00	70.00	76.50	53.50	74.50	66.00	75.05
A 9	49.50	61.00	60.00	54.00	48.00	54.00	63.00	57.00	51.00	55.00	48.00	54.59
A 12	24.00	25.00	24.00	29.00	28.00	26.00	22.00	26.00	21.00	25.00	22.00	24.73
A 13	49.00	53.50	60.00	62.00	49.00	60.50	60.00	58.00	55.00	56.00	48.00	55.55
A 14	67.00	71.00	61.00	51.00	57.00	49.00	50.50	59.00	60.00	52.00	45.50	56.64
A 16	62.00	68.50	70.00	56.00	62.00	48.00	74.00	73.00	54.50	63.50	46.50	61.64
A 17	27.50	30.00	27.00	29.00	32.00	28.00	29.00	31.50	32.50	36.50	32.50	30.50
A 18	40.00	43.50	44.00	32.00	35.00	30.00	33.00	25.00	23.00	31.00	35.00	33.77
A 19	40.00	47.00	51.00	40.00	37.00	51.00	42.00	44.00	44.00	39.50	37.00	42.96
A 22	45.50	63.00	76.50	71.00	58.00	52.00	68.50	70.50	46.50	50.00	44.50	58.91
A 24	76.00	65.00	69.00	75.00	69.50	52.00	63.50	72.00	54.00	62.50	49.50	64.36
A 25	66.00	64.50	84.00	61.00	54.00	47.00	67.50	71.00	58.00	55.00	50.50	61.68
A 27	41.00	42.50	44.00	36.50	53.50	42.00	35.00	35.00	50.50	47.50	30.00	41.59
A 28	51.00	65.00	54.00	49.00	55.00	40.00	40.00	47.00	31.00	50.50	38.00	47.32
A 33	124.00	124.00	90.00	62.00	34.00	46.00	71.50	76.50	61.00	72.00	63.00	74.91
A 34	26.00	32.50	33.00	36.00	34.00	29.00	33.00	37.00	26.00	35.00	28.00	31.77
A 35	35.00	33.00	37.00	33.00	36.50	35.00	34.00	38.00	27.00	41.00	32.00	34.68
A 39	30.00	36.50	36.00	38.00	39.50	36.50	36.00	34.00	34.00	45.00	32.00	36.14
A 40	70.00	64.00	63.00	43.00	38.00	33.00	37.50	30.00	44.00	47.50	43.50	46.68
A 41	65.50	55.50	52.00	37.00	39.00	32.00	38.50	33.50	44.00	41.50	32.00	42.77
A 43	44.50	34.00	38.00	35.00	54.00	34.00	39.50	51.00	42,50	46.00	30.00	40.77
Overall mean	52.32	55.10	54.68	46.28	44.82	41.64	47.10	48.38	42.56	48.10	39.90	
C.D. (p=0.05)	9.97	6.88	6.15	6.48	5.21	7.14	5.65	6.94	9.84	7.00	6.54	

