

**PHYSIOLOGICAL ASSESSMENT OF SWEET SORGHUM  
(*Sorghum bicolor* (L.) Moench) CULTIVARS AND THEIR  
SUITABILITY IN COASTAL ANDHRA**

**By  
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**Thesis Submitted to the  
Acharya N. G. Ranga Agricultural University  
in partial fulfillment of the requirements  
for the award of the Degree of**

**Master of Science in Agriculture**



**DEPARTMENT OF PLANT PHYSIOLOGY  
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## **CERTIFICATE**

**Mr. M. Ravi Babu** has satisfactorily prosecuted the course of research and that the thesis entitled “**Physiological Assessment of Sweet Sorghum (*Sorghum bicolor* (L.) Moench) Cultivars and Their Suitability in Coastal Andhra**” submitted is the result of original research work and of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by him for a degree of any University.

Date :

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Place :

Major Advisor

## CERTIFICATE

This is to certify that the thesis entitled “**Physiological Assessment of Sweet Sorghum (*Sorghum bicolor* (L.) Moench) Cultivars and Their Suitability in Coastal Andhra**” submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** in the major field of **Plant Physiology** of the Acharya N. G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr. M. Ravi Babu** under our guidance and supervision. The Student’s Advisory Committee has approved the subject of the thesis.

The student for any other degree or diploma has submitted no part of the thesis. The published part has been fully acknowledged. The author of the thesis has duly acknowledged all the assistance and help received during the course of investigations.

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*Place:*

*Date:*

**(Ravi Babu Mangam)**

## **DECLARATION**

I, **Mr. M. Ravi Babu** hereby declare that the thesis entitled **“Physiological Assessment of Sweet Sorghum (*Sorghum bicolor* (L.) Moench) Cultivars and Their Suitability in Coastal Andhra”** submitted to the Acharya N. G. Ranga Agricultural University for the degree of Master of Science in Agriculture in the major field of **Plant Physiology** is the result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier.

**Date :**

**(M. RAVI**

**BABU)**

**Place : Bapatla**

## LIST OF SYMBOLS AND ABBREVIATIONS USED

%	=	per cent
@	=	at the rate of
a.i.	=	active in gradient
B <sup>0</sup>	=	Brix
CCS	=	commercial cane sugar
CD	=	critical difference
CGR	=	crop growth rate
cm	=	centimeter
CV	=	coefficient of variance
Cv.	=	cultivar
CY	=	cane yield
DAS	=	days after sowing
EC	=	Electric conductivity
g	=	gram
ha	=	hectare
ha <sup>-1</sup>	=	per hectare
<i>i.e.</i> ,	=	that is
ICRISAT	=	International Crops Research Institute for
IISR	=	Indian Institute of Sugarcane Research
IU	=	International Unit
K	=	Potassium
kg	=	Kilogram
L	=	litre
m	=	metre
M/s	=	manufactures
mg	=	milligram
NS	=	non-significant
ppm	=	parts per million
SED	=	standard error difference
sig.	=	significant
t	=	tonnes
var.	=	variety
<i>viz.</i>	=	namely

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## ABSTRACT

Name of Author : **Ravi Babu Mangam**  
Title of the thesis : **Physiological Assessment of Sweet Sorghum (*Sorghum bicolor* (L.) Moench) Cultivars and Their Suitability in Coastal Andhra**  
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A field experiment entitled “Physiological assessment of sweet sorghum (*Sorghum bicolor* (L) Moench) cultivars and their suitability in coastal Andhra” was carried out at the Agricultural College Farm, Bapatla, during *Maghi* season of 2004-2005.

Fifteen sweet sorghum cultivars *viz.*, SSV 84, SS V 74, Sredo, NTJ<sub>2</sub>, ICSV 574, Ent64 DTN, ICSV 700, ICSV 93046, ICSR 37, ICSV 56, ICRR 108, ICSR 196, ICSV 96117, S 35 and ICSR 93034, were tried as treatments replicated thrice in a randomized block design.

The results indicated that the cultivars SSV 84, SSV 74, ICSV 700, ICSV 93046, NTJ<sub>2</sub> and S 35 recorded higher plant height, internodal length and

basal diameter at different growth stages compared to those recorded from the other cultivars in the study.

Physiological growth parameters such as leaf area index, CGR, RGR, NAR and drymatter production were higher with the cultivars SSV 84, SSV 74, NTJ<sub>2</sub> and S 35. The cultivars like ICSR 37, Seredo, and SSV 74, took less number of days to 50 % flowering and maturity than that taken by the other cultivars.

Yield and yield components like panicle length, grain weight per panicle, test weight and total grain yield were significantly higher in cultivars ICSR 37 Seredo, SS V 84, SSV 74, NTJ<sub>2</sub>, S 35 and ICSR 93034 than the other cultivars.

Bio-chemical characters like TSS, reducing sugars, non-reducing sugars, fermentable sugar yield and ethanol production were significantly higher in cultivars like SSV 84, SSV 74, NTJ<sub>2</sub> and S 35 than those exhibited by the other cultivars both at flowering and harvesting.

Overall, it can be concluded from the study that the cultivars like SSV 84 and SSV 74 can be cultivated for ethanol production and cultivars like SSV 84, ICSR 37 and Seredo can be grown for grain purpose in coastal Andhra.

## CHAPTER – I

### INTRODUCITON

India accounts for about 40 per cent of the world's millet output. The total production of millets in India was around 23.04 m t, which was about 10.9 per cent of total food grains production, in 2003-2004 (Survey of Indian Agriculture, 2005). Sorghum was grown over 9.49 m ha during 2003-04 and the total production was 7.33 m t with an average productivity of 772 kg/ha. Sorghum is cultivated both in *khariif* (rainy) and *rabi* (post-rainy) seasons in India.

Sorghum is one of the five major cultivated species of the cereals in the world in both area and production. It can out produce other cereals under marginal environmental conditions, particularly under hot and dry conditions, Eighty per cent of sorghum cultivated area in the world is located in Africa and Asia.

The present forecast on the exhaust of fossil fuels by 2050 needs search for exploring alternative source of fuels, which should be economical as well as eco-friendly. Bio fuels offer an alternate source of energy, as these are renewable resources.

With the encouragement from the Government of India to blend ethanol with petrol, the demand for production of ethanol is increasing. As the quantity

of molasses from sugar industry is inadequate to meet this demand, search for alternative sources has begun.

Sweet sorghum crop that can be raised in four months with minimal requirement of inputs (especially water) can be an alternative. Sweet sorghum can produce 3 t ha<sup>-1</sup> grain, 2.03 t ha<sup>-1</sup> sugar, 1.605 t ha<sup>-1</sup> white spirit and 11.74 t ha<sup>-1</sup> vinegar (Licufuifeng *et al.*, 1997). Apart from these, other products such as Jaggery, silage, syrup, sweetener, wine, pulp, paper and energy (electricity) etc. can also be produced from the sweet sorghum (Seetharama *et al.* 2002 ; Reddy and Reddy, 2003).

Variation in stripped stalk yield of sweet sorghum cultivars was observed over different locations ranging from 45 to 60 t ha<sup>-1</sup> and 35 to 40 t ha<sup>-1</sup>, respectively, in Italy (Schaffert and Gourley, 1982). Selection of suitable sweet sorghum cultivars for a given area appears to be the most important factor in determining yield of grain, stripped stalk and ethanol production

Sweet sorghum as a cash crop is a new one for the coastal Andhra and a little information is available on its performance and suitability. So it is imperative to go for physiological assessment of sweet sorghum cultivars and to find out their suitability in Coastal Andhra, where sugar factories exist in large number, which can be utilized to process sweet sorghum as well. Therefore, the present study is conducted with the following objectives:

1. To study the growth parameters in different sweet sorghum cultivars.
2. To study the pattern of drymatter partitioning in different cultivars.

3. To analyse the qualitative aspects of sweet sorghum juice *viz.*, total soluble sugars (brix), reducing and non-reducing sugars.
4. To assess the productive efficiency of cultivar in respect of grain, stripped stalk and ethanol.

## **CHAPTER – II**

### **REVIEW OF LITERATURE**

The present investigation was undertaken to assess different physiological and biochemical characters in fifteen sweet sorghum (*Sorghum bicolor* (L.) Moench) cultivars.

Several attempts were made earlier by several workers to assess different aspects of sweet sorghum to compensate for the sugarcane under different conditions. Sweet sorghum is grown as a substitute to sugarcane crop where the sugarcane crop was not suitable to grow.

In the following paragraphs, the work of several scientists was narrated under different sub-heads mainly concentrating on the differences in sweet sorghum cultivars on growth, yield and their chemical composition.

#### **2.1 MORPHOLOGICAL CHARACTERS**

##### **2.1.1 Plant Height**

Variation in plant height of sweet sorghum was observed at different stages. Observations made from several years of experimentation indicated that, plant size correlated to length of the life cycle that had remarkable role in determination of the productive performance for the optimum height (Reevers *et al.*, 1979; Miller and Creelman 1980). Smith and Reeves (1981) recorded the maximum height of 217 cm in 'X 1477' variety of sweet sorghum. Monk

*et al.* (1984a) observed that the lodging tendency in sweet sorghum was always registered in the tallest cultivars.

Monk *et al.* (1984b) established a positive and significant association of sucrose content in juice with plant height and number of internodes in sugarcane. Putnum *et al.* (1991) explained that the plant height was more comparative unit for ethanol production in sweet sorghum. Patil (1993) evaluated different sweet sorghum hybrids suitable for post rainy season in Northern Karnataka, and recorded the plant height of 254.7 cm in the hybrid SPH 1026. Almodares and Sepahi (1997) recorded the maximum plant height of 307.7 cm and 244.6 cm in sweet sorghum cultures 'D' and 'Rio', respectively. Similarly, Agnal (2001) recorded a plant height of 309.13 cm in sweet sorghum.

### **2.1.2 Stem Girth (Basal Diameter)**

Basal diameter of the stem is an important factor for stalk yield as well as juice and sugar extraction. The weight of the stalk mainly depends on stem diameter and juiciness of stem. Monk *et al.* (1984a) opined that the basal diameter of stalk was the important factor of plant size, which may influence the drymatter, juice production and stalk yield of sweet sorghum. Parrish *et al.* (1985) estimated the stem girth of HH 81 variety of fodder sorghum up to 5.17 cm.

Davis (1993) reported similar size of stem girths around 4.36 cm in sorghum varieties like HH 2, HH 88 and HH 82. Similarly, Pateil *et al.* (2003)

reported that the sorghum variety JS 20 recorded the stem diameter of about 6.5 cm.

### **2.1.3 Internodal Length**

Inter nodal length of about 20 cm was estimated in sugarcane by Burr *et al.* (1957). Miller and Creelman (1980) recorded, an internodal length of 30 cm in a sweet sorghum variety Keller. Nayeem (1980) reported that water stress affects the growth of sugarcane crop resulting in decreased internodal length and final cane yield. Reeves *et al.* (1981) recorded more internodal length in X1415 culture of sweet sorghum. Narkheda *et al.* (2000) observed a mean internodal length of 18.8 cm in sorghum cultivars that they have studied.

## **2.2 PHYSIOLOGICAL PARAMETERS**

### **2.2.1 Leaf Area Index**

Singh *et al.* (1976) observed a significant positive association of leaf area and brix per cent at physiological maturity, but delayed harvesting declined the brix and leaf area drastically in sweet sorghum. Leaf area index was positively correlated with both cane and biological yields, especially during early stages of growth in sugarcane (Singh and Srivastava 1993).

Channa Naik and Jayakumar (1994) also observed high leaf area index of 5.55 at a higher dosage of nitrogen (125 kg ha<sup>-1</sup>) with SSV84 sweet sorghum

cultivar. Naik and Muniyappa (1995) studied the relationship between leaf area and distribution of sugars/starch into stem or grain in different sweet sorghum cultures and recorded 1185 cm<sup>2</sup> leaf area per plant in HES-6 cultivar.

Khajan Singh and Lata Choudari (2000) reported that leaf area per plant and flag leaf area per plant in sorghum ultimately determined the sorghum yield per unit area. Patil *et.al.* (2003) observed a positive correlation between leaf area index and grain yield.

### **2.2.2 CGR, RGR and NAR**

The genetic variation in the production capacity of a crop is dependent on such physiological parameters like CGR, RGR, NAR, and portioning of photosynthates into economic sinks. So, to evaluate plant growth in any crop, the growth parameters like CGR, RGR and NAR are very important. RGR is the rate of increase in biomass per unit of phytomass present per unit time and it can be regarded as the efficiency index of the crop.

Relative growth rates of different sorghum cultivars were reported earlier by several workers (Radford 1967). NAR is the net increase in drymatter per unit leaf area per unit time. Bhattacharya and Jayakumar (1985) computed NAR in different crops including sorghum.

Veerabhadran and Kennedy (2001) correlated higher values of NAR, RGR and CGR with increasing yield in sorghum. Chandrasekhar *et al.* (2001)

studied the effect of different physiological parameters like CGR, RGR, NAR, LAI and drymatter production on growth and productivity in hybrid rice.

### **2.2.3 Drymatter Production**

Loomis and Williams (1963) observed high drymatter accumulation rates on daily basis in sorghum. In sugarcane, drymatter production in leaf spindle increased during floral initiation period, which continued till the growth of inflorescence, reached to 4-6 mm length at the apex (Singh and Reddy, 1976).

Cundiff and Parrish (1985) reported that drymatter did not change in whole sweet sorghum stems stored in ambient conditions, but when it was delayed up to 30 days after harvest, juice content of stem was declined drastically. Lueschen *et al.* (1991) suggested for higher emphasis on drymatter production in high-energy sorghum (HE) hybrids and observed lower drymatter production with higher brix percentage.

Drymatter production and accumulation of different plant parts (portioning) of sorghum can be dependent on heterosis, vigour and different growth stages of the crop (Rood *et.al.*, 1992). Channa Naik and Jayakumar (1994) observed that the biomass production in sweet sorghum was increased with increasing level of nitrogen. Shukla and Sharma (1994) also reported the

similar increase in biomass content with more nitrogen level in sweet sorghum. Silli *et al.* (2001) recorded that total drymatter per plant was 78.80 g plant<sup>-1</sup> and green fodder yield was 54.60 t ha<sup>-1</sup>. Arora *et al.* (2002) reported that high drymatter accumulation of 3.4 t ha<sup>-1</sup> in sorghum cultivar 3S4-59 b.

#### **2.2.4 Days to 50 per cent Flowering**

For increasing grain and fodder yield, selection of varieties with more days to 50% flowering, plant height, stem girth, brix and leaf area at harvest is important. The primaries and secondaries of panicle, panicle length and test weight at harvest are the major components influencing grain yield in sweet sorghum. Nayeem (1980) observed that direct effect of brix percentage at physiological maturity and its interrelationship with leaf area at 50 per cent flowering, and correlative relation with grain yield and stalk yield. Chaudhari (1988) and Belletti and Petrini (1991) observed that the high-energy sorghum lines took more days to 50 per cent flowering and recorded the maximum values of brix and basal diameter of the sweet sorghum stalk. Patel *et al.* (1994) studied the interrelationship of days to 50 per cent flowering, plant height and brix at harvest and showed a negative direct effect on grain yield in sweet sorghum.

### **2.3 BIOCHEMICAL PARAMETERS**

#### **2.3.1 Total Soluble Sugars, Non-reducing Sugars, Reducing Sugars and Fermentable Sugars**

Several workers (Ranganna, 1977; Reddy and Reddy 1977; Chopra and Kanwar 1980) did estimation of reducing and non-reducing sugars in different sweet sorghum varieties. Lamb *et al.* (1982) and Monk *et al.* (1984a) reported that juice yield of sweet sorghum was 46% of their stripped stalk yield. Monk *et al.* (1984b) reported that the biomass production capacity of sweet sorghum was equal or superior to sugarcane in the tropics. Similarly, Parrish *et al.* (1985) recorded more carbohydrates per hectare in sweet sorghum than that produced in corn. Kishan Singh and Bakthawar Singh (1986) reported that sweet sorghum as an ancillary sugar crop, produced more brix percentage of 18 to 19 and reducing sugars 8.8 per cent with varieties Rio, Brawley and Roma.

Linden *et al.* (1986) suggested that the sweet sorghum bagasse can be used as a satisfactory feed stock for cellulose conversion and recorded the fermentable sugar yields ranged from 6 to 8 t ha<sup>-1</sup>. Smith *et al.* (1987) noticed that the phenomena of decreased juice recovery with the delay in harvesting of sweet sorghum, and they further reported that sweet sorghum juice contains 78.1 per cent sucrose and 8.8 per cent reducing sugars whereas in case of sugarcane it was 84.2 and 7.5 per cent respectively. Similarly, Belletti and Petrini (1991) reported the fermentable sugar production in sweet sorghum was ranged from 4 to 7 t ha<sup>-1</sup>.

Ravi *et al.* (1997) studied the response of sweet sorghum to fertilizer application by using sixteen culture combinations and reported that at physiological maturity, the genotypes differed significantly for all aspects of juice quality, available sugars, brix reading, reducing sugars, non-reducing

sugars, pH and specific gravity of the juice. Among the genotypes 'Rio' recorded significantly best quality juice followed by 'SSV-84'. Ghatod *et al.* (1991) observed the sugar content and juice quality of sweet sorghum at different physiological stages, and reported that fresh canes will give more recovery percentage of juice and total soluble sugar percentage. Mallikarjun *et al.* (1998) conducted an experiment on four genotypes of sweet sorghum *i.e.*, Rio, SSV-53, SSV-84 and SS 121611 and recorded the highest brix value of 17.5 per cent in 'Rio' followed by 'SSV-84'.

Belletti and Petrini (1991) studied 39 varieties of sweet sorghum in several locations of Italy, from 1981 to 1987 and found that varieties such as Rio, Dale, Keller, M 81 E and Mn 1500 performed well with fresh stalk yields ranged from 55.5 to 69.7 t ha<sup>-1</sup> and fermentable sugar yields 6 to 8.1 t ha<sup>-1</sup>. Lueschen *et al.* (1991) recorded more fermentable sugar yields in early sown sweet sorghum cultivar. Channa Naik and Jayakumar (1994) found that the cultivar SSV-84 contained higher brix value of 10.8. Almodares *et al.* (1997) reported that cultivation of sweet sorghum was so economical due to its extensive root system and short growing period. They further recorded grain yield ranged from 1.5 to 7.5 t ha<sup>-1</sup>, brix reading from 13 to 24, sucrose from 7.2 to 15.5 per cent, stalk yield from 24 to 120 t ha<sup>-1</sup> and the fermentable sugar yields were ranges from 4 to 7.5 t/ha. Ganesh *et al.* (1995) also reported similar results in case of total soluble sugars reducing sugars and non-reducing sugars in sweet sorghum.

### **2.3.2 Ethanol Production**

The efficiency of sugar conversion to ethanol in sorghum stalk varied between 73 per cent and 79 per cent (Miller and Creelman 1980). Lamb *et al.* (1982) reported that the extraction of juice was 45.4 L from one tonne of chopped stalk and 42.1 L from one tonne of shredded stalk. Putnum *et al.* (1991) studied the multiple uses of sorghum including grain and fermentation of juice.

South Eastern Gasohol Association (1980) reported that, Sorghum stalks are ideal for ethanol production, as the ethanol from sweet sorghum was significantly cleaner than that from sugarcane. Seetharama *et al.* (2002) reported that sorghum as a new crop for alcohol production can yield 4.5 kilo litres of ethanol per hectare.

## **2.4 YIELD AND YIELD ATTRIBUTES**

### **2.4.1 Panicle (Ear Head) Length**

Patil and Ugale (1994) measured panicle length of 24 cm in sorghum variety SPH 1026. Similarly, Sankarapandian *et al.* (1995) also recorded panicle length up to 24 cm in sweet sorghum cultivar SSV-84. Reddy and Reddy (2002) reported panicle length of 22.9 cm in sorghum variety SPH 1089 grown in vertisols. Patil *et al.* (2003) recorded the panicle length of 22.3 cm in sorghum variety M35-1 grown under vertisols.

### **2.4.2 Test Weight, Stalk Yield and Grain Yield**

Kishan Singh and Bakhawar Singh (1986) reported that the stalk yield varied between 20.18 and 33.99 t ha<sup>-1</sup> in nine sweet sorghum varieties *i.e.*, Rio, Brawley, Rex, Collier, Rome, Sart, Trary Brandes and Willey. Belletti and Petrini (1991) has reported that stalk yield of sweet sorghum varied from 54 to 69.7 t ha<sup>-1</sup> of fresh stalks in cultivars like Bale, Keller and M81 E. Almodares *et al.* (1994) reported 48 t ha<sup>-1</sup> of fresh biomass yield in sweet sorghum variety Rio. Patel *et al.* (1994) observed that panicle length and test weight at harvest were the major components influencing grain yield in sweet sorghum.

A significant relationship between biomass and stripped stalk yield and brix sucrose was observed among the 36 sweet sorghum cultivars by Almodares and Sepahi, (1997). The high-energy type sorghum hybrids characterized by high production coupled with negative development with non-senescent leaves and can accumulate photosynthates in the stem even after grain filling (Miller and Creelman, 1998). Patil *et al.* (2003) reported that grain yield of sweet sorghum was positive and significantly correlated with yield components like panicle weight, panicle length and 1000 grain weight.

## **CHAPTER – III**

### **MATERIALS AND METHODS**

A field experiment was conducted at the Agricultural College Farm, Bapatla (Northern block field No. 28) during *Maghi* season of 2004-2005, to assess the physiological and biochemical characters of fifteen sweet sorghum (*Sorghum bicolor* (L.) Moench) cultivars.

The materials used and methods followed during the experimentation were furnished in this chapter.

#### **3.0 LOCATION**

The Agricultural College Farm, Bapatla is located on the Eastern side of the peninsular India situated at an altitude of 5.49 m above mean sea level, 15<sup>o</sup> 54' Northern latitude, 80<sup>o</sup> 25' Eastern longitude and about 7 km away from the Bay of Bengal in the Krishna-Godavari Agro-climatic zone of Andhra Pradesh.

#### **3.1 CLIMATE**

The weekly mean maximum and minimum temperatures ranged from 28.9<sup>o</sup>C to 37.9<sup>o</sup>C and 16.8<sup>o</sup>C to 30.2<sup>o</sup>C, respectively, while the average maximum and minimum temperatures during the crop period were 32.4<sup>o</sup>C and 21.7<sup>o</sup>C, respectively. The monthly means of weather data for the period of 2004 September to 2005 January are presented in Table 3.1.

