

THE EFFECT OF PLANTING DATES AND IRRIGATION
ON THE YIELD OF TWO RAINY SEASON
SORGHUM CULTIVARS

(*Sorghum bicolor* (L.) Moench)

Thesis submitted to the
Andhra Pradesh Agricultural University
in partial fulfilment of the requirements
for the award of the
Degree of Master of Science

By
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B.Sc.(Hons.) Agriculture

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August 1987

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August 1987

CERTIFICATE

Mr. Mohamed Ahmed Mao has successfully prosecuted the course of research and that the thesis entitled "The Effect of Planting Dates and Irrigation on the Yield of two rainy season Sorghum Cultivars", submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

August 1987




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CERTIFICATE

This is to certify that the thesis entitled "The Effect of Planting Dates and Irrigation on the Yield of two rainy season Sorghum Cultivars", submitted in partial fulfilment of the requirements for the degree of "Master of Science in Agriculture" of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr. Mohamed A. Mao, under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. Published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.


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Title : Effect of planting dates and irrigation on the yield of two rainy season sorghum cultivars (*Sorghum bicolor* (L.) Moench).

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ABSTRACT

An experiment was conducted at the Center of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, on Alfisol during the rainy season of 1986 to assess the effects of various planting dates and irrigation on growth, yield and yield components of sorghum genotypes. Grain sorghums (*Sorghum bicolor* (L.) Moench), hybrid CSH-5 and local Pacha Jonna were planted on June 17, July 1, 15 and 30. Irrigated treatments received water once at fortnightly intervals; the aim was to avoid any water deficit during the crop growth.

Significant increase in the growth parameters, yield and yield components were observed in irrigated treatments compared with rainfed treatments at all planting dates.

The highest total yields of dry matter was obtained from the first date of planting (June 17). The grain yield and its components were reduced significantly with successive later plantings due to shoot-fly and ear head bug damage. The advantage of the hybrid over the local variety was more marked under irrigated conditions and at early sowing.

The interaction between water regimes and planting dates had an additive effect on yield. Adequate soil moisture supply and early planting of the sorghum genotypes resulted in significant yield increase.

INTRODUCTION

I
INTRODUCTION

In Somalia rainfed sorghum has become important as sole crop or intercropped with legumes. In most situations crop production is limited by the amount of water available. Often rainfall is inadequate for crop maturity. Such high risk of crop failure inhibits farmers from investing more labour and capital on the crop (ISNAR, 1986).

The time of sowing is considered as one of the important factors limiting crop yield. In tropical climates, soil-moisture, rainfall pattern, variety and insect problems influence the choice of the proper time of sowing (Singh, 1982).

Planting date may affect the water use by sorghum either through its direct effect on plant growth or through the indirect effect on seasonal climate prevailing during plant growth.

Several workers have stressed the importance of early planting in sorghum as later planting decreases the grain yield. Grain yields usually increase with the amount of irrigation applied.. Irrigation to supplement precipitation has made it possible to double and even triple grain sorghum yields in drought prone environments.

Total water use by a sorghum crop depends on climatic conditions as well as on plant factors (Hanks *et al.*, 1968; Hanks *et al.*, 1969 and Ritchie, 1971).

Mirhadi and Kobayashi (1981) reported that there was a substantial increase in plant height, panicle length, number of leaves per plant, number of grains per panicle, grain and forage yields and their nitrogen contents in irrigated treatments compared with non-irrigated treatments at all planting dates. Early planting resulted in higher grain and protein yields in both irrigated and non-irrigated treatments compared with later planting.

Ali *et al.*, (1981). Observed that early planting of kharif crops e.g. in India under dryland conditions led to highest production and economic return which decreased when planting was delayed.

In Somalia, Marvin (1969) reported that dry sowing of sorghum just before the onset of the seasonal rains permits the seedlings to escape infestation of shootfly while late planted sorghums were seriously attacked.

To optimise sorghum production, it is important to ensure good seed bed preparation, accurate seed placement, adequate seedling density, provide effective seedling protection and plant at the correct density.

This experiment is designed to measure the crop response to various aspects of environment with the following objectives:

- 1) To determine the effect of various sowing dates on yield of sorghum genotypes.
- 2) To study the interaction effects between genotypes and water regimes.

LITERATURE REVIEW

II

LITERATURE REVIEW

Sorghum (*Sorghum bicolor* (L.) Moench) crop has historically been cultivated for grain to a varying degree in almost all tropical and sub-tropical countries of the world (Posner, 1975).

As a world food crop, sorghum ranks fourth in importance among cereal crops after wheat, rice, and maize. It is one of the major food crops grown for human consumption in arid and semi-arid regions of Africa and Asia (Salunkhe *et al.*, 1985). There were 50 million hectares of sorghum in the world with a production of 77 million metric tons (FAO, 1985). Asia, North Central America and Africa contribute to most of the world production of sorghum. India, China, Nigeria, and Sudan are the major sorghum - producing countries (Salunkhe *et al.*, 1985).

In India, sorghum is the third major cereal and is grown on dryland during the rainy season and on receding soil moisture during post-rainy season in 10 and 6.2 million hectares respectively. In the last two decades, total sorghum area has dropped by two million hectares. However, production has shown a remarkable annual growth rate of 2 percent during the same period. But the increase in production was confined to the rainy season crop (Rana, 1985).

Sorghum is one of the most important food crops in the semi-arid tropics, as it can be grown successfully under conditions too dry or too hot for corn (Hibbler and Stanley, 1981).

Most countries of the semi-arid tropical belt of Africa, Asia, and Latin America have exhibited a dramatic downward trend in levels of food self-sufficiency over the last 15 years. This decline has been reflected in both a general decline in total annual rainfall (Motha and Sakamoto, 1979) and largely year to year fluctuations in the amount of rainfall.

Profitable yields of sorghum depends to a considerable extent upon good cultural practices. Sowing dates and supplementary irrigations play an important role in determining the yield. It is the aim of this study to review the available literature concerning the effect of sowing dates and water regimes on the yield and other characteristics of grain sorghum.

2.1 Effect of planting dates on plant development and yield :

Many attempts have been made to increase yields by planting at an appropriate time for a given locality. In tropical climates, soil temperature is usually not a restraint but other factors, such as soil moisture reserves, rainfall pattern, variety duration and seedling insect problem make the choice of proper planting date as an important factor. The objective is to adjust the planting date of sorghum so that the crop variety grown completes its life cycle at the most optimum environmental conditions for growth and development (Wall and Ross, 1970).

Early sowing makes it possible for the plant to take the greatest advantage of the moisture stored in the soil prior to sowing. With early planting, the crop shades the soil earlier in the season thereby reducing water losses due to evaporation.

Early sowing also escapes shoot-fly attack in the early stage and midge infestation at ear stage (Arnon, 1972).

The optimum sowing time for grain sorghum during rainy season in India appeared to be the onset of first monsoon shower. Progressive delays of 7, 14, or 21 days after the first monsoon rain caused substantial yield reductions. The greatest reduction was found at Indore, Dharwar, and Parbhani and the least at Pantnagar (Singh *et al.*, 1976).

In Udaipur, Rathore, *et al.*, (1980) studied the response of Hybrid CSH-5 to dates of sowing under dryland conditions to determine the optimum time of sowing of kharif sorghum. They stated that among different dates of sowing, first sowing (earliest) produced maximum grain and stover yields.

Srivastava and Singh (1981) reported that earlier sowings gave significantly higher grain yield than the later dates. Fodder yield was also reduced with delay in sowing.

Ali *et al.*, (1981), while studying the productivity and profitability of dry-land crops of Bundelkhand region (India) reported that early planting led to highest production and return from sorghum and decreased when planting was delayed.

In Canada, Hume and Kebebe (1981) reported that grain yield of hybrids decreased by about 10% per week when plantings were delayed by 2 or 4 weeks.

A field experiment was conducted by Subbian *et al.*, (1983) at Bhavanisagar, Tamil Nadu, India to study the response of

sorghum varieties to time of sowing and N levels in different seasons. The results revealed that among the different time of sowings, sowing in early February and early July were found to be optimum for getting maximum yields in summer and kharif seasons.

Umran and Patil (1983) reported that early sown cultivars yielded more grain and fodder than late sown cultivars on both shallow and medium deep soils. The percent reduction in grain yield.ha⁻¹ due to delayed sowing was 27% and 66% respectively, for the shallow soils and 16% and 35%, respectively for the medium deep soils. Fodder yields increased more in the early sowings on both the types of soils than from later sowings.

Assis *et al.* (1984) studied the response of two sweet sorghum cvs. to different dates and rates of sowings. They found that average fresh yield were more in early with the highest rate of sowings. Delay in sowings reduced the sugar content of the cultivars.

Francis *et al.* (1986) while studying the interactions of grain sorghum hybrid with tillage and planting date concluded that mean grain yields ranged from 8790 kg.ha⁻¹ in early planted zero tillage plots to 5740 kg.ha⁻¹ in late planted conservation tillage plots. Highest yields consistently occurred with zero tillage and early planting. Interaction of hybrid grain yield with planting date or tillage system was minimal. Grain yields obtained at the 3 sowing dates varied with the season; dry matter yields were highest at the early sowing date for all 4 localities.

Itinal *et al.* (1986) concluded that time of sowing had greater influence in enhancing the crop yield. It was also observed that the fertilizer use efficiency was higher with early sowing as compared to late sowing.

Pauli *et al.* (1964) reported that earlier planting dates of sorghum crop increased the time to floral initiation, prolonged the time between floral initiation and anthesis, shortened the grain filling period, and generally lengthened the duration between planting and maturity. Blum (1972) also reported an increase in the number of days from emergence to heading with earlier planting. Ogunlela (1982) conducted a field experiment at Samaru in northern Nigeria to compare the effect of sowing date of sorghum on growth and development of photo-sensitive and photo-insensitive sorghums. He pointed out that both cultivars responded differentially to sowing date. Heading, 50% bloom and physiological maturity were markedly delayed by delayed sowing in one cultivar compared with the other. However, the length of grain filling phase was shortened in both cultivars. Total dry matter production and plant height decreased in both cultivars when sowing was delayed.

Information of this type has also been reported by Karper *et al.* (1931) who found that medium to late planting dates generally resulted in a shorter total growth period than early plantings. Results obtained by Paulson (1962) generally agree with the above finding. Four varieties of grain sorghum required progressively shorter period to reach 50% full bloom as date of planting was delayed.

Ogunlela (1985) while studying the differential yield response of photo-sensitive and photo-insensitive sorghum varieties to delayed sowing in semi-arid Nigeria, reported that late sowing caused marked reduction in grain and straw yields in photo-sensitive sorghum (*Sorghum bicolor* (Linn) Moench). The late sown crop of photo-insensitive sorghum yielded more but less straw than early-sown crops. Much of the yield loss in the late-sown crops was caused by sorghum shoot-fly (*Atherigona soccata* R.), and soil moisture depletion. Late-sowing reduced panicle weight, grain number and grain weight in photo-sensitive sorghum but it increased grain number in photo-insensitive sorghum varieties.

According to Arnon (1964) early planted sorghum can escape heavy damage by the sorghum fly (*Atherigona exigua*). Doggett (1976) has reported that in most of the African countries, the optimum date of planting is at the onset of rain shower. A delay in planting often resulted in severe shoot-fly damage and midge infestation late in the season. Early sowing is still the only practical method of avoiding heavy damage by the sorghum fly (*Atherigona exigua*). Long intervals between sowing and emergence favor insect damage to the 'seed' and seedling.

Wheatley (1961) from Kenya reported that losses in yield were negligible in timely sown sorghum, while the late sown sorghum suffered moderate losses. Sowing immediately after the break of rains, possibly within a period of two weeks in any area, was recommended (Young, 1981). In Somalia, limited observations at CARS (Central Agricultural Research Station)

Afgoi, indicated that early planting of sorghum, just before the onset of the seasonal rains, permits the seedlings to escape infestation of shoot-fly while late planted sorghum were seriously attacked (Marvin, 1969).

In Thailand, it has been reported that in areas where plantings are done at different times, the earliest planted crops are usually free from serious infestation, while those planted late often encounter severe infestation. Thus, it is suggested that planting should be done as early as possible and at the same time over large areas to avoid heavy infestation (Young, 1981).

Early sowing of sorghum has been recommended in many countries of the semi-arid region to prevent the heavy incidence of sorghum shoot fly, stem borer and midge (Ingram, 1958; Nye, 1960; Delobel and Unnithan 1981; Zein El Abdin, 1981 and Seshu Reddy, 1983).