Appendix XII. Mean days to 50% bolting in unicut rows for 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	55.50	51.00	60.50	40.00	43.50	45.00	53.50	50.00	49.50	50.00	48.50	49.73
A 3	63.50	62.00	58.00	54.50	48.50	59.50	64.00	70.00	48.00	54.50	51.50	57.64
A 4	55.00	56.50	64.50	47.00	54.00	56.50	62.00	73.00	59.00	58.00	50.50	57.82
A 5	62.50	71.00	79.00	52.00	58.50	71.00	66.00	71.00	67.00	65.50	50.00	64.86
A 6	121.00	121.00	90.00	57.00	45.00	72.50	81.00	85.00	59.00	74.50	70.00	79.64
A 9	67.00	74.00	76.00	58.00	63.00	76.00	85.00	87.00	61.50	69.50	62.00	70.82
A 12	29.50	32.00	24.00	28.00	34.00	33.00	36.00	30.00	27.50	27.00	40.00	31.00
A 13	62.00	65.00	79.00	68.00	60.50	54.50	75.00	80.00	65.50	72.00	66.00	67.96
A 14	55.00	78.50	73.00	54.50	67.00	73.00	67.00	83,00	62.50	65,50	62.00	67.36
A 16	76.50	72.00	81.00	62.00	70.00	65.00	90.00	88.00	65.00	71.50	58.00	72.64
A 17	54.00	33.00	31.00	43.00	36.00	37.00	44.00	42.00	48.50	52.50	43.00	42.18
A 18	53.00	55.00	55.00	34.00	44.00	55.00	50.00	46.00	32.00	41.00	44.50	46.32
A 19	53.00	59.00	57.00	43.00	49.00	61.00	61.50	68.00	58.50	54.50	48.00	55.68
A 22	68.50	76.50	81.00	70.00	72.50	70.50	69.00	94.50	53.00	68.00	60.00	71.23
A 24	71.00	78.00	78.00	84.00	77.00	78.00	76.00	96.00	71.00	78.00	70.00	77.91
A 25	75.00	72.00	88.00	70.00	72.00	70.00	81.00	90.00	65.00	62.00	70.00	74.09
A 27	59.50	54.00	64.00	43.00	62.00	58.50	50.50	74.50	53.50	55.50	51.00	56.91
A 28	65.50	71.00	65.50	61.00	59.50	61.00	50.00	65.50	48.00	53.50	49.00	59.05
A 33	124.00	124.00	90.00	62.00	49.00	67.00	88.00	87.50	70.50	72.00	70.00	82.18
A 34	39.00	47.00	39.00	35.00	39.00	44.00	56.50	49.50	39.00	48.00	41.50	43.41
A 35	50.00	50.50	60.00	34.00	43.00	55.00	50.00	48.00	45.00	54.00	45.00	48.59
A 39	48.50	48.00	45.00	40.00	50.00	53.50	48.00	69.00	50.50	60.00	43.50	50.55
A 40	70.00	74.00	66.00	47.00	50.00	58.00	51.00	66.00	54.00	66.50	54.00	59.68
A 41	59.50	69.00	58.00	41.00	49.00	51.00	52.00	55.00	50.00	49.00	49.00	52.96
A 43	51.50	50.00	49.00	42.00	59.00	49.00	55.50	73.00	53.50	51.00	44.00	52.50
Overall mean	63.58	65.76	64.46	50.80	54.20	58.98	62.50	69.66	54.26	58.94	53.64	
C.D. (p=0.05)	6.53	5.02	5.09	6.78	4.33	17.60	8.80	13.04	5.71	11.15	5.88	

Appendix XIII. Mean nodes on bolting day for 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	13.80	15.58	16.63	15.00	16.65	16.27	16.00	16.10	18.63	15.50	11.33	15.59
A 3	20.70	16.40	20.50	13.78	17.75	17.40	14.88	16.28	16.38	15.00	18.67	17.07
A 4	19.60	18.60	15.30	13.10	13.34	22.04	12.78	26.25	19.00	17.71	26.90	18.60
A 5	23.30	18.50	19.60	16.63	18.00	32.42	18.08	29.60	27.50	18.29	19.17	21.92
A 6	38.15	38.15	31.80	22.00	16.17	24.27	19.38	24.00	36.00	24.34	28.00	27.48
A 9	21.10	19.21	22.10	22.13	16.17	23.88	20.00	29.90	20.00	21.12	20.67	21.48
A 12	11.50	10.10	11.00	10.40	14.13	10.71	11.01	11.88	10.60	10.63	11.33	11.20
A 13	20.80	15.00	17.00	16.38	17.71	18.25	16.05	24.34	15.38	18.38	18.34	18.01
A 14	15.80	16.50	21.03	18.75	17.42	23.50	18.75	25.38	17.98	21.84	15.17	17.76
A 16	27.20	28.10	28.33	21.50	33.00	31.30	22.63	35.88	29.25	20.44	26.50	27.65
A 17	11.60	13.00	19.20	16.60	18.17	24.08	19.50	20.43	19.50	16.75	12.33	17.38
A 18	18.90	15.67	17.90	16.40	14.00	16.13	16.25	10.98	16.60	18.75	18.34	16.36
A 19	17.50	14.40	18.20	15.90	17.42	19.21	18.50	19.50	16.20	17.00	20.42	17.66
A 22	21.20	21.45	24.30	22.63	22.75	21.50	22.63	25.30	24.63	22.63	22.74	22.89
A 24	31.70	28.38	32.23	28.63	18.50	27.60	22.88	32.58	28.63	32.17	22.17	27.77
A 25	29.90	33.50	29.30	29.67	24.25	28.88	24.50	36.20	27.84	34.00	26.34	29.49
A 27	19.40	15.90	18.80	15.10	17.00	22.03	19.18	19.25	31.88	19.50	20.67	19.88
A 28	21.20	19.79	16.03	13.60	17.70	20.88	17.58	19.85	18.53	20.17	25.17	19.13
A 33	38.20	38.20	32.20	22.75	16.67	21.63	22.13	25.10	37.25	25.67	24.21	27.64
A 34	13.80	16.60	19.25	17.90	16.34	16.00	17.30	18.00	18.70	20.38	26.50	18.25
A 35	20.40	17.30	19.48	16.90	17.60	20.78	19.38	22.25	20.13	20.50	19.17	19.45
A 39	14.00	14.90	15.70	14.50	14.21	14.88	13.90	15.10	16.50	16.75	15.50	19.09
A 40	27.90	21.04	22.50	14.70	18.54	17.60	21.23	15.90	21.50	24.21	24.17	20.84
A 41	16.80	19.46	16.48	14.90	16.80	14.74	16.38	13.70	15.60	18.00	17.67	16.41
A 43	16.83	17.63	13.00	12.66	19.92	16.00	16.75	20.43	17.00	16.38	17.50	16.74
Overall mean	21.25	20.13	20.71	17.70	17.33	20.88	18.30	22.17	21.65	20.24	20.38	
C.D. (p=0.05)	4.70	2.80	4.37	1.85	2.89	4.61	4.40	5.05	6.22	4.19	9.83	