### 3.2 SOIL

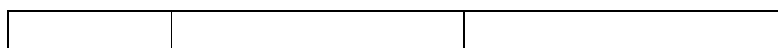
Soil samples from 0 to 30 cm depth were collected from the experimental field before sowing of the crop and were analysed (Bremner, 1965) for the physical and chemical properties and the results were furnished hereunder.

Colour	-	Dark grayish brown
Texture	-	Clay loam
HCl reaction	-	Feasible
pH	-	7.2
EC (d sm <sup>-1</sup> )	-	0.38
Organic Carbon	-	low
Available Nitrogen	-	low
Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	-	50 – Medium
Available K <sub>2</sub> O (kg ha <sup>-1</sup> )	-	674 - High

### 3.3 CROPPING HISTORY

Before sowing the experimental sorghum crop, blackgram was grown in *kharif* 2004. The cropping history of the experimental field is given below

Year	<i>Kharif</i>	<i>Rabi</i>
2001-02	Maize	Groundnut
2002-03	Fallow	Blackgram
2003-04	Blackgram	Present investigation ( <i>Maghi</i> )



### 3.4 EXPERIMENTAL DETAILS

#### 3.4.1 Experimental Design and Layout

The field experiment was laid out in randomized block design with fifteen treatments and replicated thrice. The field layout plan along with other necessary details is graphically depicted in fig. 3.1

Design	-	R. B. D.
Season	-	<i>Maghi</i> (September-October) 2004-05
Plot size	a)	Gross: 3.6 m X 4.5 m
	b)	Net : 1.8 m X 3.0 m
Total area	-	810 m <sup>2</sup>
Spacing	-	45 cm X 15 cm

#### **Treatments:**

##### **15 Sweet Sorghum Cultivars**

V <sub>1</sub> SSV 84	V <sub>6</sub> Ent 64 DTN	V <sub>11</sub> ICRR-108
V <sub>2</sub> SSV 74 ICSR-196	V <sub>7</sub> ICSV 700	V <sub>12</sub>
V <sub>3</sub> Seredo 96117	V <sub>8</sub> ICSV 93046	V <sub>13</sub> ICSV-
V <sub>4</sub> NTJ 2 35	V <sub>9</sub> ICSV-37 (70310)	V <sub>14</sub> IS-
V <sub>5</sub> ICSV-574 (SPV 422) ICSR-93034	V <sub>10</sub> ICSV-56 (70325)	V <sub>15</sub>

### 3.5 FIELD OPERATIONS

The following field operations were carried out.

### **3.5.1 Field Preparation and Sowing**

The experimental field was ploughed with a tractor drawn cultivator followed by disc harrow thrice to get a fine tilth and later levelled by working with a plank.

The seeds were treated with 0.2 per cent carbandazim for the control of seed born diseases. Seeds of fifteen sweet sorghum cultivars were sown to a depth of 2 to 3 cm on the 27<sup>th</sup> September 2004.

### **3.5.2 Fertilizers**

Nitrogen was applied in the form of urea in two split doses, one each at sowing ( $100 \text{ kg N ha}^{-1}$ ) and at 30 DAS ( $50 \text{ kg N ha}^{-1}$ ). Phosphorus ( $50 \text{ kg ha}^{-1}$ ) and Potash ( $50 \text{ kg ha}^{-1}$ ) in the form of SSP and MOP were applied respectively, at the time of sowing.

### **3.5.3 Gap filling**

Gap filling was done wherever necessary at 15 days after sowing to maintain optimum population.

### **3.5.4 Irrigation**

For ensuring proper germination and stand of the crop pre-sowing irrigation was given. Subsequent irrigations were provided as and when required.

### **3.5.5 Plant Protection measures**

The experimental area was kept weed free up to 75 DAS by manual weeding. In order to control shootfly and stemborer infestation monocrotophos @ 1.6 ml L<sup>-1</sup> at 30 DAS and carbofuron @ 8 kg ha<sup>-1</sup> at 45 DAS was applied, respectively.

### **3.5.6 Earthing Up**

Earthing up was done at 30 days age of the crop by manual labour.

### **3.5.7 Harvesting**

The crop was harvested as and when the treatments come to maturity (after 95 to 110 days during the month of January). Net plots were harvested separately in each treatment to record the stalk and grain yields.

## **3.6 OBSERVATIONS ON GROWTH CHARACTERS**

### **3.6.1 Morphological Characters**

The data on the following morphological characters was collected from three replications in each treatment at 15 days interval and average values were assessed.

### **3.6.2 Plant Height**

The height of the plant was measured from the base of stem to the tip of the terminal leaf and expressed in cm

### **3.6.3 Length of Internode**

The mean length of internode was measured in cm by taking average of the lengths of bottom, middle and top portions of internodes from five sampled stalks by using scale.

### **3.6.4 Basal Diameter of Stalk**

The mean basal diameter of stalk was measured in cm at the base of the plant with help of the Vernier callipers.

## **3.7 PHYSIOLOGICAL CHARACTERS**

### **3.7.1 Leaf Area Index**

The leaf area index was calculated at 15 days interval by specific leaf area method.

$$LAI = \frac{A}{P}$$

Where A = leaf area; P = Unit land area

LAI = leaf area index

### 3.7.2 Crop Growth Rate (CGR)

It is the rate of drymatter production per plant per unit ground area per unit time and expressed in  $\text{g m}^{-2} \text{ day}^{-1}$  (Watson, 1952)

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{P} \quad (\text{g m}^{-2} \text{ d}^{-1})$$

Where  $W_1$  = Weight of drymatter per  $\text{m}^2$  at time  $t_1$

$W_2$  = Weight of drymatter per  $\text{m}^2$  at time  $t_2$

P = Total ground area ( $\text{m}^2$ )

### 3.7.3 Relative Growth Rate (RGR)

Blackman (1969) considered the increase in drymatter of plants as a process of continuous compound interest, where in the increment in any interval adds to the capital for subsequent growth. The rate of increment is known as “Relative Growth Rate” and was calculated according to the following formula.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \quad (\text{mg g}^{-1} \text{ d}^{-1})$$

Where  $W_1$  = Dry weight of the plant at time  $t_1$

$W_2$  = Dry weight of the plant at time  $t_2$

$\text{Log}_e$  = Natural logarithm

The RGR was worked out at 15 days interval from sowing to harvesting and the average values were assessed.

#### **3.7.4 Net Assimilation Rate (NAR)**

NAR may be defined as the increase in weight of drymatter of a plant per unit leaf area per unit time and was calculated according to the formula given by Williams (1946).

$$\text{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log e A_2 - \log e A_1}{A_2 - A_1} \text{ (mg cm}^{-2} \text{ d}^{-1}\text{)}$$

Where  $w_1$  and  $w_2$  represent drymatter at beginning and end of the time interval  $t_1$  and  $t_2$  respectively.  $A_1$  and  $A_2$  represent the average leaf areas at time  $t_1$  and  $t_2$  respectively. The NAR values were worked out at 15 days interval from sowing to harvesting and the average values were assessed.

#### **3.7.5 Drymatter Production**

Destructive growth analysis was carried out at every 15 days interval from the demarked sampling area of each plot. Five plants were selected and pulled out to the laboratory. These plants were separated in to leaves, stem, root and reproductive parts. These plant parts were sun dried later on oven dried at 85<sup>0</sup> C for three days to attain constant dry weight.

### **3.7.6 Days to 50 per cent Flowering**

The number of days taken from date of sowing to 50 per cent of plants showed ear head emergence from each plot was counted as number of days to 50 per cent flowering.

## **3.8 BIO-CHEMICAL PARAMETERS**

Bio-chemical parameters such as total soluble sugars (brix) in juice, reducing sugars, non-reducing sugars, fermentable sugars in juice and ethanol content at flowering stage and maturity stages were estimated.

Five selected millable stalks were sampled from each plot. The leaves and ear heads of the plants were removed and stalks were squeezed with a two-roll mill, to collect a juice sample. The collected juice was poured in clean juice bottles, labelled and kept in a tub of water for half an hour to cool the juice to the laboratory temperature and to remove the air bubbles before the actual analysis.

### **3.8.1 Total Soluble Sugars**

The TSS was measured by using hand refractometer in brix ( $B^0$ ) scale from the raw juice.

### **3.8.2 Reducing Sugars**

The content of glucose in the stalk juice was estimated by titrating the filtered juice with 5 ml of Fehlings A (Alkaline tartrate solution) and 5 ml of Fehlings B (standard copper sulphate solution).

### **3.8.2.1 Preparations of Fehlings A**

To prepare Fehling A solution 34.65 g of  $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$  was dissolved in 500 ml of water and filtered through prepared asbestos.

### **3.8.2.2 Preparation of Fehlings B**

To prepare Fehling B solution, 173 g of Rochelle salt and 50 g of sodium hydroxide was dissolved in 500 ml of water and kept standing for two days and filtered through prepared asbestos.

### **3.8.2.3 Procedure for estimation of glucose %**

To estimate glucose per cent in stalk, 4 ml of fehlings A and 5 ml of fehlings B solutions were taken in a cleaned elenmeyer flask and added 40 ml of distilled water. A few glass beads were put in to the flask to regulate the soiling and avoid bumping the contents of flasks and titrated against corresponding stalk juice until the solution acquired slight brick red colour.

A few drops of methylene blue was added to the solution and titrated against stalk juice till the blue colour of the methylene blue disappeared and the

volume (V) of the juice was noted. The per cent of glucose in stalk juice was calculated as per the formula (Brown and Zerban, 1941) given below.

$$\text{Glucose \%} = \frac{0.05 \times 100 \times 250 \times 2.5}{V \times 325}$$

Where V = Volume of juice.

### **3.8.3 Non-Reducing Sugars**

After taking the brix readings from raw stalk juice, the juice was transferred into a 100 cc measuring flask and added 3 g of lead acetate. The contents were shaken well, filtered and polarized in a 200 nm tube through Bauch and lomb polariscope. The polariscope reading gives the pole per cent of the stalk juice. The sucrose values in the juice were determined with uncorrected brix values and pole readings by using the table values as indicated by Brown and Zerban (1941) and expressed in per cent.

### **3.8.4 Fermentable Sugar Yield**

Fermentable sugar was measured by taking B<sup>0</sup> (brix) reading using hand-refractometer after allowing the fermentation. The fermentable sugar yield was assumed by multiplying total plant sap content (extractable juice) with TSS (B<sup>0</sup>) (Almodares *et. al.* ,1994)

### **3.8.5 Ethanol Estimation**

Fermentable carbohydrates concentration was measured at flowering and harvesting stages, by using Reichert temperature compensated hand-refractometer of model 10430.

Individual plant parts were placed in a forced air-oven at 150<sup>o</sup> F until they become dry. Total carbohydrate yields were calculated by B<sup>o</sup> (brix) multiplied by total estimated sap yields from stalks, excluding leaves and heads. Ethanol yield was calculated from fermentable carbohydrates using the conversion factor i.e., 14.7 lb fermentable sugar yield was equal to 1 gallon of ethanol (Southeastern Coastal Association, 1980).

### **3.9 OBSERVATIONS ON YIELD AND YIELD ATTRIBUTES**

The data on yield and yield attributes was recorded for each individual plot and average values are furnished.

#### **3.9.1 Stalk Yield**

Five randomly sampled plants were selected from each individual plot at the time of flowering and maturity. The weight of the stalk was estimated after separating leaves and ear heads and expressed as stalk yield in t ha<sup>-1</sup>.

#### **3.9.2 Length of panicle (Ear Head)**

The length of ear head was measured from the base to the tip of the ear head. The average values for five ear heads from each treatment were assessed in cm.

### 3.8.3 Test Weight

A small sample of seed was drawn from the bulk seed obtained from each plot. Thousand seeds from the sample were counted and recorded as test weight in grams.

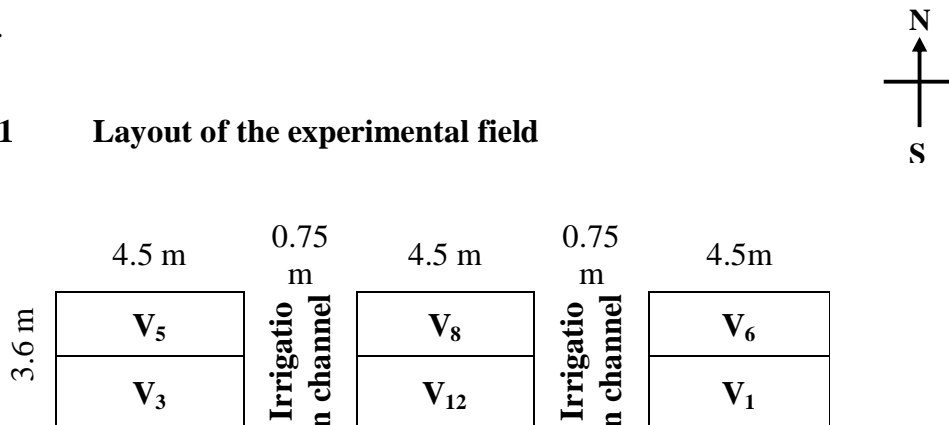
### 3.9.4 Total Grain Yield

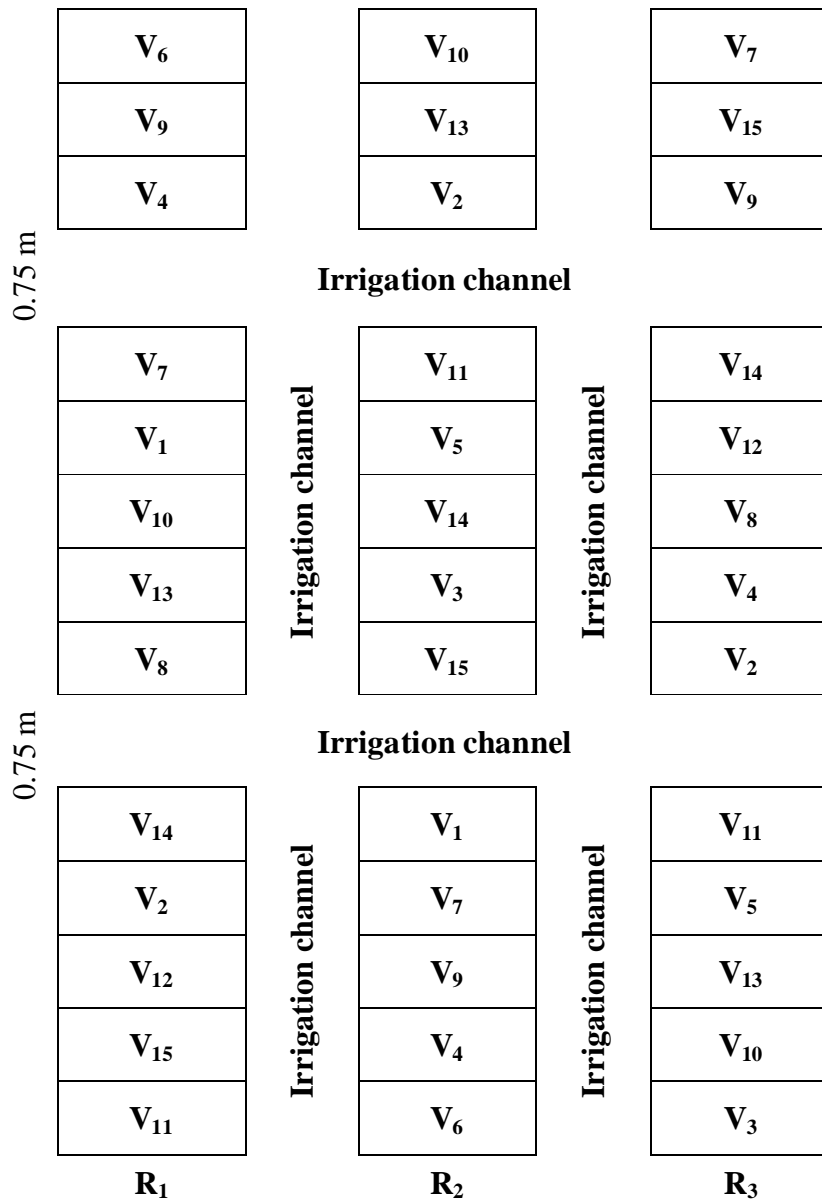
The total weight of the grain ( $t\ ha^{-1}$ ) obtained from each plant was recorded and the treatment average were assessed.

### 3.10 Statistical Analysis

The data was analyzed statistically by following the analysis of variance (ANOVA) technique as suggested by Panse and Sukhatme (1978). The statistical hypothesis of equalities of treatment means was tested by the test in ANOVA at 5 per cent level of significance to compare different treatment means.

**Fig.3.1** Layout of the experimental field





Season : *Maghi* (September-October) 2004-05      Design : RBD

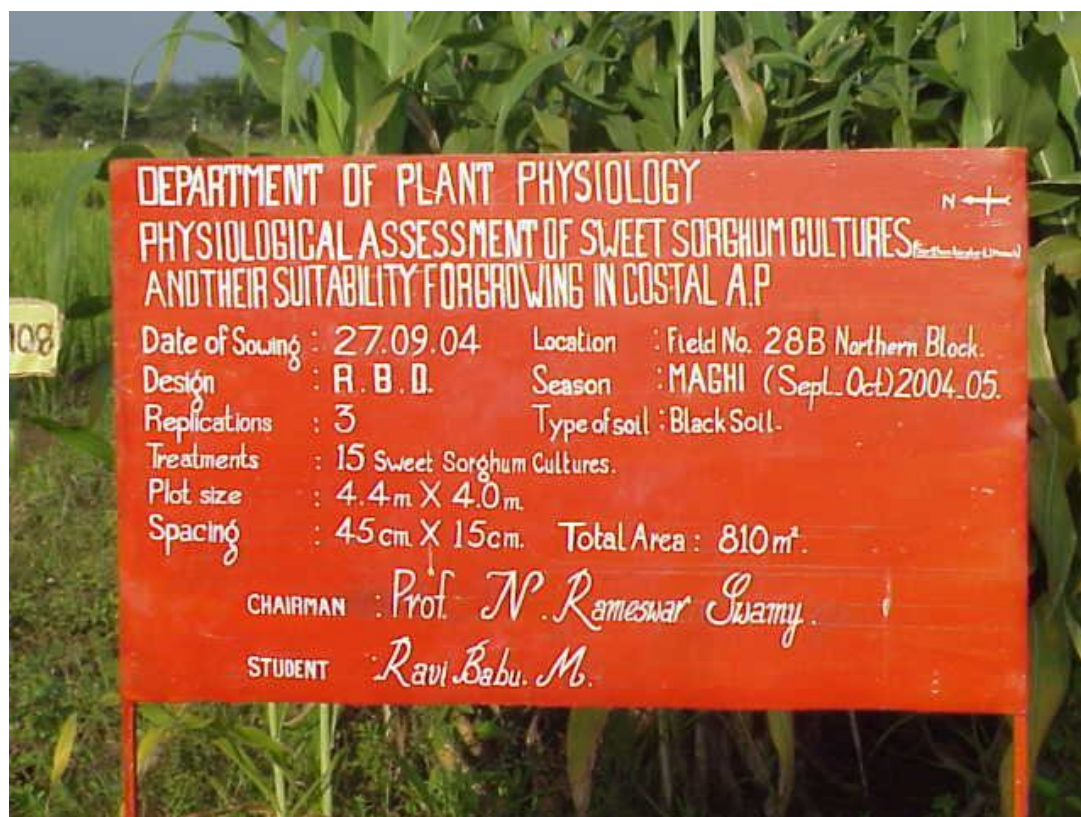
Plot size : 3.6m x 4.5 m                                      Replications : 3

Treatments : 15 (Sweet sorghum cultures)              Total Area : 832.5 m<sup>2</sup>

Spacing : 45cm x 15 cm

**Table 3.1: Fortnight weather data during the crop growth period (27<sup>th</sup> September 2004 to 24<sup>th</sup> January, 2005)**

Duration	Mean Temperature (°C)		Mean Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
27-09-04 to 11-10-04	32.13	24.54	86.46	74.80	6.00
12-10-04 to 26-10-04	32.05	23.66	86.53	70.56	1.60
27-10-04 to 10-11-04	29.68	22.01	90.40	80.60	4.28
11-11-04 to 26-11-04	28.90	17.20	84.86	72.86	1.03
27-11-04 to 10-12-04	28.17	18.36	83.46	66.33	0.00
11-12-04 to 26-12-04	30.26	18.40	93.80	73.13	0.00
27-11-04 to 08-01-05	26.20	16.82	91.00	68.00	0.00
09-01-05 to 24-01-05	30.22	17.82	93.00	69.80	0.18



**Plate 1: View of experimental details**

## **CHAPTER – IV**

### **RESULTS**

The investigation consists of field experiment conducted at the Agricultural College Farm, Bapatla during the *Maghi* season, 2004-2005 to study the physiological assessment of 15 sweet sorghum cultivars *viz.*, SSV 84, SSV 74, Seredo, NTJ<sub>2</sub>, ICSV 574 (SPV 472), Ent 64 DTN, ICSV 700, ICSV 93046, ICSV 37 (70310), ICSV 56 (70325), ICRR 108, ICSR-196, ICSV 96117, S 35 and ICSR 93034, and their suitability in coastal Andhra.

Data collected on various morphological, physiological, biochemical and yield parameters in sweet sorghum cultivars were statistically analysed and the results are presented in this chapter.

#### **4.1 MORPHOLOGICAL CHARACTERS**

##### **4.1.1 Plant Height**

The data on plant height of 15 sweet sorghum cultivars were recorded at an interval of 15 days and statistically analyzed data are presented in Table 4.1 and Fig. 5.1.

Plant height increased gradually reaching maximum level at maturity with the advancement of crop age in all cultivars. At 15 DAS significant differences were observed in plant height among the sweet sorghum cultivars under trial. The cultivar SSV 84 (17.0 cm) attained significantly the maximum

plant height than the rest of the cultivars followed by the other cultivars NTJ<sub>2</sub>, Ent 64 DTN, SSV 74, S-35 and ICSR 93034 which were on a par with each other in respect of plant height. While the cultivar ICSR-37 recorded significantly lesser plant height at 15 DAS.

The cultivar SSV 84 (137.7 cm) along with other cultivars like SSV 74, Ent 64 DTN NTJ<sub>2</sub> and S-35 recorded significantly higher plant height than the remaining cultivars. While the lowest being with the cultivar ICSR 37 (96.0 cm) and ICRR 108 (100 cm) at 30 DAS.

Gradual increase with plant height was observed in all cultivars with the advancement of crop growth. The cultivar SSV 84 (284.0 cm) followed by SSV74 (265.3 cm) recorded significantly more plant height than S 35, NTJ<sub>2</sub>, ICSV 700 and ICSV 93046 which were in turn superior to rest of the cultivars at 45 DAS. Similar trend in plant height was noticed at 60 DAS also.