2.2 Irrigation influence on yield and yield components :

Sorghum is known to be a drought resistant crop, but in many areas of the world where there is insufficient rainfall during the growing season, without supplementary irrigation, higher yields cannot be obtained.

The amount of water used by the sorghum plant is affected by many factors such as temperature, humidity, wind movement, soil moisture, variety, duration of growth period and also agroclimatic conditions. The most effective use of water is obtained when the sorghum crop is provided with adequate water

for continuous vigorous growth. Attempts have been made by several scientists to estimate the optimum moisture regime for sorghum grain production and it was generally agreed that the limit of available soil moisture within the active root zone of sorghum (about 0-60 cm) should not go below 25 percent. Yields go down abruptly if the available soil moisture falls below 25 percent (Wall and Ross, 1970).

According to many authors, the maximum yield of sorghum can be obtained with irrigation. In Southern Italy, Currente and Bertoldi (1962) found that although sorghum is drought resistant, good yields of this crop required irrigation. Scarascia, *et al.* (1983) reported that yields and yield components of sorghum increased with increasing irrigation upto 300 mm. ha⁻¹ above which they remained constant. Farah (1983) reported that grain yield of sorghum and its components and straw yield were significantly affected by the irrigation treatments, which were themselves considerably affected by rainfall. He further concluded that high yields of rainfed sorghum can be obtained if water deficit are avoided by supplementary irrigation during one or more of its growth period. Brown *et al.* (1964) obtained significantly more dry-matter and grain from irrigated plots than from non-irrigated plots. Musick *et al.* (1963) reported that maximum sorghum grain yield was obtained with adapted hybrids under high levels of irrigation and nitrogen.

Reddy *et al.* (1978) studied the performance of sorghum varieties to nitrogen under rainfed and irrigated conditions and recorded average grain yields from 1.61 to 3.83 t.ha⁻¹ under

rainfed conditions and from 1.53 to 4.98 t.ha⁻¹ with irrigation in the kharif (monsoon) season. Muldoon (1985) studied the growth, mineral composition and grain yield of irrigated and rainfed millets and sorghum and concluded that irrigated sorghum consistently produced the highest grain yields over the other treatments.

In a field trial at ICRISAT, Hyderabad, pearl millet (*Pennisetum americanum*) was grown on a medium - deep Alfisol under irrigated and rainfed conditions. The results indicated that nutrient uptake, plant dry weight and nutrient content at harvest were higher in irrigated than in the rainfed crop (Gregory, 1979). Increase in dry matter production with increase in available soil moisture was reported by Ravindranath (1970) and Satyanarayana (1970). Quinby and Marion (1960) reported that the use of irrigation increases forage sorghum production per acre in comparison with dry-land production.

2.3 Effect of planting date and irrigation on plant development and yield of sorghum

Although sorghum is considered drought-tolerant and able to give very good yields under dryland conditions, it responds very well to irrigation (Karper and Quinby, 1947; Wilson and Mayers, 1953; and Arnon, 1972). If facilities for irrigation are available, much higher yield can be expected (Wall and Ross, 1970). The work of a number of investigators (Anonymous, 1962; Brown *et al.*, 1954; Currente *et al.*, 1962; Grimes and Musick, 1960; Harrington, 1963; Martin *et al.*, 1959; Musick and Grimes, 1961 and Painter *et al.* 1953) indicated that high yields of grain

yields and fodder sorghum can be produced with application of irrigation water.

More systematic work on water needs of kharif sorghum was done at Rahuri, Maharashtra, India (MPKV, 1980). It revealed that the water need for CSH-1 sorghum hybrid was 394 mm whereas slightly longer maturing hybrid CSH-5 required 457 mm water. In the semi-arid summer rainfall regions of the United States, it is estimated that in favorable season, the water requirement of sorghum may be 400 to 500 mm, while in hot dry years, 600 mm may be required for maximum yields (Swanson and Thaxton, 1957).

Under irrigated conditions in kharif season, the optimum sowing time varied from 4th week of June for Madhya Pradesh and 1st week of June for Tamil Nadu. Similar results were reported by Singh *et al.* (1968); Lingegowda *et al.* (1971a) and Chandrawanshi *et al.* (1973).

Mirhadi and Kobayashi (1981) studied the effect of various planting dates on the growth, grain yield and protein content of irrigated and non-irrigated grain sorghum and reported that there was a remarkable increase in plant height, panicle length, number of leaves per plant, number of grains per panicle, grain and forage yields and their nitrogen contents in irrigated treatments compared with non-irrigated treatments at all planting dates. Compared with later planting, early planting resulted in higher grain and protein yields in both irrigated and non-irrigated treatments.

Blum (1972) reported that, early planting as compared with late planting, increased grain yield through increased tillering and greater weight per panicle. During the period from emergence to 51 days, early planted sorghum used about half as much water as late-planted sorghum. Total amount of water used at maturity did not differ between planting dates, apparently due to the longer period of growth and the larger amount of stover and dry matter in early planted sorghum, which served to offset the decreased water use during the earlier phase of growth.

Three grain sorghum cvs. ranging from short to medium maturity were grown at a range of population densities, either with adequate irrigation (wet) or with no irrigation other than at sowing (dry) were studied by Mayers *et al.* (1986), during the rain-free dry season in the Ord irrigation area in north Western Australia. They reported that without irrigation, the crops matured eight days earlier and produced less total dry matter and less grain. Irrigated and cultivar effects on grain yield were largely associated with variation in grain size.

Inuyam (1978) claimed that grain yields of sorghum were increased by irrigation. With irrigation grain yield was highest with the earliest sowing date but without irrigation was highest with the latest sowing date. The effect of drought were greatest at booting.

**MATERIALS
AND
METHODS**

III

MATERIALS AND METHODS

3.1. Location:

The experiment was conducted at ICRISAT Centre at 18° N, 78° E, 500 m elevation, near Patancheru village, Andhra Pradesh, 26 km northwest of Hyderabad, during the rainy season, also known as the monsoon or Kharif season (June to October) of 1986.

The experimental plot was of a red soil (Alfisols) which is light, with an available water holding capacity (AWHC) in the top 127 cm of soil of about 90-100 mm. The soils are relatively shallow, well-drained and have a reasonable hydraulic conductivity. In the dry season, the soils are difficult to cultivate because of surface hardness. The physical and chemical characteristics of the soil are given in tables 1a and 1b. These soils are low in nitrogen and available phosphorous but high in potassium.

3.2. Climatic conditions:

The climate of ICRISAT Centre is typical of a semi-arid tropics characterized by a short rainy season (3-4 months) and a prolonged dry weather (8-9 months) (ICRISAT, 1984). The normal rainy season is approximately from mid-June to end of September and an average of 86% of the annual total rainfall is received during this period. Rainfall is very erratic, with an annual coefficient of variation of 26% (Virmani, 1979). The mean annual maximum temperature is 35.5° C and the minimum is 18.5° C. The

average daily U.S.W.B. Class A pan evaporation varies from 3.8 to 12.3 mm (ICRISAT, 1984).

The total rainfall received during the period of experimentation from June 1986 to November 1986 was 572.7 mm in 50 rainy days. The mean maximum and minimum temperatures were 31.5 and 22.0°C respectively. The average daily pan-evaporation was 6.5 mm.day⁻¹. The climatological parameters from June to November 1986 are presented in Appendix I, and the trends are shown in Fig. 2.

Table 1a. Chemical properties of the soil under experimentation:

Soil depth (cm)	pH	EC%	Exch. K (ppm)	Available P (ppm)	Organic carbon (%)	NH ₄ (ppm)	NO ₃
0-15	8.43	0.36	158	6.25	0.77	3.6	6.0
15-30	8.37	0.24	129	2.75	0.58	2.2	0.9
30-60	8.27	0.35	159	1.50	0.53	3.3	12.7

3.3. Cropping history:

The experimental plot for the past three years was under intercropping trial (millet/groundnut) during the rainy season and fallow during the post rainy and summer seasons. Fertilizer was applied at the rate of 60 kg ha⁻¹ nitrogen in the form of urea and 46 kg ha⁻¹ of P₂O₅ in the form of superphosphate. All the phosphorous fertilizer and 18 kg of nitrogen fertilizer were applied prior to planting as basal dressing, while 42 kg of nitrogen was applied by row placement after 30 days of emergence as top dressing.

Table 1b. Physical properties of the soil under experimentation.

Soil depth (cm)	Mechanical fractions (%)				Soil moisture (%)		Bulk density (g/cm ³)
	Coarse sand	Fine sand	Silt	clay	F.C.* (1/3 bar)	W.P.** (15 bar)	
0-15	39	21	11	29	17.9	12.4	1.5
15-30	40	22	8	30	16.6	15.1	1.6
30-60	40	17	8	35	20.3	15.0	1.6
60-90	37	14	12	38	21.9	16.9	1.6

*at field capacity

**at wilting point.

3.4. Experimental details:

The effects of sowing dates and water regimes on two kharif grain sorghums [*Sorghum bicolor* (L.) Moench] of a medium maturity group were evaluated at ICRISAT experimental farm (field RP4).

The trial was laid out in a split-split-plot design with four replications. The main-plot treatments were consisted of two water regimes viz., irrigated and rainfed. The sub-plot treatments consisted of four planting dates viz., June 17, July 1, July 15 and July 30 of 1986. The sub-sub-plot treatments consisted of two genotypes viz., the local Pacha Jonna and the hybrid CSH-5 (description of genotypes are given in Appendix C).

The two water treatments were as follows:

- 1) Furrow irrigation at 15 day intervals; the aim of this treatment was to avoid any water deficit during the crop growth. Irrigation schedules were adopted in such a way that moisture was not a limiting factor as approximately

60 mm of water was provided at each application. The amount of water applied varied according to the soil moisture content at the time of application. This soil moisture content was determined by gravimetric method.

- 2) Fully rainfed, where no supplementary irrigation was applied.

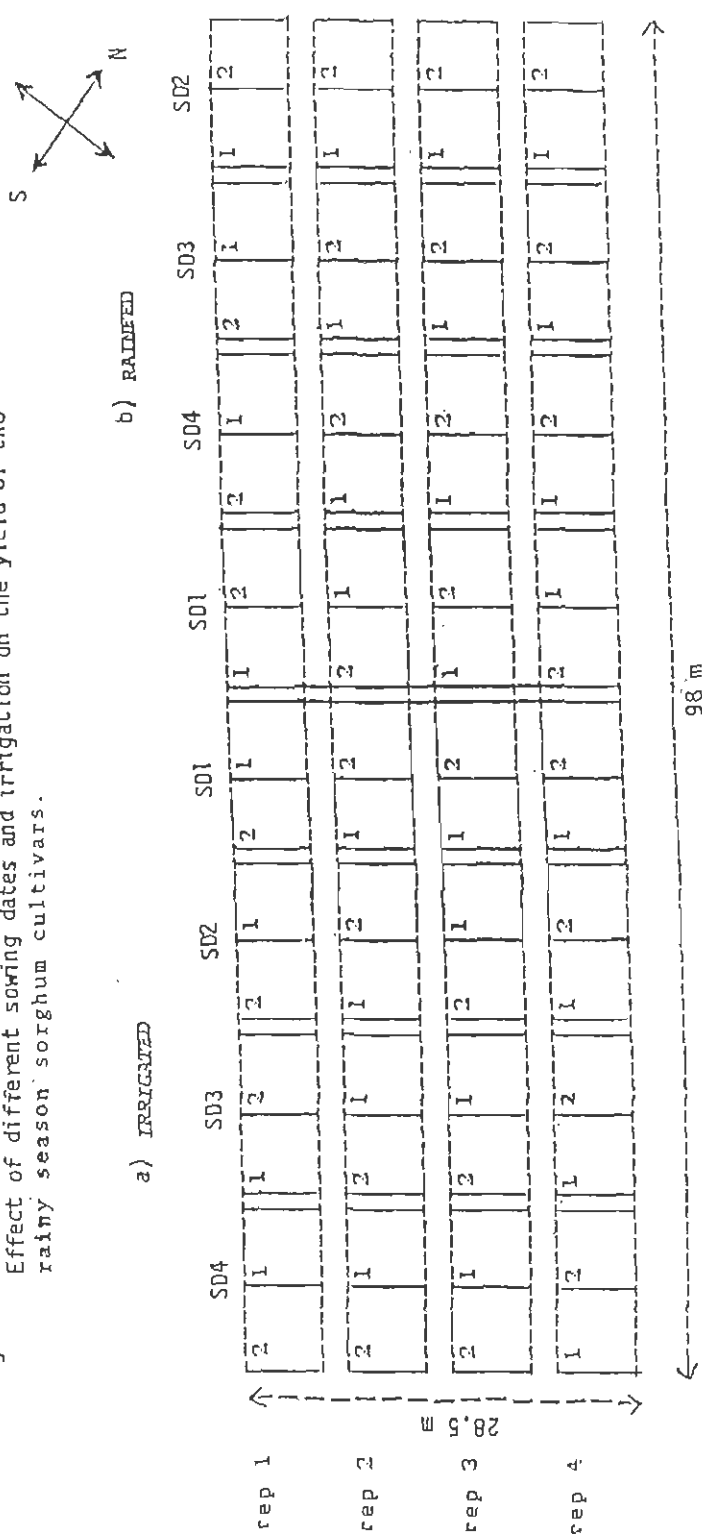
Planting was done by hand in 75 cm rows and stand was thinned two weeks after emergence to 6.6 plants m^{-2} . The total experimental area was 0.23 ha. Each sub-sub-pot consisted of eight rows, 6 m long and 20 cm between plants. The central 4 m of four furrows giving an area of 12 m^2 were harvested for estimation of dry matter and grain yield. The field layout of the experiment was shown in Fig. 1. Carbofuran granules were applied at the rate of 40 kg ha^{-1} in the rows along with the seed at planting to protect the crop against shootfly attack. Since there was a heavy incidence of shoot fly in the late sown crop viz; second, third and fourth sowing dates, repeated applications of Carbofuran was applied every week after germination in the whorls of the plant. The crop was also uniformly protected from the incidence of other insect pests. The plant protection measures taken were presented in Table 2. Weeds were removed throughout the season whenever necessary by hand weeding.