Appendix XIV. Mean leaves on bolting day for 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	23.00	26.78	24.40	13.20	14.83	14.60	22.25	12.63	19.88	26.17	23.17	20.09
A 3	26.30	23.00	12.30	12.90	12.59	13.80	12.75	12.55	18.00	22.00	23.67	17.26
A 4	32.30	25.80	47.50	10.40	10.00	17.67	31.34	22.00	36.38	41.34	32.04	27.88
A 5	26.90	23.75	19.20	17.50	16.50	23.37	20.13	20.75	20.00	21.25	23.00	21.12
A 6	28.65	28.65	28.90	17.50	16.00	22.64	24.17	31.67	28.13	30.63	34.67	26.51
A 9	26.40	18.09	31.37	21.63	11.00	19.90	15.25	19.57	28.17	25.84	21.57	21.71
A 12	13.40	14.00	14.10	10.60	13.75	12.88	11.93	11.25	13.00	14.17	13.67	12.98
A 13	25.30	22.00	16.03	16.63	15.65	17.60	13.75	17.38	28.00	18.00	18.50	18.98
A 14	21.30	31.30	28.95	23.13	15.67	19.84	22.50	17.50	26.00	24.84	20.17	22.84
A 16	23.70	30.93	25.63	21.00	27.85	22.50	21.88	21.38	29.00	21.00	24.67	24.50
A 17	15.60	13.13	16.10	11.60	12.50	20.50	10.50	15.88	14.58	18.84	16.17	15.04
A 18	33.40	52.84	30.80	15.70	21.75	13.29	14.75	10.60	33.42	22.50	27.17	25.11
A 19	24.60	23.20	16.88	13.30	14.29	15.75	18.54	15.98	26.88	17.75	23.00	19.11
A 22	34.30	21.23	21.30	21.88	17.63	19.63	18.50	17.60	29.23	25.09	34.34	23.70
A 24	33.90	32.70	29.50	25.38	14.33	21.20	17.63	26.38	35.54	24.63	24.84	26.00
A 25	31.60	32.80	34.65	25.75	20.17	24.40	22.67	22.98	36.96	29.25	33.50	28.61
A 27	20.40	24.20	21.17	12.25	10.84	17.80	15.75	19.25	27.09	22.54	22.67	19.45
A 28	23.20	24.84	13.70	13.75	14.88	14.90	20.00	12.25	22.79	15.42	25.17	18.26
A 33	26.00	26.00	27.00	14.88	20.17	17.30	18.13	34.79	40.50	27.75	33.50	26.00
A 34	48.40	65.80	46.03	23.75	23.15	47.17	15.75	15.19	38.54	39.67	49.50	37.54
A 35	54.40	31.15	47.30	20.80	20.25	17.50	23.63	20.34	30.42	32.83	35.84	30.40
A 39	27.50	29.50	46.03	16.50	14.17	22.00	12.50	17.74	25.63	32.00	33.00	25.14
A 40	60.70	38.07	52.80	16.60	13.54	50.50	21.79	25.96	41.25	37.84	50.67	37.25
A 41	36.50	42.96	42.25	23.00	28.13	44.04	35.04	40.04	43.96	35.42	41.00	37.49
A 43	44.88	80.59	83.88	65.33	44.50	40.42	30.38	21.50	53.93	50.59	59.00	52.27
Overal mean	30.51	31.33	31.11	19.40	17.77	22.84	19.66	20.12	29.89	27.09	29.78	
C.D. (p=0.05)	8.51	17.43	11.21	5.06	7.27	6.79	12.60	9.11	13.51	12.40	12.04	