At 75 DAS also the cultivar SSV 84 (306.3 cm) registered significantly more plant height over the cultivars ICSV-700 SSV 74 and S-35 which were in turn superior to the rest of the cultivars. The cultivar ICSR-37 (153.7 cm) continued to record significantly lesser plant height at this stage also.

Cultivar SSV 84 (309.7 cm) maintained its superiority in plant height over the rest of cultivars at 90 DAS, followed by ICSV 700, ICSV 93046 and SSV 74 which were at par with each other and in turn superior to other cultivars. However, at maturity the maximum plant height of 318 cm was

recorded with the cultivar ICSV 700 (318 cm). However, It was on a par with the cultivars ICSV 93046, SSV 84 and SSV74.

#### **4.1.2 Internodal Length**

The mean data on the internodal length are presented in Table 4.2 and Fig. 5.2. There was a gradual increase in internodal length of stalk from flowering to harvesting stage. Internodal length was significantly more in cultivar SSV 84 (25.16 cm) than all other cultivars. It was followed by the cultivars SSV 74, ICSV 700, S-35, ICSV 93034, NTJ<sub>2</sub> and ICSV 93046 which were in turn superior to the rest of the cultivars at flowering stage. The cultivars ICSV 700 followed by, ICSV 93046 and SSV 84 recorded significantly more internodal length (cm) than that of other cultivars at harvest.

The cultivar ICSR-37 (8.83 cm) recorded significantly lower internodal length throughout the crop duration when compared to other cultivars in the study.

#### **4.1.3 Basal Stalk Diameter**

Mean data on the basal stalk diameter was recorded at flowering and maturity are presented in Table 4.2.

Basal stalk diameter was significantly more in the cultivars *viz.*, SSV 84 (2.32 cm), ICSR 37 (2.31 cm), ICSV 56 (2.15 cm) and S-35 (2.13 cm) when compared to other cultivars. At harvest the cultivars ICSR 37 (2.80 cm), ICSV 700 (2.80 cm) and ICSV 93046 (2.74 cm) attained significantly more basal

diameter over the remaining cultivars. The cultivar Seredo attained the lowest basal diameter at both stages *i.e.*, flowering and harvesting stages.

## **4.2.0 PHYSIOLOGICAL PARAMETERS**

### **4.2.1 Leaf Area Index (LAI)**

The mean data pertaining to LAI of 15 sweet sorghum cultivars are presented in Table 4.3 and Fig. 5.3.

An increase in the Leaf Area Index in all the 15 sweet sorghum cultivars was noticed with the advancement of crop growth up to flowering stage and thereafter it decreased gradually.

There was no significant variation in LAI among the cultivars under trial at 15 DAS. After 30 DAS the cultivar SSV 84 (1.46) followed by cultivar SSV 74 (1.34) recorded significantly higher LAI over the rest of the cultivars. These were followed by the cultivars NTJ<sub>2</sub>, Ent 64 DTN and S-35, which recorded LAI at par with cultivar SSV 74. No significant variation in LAI among different cultivars at 45 DAS was observed.

At 60 DAS significantly more LAI was recorded by the cultivars SSV 84 (4.07), ICSR-37 (4.03) and NTJ<sub>2</sub> (3.69) over rest of the cultivars. The cultivar SSV 84 (3.88) recorded significantly maximum LAI over the rest of the cultivars at 75 DAS. However, it was on a par with the cultivars r SSV 74, ICSR 37, ICSV 700, ICSV 93046, S-35 and ICSV 93034. A gradual decrease

in LAI from 75 DAS onwards observed in all cultivars. Similar trend in variation of leaf area index among the cultivars was observed at 90 DAS also.

At harvest LAI the cultivars in SSV 84 followed by SSV 74, ICSV 700, ICSV 93046, ICSR 37, NTJ<sub>2</sub>, S-35, ICSR 93034, ICSV 574 and Ent 64 DTN recorded higher LAI when compared to the rest of the treatments. Where as the cultivar Seredo (2.06) recorded the lowest LAI from 75 DAS to maturity.

#### **4.2.2 Crop Growth Rate (CGR) ( $\text{g m}^{-2} \text{d}^{-1}$ )**

The data on crop growth rate of 15 sweet sorghum cultivars are presented in Table 4.4 and graphically represented in Fig. 5.4. CGR, which is a measure of rate of biomass production per unit ground area per unit time, was increased with the advancement of crop age up to 90 DAS.

At 15-30 DAS, cultivar SSV 84 (0.457) recorded the highest CGR. However it was on a par with the cultivars like NTJ<sub>2</sub>, Ent 64 DTN, SSV 74, S-35, ICSR 93034, and ICSV 96117. Similarly, CGR recorded between 30-45 DAS was significantly higher with the cultivar SSV 84 (4.53) followed by the Ent 64 DTN, SSV 74 NTJ<sub>2</sub>, S-35, ICSV 93034, ICSV 574, ICSV 700, and ICSR 37 and these were superior to Seredo, ICSV 96117 and ICSV 93046.

At 45-60 DAS, the cultivar SSV 84 (3.70) continued to register higher CGR, which was on a par with the cultivars SSV 74, S-35 NTJ<sub>2</sub> ICSR 93034, ICSV 700, ICSR 37 and ICSV 93046 and these were significantly superior to Seredo, ICSV 56, ICRR 108, ICSR 196 and ICSV 96117. Almost a similar

trend was observed at 65- 75 DAS. However the lowest CGR was recorded with the cultivar ICRR 108 at this stage.

At 75-90 DAS the cultivar SSV 84 (12.00) retained significantly highest CGR values followed by ICSV 700, SSV 74, NTJ<sub>2</sub>, S-35, ICSV 93046 and ICSR 93034 when compared to the rest of the cultivars except Ent 64 DTN, ICSV 574 and ICSR 37.

At maturity (90-110 DAS), cultivar SSV 84 (5.06) followed by ICSV 700, ICSV 93046, SSV 74, NTJ<sub>2</sub> and S-35 recorded significantly higher CGR values over the rest of the cultivars except ICSR 93034, and Ent 64 DTN.

In general, the cultivars *viz.*, SSV 84, SSV 74, ICSV 700, S-35, ICSV 93046 and NTJ<sub>2</sub> maintained higher CGR from 60 DAS up to maturity.

#### **4.2.3 Relative Growth Rate (RGR)**

The mean data on Relative growth rate of 15 sweet sorghum cultivars are presented in Table 4.5 and Fig. 5.5. RGR is the measure of rate of drymatter production per unit of drymatter present per unit time. The RGR was highest at initial stage (15-30 DAS) and decreased gradually by advancement of crop age untill 60 DAS and then again increased between 75-90 DAS. The RGR was less at maturity.

The RGR observed with SSV 84 (61.0) was significantly superior to the rest of the cultivars. However it was on a par with the cultivars SSV74 (60.3),

NTJ<sub>2</sub> (60.0), Ent64DTN (60.0), S-35 (60.0) and ICSV 93034 (60.0) at 15-30 DAS.

The cultivar SSV 84 (V<sub>1</sub>) (28.60) recorded highest RGR between 30-45 DAS followed by cultivars like SSV 74 (28.30), Ent 64 DTN (28.0) and NTJ<sub>2</sub> (27.6). RGR was significantly higher with the cultivars SSV 84 (22.0), SSV 74 (21.5), NTJ<sub>2</sub> (21.3), S-35 (21.3) and ICSR 93034 (21.0) than that recorded with the cultivars Seredo (19.0), ICSV 56 (18.67), ICSR 196 (18.53) and ICRR 108 (18.3) at 45-60 DAS.

The cultivars *viz.*, SSV 84 (39.0), SSV 74 (38.5) and ICSV 700 (38.3) were found superior to rest of the cultivars in respect of RGR at 60-75 DAS.

At 75-90 DAS also the above cultivars in addition to ICSV 93046 and S 35 attained superior RGR compared to rest of the cultivars. At maturity (90-110 DAS) RGR was significantly higher with the cultivars ICSV 93046 (21.3) and ICSV 700 (20.0) than the rest of the cultivars

#### **4.2.4 Net Assimilation Rate (NAR)**

The data on net assimilation rate of 15 sweet sorghum cultivars at different stages are presented in Table 4.6 and Fig. 5.6. NAR, which is a measure of rate of drymatter production per unit leaf area (assimilatory apparatus) per unit time, was found to be the maximum between 30-45 DAS. Afterwards it decreased gradually and reached the least value at harvest.

Significant variation in NAR was observed at 30-45, 45-60 and 60-75 DAS only. The differences among different cultivars with regard to NAR were not significant at the remaining stages.

NAR at 30-45 DAS was significantly higher in cultivars like SSV 84, SSV 74 and S-35 when compared to ICSV 56, ICSR 196, ICRR 108 and Seredo .At 45-60 DAS cultivar SSV 84 (1.69) and SSV 74 (1.64) recorded significantly more NAR than that recorded with the cultivars ICSV 56 and ICRR 108.

At 60-75 DAS NAR was significantly higher in SSV 84 (0.38), ICSV 700 (0.38), ICSR 37 (0.38), SSV 74 (0.36), S-35 (0.36), ICSV 93046 (0.35) and ICSV 574 (0.35) than that recorded with the cultivar ICRR 108 (0.31).

## **4.2.5 Drymatter Partitioning**

### **4.2.5.1 Root Dry Weight**

Mean data recorded at different stages on the drymatter ( $t\ ha^{-1}$ ) partitioning in to different plant parts *viz.*, roots, stems, leaves and reproductive organs in 15 sweet sorghum cultivars are presented in Table 4.7 and graphically represented in Fig. 5.7. At vegetative stage, NTJ<sub>2</sub> (2.82) produced significantly higher root drymatter over other cultivars. However it was on a par with the cultivars like ICSR 196 (1.68), ICSR 37 (1.66), ICSV 56 (2.11), ICSR 93034 (1.61), ICSV 574 (1.51) in increasing root dry weight.

At flowering stage root drymatter was significantly more in ICSV 700 (3.04) followed by the cultivars SSV 84 (3.02) and SSV 74 (3.00) over the rest of the cultivars.

At maturity cultivars ICSV 700 (4.03) and SSV 84 (3.85) recorded significantly high root dry weight followed by ICSV93046 (3.38), SSV74 (3.25), ICSR93034 (3.01) ICSV 56 (3.04) Ent64DTN (3.02) and S-35 (3.01), when compared to all other cultivars like ICSV 574 (2.45), ICSR 196 (2.57), ICRR 108 (2.62), ICSR-37 (2.73), ICSV 96117 (2.63) and Seredo (2.70)

#### **4.2.5.2 Stem Dry weight**

The mean data on stem dry weight recorded at three growth stages *viz.*, vegetative, flowering and harvesting are presented in Table 4.7 and Fig. 5.7.

The cultivar SSV 84 (5.28) recorded the maximum stem dry weight at vegetative stage. However the stem dry weight attained by the remaining cultivars were statistically at par with SSV 84 except ICSR37 (3.19) which recorded the lowest stem dry weight.

However, the drymatter accumulation was increased up to two folds from vegetative stage to flowering stage and marginal increase was observed at harvesting stage. Among all the cultivars the cultivars ICSR 37 (6.60 and 7.47) recorded significantly lower stem dry mater at all growth stages. The cultivars SSV 84 (10.48) and other cultivars continued to produce more stem dry weight, and the differences among most of these cultivars were not significant.

However, cultivars like ICSR 37, ICSV 56, ICSR 196 and Seredo recorded significantly lower stem dry weight compared to the rest of the cultivars at flowering.

At maturity, cultivar ICSV 700 (12.48) accumulated significantly more drymatter in stem over cultivars SSV 84 (11.65), SSV 74 (11.06), ICSV 93046 (11.05), S-35 (10.38), NTJ<sub>2</sub> (10.31), ICSV 574 (10.13) which were in turn significantly superior to the rest of the cultivars under trial. Stem drymatter in the cultivars ICRR 108, ICSV 37, and Seredo was significantly the lowest among all sweet sorghum cultivars.

#### **4.2.5.3 Leaf Dry weight**

The data on leaf dry weight of fifteen sweet sorghum cultivars recorded at vegetative, flowering and harvesting stages are presented in Table 4.7 and Fig. 5.7.

At vegetative stage, the cultivars ICSV 93046 (3.79), Ent 64 DTN (3.69), SSV 84 (3.67) and SSV 74 (10.72) were superior in leaf drymatter accumulation to cultivars S-35 (3.43), ICSR 93034 (3.42) and ICSV 574 (3.36), which were in turn produced significantly more leaf drymatter when compared to rest of the cultivars.

There was an increase in leaf drymatter with the advancement of crop age up to flowering stage and a little reduction in leaf drymatter was observed in all cultivars at maturity. Leaf drymatter at flowering stage was significantly

more in ICSV 93046 (6.47), SSV 84 (6.40) and ICSV 700 (6.39) when compared to ICSR 196 (4.40), ICSV 96117 (3.92), ICRR 108 (4.21) except the cultivars ICSR-37 (5.88), NTJ<sub>2</sub> (5.07), S 35 (5.80), ICSR 93034 (4.61), ICSV 574 (5.72) and Ent 64 DTN.

At maturity stage, leaf drymatter was significantly higher in cultivars SSV 84 (5.43), ICSV 700 (5.41), Ent 64 DTN (5.15) and ICSR 93034 (5.09) when compared to the Seredo (3.61) and ICRR 108 (3.60) at maturity stage.

#### **4.2.5.4 Dry weight of Panicle**

The data on panicle dry weight recorded at flowering and harvesting stages are presented in Table 4.7 and Fig. 5.7. Significantly higher panicle dry weight was recorded by ICSR 56 (2.22) and ICSV 93046 (2.19) at flowering stage when compared to NTJ<sub>2</sub> (1.12) and ICRR 108 (1.11) and the rest of the cultivars were found to be on a par with ICSV 93046 and ICSR 56.

However, at maturity the cultivar ICSR 37 (3.54) possessed significantly higher panicle dry weight followed by cultivars SSV 84 (3.30), Seredo (3.18), S-35 (2.97), SSV 74 (2.82) and ICSR 93034 (2.79) when compared to the remaining cultivars. The lowest dry weight of the panicle was recorded by ICSV 96117 (1.49).

#### **4.2.5.5 Total Drymatter**

The data on total drymatter of 15 sweet sorghum cultivars are presented in Table 4.7 and Fig. 5.7. There was an increasing trend in total drymatter

accumulation in plant throughout the crop growth period reaching the maximum dry weight in all cultivars at maturity stage. The cultivar SSV 84 (11.45) followed by SSV 74 (10.72), S-35 (10.30), ICSV 93034 (10.18), NTJ<sub>2</sub> (10.13) possessed significantly higher total drymatter than rest of the cultivars at vegetative stage.

At flowering stage, cultivars SSV 84 (22.07), ICSV 700 (21.99), SSV 74 (21.30), ICSV 93046 (20.09), S-35 (19.73) were superior to rest of the cultivars except Ent 64 DTN (19.25), NTJ<sub>2</sub> (19.16), ICSR 93034 (19.03) and ICSV 574 (18.71) in producing total drymatter.

At maturity, total drymatter was significantly higher in SSV 84 (24.23), ICSV 700 (23.67) than SSV 74 (21.93), ICSV 93046 (20.89), S-35 (20.50), ICSR 93034 (20.12), Ent 64 DTN (19.94), NTJ<sub>2</sub> (19.87) which were in turn superior to rest of the cultivars except ICSV 574 (19.45), ICSR 56 (18.71).

#### **4.2.3 Days to 50 per cent Flowering**

The mean data on number of days taken for 50 per cent flowering are presented in Table 4.8. There was a significant variation in number of days to attain 50 per cent flowering among 15 sweet sorghum cultivars under trial.

The cultivars ICSV 93046 and ICSV 700 recorded significantly more days for 50 per cent flowering than the rest of the cultivars. The cultivars ICSR 196, ICSV 96117, ICRR 108, ICSV 574 and ICSV 93034 also took more number of days to flowering over the cultivars Ent 64 DTN, SSV 84, Seredo,

SSV 74, IS-35 and NTJ<sub>2</sub>. The cultivar ICSR 37 took very less number of days (49) for 50 per cent flowering.

### **4.3 BIO-CHEMICAL CHARACTERS**

#### **4.3.1 Total Soluble Sugars**

The data pertaining to total soluble sugars (TSS) in brix percentage in the stalk juice are furnished in Table 4.10.

Total soluble sugars at flowering were significantly higher in SSV 84 (12.5) and SSV 74 (12.3) over all other cultivars. It was followed by NTJ<sub>2</sub> (11.5), S-35 (11.3), Ent 64 DTN (11.3), Seredo (11.0), ICSV 93034 (11.0) and ICSV 96117 (10.8). The cultivars ICSV 93046 (5.7) and ICSR 37 (5.3) recorded the lowest brix percentage.

At maturity also, cultivars SSV 84 (14.5) and SSV 74 (14.3) produced significantly higher TSS when compared to rest of the cultivars followed by Seredo (10.8) and S-35 (10.6). TSS content was significantly less in ICSV 700 (4.5), ICSV 93046 (4.5) and ICSR 37 (4.2) than in the rest of the cultivars.

#### **4.3.2 Reducing Sugars**

The data pertaining to reducing sugars in stalk juice are summarized in Table 4.10. Significant differences were observed in reducing sugars among all cultivars both at flowering and harvesting stages.

At flowering stage, the cultivar Seredo (4.9) accumulated maximum percentage of reducing sugars followed by SSV 84 (4.4) and SSV 74 (4.3), these were significantly superior to rest of the cultivars except the cultivars ICSV 574 and ICSV 56.

At maturity reducing sugars were significantly lower in cultivars ICSV 93046 (1.5), ICSV 700 (1.5) and ICSR 37 (1.0). While the differences among the rest of the treatments in respect of reducing sugars in stalk juice was not significant.

#### **4.3.3 Non-Reducing Sugars**

The data on non-reducing sugars at both flowering and harvesting stages are presented in Table 4.10.

Non-Reducing Sugars (NRS) were significantly higher in SSV 84 (7.1) followed by SSV 74 and NTJ<sub>2</sub> when compared to remaining cultivars at flowering stage.

At maturity significantly, higher NRS values are recorded in SSV 84 (7.5), SSV 74 (7.4) followed by NTJ<sub>2</sub> (4.2), S-35 (3.8) when compared to the rest under study and very less values were observed in ICSV 700 (3.5), ICSV 93046 (3.3) and ICSR 37 (3.3).

#### **4.3.5 Fermentable Sugar Yield**

The mean data of Fermentable Sugar Yield at flowering and harvesting stages are presented in Table 4.10.

At flowering, the cultivars SSV 84 (4.9), SSV 74 (4.8), NTJ<sub>2</sub> (4.5), Ent 64 DTN (4.2) and S-35 (3.83) were found superior in higher sugar yield (t/ha) to the rest of the cultivars.

At maturity, the cultivars *viz.*, SSV 84 (5.0), SSV 74 (4.9), NTJ<sub>2</sub> (3.33) and S-35 (3.31) recorded significantly higher Fermentable Sugar Yields (t/ha) when compared to the remaining treatments under study.

#### **4.3.6 Ethanol Estimation (L/ha)**

The data presented in Table 4.10 and Fig. 5.10 showed that ethanol production was comparatively more at flowering stage rather than at harvesting. Significant difference in ethanol production was observed among the sweet sorghum cultivars under trial.

Among all the cultivars, SSV 84 (3012), SSV 74 (2944) and NTJ<sub>2</sub> (2779) produced significantly more ethanol at flowering when compared to rest of the cultivars except the cultivar S-35 (2368).

The cultivars SSV 84 (3072) and SSV 74 (3002) were found superior to all the remaining cultivars, NTJ<sub>2</sub> (2057), S-35 (2045) which, in turn produced significantly more ethanol at both stages *i.e.*, flowering and harvesting when compared to remaining cultivars under trial.

However, ethanol production was very less in some of the high grain yielded cultivars like ICSR 37, both at flowering (959) and harvesting (451) stages.

## **4.4 YIELD AND YIELD COMPONENTS**

### **4.4.1 Cane Length**

The data pertaining to cane length of different sweet sorghum cultivars recorded at flowering and harvesting are presented in Table 4.9 and Fig. 5.2. The cane length was important factor for milling, juice yield, as well as the stalk yield for ethanol production. Marginal increase in cane length was observed with advancement of crop age. However, significantly higher cane length was observed at flowering in the cultivar SSV 84 over the rest of the cultivars followed by SSV 74. The cultivars ICSV 700 and ICSV 93046 were next in the order of increased cane length compared to the other treatments at flowering. However, at maturity stage ICSV 700 and ICSV 93046 along with SSV 84 recorded significantly more cane length when compared to other cultivars under trial.

### **4.4.2 Stripped Stalk Yield**

The data on stalk yield of 15 sweet sorghum cultivars recorded at both flowering and maturity stage are presented in Table 4.9 and Fig. 5.2.

Stripped stalk yield at flowering was significantly more in ICSV 700, SSV 84 and SSV 74 when compared to the remaining cultivars and the lowest stalk yield was observed with ICSR 37 both at flowering and maturity stage. While the cultivars ICSV 700 and SSV 84 produced the maximum stalk yield over the remaining all the cultivars at maturity.

#### **4.4.3 Panicle Length**

The data on panicle (ear head) length of 15 sweet sorghum cultivars is presented in Table 4.8. There was a significant difference in panicle length among all cultivars. The cultivar ICSR 37 possessed maximum panicle length and it was on a par with the cultivars SSV 84, SSV 74, Seredo, IS-35, ICSR 93034, Ent 64 DTN and NTJ<sub>2</sub>. The cultivars ICSV 700, ICSV 93046 and ICSV 96117 recorded smaller panicles compared to the other cultivars.

#### **4.4.4 Grain Weight per Panicle**

The data on grain weight per panicle (ear head) is represented in Table 4.8. Significant differences were observed among all 15 sweet sorghum cultivars.

The cultivar ICSR 37 recorded significantly more grain weight per panicle, on a par with the cultivars Seredo, SSV 84, SSV 74, S-35 over ICSV 93034 when compared to the rest of the cultivars except Ent 64 DTN and ICSV 56.

#### **4.4.5 Test Weight**

The mean data on the test weight for 15 sweet sorghum cultivars are presented in Table 4.8. Significant differences were observed among all the cultivars.

The cultivar ICSR 37 recorded significantly more test weight followed by Seredo, SSV 84 and IS-35, SSV 74, ICSV 93034 and Ent 64 DTN when compared to rest of the cultivars, and the least being in the cultivars ICSV 96117 and ICSV 93046,

#### **4.4.6 Total Grain Yield**

Mean data on the total grain yield (t/ha) of 15 sweet sorghum cultivars under trial are presented in Table 4.8.

