

**EFFECT OF SOWING DATES ON GROWTH  
AND YIELD OF GRAIN AMARANTH  
GENOTYPES**

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**G. LOHITHA**

**DEPARTMENT OF AGRONOMY  
UNIVERSITY OF AGRICULTURAL SCIENCES,  
GKVK, BANGALORE -560 065  
SEPTEMBER 2001**

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AND YIELD OF GRAIN AMARANTH  
GENOTYPES**

**G. LOHITHA**

Thesis submitted to the  
**University of Agricultural Sciences, Bangalore**  
in partial fulfillment of the requirements  
for the award of the Degree of

*Master of Science (Agriculture)*  
*in*  
*Agronomy*

**BANGALORE**

**SEPTEMBER, 2001**

*Dedicated to*  
*My beloved*  
*Parents, Sisters*  
*&*  
*Brother*

**DEPARTMENT OF AGRONOMY**  
**UNIVERSITY OF AGRICULTURAL SCIENCES,**  
**GKVK, BANGALORE -560 065**

**CERTIFICATE**

*This is to certify that the thesis entitled "Effect of sowing dates on growth and yield of grain amaranth genotypes" submitted in partial fulfillment of the requirement for the degree of Master of Science in Agronomy to the University of Agricultural Sciences, Bangalore, is a record of research work done by Mr. G. Lohitha under my guidance and supervision and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

Bangalore -560 065  
November 19, 2001


  
(G.N. DHANAPAL)  
Major Advisor

**APPROVED BY :**

Chairman :

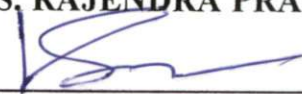
  
\_\_\_\_\_  
(G.N. DHANAPAL)

Members :

1.   
\_\_\_\_\_  
(K.N. GANESHAIAH)

2.   
\_\_\_\_\_  
(K. SEENAPPA)

3. \_\_\_\_\_  
(S. RAJENDRA PRASAD)

4.   
\_\_\_\_\_  
(K. SOMASHEKAR)

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Bangalore - 560065

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*G. LOHITHA*  
(G. LOHITHA)

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# INTRODUCTION

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## I. INTRODUCTION

Grain amaranth (*Amaranthus hypochondriacus* L.) is also called as 'Gentle giant' is one of the forgotten food crops of the world. It is a potential subsidiary food crop and plays an important role in feeding the hunger mouths. The crop belongs to the family *Amaranthaceae* and the genus *Amaranthus*. This genus consist of as many as 60 species of annual herbs, which are native of America and are distributed in the tropics, of which, about 25 species occur in India. There are four cultivated species of grain amaranth viz., *A. hypochondriacus* L., *A. cruentus* L., *A. caudatus* L. and *A. edulis* L. The crop is cultivated as a minor crop in many parts of the world (Mexico, Guatemala, Peru, India, Nepal etc). In India, it is cultivated both in the hilly and plains of Himachal Pradesh, Gujarat , Maharashtra and Karnataka.

It has a very high nutritional value; higher grain protein (13 to 19%) with high lysine (6.0 g/100g protein) and other sulphur containing amino acids (4.4%), which are limiting in other conventional grains (Joshi and Rana, 1991). Amaranth grain is a good source of vitamins and minerals, being exceptionally rich in calcium, magnesium, iron, phosphorus,  $\beta$ -carotene and folic acid and hence daily inclusion of grain amaranth in the diet of children can help to alleviate their iron and vitamin-A deficiency and to increase the blood haemoglobin level. Amaranth grain has 6 to 10 per cent oil which is found in the germ (Garcia *et al.*, 1987). Predominantly, it is a unsaturated oil (76%) and linoleic acid is in high quantity which is very much essential for human nutrition.

Grain amaranth is a crop with multiple uses; its tender leaves are used as vegetable, while grain is being used in different culinary preparation and in elaborating various bakery products and lysine rich baby foods. It has great potential for application in high quality plastics, cosmetics, pharmaceuticals and natural dyes. Tribals of India use grain for treatment of measles and snake bites as well as for foot and mouth disease in animals (Joshi and Rana, 1991).

Grain amaranth is highly adoptive, fast growing, drought and disease resistant  $C_4$  plant with a high yielding potentiality. It could thrive well under water stress and reduced field capacity (Miller *et al.*, 1984). Recent research findings have also suggested that certain amaranth cultivars can tolerate unfavourable soil conditions like high salinity or alkalinity. Hence, it is very much essential to study the adaptability, yield potentiality and performance of the crop in different agro climatic regions.

An understanding of the nature and interaction played by a genotype with environmental components is a basic requirement for a programme aimed at higher crop production.

It is a fact, that a specific genotype does not exhibit the same phenotypic characteristics under different environments and different genotypes respond differently to a specific environment and their relative ranking usually differs (Eberhart and Russell, 1966). Ultimately, the deciding factor for selection of genotypes for a particular or different sowing date is the yield stability and higher yield.

Genotypes play an important role in crop production. Efforts made at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi at its different research centers have shown that, with the development of high yielding cultivars, it is now possible to grow amaranth profitably than conventional cereal crops (Joshi and Rana, 1991). A cultivar would express its full potentiality only when backed up by good agronomic practices. In order to exploit the yield potential of these improved genotypes of grain amaranth, agronomic practices like date of sowing has to be optimized.

Although general recommendations are available, no data have been published on sowing date of grain amaranth in the eastern dry zone of Karnataka (zone-5). Keeping all these points in view, the present investigation entitled "Effect of sowing dates on growth and yield of grain amaranth

genotypes" was planned and conducted during *kharif* 2000 with the following objectives.

- (1) To find out the optimum time of sowing for grain amaranth genotypes during *kharif* season.
- (2) To study the growth and yield parameters of grain amaranth genotypes in relation to date of sowing.
- (3) To find out the interaction effects of dates of sowing and genotypes.

# *REVIEW OF LITERATURE*

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## II. REVIEW OF LITERATURE

Reviews of research work, relevant to the present investigation are presented in this chapter to update the knowledge of work undertaken so far in the line of concerned study.

### 2.1 Effect of sowing date on grain amaranth

Sowing date is a non-cash agronomic input, which influences growth, flowering, yield, disease and pest incidence.

Grain amaranth is a warm-season C<sub>4</sub> plant, which grows well at warm temperatures and high light intensities (El-Sharkawy *et al.*, 1968; Anon., 1984). The phasic development study of grain amaranth by Angus *et al.* (1982) in Australia revealed that the *Amaranthus mantegazzianus* was strongly photosensitive both before and after floral initiation and to a small extent after anthesis. Therefore, this crop is unsuited as a grain crop in temperate latitudes, being ruled out by the long photoperiod in summer and low temperature in other seasons.

Germination of grain amaranth depends on soil temperature and moisture content. Webb (1985) reported 13°C as the minimum soil temperature for germination of grain amaranth is and germination rate increased with increase in soil temperature. Germination of the palmer amaranth seed was poor at 16°/10°C; it may account for the slow germination of seed observed in the field in the months of March and April in USA (Keeley *et al.*, 1987).

Field experiments in Pennsylvania showed a differential response of cultivars and species to low soil temperature at planting (Haas and Schaver, 1985). Rabinson (1986) suggested delaying planting until June in Minnesota to ensure warm soil temperature. Myers and Putnam (1988) recommended late May to early June for planting of grain amaranth in Minnesota and Nebraska, respectively. Selection of a suitable planting date for grain amaranth depends on

soil temperature and moisture status, cultivar maturity and the expected date of the last frost in spring and first frost in Fall (Putnam, 1990). In general, planting is recommended as soon as possible after a near optimal soil temperature has been reached, especially in regions prone to hot dry winds (Weber, 1990).

Baltensperger *et al.* (1991) in Nebraska reported the several disadvantages of delayed planting on crop performance, including lower yield due to shortening of the growing seasons, more aggressive weed competition and frost damage before reaching maturity. In a study on the effect of photoperiod on seed yield of amaranth, Chandwade *et al.* (1993) reported that for Lal Rajagira, a 9 hour photoperiod followed by 15 hour dark was optimum for producing higher grain yield. A cropping season with photoperiod of 9 hour should be considered as optimum for grain purpose.

### **2.1.1 Morphological characters**

#### **2.1.1.1 Plant height**

The variation in plant height among the different sowing dates in grain amaranth has been reported. Angus *et al.* (1982) showed that the crop sown in November reached a height of 1.8m, while the crop sown in March reached only 0.6 m. Keeley *et al.* (1987) noticed that the final height of plants in March to July sowings were not greatly differ, where as the height of plants after July sowing tend to be reduced due to the shorter growing period. Vireshwar Singh *et al.* (1991) reported that early sowing(31<sup>st</sup> August) gave significantly higher plant height than late sowing (16<sup>th</sup> November). Significantly higher (149.2 cm) plant height was observed when crop sown during 3<sup>rd</sup> week of July compared to early or late sowings (Phogat *et al.*, 1994).

#### **2.1.1.2 Number of leaves per plant**

Sree Rangasamy *et al.* (1980) showed no phenotypic variation for number of leaves in April and July sowings. In a sowing date trial at hilly regions of

India, Joshi and Rana (1991) reported maximum number of leaves (41.9) for 17<sup>th</sup> June sown crop compared to early (2<sup>nd</sup> June) and late sowings (2<sup>nd</sup> July and 17<sup>th</sup> July).

#### 2.1.1.3 Leaf area per plant

A considerable variation with respect to leaf area among the sowing dates of grain amaranth has been reported. Joshi and Rana (1991) reported maximum leaf area for 17<sup>th</sup> June sown crop followed by 2<sup>nd</sup> June sowing and least was recorded in 17<sup>th</sup> July sowing. Waghmode *et al.* (1998) noticed the maximum leaf area in 1<sup>st</sup> October sown crop than 1<sup>st</sup> November sown crop.

#### 2.1.1.4 Number of days to flowering

The two planting dates (May 16<sup>th</sup> and June 6<sup>th</sup>) showed significant differences for flowering time (Hauptli and Jain, 1980). Keeley *et al.* (1987) at Shafter in USA reported that early planting (March to June) did not result in flowering until 5 to 6 weeks after planting, whereas under late plantings (July to September) flowering began within 3 to 4 weeks after planting. Days taken for 50 per cent flowering was significantly less in August sown crop due to coincidence of high temperature compared to later sowings (Vireshwar Singh *et al.*, 1991).

Misra *et al.* (1996) at Lucknow in U.P. noticed that the crop sown after July 15<sup>th</sup>, flowered early with simultaneous reduction in total growth duration. Days to 50 per cent flowering differed significantly among the sowing dates, December and January sown crop took maximum number of days (74.75 to 70.59), while July sowing took the least number of days (50.64) to attain 50 per cent flowering at Bangalore (Srinivasaiah, 1998).

#### 2.1.1.5 Days to maturity

Varied maturity periods in grain amaranth sowing dates have been reported. Vireshwar Singh *et al.* (1991) at Hissar noticed that the November 16<sup>th</sup>

sown crop took maximum number of days for maturity (163), while September 15<sup>th</sup> sowing took the least number of days (118) to attain maturity.

Misra *et al.* (1996) showed wide range of variations in crop duration, days taken to maturity ranged from 121 days in September and October sown crop to 159 days in July sown crop in the alluvial plains of U.P. Srinivasaiah (1998) noticed that days to maturity differed significantly among the sowing dates. December sown crop took more number of days to maturity (110.4), while July sown crop took the least number of days (93.3).

#### 2.1.1.6 Rate of dry matter production

Angus *et al.* (1982) observed wide variation in the above ground biomass at physiological maturity among different sowing dates, highest biomass (15.5 t/ha) recorded in November sown crop, while least biomass (7 t/ha) was with the March sown crop in Australia. Increase in temperature and day length hastened the total dry matter accumulation (814 g/plant) in June 1<sup>st</sup> sown crop at 12 weeks after planting compared to early or late planting dates in palmer amaranth in USA (Keeley, 1987).

Dry weight of panicle differed significantly among the sowing dates. The maximum panicle dry weight (513 g/plant) was recorded in July 15<sup>th</sup> sowing and minimum was recorded in October 30<sup>th</sup> sowing (Misra *et al.*, 1996). Henderson *et al.* (1998) at Northern Great Plains reported that the response of biomass yield to the planting date was very dissimilar among years where the greatest biomass yield occurred from 15<sup>th</sup> June in 1989, 1<sup>st</sup> May and 15<sup>th</sup> June in 1990 and 1<sup>st</sup> May and 15<sup>th</sup> May sown crop in 1992. Panicle weight per plant differed significantly among the sowing dates. The maximum panicle weight (72.3 g) was recorded in November sowing and minimum (27.3 g) was recorded in December sowing in Bangalore (Srinivasaiah, 1998).

## 2.1.2 Yield and yield components

### 2.1.2.1 Panicle length and number of panicles per plant

Joshi and Rana (1991) noticed wide variation in panicle and spikelets number. Maximum length of panicle (60.7 cm) and number of spikelets (55.0) were recorded for the 2<sup>nd</sup> June sown crop and minimum length of panicle (49.1 cm) as well number of spikelets recorded for 17<sup>th</sup> June sown crop. Phogat *et al.* (1994) reported that the significantly higher panicle length (38.5cm) was recorded for crop sown during 3<sup>rd</sup> week of July and least panicle length (14.7cm) for the crop sown during 2<sup>nd</sup> week of December in New Delhi.

At Lucknow the average length of panicles found to increase up to September 15<sup>th</sup> sowing and decreased sharply in October sowing (Mistra *et al.*, 1996). Srinivasaiah (1998) reported that the maximum number of panicle per plant (14.07) was recorded in November sowing and minimum number of panicles per plant (6.95) was recorded in July sowing. He also observed highest panicle length (30.69cm) in November sowing and lowest (18.93cm) in February sowing.

### 2.1.2.2 Grain yield

Grain yield of amaranth differed significantly among the sowing dates. Hauptli and Jain (1980) reported a significant yield advantage of *A. cruentus* in the early plantings at May 16<sup>th</sup> than late planting at June 6<sup>th</sup> in California. Angus *et al.* (1982) stated that March sown crop produce highest yield of grain (21.5 q/ha) while the grain yields for crop sown in November, December and January were uniformly lower (6.0 q/ha). Jamriska (1991) noticed that sowing of *A. hypochondriacus* in the months of April 20 to 27 gave higher yield of 24 q/ha followed by 17.9 and 19.5 q/ha when crop was sown in month of May 5 to 11 and May 16 to 24, respectively.

Joshi and Rana (1991) while standardizing the optimum time of sowing for amaranth in the hilly regions of India found that, highest grain yield of 16.1 q/ha was obtained when sowing was done on 2<sup>nd</sup> June followed by 17<sup>th</sup> June and the least grain yield of 8.6 q/ha was recorded on 17<sup>th</sup> July sown crop. Vireshwar Singh *et al.* (1991) observed that 1<sup>st</sup> November sown crop produced significantly higher grain yield (10.7 q/ha) than all other early and late sowings. Out of three dates of sowing viz., 8<sup>th</sup> October, 5<sup>th</sup> November and 6<sup>th</sup> January, the highest yield (33.0 q/ha) was recorded in November sown crop of amaranthus (Kim *et al.*, 1993).

Phogat *et al.* (1994) reported that the crop sown on 1<sup>st</sup> week of August produced significantly higher seed yield (8.26 q/ha) than early and late sowings in New Delhi. Misra *et al.* (1996) at Hissar, noticed that sowing of *A. hypochondriacus* in the month of September (15<sup>th</sup>) gave higher yield of 15.6 q/ha followed by 8.9 q/ha with the late sowing (October 30<sup>th</sup>).

Henderson *et al.* (1998) recorded the grain yield with respect to planting date was very dissimilar among years where the greatest grain yield occurred from 15<sup>th</sup> June sowing in 1989, 1<sup>st</sup> and 15<sup>th</sup> June sowing in 1990 and 1<sup>st</sup> May and 15<sup>th</sup> May sowing in 1992. Waghmode *et al.* (1998) at Rahuri noticed that sowing in 1<sup>st</sup> week of October provided most suitable environment for yield and its components. Srinivasaiah (1998) recorded highest grain yield (13.6 q/ha) in November sown crop and lowest (2.71 q/ha) in July sown crop in vegetable amaranth.

### 2.1.2.3 Test weight

Joshi and Rana (1991) noticed that the 1000-grain weight of 2<sup>nd</sup> July sown crop was maximum (1.2 g) than 2<sup>nd</sup> June and 17<sup>th</sup> June sown crop (1.1 g). Grain weight per unit volume (100 cc) did not vary significantly due to sowing between 15<sup>th</sup> July to 15<sup>th</sup> September (Misra *et al.*, 1996). Srinivasaiah (1998) reported that the 1000-seed weight differed significantly among the sowing

dates. The highest seed weight was recorded in November sowing and it was lowest in July sowing (0.75g).

#### 2.1.2.4 Harvest index

Hauptli and Jain (1980) observed the difference in harvest index of two planting dates. Maximum harvest index (0.27) was recorded in 16<sup>th</sup> May sown crop than 6<sup>th</sup> June sown crop (0.26) in very early genotypes. Angus *et al.* (1982) found that, the harvest index was higher for the late sown crop (March) due to reduction in vegetative biomass and an increase in seed yield. Henderson *et al.* (1998) showed significant differences in harvest index among sowing dates. Maximum harvest index was recorded in June 1<sup>st</sup> sowing (0.27) and it was least in May 15<sup>th</sup> sowing(0.25).

#### 2.1.2.5 Grain crude protein content

One of the attractive feature of grain amaranth is its protein content which is present in relatively higher amount than in common cereal grains.

Angus *et al.* (1982) observed that seed protein content was constant at 17 per cent in all the sowing dates. Waghmode *et al.* (1998) reported that the sowing of grain amaranth during 1<sup>st</sup> November was most favorable for grain protein content than 1<sup>st</sup> October sowing.

## 2.2 Performance of grain amaranth genotypes

Genotypes play a vital role in crop production within genetic limits, the environment sets the yield potential of a genotype. Hence, the combination of genotypes and environmental factors can bring about increase in production.

## 2.2.1 Morphological characters

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### 2.2.1.1 Plant height

The plant height of grain amaranth differed widely among the genotypes have been reported. Plant height showed wide range of genetic advance to twenty promising cultivars of grain amaranth (Joshi, 1986). Pushpa Rekha (1986) revealed a wide range of variation for plant height with lowest value of 82.73 cm in Cv. Annapurna and highest value of 243.4 cm in Cv. peruana.