Appendix XV. Mean plant height (cm) on bolting day for 25 amaranth genotypes

Geno-types	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	60.80	57.88	51.48	31.60	42.38	35.25	23.50	39.80	31.25	37.17	64.17	43.21
A 3	62.65	46.30	34.00	25.83	28.34	40.80	32.75	36.25	42.04	37.17	51.00	39.74
A 4	57.85	53.00	34.10	38.13	34.17	65.90	39.54	44.38	45.21	45.50	74.20	48.36
A 5	66.90	76.75	31.20	30.38	33.50	79.38	32.38	48.50	47.29	63.17	90.83	54.57
A 6	154.00	154.00	106.40	95.50	27.84	62.60	27.33	63.13	58.88	61.84	109.00	85.68
A 9	81.20	82.46	55.60	54.75	28.34	67.20	39.00	49.50	52.13	58.50	64.97	57.60
A 12	13.84	14.35	16.10	12.50	13.33	21.75	14.35	15.03	18.75	17.50	32.34	17.26
A 13	75.60	75.90	30.40	26.88	44.46	52.30	25.50	62.25	40.13	38.84	97.84	51.83
A 14	60.60	39.30	62.50	62.25	35.75	70.27	36.25	52.50	46.88	63.77	63.17	53.92
A 16	75.30	122.05	69.15	75.63	56.79	57.40	46.25	53.80	51.04	56.33	87.67	68.31
A 17	27.95	27.68	25.00	21.80	25.17	30.50	29.88	25.88	28.25	29.00	37.67	29.07
A 18	43.35	34.50	36.95	25.90	20.24	28.63	20.84	15.70	36.13	31.67	36.42	30.03
A 19	43.80	35.60	46.30	18.90	31.79	35.80	29.67	34.70	45.00	41.67	46.17	37.22
A 22	61.30	77.73	48.40	54.63	46.96	53.90	45.34	42.70	48.65	45.84	63.46	53.53
A 24	81.95	120.63	64.60	58.63	37.84	60.05	36.88	61.00	61.25	53.35	80.87	65.19
A 25	90.60	120.90	74.20	69.17	59.84	67.00	37.14	64.15	61.25	54.50	101.17	72.72
A 27	73.25	52.00	34.80	26.90	50.83	51.90	27.35	42.68	31.88	48.83	57.00	45.17
A 28	93.55	81.67	35.65	41.25	35.45	43.80	26.25	44.38	43.09	31.34	69.34	49.61
A 33	156.80	156.80	100.20	90.25	32.63	46.40	33.50	69.08	58.50	53.67	96.50	81.30
A 34	49.00	44.10	34.15	25.83	20.96	41.38	21.00	37.00	38.09	36.84	42.17	35.50
A 35	68.70	40.60	34.20	23.70	22.34	39.30	28.13	37.40	39.99	42.00	52.92	39.03
A 39	46.90	49.00	35.40	19.38	32.54	47.50	25.63	44.60	41.75	42.17	46.00	39.17
A 40	91.40	87.27	59.80	22.10	39.84	40.90	25.25	35.00	56.50	44.67	81.84	53.14
A 41	39.50	63.38	29.80	18.60	24.94	38.00	21.00	28.65	32.38	34.67	64.50	35.95
A 43	34.18	55.34	39.80	32.50	23.54	35.60	30.78	32.55	30.75	36.34	60.00	37.39
Overall mean	68.44	70.77	47.59	40.12	33.99	48.54	30.22	43.22	43.48	44.25	66.85	
C.D. ($p=0.05$)	17.36	20.69	10.68	8.74	15.36	18.19	7.85	10.14	26.38	16.11	17.18	