3.5. Parameters evaluated:

1. Initial soil fertility analysis:

Six random soil samples were taken before planting from 0-15

Fig. 1: Field layout
 Effect of different sowing dates and irrigation on the yield of two rainy season sorghum cultivars.



Design: Split-split-plot

1. Main treatment: Water regimes
 a) Irrigated
 b) Rainfed

2. Sub-treatment: Sowing dates
 SD1 = June 17
 SD2 = July 1
 SD3 = July 15
 SD4 = July 30
 SD = Sowing Date

3. Sub-sub-treatment:
 Genotypes =
 1) Hybrid - CSH5
 2) Local - Pacha Jenna

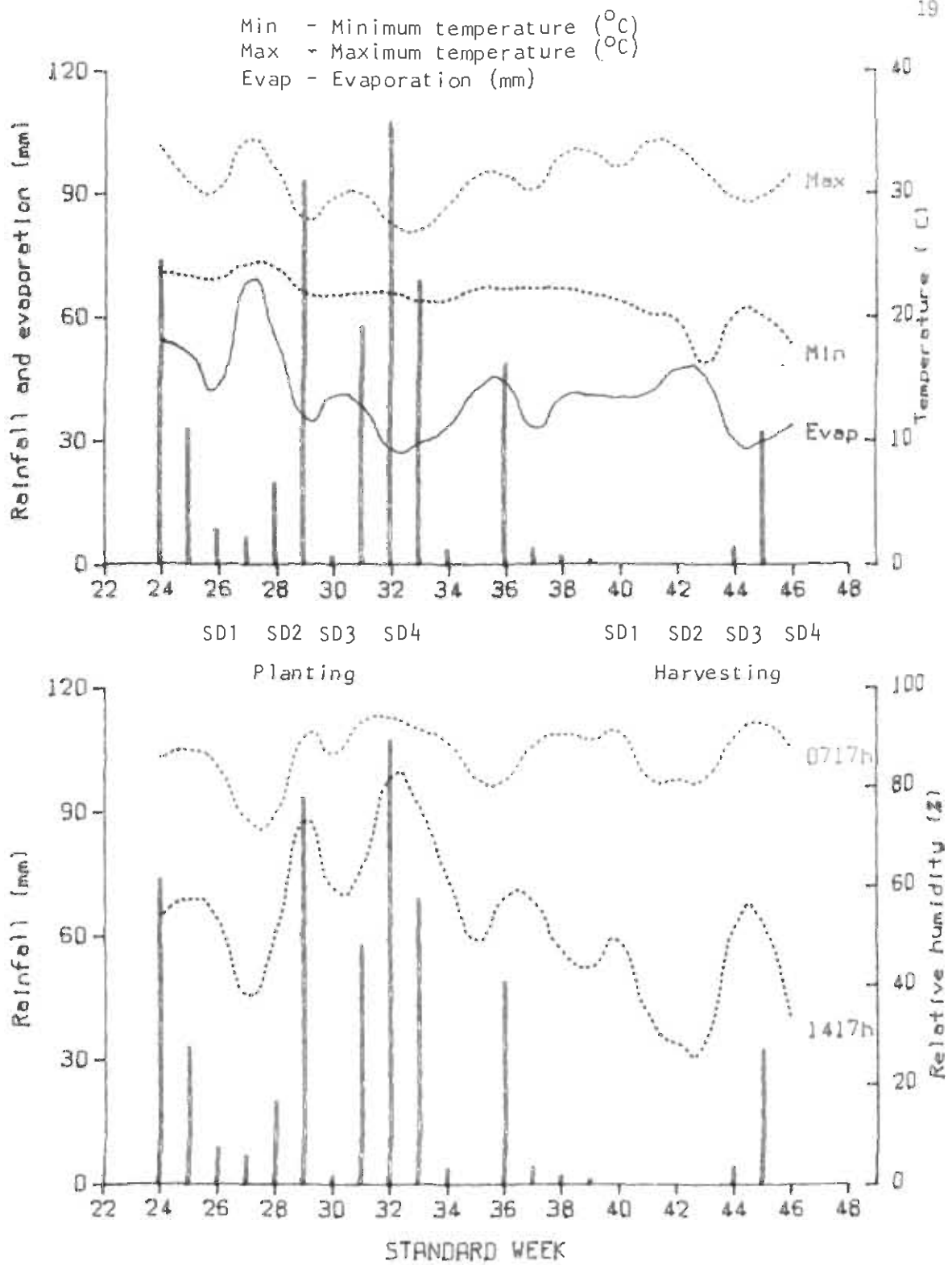


Fig. 2. Rainfall and evaporation (mm), mean maximum and minimum temperature (°C) and relative humidity (%) for standard weeks 24 to 46 of 1986, at ICRISAT Center.

0717 h - Relative humidity (%) at 0714 h
 1417 h - Relative humidity (%) at 1417 h
 SD - Sowing Date

cm, 15-30 cm and from 30-60 cm depth by using a scaled soil auger. These were bulked into a composite sample for each depth and oven dried at 105^o C till a constant weight is obtained.

Table 2: Dates and chemicals sprayed during growth period.

Date sprayed	Insect	Chemical	Rate	Remarks
28.6.86	Shootfly	Thiodan	0.35%	SD1*
05.7.86	Shootfly	Thiodan	0.35%	SD1
31.7.86	Shootfly & Cutworms	Thiodan	0.35%	SD1 + SD2
04.8.86	Cutworms & Stem borer	Thiodan	0.35%	SD2 + SD3
18.8.86	Shootfly	Thiodan	0.35%	SD3 + SD4
20.8.86	Shootfly	Thiodan	0.35%	SD4
27.8.86	Head bugs & cutworms	Thiodan	0.35%	SD2 + SD3 + SD4
16.9.86	Head bugs	Thiodan	0.35%	SD2 + SD3
25.9.86	Head bugs	Sevin	2 kg ha ⁻¹	SD3
30.9.86	Heliothis	Thiodan	0.35%	SD3
14.10.86	Head bugs	Sevin	2 kg ha ⁻¹	SD4

* SD = sowing date

The same sample was used to determine the mechanical composition and the initial fertility status (Table 1a and 1b).

The mechanical composition of the soil was determined according to the conventional schemes of the International Society of Soil Science (ISSS) for classification of textural fractions of soil. Total nitrogen content of the soil was determined by Kjeldahl method as described by Bremner and Keeney

(1965). Available phosphorous was determined by the Olsen's method (Olsen and Dean 1954) and available potassium by atomic absorption spectro-photometer method (Pratt 1965). Determination of pH and electrical conductivity by pH and EC meters on a soil suspension and supernatant of 1:2 soil and water respectively (Michael, 1965).

2. Date of sowing:

This is the date on which the crop was sown in the field.

3. Date of crop emergence:

Date on which about 90% of the seedlings had emerged.

4. Days to 50% flowering:

Number of days from emergence up to 50% anthesis in the panicles of 50% plants in a plot (IBPGR, 1980).

5. Days to maturity:

This was recorded from the date of emergence to physiological maturity.

6. Crop stand:

Stand count was taken two weeks after emergence of the crop and excess plants were thinned. Another count was taken at the time of harvest.

7. Plant height:

Average height from ground to the top of the head in centimeters measured after flowering based on ten randomly chosen plants (IBPGR, 1980).

8. Panicle length:

Mean length from the neck of the panicle to the tip was measured in centimeters based on the length of panicle from 10 randomly chosen plants (IBPGR, 1980).

9. Total dry matter and grain yield:

Grain and total dry matter yields were recorded by harvesting a net area of 12 m² for each sub-sub-plot. Stalk of plants within the harvest area were weighed on the field and samples of 10 plants were randomly selected and weighed. The samples and panicles were sun-dried for a week to a constant weight and weighed. The panicles were threshed and the grain and stover weights were determined from the panicles and the samples respectively. Other yield parameters determined were:

a. Harvest index:

Harvest index was calculated as the ratio of grain yield to the biological yield.

b. 1000 grains weight:

The weight of 1000 grains was calculated from the sample obtained from the net plot and was recorded in grams.

c. Threshing percentage:

The threshing percentage was derived as follows:

$$\text{Threshing \%} = \frac{\text{Plot grain yield}}{\text{Plot panicle weight}} \times 100$$

10. Total panicle weight:

The total head weight in grams from each plot within harvested area was recorded and weighed.

11. Total grain weight:

The total grain weight in grams from each plot within harvested area was recorded and weighed.

12. Light interception:

Light interception was recorded at a fortnight intervals at

three growth stages; booting stage, flowering stage and maturity stage. Measurements were taken with the help of a T-meter at one randomly chosen spot in the net plot area. At each spot readings were taken covering the total width of the net plot. The following are the components of T-meter (Mathews and Saffell, 1987).

- a. A one meter tube containing the photocells to measure the photosynthetically active radiation (PAR). This was placed across rows below the canopy to measure the radiation transmitted to the ground.
- b. A vertical stand with a photocell to measure the total incoming radiation (i.e. control).
- c. An integrator to calculate the percentage of light transmitted through the canopy. Per cent light intercepted by the crop can be obtained by subtracting the percentage transmission from 100.

13. Statistical analysis:

The results were analysed according to the analysis of the variance (ANOVA) scheme for the split-split-plot design (Gomez and Gomez, 1984). Summary of the analysis of variance for the different parameters were presented in Appendix B. Whenever a F-test was significant, a critical difference (CD) was computed at the 5% level for comparing the treatment differences.

14. Correlation studies:

Simple and partial correlation coefficient were established between grain yield and various environmental factors.

EXPERIMENTAL RESULTS

IV

EXPERIMENTAL RESULTS

The observations recorded on plant characters and yield components of two rainy season sorghum cultivars as affected by various sowing dates and water regimes during rainy season of 1986 are presented under the following sections:

4.1. Developmental phase:

- 4.1.1. Days to 50% flowering
- 4.1.2. Days to physiological maturity
- 4.1.3. Light interception
- 4.1.4. Plant height
- 4.1.5. Number of leaves
- 4.1.6. Plant stand and number of panicle m^{-2}
- 4.1.7. Percentage of barren plants

4.2. Panicle characters

- 4.2.1. Panicle length
- 4.2.2. Grain weight per panicle
- 4.2.3. Number of grains per panicle
- 4.2.4. Total panicle weight and weight per plant

4.3. Yield and yield components

- 4.3.1. Total dry matter and dry weight per plant
- 4.3.2. Grain yield
- 4.3.3. Stover yield and stover per plant
- 4.3.4. Harvest index and seed weight
- 4.3.5. Threshing percentage

The results are presented in tables 1 to 20, and the analysis of variance (ANOVA) tables are presented in Appendix B. The critical difference (CD) values at 5% levels of significance are reported under each table. The coefficient of variations (CV%) of the experiment are also reported under each table for various characters analysed.