Lohithaswa (1992) and Raju (1992) reported that the range of variation in plant height among different genotypes was between 58.3 (IC 35380) to 144.9 cm (BDJ 89-384) and 51.6 (AG-18) to 99.3 cm (AG-27), respectively. The plant height of currently available amaranth cultivars ranges from less than 1.0m to more than 2.5m (Elbehri *et al.*, 1993). In a study of genetic diversity in grain amaranth, Joshi and Rana (1995) observed varied plant height (212.1 to 250.7 cm) among different genotypes.

In studies on growth and yield performance of grain amaranth genotypes, Koppa *et al.* (1997) reported that the genotypes differed significantly with respect to plant height; Akola local recorded highest plant height (114.3 cm) and lowest with IC 35711 (79.4 cm). Plant height was also affected by cultivars. The less branched cultivars (K-283 and MT-3) and branched cultivar (K-343) produced similar plant height, which was 25 to 45 per cent greater than K-432 (Henderson *et al.*, 2000).

### 2.2.1.2 Number of green leaves per plant

Joshi (1981) observed the differences in number of leaves in various genotypes. Joshi and Mehra (1983) reported that wide range variability exist for number of green leaves per plant in the genetic resources of grain amaranth.

In AICRP multilocation trials, the mean number of green leaves per plant varied between 12 and 69 among different genotypes (Anon., 1987). The range

of variability with respect to number of green leaves per plant among the different amaranth cultivars was between 18.6 and 19.4 (Maruthi, 1987). Raju (1992) noticed the number of green leaves per plant ranged from 31.0 (AG-18) to 53.6 (AG-58). Cultivar Annapurna recorded more number of green leaves per plant than Cv. Suvarna at all growth stages (Malligawad, 1994). In genetic diversity study of grain amaranth, Joshi and Rana (1995) revealed that the number of green leaves per plant varies from 42.8 (IC 38234) to 58.8 (IC 38280 and IC 42254). Among the different genotypes tried IC 35463 recorded significantly higher number of green leaves per plant (69.9) and lowest number of green leaves per plant was noticed in IC 35711 (47.6) (Koppa *et al.*, 1997).

#### 2.2.1.3 Leaf area per plant

Amaranth plant is capable of producing leaves quickly than inflorescence which counteract the total weight of leaves at later stage (Grubben, 1976). In a grain amaranth cultivars study, Olufolaji and Tayo (1980) reported that the optimum leaf production in plant was attained at 5 to 6 weeks of sowing. The leaf area of 40 to 60 dm<sup>2</sup>/plant has been observed in grain amaranth species (Tucker, 1986).

#### 2.2.1.4 Number of days to flowering

In the populations of Indian amaranth, Vaidya (1984) observed significant difference in days to flowering. Lohithaswa (1992) reported that the range of variation for 50 per cent flowering was 29.7 (IC 35736) to 55.0 days (IC 5564) among different genotypes. Significantly earlier flowering observed in Annapurna (33 days) than Suvarna (45 days) (Mohamed, 1997).

#### 2.2.1.5 Days to maturity

Varied maturity periods in grain amaranth cultivars have been reported. Mohideen *et al.* (1983) classified amaranth types as long duration types (>75 days) and medium short duration (60 to 75 days) types. In twenty promising

cultivars of grain amaranth, Joshi (1986) observed wide range of variability for days to maturity. Lohithaswa (1992) noticed that the mean days to maturity ranged from 96.5 to 131.5 days among different genotypes.

#### 2.2.1.6 Rate of dry matter production

Naidu *et al.* (1982) observed the wide variation in the dry weight of shoot at the vegetative stage among the four species of grain amaranth. The higher dry matter accumulation was noticed in *A. caudatus* than in *A. hypochondriacus* during grain filling stage due to the faster growth rate in *A. caudatus*. The greater dry matter accumulation in the shoots of *A. hypochondriacus* than the other three species was mainly attributed to bigger panicles of the former species. A rapid shift in sink strength from one organ to another in *A. cruentus* species was observed by Reuben and Mnzava (1982).

Considerable variation in the total dry matter per plant among the grain amaranth cultivars was reported. Pushpa Rekha (1986) noticed the wide range of variation in the total dry weight of the plant was 76.6 g (Sozhi local) to 441.4 g (IC 42006). The genotypes differed widely with respect to the total dry matter per plant. The lowest value of total dry matter 17.9 g was observed in EC-16930 and highest value of 136.9 g in EC-169627 (Maruthi, 1987).

In AICRP multilocation trials (Anon., 1987), Cv. Suvarna recorded significantly higher total dry matter per plot (3117 g) than Cv. Annapurna (1823g). The stem dry matter produced per plot in Suvarna was also more (293 g) compared to Cv. Annapurna which recorded 260 g (Anon., 1988).

Ramachandra (1990) reported that Cv. Suvarna recorded significantly higher total dry matter per plant at 55 days after sowing and at harvest (17.7 and 42.9 g), respectively compared to Cv. Annapurna (12.2 and 22.6 g). Koppa *et al.* (1997) noticed the significantly higher dry matter per plant in IC 35463 (125.7 g) and least was *Aedulis* (87.8 g).

Henderson *et al.* (2000) found that the cultivar K-283 and the K-432 produced lower biomass than K-343 and MT-3.. Significantly higher total dry matter per plant was recorded in Suvarna (39.4 g) as compared to K-482 (9.7 g) (Anand, 2000).

### 2.2.1.7 Growth parameters

Leaf area index (LAI) varies according to the grain amaranth species. Edwards and Volak (1979) reported that Mexican *cruentus* grain amaranth type 79S-1011 showed higher LAI (2.58) than African *cruentus* type 79S-1034 (0.955). Olufolaji and Tayo (1980) reported that the net assimilation rate (NAR) of three grain amaranth cultivars of *A. cruentus* increased until the highest values were obtained at 7 to 9 weeks in Cv. 'Light Red' and at 9 to 11 weeks in Cv. 'Large leaf' and Cv. 'Local Green'.

In a study with twenty cultivars belonging to four cultivated grain amaranth species, Pushpa Rekha (1986) reported that LAI varied from 0.60 to 4.36 among different cultivars. Ramachandra (1990) observed that the absolute growth rate (AGR) and crop growth rate (CGR) in Suvarna and Annapurna cultivars of grain amaranth increased with age till maturity, while leaf area duration (LAD) increased up to 55 days after sowing and thereafter it declined. Further, the growth parameters such as AGR, CGR and LAD were higher in Cv. Suvarna than Cv. Annapurna.

## 2.2.2 Yield and yield components

### 2.2.2.1 Panicle length and number of panicles per plant

Mohideen and Rajagopal (1975) noticed that the amaranth plants with longer inflorescence resulted in higher grain yield than those with shorter inflorescence.

Joshi and Mehra (1983) reported that the genetic resources of grain amaranth collected from Shiwalik Kumaon and Garhwal regions of Himalayas,

exhibited a wide range of variability for yield components such as inflorescence length and spikelets per inflorescence. Lohithaswa (1992) and Raju (1992) noticed that the range of variation in inflorescence length from 31.7 (Annapurna) to 66.2 cm (IC 35546) and 29.67 (AG-18) to 39.97 cm (AG-27), respectively.

In a genetic divergence study of grain amaranth, Joshi and Rana (1995) reported wide range of variability for length of inflorescence (65.0 to 97.6 cm) and number of spikelets (51.8 to 61.0). Koppa *et al.* (1997) found significant differences in inflorescence length and number of spikelets.

Srinivasaiah (1998) observed the significant differences in panicle length and panicle number of vegetable amaranth. Maximum panicle number and length was recorded in AG-114 and minimum was observed in Arka suguna.

#### 2.2.2.2 Grain yield

Wide variation in grain yield of amaranth cultivars in different environments has been reported. Mohideen *et al.* (1983) reported that the significant difference in the grain yield of amaranth, which varied from 712 kg/ha (A-62) to 2657 kg/ha (A-144). Joshi (1986) found that the twenty promising varieties of grain amaranthus showed a wide range of variability for grain yield per plant. Schaeffer *et al.* (1989) observed that Cv. Montana -3 (MT-3), *A. cruentus* type had a yield potential of 4800 kg/ha under irrigated conditions. He further reported that same genotype was capable of yielding from 200 to 1300 kg/ha in dry lands.

In USA, Schaeffer *et al.* (1989) noticed that the mean grain yield recorded for MT-3, RRC-K 283, RCC-K 266 and RRC-K 343 cultivars were 5341, 3034, 2714 and 2483 kg/ha, respectively. Experimental yields of grain amaranth in USA ranged from 137 to 4383 kg/ha (Weber *et al.*, 1989).

Koppa (1989) reported that Cv. IC-35463 recorded higher grain yield (825 kg/ha) compared to cultivars IC-42006 (808 kg/ha) and IC-21980 (746

kg/ha), during *kharif* season on black clay loam soils of Dharwad. Ramachandra (1990) noticed that the significant difference in yield between two genotypes of grain amaranth (R-104-1-1 and Annapurna). Grain yield of Cv. Annapurna was 8 per cent higher than that of Cv. Suvarna (2835 and 2601 kg/ha respectively) (Malligawad, 1994).

Joshi and Rana (1995) opined the significant difference in the grain yield per plant. Among twenty different genotypes maximum grain yield (55.1 g) was recorded in IC 38280 where as lowest grain yield (33.5 g) was recorded in IC 38243. Koppa *et al.* (1997) noticed significant difference in grain yield among different genotypes. Highest grain yield was recorded in genotype IC 35463 (8.25 q/ha) and least was in IC 35711 (4.19 q/ha). Henderson *et al.* (1998) reported that there was no significant difference in grain yield among the four genotypes viz, K- 283, K-343, K-432 and MT-3.

#### 2.2.2.3 Test weight

Joshi (1985) reported 1000-seed weight was 0.8 g to 0.9 g in Cv. Annapurna. Raju (1992) noticed the variation in 1000-seed weight from 0.8 g (AG-18) to 1.12 g (AG-46).

Elbehri *et al.* (1993) noticed that the cultivars of *A. hypochondriacus* had higher 1000-grain weight (0.64 g) compared to cultivars of *A. cruentus* (0.62 g). Joshi and Rana (1995) noticed the higher 1000-grain weight (1.15 g) was in IC 42258-1 and IC 42264-14 and least was recorded in IC 38234 (0.95 g). Mohamed (1997) found that the 1000-seed weight differed significantly among the varieties. Suvarna recorded the highest 1000-seed weight (0.69 g) while the lowest seed weight was recorded by GA-1 (0.47 g) and IC 35604 (0.48 g).

#### 2.2.2.4 Harvest index (HI)

Harvest index differed among the cultivars of grain amaranth. Ramachandra in 1990, observed that Cv. Annapurna had higher harvest index

(0.36) compared to tall Cv. Suvarna (0.24). In a grain amaranth varietal study, Elberhri *et al.* (1993) found that harvest index ranged from 0.099 for Cv. K-283 (*A. cruentus*) to 0.152 for Cv. K-266 (*A. hypochondriacus*). Koppa *et al.* (1997) found that there was no significant difference in harvest index of amaranth genotypes. The Cv. IC 21930 recorded highest harvest index (0.171) where as the lowest harvest index recorded in IC 35711 (0.007) among different genotypes.

#### 2.2.2.5 Grain crude protein content

Misra *et al.* (1983) observed that the grain crude protein content among the different amaranth cultivars varied between 15.3 and 22.1 per cent. Widest range of protein content (11% in *A. spinosus* to 23.3% in *A. teunifolius*) among amaranth species was reported by Singhal and Kulkarni (1988).

Ramachandra (1990) and Elbehri *et al.* (1993) observed variation in grain crude protein content from 15.7 to 17.7 per cent in *A. cruentus* and *A. hypochondriacus*, respectively. Raju (1992) noticed that the variation in protein content from 13.2 per cent (AG-18) to 16.9 per cent (AG-58) among different genotypes. Waghmode *et al.* (1998) observed that the grain crude protein content differed among the amaranth cultivars which varied between 14.31 to 18.76 per cent.

# **MATERIAL AND METHODS**

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### III. MATERIAL AND METHODS

A field experiment was conducted to study the “Effect of sowing dates on growth and yield of grain amaranth genotypes” during *kharif* 2000 at the field unit of the project on Under Utilized Crops, MRS, UAS, Hebbal, Bangalore. The details of the materials used and the methods adopted during the course of investigation are presented in this chapter.

#### 3.1 Location of the experimental site

The Main Research Station, Hebbal is located at a latitude of 12°58' North, a longitude of 77°35' East and at an altitude of 899 meters above the mean sea level.

#### 3.2 Soil characteristics of the experimental site

The experiment was conducted on red sandy loam soil. Before the initiation of the experiment, composite soil sample from experimental site was collected from top 0-15 cm depth. Soil sample was air dried, powdered and passed through 2 mm sieve and was analyzed for different physical and chemical properties by following the standard procedures (Table 1). The chemical analysis indicated that, pH of the soil was 6.1 and soil contains 0.042% total N, 22 kg of available P<sub>2</sub>O<sub>5</sub> and 156 kg available K<sub>2</sub>O per ha.

#### 3.3 Climatic conditions

The normal (1990-99) as well as the actual weather conditions during the crop growth period under study (June 2000-November 2000) and deviations from the normal with respect to rainfall (mm), maximum and minimum temperature (°C), mean relative humidity (%), hours of bright sunshine and open pan evaporation (mm/day) are presented in Table 2

**Table 1 : Physical and chemical properties of soil at experimental site, Main Research Station, Hebbal, Bangalore**

Sl No.	Particulars	Value (0-15 cm)	Method employed
<b>A</b>	<b>Physical properties</b>		
pa)	Bulk density (g/cc)	1.56	Core sampling method (Dastane, 1967)
b)	Mechanical composition (%)		International Pippet method (Piper, 1966)
(i)	Coarse sand	33.5	
(ii)	Fine sand	37.0	
(iii)	Silt	9.6	
(iv)	Clay	19.9	
c)	Texture	Red Sandy loam	
<b>B</b>	<b>Chemical properties</b>		
a)	Total nitrogen (%)	0.042	Modified Kjeldahl's method (Jackson, 1973)
b)	Available P <sub>2</sub> O <sub>5</sub> (kg/ha)	22	Olsen's method (Jackson, 1973)
c)	Available K <sub>2</sub> O (kg/ha)	156	Neutral normal NH <sub>4</sub> OAC method (Jackson, 1973)
d)	Organic carbon (%)	0.49	Walkey and Back's wet oxidation method (Piper, 1966)
e)	pH (1:2.5 soil water suspension)	6.1	Buckman's Zeromatic pH meter (Piper, 1966)
f)	EC (dS/m)	0.05	Conductivity bridge method (Jackson, 1973)

### 3.3.1 Normal climatic conditions

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The normal annual rainfall of the station was 873.53 mm. The major portion of it was received during May to November with highest rain fall in the months of September (152.35 mm) and October (191.94 mm). The mean maximum air temperature ranged between 26.85°C to 30.47°C and mean minimum air temperature ranged between 17.56 to 20.64°C. Highest temperature was recorded during June (30.47°C) which is followed by July (28.84°C) (Table 2).

The mean monthly relative humidity ranged from 72.6 per cent in June to 78.5 per cent in October. The mean monthly normal sunshine hours was maximum during November (6.4 hr/day) and minimum mean monthly sunshine hours was recorded during July (4.2 hr/day). The mean open pan evaporation gradually decreased from June to November.

### 3.3.2 Actual climatic conditions during the crop growth period of experimentation

The rainfall received was more during July, August, September and October followed by June and the least during November month. Actual rainfall was more than the normal during July, August and October months.

The average maximum air temperature was recorded in the month of June (28.90°C) followed by September (28.70°C). Maximum air temperature was more than the normal during October and November. The mean minimum temperature was less than the normal during June, July, August and September.

The mean monthly relative humidity ranged from 73.5 per cent in November to 81.0 per cent in August. The decreasing trend in mean relative humidity from the month of September to November was noticed. The mean hours of bright sunshine was least during June and July months (3.0 hr/day) and all the specified months recorded lower mean hours of bright sunshine than the normal. Maximum hours of bright sunshine was recorded in the month of

Table 2: Normal (1990-1999) and actual (June 2000 to December 2000) mean monthly weather data at Main Research Station, Hebbal, Bangalore

	Total rainfall (mm)		Mean maximum temperature (°C)		Mean minimum temperature (°C)		Mean relative humidity (%)		Mean hours of bright sunshine /day		Mean open pan evaporation (mm/day)							
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual						
June	89.39	77.00	-12.39	30.47	28.90	-1.57	20.64	20.00	-0.64	72.60	77.00	+4.4	6.00	3.00	-3.00	5.62	4.90	-0.72
July	77.20	126.50	+49.30	28.84	28.50	-0.34	20.21	19.70	-0.51	75.60	74.50	-1.10	4.20	3.00	-1.20	4.94	3.70	-1.24
August	151.15	283.80	+132.65	28.28	27.40	-0.88	19.83	19.60	-0.23	77.70	81.00	+3.3	4.30	3.30	-1.00	4.39	3.60	-0.79
September	152.35	123.70	-28.65	28.83	28.70	-0.13	19.73	19.40	-0.33	76.50	79.00	+2.5	5.60	4.60	-1.00	4.23	4.00	-0.23
October	191.94	233.10	+41.16	28.08	28.10	+0.02	19.29	17.80	-1.49	78.50	78.00	-0.50	5.60	3.40	-2.20	3.53	3.40	-0.13
November	68.55	5.80	-62.75	26.85	27.60	+0.75	17.56	16.80	-0.76	76.00	73.50	-2.50	6.40	4.50	-1.90	3.26	3.50	+0.24

September (4.6 hr/day) followed by November (4.5 hr/day). The mean open pan evaporation ranged between 3.4 to 4.9 mm per day.

### 3.4 Experimental details

The experiment had 10 treatments involving two genotypes and five sowing dates allocated in a split plot design with three replications.