The grain yield recorded was significantly higher with the cultivar ICSR 37 followed by SSV 84 and Seredo when compared to other cultivars. The lowest grain yields were recorded with ICSV 96117 followed by ICSV 93046.

**Table 4.1: Plant height (cm) of sweet sorghum cultivars at different stages of crop growth**

Cultivar	Days after sowing						
	15	30	45	60	75	90	110 (Maturity)
<b>SSV 84</b>	17.0	137.7	284.0	294.3	306.3	309.7	310.7
<b>SSV 74</b>	15.0	136.7	265.3	280.0	292.0	298.3	302.3
<b>Seredo</b>	11.0	112.3	179.7	187.7	193.7	197.7	198.0
<b>NTJ2</b>	15.5	135.0	235.0	252.0	278.3	281.7	289.3
<b>ICSV 574</b>	12.0	118.0	205.3	234.3	248.0	257.7	261.7
<b>Ent 64 DTN</b>	15.2	135.0	225.7	238.0	260.7	270.3	271.3
<b>ICSV 700</b>	10.5	113.7	234.0	260.0	292.7	300.7	318.0
<b>ICSV 93046</b>	10.0	112.3	226.7	246.0	273.3	299.7	315.0
<b>ICSR 37</b>	8.5	96.0	132.3	149.3	153.7	162.0	162.3
<b>ICSV 56</b>	12.5	107.3	170.0	185.7	210.0	216.8	222.0
<b>ICRR 108</b>	12.3	100.0	142.0	164.3	174.7	176.0	180.3
<b>ICSR 196</b>	12.5	106.3	169.3	182.7	188.0	200.3	206.0
<b>ICSV 96117</b>	13.2	107.7	185.0	210.7	217.6	224.7	226.0
<b>S 35</b>	15.0	132.3	241.0	259.7	285.0	287.0	289.0
<b>ICSR 93034</b>	14.7	118.7	235.0	256.0	266.3	271.7	285.0
<b>SEm ±</b>	0.37	3.11	3.62	4.17	4.17	2.56	2.95
<b>CD (p=0.05)</b>	0.95	7.81	9.37	10.47	10.87	7.02	8.04
<b>CV (%)</b>	4.95	4.50	3.00	8.90	5.60	6.17	6.98

**Table 4.2: Internodal length and basal stalk diameter of sweet sorghum cultivars at flowering and harvesting**

Cultivar	Internodal length (cm)		Basal stalk diameter (cm)	
	Flowering	Maturity	Flowering	Maturity
<b>SSV 84</b>	25.16	28.10	2.32	2.35
<b>SSV 74</b>	24.00	27.50	2.04	2.33
<b>Seredo</b>	12.10	12.58	1.68	1.99
<b>NTJ<sub>2</sub></b>	21.73	23.66	2.11	2.34
<b>ICSV 574</b>	17.33	20.03	1.80	2.19
<b>Ent 64 DTN</b>	18.33	21.00	1.97	2.20
<b>ICSV 700</b>	22.73	28.33	1.79	2.80
<b>ICSV 93046</b>	21.66	28.16	1.75	2.74
<b>ICSR 37</b>	8.10	8.83	2.31	2.80
<b>ICSV 56</b>	9.96	14.46	2.15	2.30
<b>ICRR 108</b>	8.96	9.33	1.94	2.10
<b>ICSR 196</b>	9.45	12.58	2.03	2.21
<b>ICSV 96117</b>	16.40	17.30	2.07	2.19
<b>S 35</b>	22.50	23.66	2.13	2.40
<b>ICSR 93034</b>	21.83	23.30	2.08	2.32
<b>SEm ±</b>	0.36	0.31	0.08	0.12
<b>CD (p=0.05)</b>	0.98	0.86	0.23	0.31
<b>CV (%)</b>	6.30	6.20	6.67	8.43

**Table 4.3: Leaf area index of sweet sorghum cultivars at different stages of crop growth**

Cultivar	Days after sowing						
	15	30	45	60	75	90	110 (Maturity)
<b>SSV 84</b>	0.27	1.46	3.13	4.07	3.88	3.38	3.20
<b>SSV 74</b>	0.26	1.34	3.11	4.00	3.76	3.28	3.10
<b>Seredo</b>	0.13	0.97	2.01	3.07	2.89	2.15	2.06
<b>NTJ<sub>2</sub></b>	0.19	1.11	2.86	3.69	3.06	3.05	3.01
<b>ICSV 574</b>	0.18	1.01	2.66	3.38	3.01	2.98	2.92
<b>Ent 64 DTN</b>	0.18	1.08	2.83	3.43	3.06	2.99	2.90
<b>ICSV 700</b>	0.14	0.88	2.85	3.80	3.69	3.15	3.06
<b>ICSV 93046</b>	0.13	0.86	2.62	3.76	3.44	3.11	3.05
<b>ICSR 37</b>	0.20	1.01	3.05	4.03	3.72	3.22	3.04
<b>ICSV 56</b>	0.17	0.80	2.66	3.04	2.99	2.94	2.56
<b>ICRR 108</b>	0.14	0.77	2.56	3.02	2.96	2.80	2.45
<b>ICSR 196</b>	0.16	0.80	2.65	3.03	3.03	2.87	2.53
<b>ICSV 96117</b>	0.16	0.75	2.54	3.00	3.00	2.93	2.65
<b>S 35</b>	0.23	1.08	2.95	3.62	3.40	2.97	2.96
<b>ICSR 93034</b>	0.21	1.05	2.88	3.48	3.21	3.08	2.94
<b>SEm±</b>	0.01	0.89	0.56	0.35	0.29	0.30	0.26
<b>CD (p=0.05)</b>	NS	0.27	NS	0.87	0.75	0.76	0.69
<b>CV (%)</b>	4.90	5.6	3.5	5.17	3.39	5.18	5.19

**Table 4.4: Crop growth rate ( $\text{g m}^{-2} \text{d}^{-1}$ ) of sweet sorghum cultivars at different stages of crop growth**

Cultivar	Days after sowing					
	15 -30	30-45	45-60	60-75	75-90	110 (Maturity)
<b>SSV 84</b>	0.46	4.53	3.70	8.50	12.00	5.06
<b>SSV 74</b>	0.39	4.34	3.67	8.23	11.30	4.23
<b>Seredo</b>	0.32	3.90	3.10	4.03	6.60	1.76
<b>NTJ<sub>2</sub></b>	0.42	4.27	3.60	5.20	10.00	4.13
<b>ICSV 574</b>	0.27	4.13	3.30	4.50	8.26	2.86
<b>Ent 64 DTN</b>	0.43	4.37	3.40	4.60	8.33	3.26
<b>ICSV 700</b>	0.32	4.10	3.50	7.76	12.00	5.03
<b>ICSV 93046</b>	0.26	3.90	3.43	5.23	9.90	4.80
<b>ICSR 37</b>	0.30	4.10	3.45	5.20	7.86	1.56
<b>ICSV 56</b>	0.35	3.56	2.80	2.60	6.16	2.83
<b>ICRR 108</b>	0.32	3.46	3.10	1.96	5.30	1.70
<b>ICSR 196</b>	0.32	3.50	2.77	2.20	5.33	1.96
<b>ICSV 96117</b>	0.36	3.90	3.13	4.16	6.76	2.83
<b>S 35</b>	0.39	4.17	3.63	7.40	11.00	4.10
<b>ICSR 93034</b>	0.38	4.15	3.57	5.30	9.66	3.33
<b>SEm±</b>	0.04	0.17	0.18	0.15	0.70	0.32
<b>CD (p=0.05)</b>	0.10	0.40	0.45	0.46	2.10	1.15
<b>CV (%)</b>	4.99	9.87	4.66	5.54	14.81	10.12

**Table 4.5: Relative growth rate ( $\text{mg g}^{-1} \text{d}^{-1}$ ) of sweet sorghum cultivars at different stages of crop growth**

Cultivar	Days after sowing					
	15 -30	30-45	45-60	60-75	75-90	110 (Maturity)
<b>SSV 84</b>	61.0	28.60	22.0	39.0	40.8	18.0
<b>SSV 74</b>	60.3	28.30	21.5	38.5	39.0	16.3
<b>Seredo</b>	57.5	25.0	19.0	21.6	18.0	12.3
<b>NTJ<sub>2</sub></b>	60.0	27.6	21.3	26.3	31.0	16.0
<b>ICSV 574</b>	55.5	26.6	20.0	22.3	24.0	9.5
<b>Ent 64 DTN</b>	60.6	28.0	20.3	22.6	29.0	10.0
<b>ICSV 700</b>	58.0	26.0	20.6	38.3	39.5	20.0
<b>ICSV 93046</b>	56.0	25.3	20.5	24.3	38.0	21.3
<b>ICSR 37</b>	55.0	24.0	20.5	24.0	19.0	8.0
<b>ICSV 56</b>	56.5	23.3	18.67	21.0	16.5	9.0
<b>ICRR 108</b>	56.2	22.0	18.3	20.0	15.0	10.0
<b>ICSR 196</b>	57.0	23.0	18.53	20.6	15.6	11.0
<b>ICSV 96117</b>	57.2	24.33	19.6	21.8	17.6	9.5
<b>S 35</b>	60.0	27.6	21.3	29.6	32.0	14.0
<b>ICSR 93034</b>	60.0	27.3	21.0	26.6	30.0	13.0
<b>SEm±</b>	1.44	1.89	0.76	1.41	4.01	1.71
<b>CD (p=0.05)</b>	2.68	4.70	1.98	3.8	10.93	3.05
<b>CV (%)</b>	12.50	12.6	4.8	9.37	8.5	13.08

**Table 4.6: Net assimilation rate ( $\text{mg cm}^{-2} \text{d}^{-1}$ ) of sweet sorghum cultivars at different stages of crop growth**

Cultivar	Days after sowing					
	15 -30	30-45	45-60	60-75	75-90	110 (Maturity)
<b>SSV 84</b>	0.49	1.98	1.69	0.38	0.36	0.14
<b>SSV 74</b>	0.47	1.92	1.64	0.36	0.34	0.13
<b>Seredo</b>	0.46	1.26	1.40	0.33	0.30	0.11
<b>NTJ<sub>2</sub></b>	0.49	1.64	1.46	0.34	0.32	0.12
<b>ICSV 574</b>	0.43	1.60	1.50	0.35	0.30	0.10
<b>Ent 64 DTN</b>	0.45	1.65	1.52	0.36	0.31	0.12
<b>ICSV 700</b>	0.46	1.59	1.65	0.38	0.47	0.15
<b>ICSV 93046</b>	0.46	1.56	1.60	0.36	0.46	0.16
<b>ICSR 37</b>	0.45	1.63	1.64	0.38	0.30	0.10
<b>ICSV 56</b>	0.42	1.43	1.26	0.33	0.30	0.12
<b>ICRR 108</b>	0.41	1.40	1.25	0.31	0.28	0.11
<b>ICSR 196</b>	0.41	1.42	1.30	0.32	0.29	0.12
<b>ICSV 96117</b>	0.43	1.47	1.45	0.34	0.24	0.13
<b>S 35</b>	0.49	1.90	1.59	0.36	0.34	0.14
<b>ICSR 93034</b>	0.44	1.87	1.55	0.35	0.30	0.13
<b>SEm±</b>	0.04	0.15	0.15	0.02	0.08	0.10
<b>CD (p=0.05)</b>	NS	0.41	NS	0.05	NS	NS
<b>CV (%)</b>	2.52	6.14	3.80	4.12	3.28	7.11

**Table 4.7: Drymatter partitioning into different plant parts of sweet sorghum cultivars at different stages of crop growth**

Cultivar	Vegetative Stage (t ha <sup>-1</sup> )				Flowering Stage (t ha <sup>-1</sup> )					Maturity Stage (t ha <sup>-1</sup> )				
	Root	Stem	Leaves	Total	Root	Stem	Leaves	Panicle	Total	Root	Stem	Leaves	Panicle	Total
<b>SSV 84</b>	2.46	5.28	3.67	11.45	3.02	10.48	6.40	2.17	22.07	3.85	11.65	5.43	3.30	24.23
<b>SSV 74</b>	2.14	4.99	3.59	10.72	3.00	10.33	5.95	2.09	21.30	3.25	11.06	4.80	2.82	21.93
<b>Seredo</b>	1.89	3.91	2.87	8.69	2.24	8.10	5.33	1.23	16.90	2.70	8.76	3.61	3.18	17.25
<b>NTJ<sub>2</sub></b>	2.82	5.26	2.17	10.13	2.67	10.30	5.07	1.12	19.16	2.98	10.31	4.30	2.28	19.87
<b>ICSV 574</b>	1.51	4.24	3.36	9.11	2.16	9.49	5.72	1.34	18.71	2.45	10.13	4.70	2.17	19.45
<b>Ent 64 DTN</b>	2.05	3.63	3.69	9.37	2.77	8.74	6.15	1.59	19.25	3.02	9.39	5.15	2.38	19.94
<b>ICSV 700</b>	1.96	4.84	2.79	9.59	3.04	10.22	6.39	1.75	21.40	4.03	12.48	5.41	2.14	24.06
<b>ICSV 93046</b>	1.90	3.78	3.79	9.47	2.71	9.53	6.47	1.70	19.87	3.38	11.05	4.81	2.19	21.43
<b>ICSR 37</b>	1.66	3.19	2.38	7.23	2.29	6.60	5.88	1.18	15.90	2.73	7.47	4.47	3.54	18.21
<b>ICSV 56</b>	2.11	3.49	2.82	8.42	2.39	7.65	5.43	2.18	17.65	3.04	9.70	3.81	2.22	18.77
<b>ICRR 108</b>	1.64	3.25	2.53	7.42	2.09	6.89	4.21	1.11	14.31	2.62	7.19	3.60	1.89	15.30
<b>ICSR 196</b>	1.68	3.63	2.25	7.56	2.05	7.41	4.40	1.50	15.36	2.57	8.66	4.45	1.83	17.51
<b>ICSV 96117</b>	2.05	4.42	2.38	8.85	2.88	9.18	3.92	1.42	17.40	2.63	8.71	4.21	1.49	17.04
<b>S 35</b>	2.12	4.76	3.43	10.30	2.30	10.33	5.80	1.30	19.73	3.01	10.38	4.20	2.97	20.56
<b>ICSR 93034</b>	1.61	5.15	3.42	10.18	2.80	10.21	4.61	1.41	19.03	3.12	9.12	5.09	2.79	20.12
<b>SEm±</b>	0.40	0.80	0.11	0.61	0.30	0.70	0.70	0.42	0.70	0.10	0.10	0.50	0.12	0.61
<b>CD (p=0.05)</b>	1.00	2.06	0.27	1.76	0.74	1.91	1.95	1.07	2.01	0.26	0.28	1.47	0.32	1.59
<b>CV (%)</b>	3.09	3.61	63.00	11.58	5.55	6.60	6.16	7.58	10.92	10.56	9.50	3.56	10.61	10.00

**Table 4.8: Bio-chemical parameters of sweet sorghum cultivars at flowering and maturity**

Cultivar	T.S.S (B <sup>0</sup> ) %		Fermentable sugar yeild (t ha <sup>-1</sup> )		Reducing Sugar (%)		Non-Reducing Sugar (%)		Ethanaol Estimation (L ha <sup>-1</sup> )	
	Flowering	Maturity	Flowering	Maturity	Flowering	Maturity	Flowering	Maturity	Flowering	Maturity
<b>SSV 84</b>	12.5	14.5	4.9	5.0	4.4	3.0	7.1	7.5	3012	3072
<b>SSV 74</b>	12.3	14.3	4.8	4.9	4.3	3.0	7.0	7.4	2944	3002
<b>Seredo</b>	11.0	10.3	3.4	3.1	4.9	2.4	6.2	3.5	2071	1923
<b>NTJ<sub>2</sub></b>	11.5	10.2	4.5	3.3	4.0	3.0	6.6	4.2	2779	2057
<b>ICSV 574</b>	10.0	8.3	3.5	2.6	3.5	2.2	5.5	3.1	2139	1876
<b>Ent 64 DTN</b>	11.3	9.2	4.2	3.0	4.0	2.5	6.3	3.7	2596	1676
<b>ICSV 700</b>	7.2	4.5	3.0	1.7	2.5	1.5	3.7	1.7	1675	1078
<b>ICSV 93046</b>	5.7	4.5	2.4	1.6	1.9	1.5	2.6	1.7	1481	971
<b>ICSR 37</b>	5.3	4.2	1.6	0.7	1.9	1.0	2.6	1.8	959	451
<b>ICSV 56</b>	9.2	8.1	2.6	1.8	3.2	2.1	5.0	3.0	1591	1089
<b>ICRR 108</b>	8.7	5.8	2.4	1.5	3.0	1.9	4.7	2.5	1468	935
<b>ICSR 196</b>	8.9	7.7	2.5	1.7	3.1	2.0	4.7	2.7	1565	1057
<b>ICSV 96117</b>	10.8	9.0	3.3	2.3	3.9	2.2	6.2	3.3	2031	1421
<b>S 35</b>	11.3	10.6	3.9	3.3	4.0	2.5	6.3	3.8	2368	2045
<b>ICSR 93034</b>	11.0	8.7	3.5	2.6	3.9	2.3	6.3	3.2	2170	1589
<b>SEm±</b>	0.25	0.24	0.40	0.66	0.27	0.63	0.14	0.18	83.6	67.0
<b>CD (p=0.05)</b>	0.72	0.69	1.09	1.80	0.77	1.83	0.41	0.52	252.1	203.8
<b>CV (%)</b>	4.42	6.50	5.04	4.82	1.31	4.98	4.50	10.02	8.24	8.27

**Table 4.9: Cane length and stripped stalk yield of sweet sorghum cultivars at flowering and maturity**

Cultivar	Cane length (cm)		Stripped Stalk yeild (t ha <sup>-1</sup> )	
	Flowering	Maturity	Flowering	Maturity
<b>SSV 84</b>	183.56	192.03	52.86	53.04
<b>SSV 74</b>	177.16	188.00	51.91	51.95
<b>Seredo</b>	117.46	125.00	40.13	40.15
<b>NTJ<sub>2</sub></b>	158.13	180.33	50.54	50.69
<b>ICSV 574</b>	147.00	163.00	41.86	41.90
<b>Ent 64 DTN</b>	149.00	169.33	42.13	42.22
<b>ICSV 700</b>	166.10	198.66	53.25	54.58
<b>ICSV 93046</b>	157.00	198.03	49.95	52.26
<b>ICSR 37</b>	101.05	101.10	35.72	35.82
<b>ICSV 56</b>	116.00	135.00	40.77	40.90
<b>ICRR 108</b>	105.00	114.33	39.54	39.82
<b>ICSR 196</b>	115.40	130.00	39.67	40.17
<b>ICSV 96117</b>	127.33	138.86	41.40	41.85
<b>S 35</b>	164.33	180.00	50.65	50.80
<b>ICSR 93034</b>	161.96	176.66	47.17	47.24
<b>SEm±</b>	2.19	1.85	0.72	0.76
<b>CD (p=0.05)</b>	6.00	5.08	1.93	2.00
<b>CV (%)</b>	2.60	2.02	7.32	8.25

**Table 4.10: Yield components of sweet sorghum cultivars at different stages of crop growth**

<b>Cultivar</b>	<b>Days to 50% flowering</b>	<b>Days to maturity</b>	<b>Panicle length (cm)</b>	<b>Grain weight/panicle</b>	<b>Test weight (g/1000 grain)</b>	<b>Total grain yield (g m<sup>-2</sup>)</b>	<b>Total grain yield (t ha<sup>-1</sup>)</b>
<b>SSV 84</b>	51.7	100.0	24.2	28.3	23.7	346.9	3.5
<b>SSV 74</b>	51.0	100.0	24.2	27.8	23.3	304.2	3.0
<b>Seredo</b>	49.7	95.0	24.2	30.4	25.1	333.4	3.3
<b>NTJ<sub>2</sub></b>	51.7	100.0	23.3	26.5	22.3	298.6	3.0
<b>ICSV 574</b>	56.7	102.0	21.0	26.4	22.2	289.0	2.9
<b>Ent 64 DTN</b>	52.3	100.0	23.3	27.5	23.2	301.7	3.0
<b>ICSV 700</b>	60.0	110.0	18.0	20.5	19.4	248.9	2.5
<b>ICSV 93046</b>	67.7	110.0	17.5	18.9	18.0	207.9	2.1
<b>ICSR 37</b>	49.0	93.0	25.2	32.1	26.4	359.3	3.6
<b>ICSV 56</b>	51.0	98.0	21.5	27.1	20.5	296.5	3.0
<b>ICRR 108</b>	57.0	98.0	20.8	23.8	19.8	269.5	2.7
<b>ICSR 196</b>	58.0	98.0	20.3	24.1	20.0	258.5	2.6
<b>ICSV 96117</b>	58.0	98.0	17.3	17.8	15.2	196.1	2.0
<b>S 35</b>	51.0	100.0	24.1	28.0	23.5	309.1	3.1
<b>ICSR 93034</b>	56.3	100.0	24.0	27.9	23.3	302.6	3.0
<b>SEm±</b>	0.5	0.7	1.5	0.2	0.2	11.2	0.1
<b>CD (p=0.05)</b>	1.4	2.0	4.0	0.7	0.6	32.4	0.2
<b>CV (%)</b>	0.1	0.1	1.3	6.0	5.9	7.0	4.0

## **CHAPTER – V**

### **DISCUSSION**

Sweet sorghum (*Sorghum bicolor* (L.) Moench) can be used not only for production of ethanol and derivatives from the fermentation of sugars present in stem juice but also for grain production. Renewable-energy from bio-fuel (bio-ethanol) is regarded as a key element for the future sustainable mix.

In this present investigation “Physiological assessment of sweet sorghum cultivars and their suitability in Coastal Andhra”, the data on morphological, physiological and growth parameters, yield and yield components, and biochemical parameters of fifteen sweet sorghum cultivars at different growth stages were presented in the previous chapter are discussed in this chapter.

#### **5.1 MORPHOLOGICAL CHARACTERS**

Morphological characters operate indirectly in improving the economic sinks like grain yield (Chandrasekhar *et al.*, 2001) and stem in case of sweet sorghum (Sankarapandian *et al.*, 1995).