4.1. The data on growth observations and post harvest observations have been summarized and presented below along with the results of statistical analysis. Some parameters have been shown in figures.

4.1.1. Days to 50% flowering

Days taken to reach 50% flowering for genotypes at different sowing dates and water regimes are presented in Appendix A.1.

The persual of the data indicated that the panicle emergence of sorghum was not influenced by water regime treatments. The average number of days to 50% flowering decreased as planting was delayed. This was evident in the late sowing date when compared to first sowing date. However, there was no significant differences.

The hybrid came to flowering earlier than the local variety at all the planting dates and the duration of days to 50% flowering decreased as plantings were delayed from June 17 through July 30.

4.1.2. Days to physiological maturity

The average number of days to physiological maturity of the genotypes are presented in Appendix A.2.

The number of days to physiological maturity of the two genotypes were not affected by different water regime treatments. The range of average days to maturity among the sowing dates were from 101 to 97 days under the first and the last sowing dates, respectively. However, the differences were not significant.

4.1.3. Light interception

The seasonal trend in the percentage light interception by the sorghum canopies at various sowing dates and water regimes are shown in Fig.3.

Intercepted radiation was significantly affected by water regime treatments. The hybrid and the local cultivar intercepted more light in the irrigated than in the rainfed treatments. The peak interception value of 90% was reached at boot leaf stage in the irrigated treatments and after flowering it declined to 80%.

Light interception percentage of the hybrid and local genotypes in the rainfed treatments followed the same pattern observed in the irrigated treatments. After attaining a peak of 85 and 81% at boot leaf stage by the hybrid and local, respectively, the percent light interception declined to 75 and 67% at physiological maturity.

Light interception for other sowing dates followed similar pattern as that of first sowing date, except that at boot leaf stage, the local in the third sowing date intercepted less light in the irrigated than in the rainfed treatments. However, the light interception was improved at anthesis.

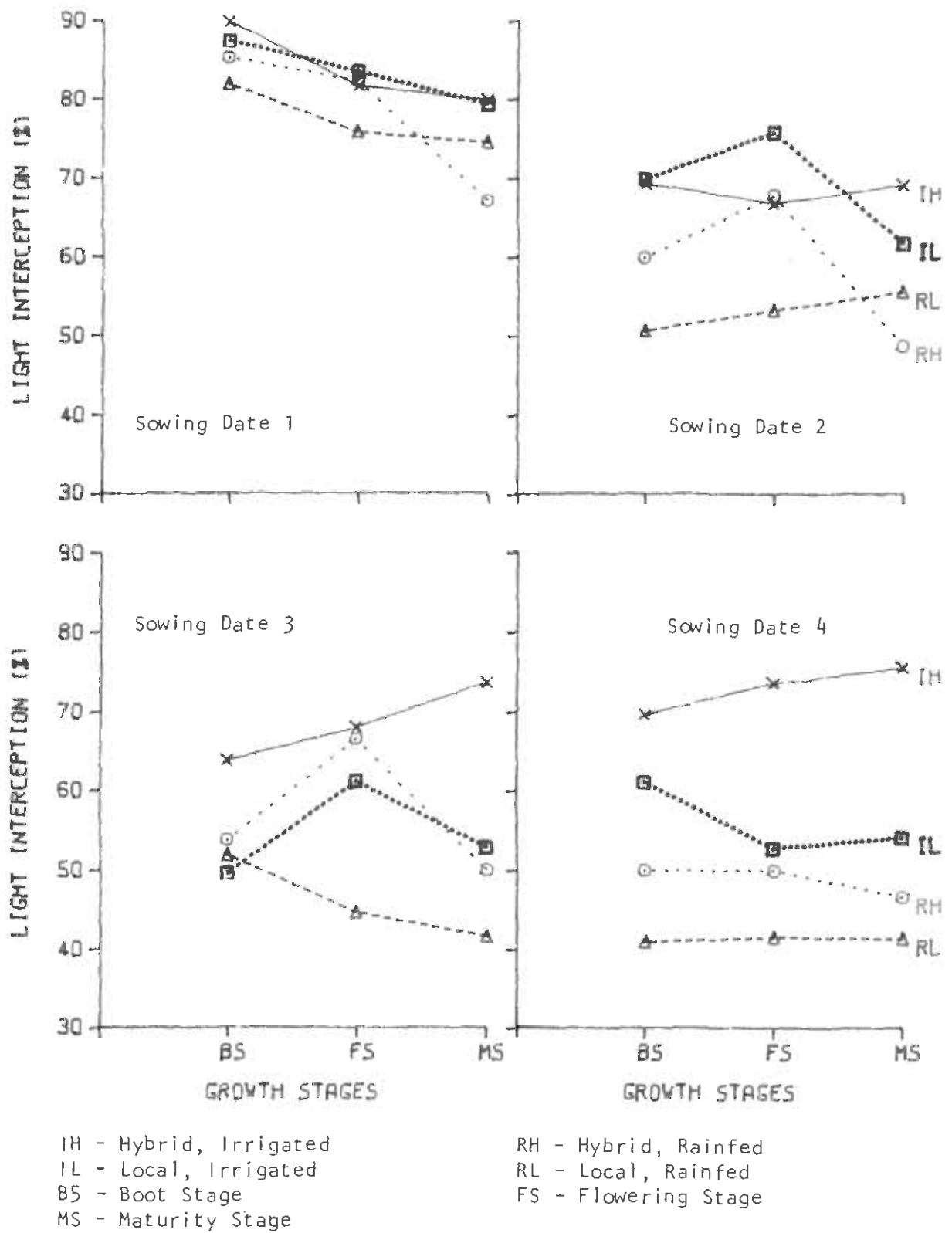


Fig. 3. Light interception (%) of sorghum genotypes as affected by sowing dates and water regimes during rainy season, 1986.

The reduction in light interception at later sowing dates was due to the reduction in plant stand per unit area and moisture shortage in rainfed treatments.

4.1.4. Plant height

The data on plant height recorded at harvest time stage are shown in Fig.4 and in table 3.

The plant height (cm) at harvest was influenced by water regimes as well as the sowing dates.

A maximum plant height of 200 cm was recorded in irrigated treatments. A significantly lower plant height of 173 cm was observed in rainfed plots. The maximum increase in plant height due to irrigation was 14 percent.

Highly significant differences in plant height was also found among the sowing dates. Plant height decreased with delay in sowing dates. The plant height was 235 cm followed by 184, 166 and 160 cm under first, second, third and fourth sowing dates respectively. A difference of 33% was observed between the lowest and the highest plant height.

Highly significant differences in average plant height was observed between the genotypes. The local cultivar was significantly taller (203 cm) than the hybrid (169 cm) under both irrigated and rainfed conditions at all planting dates.

There was a considerable decrease in plant height with the delay in sowing from June 17 to July 1 for the hybrid in irrigated conditions. The variation in heights were significant,

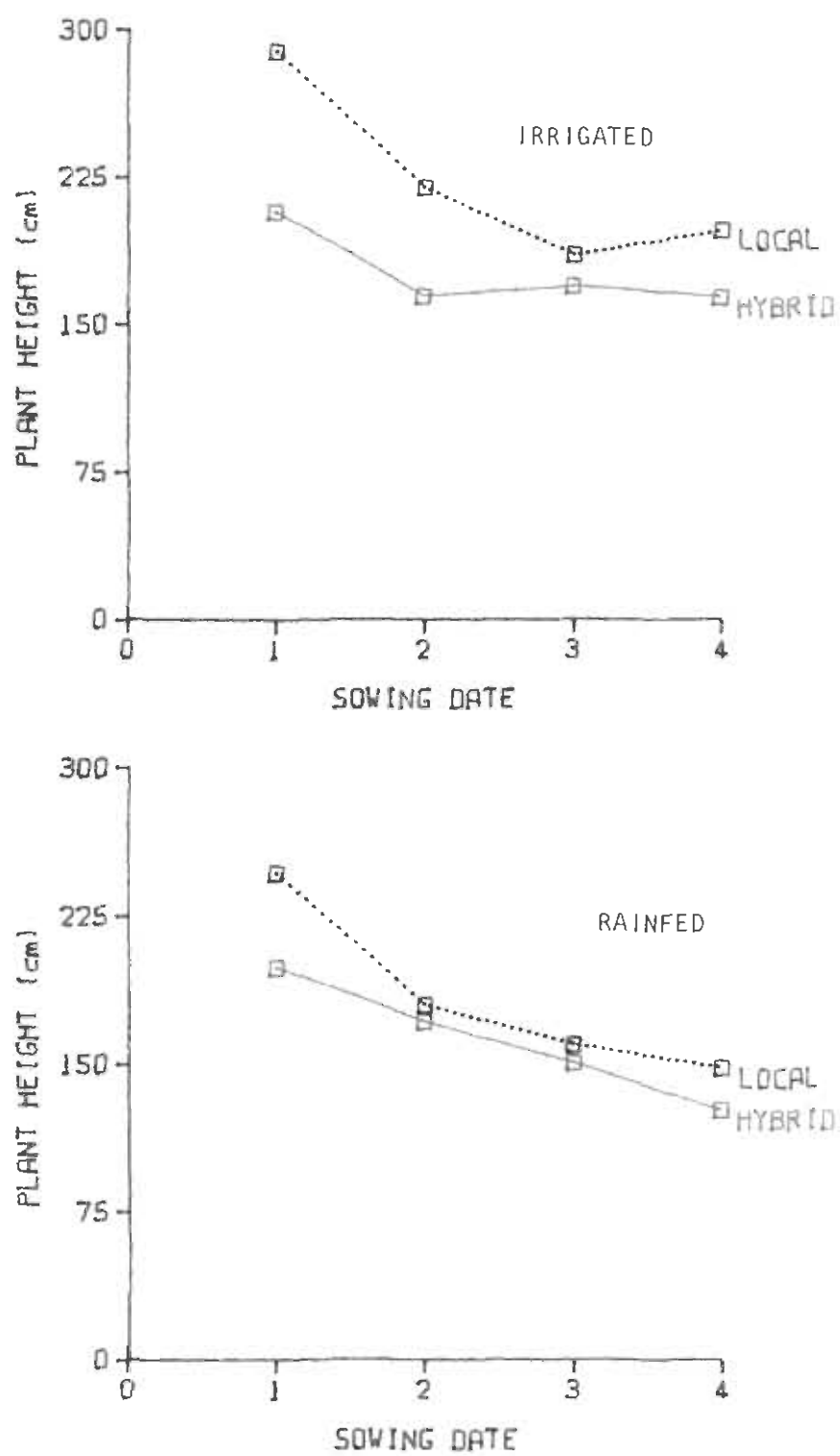


Fig. 4. Plant height (cm) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

Table 3: Plant height (cm) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	207	165	170	164		
	Local	289	219	185	198	200 (W1)	169
	Mean	248	192	177	181		
Rainfed (W2)	Hybrid	199	172	150	127		
	Local	247	180	159	148	173 (W2)	203
	Mean	223	176	155	137		
Average		235	184	166	159		

Treatments	SE _F	CD(5%)
Water (WAT)	2.8**	13
Sowing Dates (SD)	2.8***	8
Genotypes (GENO)	2.0***	6
WAT x SD	4.4*	13
WAT x GENO	3.4***	10
SD x GENO	4.0***	12
WAT x SD x GENO	6.0*	17
CV(%)	6.1	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

but the heights were practically the same from the second, third and fourth sowing dates. While under rainfed condition, the reduction in heights were linear from June 17 through July 30.

A highly significant interactions between water regimes x genotypes and between sowing dates x genotypes were found to be significant indicating that both genotypes did not react similarly to different water regimes and sowing date treatments. The water regime x sowing date interaction effects were also significant.

4.1.5. Number of leaves per plant

Data on number of leaves per plant as affected by sowing dates and water regimes recorded after flowering stage are presented in table 4 and shown in Fig.5.

There was no significant difference in the number of leaves per plant under water regime treatments. They were on par with each other. This suggests that irrigation did not play a significant role in influencing number of leaves per plant.

There was a highly significant difference in the number of leaves per plant among sowing dates. Maximum number of leaves were produced in the first sowing date (11.8), followed by 11.1, 9.9 under the second and fourth sowing date, the least number of 8.8 was produced under the third sowing date.