The details of the treatments involved are as follows

#### Main plot : Genotypes

G<sub>1</sub> – Suvarna

G<sub>2</sub> – K-432

Sub plot : sowing dates	Actual date of sowing
D <sub>1</sub> - Second fortnight of June	30-06-2000
D <sub>2</sub> - First fortnight of July	14-07-2000
D <sub>3</sub> - Second fortnight of July	29-07-2000
D <sub>4</sub> - First fortnight of August	12-08-2000
D <sub>5</sub> - Second fortnight of August	30-08-2000

#### Other details

Gross plot size = 4.0 m x 3.0 m

Net plot size = 2.25 m x 2.40 m

Spacing = 45 cm x 15 cm

Recommended dose of fertilizer = 40:40:20 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O/ha

The plan and layout of the experiment indicating the details of treatment allocations are shown in Fig 3.1

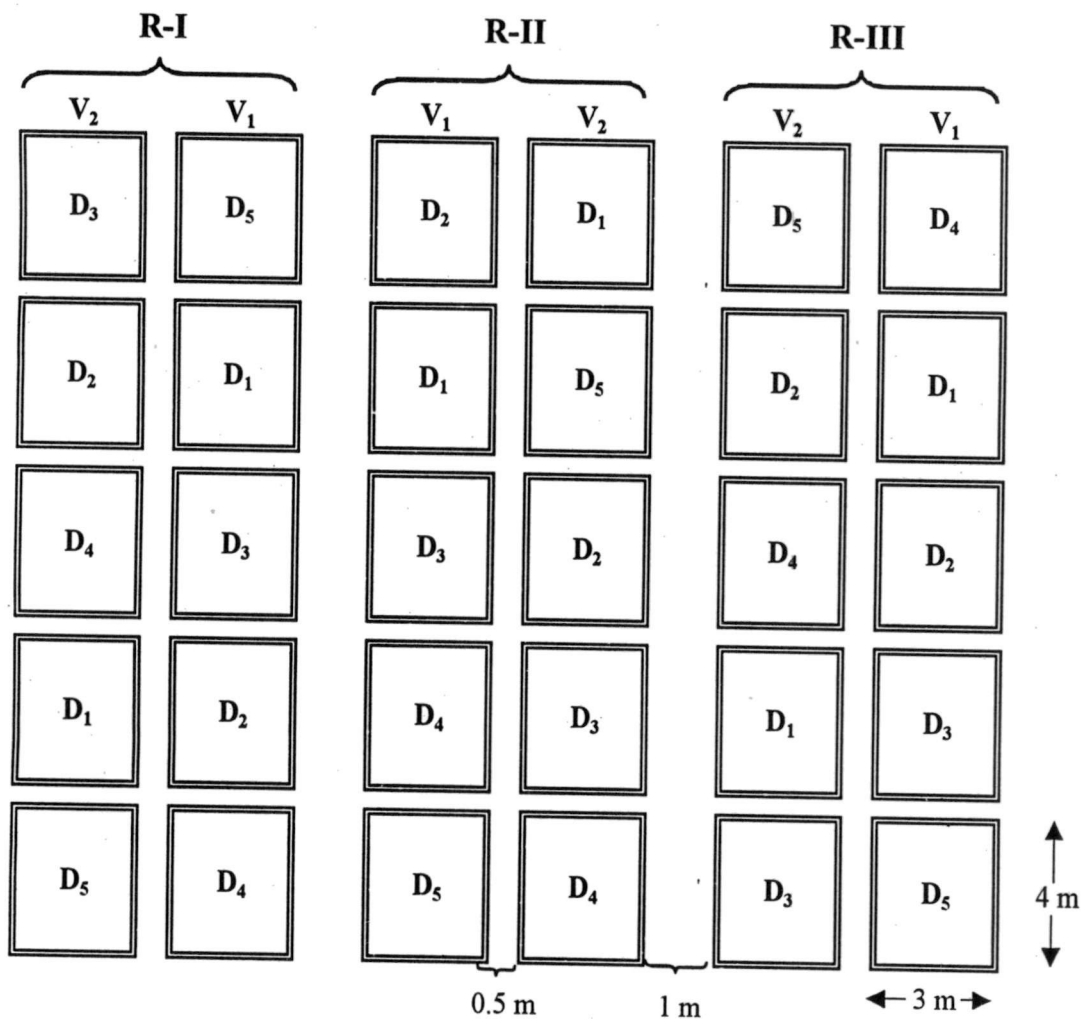


Fig. 3.1 : PLAN AND LAYOUT OF THE EXPERIMENT

**Main Plot : Genotype**

G<sub>1</sub> - Suvarna

G<sub>2</sub> - K-432

**Sub Plot : Sowing dates**

D<sub>1</sub> - Second fortnight of June (30-06-2000)

D<sub>2</sub> - First fortnight of July (14-07-2000)

D<sub>3</sub> - Second fortnight of July (29-07-2000)

D<sub>4</sub> - First fortnight of August (12-08-2000)

D<sub>5</sub> - Second fortnight of August (30-08-2000)

Sl. No.	Genotype characters	Genotypes	
		Suvarna	K-432
1.	Species	<i>A. hypochondriacus</i> L.	<i>A. hypochondriacus</i> L.
2.	Plant height (cm)	Tall plants, 120-180	Dwarf plants, 50-100
3.	Plant colour	Green	Reddish brown
4.	Days to 50 percent flowering	44-45	28-30
5.	Inflorescence type	Open	Open
6.	Days to maturity	90-95	62-65
7.	Grain colour	Crimson yellow	Amber cream
8.	Mean yield (Kg/ha)	1500-1800	800-1000
9.	Per day grain yield (Kg/ha)	17.84	14.20

### 3.6 Cultural operations

The details regarding various cultural operations carried out during the course of investigation are furnished below.

#### 3.6.1 Land preparation

The land was ploughed once by tractor drawn disc plough and cultivator was passed twice. The soil was brought to fine tilth. Before imposing all sowing treatments, plot was manually digged, weeds were handpicked and properly leveled.

#### 3.6.2 Fertilizer application

A recommended dose of fertilizer (40 : 40 : 20 kg NPK/ ha) was applied. N in the form of urea (46%N), P<sub>2</sub>O<sub>5</sub> in the form of single super phosphate (16% P<sub>2</sub>O<sub>5</sub>) and K<sub>2</sub>O in the form of muriate of potash (60% K<sub>2</sub>O). All the fertilizers were mixed thoroughly and applied uniformly by mixing well with soil 6" away from the sowing line before sowing the seeds.

### **3.6.3 Sowing**

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As per the subplot treatments, the sowing time was staggered as described in 3.4. The seeds were hand sown uniformly in a line at a depth of 2-3 cm. Immediately after sowing the seeds were covered uniformly with moist soil. After germination, one healthy seedling was retained at a spacing of 45cm x 15cm.

### **3.7 Aftercare**

Sowing at all dates was done at optimum moisture content in the soil. The crop was raised under rainfed conditions. Irrigations were given at early stage of establishment of crop to different sowing dates in order to obtain good initial stand of the crop.

#### **3.7.1 Thinning**

Manually thinning was done at 20 days after sowing (DAS) to each sowing date, in order to maintain required plant density in each plot and only one seedling was retained at each hill at 15 cm intra row spacing.

#### **3.7.2 Weeding**

Hand weeding was done at 25 DAS to each sowing date.

#### **3.7.3 Earthing up**

Immediately after weeding, earthing up was done to maintain good aeration and to avoid lodging.

#### **3.7.4 Plant protection measures**

One plant protection spray of Monocrotophos was given at sixth week after D<sub>1</sub> (second fortnight of June) sowing to control stem borer.

The crop was harvested as and when each sowing date of amaranthus genotype reached maturity. Harvesting was done when the seeds of middle panicle of the genotype were ripened but leaves remained still green to avoid grain shattering. Then panicles of both genotypes from each net plot area were hand harvested and were dried under sun. Dried material were hand threshed on a tarpaulin to separate grains. Later, grains were air dried and bagged to record grain weight.

### 3.8 Collection of experimental data

For recording various biometric observations, a sample consisting of five plants were selected at random from each net plot. For each sample, observations on various growth and yield parameters were made at different stages of crop growth viz., vegetative stage, panicle stage and maturity stage. The differences in the genotypes duration and influence of weather conditions due to different sowing dates, the time taken for maturity was decreased with delayed sowings. Therefore, the number of days taken for different stages was fixed based on field observations in the following way.

Treatment	Vegetative stage	Panicle stage	Maturity stage
G <sub>1</sub> D <sub>1</sub>	41	65	92
G <sub>1</sub> D <sub>2</sub>	41	65	92
G <sub>1</sub> D <sub>3</sub>	40	64	90
G <sub>1</sub> D <sub>4</sub>	39	63	88
G <sub>1</sub> D <sub>5</sub>	39	63	88
G <sub>2</sub> D <sub>1</sub>	31	47	65
G <sub>2</sub> D <sub>2</sub>	30	46	64
G <sub>2</sub> D <sub>3</sub>	30	46	64
G <sub>2</sub> D <sub>4</sub>	30	45	62
G <sub>2</sub> D <sub>5</sub>	29	45	62

G- Genotype, D- sowing date

### 3.8.1 Plant height

The plant height (cm) was recorded from the base of the plant to the tip of main shoot up to panicle initiation and from base of plants to the tip of the primary panicle after panicle initiation.

### 3.8.2 Number of green leaves per plant

Number of full opened green leaves from the five randomly selected plants were counted and the mean value were computed.

### 3.8.3 Leaf area per plant

Leaf area was measured by disc method as suggested by Vivekanandan *et al.* (1972). Thirty discs of known size were taken through a cork borer from randomly selected leaves from sample plants. Both the discs and remaining leaf blades were oven dried and leaf area was calculated by using the following formula.

$$LA = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (cm<sup>2</sup>)

Wa = Weight of all leaves (including 30 discs weight) in g

Wd = Weight of 30 discs in g

A = Area of 30 discs (cm<sup>2</sup>)

### 3.8.4 Dry matter accumulation and distributions

Dry matter accumulation was determined for only the above ground portion of the plant. Randomly selected five plants were partitioned into different parts like leaf, stem and panicle and dried at 65-70°C in hot air oven. The complete dried samples were weighed to constant weight and recorded as gram per plant. These primary data were used to estimate the total dry weight per plant.

### 3.8.5 Days to 50 per cent flowering

The number of plants flowered out of the total plants present in net plot were counted, when half of the plants were flowered, it was taken as the days for 50 per cent flowering from the date of sowing.

### 3.8.6 Days taken for physiological maturity

The days taken from sowing of crop to attain physiological maturity stage was considered and recorded as days taken for physiological maturity, based on maturity symptoms like change in colour of the panicles (from green to yellowish with the senescence of leaves).

### 3.8.7 Leaf Area Index (LAI)

It is the ratio of leaf area of total plant cover to the land area occupied. LAI was calculated by using the formula suggested by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area of a plant (cm}^2\text{)}}{\text{Land area occupied by that plant (cm}^2\text{)}}$$

### 3.8.8 Leaf Area Duration (LAD)

It is the integral of leaf area index over time expressed in days. This was ascertained by the formula suggested by Power *et al.* (1967).

$$\text{LAD} = \frac{\text{LAI}_{(i)} + \text{LAI}_{(i+1)}}{2} \times (t_2 - t_1)$$

Where,

$\text{LAI}_{(i)}$  = Leaf area index at  $i^{\text{th}}$  stage

$\text{LAI}_{(i+1)}$  = Leaf area index at  $(i+1)^{\text{th}}$  stage

$t_2 - t_1$  = Time interval between  $(i+1)$  and  $i^{\text{th}}$  stages

### 3.8.9 Absolute Growth Rate (AGR)

It is the daily rate of dry matter production as the increment in dry matter of plant per unit time expressed in g/plant/day. This was ascertained by the formula suggested by West *et al.* (1920).

$$\text{AGR} = \frac{W_2 - W_1}{t_2 - t_1} \quad \text{g/plant/day}$$

Where,  $W_1$  = Dry matter of plant at time 't<sub>1</sub>'

$W_2$  = Dry matter of plant at time 't<sub>2</sub>'

### 3.8.10 Net Assimilation Rate (NAR)

It is the rate of increase in the dry matter per unit leaf area per unit time and expressed as g/dm<sup>2</sup>/day. It was calculated by the formula as suggested by Gregory (1926).

$$\text{NAR} = \frac{(\text{Log}_e L_2 - \text{Log}_e L_1) (W_2 - W_1)}{(t_2 - t_1) (L_2 - L_1)} \quad \text{g/dm}^2/\text{day}$$

Where,

$\text{Log}_e$  = Logarithm to the base 'e' (Naperian constant)

$W_1$  and  $L_1$  = Dry matter and leaf area of plant at time 't<sub>1</sub>'

$W_2$  and  $L_2$  = Dry matter and leaf area of plant at time 't<sub>2</sub>'

### 3.8.11 Crop Growth Rate (CGR)

It is the absolute growth rate per unit area of land and expressed as g/dm<sup>2</sup>/day. It was worked out by adopting the formula suggested by Watson (1952).

$$\text{CGR} = \text{NAR} \times \text{Mean LAI}$$

Where,

NAR = Net assimilation rate

Mean LAI = Mean of leaf area index at time 't<sub>1</sub>' and 't<sub>2</sub>'

### **3.9 Observations on yield and yield components**

Randomly selected five plants were utilized for recording the observations on the following yield components.

#### **3.9.1 Panicle length**

Length from the base of the panicle to the tip was measured in all the randomly selected plant and the mean was recorded as panicle length in centimeters.

#### **3.9.2 Number of panicles per plant**

Number of panicles present on main shoot (since no branching) was counted at both panicle and maturity stage and mean of five plants was recorded as panicle number per plant.

#### **3.9.3 Dry weight of panicle per plant**

The five plants panicles were dried in hot air oven at 70°C, then the average weight of five plants panicle was recorded in grams as dry weight of panicle per plant at both panicle and maturity stage.

#### **3.9.4 Grain weight per plant**

The five randomly selected plants panicles were separately hand threshed, grains were air-dried and the mean grain weight recorded in grams.

#### **3.9.5 Test weight of grains**

Five ml grains were measured from grain yield of each net plot and the weight was recorded in grams.

### 3.9.6 Grain yield

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Grain yield from net plot area was recorded in kg, after threshing the panicles and winnowing. On the basis of seed yield per net plot, seed yield per hectare was worked out in kg/ha.

### 3.9.7 Harvest index

Harvest index was calculated as the ratio of the economic yield to the total biological yield as suggested by Donald (1962). It was calculated as follows.

$$\text{Harvest index} = \frac{\text{Grain yield / plant}}{\text{Biological yield / plant}}$$

### 3.10 Quality parameters

#### 3.10.1 Protein content (%)

Nitrogen content in the grains of amaranth was estimated by Kjeldahl's method (Jackson, 1973). The protein per cent in the seeds was calculated by multiplying the nitrogen content by a factor 6.25.

#### 3.10.2 Protein yield

Protein yield per hectare was worked out on the basis of grain protein content and grain yield of grain amaranth.

$$\text{Protein yield (kg /ha)} = \text{seed protein content} \times \text{seed yield (kg /ha)}$$

### 3.11 Statistical analysis

The observations recorded in these studies were analysed statistically for test of significance following the Fisher's method of "Analysis of variance (ANOVA)" appropriate to the design as described by Sunderaraj *et al*(1972). The level of significance on 'F' and 't' test was tested at five per cent. The results have been discussed at critical difference of 5 per cent

# EXPERIMENTAL RESULTS

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## IV. EXPERIMENTAL RESULTS

The results of the experiment entitled “Effect of sowing dates on growth and yield of grain amaranth genotypes” conducted during *kharif* 2000 at Main Research Station, University of Agricultural Sciences, Hebbal, Bangalore are presented in this chapter.

### 1. Plant height (cm)

The data on plant height as influenced by genotypes, sowing dates and their interaction at vegetative stage, panicle stage and maturity stage are presented in Table 3.

#### Vegetative stage

The plant height differed significantly between the genotypes. The genotype Suvarna recorded significantly higher plant height (35.3 cm) as compared to K-432 (21.4 cm).

The plant height was significantly influenced by dates of sowing. Sowing during July first fortnight recorded significantly higher plant height (32.6 cm) as compared to other date of sowings (22.2–28.6 cm) except June Second fortnight (32.3 cm). However, significantly lowest plant height (22.2 cm) was recorded in August second fortnight sown crop.

The interaction effects of genotypes and sowing dates significantly influenced plant height. The genotype Suvarna recorded significantly higher plant height (42.3 cm) in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but on par with itself in June second fortnight sowing (41.0 cm). The lowest plant height (19.1 cm) was recorded by K-432 in the August second fortnight sowing.

### **Panicle stage**

The plant height differed significantly between the genotypes. Maximum plant height was noticed with Suvarna (87.4 cm) as compared to K-432 (39.9 cm).

The plant height varied significantly due to different sowing dates. Significantly higher plant height (67.6 cm) was recorded in July first fortnight sowing, which was on par with August first and June second fortnight (63.9 - 67.0 cm) sowings. Significantly lowest plant height (57.0 cm) was recorded in August second fortnight sowing.

The plant height did not differ significantly due to interaction effects of genotypes and sowing dates. However, maximum plant height (93.3 cm) was recorded in Suvarna when sown during July first fortnight and the lowest plant height (35.1 cm) was recorded in August second fortnight sowing of K-432.

### **Maturity Stage**

Significant difference between the genotypes with respect to plant height was recorded. Maximum plant height was noticed in Suvarna (98.0 cm) as compared to K-432 (50.9 cm).

The plant height differed significantly due to sowing dates. Sowing of grain amaranth during July first fortnight recorded significantly higher plant height (80.8 cm) as compared to other dates of sowing (62.5-75.8 cm) except June second fortnight (80.7 cm). Sowing during August second fortnight recorded significantly lowest plant height (62.5 cm). Sowing during July second and August first fortnight recorded intermediate plant height (72.3-75.8 cm), which however did not differ from each other.

The interaction effects of genotypes and sowing dates significantly influenced plant height. The genotype Suvarna recorded significantly higher plant height (105.8 cm) in July first fortnight sowing which was significantly

Table 3 : Plant height of grain amaranth genotypes as influenced by sowing dates

Treatments	Plant height (cm)		
	Vegetative stage	Panicle stage	Maturity stage
<b>Genotypes</b>			
Suvarna (G <sub>1</sub> )	35.3	87.4	98.0
K-432 (G <sub>2</sub> )	21.4	39.9	50.9
<b>SEm±</b>	<b>0.45</b>	<b>0.40</b>	<b>0.81</b>
<b>C.D. (0.05)</b>	<b>2.77</b>	<b>2.44</b>	<b>4.94</b>
<b>Sowing dates</b>			
June second fortnight (D <sub>1</sub> )	32.3	67.0	80.7
July first fortnight (D <sub>2</sub> )	32.6	67.6	80.8
July second fortnight (D <sub>3</sub> )	25.9	62.4	72.3
August first fortnight (D <sub>4</sub> )	28.6	63.9	75.8
August second fortnight (D <sub>5</sub> )	22.2	57.0	62.5
<b>SEm±</b>	<b>0.99</b>	<b>1.47</b>	<b>1.54</b>
<b>C.D. (0.05)</b>	<b>2.99</b>	<b>4.41</b>	<b>4.61</b>
<b>Interactions</b>			
G <sub>1</sub> D <sub>1</sub>	41.0	89.5	103.0
G <sub>1</sub> D <sub>2</sub>	42.3	93.3	105.8
G <sub>1</sub> D <sub>3</sub>	31.4	88.0	100.1
G <sub>1</sub> D <sub>4</sub>	36.3	87.0	98.7
G <sub>1</sub> D <sub>5</sub>	25.4	79.0	82.1
G <sub>2</sub> D <sub>1</sub>	23.6	44.6	58.5
G <sub>2</sub> D <sub>2</sub>	22.9	41.9	55.8
G <sub>2</sub> D <sub>3</sub>	20.5	36.7	44.6
G <sub>2</sub> D <sub>4</sub>	20.9	40.7	53.0
G <sub>2</sub> D <sub>5</sub>	19.1	35.1	42.8
<b>SEm± for 'D' at same level of 'G'</b>	<b>1.41</b>	<b>2.08</b>	<b>2.18</b>
<b>C.D. (0.05)</b>	<b>4.24</b>	<b>NS</b>	<b>6.53</b>
<b>SEm± for 'G' at same/diff.level of 'D'</b>	<b>1.34</b>	<b>1.90</b>	<b>2.11</b>
<b>C.D. (0.05)</b>	<b>4.50</b>	<b>NS</b>	<b>7.29</b>

superior over K-432 in same or different sowing dates, but on par with only itself in June second and July second fortnight sowings (103.0–100.1 cm). The lowest plant height (42.8 cm) was recorded by K-432 in the August second fortnight sowing. In general, delayed in sowing resulted in significantly reduction in plant height.