##### **5.1.1 Plant Height**

In general growth in terms of plant height (Table 4.1 and Fig.5.1) in all sweet sorghum cultivars increased several folds at 30 DAS and was almost double at 45 DAS, during vegetative phase. This was due to favourable

environmental conditions *viz.*, more rainfall, high relative humidity and high temperature prevailed during this period. These findings are in agreement with that of Barnes *et al.* (1953), who observed a close relationship between climatic factors like temperature, rainfall and stalk elongation in sugarcane. Having advantage of early vigour and growth using favourable environmental conditions the cultivars SSV84, SSV74, S35 and NTJ<sub>2</sub> recorded significantly more plant height at 45 DAS.

At 60 DAS (flowering stage) in addition to the above cultivars, the cultivars ICSV 700, ICSV 93046 Ent 64 DTN and ICSR 93034 also recorded significantly more plant height than other cultivars. The cultivars SSV 84, SSV 74, ICSV 700 and ICSV 93046 maintained more plant height from this stage onwards till maturity. The cultivars ICSV 700 and ICSV 93046 showed less plant height due to initial lag in vigour and growth until 45 DAS (vegetative stages), and these were more vigorous from 60 DAS onwards as these are long-duration cultivars. Plant height, related to the length of life cycle, has also a remarkable role in the determination of productive performance. These results are in agreement with that of Stephans & Hollaul (1954).

When compared to the other cultivars, the cultivars ICSR 37 and Seredo recorded less plant height, which may be due to their short duration in nature resulting in less growth and also ultimately productivity *i.e.*, fermentable sugars. The above results are in agreement with the findings of Putnum *et al.* (1991) who reported that plant height was more determinant factor for ethanol production in sweet sorghum varieties. Almodares and Sepahi (1997) also

found that plant height and fodder yield had a positive correlation with yield in sweet sorghum cultivars.

### **5.1.2 Internodal Length**

Cultivars like SSV 84, SSV 74, ICSV 700, S 35, ICSR 93034, NTJ<sub>2</sub> and ICSV 93046 were superior to the rest of the cultivars in respect of inter nodal length at flowering stage (Fig. 5.2). While the cultivars ICSV 700, ICSV 93046, SSV 84 and SSV 74 recorded significantly more internodal length than that of other cultivars at maturity and the least being with cultivars ICSR 37. These observations corroborate with the findings of Miller and Creelman (1980) and Narkhada *et al.* (2000), who reported mean internodal length of 30 cm in sweet sorghum variety keller and 18.8 cm in 6 sorghum varieties, respectively.

### **5.1.3 Basal Diameter**

It was evident from the data (Table 4.2 and Fig. 5.2), basal diameter (cm) was significantly more in cultivars SSV 84, ICSR 37, ICSV 56 and S 35 when compared to other cultivars at flowering stage. While the cultivars ICSR 37, ICSV 700 and ICSV 93046 attained significantly more basal diameter (cm) over the remaining cultivars at maturity. The cultivar Seredo recorded significantly less diameter at both stages *i.e.*, flowering and maturity.

Cultivars having more basal diameter have been consistently correlated with the lodging resistant and more accumulation of starch in the pith, there by the less conversion of sugars in sorghum cultivars causes more drymatter production (non sugars) (Dillewijn, 1957). Similarly, Sankarapandian *et al.* (1995) also observed stem girth of 1.07 to 2.89 cm in different sweet sorghum cultivars. Monk *et al.* (1984a) reported that basal diameter is a factor of plant size, which may influence the drymatter and juice production in stalk of sweet sorghum cultivars.

## **5.2 PHYSIOLOGICAL PARAMETERS**

The genetic variation in productivity of a crop is related to such parameters as LAI, CGR, RGR, NAR and partitioning of total photosynthates into economic organs.

### **5.2.1 Leaf Area Index**

At early stages *i.e.*, 15 and 45 DAS, non-significant differences in LAI among cultivars were observed (Fig. 5.3). At 30 DAS the cultivars SSV 84, SSV 74 recorded significantly more LAI. At flowering, cultivars SS 84, ICSR 37, SSV 74 recorded more LAI. From flowering stage onwards the cultivars SSV 84, ICSR 37, SSV 74, ICSV 700, ICSV 93046, NTJ<sub>2</sub>, S 35 in general maintained higher LAI.

The LAI was increased up to 60 DAS and afterwards, it declined. High LAI during 60 DAS might have intercepted more light and enhanced their

photosynthetic rate (NAR), which ultimately resulted in higher drymatter production stalk yield, 1000 seed weight, grain weight per panicle and grain yield. These are in confirmity with the findings of Chandrasekhar *et al.* (2001) in rice and Patil *et al.* (2003) in sweet sorghum. Naik and Muniyappa (1995) also observed relationship with leaf area and distribution of sugars and starch into stem and grain in sweet sorghum cultivars as LAI play crucial role in enhancing the photosynthetic assimilation.

### **5.2.2 Crop Growth Rate**

Crop growth rate (CGR), which is a measure of rate of biomass production per unit of ground area per unit time, was initially low in the sweet sorghum cultivars under the study and increased with advancement of crop age (Fig. 5.4). Variation in CGR leads to differential dry mater accumulation in different plant parts of cultivars with different crop duration.

In general the cultivar *viz.*, SSV 84, SSV 74, S 35, NTJ2 maintained higher CGR throughout the crop period while the cultivars ICSV 700, ICSV 93046 recorded higher CGR from 30 to 45 DAS onwards till maturity due to slow growth or vigour at initial stages *i.e.*, at 15 and 30 DAS in these cultivars. As these two are long duration cultivars slow increase in CGR during early vegetative phases was associated with poor growth of stem and leaves. As season advanced, CGR progressively increased in the cultivars with the receipt of good rainfall, other environmental conditions like more temperature and

high relative humidity. Rapid increase in CGR after ear head (panicle) formations resulted in increased accumulation of drymatter in the reproductive organs and economic sinks.

As such higher CGR at all growth stages resulted in higher total drymatter, better partitioning of drymatter, more grain yield and stalk yield in sweet sorghum cultivars, *i.e.*, SSV 74 NTJ<sub>2</sub>, S 35 and grain yield. These findings are in confirmity with those of Chandrasekhar *et al.* (2001) in rice and Veerbadhran and Kennedy (2001) in sorghum.

### **5.2.3 Relative Growth Rate**

Relative growth rate (RGR) is a measure of rate of drymatter increase per unit drymatter per unit time. It is evident from the data (Table 4.5 and Fig. 5.5), RGR in different sweet sorghum cultivars was maximum at 15-30 DAS which gave a push to the transition to flowering (reproductive phase) with slight reduction at 60 DAS and again slightly increased at 60-75 DAS and 75-90 DAS and thereafter reduced at maturity. Similar decrease in RGR with crop age in rice was observed by Chandrasekhar *et al.* (2001).

The cultivars SSV 84, SSV 74, NTJ<sub>2</sub>, S 35 and ICSR 93034 maintained more RGR throughout the crop growth period. Cultivars ICSV 700, ICSV 93046 also recorded more RGR only at later stages *i.e.*, from flowering stage onwards until maturity since these are long duration cultivars. Proso millet

cultivars having higher RGR recorded more grain yield (Dhawale *et al.*, 2003) as NAR, RGR and CGR showed a positive correlation with total drymatter and thereby yield in sorghum (Kulakarni *et al.*, 1982). Sorghum hybrids exhibited high heterosis for grain yield and were found heterotic for LAI, RGR, and total drymatter production (Nayeem 1980). Veerabadhran and Kennedy (2001) also reported higher values of NAR, RGR and CGR with increasing yield in sorghum. These observations confirmed findings of the present investigation.

#### **5.2.4 Net Assimilation Rate**

The production of a crop is dependent on its inherent capacity of net assimilation rate (NAR) and photosynthetic area (LAI). NAR in general was maximum between 30-45 DAS and thereafter reduced gradually to reach a minimum level at maturity, which may be due to severe mutual shading and senescence of older leaves. The cultivars SSV 84, SSV 74, and S 35 recorded higher NAR from 30-45 DAS (vegetative) to 60-75 DAS (post flowering) stage (Fig. 5.6). In addition to the above cultivars ICSV 574, ICSV 700, ICSV 93046 and ICSR 93034 also recorded higher NAR at 60-75 DAS. Cultivars did not differ significantly from 75-90 DAS onwards.

This may be due to mutual shading and senescence of older leaves as with an increase the age or growth advances. The increased demand for assimilates is due to rapid growth of stem and grain or grain filling. Uniform distribution of solar radiation throughout the crop canopy and efficient absorption of nutrients ensure more NAR and RGR, which may lead to higher

productivity of crop. Thus physiological parameters like NAR, RGR vary in the cultivars according to growth stages and environmental conditions prevailing during growth period (Nayeem 1980). Veerabadhran and Kennedy (2001) also observed higher value of NAR, RGR, and CGR with increasing yield in sorghum.

### **5.2.5 Drymatter Partitioning into Different Plant Parts**

The balanced distribution of drymatter among different plant organs (partitioning) is a major determinant factor for both total dry matter production and economic yield. In general drymatter partitioning in different plant parts *viz.*, root, stem, leaf, panicle and also total plant biomass in different cultivars increased with advancement of crop growth and crop age (Table 4.7 and Fig. 5.7, 5.8 and 5.9).

#### **5.2.5.1 Root Dry Weight**

At vegetative stage, NTJ<sub>2</sub> recorded significantly more root dry weight than cultivars ICSR 196, ICSR 37, ICRR 108, ICSR 93034 and ICSV 574 while the remaining cultivars *viz.*, SSV 84, SSV 74, S 35, ICSV 56, ICSR 196, ICSV 96117, Ent 64 DTN and Seredo were at par with NTJ<sub>2</sub>.

The drymatter accumulation in root was more in cultivars ICSV 700, SSV 84, SSV 74 Seredo, ICSV 574, ICSR 37, ICSV 56, ICRR 108 and ICSR 196 at both flowering and maturity. Thus these cultivars had a better root

growth and root system at different growth stages resulting in improved nutrients and water uptake from soil leading to improved growth parameters which might be responsible for higher yield of economic sinks *viz.*, grain and stalk or ethanol production.

#### **5.2.5.2 Stem Dry Weight**

At different growth stages the drymatter accumulation in stem increased in all sweet sorghum cultivars with an advancement of crop growth and age. The synthesis of photosynthates (NAR) and finally either converted into sucrose in stem itself (or) translocated to grains depending on cultivars and the genetic potential and environmental conditions

In general the drymatter accumulation increased two folds from vegetable stage to flowering stage in all cultivars and only a marginal increase in most of the cultivars was observed at maturity.

The cultivars SSV 84 and NTJ<sub>2</sub> recorded significantly higher stem dry weight than ICSR 37 at vegetative stage.

At flowering, the cultivars SSV 84, SS V 74, S 35, NTJ<sub>2</sub>, ICSV 700, ICSR 93034, ICSV 93046, ICSV 574, ICSV 96117 and Ent 64 DTN recorded significantly more stem dry weight. Stem drymatter accumulation was more in ICSV 700, SSV 84, SSV 74, ICSV 93046, S 35, NTJ<sub>2</sub> and ICSV 574 at maturity. Significantly more dry weight in stem was due to more LAI, CGR and NAR in these cultivars. The of photosynthates (NAR) finally either converted into sucrose in stem itself (or) translocated to grains depending on

cultivars and the genetic potential and environmental conditions. Similar observations were also made in rice by Chandrasekhar *et al.* (2001).

#### **5.2.5.3 Leaf Drymatter**

There was an increase in leaf drymatter with the advancement of crop age up to the flowering stage and then it declined at maturity. Leaf dry weight was higher in cultivars ICSV 93046, Ent 64 DTN, SSV 84, SSV 74, S 35, ICSR 93034 and ICSV 574 at vegetative stage. The cultivars ICSV 93046, SSV 84, ICSV 700, ICSR 37, NTJ<sub>2</sub>, S 35, ICSR 93034, ICSV 574 and Ent 64 DTN recorded more leaf dry weight at flowering.

At flowering stage, the physiological parameter like CGR, and RGR, were higher due to more NAR and LAI resulting in increased photosynthates in leaves. Later on these photosynthates were distributed to economic sinks of the plants *i.e.*, stem and grain.

At maturity SSV 84, ICSV 900, Ent 64 DTN and ICSR 93034 recorded more leaf dry weight. The leaf dry weight was in general decreased at maturity due to remobilization of photosynthates to economic sinks and also due to senescence of older leaves. These results are in agreement with the observations of Gardenor (1985) who observed that there was an increase in storage of photosynthates in the reproductive parts (grain), while the leaf drymatter (weight) was marginally decreased.

#### **5.2.5.4 Dry Weight of Panicle**

The cultivars ICSV 93046 and ICSV 56 recorded significantly higher panicle dry weight when compared to NTJ<sub>2</sub> and ICRR 108 at flowering stage. However at maturity the cultivars ICSR 37, SSV 84, Seredo, S 35, SSV 74, and ICSR 93034 recorded higher panicle dry weight. Higher panicle dry weight in these cultivars led to increase in grain weight per panicle and length of the panicle, which ultimately resulted in higher grain yield of these cultivars. These findings are in agreement with observations of Sankarapandian *et al.* (1995) in sweet sorghum.

#### **5.2.5.5 Total Drymatter**

An increasing trend was observed in total drymatter production of different sweet sorghum cultivars across different growth stages. However, total drymatter was almost doubled at flowering.

At vegetative stage, cultivars SSV 84, SSV 74, S 35, ICSR 93034 and NTJ<sub>2</sub> recorded significantly higher total drymatter production. At flowering stage cultivars SSV 84, ICSV 700, SSV 74, ICSV 93046 and S 35 recorded significantly more total drymatter. However, in addition to above cultivars, the cultivars ICSR 93034, Ent 64 DTN and NTJ<sub>2</sub> also produced more total drymatter at maturity.

Higher drymatter production was due to their genetic potential and vigour of these sweet sorghum cultivars and also in response to environmental conditions prevailing during different growth stages. As such the cultivars that possessed more NAR, LAI, CGR and RGR recorded more total drymatter

accumulation. The balanced or higher distribution of drymatter into economic sinks in these cultivars resulted in higher grain yield/stalk yield. Loomis and Williams (1963) had appropriately stated that assimilate partitioning during growth and development was a key factor in improvement of crop productivity.

Though more drymatter accumulation was observed in the cultivars ICSV 700 and ICSV 93046, appreciable production and grain and fermentable sugar yield (ethanol) could not be realized in these cultivars. This might be due to more drymatter partitioning into structural tissues like fibre in stem and other plant parts, instead of sugars in stem and grain. These results corroborate with the findings of Putnum *et al.* (1991) and Rood *et al.* (1992).

#### **5.2.5.6 Days to 50 per cent flowering**

Days to 50 per cent flowering was an important factor for determining grain yield. As ICSR 196, ICRR 108, ICSV 574 and ICSR 93034 having optimum days to 50 per cent flowering and optimum duration of reproductive period might have resulted in proper drymatter partitioning and moderate grain yield (Table 4.10 and Fig. 5.12). The cultivars ICSV 93046, and ICSV 700 recorded more days to 50 per cent flowering and less reproductive phase which might have resulted in less grain yield and less fermentable sugars. These results are in agreement with Patil and Ugale (1994). The cultivars SSV 84, SSV 74, S 35, NTJ<sub>2</sub>, recorded 50 days for days to 50 per cent flowering and have more duration of reproductive phase resulting in more grain yield and more Fermentable sugars. There was a positive relation for days to 50 per cent

flowering with other parameters like LAI, CGR, RGR and NAR, which are determinant factors for drymatter production and its partitioning into economic sinks *viz.*, stalk and grain. These observations are confirmed with the findings of Patel *et al.* (1994).

### **5.3 BIO-CHEMICAL CHARACTERS**

#### **5.3.1 Total Soluble Sugars**

The total soluble sugars (TSS) were higher in SSV 84 (12.5), SSV 74 (12.3), NTJ<sub>2</sub> (11.0), S 35, (11.3), Ent 64 DTN (11.3), Serede (11.0), ICSR 93034 (11.0), and ICSV 96117 (10.8) and the least being in cultivars ICSV 93046 (5.7) and ICSR 37 (5.3) at flowering stage (Table 4.8).

However, sweet sorghum cultivars SSV 84 (14.5), SSV 74 (14.3), Serede (10.3) NTJ<sub>2</sub> (10.2) and S 35 (10.6) recorded significantly more TSS contents at maturity.

In sweet sorghum cultivars TSS accumulation was more during reproductive phase, as favourable climatic conditions of low temperature, high relative humidity prevailed during November to December (during reproductive stage), which favoured the conversion of glucose to sucrose and ultimately led to increased juice quality. Thus the sweet sorghum cultivars stored most of its carbohydrates as soluble sugars distributed through out the stalk. These results are in confirmation with the findings of Singh and Reddy (1976), Perish *et al.* (1985), Bapat *et al.* (1986), Almodares *et al.* (1996) and

Seetharama *et al.* (2000). The cultivars like SSV 84, SSV 74, Serede, S 35 and NTJ<sub>2</sub> recorded more TSS content even at maturity while decline in TSS was observed in Ent 64 DTN, ICSR 93034 and ICSV 96117. The sweet sorghum cultivars produced high level of carbohydrates and some of sugars accumulated in the stem might be re-distributed to the other economic sink grains during grain filling, resulting in a decrease in TSS from anthesis to black layer formation in grain in sorghum.

### **5.3.2 Reducing Sugars**

At flowering stage reducing sugars were significantly higher in Serede, SSV 84, SSV 74, NTJ<sub>2</sub>, S 35, Ent 64 DTN, ICSV 96117, ICSV 93034 and ICSV 56. A slight reduction in reducing sugars in all cultivars was observed at maturity. The cultivars SSV 84, SSV 74, NTJ<sub>2</sub>, S 35, Ent 64 DTN recorded more reducing sugars at maturity also when compared to ICSV 700, ICSV 93046 and ICSR 37. These results are in confirmity with Huilgol *et al.* (2002) and Seetharama *et al.* (2002). The reducing sugars decreased from flowering to harvesting. During flowering, vegetative growth was still vigorous, reducing sugars in the cane juice was high due to increase in the activity of vascular acid invertase enzyme for the conversion of cytoplasmic hexoses to reducing sugars (Alexander, 1969). The quality characters of juice was mostly dependent on the factors like age of the crop, soil type and agro climatic factors (Almodares and Sepahi, 1997).

### **5.3.3 Non-Reducing Sugars**

Non-reducing sugars were significantly higher in SSV 84, SSV 74, NTJ<sub>2</sub>, Ent 64 DTN, S 35, ICSR 93034, ICSV 96117 and Serede at flowering stage. At maturity also the cultivars SSV 84, SSV 74 and NTJ<sub>2</sub> recorded more non-reducing sugars. The non-reducing sugars in juice were mostly dependent on the properties of reducing sugars. The results were in agreement with findings of Bapat *et al.* (1986) and Ganesh *et al.* (1995).

#### **5.3.4 Fermentable Sugar Yield (t/ha)**

In the present study fermentable sugar yield ranged from 1.6 to 4.9 t/ha and 0.7 to 5.0 t/ha in 15 sweet sorghum cultivars at flowering and maturity respectively. These findings were in agreement with results of Smith *et al.* (1987). More fermentable sugar yields (t/ha) were recorded by the cultivars SSV 84, SSV 74, NTJ<sub>2</sub> and S 35 at both flowering and maturity. Fermentable sugar yield was more in Ent 64 DTN at flowering but reduced at maturity. The fermentable sugar yields ultimately depends on total juice quantity and TSS content of cane juice.

#### **5.3.5 Ethanol Estimation**

It is evident from data (Table 4.8 and Fig. 5.10), that among all the cultivars, SSV 84 (3012), SSV 74 (2944), NTJ<sub>2</sub> (2729), Ent 64 DTN (2596) and S 35 (2368) recorded more ethanol at flowering while SSV 84 (3072), SSV 74 (3002), NTJ<sub>2</sub> (2057) and S 35 (2045) recorded more ethanol at maturity. The cultivar ICSR 37 produced less ethanol production at both stages. These observations were in agreement with the findings of Seetharama *et al.* (2002)

who reported that ethanol production was more in varieties like Keller and SSV 84 at flowering and reduced in some other varieties at maturity. The ethanol content was purely determined by the total fermentable sugar yields of the juice, TSS content and total drymatter production of the cultivar. Ethanol production was ultimately dependent on plant height to increase more stalk yield and in turns to increase more fermentable sugar yields of the cane (Putnum, 1991). The results were also supported by the findings of Almodares and Sepahi (1997) and Miller and Creelman (1998).

## **5.4 YIELD AND YIELD COMPONENTS**

### **5.4.1 Cane Length**

Cane length (cm) is an important factor for milling, stalk yield as well as juice yield for ethanol production. Maximum cane length was observed in all the cultivars at flowering stage and thereafter only marginal increase in cane length was observed at maturity (Table 4.9 and Fig. 5.11).

The cultivars SSV 84, SSV 74, ICSV 700, S 35, ICSR 93034, NTJ<sub>2</sub> and ICSV 93046 recorded more cane length at both flowering and harvesting.

Due to favourable environmental conditions *viz.*, high rainfall, high relative humidity, high temperature during vegetative phase (30-45 DAS), plant height increased several folds at 30 DAS and was almost doubled at 45 DAS, resulting in increased internodal length and internodes, which finally led to the higher stalk yield (cane length). Plant height, internodal length and internodes are major factors determining cane length. Thus the cane length varied with

the sweet sorghum cultivars due to their genetic potential and also their responses to environment. These findings are in confirmity with observations of Dillewijn (1957) in sugarcane and Barnes *et al.* (1953) in sorghum.

#### **5.4.2 Stripped Stalk Yield**

More stripped stalk yield was recorded with cultivars SSV 84, SSV 74, ICSV 700, ICSV 93046, S 35 and NTJ<sub>2</sub> at both flowering and maturity, the least being in ICSR 37 (Fig.5.11). This increase in stalk yield of sweet sorghum cultivars in the present study was due to more plant height, internodal length, diameter and length of the stalk (cane) and more drymatter accumulation in stalk. These results were in agreement with observations made by Almodares and Sepahi (1997).

Almodares *et al.* (1994) reported that the stalk yield ranged from 24 to 120 t/ha in sweet sorghum genotypes. Belletti and Petrini (1991) also reported that stalk yield of sweet sorghum ranged from 55.5 to 69.7 t/ha and drymatter yield from 16.7 to 19.4 t/ha. More juicyness and more brix may result in the high fresh weight of sweet sorghum stalk in the present study. These results are in confirmity with that of Seetharama *et al.* (2002), who reported that stalk production was 25 t/ha and its juice yield 1638 L/ha.