Genotypic effects showed a highly significant difference in the number of leaves per plant. The hybrid CSH-5 had more leaves per plant (11.4) than the local variety (9.4). In general, the

Table 4: Number of leaves per plant as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	13.1	11.0	9.2	12.3		
	Local	11.2	9.5	8.3	8.5	10.4 (W1)	11.4
	Mean	12.2	10.3	8.7	10.4		
Rainfed (W2)	Hybrid	12.7	12.4	9.7	10.7		
	Local	10.1	11.6	8.2	8.1	10.4 (W2)	9.4
	Mean	11.4	12.0	8.9	9.4		
Average		11.8	11.1	8.8	9.9		

Treatments	SEm	CD(5%)
Water (WAT)	0.19ns	-
Sowing dates (SD)	0.16***	0.5
Genotypes (GENO)	0.14***	0.4
WAT x SD	0.27***	0.8
WAT x GENO	0.23ns	-
SD x GENO	0.25**	0.7
WAT x SD x GENO	0.38ns	-
CV(%)	7.5	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

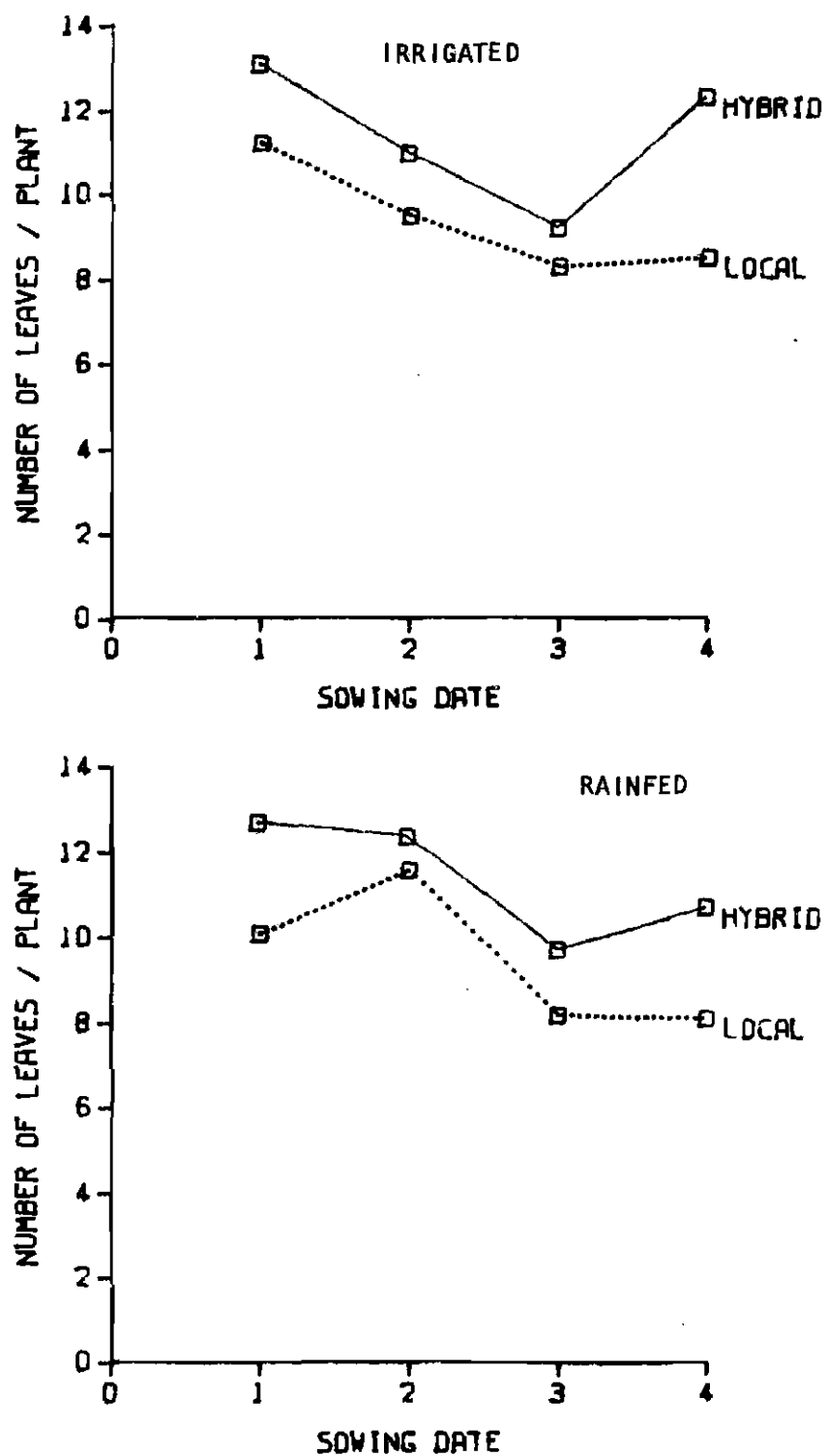


Fig. 5. Number of leaves/plant of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

hybrid produced significantly more number of leaves than the local variety both in irrigated and rainfed treatments at all planting dates. The water regime x sowing dates interaction effect showed highly significant differences in number of leaves per plant. Sowing dates x genotypes interaction also showed significant differences in the number of leaves per plant at $P < 0.01$ probability, whereas water regimes x genotypic interaction effects were not significant.

4.1.6. Plant stand and number of panicles, m^{-2}

The plant stand of the genotypes measured after flowering stage as affected by sowing dates and water regimes are given in the Appendix A.3.

The water treatments (irrigated vs non-irrigated) did not show any significant differences in plant stand per unit area.

The effects of sowing dates were highly significant. The number of plants m^{-2} were reduced from 71.9 to 63.9 plants m^{-2} as sowing date was delayed from June 17 (first sowing date) to July 30 (fourth sowing date). The stand achieved in the first sowing date could be regarded as sufficient for getting the potential yield, while, the stand in the later sowing dates was below the optimum level. Although it was aimed for a higher stand (66-70 plants m^{-2}), the desired level could not be achieved because of shoot fly damage during the growing season.

Genotypic effects, water regime x sowing date interactions, water regime x genotype interactions and water regime x sowing

date x genotype interactions had no significant differences on crop stand m^{-2} .

The panicle number per unit area followed similar trend (Appendix A.3). Water regime treatment did not significantly affect the panicle number m^{-2} . The range of the panicle — number m^{-2} in irrigated and drained treatments were 56.0 to 52.5 panicle m^{-2} , respectively. This reduction in the number of panicle could be due to the effect of barren plants (Table 3).

Highly significant differences were observed among sowing dates. First sowing date produced significantly higher number of panicles (70.8 panicles m^{-2}), followed by 53.8, 49.8 and 41.6 panicles m^{-2} under the second, third and fourth sowing dates, respectively.

Significant differences were also observed due to different genotypes. The hybrid produced significantly more panicles of 56.0 m^{-2} than the local variety which produced 51.5 panicles m^{-2} .

Water regimes x sowing dates and sowing dates x genotypes interaction effect were found to be significant at a $P < 0.05$ probability (Appendix A.4).

4.1.7. Percentage of barren plants

The mean percent of barren plants as affected by sowing dates and water regimes of sorghum are presented in table 5 and the trends are shown in Fig.6.

The mean percent of barren plants was not significantly different under the two water regime treatments. However, under

Table 5: Percentage of barren plants as affected by various sowing dates and water regimes during rainy season, 1986

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	2.5	4.4	14.8	39.5		
	Local	3.0	10.7	22.6	39.7	17.1 (W1)	16.3
	Mean	2.7	7.5	18.7	39.6		
Rainfed (W2)	Hybrid	3.3	10.1	24.2	31.5		
	Local	1.8	46.8	33.0	32.8	22.9 (W2)	23.8
	Mean	2.5	28.5	28.6	32.2		
Average		2.6	18.0	23.6	35.9		

Treatments	SEm	CD(5%)
Water (WAT)	3.17ns	-
Sowing dates (SD)	3.54***	10.52
Genotypes (GENO)	1.65**	4.82
WAT x SD	5.37ns	-
WAT x GENO	3.58ns	-
SD x GENO	5.24*	15.30
WAT x SD x GENO	6.31ns	-
CV(%)	47	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

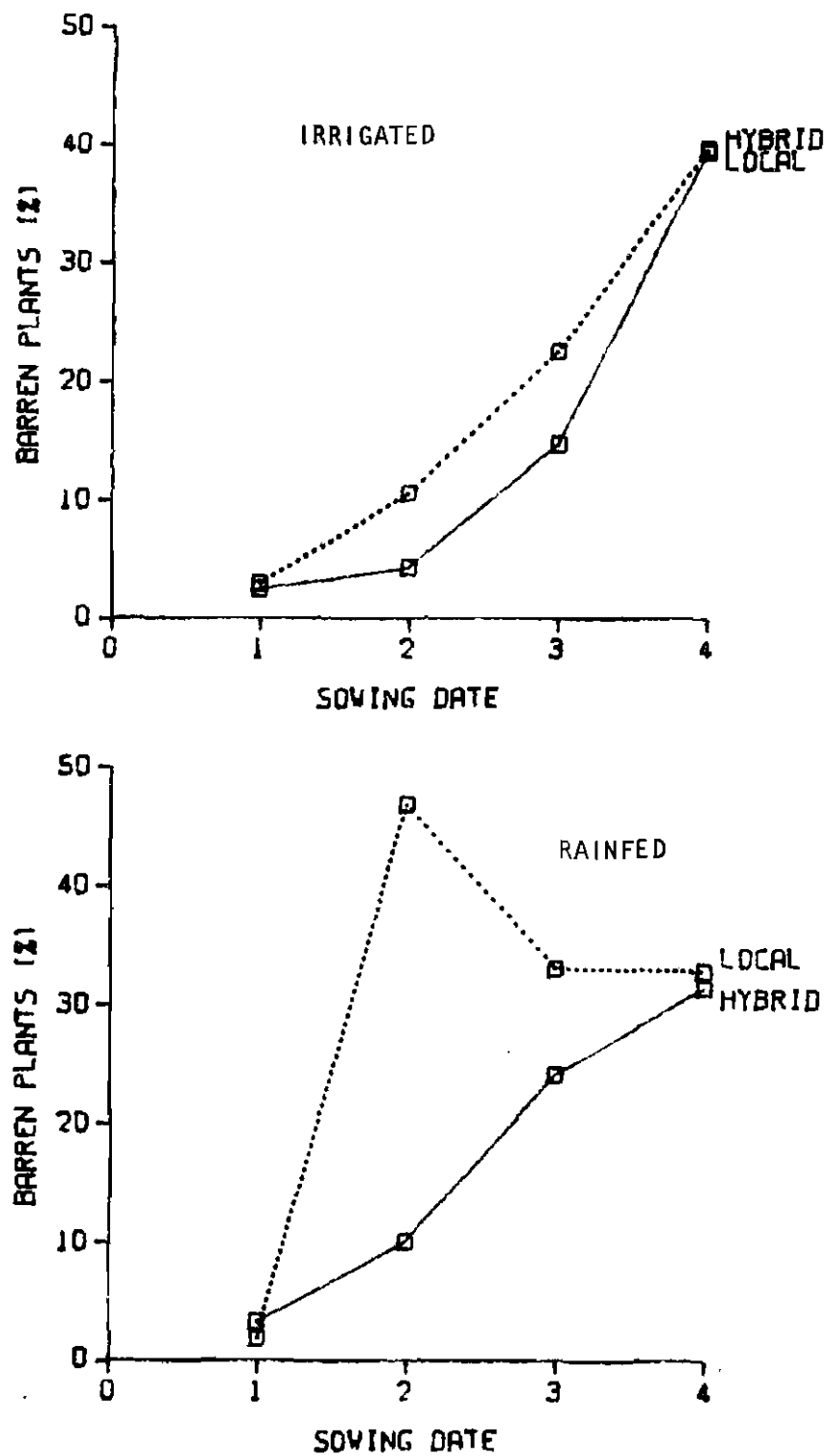


Fig. 6. Percentage of barren plants of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

irrigated treatments, the genotypes produced less barren plants of 17.1% against 22.9% of barren plants produced under rainfed treatments.

Planting dates had significant effects on percent of barren plants. First sowing date had less barren plants of 2.6%, followed by 18.0, 23.6 and 35.9% under second, third and fourth sowing dates, respectively.