## **2. Number of green leaves per plant**

The data on number of green leaves per plant as influenced by genotypes and sowing dates at vegetative stage, panicle stage and maturity stage are presented in Table 4.

### **Vegetative stage**

The number of green leaves per plant differed significantly due to genotypes. Significantly higher number of green leaves per plant was recorded in Suvarna (10.5) as compared to K-432 (7.5).

The number of green leaves per plant were found to be significant among different dates of sowing. Sowing during July first fortnight recorded significantly higher number of green leaves per plant (10.1) which was on par with the June second and August first fortnight sowings. However, significantly lowest number of green leaves per plant (7.7) was recorded in August second fortnight sowing.

The number of green leaves per plant did not differ significantly due to interaction effects of genotypes and sowing dates.

### **Panicle stage**

The number of green leaves per plant differed significantly between the genotypes. The genotype Suvarna recorded significantly higher number of green leaves per plant (15.4) as compared to K-432 (11.3).

**Table 4 : Number of green leaves per plant of grain amaranth genotypes as influenced by sowing dates**

Treatments	Number of green leaves/plant		
	Vegetative stage	Panicle stage	Maturity stage
<b>Genotypes</b>			
Suvarna (G <sub>1</sub> )	10.5	15.4	11.2
K-432 (G <sub>2</sub> )	7.5	11.3	9.6
<b>SEm±</b>	<b>0.08</b>	<b>0.44</b>	<b>0.90</b>
<b>C.D. (0.05)</b>	<b>0.49</b>	<b>2.69</b>	<b>NS</b>
<b>Sowing dates</b>			
June second fortnight (D <sub>1</sub> )	9.9	15.1	11.9
July first fortnight (D <sub>2</sub> )	10.1	15.0	12.5
July second fortnight (D <sub>3</sub> )	8.4	12.9	9.4
August first fortnight (D <sub>4</sub> )	9.0	13.1	9.8
August second fortnight (D <sub>5</sub> )	7.7	10.6	8.6
<b>SEm±</b>	<b>0.46</b>	<b>0.46</b>	<b>0.64</b>
<b>C.D. (0.05)</b>	<b>1.38</b>	<b>1.38</b>	<b>1.93</b>
<b>Interaction</b>			
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.654</b>	<b>0.651</b>	<b>0.910</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>
<b>SEm± for 'G' at same/diff.level of 'D'</b>	<b>0.590</b>	<b>0.731</b>	<b>0.887</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>

The number of green leaves per plant differed significantly among the different sowing dates. The data indicated that, sowing of grain amaranth during June second fortnight recorded significantly higher number of green leaves per plant (15.1) as compared to other sowing dates (10.6-13.1) except sowing during July first fortnight (15.0). Sowing during August second fortnight recorded lowest number of leaves per plant (10.6).

The interaction effects of genotypes and sowing dates were found to be non significant with respect to the number of green leaves per plant.

### **Maturity stage**

The number of green leaves per plant did not differ significantly due to genotypes at this stage.

The number of green leaves per plant differed significantly due to sowing dates. Sowing during July first fortnight recorded the significantly higher number of green leaves per plant (12.5) as compared to other sowing dates except June first fortnight (11.9). Significantly lowest number of green leaves per plant (8.6) was recorded in August second fortnight sowing.

The number of green leaves per plant did not differ significantly due to interaction effects of genotypes and sowing dates.

### **3. Days taken to 50 per cent flowering**

The data pertaining to the number of days taken to 50 per cent flowering as influenced by genotypes, sowing dates and their interaction are presented in Table 5.

Days taken to 50 per cent flowering differed significantly between the genotypes. Significantly more number of days taken in Suvarna (48.8) as compared to K-432 (29.9).

The number of days taken to 50 per cent flowering significantly influenced by sowing dates. Significantly more number of days taken in June second and July first fortnight sowing (40.5) which was on par with July second fortnight sowing (39.3). The lowest number of days taken to 50 per cent flowering was recorded in August second fortnight sowing (38.1).

Days taken to 50 per cent flowering was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher number of days taken to 50 per cent flowering (50.6) in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but on par with itself in June second fortnight sowing (50.3). The lowest number of days taken to 50 per cent flowering (29.3) was recorded by K-432 in the August second fortnight sowing.

#### 4. Days to physiological maturity

The data on days taken to physiological maturity as influenced by genotypes, sowing dates and their interaction are presented in Table 5.

Days taken to physiological maturity differed significantly between the genotypes. The genotype Suvarna recorded significantly higher number of days (89.9) as compared to K-432 (63.4).

The June first fortnight sowing recorded significantly higher number of days taken to physiological maturity (78.5) which was on par with July first fortnight sowing (78.2). The lowest number of days taken to physiological maturity was recorded in August second fortnight sowing (74.6).

Days taken to physiological maturity as influenced by interaction effects of sowing dates and genotypes differed significantly. The genotype Suvarna sown in June second and July first fortnight took more number of days (92) to attain physiological maturity which was significantly superior over itself and with K-432 in same or different sowing dates. The less number of days were

**Table 5 : Days taken to 50% flowering and physiological maturity of grain amaranth genotypes as influenced by sowing dates**

<b>Treatments</b>	<b>Days taken to 50% flowering</b>	<b>Days taken to physiological maturity</b>
<b>Genotypes</b>		
Suvarna (G <sub>1</sub> )	48.8	89.9
K-432 (G <sub>2</sub> )	29.9	63.4
<b>SEm±</b>	<b>0.13</b>	<b>0.04</b>
<b>C.D. (0.05)</b>	<b>0.76</b>	<b>0.27</b>
<b>Sowing dates</b>		
June second fortnight (D <sub>1</sub> )	40.5	78.5
July first fortnight (D <sub>2</sub> )	40.5	78.2
July second fortnight (D <sub>3</sub> )	39.3	76.8
August first fortnight (D <sub>4</sub> )	38.3	75.2
August second fortnight (D <sub>5</sub> )	38.1	74.6
<b>SEm±</b>	<b>0.50</b>	<b>0.21</b>
<b>C.D. (0.05)</b>	<b>1.50</b>	<b>0.64</b>
<b>Interactions</b>		
G <sub>1</sub> D <sub>1</sub>	50.3	92.0
G <sub>1</sub> D <sub>2</sub>	50.6	92.0
G <sub>1</sub> D <sub>3</sub>	49.0	89.6
G <sub>1</sub> D <sub>4</sub>	47.0	88.3
G <sub>1</sub> D <sub>5</sub>	47.0	87.7
G <sub>2</sub> D <sub>1</sub>	30.6	65.0
G <sub>2</sub> D <sub>2</sub>	30.3	64.3
G <sub>2</sub> D <sub>3</sub>	29.6	64.0
G <sub>2</sub> D <sub>4</sub>	29.6	62.0
G <sub>2</sub> D <sub>5</sub>	29.3	61.7
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.50</b>	<b>0.30</b>
<b>C.D. (0.05)</b>	<b>1.50</b>	<b>0.91</b>
<b>SEm± for 'G' at same/ diff.level of 'D'</b>	<b>0.46</b>	<b>0.27</b>
<b>C.D. (0.05)</b>	<b>1.50</b>	<b>0.85</b>

taken by K-432 (61.7) sown in August second fortnight. In general, days taken to attain physiological maturity in both the genotypes were gradually decreased with delay in sowing.

### **5. Number of panicles per plant**

The data pertaining to the number of panicles per plant as influenced by genotypes, sowing dates and their interaction at panicle and maturity stage are presented in Table 6.

#### **Panicle stage**

Number of panicles differed significantly between the genotypes. Significantly more number of panicles were recorded in Suvarna (22.6) as compared to K-432 (8.4).

The number of panicles differed significantly due to sowing dates. Significantly higher number of panicles (17.5) were produced in July first fortnight sown crop which was on par with June second fortnight sowing (17.0). The lowest number of panicles were recorded with very late sowing in August second fortnight (13.0).

The number of panicles per plant did not differ significantly due to interaction effects of genotypes and sowing dates.

#### **Maturity stage**

The number of panicles per plant differed significantly due to genotypes. The data indicated that, significantly higher number of panicles per plant was obtained with the genotype Suvarna (28.7) as compared to K-432 (9.3).

Sowing date significantly influenced the number of panicles per plant. Significantly higher number of panicles per plant (22.1) was recorded in July first fortnight sowing, compared to other dates of sowing except June second

fortnight sowing (21.7). However, significantly lowest number of panicles per plant (14.8) was recorded in August second fortnight sown crop.

The genotypes and the dates of sowing significantly interacted; the genotype Suvarna recorded significantly maximum number of panicles per plant (33.9) in July first fortnight sowing which was on par with itself in June second fortnight sowing (32.2) and significantly superior over K-432 in same or different sowing dates. The lowest number of panicles per plant (7.7) was recorded by K-432 in the August second fortnight sowing.

#### **6. Panicle length (cm)**

The panicle length of two grain amaranth genotypes as influenced by sowing dates at panicle stage and maturity stage are presented in Table 6.

##### **Panicle stage**

The panicle length differed significantly due to genotypes. Significantly higher panicle length was obtained in K-432 (16.4 cm) as compared to Suvarna (10.8 cm).

Panicle length differed significantly due to sowing dates. Significantly higher panicle length (14.6 cm) was recorded in July first fortnight sowing which was on par with June second fortnight sowing (14.5 cm). Significantly lowest panicle length (12.1 cm) was recorded in August second fortnight sowing. However, intermediate (13.4 – 13.2 cm) panicle length recorded in July second and August first fortnight sowing, which did not differ each other.

Panicle length did not vary significantly due to interaction of genotypes and sowing dates. However higher panicle length (18.0 cm) was noticed in K-432 when sown during June second fortnight and lowest panicle length (9.5 cm) was recorded in Suvarna when sown during August second fortnight.

Table 6 : Number of panicles per plant and panicle length of grain amaranth genotypes as influenced by sowing dates

Treatments	Numebr of panicles/plant		Panicle length (cm)	
	Panicle stage	Maturity stage	Panicle stage	Maturity stage
<b>Genotypes</b>				
Suvarna (G <sub>1</sub> )	22.6	28.7	10.8	12.1
K-432 (G <sub>2</sub> )	8.4	9.3	16.4	17.2
<b>SEm±</b>	<b>0.47</b>	<b>0.36</b>	<b>0.34</b>	<b>0.70</b>
<b>C.D. (0.05)</b>	<b>2.86</b>	<b>2.20</b>	<b>2.05</b>	<b>2.10</b>
<b>Sowing dates</b>				
June second fortnight (D <sub>1</sub> )	17.0	21.7	14.5	15.7
July first fortnight (D <sub>2</sub> )	17.5	22.1	14.6	15.8
July second fortnight (D <sub>3</sub> )	15.1	18.2	13.4	14.4
August first fortnight (D <sub>4</sub> )	14.8	18.1	13.2	14.1
August second fortnight (D <sub>5</sub> )	13.0	14.8	12.1	13.3
<b>SEm±</b>	<b>0.62</b>	<b>0.56</b>	<b>0.32</b>	<b>0.50</b>
<b>C.D. (0.05)</b>	<b>1.85</b>	<b>1.68</b>	<b>0.95</b>	<b>1.50</b>
<b>Interactions</b>				
G <sub>1</sub> D <sub>1</sub>	23.9	32.2	11.1	12.7
G <sub>1</sub> D <sub>2</sub>	25.7	33.9	12.5	13.8
G <sub>1</sub> D <sub>3</sub>	22.8	28.5	10.9	12.1
G <sub>1</sub> D <sub>4</sub>	21.5	26.9	10.0	11.1
G <sub>1</sub> D <sub>5</sub>	19.1	21.9	9.5	10.7
G <sub>2</sub> D <sub>1</sub>	10.1	11.1	18.0	18.7
G <sub>2</sub> D <sub>2</sub>	9.4	10.3	16.7	17.8
G <sub>2</sub> D <sub>3</sub>	7.4	7.9	16.0	16.7
G <sub>2</sub> D <sub>4</sub>	8.1	9.5	16.5	17.1
G <sub>2</sub> D <sub>5</sub>	6.9	7.7	14.8	15.9
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.87</b>	<b>0.79</b>	<b>0.45</b>	<b>0.71</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>2.38</b>	<b>NS</b>	<b>NS</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.91</b>	<b>0.79</b>	<b>0.52</b>	<b>0.69</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>2.88</b>	<b>NS</b>	<b>NS</b>

### **Maturity stage**

Panicle length differed significantly between genotypes. Significantly higher panicle length was noticed in K-432 (17.2 cm) as compared to Suvarna (12.1 cm).

Panicle length differed significantly due to sowing dates. Maximum panicle length (15.8 cm) was recorded in July first fortnight which was on par with the June second and July second fortnight sowings (15.7–14.4 cm). Significantly lowest panicle length (13.3 cm) was recorded in August second fortnight sowing.

Panicle length did not differ significantly due to interaction effects of genotypes and sowing dates. However, the genotypes K-432 recorded higher panicle length (18.7 cm) when sown during June second fortnight and lowest panicle length (10.7 cm) was recorded in Suvarna when sown during August second fortnight.

### **7. Leaf dry weight per plant (g)**

The data on leaf dry weight per plant at vegetative stage, panicle stage and maturity stage as influenced by genotypes, sowing dates and their interaction are presented in Table 7.

#### **Vegetative stage**

The leaf dry weight differed significantly between the genotypes. Significantly the highest leaf dry weight obtained in Suvarna (1.35 g) as compared to K-432 (0.63 g).

The leaf dry weight per plant differed significantly due to sowing dates. Significantly higher leaf dry weight (1.19 g) was recorded in July first fortnight sowing, which was on par with the June second and August first fortnight

sowings (1.15-1.08g). However, significantly lowest leaf dry weight (0.73 g) was noticed in August second fortnight sowing.

Leaf dry weight was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher (1.72 g) leaf dry weight in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but it was on par with itself in June second and August first fortnight sowings (1.59-1.53g). The lowest leaf dry weight (0.56g) was found in K-432 in August second fortnight sowing.

### **Panicle stage**

Significant difference between the genotypes with respect to the leaf dry weight was recorded. Maximum leaf dry weight was noticed in Suvarna (4.98g) as compared to K-432 (1.48g).

The leaf dry weight varied significantly due to sowing dates. Significantly higher leaf dry weight (3.76 g) was recorded in July first fortnight sowing. It was on par with June second and July second fortnight sowings (3.71–3.33 g). Significantly the lowest leaf dry weight (2.29 g) was recorded in very late sowing in August second fortnight. In general, delay in sowing decreased leaf dry weight of amaranthus irrespective of genotypes.

The leaf dry weight differed significantly due to interaction of genotypes and sowing dates. Sowing of genotype Suvarna during July first fortnight recorded significantly higher leaf dry weight (5.98 g) which was significantly superior over K-432 in same or different sowing dates, but it was on par with itself in June second and July second fortnight (5.83–5.24 g). The minimum leaf dry weight was recorded in very late sowing of K-432 during August second fortnight sowing (1.37 g).

**Table 7 : Leaf dry weight per plant of grian amaranth genotypes as influenced by sowing dates**

Treatments	Leaf dry weight /Plant (g)		
	Vegetative stage	Panicle stage	Maturity stage
<b>Genotypes</b>			
Suvarna (G <sub>1</sub> )	1.35	4.98	3.68
K-432 (G <sub>2</sub> )	0.63	1.48	1.43
<b>SEm±</b>	<b>0.40</b>	<b>0.08</b>	<b>0.18</b>
<b>C.D. (0.05)</b>	<b>0.22</b>	<b>0.50</b>	<b>1.13</b>
<b>Sowing dates</b>			
June second fortnight (D <sub>1</sub> )	1.15	3.71	2.52
July first fortnight (D <sub>2</sub> )	1.19	3.76	3.26
July second fortnight (D <sub>3</sub> )	0.79	3.33	2.37
August first fortnight (D <sub>4</sub> )	1.08	3.09	2.35
August second fortnight (D <sub>5</sub> )	0.73	2.29	2.26
<b>SEm±</b>	<b>0.04</b>	<b>0.20</b>	<b>0.15</b>
<b>C.D. (0.05)</b>	<b>0.12</b>	<b>0.60</b>	<b>0.45</b>
<b>Interaction</b>			
G <sub>1</sub> D <sub>1</sub>	1.59	5.83	3.51
G <sub>1</sub> D <sub>2</sub>	1.72	5.98	5.05
G <sub>1</sub> D <sub>3</sub>	1.01	5.24	3.38
G <sub>1</sub> D <sub>4</sub>	1.53	4.67	3.27
G <sub>1</sub> D <sub>5</sub>	0.88	3.20	3.17
G <sub>2</sub> D <sub>1</sub>	0.71	1.59	1.54
G <sub>2</sub> D <sub>2</sub>	0.65	1.53	1.47
G <sub>2</sub> D <sub>3</sub>	0.58	1.42	1.36
G <sub>2</sub> D <sub>4</sub>	0.63	1.51	1.43
G <sub>2</sub> D <sub>5</sub>	0.56	1.37	1.35
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.06</b>	<b>0.28</b>	<b>0.21</b>
<b>C.D. (0.05)</b>	<b>0.18</b>	<b>0.85</b>	<b>0.63</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.06</b>	<b>0.27</b>	<b>0.26</b>
<b>C.D. (0.05)</b>	<b>0.26</b>	<b>0.88</b>	<b>1.19</b>

## **Maturity stage**

The leaf dry weight varied significantly between the genotypes. Significantly higher leaf dry weight (3.68 g) was recorded in genotype Suvarna as compared to K-432 (1.43 g).