#### **5.4.3 Panicle Length**

Panicle length (cm) was an important yield attribute, which determines the grain yield of the crop. The cultivars ICSR 37, SSV 84, SSV 74, Seredo, S 35, ICSR 93034, Ent 64 DTN and NTJ<sub>2</sub> recorded more panicle length while

less panicle length was recorded by the cultivars ICSV 96117, ICSV 93046 and ICSV 700. Panicle length had direct influence on the number of grain and grain weight per panicle leading to high grain yield in these sweet sorghum cultivars. High panicle dry weight influencing panicle length and test weight on grain yield in sorghum was reported by Nayeem (1980) Rood *et al.* (1992) and Narkheda *et al.* (2000). Hybrids are more efficient than parent-lines in drymatter accumulation particularly into panicle resulting in increased panicle length and weight (Patel *et al.*, 2003).

#### **5.4.4 Grain Weight per Panicle**

The cultivars ICSR 37, Seredo, SSV 84, SSV 74, S 35 and ICSR 93034 recorded more grain weight per panicle and very less grain weight per panicle was noticed by ICSV 96117, ICSV 93046 and ICSV 700.

More grain weight per panicle in these cultivars was due to more drymatter accumulation in panicle (ear head) and size of the grain or test weight, which ultimately resulted in higher grain yield. These findings are in confirmity with those of Patel (2003) in sorghum.

#### **5.4.5 Test Weight**

Significantly more test weight was recorded in ICSR 37, Seredo, SSV 84, NTJ<sub>2</sub>, SSV 74, ICSR 93034 and Ent 64 DTN and very less test weight in ICSV 96117 and ICSV 93046. This attribute was determined by accumulation of photosynthates in grains. These above sweet sorghum cultivars having more

test weight might have contributed more grain yield. These results are in corroboration with the findings of Shankarpandian *et al.* (1995).

#### **5.4.6 Grain Yield**

Higher grain yield ranging from 3.03 to 3.46 t/ha was recorded with the cultivars ICSR 37 (3.98), SSV 84 (3.46), Seredo (3.33), S 35 (3.09), SSV 74 (3.04) and ICSV 93034 (3.03) (Table 4.10 and Fig. 5.12). More grain yield in SSV 84, SSV 74, HES 4, SSV 7073 and IS 4917, SSV 2525 was also reported by Sankarpandian *et al.* (1995) in sweet sorghum. The higher grain yield was due to the more length of panicle diameter, size and number of grains per panicle, which might be due to more plant height, LAI, CGR, RGR, NAR and drymatter production per plant and drymatter accumulation in panicle leading to bigger panicle size (length) and grains per panicle. The above growth and yield components ultimately determined the grain yield in sweet sorghum cultivars. Licufuifeng *et al.* (1997) also recorded 3 t/ha of grain yield in sweet sorghum cultivars.

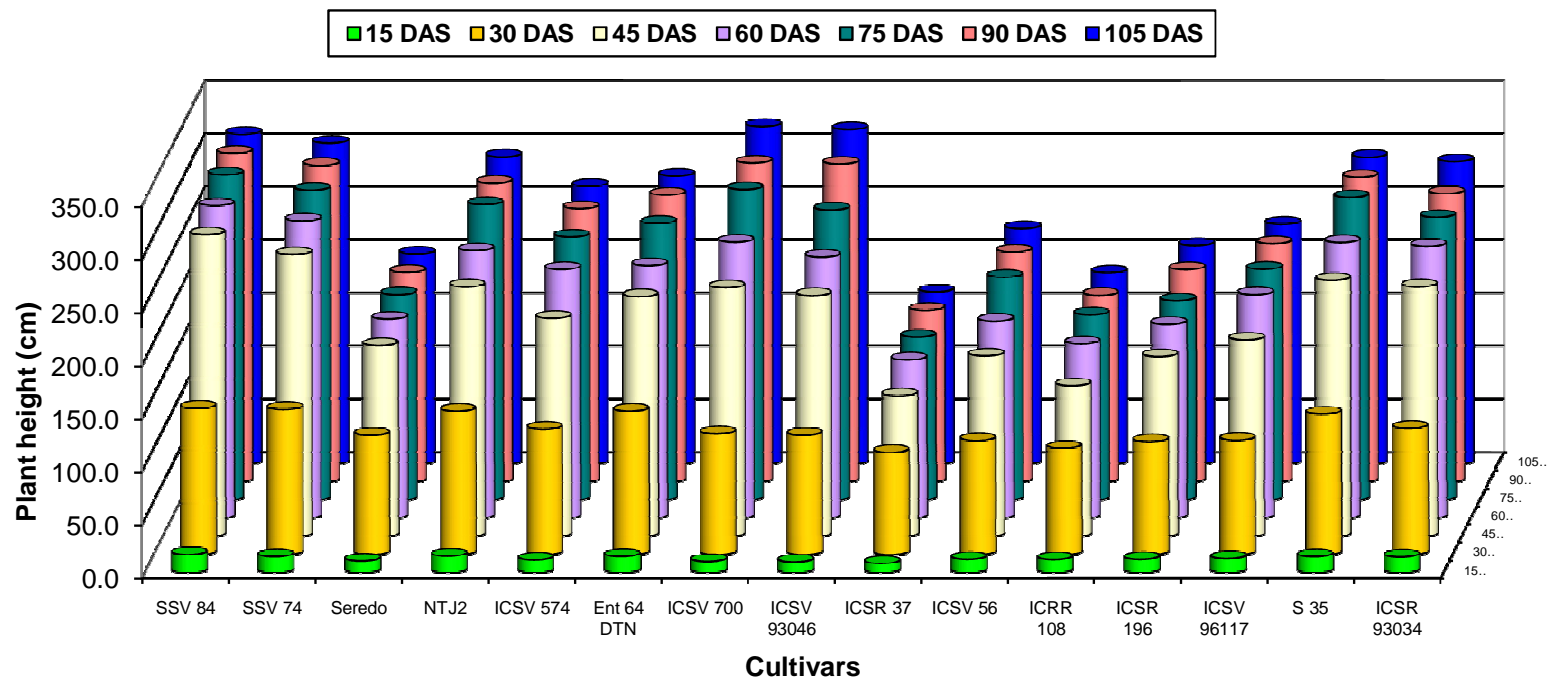
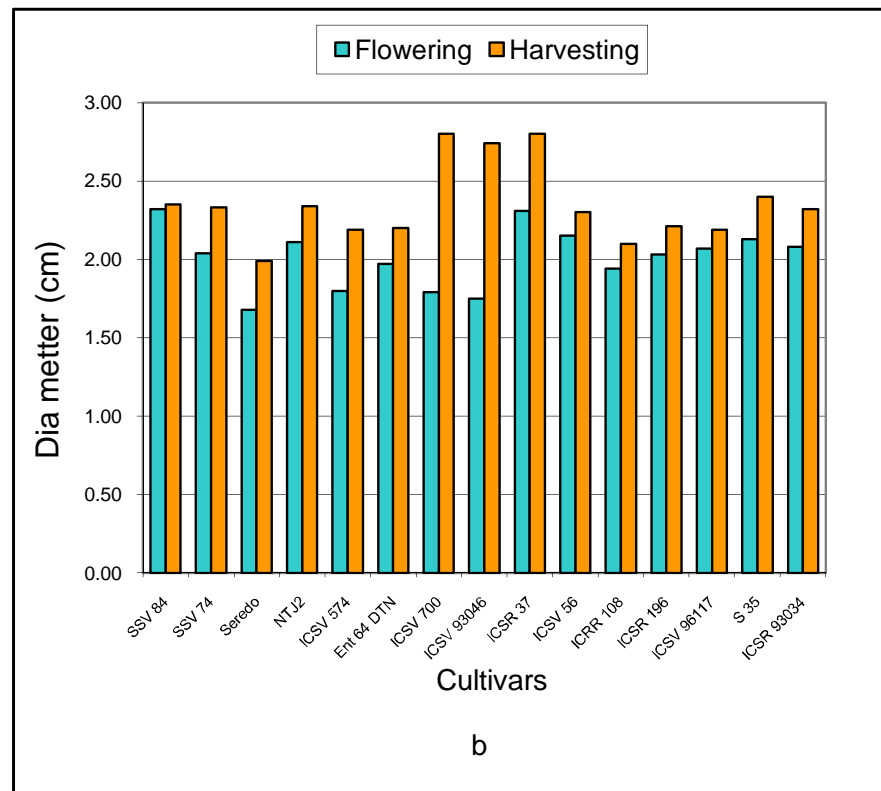
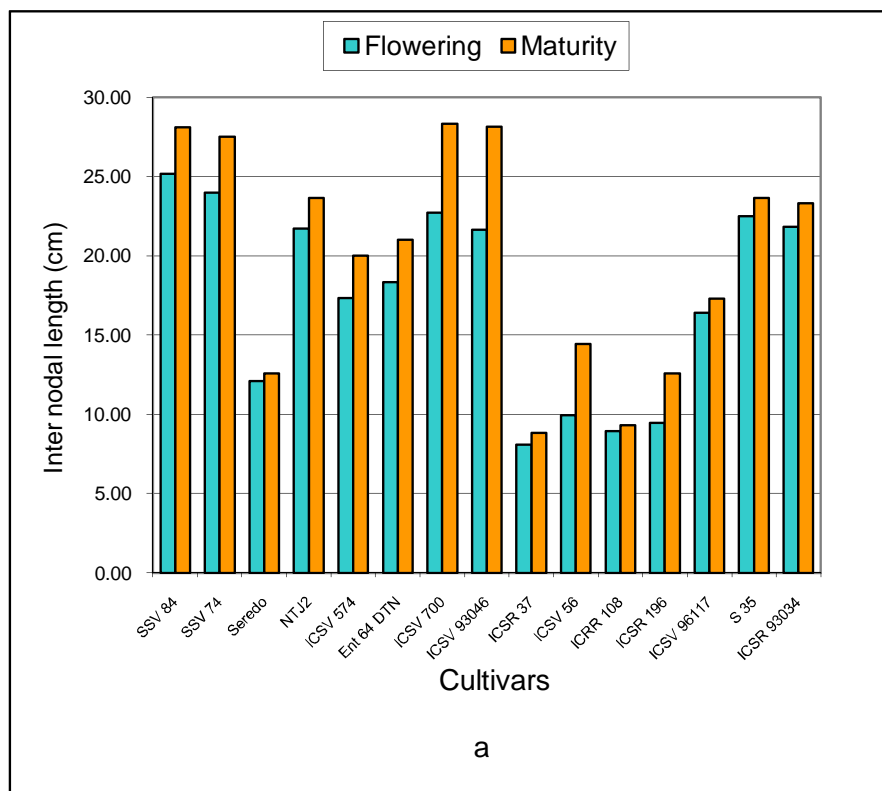
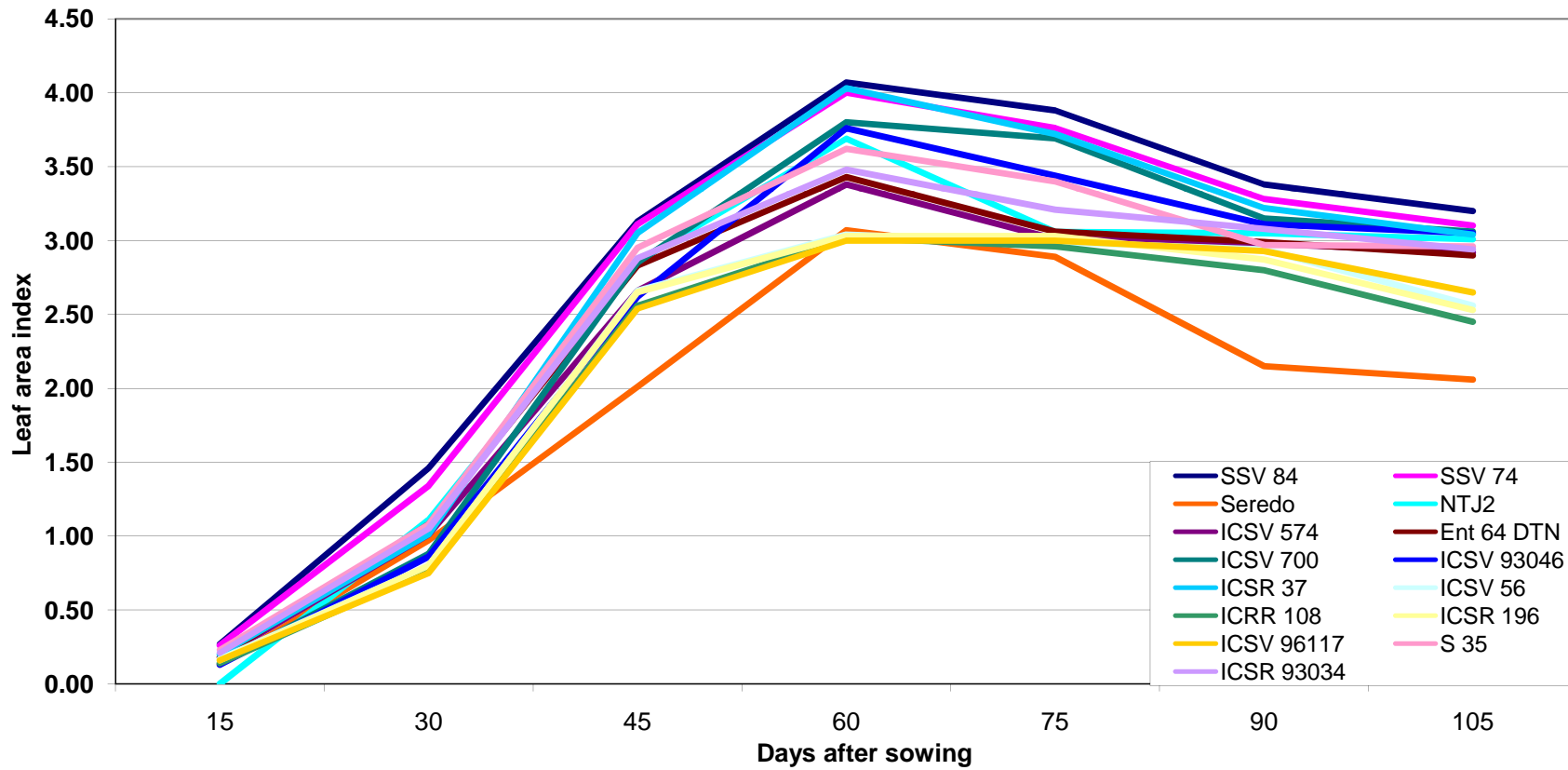


Fig.5.1: Plant height (cm) of sweet sorghum cultivars at different stages of crop growth



**Fig. 5.2: Internodal length (a) and basal stalk diameter (b) of sweet sorghum cultivars at flowering and harvesting**



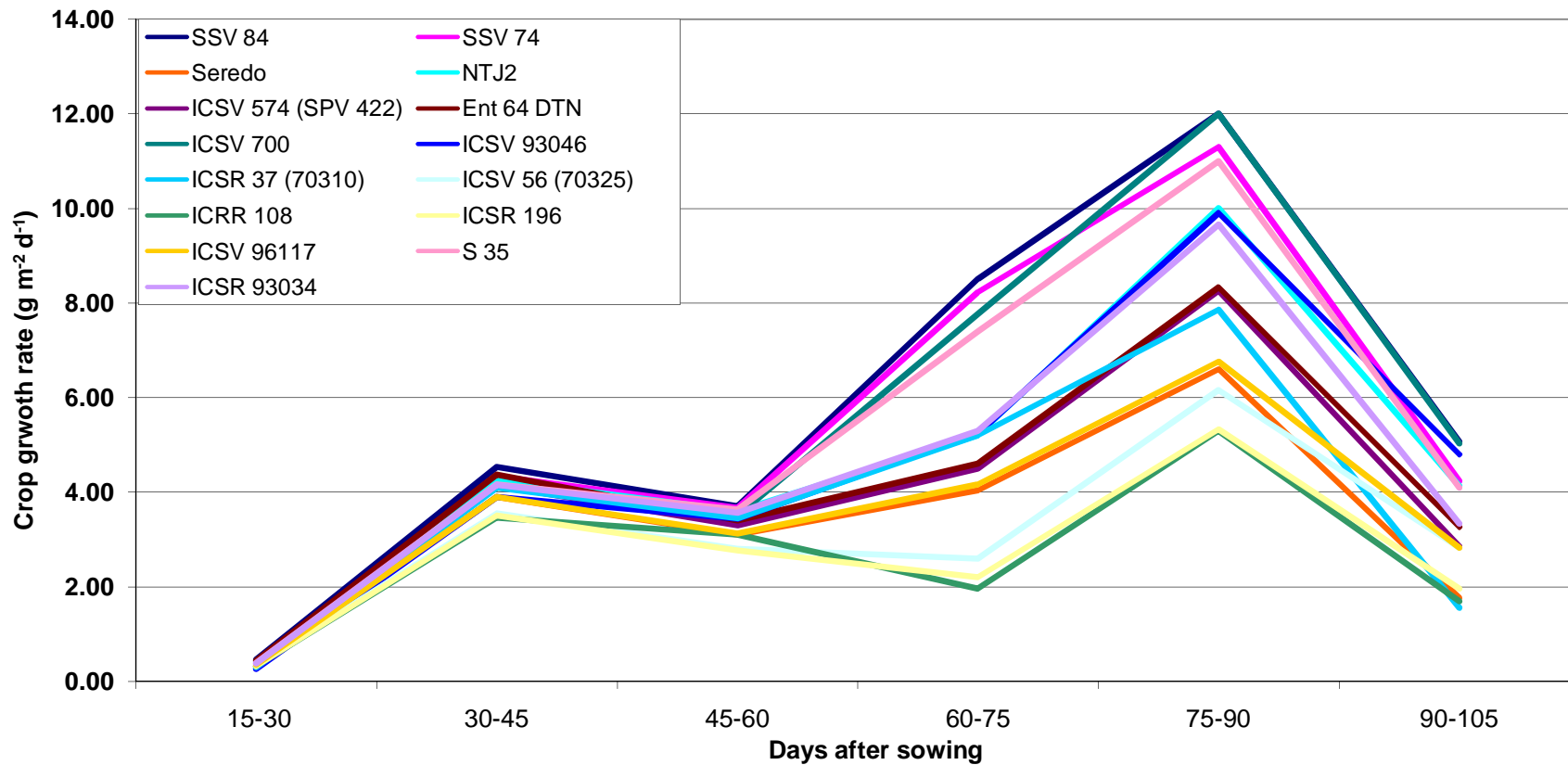
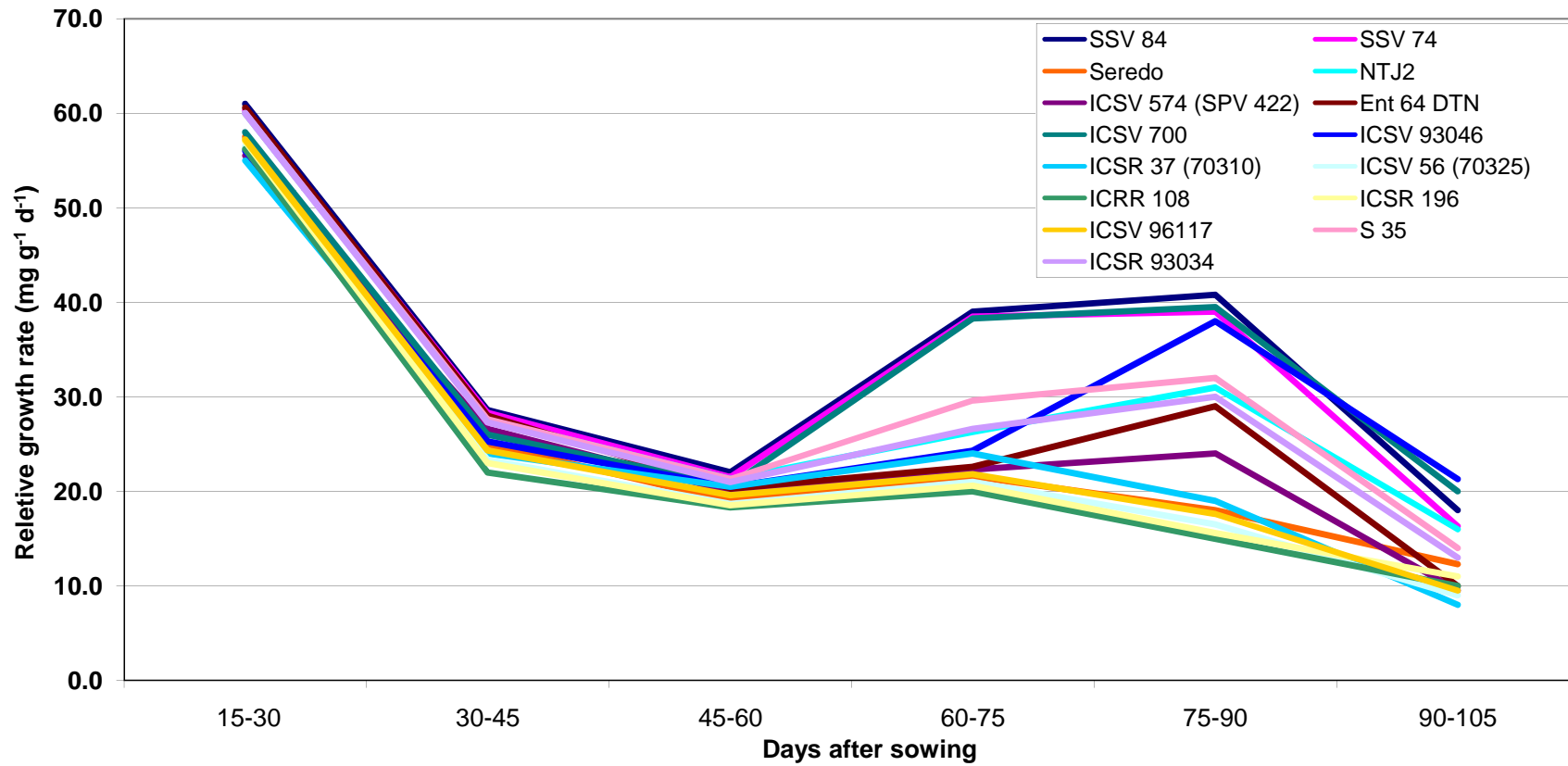
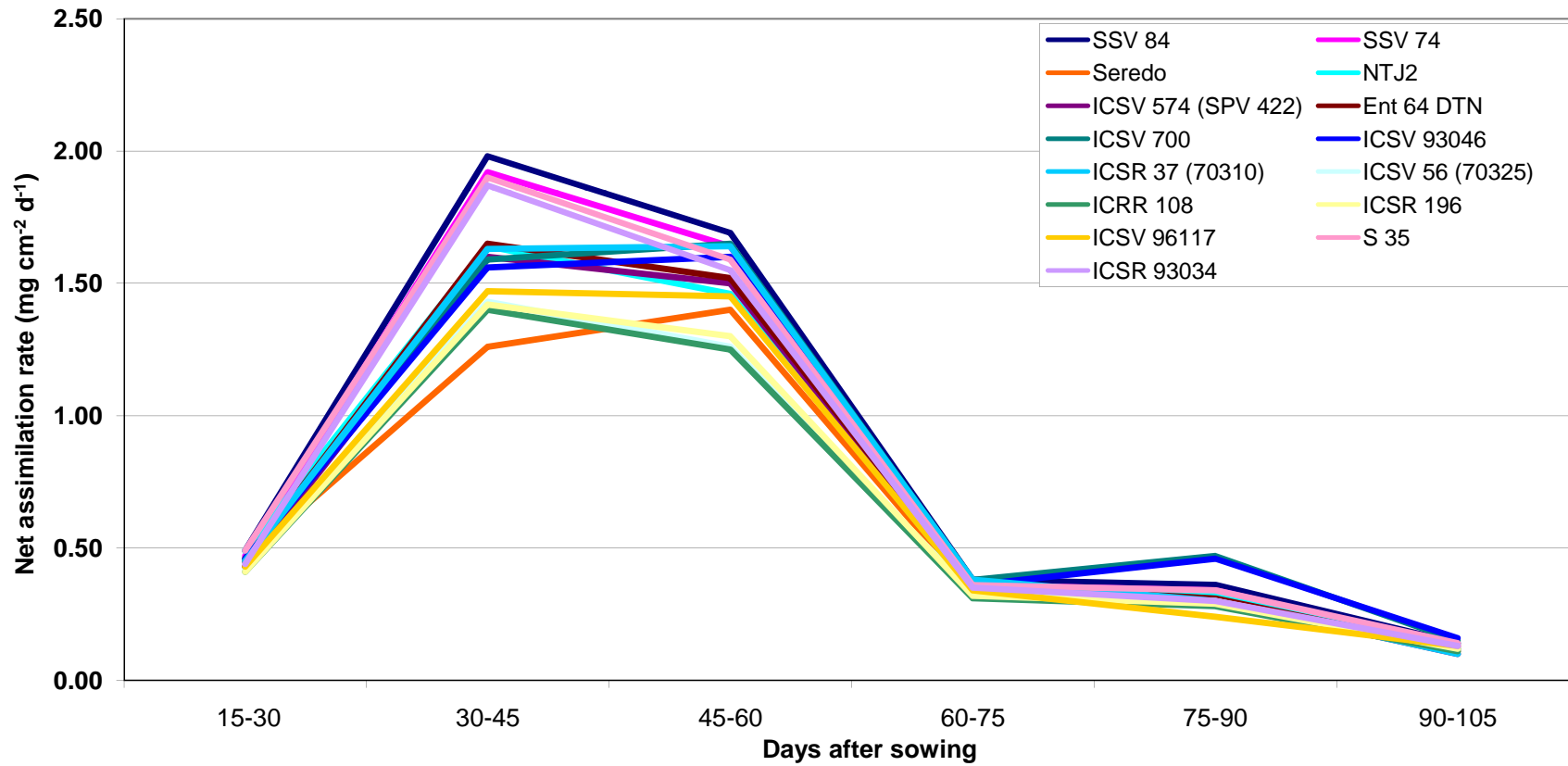
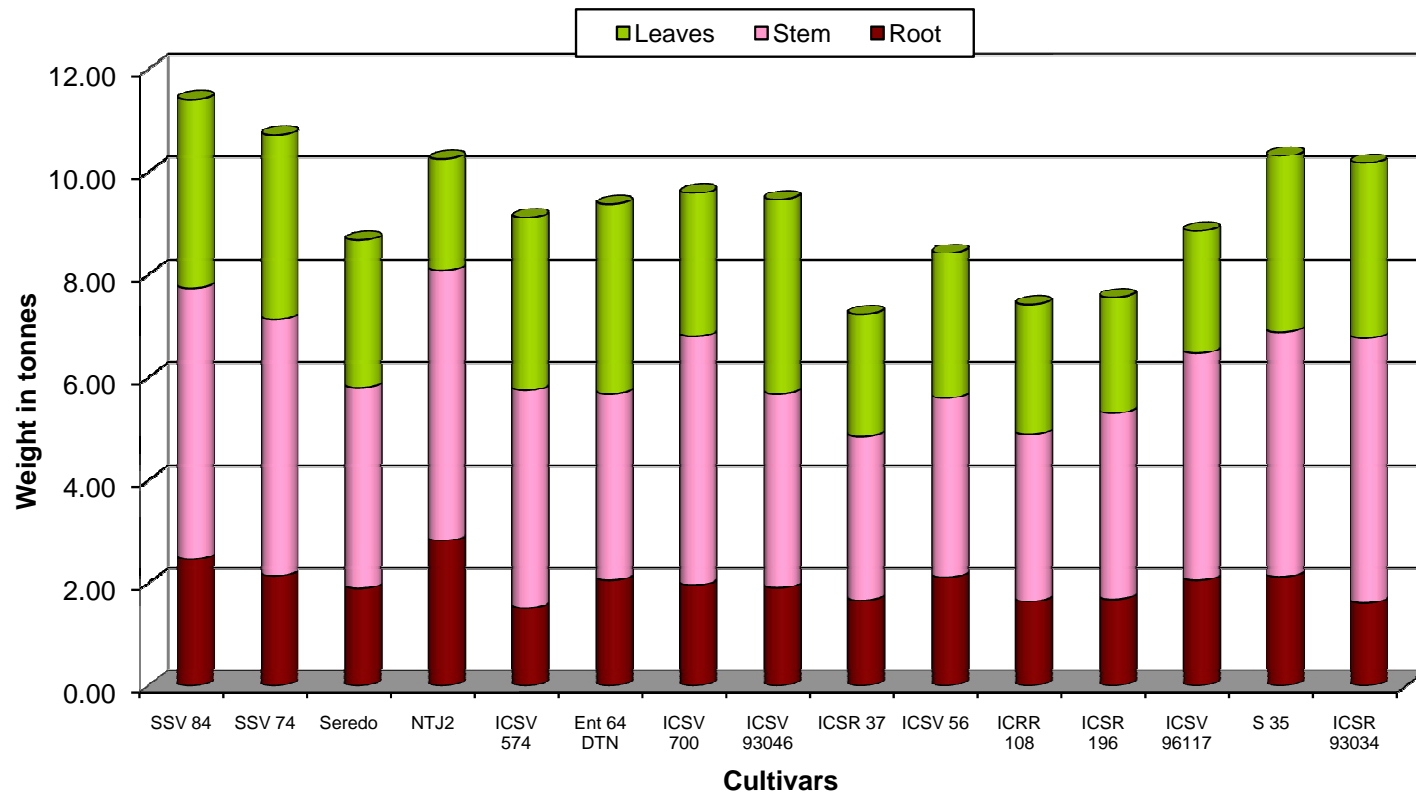