The variety Pacha Jonna showed a higher percentage of barren plants (23.8%) as compared to CSH-5 (16.3%) due to an increased incidence of head bugs. However, both genotypes suffered from the acute shortage of available soil moisture during the grain filling period.

The only interaction effect found to be significant was sowing dates x genotypes at a $P < 0.05$ level of significance.

4.2. The data on the effect of sowing dates and water regimes on the panicle characters of two sorghum genotypes planted during rainy season 1986 have been summarized below:

4.2.1. Panicle length per plant (cm)

The data pertaining to panicle length as affected by sowing dates and water regimes are presented in table 6 and the trends are shown in Fig.7.

Panicle length was greatly affected by water regimes. Maximum length of 23.1 cm was recorded at rainfed followed by 22.4 cm under irrigated conditions.

Table 6: Panicle length per plant (cm) as affected by various sowing dates and water regimes during rainy season, 1986

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	30.1	27.0	31.1	26.2		
	Local	14.5	14.7	15.6	19.9	22.4(W1)	29.0
	Mean	22.3	20.8	23.3	23.1		
Rainfed (W2)	Hybrid	30.3	29.7	31.6	26.1		
	Local	16.2	15.3	16.6	19.3	23.1(W2)	16.5
	Mean	23.2	22.5	24.1	22.7		
Average		22.8	21.7	23.7	22.9		
<u>Treatments</u>		<u>SEM</u>	<u>CD(5%)</u>				
Water (WAT)		0.04***	0.2				
Sowing dates (SD)		0.05*	0.2				
Genotypes (GENO)		0.95***	2.8				
WAT x SD		0.62ns	-				
WAT x GENO		0.95ns	-				
SD x GENO		1.44ns	-				
WAT x SD x GENO		2.00ns	-				
CV(%)		23.6					

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

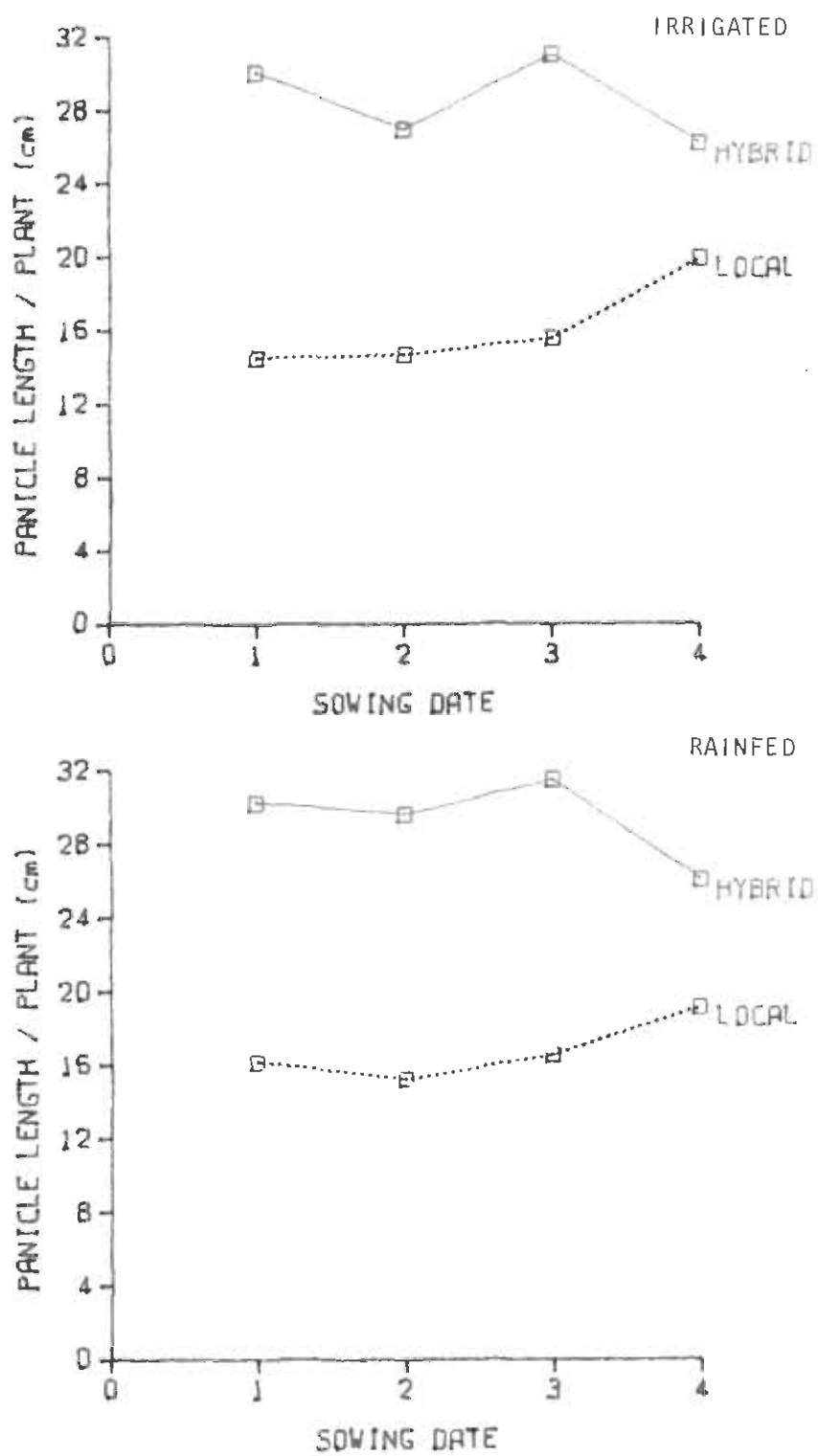


Fig. 7. Panicle length/plant (cm) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

The sowing dates also influenced the length of panicle significantly. Delay in sowing dates decreased the length of the panicle. Maximum length of panicle (22.8 cm) was recorded in third sowing date, followed by 22.9, 22.8 and 21.7 cm under fourth, first and second sowing dates, respectively. The interactions between water regimes, sowing dates and genotypes were not significant.

Genotype effects had highly significant differences on panicle length per plant. The hybrid produced maximum length of 29.0 cm and a length of 16.5 was observed in the local variety. The hybrid generally produced longer panicles than the local at all planting dates.

Interactions between water regimes x sowing dates, water regimes x genotypes and sowing dates x genotypes were not found to be significant.

4.2.2. Grain weight per panicle

Data on the grain weight per panicle in grams are presented in Appendix A.5 and shown in Fig.8.

There was no significant differences in grain weight per panicle due to different water regimes. However, sowing dates had significant effect. The grain weight per panicle decreased with delay in sowing dates. The grain weight under first sowing date (48.9 g) was maximum, followed by third sowing date (31.7 g), fourth sowing date (20.4 g) and second sowing date (18.0 g), respectively. The increase in grain weight per panicle was 63.2 percent from the best to worst sowing dates. Sowing dates had

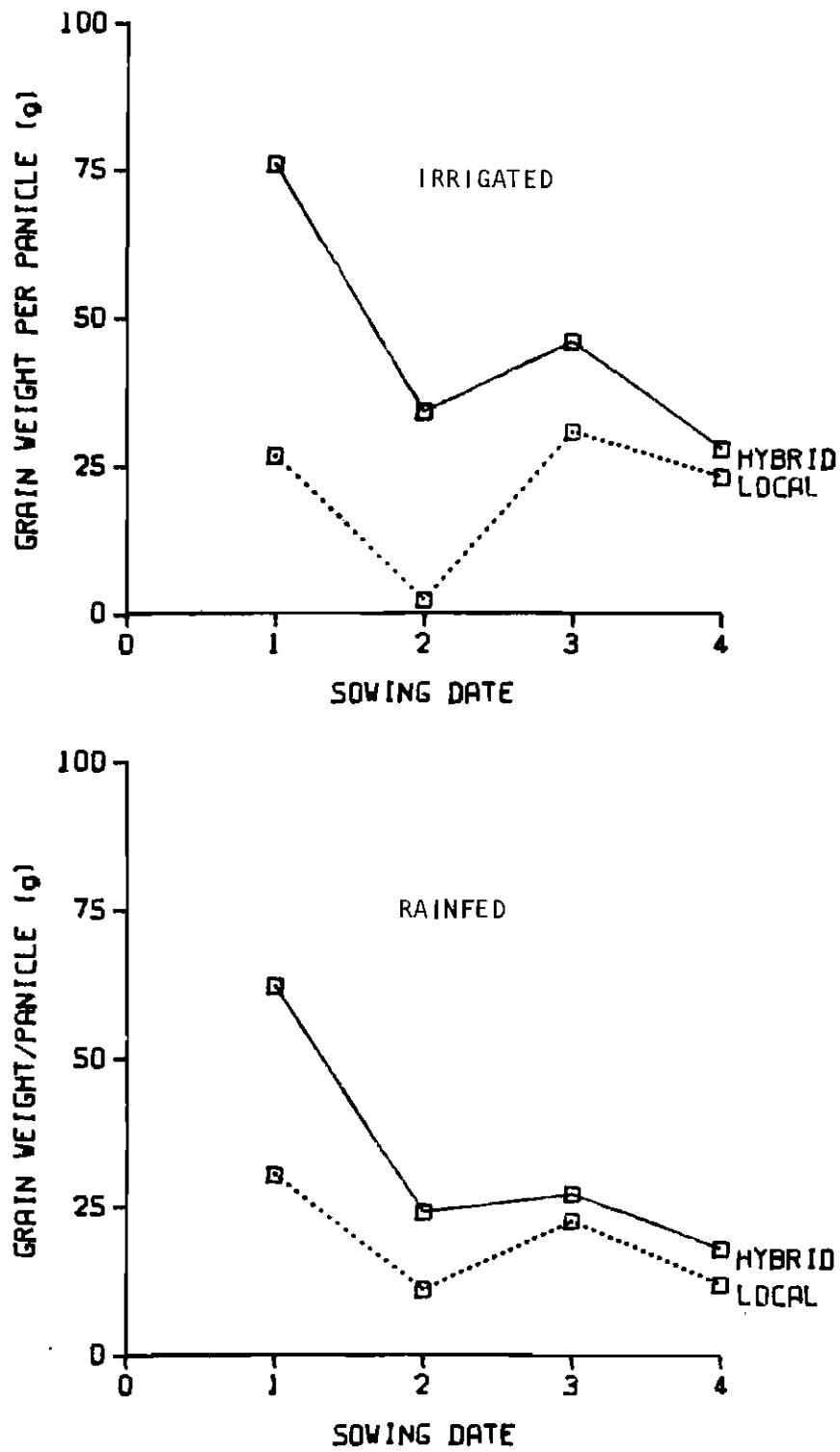


Fig. 8. Grain weight/panicle (g) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

greater effects on yield.panicle⁻¹ and decreased drastically with delay in sowing.

On average, the hybrid had a higher and significant grain weight per panicle of 39.6 g than the local variety (19.9 g). In general, the hybrid surpassed the local variety at all planting dates.

There were no significant differences in the interactions of water regimes x sowing dates x genotypes in grain weight.panicle⁻¹, but highly significant differences were observed on the interaction of water regimes x genotypes as well as sowing dates x genotypic interaction.

This important yield characteristics of sorghum account for much variation in yield performance of the crop.

4.2.3. Number of grains per panicle

There were no significant differences in the number of grains per panicle between irrigated and non-irrigated treatments (Fig.9 and Appendix A.6).

There were significant differences in the number of grains per panicle among the sowing dates. Plants sown on date 1 had more grains per panicle (2625), followed by 2164 and 1700 under date 3 and 4, respectively. The least was obtained in date 2. Delaying sowings had adverse effects on the number of grains per panicle.