The leaf dry weight differed significantly due to sowing dates. Sowing during June first fortnight recorded significantly the highest leaf dry weight (3.26 g) as compared to rest of the sowing dates. However, lowest (2.26 g) leaf dry weight was noticed in August second fortnight sowing.

Leaf dry weight was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher leaf dry weight (5.05 g) in July first fortnight sowing which was significantly superior over itself with rest of sowing dates and with K-432 in same or different sowing dates. The lowest leaf dry weight (1.35 g) was recorded by K-432 in the very late sowing i.e. August second fortnight.

## **8. Stem dry weight per plant (g)**

The data on stem dry weight per plant as influenced by genotypes, sowing dates and their interaction effects at vegetative stage, panicle stage and maturity stage are presented in Table 8.

### **Vegetative stage**

The stem dry weight per plant varied significantly between the genotypes. The genotype Suvarna recorded significantly higher stem dry weight (1.69 g) as compared to K-432 (0.84 g).

The stem dry weight varied significantly due to sowing dates. Significantly higher stem dry weight per plant (1.52 g) was obtained in July first fortnight sowing which was on par with June second fortnight sowing (1.41 g).

While, the lowest (0.98 g) stem weight was recorded in August second fortnight sowing.

Stem dry weight per plant was significantly influenced by the interaction effect of genotypes and sowing dates. Suvarna recorded significantly higher stem dry weight (2.13 g) in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but on par with itself in June second fortnight sowing (1.92 g). The lowest stem dry weight (0.75 g) was recorded by K-432 in the August second fortnight sowing.

### **Panicle stage**

The stem dry weight varied significantly between the genotypes. Significantly higher stem dry weight was recorded in Suvarna (7.34 g) as compared to K-432 (1.44 g).

The stem dry weight differed significantly due to sowing dates. Sowing of grain amaranth during July first fortnight recorded significantly higher stem dry weight (5.80 g) as compared to other sowing dates. However, lowest stem dry weight (3.29) was noticed in August second fortnight sowing.

The interaction effect of genotypes and sowing dates significantly influenced stem dry weight. The genotype Suvarna recorded significantly higher stem dry weight (10.05 g) in July first fortnight sowing which was significantly superior over itself with other sowing dates and with K-432 in same or different sowing dates. The lowest stem dry weight (1.29 g) was found in K-432 in the August second fortnight sowing. In general there was gradual decline in stem dry weight with delay in sowing.

### **Maturity stage**

The stem dry weight varied significantly between the genotypes. Significantly higher stem dry weight was recorded in the genotype Suvarna (11.14 g) as compared to K-432 (1.86 g).

**Table 8 : Stem dry weight per plant of grain amaranth genotypes as influenced by sowing dates**

Treatments	Stem dry weight /plant (g)		
	Vegetative stage	Panicle stage	Maturity stage
<b>Genotypes</b>			
Suvarna (G <sub>1</sub> )	1.69	7.34	11.14
K-432 (G <sub>2</sub> )	0.84	1.44	1.86
<b>SEm±</b>	<b>0.02</b>	<b>0.12</b>	<b>0.19</b>
<b>C.D. (0.05)</b>	<b>0.14</b>	<b>0.73</b>	<b>1.19</b>
<b>Sowing dates</b>			
June second fortnight (D <sub>1</sub> )	1.41	4.40	6.88
July first fortnight (D <sub>2</sub> )	1.52	5.80	7.76
July second fortnight (D <sub>3</sub> )	1.11	4.20	6.50
August first fortnight (D <sub>4</sub> )	1.29	4.24	6.38
August second fortnight (D <sub>5</sub> )	0.98	3.29	5.01
<b>SEm±</b>	<b>0.06</b>	<b>0.42</b>	<b>0.25</b>
<b>C.D. (0.05)</b>	<b>0.18</b>	<b>1.27</b>	<b>0.76</b>
<b>Interaction</b>			
G <sub>1</sub> D <sub>1</sub>	1.92	7.25	11.69
G <sub>1</sub> D <sub>2</sub>	2.13	10.05	13.58
G <sub>1</sub> D <sub>3</sub>	1.41	7.08	11.27
G <sub>1</sub> D <sub>4</sub>	1.77	7.01	10.81
G <sub>1</sub> D <sub>5</sub>	1.23	5.30	8.38
G <sub>2</sub> D <sub>1</sub>	0.91	1.56	2.07
G <sub>2</sub> D <sub>2</sub>	0.91	1.55	1.94
G <sub>2</sub> D <sub>3</sub>	0.81	1.31	1.73
G <sub>2</sub> D <sub>4</sub>	0.82	1.48	1.94
G <sub>2</sub> D <sub>5</sub>	0.75	1.29	1.64
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.08</b>	<b>0.59</b>	<b>0.36</b>
<b>C.D. (0.05)</b>	<b>0.25</b>	<b>1.79</b>	<b>1.08</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.08</b>	<b>0.55</b>	<b>0.38</b>
<b>C.D. (0.05)</b>	<b>0.25</b>	<b>1.72</b>	<b>1.44</b>

The stem dry weight significantly influenced by dates of sowing. Significantly higher stem dry weight was noticed in July first fortnight sowing (7.76 g). While, significantly lowest stem weight (5.01 g) was recorded in August second fortnight sowing.

Stem dry weight was significantly influenced by the interaction effect of genotypes and sowing dates. The genotype Suvarna recorded significantly higher stem dry weight in July first fortnight sowing (13.58 g), which was significantly superior over itself with rest of the sowing dates and with K-432 in same or different sowing dates. The lowest stem dry weight (1.64 g) was recorded by K-432 in the last (August second fortnight) sowing date.

#### **9. Panicle dry weight per plant (g)**

The data on panicle dry weight per plant at panicle stage and maturity stage as influenced by genotypes, sowing dates and their interaction are presented in Table 9.

##### **Panicle stage**

Panicle dry weight per plant differed significantly between the genotypes. Significantly higher panicle dry weight was recorded in Suvarna (7.37 g) as compared to K-432 (3.6 g).

The panicle dry weight varied significantly due to sowing dates. Among sowing dates, significantly higher panicle dry weight (6.77 g) was recorded in July first fortnight sowing compared to rest of the sowing dates except June second fortnight sowing (6.15 g). Sowing during August second fortnight recorded significantly lowest panicle dry weight (3.75 g). Sowing during June second, July second and August first fortnight did not differ significantly in panicle dry weight.

Panicle dry weight was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly

higher panicle dry weight (9.77 g) in July first fortnight sowing, which<sup>19</sup> was significantly superior over K-432 in same or different sowing dates, but it was found to be on par with only itself in June second fortnight sowing (8.1 g). The lowest panicle dry weight was recorded in very late sowing of K-432 during August second fortnight sowing (3.12 g).

### **Maturity stage**

Significant difference with respect to Panicle dry weight per plant was recorded in genotypes. Significantly higher panicle dry weight produced in Suvarna (15.61 g) as compared to K-432 (6.14 g).

The panicle dry weight per plant differed significantly due to sowing dates. Among sowing dates, sowing of grain amaranth during July first fortnight recorded significantly higher panicle dry weight (14.16 g) compared to other sowing dates, except June second fortnight sown crop (13.46 g). Significantly lowest panicle dry weight (6.57 g) was recorded in August second fortnight sowing. Intermediate panicle dry weight (10.45–9.75g) was recorded in July second and August first fortnight, which however did not differ from each other.

The genotypes and the dates of sowing significantly interacted. The genotype Suvarna recorded significantly higher panicle dry weight (21.6 g) in July first fortnight sowing, which was superior over K-432 in same or different sowing dates, but it was on par with itself in June first fortnight sowing (19.88 g). The lowest panicle dry weight (4.68 g) was recorded by K-432 in the August second fortnight sowing. In general, there was decreasing trend in panicle dry matter production with each successive fortnight delayed sowing, except in August second fortnight sowing of K-432. In general there was gradual decline in panicle dry weight with delay in sowing.

**Table 9 : Panicle dry weight per plant of grain amaranth genotypes as influenced by sowing dates**

Treatments	Panicle dry weight /plant (g)	
	Panicle stage	Maturity stage
<b>Genotypes</b>		
Suvarna (G <sub>1</sub> )	7.37	15.61
K-432 (G <sub>2</sub> )	3.60	6.14
<b>SEm±</b>	<b>0.29</b>	<b>0.16</b>
<b>C.D. (0.05)</b>	<b>1.79</b>	<b>0.95</b>
<b>Sowing dates</b>		
June second fortnight (D <sub>1</sub> )	6.15	13.46
July first fortnight (D <sub>2</sub> )	6.77	14.16
July second fortnight (D <sub>3</sub> )	5.43	10.45
August first fortnight (D <sub>4</sub> )	5.31	9.75
August second fortnight (D <sub>5</sub> )	3.75	6.57
<b>SEm±</b>	<b>0.34</b>	<b>0.46</b>
<b>C.D. (0.05)</b>	<b>1.02</b>	<b>1.39</b>
<b>Interaction</b>		
G <sub>1</sub> D <sub>1</sub>	8.10	19.88
G <sub>1</sub> D <sub>2</sub>	9.77	21.60
G <sub>1</sub> D <sub>3</sub>	7.70	14.92
G <sub>1</sub> D <sub>4</sub>	6.89	13.19
G <sub>1</sub> D <sub>5</sub>	4.38	8.46
G <sub>2</sub> D <sub>1</sub>	4.21	7.03
G <sub>2</sub> D <sub>2</sub>	3.77	6.71
G <sub>2</sub> D <sub>3</sub>	3.15	5.98
G <sub>2</sub> D <sub>4</sub>	3.74	6.31
G <sub>2</sub> D <sub>5</sub>	3.12	4.68
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.48</b>	<b>0.65</b>
<b>C.D. (0.05)</b>	<b>1.44</b>	<b>1.96</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.52</b>	<b>0.60</b>
<b>C.D. (0.05)</b>	<b>2.08</b>	<b>1.94</b>

## 10. Total Dry Matter Production (TDMP) per plant (g)

The data on total dry matter production per plant at vegetative stage, panicle stage and maturity stage as influenced by genotypes, sowing dates and their interaction are presented in Table 10.

### Vegetative stage

Significant difference with respect to TDMP per plant between the genotypes was noticed. Significantly higher TDMP was recorded in Suvarna (3.04g) as compared to K-432 (1.47 g).

TDMP per plant differed significantly due to sowing dates. Significantly higher TDMP was noticed in July first fortnight sowing (2.70 g), which was on par with the June second fortnight sowing (2.56 g). Significantly lowest panicle dry weight (1.71 g) was noticed with August second fortnight sowing.

The genotypes and dates of sowing significantly interacted. The genotype Suvarna recorded significantly higher TDMP of 3.85g at July first fortnight sowing which was significantly superior over with itself in other sowing dates and with K-432 in same or different sowing dates. The lowest TDMP was recorded by K-432 in the very late sowing during August second fortnight (1.32 g).

### Panicle stage

Total dry matter production per plant varied significantly between the genotypes. Significantly higher TDMP was recorded in Suvarna (19.69 g) as compared to K-432 (6.52 g).

The TDMP varied significantly due to sowing dates. Significantly higher TDMP was recorded in July first fortnight sowing (16.33 g). Significantly lowest TDMP (9.33 g) was recorded in August second fortnight sowing. Sowing of

grain amaranth during June second, July second and August first fortnight did not differ significantly in TDMP.

TDMP was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher TDMP (25.8 g) which was significantly superior over itself in other dates of sowing and with K-432 in same or different sowing dates. The minimum panicle dry weight was recorded in very late sowing of K-432 during August second fortnight (5.78 g).

### **Maturity stage**

Total dry matter production per plant varied significantly between the genotypes. Significantly higher TDMP was recorded in Suvarna (30.43 g) as compared to K-432 (9.43 g).

TDMP per plant varied significantly with respect to sowing dates. Sowing of grain amaranth during July first fortnight recorded significantly higher TDMP (25.18 g) as compared to the rest of the sowing dates. Significantly the lowest TDMP (13.85 g) was recorded in August second fortnight sowing. Intermediate TDMP was noticed in July second and August first fortnight sowing, which did not differ from each other (19.31–18.48 g).

The genotypes and the dates of sowing significantly interacted; the genotype Suvarna produced significantly higher TDMP (40.23 g) in July first fortnight sowing, which was significantly superior over itself with rest of the sowing dates and with K-432 in same or different sowing dates. The minimum panicle dry weight was recorded in very late sowing of K-432 during August second fortnight (7.68 g). In general delay in sowing decreased TDMP of grain amaranthus in both the genotypes.

**Table 10 : Total dry matter production per plant of grain amaranth genotypes as influenced by sowing dates**

Treatments	Total dry matter production per plant (g)		
	Vegetative stage	Panicle stage	Maturity stage
<b>Genotypes</b>			
Suvarna (G <sub>1</sub> )	3.04	19.69	30.43
K-432 (G <sub>2</sub> )	1.47	6.52	9.43
<b>SEm±</b>	<b>0.03</b>	<b>0.34</b>	<b>0.15</b>
<b>C.D. (0.05)</b>	<b>0.20</b>	<b>2.05</b>	<b>0.90</b>
<b>Sowing dates</b>			
June second fortnight (D <sub>1</sub> )	2.56	14.27	22.86
July first fortnight (D <sub>2</sub> )	2.70	16.33	25.18
July second fortnight (D <sub>3</sub> )	1.90	12.95	19.31
August first fortnight (D <sub>4</sub> )	2.37	12.64	18.48
August second fortnight (D <sub>5</sub> )	1.71	9.33	13.85
<b>SEm±</b>	<b>0.05</b>	<b>0.57</b>	<b>0.70</b>
<b>C.D. (0.05)</b>	<b>0.14</b>	<b>1.72</b>	<b>2.09</b>
<b>Interaction</b>			
G <sub>1</sub> D <sub>1</sub>	3.51	21.19	35.08
G <sub>1</sub> D <sub>2</sub>	3.85	25.80	40.23
G <sub>1</sub> D <sub>3</sub>	2.42	20.01	29.57
G <sub>1</sub> D <sub>4</sub>	3.30	18.56	27.27
G <sub>1</sub> D <sub>5</sub>	2.10	12.89	20.01
G <sub>2</sub> D <sub>1</sub>	1.62	7.35	10.64
G <sub>2</sub> D <sub>2</sub>	1.56	6.85	10.11
G <sub>2</sub> D <sub>3</sub>	1.39	5.89	9.05
G <sub>2</sub> D <sub>4</sub>	1.45	6.73	9.69
G <sub>2</sub> D <sub>5</sub>	1.32	5.78	7.68
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.09</b>	<b>0.81</b>	<b>0.98</b>
<b>C.D. (0.05)</b>	<b>0.27</b>	<b>2.43</b>	<b>2.95</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.09</b>	<b>0.80</b>	<b>0.89</b>
<b>C.D. (0.05)</b>	<b>0.27</b>	<b>2.80</b>	<b>2.75</b>

## 11. Leaf area per plant (cm<sup>2</sup>)

The data on leaf area per plant as influenced by genotypes, sowing dates and their interaction at vegetative stage, panicle state and maturity stage are presented in Table 11.

### Vegetative stage

The leaf area differed significantly between the genotypes. The genotype Suvarna recorded significantly higher leaf area (291.0 cm<sup>2</sup>) as compared to K-432 (152.1 cm<sup>2</sup>).

Sowing date significantly influenced on leaf area per plant. Sowing of grain amaranth during July first fortnight recorded significantly higher leaf area (259.9 cm<sup>2</sup>) which was on par with August first and June second fortnight sowings (246.5–255.5 cm<sup>2</sup>). However, significantly lowest leaf area (165.1 cm<sup>2</sup>) was noticed in August second fortnight sowing.

Leaf area per plant was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher (364.4 cm<sup>2</sup>) leaf area in July second fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but it was on par with itself in June second and August first fortnight sowings (345.0 – 339.4 cm). The lowest leaf area (140.5 cm<sup>2</sup>) was recorded by K-432 in the August second fortnight sowing.

### Panicle stage

Significant differences between the genotypes with respect to leaf area per plant. Significantly higher leaf area was recorded in Suvarna (1075.9 cm<sup>2</sup>) as compared to K-432 (306.3 cm<sup>2</sup>).

The leaf area differed significantly due to sowing dates. Sowing of grain amaranth during July first fortnight recorded maximum leaf area (792.5 cm<sup>2</sup>)

which was on par with all other sowing dates (775.4–660.7 cm<sup>2</sup>) except sowing during August second fortnight (473.8 cm<sup>2</sup>).

The interaction effect due to genotypes and sowing dates found significant with respect to leaf area. The genotype Suvarna recorded significantly higher leaf area (1268.6 cm<sup>2</sup>) in July first fortnight sowing, which was significantly superior over K-432 in same or different sowing dates, but on par with itself in June second (1220.5 cm<sup>2</sup>) and July second fortnight sowings (1200.7 cm<sup>2</sup>). The lowest leaf area (264.7 cm<sup>2</sup>) was recorded in very late sowing of K-432 during August second fortnight sowing.

### **Maturity stage**

The leaf area per plant differed significantly between the genotypes. Significantly higher leaf area was recorded in Suvarna (785.6 cm<sup>2</sup>) as compared to K-432 (279.9 cm<sup>2</sup>).

Leaf area per plant differed significantly due to sowing dates. Significantly higher leaf area (660.8 cm<sup>2</sup>) was noticed in July first fortnight sowing as compared to rest of the sowing dates. However, significantly lowest leaf area (461.2 cm<sup>2</sup>) was recorded in very late sowing, during August second fortnight.

The interaction effects due to genotypes and sowing dates found significant difference on leaf area. The genotype Suvarna recorded significantly higher leaf area (1035.6 cm<sup>2</sup>) in July first fortnight sowing which was significantly superior over itself in rest of the sowing dates and with K-432 in same or different sowing dates. The minimum leaf area per plant was recorded in very late sowing of K-432 during August second fortnight (251.5 cm<sup>2</sup>).