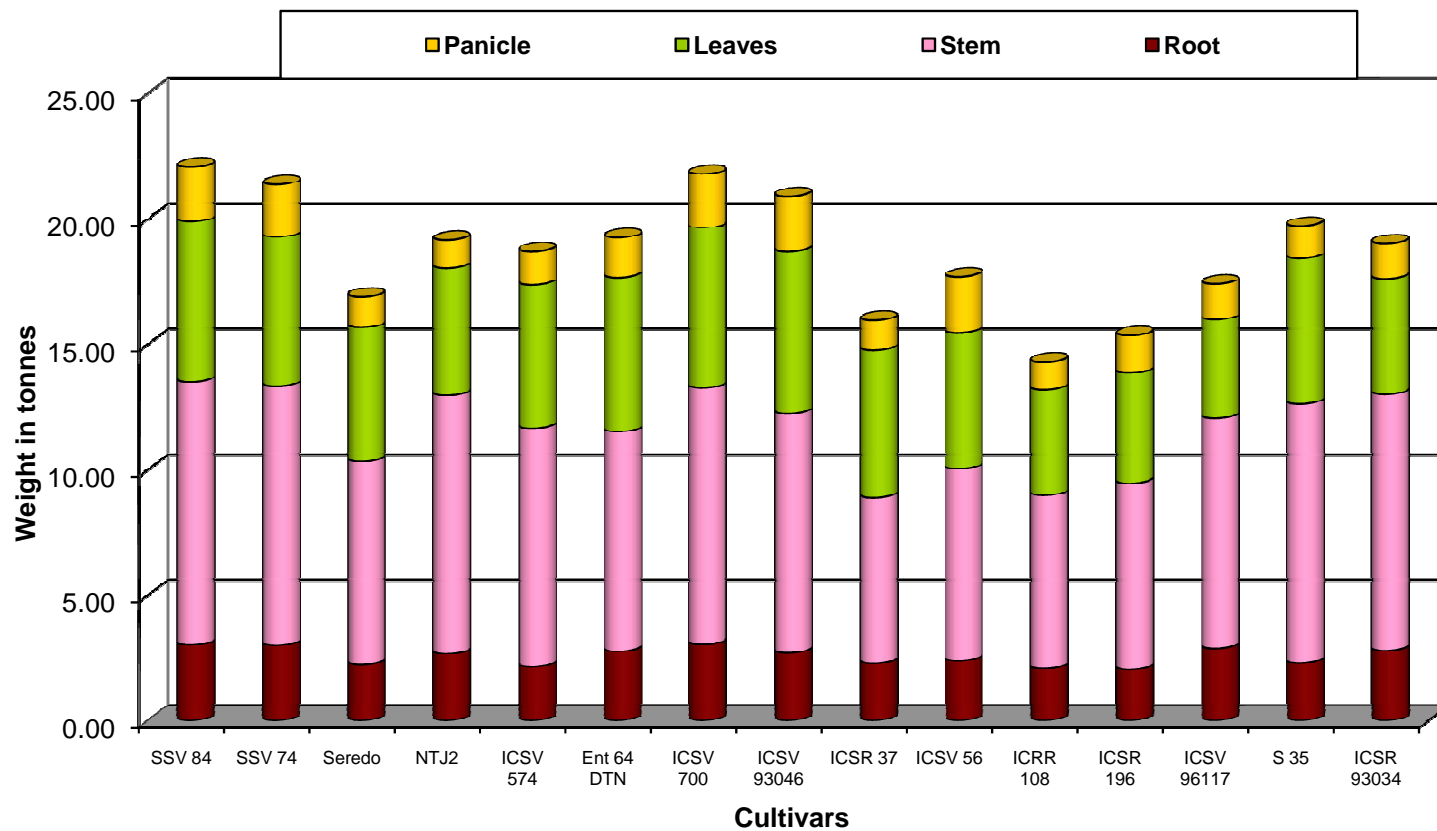
Fig.5.4: Crop growth rate (g m<sup>-2</sup> d<sup>-1</sup>) of sweet sorghum cultivars at different stages of crop growth



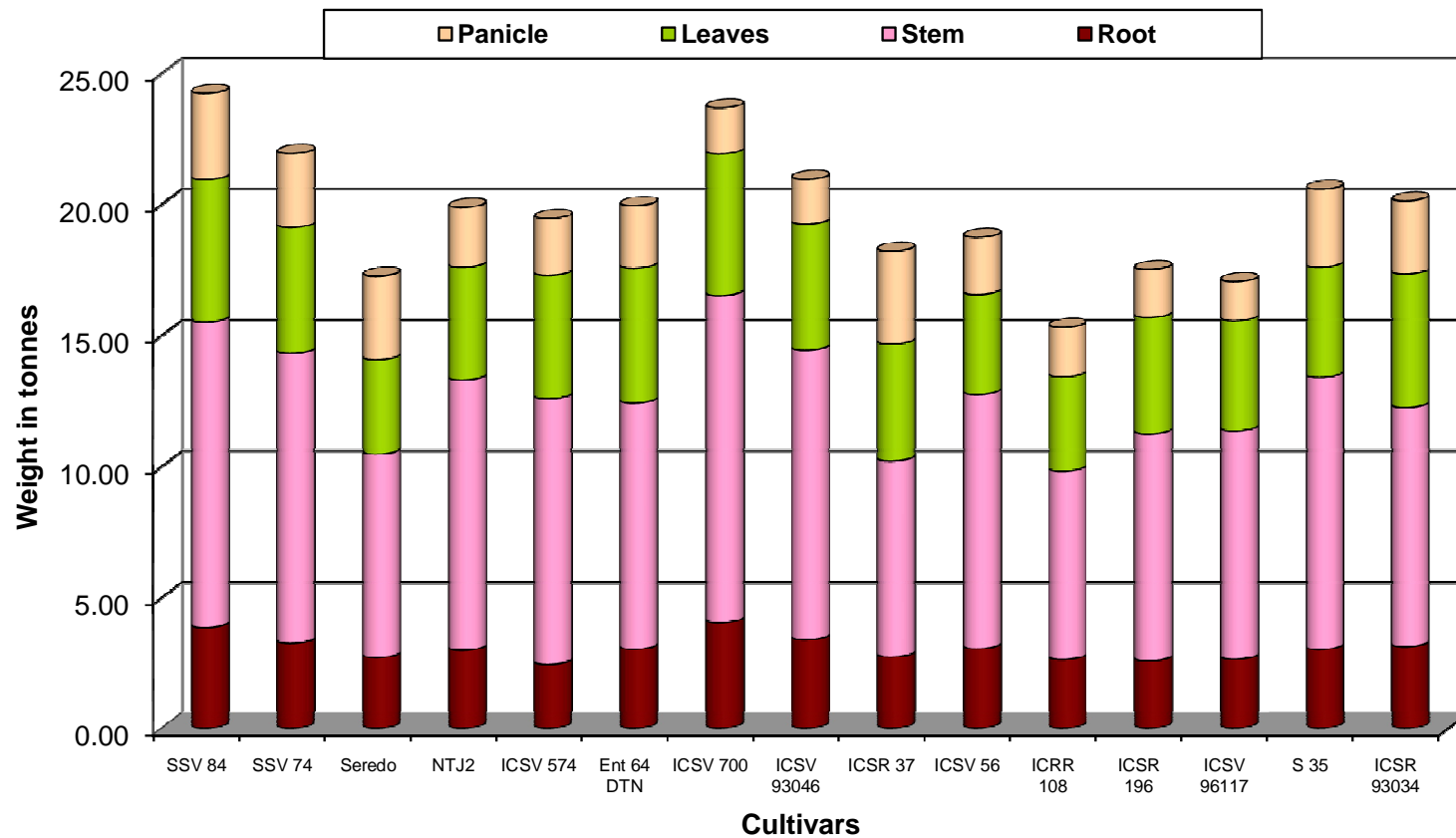




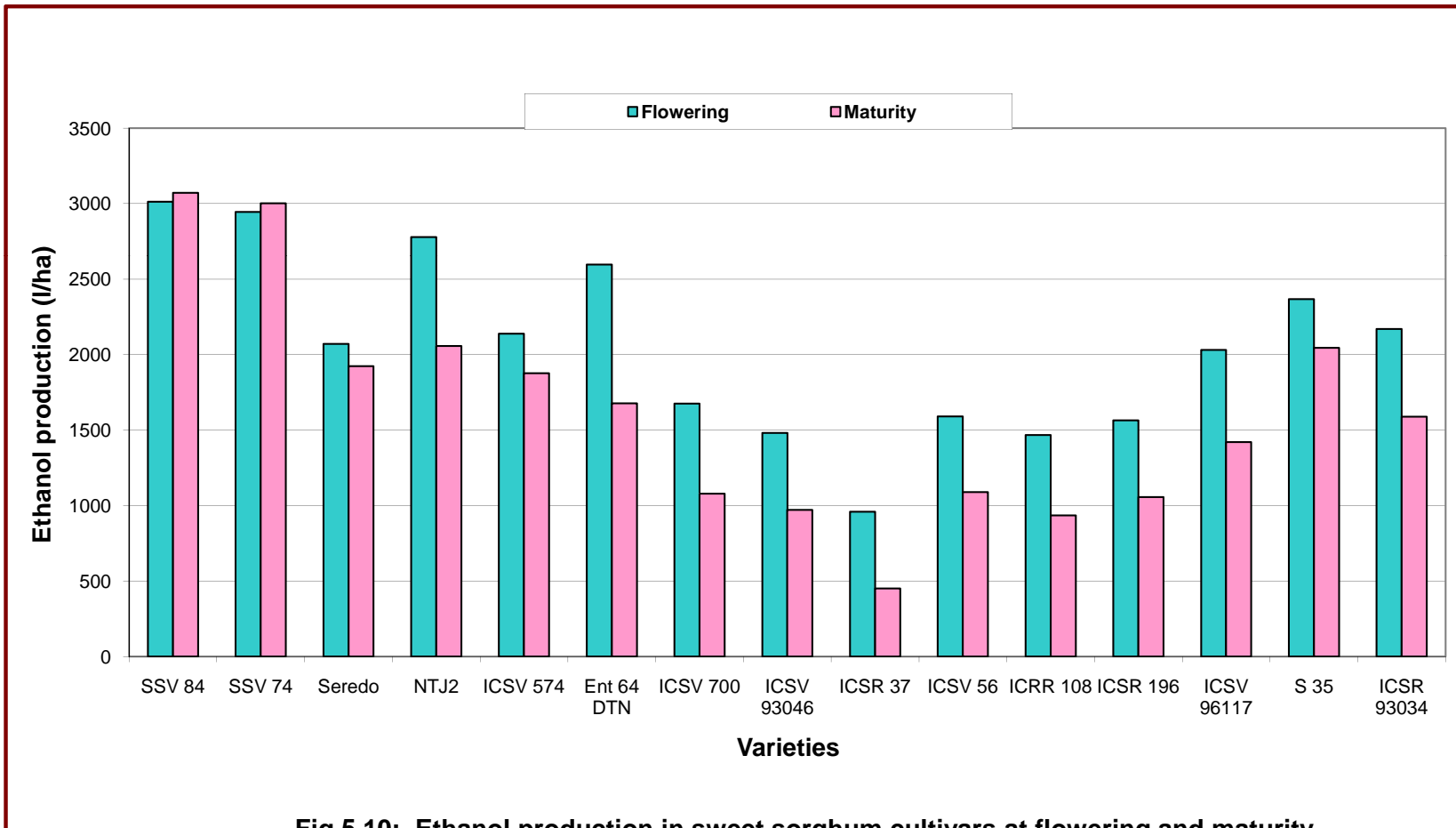
**Fig.5.7: Drymatter partitioning into different plant parts of sweet sorghum cultivars at vegetative stage of crop growth**



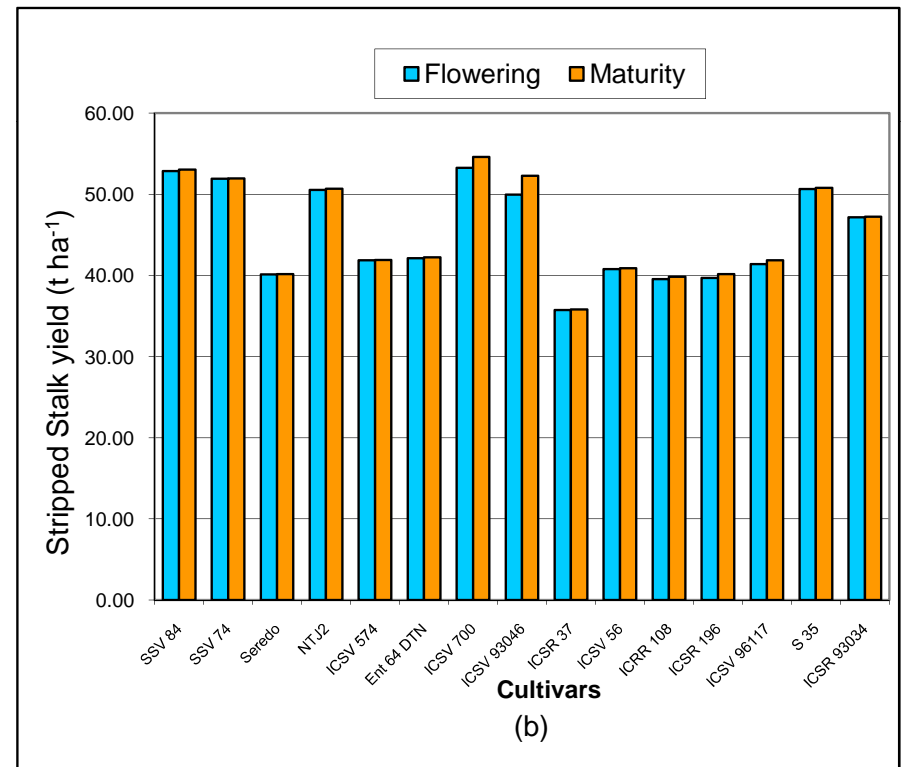
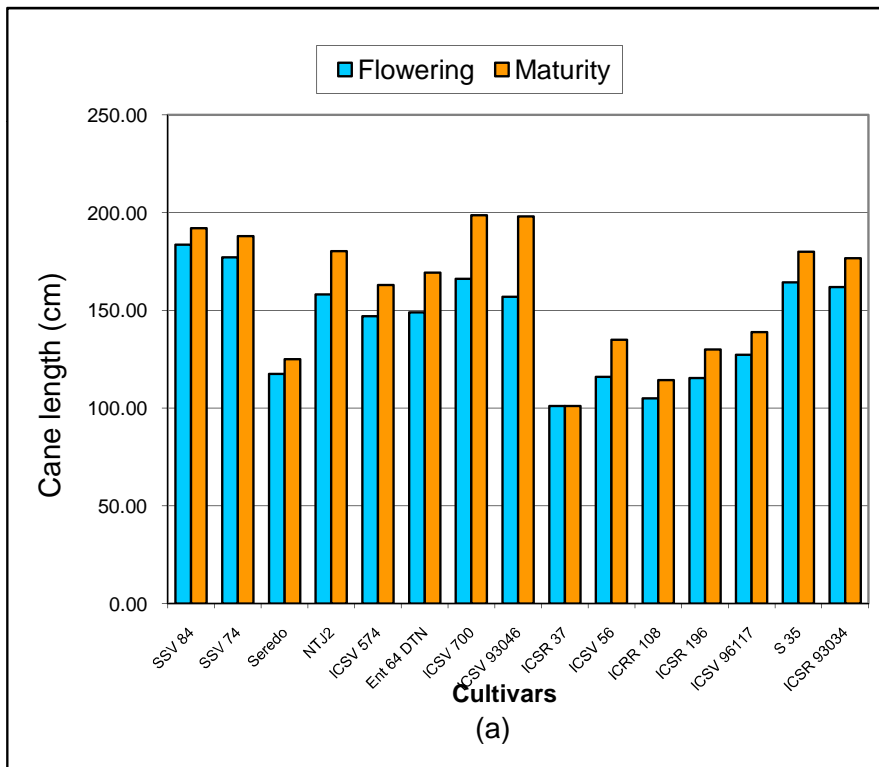
**Fig.5.8: Drymatter partitioning into different plant parts of sweet sorghum cultivars at flowering stage of crop growth**