The overall hybrid mean (2744) was higher than the local (1073), and the effects on the number of grains per panicle was

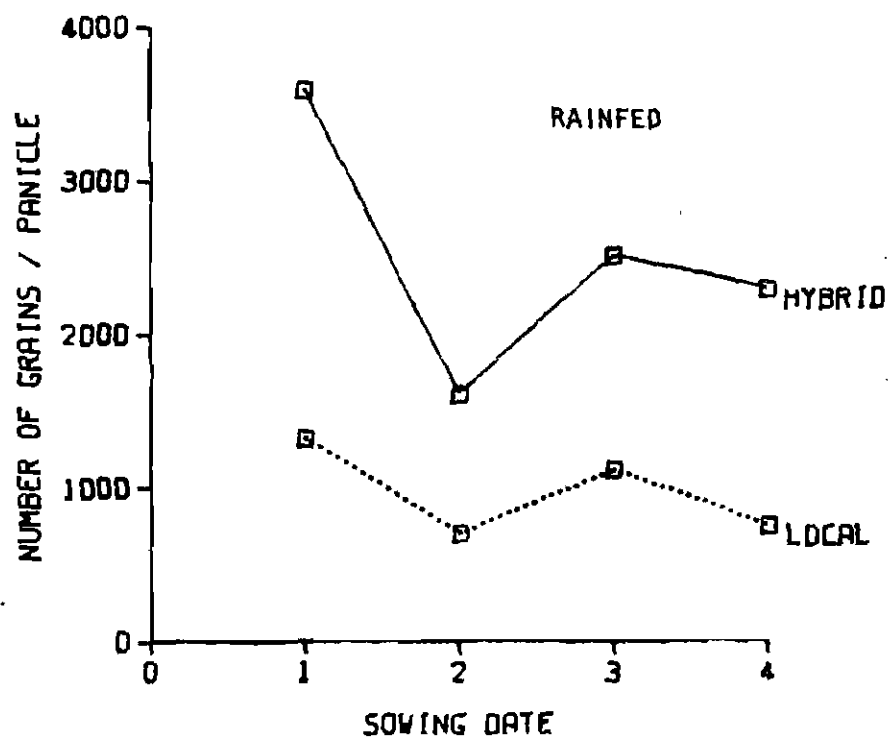
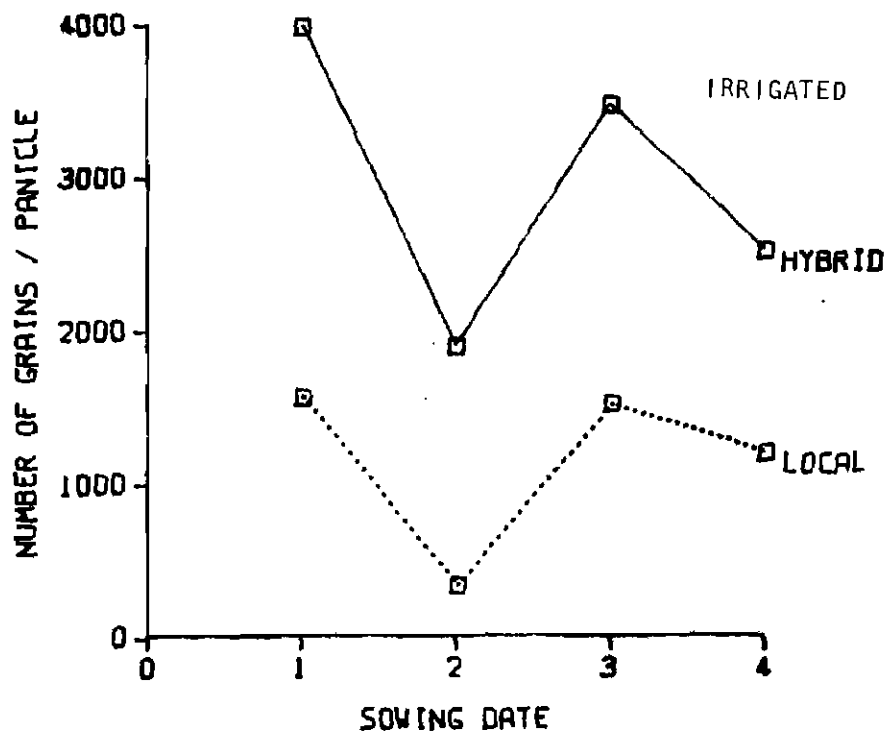


Fig. 9. Number of grains/panicle of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

highly significant. Sowing date x genotypes interaction effects were highly significant. There were no significant differences of water regimes x sowing dates x genotypes interactions on grain number.panicle⁻¹.

4.2.4. Total panicle weight,ha⁻¹ and weight per plant

The water regime treatments had no significant effects on total panicle weight,ha⁻¹ and that of panicle weight per plant. From Fig.10 and Appendix A.7, it can be seen that the highest weight of 4.5 t.ha⁻¹ were recorded in date 1, followed by 2.4, 1.8 and 1.5 t.ha⁻¹ under dates 3, 2 and 4, respectively.

The hybrid CSH-5 produced maximum total panicle weight,ha⁻¹ when compared with the local at all planting dates.

Water regimes x sowing dates x genotypes interaction effects were not significant. However, all other interaction effects were highly significant.

The panicle weight,plant⁻¹ was reduced when sowings were delayed (Fig.11). Date 1 treatment produced significantly heavier heads of 60.1 g followed by 45.7, 33.2 and 31.5 g under third, fourth and second date of planting, respectively.

The mean panicle weight per plant of the two genotypes of sorghum show that the hybrid significantly produced heavier panicle per plant of 55.0 g and a minimum of 30.2 g was secured from the local variety.

The interaction between water regimes and genotypes and between sowing dates and genotypes were found to be significant.

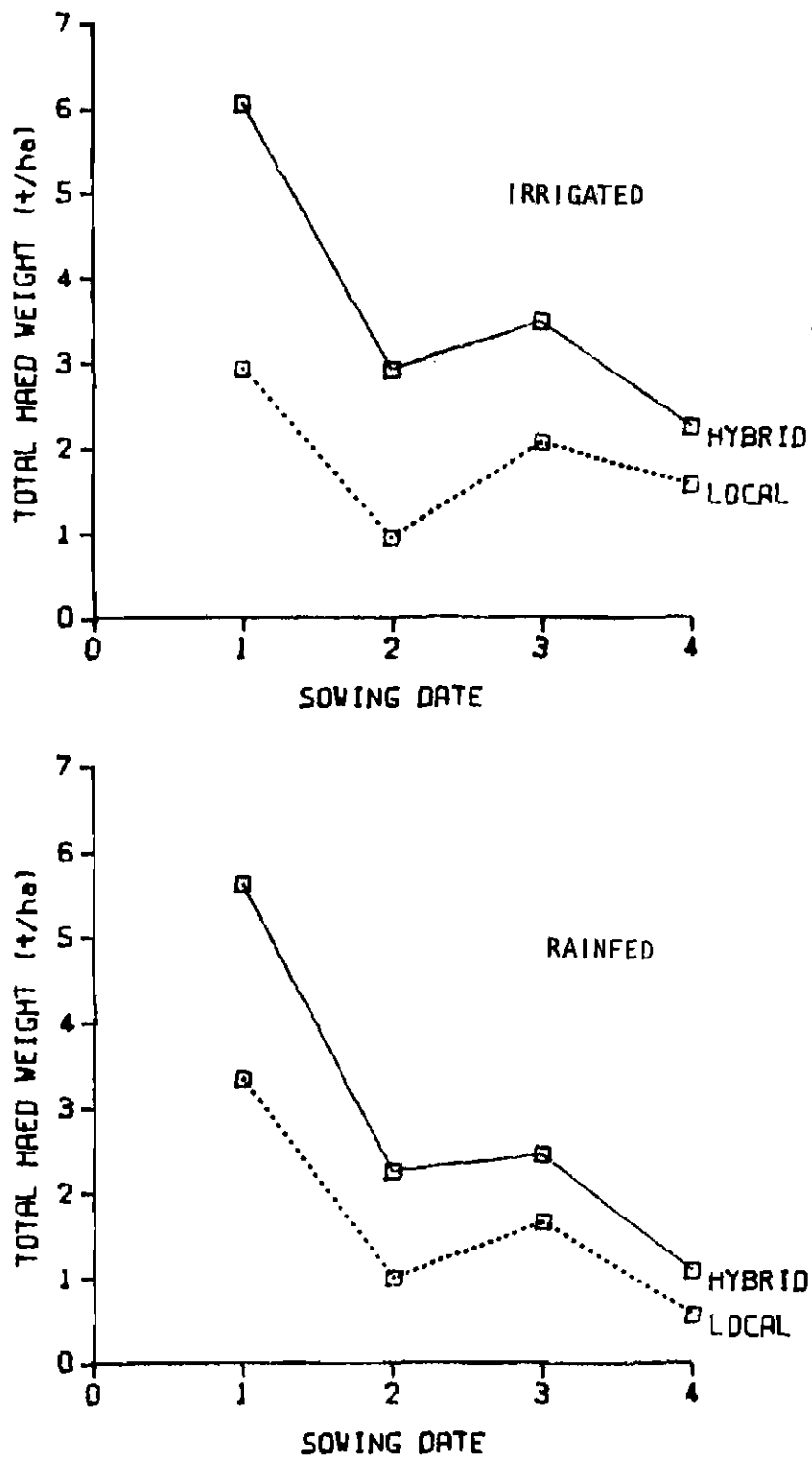


Fig.10. Total panicle weight ($t\ ha^{-1}$) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

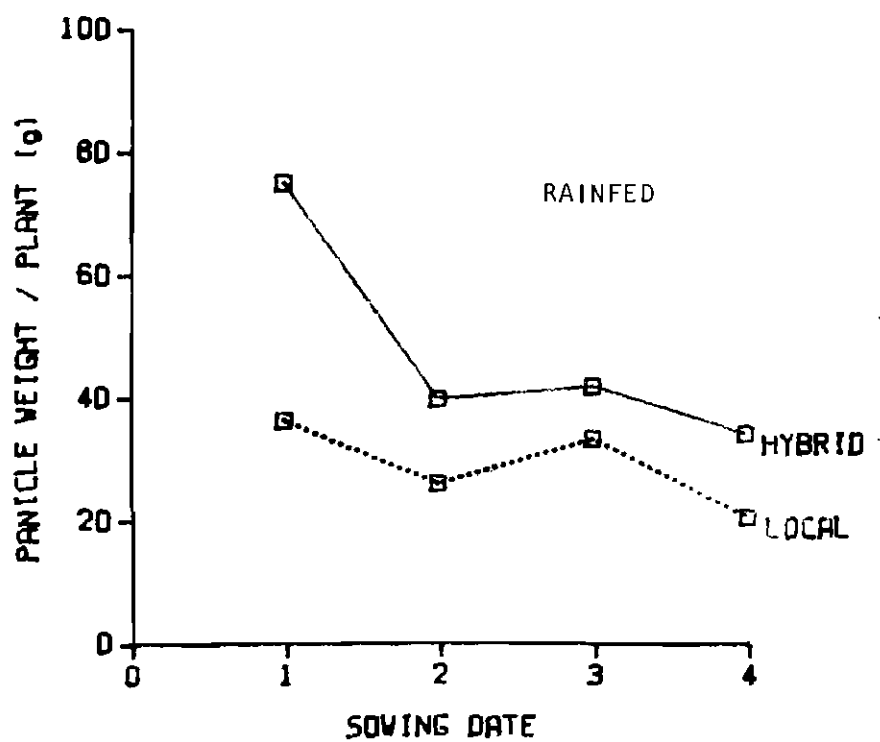
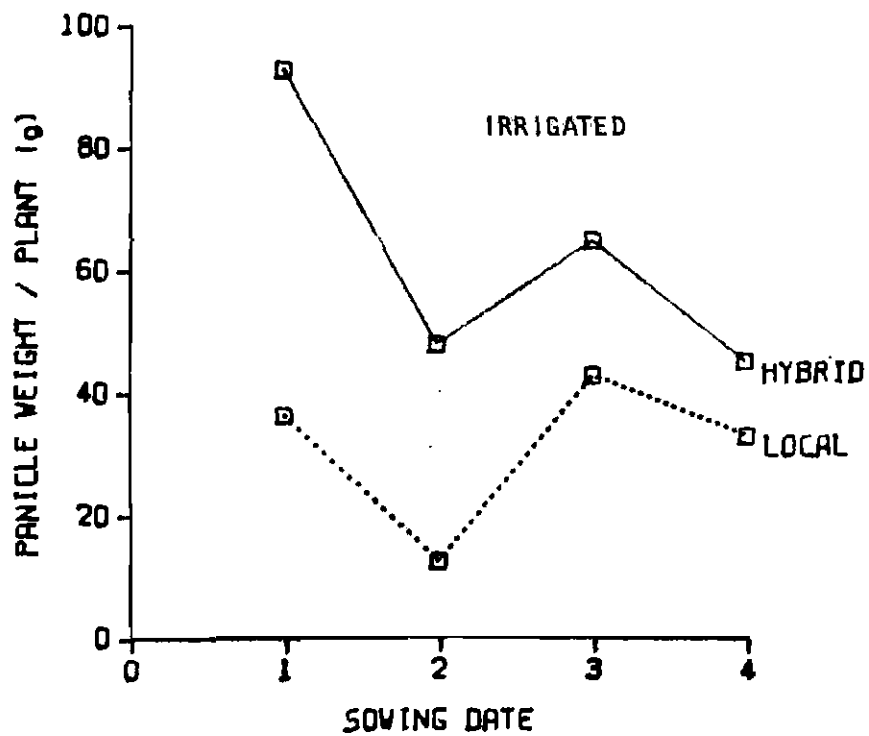


Fig. 11. Panicle weight/plant (g) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

Water regimes x sowing dates, water regimes x genotypes and sowing dates x genotypes interaction effects were found to be highly significant.