Table 11 : Leaf area per plant of grain amaranth genotypes as influenced by sowing dates

Treatments	Leaf area/plant (cm <sup>2</sup> )		
	Vegetative stage	Panicle stage	Maturity stage
<b>Genotypes</b>			
Suvarna (G <sub>1</sub> )	291.00	1075.90	785.60
K-432 (G <sub>2</sub> )	152.10	306.30	279.90
<b>SEm±</b>	<b>7.23</b>	<b>21.47</b>	<b>17.60</b>
<b>C.D. (0.05)</b>	<b>44.02</b>	<b>130.63</b>	<b>107.11</b>
<b>Sowing dates</b>			
June second fortnight (D <sub>1</sub> )	255.50	775.40	536.60
July first fortnight (D <sub>2</sub> )	259.90	792.50	660.80
July second fortnight (D <sub>3</sub> )	180.80	753.70	498.60
August first fortnight (D <sub>4</sub> )	246.50	660.70	506.60
August second fortnight (D <sub>5</sub> )	165.10	473.80	461.20
<b>SEm±</b>	<b>8.17</b>	<b>52.51</b>	<b>39.80</b>
<b>C.D. (0.05)</b>	<b>24.50</b>	<b>157.44</b>	<b>119.30</b>
<b>Interaction</b>			
G <sub>1</sub> D <sub>1</sub>	345.00	1220.50	754.80
G <sub>1</sub> D <sub>2</sub>	364.40	1268.60	1035.60
G <sub>1</sub> D <sub>3</sub>	216.40	1200.70	744.30
G <sub>1</sub> D <sub>4</sub>	339.40	1006.70	722.50
G <sub>1</sub> D <sub>5</sub>	189.80	682.90	670.90
G <sub>2</sub> D <sub>1</sub>	165.90	330.30	318.40
G <sub>2</sub> D <sub>2</sub>	155.40	316.40	286.10
G <sub>2</sub> D <sub>3</sub>	145.20	306.60	252.90
G <sub>2</sub> D <sub>4</sub>	153.60	314.60	290.80
G <sub>2</sub> D <sub>5</sub>	140.50	264.70	251.50
<b>SEm± for 'D' at same level of 'G'</b>	<b>11.55</b>	<b>74.27</b>	<b>56.26</b>
<b>C.D. (0.05)</b>	<b>34.64</b>	<b>222.66</b>	<b>168.67</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>12.61</b>	<b>74.27</b>	<b>53.30</b>
<b>C.D. (0.05)</b>	<b>50.62</b>	<b>222.70</b>	<b>177.80</b>

## 12. Leaf Area Index (LAI)

The data pertaining to LAI as influenced by genotypes, sowing dates and their interaction at vegetative stage, panicle stage and maturity stage are presented in Table 12.

### Vegetative stage

The LAI per plant differed significantly between the genotypes. Significantly higher LAI was recorded in Suvarna (0.431) as compared to K-432 (0.225).

The LAI significantly influenced by the sowing dates. Significantly higher LAI (0.385) was recorded when crop sown during July first fortnight which was on par with the June second (0.378) and August first fortnight sowing (0.365). While, significantly the lowest LAI (0.245) was recorded in very late (August second fortnight) sowing.

LAI was significantly influenced the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher LAI (0.540) in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but on par with itself in June second (0.511) and August first fortnight (0.502) sowing. The lowest LAI (0.208) was recorded in very late sowing of K-432, during August second fortnight sowing.

### Panicle stage

The LAI per plant differed significantly between the genotypes. Significantly higher LAI was recorded in Suvarna (1.593) as compared to K-432 (0.454).

The LAI varied significantly due to sowing dates. Maximum LAI of 1.174 was noticed in July first fortnight sowing, which was on par with other sowing dates (1.148-0.979) except August second fortnight (0.702)

**Table 12 : Leaf area index (LAI) of grain amaranth genotypes as influenced by sowing dates**

Treatments	LAI		
	Vegetative stage	Panicle stage	Maturity stage
<b>Genotypes</b>			
Suvarna (G <sub>1</sub> )	0.431	1.593	1.164
K-432 (G <sub>2</sub> )	0.225	0.454	0.415
<b>SEm±</b>	<b>0.011</b>	<b>0.032</b>	<b>0.026</b>
<b>C.D. (0.05)</b>	<b>0.065</b>	<b>0.193</b>	<b>0.159</b>
<b>Sowing dates</b>			
June second fortnight (D <sub>1</sub> )	0.378	1.148	0.795
July first fortnight (D <sub>2</sub> )	0.385	1.174	0.979
July second fortnight (D <sub>3</sub> )	0.268	1.117	0.739
August first fortnight (D <sub>4</sub> )	0.365	0.979	0.751
August second fortnight (D <sub>5</sub> )	0.245	0.702	0.683
<b>SEm±</b>	<b>0.012</b>	<b>0.078</b>	<b>0.059</b>
<b>C.D. (0.05)</b>	<b>0.036</b>	<b>0.233</b>	<b>0.176</b>
<b>Interaction</b>			
G <sub>1</sub> D <sub>1</sub>	0.511	1.807	1.118
G <sub>1</sub> D <sub>2</sub>	0.540	1.879	1.534
G <sub>1</sub> D <sub>3</sub>	0.320	1.779	1.103
G <sub>1</sub> D <sub>4</sub>	0.502	1.491	1.070
G <sub>1</sub> D <sub>5</sub>	0.281	1.012	0.994
G <sub>2</sub> D <sub>1</sub>	0.246	0.489	0.472
G <sub>2</sub> D <sub>2</sub>	0.230	0.469	0.424
G <sub>2</sub> D <sub>3</sub>	0.215	0.454	0.374
G <sub>2</sub> D <sub>4</sub>	0.227	0.466	0.431
G <sub>2</sub> D <sub>5</sub>	0.208	0.392	0.373
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.017</b>	<b>0.110</b>	<b>0.083</b>
<b>C.D. (0.05)</b>	<b>0.051</b>	<b>0.329</b>	<b>NS</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.019</b>	<b>0.103</b>	<b>0.079</b>
<b>C.D. (0.05)</b>	<b>0.075</b>	<b>0.340</b>	<b>NS</b>

LAI was significantly influenced the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher LAI (1.879) in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but on par with only itself in June second (1.807) and July second (1.779) sowing. The minimum LAI (0.392) was recorded in very late sowing of K-432, during August second fortnight sowing.

### **Maturity stage**

Significant difference between the genotypes with respect to LAI was recorded. Maximum LAI was noticed in Suvarna (1.164) as compared to K-432 (0.415).

The LAI differed significantly due to sowing dates. Significantly higher LAI of 0.979 was noticed in July first fortnight sowing compared to rest of sowing dates. Significantly lowest LAI (0.683) was recorded in August second fortnight sowing.

The LAI did not differ significantly due to interaction of genotypes and sowing dates. However, higher LAI was recorded in July first fortnight sowing of Suvarna (1.534) and lowest LAI was recorded in K-432 when sown during August second fortnight (0.373).

### **13. Leaf area duration (days)**

The data on leaf area duration (LAD) of two grain amaranth genotypes as influenced by sowing dates and their interactions are presented in Table 13.

#### **Vegetative to panicle stage**

The LAD differed significantly between the genotypes. Significant higher LAD was recorded in Suvarna (24.29 days) as compared to K-432 (5.39days).

The LAD varied significantly due to sowing dates. Significantly higher LAD (17.31 days) was recorded when grain amaranth sown during July first

**Table 13 : Leaf area duration (LAD) of grain amaranth genotypes as influenced by sowing dates**

Treatments	LAD (days)	
	Vegetative to panicle stage	Panicle to maturity stage
<b>Genotypes</b>		
Suvarna (G <sub>1</sub> )	24.29	36.02
K-432 (G <sub>2</sub> )	5.39	7.61
<b>SEm±</b>	<b>0.30</b>	<b>0.13</b>
<b>C.D. (0.05)</b>	<b>1.85</b>	<b>0.76</b>
<b>Sowing dates</b>		
June second fortnight (D <sub>1</sub> )	16.85	24.07
July first fortnight (D <sub>2</sub> )	17.31	27.05
July second fortnight (D <sub>3</sub> )	15.25	22.37
August first fortnight (D <sub>4</sub> )	14.56	19.81
August second fortnight (D <sub>5</sub> )	10.15	15.78
<b>SEm±</b>	<b>0.89</b>	<b>1.53</b>
<b>C.D. (0.05)</b>	<b>2.68</b>	<b>4.60</b>
<b>Interaction</b>		
G <sub>1</sub> D <sub>1</sub>	27.82	39.49
G <sub>1</sub> D <sub>2</sub>	29.03	46.07
G <sub>1</sub> D <sub>3</sub>	25.19	37.46
G <sub>1</sub> D <sub>4</sub>	23.92	32.01
G <sub>1</sub> D <sub>5</sub>	15.51	25.06
G <sub>2</sub> D <sub>1</sub>	5.88	8.64
G <sub>2</sub> D <sub>2</sub>	5.59	8.03
G <sub>2</sub> D <sub>3</sub>	5.31	7.29
G <sub>2</sub> D <sub>4</sub>	5.19	7.62
G <sub>2</sub> D <sub>5</sub>	4.80	6.49
<b>SEm± for 'D' at same level of 'G'</b>	<b>1.26</b>	<b>2.17</b>
<b>C.D. (0.05)</b>	<b>3.78</b>	<b>6.51</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>1.17</b>	<b>2.75</b>
<b>C.D. (0.05)</b>	<b>3.75</b>	<b>5.86</b>

fortnight which was on par with June second (16.85 days) and July second (15.25 days) fortnight sowing dates. However, significantly the lowest LAD (10.15 days) was recorded in August second fortnight.

The interaction effects of genotypes and sowing dates significantly influenced LAD. The genotype Suvarna recorded significantly higher LAD (29.03 days) in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates, but on par with itself in June second fortnight sowing (27.82 days). The lowest (6.51 days) LAD was recorded by K-432 in the August second fortnight sowing.

#### **Panicle to maturity stage**

Significant difference between the genotypes with respect to LAD. The genotype Suvarna recorded significantly higher LAD (36.02 days) as compared to K-432 (7.61 days).

The LAD varied significantly due to sowing dates. Significantly higher LAD of 27.05 days was noticed in July first fortnight sowing which was on par with the June second fortnight sowing (24.07 days). However, significantly the lowest (15.78 days) LAD was recorded in August second fortnight sowing.

The genotype and the date of sowing significantly interacted; the genotype Suvarna recorded significantly higher (46.07 days) LAD in July first fortnight sowing which was significantly superior over K-432 in same or different sowing dates. The lowest LAD (6.49 days) was recorded by K-432 in the August second fortnight sowing.

#### **14. Absolute growth rate (g/plant/day)**

The data on absolute growth rate (AGR) of two grain amaranth genotypes between the different growth stages as influenced by sowing dates are presented in Table 14.

### **Vegetative to panicle stage**

AGR differed significantly between the genotypes. Significantly higher AGR was recorded in Suvarna (0.694 g/plant/day) as compared to K-432 (0.320 g/plant/day).

The AGR differed significantly due to sowing dates. Among sowing dates, maximum AGR (0.623 g/plant/day) was recorded in July first fortnight sowing as compared to rest of the sowing dates. Sowing during August second fortnight recorded significantly lowest AGR (0.363 g/plant/day). Intermediate AGR was noticed in June second, July second and August first fortnight sowings (0.548–0.494 g/plant/day), which however did not differ from each other.

AGR was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher AGR (0.914 g/plant/day) in July first fortnight sowing, which was significantly superior over with itself in rest of the sowing dates and with K-432 in same or different sowing dates. The lowest AGR (0.279 g/plant/day) was recorded by K-432 in the August second fortnight sowing.

### **Panicle to maturity stage**

The AGR varied significantly between the genotypes. Significantly higher AGR was recorded in Suvarna (0.410 g/plant/day) as compared to K-432 (0.165 g/plant/day).

Sowing dates significantly influenced on AGR. Significantly higher AGR (0.357 g/plant/day) was recorded in July first fortnight sowing, which was on par with the June second fortnight sowing (0.349 g/plant/day). Significantly the lowest AGR (0.199 g/plant/day) was recorded in August second fortnight sowing. Sowing during July second and August first fortnight recorded intermediate AGR (0.272–0.261 g/plant/day) which did not differ from each other.

**Table 14 : Absolute growth rate (AGR) of grain amaranth genotypes as influenced by sowing dates**

Treatments	AGR (g/plant/day)	
	Vegetative to panicle stage	Panicle to maturity stage
<b>Genotypes</b>		
Suvarna (G <sub>1</sub> )	0.694	0.410
K-432 (G <sub>2</sub> )	0.320	0.165
<b>SEm±</b>	<b>0.015</b>	<b>0.007</b>
<b>C.D. (0.05)</b>	<b>0.093</b>	<b>0.045</b>
<b>Sowing dates</b>		
June second fortnight (D <sub>1</sub> )	0.548	0.349
July first fortnight (D <sub>2</sub> )	0.623	0.357
July second fortnight (D <sub>3</sub> )	0.507	0.272
August first fortnight (D <sub>4</sub> )	0.494	0.261
August second fortnight (D <sub>5</sub> )	0.363	0.199
<b>SEm±</b>	<b>0.025</b>	<b>0.025</b>
<b>C.D. (0.05)</b>	<b>0.075</b>	<b>0.076</b>
<b>Interaction</b>		
G <sub>1</sub> D <sub>1</sub>	0.737	0.515
G <sub>1</sub> D <sub>2</sub>	0.914	0.534
G <sub>1</sub> D <sub>3</sub>	0.733	0.368
G <sub>1</sub> D <sub>4</sub>	0.636	0.349
G <sub>1</sub> D <sub>5</sub>	0.448	0.285
G <sub>2</sub> D <sub>1</sub>	0.358	0.182
G <sub>2</sub> D <sub>2</sub>	0.331	0.181
G <sub>2</sub> D <sub>3</sub>	0.281	0.176
G <sub>2</sub> D <sub>4</sub>	0.253	0.174
G <sub>2</sub> D <sub>5</sub>	0.279	0.112
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.035</b>	<b>0.036</b>
<b>C.D. (0.05)</b>	<b>0.106</b>	<b>0.107</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.035</b>	<b>0.033</b>
<b>C.D. (0.05)</b>	<b>0.126</b>	<b>0.103</b>

The AGR was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher AGR (0.534 g/plant/day) in July first fortnight sowing, which was significantly superior over K-432 in same or different sowing dates, but on par with itself in June second fortnight sowing (0.515g/plant/day). The lowest AGR (0.112g/plant/day) was recorded by K-432 in the August second fortnight sowing.

### **15. Net Assimilation Rate (g/dm<sup>2</sup>/day)**

The data on net assimilation rate (NAR) of two grain amaranth genotypes between the different growth stages as influenced by sowing dates are presented in Table 15.

#### **Vegetative to panicle stage**

NAR differed significantly between the genotypes. Significantly higher NAR was recorded in K-432 (0.145 g/dm<sup>2</sup>/day) as compared to Suvarna (0.117 g/dm<sup>2</sup>/day).

The NAR did not showed significant difference due to sowing dates. However, the highest NAR was obtained with the sowing during July first fortnight (0.136 g/dm<sup>2</sup>/day) and the lowest NAR was recorded in the June second fortnight sowing (0.128 g/dm<sup>2</sup>/day).

The NAR did not differ significantly due to interaction effect of genotypes and sowing dates.

#### **Panicle to maturity stage**

NAR did not differ significantly due to genotypes. However, maximum NAR was obtained with the genotype K-432 (0.056 g/dm<sup>2</sup>/day) as compared to Suvarna (0.044 g/dm<sup>2</sup>/day).

**Table 15 : Net assimilation rate (NAR) of grain amaranth genotypes as influenced by sowing dates**

Treatments	NAR (g/dm <sup>2</sup> /day)	
	Vegetative to panicle stage	Panicle to maturity stage
<b>Genotypes</b>		
Suvarna (G <sub>1</sub> )	0.117	0.044
K-432 (G <sub>2</sub> )	0.145	0.056
SEm±	<b>0.003</b>	<b>0.003</b>
C.D. (0.05)	<b>0.017</b>	NS
<b>Sowing dates</b>		
June second fortnight (D <sub>1</sub> )	0.128	0.055
July first fortnight (D <sub>2</sub> )	0.136	0.054
July second fortnight (D <sub>3</sub> )	0.130	0.051
August first fortnight (D <sub>4</sub> )	0.130	0.049
August second fortnight (D <sub>5</sub> )	0.131	0.044
SEm±	<b>0.007</b>	<b>0.005</b>
C.D. (0.05)	NS	NS
<b>Interaction</b>		
SEm± for 'D' at same level of 'G'	<b>0.010</b>	<b>0.080</b>
C.D. (0.05)	NS	NS
SEm± for 'G' at same/diff. level of 'D'	<b>0.010</b>	<b>0.080</b>
C.D. (0.05)	NS	NS

NAR did not differ significantly due to sowing dates. However, higher NAR was recorded in June second fortnight sowing ( $0.055 \text{ g/dm}^2/\text{day}$ ) and the lowest NAR was recorded in August second fortnight sowing ( $0.044 \text{ g/dm}^2/\text{day}$ ).

The NAR did not differ significantly due to interaction effect of genotypes and sowing dates.

#### **16. Crop growth rate ( $\text{g/dm}^2/\text{day}$ )**

The data on crop growth rate (CGR) of two grain amaranth genotypes between the different growth stages as influenced by sowing dates are presented in Table 16.

##### **Vegetative to panicle stage**

CGR differed significantly between the genotypes. Significantly higher CGR was recorded in Suvarna ( $0.117 \text{ g/dm}^2/\text{day}$ ) as compared to K-432 ( $0.049 \text{ g/dm}^2/\text{day}$ ).

The CGR varied significantly due to different sowing dates. Among sowing dates, July first fortnight sowing recorded significantly higher CGR ( $0.102 \text{ g/dm}^2/\text{day}$ ), which was on par with the June second fortnight sowing ( $0.090 \text{ g/dm}^2/\text{day}$ ). However, significantly the lowest CGR recorded in August second fortnight sowing ( $0.059 \text{ g/dm}^2/\text{day}$ ).

CGR was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher CGR ( $0.152 \text{ g/dm}^2/\text{day}$ ) in July first fortnight sowing, which was significantly superior over K-432 in same or different sowing dates, but on par with itself in July second fortnight sowing ( $0.133 \text{ g/dm}^2/\text{day}$ ). The lowest CGR ( $0.043 \text{ g/dm}^2/\text{day}$ ) was recorded by K-432 in the August second fortnight sowing.