**Fig.5.9: Physiological assessment of sweet sorghum cultivars on drymatter partitioning into different plant parts at different stages at maturity stage**



**Fig 5 10: Ethanol production in sweet sorghum cultivars at flowering and maturity**



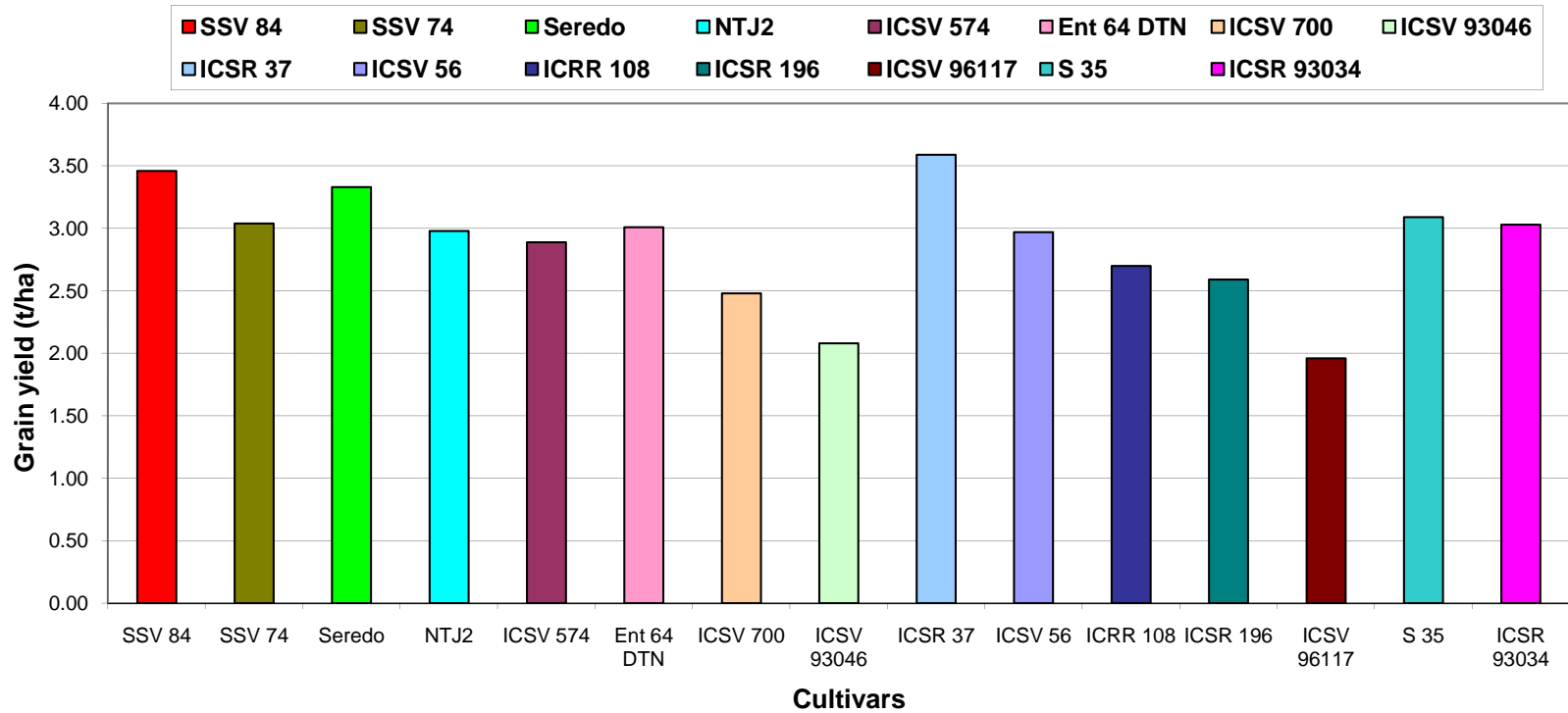


Fig.5.12: Grain yield of sweet sorghum cultivars

## CHAPTER – VI

### SUMMARY

A field experiment entitled “Physiological assessment of sweet sorghum cultivars and their suitability in Coastal Andhra” was carried out on black soils at the Agricultural College, Bapatla during *Maghi* season of 2004-2005 with following objectives.

1. To study the growth parameters in different sweet sorghum cultivars.
2. To study the pattern of dry matter partitioning in different cultivars.
3. To analyze the qualitative aspects of sweet sorghum juice *viz.*, total soluble sugars, reducing and non-reducing sugars.
4. To assess the productive efficiency of cultivars in respect of grain stripped stalk and ethanol.

The sweet sorghum cultivars *viz.*, SSV 84, SSV 74, Seredo, NTJ<sub>2</sub>, ICSV 574 (SP V 422), Ent 64 DTN, ICSV 700, ICSV 93046, ICSR 37 (73010), ICSV 56 (70325), ICRR 108, ICSR 196, ICSV 96117, S 35 and ICSR 93034 were tried as treatments in a randomized block design and replicated thrice.

Non-destructive and destructive growth analysis was carried out at fortnight interval till maturity. Non destructive growth analysis, data on plant height, internodal length and basal diameter of stem were recorded. Destructive growth analysis data on dry matter weight of different plant parts *viz.*, roots, stem, leaves and reproductive organs were recorded. Physiological growth parameters like leaf area index (LAI), CGR, RGR, and NAR were

calculated. Data on yield and yield components *viz.*, length of the panicle (ear head), grain weight panicle, test weight/panicle, total grain yield per hectare and cane (stalk) length, stripped stalk yield at flowering and harvesting were recorded as post harvest observations. The chemical characters like TSS (brix) reducing sugars, non reducing sugars were analysed. Fermentable sugar yield and ethanol estimated from the cane juice.

The studies on morphological characters revealed that cultivars *i.e.*, SSV 84, SSV 74, ICSV 700, ICSV 93046, NTJ<sub>2</sub>, S 35, ICSR 93034 and ENT 64 DTN possessed higher potential interms of plan height, internodal length, basal diameter at different sampling dates.

Observations on physiological parameters indicated that the cultivars exhibited significant differences in respect of LAI, CGR, RGR, NAR and drymatter partitioning into different plant parts. The above mentioned cultivars possessed higher values of these physiological parameters also.

The cultivars differ significantly in respect of panicle length, panicle weight and test weight of the grain. Data on yield and yield components indicated that the cultivars ICSR 37, SSV 84, Seredo, SSV 74, NTJ<sub>2</sub>, S 35 and ICSR 93034 recorded more grain yield. The higher grain yield in these cultivars due to improved panicle length, panicle dry weight, test weight and grain weight per panicle.

Significant variation in biochemical characters *viz.*, TSS (brix), reducing sugars non-reducing sugars, fermentable sugar yield and ethanol production among the sweet sorghum cultivars was observed. The cultivars SSV 84, SSV

74, NTJ<sub>2</sub> and S 35 were superior in respect of the biochemical parameters studied including ethanol production to the rest of the cultivars.

Based on the results of the present investigation the following conclusions can be drawn:

1. The cultivars *viz.*, SSV 84, SSV 74, NTJ<sub>2</sub> and S 35 produced more ethanol due to more fresh stalk yield, more CGR, RGR, NAR, drymatter accumulation, more TSS (brix) and fermentable sugar yields. These cultivars can be cultivated for ethanol production in coastal Andhra.
2. The cultivars ICSR 37, and seredo are short duration cultivars, which recorded less drymatter and produced more grain yield. These cultivars were not suitable for ethanol production due to less stalk yield, less TSS (brix) and low fermentable sugar yields.
3. The cultivars ICSV 700 and ICSV 93046 recorded more plant height and higher drymatter. However, these cultivars could yield neither grain nor ethanol in appreciable amounts, as the drymatter partitioning may be improper into economic sinks like stalk, grain and non-economic tissue like fiber.
4. The cultivars ICSV 56, ICSR 196 and ICRR 108 recorded more ethanol at flowering than that produced at maturity, but recorded moderate grain yield. The cultivar ICSV 96117 recorded moderate fermentable sugar yield, thereby ethanol, but recorded less grain yields.

5. Overall, it can be concluded from the study that the cultivars like SSV 84 and SSV 74 can be cultivated for ethanol production and cultivars like SSV 84, ICSR 37 and Seredo can be grown for grain purpose in coastal Andhra.

## LITERATURE CITED

- Agnal M B 2001 Studies on response of sweet sorghum genotypes to levels of nitrogen, phosphorous and potassium in black soils under rainfed conditions. M. Sc. (Ag.) Thesis UAS, Dharwad.
- Almodares A and Sepahi A 1997 Potential of sweet sorghum for liquid sugar production in Iran. In proceedings of the first international sweet sorghum conference held at Beijing, China, 14-19 September 1997, pp. 35-39.
- Almodares A, Aghamiri A and Sepahi A 1996 Effects of the amount and time of nitrogen fertilization on carbohydrate contents of three sweet sorghum cultivars. *Annals of Plant Physiology* 10 (1): 56-60 (1996).
- Almodares A, Sepahi A and Karve A P 1994 Effect of planting dates on yield and sugar production of sweet sorghum. *Annals of Plant Physiology* 8: 49-51.
- Almodares A, Sepahi A and Shirvani M 1997 Sweet sorghum cultural practices in Iran. P In proceedings of the first international sweet sorghum conference held at Beijing, China, 14-19 September 1997, pp. 75-183.
- Almodares A, Sepahi A, Dalilothojary H and Ghavami R 1994 Effect of phenological stages on biomass and carbohydrate contents of sweet sorghum cultivars. *Annals of Plant Physiology* 8: 42-48.
- Arora H and Thakur P S 2002 Drymatter production of fodder sorghum in *kharif* season. *Forage Research* pp:24-26.
- Bapat D R, Jadhav H D, Gaur S L and Salunkha C B 1986 Screening of sweet sorghum cultivars for production of quality syrup and jaggery. *Current Research Reports* 2: 65-71.
- Bapat D R, Salunke C B, Jadhav H D and Patil S D 1988 Breeding for improvement of sweet sorghum. Paper presented at 18<sup>th</sup> annual sorghum workshop held at C S Azad University Agricultural and Technology, Kanpur on 2-4 May.
- Barnes A C 1953 *Agriculture of the sugarcane*. Leonard Hill limited pp. 385-402.

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Note: The literature is cited as per the “Thesis Guide lines” prescribed by Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad.

Belletti A C and Petrini M A 1991 Yield potential and adoptability to Italian conditions of sweet sorghum as biomass crop for energy production. *Maydica* 36 (1991): 283-291.

Bhattacharya K and Jayakumar N 1985 Growth analysis of different cereal crops. *Crop physiology Vol 2*: 14-17

Blackman V H 1969 The compound interest law and plant growth. *Annals of Botany* 33: 353-360.

Bremner J M 1965 *Methods of soil analysis volume-11 chemical and micro biological methods*. American Society of Agronomy, Madison Wisconsin.

Brown C A and Zerban F N 1941 *Physiological and chemical methods of sugarcane analysis*. John willy and sons, New York.

Burr G O, Hart C E, Brodic H W, Tanimoto T, Kortschak H P, Takashashi P Ashton F M and Coleman R E 1957 *The sugarcane plant*. Annual Review Plant Physiology 8: 275-308.

Chandrasekhar J, Ranga Rao C, Ravindranath Reddy B and Reddy K B 2001 Physiological analysis of growth and productivity in hybrid rice (*oryza sativa* L.). *Indian Journal of Plant Physiology* 6 (N. S.): 142-146.

Channa Naik D and Jaya Kumar B 1994 Effect of time of harvest of sweet sorghum (*sorghum bicolor* L.) genotypes on its yield and juice quality for jaggery preparation. *Indian Journal of Agronomy* 39 (3): 415-417.

Chaudhari S D 1988 Evaluation of high energy sorghum lines, paper presented at XVII All India Sorghum Work Shop held at Kanpur, May 2-4, pp: 24-35.

Chopra S L and Kanwar J S 1980 *Analytical Agricultural Chemistry*. Kalyani Publishers, Ludhiana, New Delhi.

- Cundiff J S and Parrish D J 1985 Long-Term Storage of Ishole sweet sorghum stems for precessing to ethanol. Final Report USDA, Washington D C.
- Davis R E 1993 A combined automated procedure for the determination of reducing sugars and nicotine alkaloids in tobacco products. Tobacco Science 20: 139-144.
- Dhawale G N, Hiremath S M and Chetti M B 2003 Physiological basis of productivity in prosomillet (*Penicum miliaceum* L.) genotypes. National Seminar of Plant Physiology, December 12-14, 2003.
- Dillewijn C V 1957 Botany of sugarcane. Walthom Mars, U S A., The Chronica Botanica Co.
- Ganesh S, Fazallulah Khan A V, Suresh M and Shanthil M 1995 Character association for alcohol and yield in sweet sorghum. Madras Agricultural Journal 82: 361-363.
- Ghatod K S, Ralmegh V B and Kadu A B 1991 Effect of post harvest conditioning of sorgho stalks on juice quality and syrup recovery at various phenological stages. Annals of Plant Physiology 5 (2): 238-241 (1991).
- Huilgol R V, Rama Krishna and Govind Misale 2002 A trial with sweet sorghum C/o Shree Renuka Sugars Ltd., Plant : R. S. 367/1, Manoli – 591 117, Belgaum, Karnataka, India.
- Judhav M M, Chougule B A, Chavan U D and Adsule R N 1994 Assessment of Juice quality in the improved sweet sorghum varieties. Mahatma Phule Krishi Vidyapeeth, Rahuri. Journal of Maharashtra Agricultural Universities 19 (2): 233-235 (1994).
- Khajan Singh and Latha chaudhary 2000 Component analysis for sugar yield in sorghum. Annals of Arid Zone 39: 195-197.
- Kishan Singh and Bakthawar Singh 1986 Sweet sorghum an ancillary sugar crop, Indian Farming 36(4): 7-8.
- Lamb M E, Bargon K V and Bashford L L 1982 Mechanical extraction of sweet sorghum juice. ASHE Paper No. 82-3110. ASAE St. Joseph, M I.

- Lamb M L Bashford and Von Bargaen K 1982 Harvesting sweet sorghum juice. Energy Farm fact sheet No.1, University of Nebraska Lincoln.
- Licufuifeng, Zhang fuyao, Guo Junmei, Du Zhihong and Niu Tainting 1997 Development and prospect of sweet sorghum in shanxi pages 643-650 in proceedings of the first International sweet sorghum conference 14-19, September 1997, Beijing, China.
- Linden J C, Murphy V G, Honk L L and Lange K D 1986 Preserving fermentation potential of sweet sorghum via ensiling ASAE paper No. 86 6581. ASAE St. Joseph, M I
- Loomis R S and Williams W A 1963 Maximum crop productivity an estimate. Crop Science 3: 67-71.
- Lueschen W E, Putnum D H, Kanne B K and Hoverstad T R 1991 Agronomic practices for production of Ethanol from sweet sorghum. Journal of Productive Agriculture Vol. 4, No. 4.
- Mallikarjun H, Khansure S K and Kachapur M D 1998 Juice quality parameters as influenced by plant population in sweet sorghum genotypes. Madras Agricultural Journal 85 (3): 209, March, April 1988.
- Miller F R and Creelman R A 1998 Sorghum – A new fuel. Proceeding 35<sup>th</sup> Annual Corn and Sorghum Industry Research Cont. Dec. 9-11 Chicago 80.
- Miller P R and Creelman R A 1980 Sorghum – A New fuel p. 219-232 In: Loden H D and Wilkenson D (ed) proceedings 35<sup>th</sup> Annual Corn and sorghum industrial Research Conference, Chicago 9-11 December, American Seed Trade Association, Washington D C.
- Monk R L, Miller F R, and Mc Bee G G 1984 (a) Sorghum improvement for energy production, Biomass 6: 145-153.
- Monk R L, Miller F R, Mc Bee G G and Creelman R A (1984 (b) Improvement of sweet sorghum for energy production In. proceedings of the 8<sup>th</sup> annual energy from Biomass and water symposium. Institute of Gas Technology, January 30 – February 3, 1984

- Naik D C, Muniyappa T V 1995 Studies on time of harvesting of sweet sorghum genotypes on yield and juice quality for jaggary preparation UAS, Bangalore. Journal of Maharashtra Agricultural Universities 20 (1): 29-30 (1995).
- Narkheda B N, Akeda J H and Awari V R 2000 Variability studies of *rabi* sorghum local types (*Sorghum bicolor* (L.) Moench). Agronomy Journal 25 (3): 300-302.
- Nayeem K A 1980 Genetic studies of quantitative and qualitative characters in grain sorghum [*Sorghum bicolor* (L.) Moench]. Ph. D. Thesis, Marathwada Agricultural University, Parbhani (India).
- Panse V G and Sukhatne P V 1978 Statistical methods for agricultural works. Indian Council of Agriculture Research, New Delhi.
- Parrish D J, Gammon T C and Graves B 1985 Production of fermentables and biomass by six temperate fuel crops. Energy in Agriculture 4: 319-330.
- Parrish R, Reeves S A and Reeves Jr. 1985 Early assessment of sweet sorghum as an Agro-industrial crop. Australian Journal of Experimental Agriculture 21: 83-94.
- Patel D U, Makne U V and patil R A 1994 In correctionship and path coefficient studies in sweet sorghum Marathwada Agricultural University, Parbhani (India). Journal of Marathwada Agricultural University 19(1): 40-41 (1994).
- Patel D U, Makne V G, Mehta H D and Shete D M 1993 Genetic Architecture of grain yield and related characters in high energy sorghum. Journal of Maharashtra Agricultural Universities 18 (2): 261-263.
- Patil R B and Patil B D 1993 Changes in starch, sugars, Heterosis and correlation studies in sorghum. Journal of Maharashtra Agricultural Universities 18 (2): 186-188.
- Patil S L, Sheelvantar M N and Lamani V K 2003 Correlation analysis among growth and yield components of winter sorghum. ISMN 44, 2003.
- Patil S P and Ugale S D 1994 Sweet sorghum as a source of syrup/jaggery//sugar VII joint convention. The Decon Sugar

Technologists Association (India) and The Sugar Technologists Association of India, New Delhi pp. SA 43-57.

Putnum D H, Lueschen W E, Kanne B K and Hoverstad T R 1991 A comparison of sweet sorghum cultivars and maize for ethanol production. *Journal of Productive Agriculture* 4: 377-381.

Radford P J 1967 Growth Analysis Formula – their use and a base. *Crop Science* 7: 171-175.

Ranganna S 1977 Manual of analysis of Fruit and Vegetable production. Tata Me Graw Hill Publishing Company Ltd., New Delhi.

Ravi S B, Biswas P K and Elangovan M 1997 In improvement of sweet sorghum in India. Pages 304-311 in proceedings of first international sweet sorghum conference, 14-19, September, Beijing, China.

Reddy A G R and Reddy T V 1977 A New Technique for jaggery production from sweet sorghum. *Sorghum News Letter* 20: 10-11.

Reddy B V S and Sanjana Reddy 2002 “Sweet sorghum: Characteristics and potential” (ICRISAT, Patancheru, A.P., India), *ISMN* 2003 (44).

Reevers S A, Jr., Hipp B W and Smith B A 1979 Sweet sorghum biomass part I Agronomic data. *Sugar Azucar* 74: 23-20.

Rood S B, Teddy J E Witback, David J Major and Miller F R 1992 Gilberilons and heterosis in sorghum. *Crop Science* 32 (3): 713.

Sankarapandian, Savudainayagam and Chinna Swamy K N 1995 Evaluation of sweet sorghum cultivars for the production of green stalk, juice and grain yield and retooling ability. *Madras Agricultural Journal* 42 (3): 157-160.

Seetharama N, Dayakar Rao B and Karthikeyan K 2005 Facing the challenges NRCS – The Hindu Survey of Indian Agriculture 2005 pp. 50-52.

Seetharama N, Dayakar Rao B, Ratnavathi C V, Shahid Panwer Md, Binu Mathew and Bharth Kumar K A 2002 Sorghum as a raw material for alcohol production, presented at seminar on current development in

alcohol industry organized by Distillers' Association of Maharashtra, 25 August 2002, SAHAR, Mumbai, India.

Seetharama N, Rao S S, Kannababu N and Babitha M 2000 Comparative performance of *kharif* sorghum hybrids, parents and open pollinated varieties for drought tolerance and productivity. ISMN 2000 Vol. 41.

Shukla V K and Sharma P 1994 Response of multicut forage sorghum to N and P under rainfed condition. Indian Journal of Agronomy 39 (4): 648-649.

Silli M V, Hunshal C S and Patil R H 2001 Fodder yield and quality of sweet sorghum genotypes as influenced by N and P levels. K V K, Hanumanamatti, India. Journal of Maharashtra Agricultural Universities 26 (1): 065-067 (2001).

Singh M and Srivastava S 1993 Sorghum grain moisture its effected by quality. Journal of food science and technology 30 (4): 293-297.

Singh S and Reddy M S 1976 Effect of inhibition of flowering on improvement of cane yield at juice quality under Coimbatore conditions. Journal of Agricultural Sciences, Cambridge 87: 375-380.

Smith B A and Jr., Reeves S A 1981 Sweet sorghum biomass part III cultivars and plant constituents. Sugar Azucar 76 (10): 23-30.

Smith G A, Bagby M O, Lewellan R T, Doney D L, Moore P H, Hills F J, Campbell L G, Hogaboam G J, Coe G B and Freeman K 1987 Evaluation of sweet sorghum for Fermentable Sugar Production Potential. Crop Science 27: 788-793.

Southeastern Gasohol Association 1980 The alcohol fuels report – A complete guide to ethanol production. Southeastern Gasohol Association, Atlanta G A.

Stephans J C and Hollaul R P 1954 CMS for hybrid sorghum seed production. Agronomic Journal 46: 20-29.

Veerabadhran K and Kennedy B 2001 Correlative studies of sorghum in their fodder and grain yield. ISMN 2003 Vol. 44.

Watson D J 1952 The physiological basis of variation in yield. *Advances in Agronomy* 6: 103-109.

Wright B C and Roy R 1973 Sorghum growth and nutrient uptake in relation to soil fertility, dry matter accumulation pattern, yield and N content of grain. *Agronomic Journal* 65: 709-711.