Appendix XVI. Mean frequency of harvest of 25 amaranth genotypes

Genotypes	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	Varietal mean
A 2	1.50	1.00	2.00	1.00	1.00	1.00	1.00	2.00	2.50	2.50	2.00	1.59
A 3	1.50	3.00	1.50	2.00	2.00	2.00	1.00	2.50	3.00	1.50	3.50	2.14
A 4	1.00	1.50	2.00	1.00	1.00	2.00	1.00	3.00	3.00	3.50	2.50	1.96
A 5	1.50	2.00	1.50	1.50	1.00	2.50	1.50	1.50	2.50	4.00	2.00	1.96
A 6	1.00	4.00	2.50	2.00	1.00	3.50	2.50	3.50	6.00	5.00	5.00	3.27
A 9	1.00	3.00	2.00	2.00	2.00	4.00	1.50	3.00	6.00	5.00	4.50	3.09
A 12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A 13	2.00	3.50	2.00	1.50	2.00	4.00	2.50	3.50	6.00	4.00	5.00	3.27
A 14	1.50	3.50	2.00	1.50	2.00	3.00	2.00	3.00	4.00	5.00	3.00	2.77
A 16	1.00	3.00	2.00	1.50	1.00	3.50	2.00	3.50	5.00	4.00	3.00	2.68
A 17	1.50	1.50	1.00	1.00	1.00	1.00	1.00	2.00	2.00	4.00	1.50	1.59
A 18	1.50	1.50	1.00	1.00	1.00	1.00	1.00	1.00	3.00	1.50	2.00	1.41
A 19	2.00	2.00	2.00	1.00	1.00	2.00	1.00	3.00	3.00	3.50	2.50	2.09
A 22	1.50	3.50	3.00	2.00	2.00	3.50	2.00	4.00	6.00	5.00	5.00	3.41
A 24	1.00	3.00	2.00	1.50	1.00	3.00	1.50	4.00	5.00	4.00	5.00	2.82
A 25	1.50	3.00	1.50	2.00	1.00	3.50	1.50	4.00	5.00	4.00	3.00	2.73
A 27	1.00	2.00	1.50	1.00	1.00	2.50	1.00	2.00	3.00	3.50	3.00	1.96
A 28	1.00	2.50	2.00	1.50	1.50	2.00	1.50	2.00	3.50	3.00	3.50	2.18
A 33	2.00	4.00	2.00	2.00	1.00	2.50	2.50	3.50	5.00	5.00	5.00	3.14
A 34	1.00	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.05
A 35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.00	2.00	1.18
A 39	1.50	1.00	1.00	1.50	1.00	2.50	1.00	1.50	2.50	2.50	2.00	1.64
A 40	2.00	3.50	2.00	2.00	1.00	2.50	1.00	2.50	3.00	4.00	5.00	2.59
A 41	1.50	3.00	2.00	1.00	1.00	2.50	1.00	1.50	2.00	1.50	3.50	1.86
A 43	1.50	1.50	2.00	1.00	1.00	2.00	1.00	3.00	3.00	4.00	2.00	2.00
Overall mean	1.38	2.38	1.74	1.44	1.22	2.36	1.40	2.52	3.50	3.32	3.10	
C.D. ($p=0.05$)	1.11	0.79	0.64	0.84	0.29	0.73	0.17	0.94	1.35	1.19	0.99	

SCREENING FOR NON-BOLTING TYPE(S) OF AMARANTHS SUITED FOR YEAR-ROUND PLANTING

BY

DEVADAS, V. S.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the Degree

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Olericulture

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ABSTRACT

The investigation, "screening for non-bolting type(s) of amaranths suited for year-round planting" was conducted during April 1981 to March 1982 at the Instructional Farm of College of Horticulture, Vellanikkara with the following objectives--to isolate stable line(s) for yield and bolting, line(s) with negligible content of antinutrient factors i.e., nitrates and oxalates and to ascribe the reasons for bolting. The 25 amaranth genotypes belonging to four botanical species were grown in a randomised block design with 2 replications at monthly intervals. All the 25 genotypes varied significantly with regard to the total yield, yield components and bolting. The heritability, phenotypic coefficient of variation and expected genetic advance were high for all the characters. There was a very high G x E interaction also for these characters. The line A 13 was stable for bolting and A 33 and A 6 were highly unstable. Line A 13 was stable for yield also (740.46 g/0.45 m^2). Line A 6 was the highest yielder (769.09 g/0.45 m^2). The lines A 22 and A 14 were suited for high-yielding environment with regard to yield and bolting and the line A 9 was suited to low yielding environments. Hence the promising lines observed were A 6, A 13, A 14, A 22 and A 33.

The lines A 6 and A 33 were short day types and the rest, day neutrals. Number of rainy days, 13th week after sowing influenced bolting in A 6 and A 33. Mean maximum temperature during the first week of sowing determined bolting in A 5, A 17 and A 22. Mean bright sunshine hours during the first week of sowing influenced flowering in A 5, A 17 and A 19. Physical properties of soil (percentage of sand, silt and clay) had no significant correlation with days to bolting except for the line A 5, which was influenced by the percentage of clay and silt of soil.

Flowering was delayed by cutting. Red amaranths bolted late andgreen amaranths were early.

A 43 had the minimum content of free nitrate and oxalate. Maximum total chlorophyll content was estimated in A 34.

The line A 17, a variant of A. tricolor was tentatively named as A. tricolor ssp. cavicaulis due to its hollow stemmed character.