**Table 16 : Crop growth rate (CGR) of grain amaranth genotypes as influenced by sowing dates**

Treatments	CGR (g/dm <sup>2</sup> /day)	
	Vegetative to panicle stage	Panicle to maturity stage
<b>Genotypes</b>		
Suvarna (G <sub>1</sub> )	0.117	0.061
K-432 (G <sub>2</sub> )	0.049	0.023
<b>SEm±</b>	<b>0.002</b>	<b>0.001</b>
<b>C.D. (0.05)</b>	<b>0.014</b>	<b>0.009</b>
<b>Sowing dates</b>		
June second fortnight (D <sub>1</sub> )	0.090	0.050
July first fortnight (D <sub>2</sub> )	0.102	0.053
July second fortnight (D <sub>3</sub> )	0.089	0.041
August first fortnight (D <sub>4</sub> )	0.078	0.039
August second fortnight (D <sub>5</sub> )	0.059	0.029
<b>SEm±</b>	<b>0.005</b>	<b>0.006</b>
<b>C.D. (0.05)</b>	<b>0.015</b>	<b>0.019</b>
<b>Interaction</b>		
G <sub>1</sub> D <sub>1</sub>	0.124	0.078
G <sub>1</sub> D <sub>2</sub>	0.152	0.079
G <sub>1</sub> D <sub>3</sub>	0.133	0.056
G <sub>1</sub> D <sub>4</sub>	0.103	0.052
G <sub>1</sub> D <sub>5</sub>	0.076	0.042
G <sub>2</sub> D <sub>1</sub>	0.056	0.022
G <sub>2</sub> D <sub>2</sub>	0.051	0.027
G <sub>2</sub> D <sub>3</sub>	0.044	0.026
G <sub>2</sub> D <sub>4</sub>	0.054	0.025
G <sub>2</sub> D <sub>5</sub>	0.043	0.016
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.007</b>	<b>0.006</b>
<b>C.D. (0.05)</b>	<b>0.022</b>	<b>NS</b>
<b>SEm± for 'G' at same/diff.level of 'D'</b>	<b>0.007</b>	<b>0.006</b>
<b>C.D. (0.05)</b>	<b>0.230</b>	<b>NS</b>

### **Panicle to maturity stage**

CGR differed significantly between the genotypes. Significantly higher CGR was recorded in Suvarna (0.061 g/dm<sup>2</sup>/day) as compared to K-432 (0.023 g/dm<sup>2</sup>/day).

The CGR varied significantly due to sowing dates. Maximum CGR (0.053 g/dm<sup>2</sup>/day) was recorded in July first fortnight sowing, which was on par with rest of the sowing dates (0.050–0.039 g/dm<sup>2</sup>/day) except August second fortnight which recorded the lowest CGR (0.029 g/dm<sup>2</sup>/day).

The CGR did not showed significant difference due to interaction of genotypes and sowing dates. However, the genotype Suvarna recorded the highest CGR (0.079 g/dm<sup>2</sup>/day) in July first fortnight sowing and lowest CGR (0.016 g/dm<sup>2</sup>/day) was noticed in K-432 when sown during August second fortnight.

### **17. Test weight of grains (g/5ml seeds)**

The data on test weight of seeds as influenced by sowing dates of two grain amaranth genotypes is presented in Table 17.

The test weight did not differ significantly between the genotypes. However, higher test weight was recorded in K-432 (4.003g) as compared to Suvarna (3.965g).

The test weight of grain amaranth differed significantly due to sowing dates. Maximum test weight was recorded in July first fortnight sowing (4.042 g) which was on par with June second and August second fortnight sowing (4.036 and 3.982 g). The lowest test weight was recorded in August first fortnight sowing (3.909 g).

Test weight did not differ significantly due to interaction of genotypes and sowing dates. However, higher test weight was recorded in genotype K-432

when sown during June second fortnight (4.113g) and the lowest was also recorded in same genotype when sown during August second fortnight (3.887 g).

### **18. Grain yield (g/plant)**

The data on grain yield per plant as influenced by genotypes, sowing dates and their interaction is presented in Table 17.

The grain yield per plant differed significantly between the genotypes. Significantly higher grain yield per plant was obtained in Suvarna (6.96 g) as compared to K-432 (3.66 g).

The grain yield varied significantly due to sowing dates. Significantly higher grain yield (6.93 g) was recorded in July first fortnight sowing. Sowing during August second fortnight recorded significantly the lowest grain yield (3.42 g). Sowing during July second and August first fortnight recorded intermediate grain yield (5.05–4.84 g), which however did not differ from each other.

Grain yield per plant was significantly influenced by the interaction effects of genotypes and sowing dates. The genotypes Suvarna recorded significantly higher grain yield (9.8 g) in July first fortnight sowing which was significantly superior over itself with rest of sowing dates and with K-432 in same or different sowing dates. The lowest grain yield (2.78 g) was recorded by K-432 in the August second fortnight sowing. In general, there was gradual decline in grain yield with delay in sowing.

### **Grain yield (kg/ha)**

The data on grain yield per hectare as influenced by genotypes, sowing dates and their interaction is presented in Table 17.

Significant differences between genotypes with respect to grain yield. Significantly higher grain yield was obtained in Suvarna (943.8 kg/ha) as compared to K-432 (504.6 kg/ha).

The grain yield varied significantly due to sowing dates. Sowing of grain amaranth during July first fortnight gave significantly higher grain yield (937.0 kg/ha) which was on par with June second fortnight sowing (906.2 kg/ha). However, sowing during August second fortnight yielded significantly the lowest grain yield (461.5 kg/ha). Sowing during July second and August first fortnight recorded intermediate grain yield (667.5–648.8 kg/ha), which however did not differ from each other.

Grain yield was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher grain yield (1301.6 kg/ha) in July first fortnight sowing which was significantly superior over K-432 in the same or different sowing dates, but on par with itself in June second fortnight sowing (1199.3 kg/ha). The lowest grain yield (367.3 kg/ha) was obtained with K-432 in the August second fortnight sowing.

## 19. Harvest index

The data on harvest index of two grain amaranth genotypes as influenced by sowing dates is presented in Table 17.

Harvest index varied significantly between the genotypes. Significantly higher harvest index was recorded in K-432 (0.389) as compared to Suvarna (0.226).

Harvest index did not differ significantly due to sowing dates. Sowing of grain amaranth during July first fortnight recorded higher harvest index (0.323). The lowest harvest index was recorded in August second fortnight sowing (0.283).

**Table 17 : Test weight, grain yield and Harvest index of grain amaranth genotypes as influenced by sowing dates**

Treatments	Test weight (g/5ml seeds)	Grain yield (g/plant)	Grain yield (kg/ha)	Harvest index
<b>Genotypes</b>				
Suvarna (G <sub>1</sub> )	3.965	6.96	943.8	0.226
K-432 (G <sub>2</sub> )	4.003	3.67	504.6	0.389
<b>SEm±</b>	<b>0.013</b>	<b>0.121</b>	<b>18.13</b>	<b>0.007</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>0.735</b>	<b>110.36</b>	<b>0.04</b>
<b>Sowing dates</b>				
June second fortnight (D <sub>1</sub> )	4.036	6.31	906.2	0.322
July first fortnight (D <sub>2</sub> )	4.042	6.93	937.0	0.323
July second fortnight (D <sub>3</sub> )	3.952	5.05	667.5	0.309
August first fortnight (D <sub>4</sub> )	3.982	4.84	648.8	0.301
August second fortnight (D <sub>5</sub> )	3.909	3.42	461.5	0.283
<b>SEm±</b>	<b>0.030</b>	<b>0.157</b>	<b>49.55</b>	<b>0.014</b>
<b>C.D. (0.05)</b>	<b>0.089</b>	<b>0.470</b>	<b>148.55</b>	<b>NS</b>
<b>Interaction</b>				
G <sub>1</sub> D <sub>1</sub>	3.958	8.40	1199.3	0.240
G <sub>1</sub> D <sub>2</sub>	4.035	9.80	1301.6	0.244
G <sub>1</sub> D <sub>3</sub>	3.951	6.53	859.7	0.221
G <sub>1</sub> D <sub>4</sub>	3.949	6.03	802.7	0.221
G <sub>1</sub> D <sub>5</sub>	3.932	4.06	555.7	0.203
G <sub>2</sub> D <sub>1</sub>	4.113	4.29	613.0	0.403
G <sub>2</sub> D <sub>2</sub>	4.048	4.06	572.3	0.402
G <sub>2</sub> D <sub>3</sub>	3.952	3.58	475.3	0.397
G <sub>2</sub> D <sub>4</sub>	4.014	3.65	495.0	0.376
G <sub>2</sub> D <sub>5</sub>	3.887	2.78	367.3	0.363
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.042</b>	<b>0.222</b>	<b>70.07</b>	<b>0.019</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>0.665</b>	<b>210.07</b>	<b>NS</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.040</b>	<b>0.232</b>	<b>65.24</b>	<b>0.018</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>0.890</b>	<b>211.17</b>	<b>NS</b>

Harvest index did not differ significantly due to interaction of genotypes and sowing dates. However, higher harvest index was obtained with the July first fortnight sowing of K-432 (0.403) and lowest harvest index was recorded in August second fortnight sowing of Suvarna (0.203).

## 20. Protein content (%)

The data on protein content (%) of grain amaranth genotypes as influenced by sowing dates is presented in Table 18.

The protein content did not differ significantly between the genotypes. More protein content was recorded in Suvarna (13.1 %) as compared to K-432 (12.2 %).

The protein content did not differ due to sowing dates. However, more protein was recorded in July first fortnight sowing (13.4 %) and the lowest protein content was recorded in August first and second fortnight sowing (12.2 %).

The protein content did not differ significantly due to interaction of genotypes and sowing dates. However, higher protein content was recorded in July first fortnight sowing of Suvarna (14.3 %) and the lowest was in August second fortnight sowing of K-432 (11.7 %).

## Protein yield (kg/ha)

The data on protein yield of grain amaranth genotypes as influenced by sowing dates is presented in Table 18.

The protein yield differed significantly between genotypes. Significantly higher protein yield was recorded in Suvarna (125.6 kg/ha) as compared to K-432 (61.7 kg/ha).

The protein yield varied significantly due to sowing dates. Significantly higher protein yield (128.9 kg/ha) was recorded in July first fortnight sowing

**Table 18 : Protein content (%) and protein yield (kg/ha) as influenced by sowing dates**

<b>Treatments</b>	<b>Protein content (%)</b>	<b>Protein yield (kg/ha)</b>
<b>Genotypes</b>		
Suvarna (G <sub>1</sub> )	13.1	125.6
K-432 (G <sub>2</sub> )	12.2	61.7
<b>SEm±</b>	<b>0.16</b>	<b>5.06</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>30.79</b>
<b>Sowing dates</b>		
June second fortnight (D <sub>1</sub> )	12.7	114.9
July first fortnight (D <sub>2</sub> )	13.4	128.9
July second fortnight (D <sub>3</sub> )	12.80	87.6
August first fortnight (D <sub>4</sub> )	12.20	80.6
August second fortnight (D <sub>5</sub> )	12.20	56.3
<b>SEm±</b>	<b>0.36</b>	<b>7.3</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>21.8</b>
<b>Interaction</b>		
G1D1	12.8	153.3
G1D2	14.3	185.7
G1D3	13.3	116.0
G1D4	12.5	102.6
G1D5	12.6	70.5
G2D1	12.5	76.6
G2D2	12.6	72.3
G2D3	12.5	59.2
G2D4	11.8	58.7
G2D5	11.7	42.1
<b>SEm± for 'D' at same level of 'G'</b>	<b>0.51</b>	<b>10.3</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>30.8</b>
<b>SEm± for 'G' at same/diff. level of 'D'</b>	<b>0.48</b>	<b>10.5</b>
<b>C.D. (0.05)</b>	<b>NS</b>	<b>39.0</b>

which was on par with June second fortnight sowing (114.9 kg/ha). Sowing during August second fortnight recorded significantly lowest protein yield (56.3 kg/ha). Sowing during July second and August first fortnight recorded intermediate protein yield (87.6–80.6 kg/ha), which, however did not differ from each other.

Protein yield was significantly influenced by the interaction effects of genotypes and sowing dates. The genotype Suvarna recorded significantly higher protein yield (185.7 kg/ha) in July first fortnight sowing, which was significantly superior over itself in other sowing dates and with K-432 in same or different sowing dates. The lowest protein yield (42.1 kg/ha) was recorded by K-432 in the August second fortnight sowing. In general, there was gradual decline in protein yield with delay in sowing.

## DISCUSSION

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## V. DISCUSSION

Crop production in broad sense is harvesting of the solar radiation in the form of chemical energy through photochemical reaction like photosynthesis. It is a basic biological principle; the quantity and quality of growth made by plants are controlled by their genetic potential and the environmental factors, through which a series of internal physiological and biochemical processes takes place. Further more, economic yield is more important than the biological yield which results from intricate combination of many physiological processes which are inturn based on environment under which crop is grown. The synthesis of internal regulatory compounds are controlled by environmental factors such as photoperiod and light. There has to be proper balance between source and sink in order to achieve higher crop productivity. To attain high crop productivity, crop has to be sown at optimum time in order to exploit growth factors efficiently, particularly light, day length, soil moisture, temperature and nutrients throughout its growth and developmental period. The crop production technology lies in the identification of suitable genotype and to develop technology to provide optimum or near optimum conditions to achieve higher crop production.

Grain amaranth (*Amaranthus hypochondriacus* L.) is mainly grown under rainfed condition. It has fairly high yielding potentiality which can be exploited by blending suitable crop production technologies.

The experimental results presented in the previous chapter provided a detailed account of the effect of sowing dates on growth and yield of grain amaranth genotypes in the eastern dry zone (Zone-5) of Karnataka state. In this chapter, attempt has been made to discuss the significant findings giving possible explanations through cause and effect relationship.

### 5.1 Effect of sowing dates

Sowing time is one of the most important crop production technologies to exploit the potentiality of a crop. If crop is sown at optimum time, it provides

optimum growth factors viz., the requirement of light, day length, temperature, soil moisture and relative humidity. These are important especially in obligatory short day plant like grain amaranth which is influenced by both temperature and day length. So any change in sowing date definitely influence the growth and development of crop and ultimately the yield.

The grain yield (Table 17) was significantly influenced by dates of sowing. The highest grain yield of 937.0 kg/ha was recorded by sowing grain amaranth in July first fortnight which was on par with the June second fortnight sowing (906.6 kg/ha). Thus, if July first fortnight is considered as ideal and normal date of sowing, the per cent reduction in grain yield was to an extent of 3.3 per cent on June second fortnight sowing, 28.7 per cent on July second fortnight sowing and 30.7 per cent in August first fortnight sowing and there was a steep fall up to 50.7 per cent in August second fortnight sowing. The highest grain yield was obtained in July first fortnight sowing, followed by June second fortnight sowing, which was mainly due to increase in yield components viz., highest harvest index (0.323 and 0.322), number of panicles (22.1 and 21.7), panicle length (15.8 and 15.7cm), panicle dry weight (14.16 and 13.46 g), grain yield per plant (6.93 and 6.31 g) and test weight (4.042 and 4.036 g), respectively. In the present investigation, the decline in grain yield with delay in sowing was mainly due to low moisture availability, though temperature and sunshine hours were not a limiting factor. Similarly, Hauptli and Jain (1980), Jamariska(1991), Joshi and Rana (1991) reported yield advantage of grain amaranth in the early sowings. Ashoka (1996) also reported higher finger millet yield in early sowing due to favourable soil moisture

Harvest index is another useful parameter to assess the translocation efficiency. Grain yield is related to biological yield through harvest index (Yoshida, 1972). The trends were similar as that of grain yield with respect to harvest index (Table 17). Highest harvest index (0.323) was recorded in July first fortnight sowing. Harvest index declined with delay in sowing and ultimately reached the lowest (0.283) in August second fortnight sowing

(Table 17), which may be attributed to greater partitioning and translocation of dry matter into economic parts. Similarly, Ashoka (1996) found that finger millet sown during second fortnight of June had greater partitioning of dry matter into economic parts. Similar results were also reported by Henderson *et al.* (1998) in grain amaranth.

Grain yield is the product of yield contributing characters. Among the yield components, the number of panicles (Table 6) was significantly higher at both panicle and maturity stage (17.5 and 22.1) respectively, in the July first fortnight sowing which was on par with the June second fortnight sowing (17.0 and 21.7). The reduction in number of panicles was more in the last sowing in August second fortnight (13.0 and 14.8). Similarly, the panicle length (Table 6) was significantly larger at both panicle and maturity stage (14.6 and 15.8 cm) respectively, in the July first fortnight sowing which was on par with the June second fortnight sowing (14.5 and 15.7 cm). Significantly smallest panicle length (12.1 and 13.3 cm) was recorded in August second fortnight sowing. Similarly, Joshi and Rana (1991) noticed the decrease in panicle length and number of panicles with delayed sowing in grain amaranth.

Significantly higher panicle dry weight of 6.77 and 14.16 g were recorded in the July first fortnight sowing at both panicle and maturity stages respectively, which was on par with the June second fortnight sowing at both panicle and maturity stage (6.15 and 13.46 g) respectively. Delayed sowing decreased the panicle dry weight to an extent of 26.2, 31.1 and 53.6 per cent in July second, August first and August second fortnight sowings respectively, at maturity stage. Similarly, Misra *et al.* (1996) recorded decreased panicle dry weight of grain amaranth with delayed sowing. Ashoka (1996) noticed 31.0 per cent decrease in single ear weight in delayed (July second fortnight) sowing of finger millet compared to June first fortnight. This decrease in panicle numbers, panicle length and panicle dry weight with delayed sowing was due to inadequate soil moisture at grain filling stage of August first and second fortnight sowings. Inadequate soil moisture coupled with gradual decline in total dry matter

production and its partitioning into sink. Delayed sowing also slightly reduced the days taken to physiological maturity due to variation in day length and bright sunshine hours.

Test weight (Table 17) differed significantly due to sowing dates. The highest test weight (4.042 g) was recorded in July first fortnight sowing which was on par with the June second and August second fortnight sowings (4.036 and 3.982 g). The lowest test weight was recorded in August second fortnight sowing (3.909 g). The difference in test weight may be due to variations in weather conditions prevailed during crop growth period, seed development and maturation. June second and July first fortnight sowings, with more favourable weather conditions registered the highest 5 ml seed weight. Joshi and Rana (1991) and Srinivasaiah (1998) also reported that the variations in 1000 seed weight due to different dates of sowing in grain amaranth.

The grain yield per plant (Table 17) was significantly higher (6.93 g) in July first fortnight sowing and it decreased to an extent of 8.9, 27.0, 30.1 and 50.6 per cent (Table 17) in June second, July second, August first and August second fortnight sowings, respectively. This was attributed to reduced number of panicles, panicle length as well as reduced translocation from source to sink in delayed sowings.

The variation in the yield and yield components may be traced back to variation in different growth characters and dry matter production. The total dry matter production per plant at harvest (Table 10) was highest (25.18 g) in July first fortnight sowing which decreased with delayed sowing to an extent of 23.3, 26.6, 44.9 per cent in July second, August first, August second fortnight sowing, respectively where as sowing during June second fortnight decreased the total dry matter up to an extent of 9.2 per cent. The decreased trend in total dry matter production was observed with delayed in sowing, which was mainly due to slight decrease in the number of days taken to physiological maturity (Table 5).

Days to physiological maturity was highest (78.5 days) in the June second fortnight sowing which was on par with July first fortnight sowing (78.2 day). Delayed sowings decreased the days to physiological maturity up to an extent of 2.2, 4.2 and 4.9 per cent in July second, August first and second fortnight sowings, respectively. This indicated that decrease in growth period due to delayed sowings resulted in lesser total dry matter production and other growth components which caused for decreased in the yield. The decreased growth period with delayed sowing was also due to greater variation in growth factors viz., light intensity, soil moisture. Similarly, Misra *et al.* (1996) recorded reduced days to physiological maturity with delayed plantings in grain amaranth. Days to 50 per cent flowering also followed the similar trend as that of days to physiological maturity.

Plant height at all the growth stages was significantly influenced due to sowing dates. Sowing during July first fortnight recorded maximum plant height of 32.6, 67.6 and 80.8 cm and the lowest plant height of 22.2, 57.0 and 62.5 cm was recorded in August second fortnight at vegetative stage, panicle stage and maturity stage, respectively. The reason for highest plant height might be due to congenial environmental conditions prevailing during the crop growth period for the plants sown on July first fortnight. Vireshwar Singh *et al.* (1991) reported that early sowing gave greater plant heights while growth was poor in late sown plants.

Higher grain yield of grain amaranth during July first fortnight might also be related to its higher number of leaves (10.1, 15.0 and 12.5 at vegetative stage, panicle stage and maturity stage, respectively) and higher leaf area (259.9, 792.5 and 660.8 cm<sup>2</sup> at vegetative stage, panicle stage and maturity stage, respectively). These results are in conformity with the findings of Joshi and Rana (1991) and Waghmode *et al.* (1998).

Superiority of grain yield during July second fortnight was also indicated by higher LAI at vegetative stage (0.385), panicle stage (1.174) and at maturity

stage (0.979). At harvest, the decreased in LAI was to an extent of 24.5, 23.3, 30.2 and 18.8 per cent in July second, August first, August second and early sowing in June second fortnight, respectively. Increased LAI and its persistence could be revealed by increased LAD at vegetative to panicle stage (17.31 days) and panicle to maturity stage (27.05 days) in July first fortnight sowing.

At panicle to maturity stage, delayed planting decreased the LAD to an extent of 17.3, 26.7 and 41.6 per cent in July second, August first and second fortnight sowings, respectively. And also early planting decreased LAD to an extent of 11.0 per cent in June second fortnight sowing.

AGR was higher in July first fortnight sowing from panicle to maturity stage (0.357 g/plant/day) and subsequently declined to an extent 23.8, 26.8, 44.2 per cent in July second, August first and second fortnight sowings, respectively and early sowing in June second fortnight declined to the extent of 2.24 per cent.

Maximum NAR at panicle to maturity stage was observed during the June second fortnight sowing (0.055 g/dm<sup>2</sup>/day) and subsequently declined to the extent of 1.8, 7.3, 10.9 and 20.0 per cent in July first, July second, August first and second fortnight sowings, respectively.

CGR was higher in July first fortnight sowing (0.053 g/dm<sup>2</sup>/day) at panicle to maturity stage and subsequently declined to an extent of 22.6, 26.4 and 45.3 per cent in July second, August first and second fortnight, respectively and early sowing in June second fortnight declined to the extent of 5.6 per cent.

Similar results of decreased LAI, LAD, AGR, NAR and CGR due to delayed sowings was reported by Chandrappa (1993) in small millets.

Crude protein content did not differ significantly due to sowing dates. However, maximum protein content was recorded in July first fortnight sowing (13.4 %) and subsequently declined to an extent of 4.5, 8.9 and 8.9 per cent in July second, August first and second fortnight, respectively and in early sowing

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during June second fortnight to the extent 5.2 per cent. But the protein yield differed significantly due to sowing dates. Maximum protein yield (128.9 kg/ha) was recorded in July first fortnight sowing and delayed sowing declined to the extent of 32.0, 37.4 and 56.3 per cent in July second, August first and second fortnight sowing respectively. And in early sowing during June second fortnight declined to the extent of 10.8 per cent it was mainly due to decreased grain yield and protein content with delayed sowings. Similar results of no variation in protein content was reported by Angus *et al.* (1982). Contrarily, Waghmode *et al.* (1998) observed increase in crude protein content due to delay in sowing.

## 5.2 Effect of genotypes

Selection of a high yielding genotype suitable to a specific agro climatic condition goes a long way in increasing production and maximizing the economic returns per unit land area.

Grain amaranth genotypes exhibits significant differences in growth and yield attributes. The present study indicated that the genotype Suvarna recorded the highest grain yield (943.8 kg/ha) which was significantly superior over K-432 (504.6 kg/ha) when averaged over five dates of sowing. The comparison genotypes Suvarna and K-432 at 60 days after sowing in July first fortnight sown crop is given in plate 1.

Grain yield is governed by a number of factors, which have a direct or indirect impact. The main factors affected the grain yield are the yield components such as number of panicles per plant, panicle length, panicle dry weight, grain yield per plant and test weight of seeds. The growth attributes such as total dry matter production per plant and its distribution into various plant parts have indirect effect on grain yield and intern have their dependence on different growth factors viz., leaf area index, leaf area duration, rate of dry matter production, etc.



**Plate 1 : Comparison of Suvarna and K-432 at 60 days after sowing in July first fortnight sown crop**

Among the yield components, the number of panicles per plant (Table 6) were highest in Suvarna (22.6 and 28.7) compared to K-432 (8.4–9.3) at both panicle and maturity stage, respectively. But K-432 produced significantly higher length of panicle (16.4 and 17.2 cm) compared to Suvarna (10.8 and 12.1 cm) at panicle stage and at maturity stage, respectively. These are in conformity with the results of Joshi (1986), Ramachandra (1990), Malligawad (1994) and Anand (2000).

Grain yield per plant was closely associated with grain yield per hectare. The genotype Suvarna recorded significantly higher grain yield per plant (6.96 g) as compared to K-432 (3.66 g). This is in conformity with the results reported by Mohideen *et al.* (1983) and Anand (2000).

Test weight of seeds is other useful parameter to assess translocation efficiency. Even though there was no significant difference in test weight between the genotypes, maximum test weight was recorded in K-432 (4.003 g) as compared to Suvarna (3.965 g). The difference in the test weight between the genotypes may be due to the inherent genotype differences in the seed size and also may be due to the differential response of amaranth genotypes to the environmental conditions that existed during the crop growth period, seed development and maturation. Similar results of higher test weight was recorded in K-432 compared to Suvarna by Anand (2000).

Harvest index is another useful parameter to assess the translocation efficiency. Grain yield is related to biological yield through harvest index. Further, it was also reported that the yielding potential of a genotype is usually associated with increased grain to biological yield ratio (HI) (Yoshida, 1972). The total dry matter production is not only important but also how much of it is partitioned or translocated into economic parts, counts much for attaining higher economic yield. The genotypes differed significantly in harvest index (Table 17). The genotype K-432 recorded the highest harvest index (0.389) as compared to Suvarna (0.226). Similar observations were made by Ramachandra

(1990), Elbehri *et al.* (1993). Malligawad (1994) who reported that cultivars of *A. hypochondriacus* had higher harvest index compared to *A. cruentus*.

The superiority of Suvarna could be judged by the total dry matter production per plant (TDMP). The TDMP was significantly differed between the genotypes (Table 10). Suvarna had significantly higher TDMP (3.04, 19.69 and 30.43 g/plant) compared to K-432 (1.47, 6.52 and 9.43 g/plant) at vegetative stage, panicle stage and at maturity stage, respectively. The dry matter production in leaf and stem at all growth stages was significantly higher in Suvarna than K-432. This could be possibly attributed to higher TDMP in Suvarna through higher plant height (Table 3) at vegetative stage (35.3cm), panicle stage (87.4cm) and at maturity stage (98.0 cm) and also larger canopy as there was higher number of broad leaves per plant (Table 4) at vegetative (10.5), panicle stage (15.4) and at maturity stage (11.2). The TDMP in Suvarna was more due to more leaf area (291.0, 1075.9 and 785.6 cm<sup>2</sup>/plant) and leaf area index (0.431, 1.593 and 1.164) at vegetative, panicle stage and at maturity stage, respectively (Table 12) and due to long leaf area duration (24.29 and 36.02 days) between vegetative to panicle stage and panicle to maturity stage, respectively. The higher TDMP per plant in Suvarna was also due to higher AGR (0.694 and 0.410 g/plant/days) and CGR (0.117 and 0.061g/dm<sup>2</sup>/day) between vegetative to panicle stage and panicle to maturity stage, respectively (Table 14 and 15). Similar variations were observed by different workers among different genotypes of grain amaranth with respect to plant height, number of leaves, leaf area, leaf area index, leaf area duration, accumulated growth rate and crop growth rate (Puspha Rekha, 1986; Maruthi, 1987; Elbehri *et al.*, 1993; Ramachandra, 1990; Malligawad, 1994 and Anand, 2000).

Suvarna took maximum (48.8) number of days to attain 50 per cent flowering which was 18.9 days greater than K-432. Similarly in days to physiological maturity (Table 5) was maximum (89.9) in Suvarna whereas K-432 took about 63.4 days. These differences due to the genetic difference between genotypes with respect to growth in their duration of growth. Similarly

Mohideen *et al.* (1983) and Lohithaswa (1992) noticed variation in mean days to maturity among different genotypes of grain amaranth (96.5 to 131.5 days).

Even though there was no significant difference in protein content but protein content varied with genotypes. The maximum protein content was noticed in survana (13.1%) as compared to K-432 (12.2%). But the protein yield differed significantly due to significant difference in grain yield. Maximum protein yield was recorded in survana (125.6 kg/ha) as compared to K-432 (61.7 kg/ha). Similar results of variation in protein content was reported by Singhal and Kulkarni (1988). Raju (1992) also noticed that the variation in protein content 13.2 per cent (AG-18) to 16.9 per cent (AG-58) among different grain amaranth genotypes.

Dwarf nature of K-432 might have allowed lesser dry matter accumulation in stem compared to Suvarna. The contribution of stem towards the total dry matter started to decline once panicle emergence in K-432, while it continued to increase till maturity in Suvarna. Thus, dwarf nature seems to be one of the ideal character for realizing higher grain yield since in dwarf plants as growth advanced more photosynthates were diverted to the panicles than to the stem. On the other hand stem continued to accumulate more photosynthates at the expense of panicles in Suvarna. Hence, dry matter production was not sole determinant of grain yield, but the rate of dry matter accumulation in the reproductive part (panicle) would indicate the efficiency of genotypes (Watson, *et al.*, 1963).

Thus it may be concluded that Suvarna out yielded K-432 due to efficient utilization of photosynthates for grain production.

### **5.3 Interaction effect of sowing dates and genotypes**

The genotypes differed in their responses to dates of sowing. In the present investigation, the grain yield was significantly influenced by interaction effect of sowing dates and genotypes (Table 17). The highest grain yield of

1301.6 kg/ha was produced by the genotype Suvarna in July first fortnight sowing which gave 56.0 per cent higher yield in same sowing date over K-432. But it gave significantly higher grain yield than all delayed sowing dates and genotype K-432 except itself in early sowing date of June second fortnight (1199.3 kg/ha) where the extent of reduction of grain yield in genotype Suvarna was more compared to genotype K-432. The genotype K-432 gave higher grain yield in June second fortnight sowing (613.0 kg/ha) which was on par with all other sowing dates (495.0-572.3 kg/ha) except August second fortnight (367.3 kg/ha). The slight (6.64 %) reduction in grain yield of K-432 in July first fortnight sowing may be due to reduction in rainfall and variation in other weather parameters during maturation. The highest grain yield in Suvarna sown in July first fortnight was due to the highest yield attributing values, viz., higher number of panicles (33.9), panicle dry weight per plant (21.6) and grain yield per plant (9.8 g). In general, within each genotype, the grain yield was decreased with every, fortnight delay in sowing. In genotype Suvarna, the decrease in grain yield was upto an extent of 7.86, 33.95, 38.3 and 57.3 per cent respectively, in June second, July second, August first and August second fortnight sowings compared to July first fortnight sowing. In K-432, the decrease was to the extent of 6.64, 22.5, 19.2 and 40.0 per cent respectively, in July first, July second, August first and second fortnight sowings compared to June second fortnight sowing. This indicated that the decrease in grain yield of K-432 (short duration genotype) was less upto August first fortnight sowing but the decrease was drastic when sowing was done beyond August first fortnight, where in case of Suvarna (medium duration genotype), the grain yield decrease was drastic with sowing beyond July first fortnight. This less reduction in grain yield of K-432 due to better performance under moisture stress conditions. Similar results of better performance of early maturing lines of grain amaranth in less rainfall condition than late maturing lines reported by Gupta and Thimba (1992).

The higher grain yield in the July first fortnight sowing in Suvarna and June second fortnight in K-432 was due to the significant interaction effect of

sowing dates and genotypes on grain yield per plant, number of panicles per plant at maturity stage, panicle dry weight at panicle and maturity stage, leaf area and total dry matter production at all the growth stages, 50 per cent flowering, physiological maturity and LAI at vegetative and panicle stage, LAD, AGR, CGR at vegetative to panicle and panicle to maturity stage. This trend was also because of advantages of favourable soil moisture, day length in the early sowings compared to delayed sowings. Thus due to variation in weather conditions the lowest yield was obtained in last August second fortnight sowings in both the genotypes. Similar results of interaction due to sowing dates and genotypes recorded by Ashoka (1996) in finger millet. He also recorded decrease in yield due to delay in sowing of finger millet.

### **Results of practical utility**

- The optimum sowing time for genotype Suvarna (medium duration) was found to be July first fortnight, while the genotype K-432 (short duration) performed better in early as well as late, sown condition (up to August first fortnight). Therefore, the genotype K-432 is suitable for delayed sowings.
- Irrespective of genotypes the optimum sowing time for grain amaranth was found to be July first fortnight.
- Highest yield of 1301 kg/ha was obtained with Suvarna sown during July first fortnight whereas, K-432 has yielded 613 kg/ha when it was sown during June second fortnight.

### **Future lines of work**

- There is a need to evaluate some more grain amaranth genotypes for finding out the influence of different dates of sowing on growth and yield characters.

- Studies on the effect of split application of 'N' on grain amaranth are needed.
- Studies are needed on integrated nutrient management system for realizing higher productivity on a sustainable basis.
- There is a need to find out optimum time of harvesting to overcome shattering of seeds.

# SUMMARY

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## VI. SUMMARY

Grain amaranth (*Amaranthus hypochondriacus* L.) is an important pseudo-cereal. It is known to produce high protein content along with well balanced aminoacid composition. Recent interest in grain amaranth is due to its high nutritional values such as high protein (13 to 19 %), Lysine (6.0g/100g protein) and sulphur containing aminoacids (4.4 %)(Joshi and Rana,1991). Amaranth responds well to ample sunshine and warm temperature. Grain amaranth performs differential to sowing dates. A field experiment was conducted at Main Research Station, UAS, Bangalore during *kharif* season of 2000 to asses the performance of grain amaranth genotypes to sowing dates. The treatments included two genotypes as main plot and five sowing dates as sub plots. The salient findings of the experiment are summarized in this chapter.

### 6.1 Effect of sowing dates

Irrespective of genotypes, grain yield differed significantly due to sowing dates. The highest grain yield of 937.0 kg/ha was recorded in the July first fortnight sowing, followed by June second fortnight sowing (906.6 kg/ha). The decreased grain yield with subsequent fortnightly sowings with the lowest yield of 461.5 kg/ha was obtained in August second fortnight sowing. It was due to decrease in yield attributing characters viz, number of panicles, length of panicle, panicle dry weight, grain yield per plant, test weight, HI, LAI and other growth indices and total dry matter production.

Irrespective of genotypes, at maturity the July first fortnight sowing record significantly the highest values of plant height (80.8 cm), number of green leaves (12.5), number of panicles (22.1), length of panicle (15.8 cm), dry weight of stem (7.76g), leaf (3.26g) and panicle (14.16 g), days to 50 per cent flowering, (40.5), LAI (0.979), grain weight per plant (6.93 g), HI (0.323) and test weight (4.042). These growth and yield attributing parameters values were decreased with subsequent fortnightly delayed sowings being lowest in the last

sowing in August second fortnight. The crude protein content was also declined with delayed sowing being minimum in the August first and second fortnight.

## 6.2 Performance of genotypes

Irrespective of dates of sowing; the grain yield varied significantly between the two genotypes. The genotype Suvarna recorded significantly the highest grain yield of 943.8 kg/ha compared to K-432 (504.6 kg/ha). The highest yield in Suvarna was mainly due to the highest grain yield per plant (6.96), number of panicles (28.7), panicle dry weight (15.61 g), total dry matter production (30.43 g), days to 50 per cent flowering (48.8) and days to physiological maturity (89.9), LAI at all growth stages (0.431, 1.593 and 1.164) and higher LAD (24.29 and 36.02 days) AGR (0.694 and 0.410 g/plant day) and CGR (0.117 and 0.061 g/dm<sup>2</sup>/day) between vegetative to panicle stage and panicle to maturity stage. But K-432 recorded significantly higher HI (0.389), panicle length (16.4 and 17.2 cm) at panicle stage and maturity stage. Whereas test weight was highest and almost same in both K-432 (4.003 g) and Suvarna (3.965 g). The crude protein content was maximum in Suvarna (13.1%) as compared to K-432 (12.2%).

## 6.3 Interaction effects

The grain yield was significantly influenced by the interaction effect of sowing dates and genotypes. The highest grain yield of 1301.6 kg/ha was recorded in Suvarna sown in the July s first 1 fortnight which was significantly superior over K-432 in all five dates of sowing except with itself in June second fortnight sowing (1199.3 kg/ha). The highest grain yield in Suvarna sown in July first fortnight was mainly due to highest yield attributing values of grain yield per plant (9.8 g), number of panicles (25.7 and 33.9), panicle dry weight (9.77 and 21.60 g) at panicle stage and at maturity stage, total dry matter production at harvest (40.23 g), LAI (1.534) at harvest, LAD (46.07 days), AGR (0.534 g/plant/day) and CGR (0.079 g/dm<sup>2</sup>/day) at panicle to maturity stage.

Within the genotypes, the grain yield was decreased with every fortnight delay in sowing. The reduction in the grain yield of Suvarna (medium duration genotype) was more (57.3%) after July first fortnight sowing ; however, in K-432 (short duration genotype) reduction in grain yield was relatively less (40.08%) up to August first fortnight.

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\* Original not seen