Similarly, the irrigation treatment produced slightly heavier panicles than rainfed treatments though the differences were not significant (Appendix A.8).

4.3. The data on the effect of sowing dates and water regimes on yield and yield components of sorghum genotypes planted during rainy season, 1986:

4.3.1. Total dry matter and yield per plant

The total dry matter production, excluding root at various sowing date treatments and water regimes are presented in table 7. It is evident that there was reduction in dry matter production in non-irrigated treatment compared to irrigated treatments (Fig.12).

Significant differences in mean yields of dry matter were obtained from the various planting dates. Date 1 gave consistently higher dry matter than other treatments. Dry matter production decreased progressively with delay in sowing. The average dry weight exclusive of the roots varied from 13.77 t.ha⁻¹ for date 1 (June 17) to 4.42 t.ha⁻¹ for date 4 (July 30, last sowing date). There was a decrease of about 43.5%, 58.7% and 67.9% from the second, third and fourth sowing dates, respectively.

Significant differences were found in the mean total dry matter of sorghum genotypes as a result of various planting

-1

Table 7: Total dry matter (t/ha) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	14.49	8.69	8.55	6.49		
	Local	14.28	9.13	4.94	5.40	9.00 (W1)	8.45
	Mean	14.39	8.91	6.74	5.95		
Rainfed (W2)	Hybrid	12.96	7.48	5.60	3.31		
	Local	13.33	6.07	3.68	2.49	6.87 (W2)	7.41
	Mean	13.15	6.78	4.64	2.90		
Average		13.77	7.84	5.69	4.42		

Treatments	SEM	CD(5%)
Water (WAT)	0.25**	1.12
Sowing dates (SD)	0.25***	0.75
Genotypes (GENO)	0.16***	0.46
WAT x SD	0.40 ns	-
WAT x GENO	0.30 ns	-
SD x GENO	0.34**	0.98
WAT x SD x GENO	0.51*	1.48
CV(%)	11.20	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

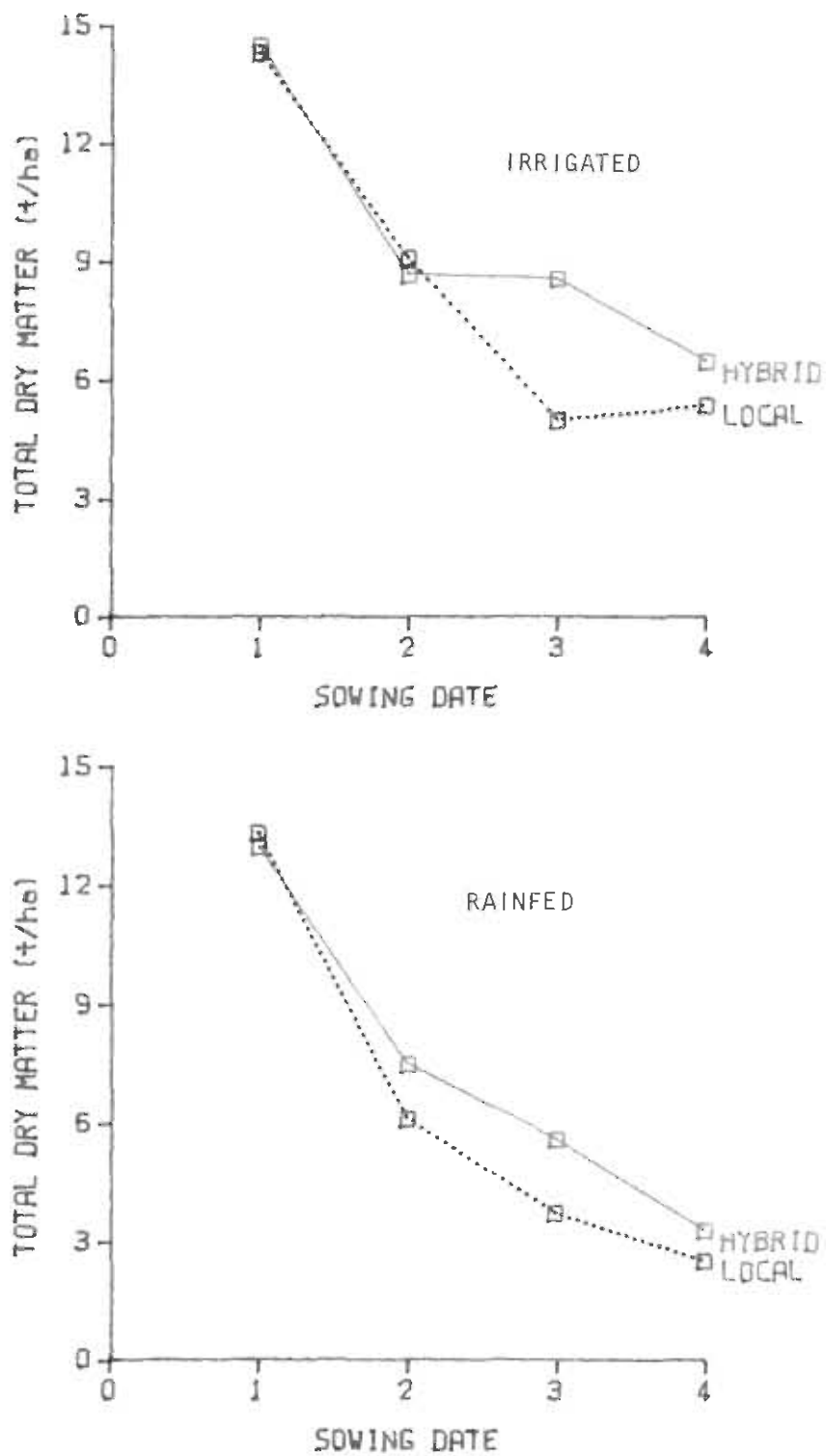


Fig. 12. Total dry matter ($t\ ha^{-1}$) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

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dates. The data show a trend of higher yields from the hybrid. The interaction between sowing dates and genotypes was found to be significant at $P < 0.01$.

Similarly, yields of dry matter per plant followed similar patterns as indicated above (Fig.13).

There were significant differences in yields of dry matter per plant due to water regime treatments. Average yields of dry matter per plant increased significantly with irrigation, while at rainfed treatment, it decreased. There was an increase of 20.2 percent at irrigated over rainfed treatments.

Sowing dates had highly significant effect. The yield of dry matter per plant decreased with delay in sowing dates beyond June 17. The yields under first sowing date (139.2 g) was maximum, followed by 109.4, 89.1 and 79.6 g under second, third and fourth sowing dates, respectively. The reduction in yield of dry matter per plant was 42.8 percent under first sowing date, when compared to last sowing date.

The genotypes exhibited very highly significant differences in yields of dry matter per plant. The hybrid outyielded the local variety at all the planting dates. The significant increase was at the order of 21.3 percent.

The interaction between water regimes and sowing dates was significant (Appendix A.9).

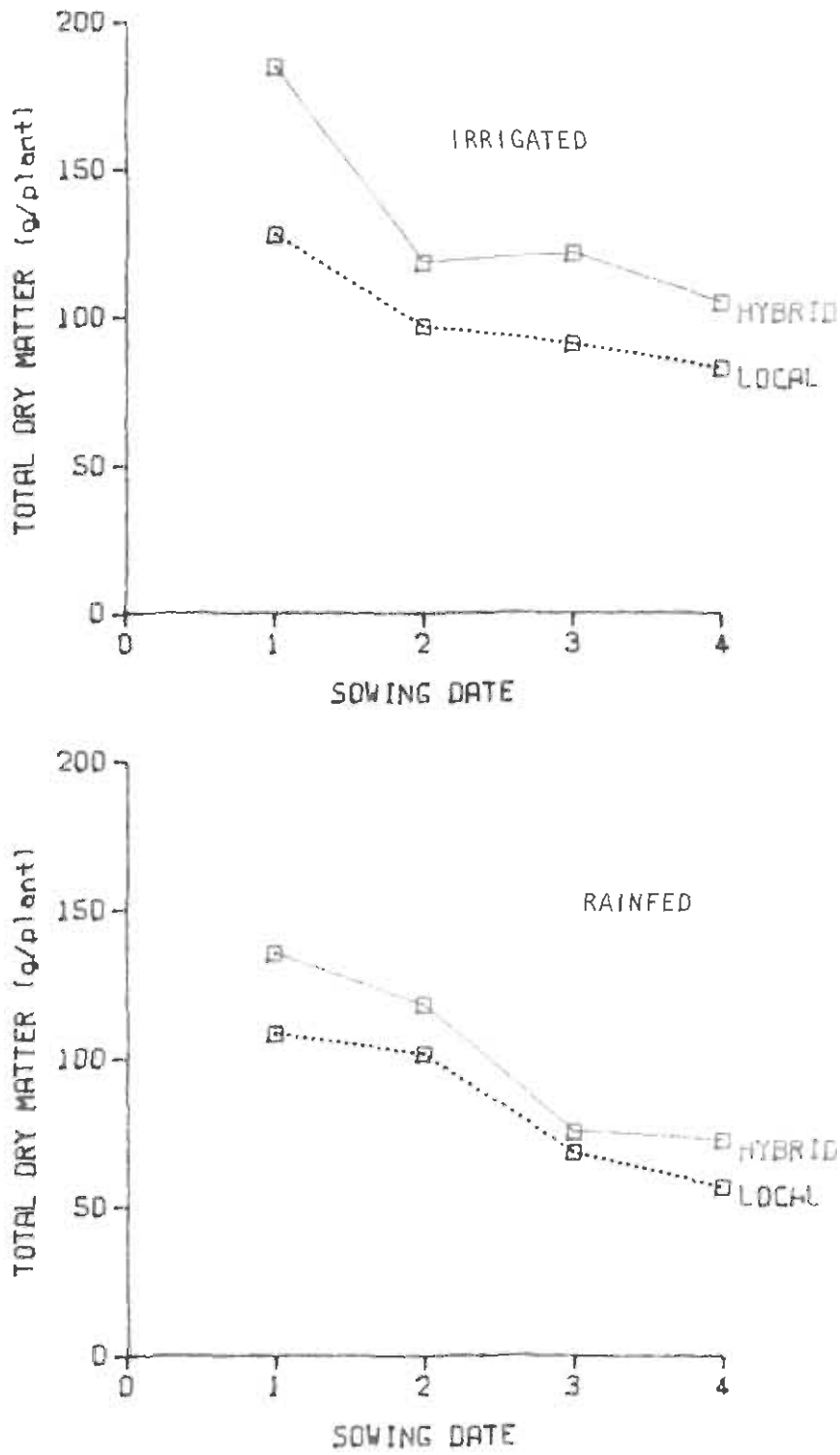


Fig. 13. Total dry matter (g plant^{-1}) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

Significant interaction effects was also found between water regimes and genotypes indicating that water regimes played a significant role in influencing yield.

4.3.2. Grain yield of sorghum genotypes (t, ha^{-1})

The grain yields from the treatments under study indicate that the different water regimes had no significant effect on sorghum yield (Table 8 and Fig.14).

Planting dates significantly influenced the grain yield and the highest mean grain yield was obtained when the crop was sown on June 17. There was a considerable decrease in grain yield with delay in sowing, and the variations in mean yields were significant. The average reduction in yield over first date were 70.6, 55.9 and 76.5% on the second, third and fourth sowing dates, respectively. Furthermore, in the late plantings, the genotypes under rainfed situation experienced soil moisture stress during reproductive stage as the precipitation practically ceased by standard week 38 (Fig.2).

The genotypes exhibited considerable variation in their productivity; CSH-5 outyielded the Pacha Jonna at all four sowing dates. The interaction of sowing dates and genotypes was significant. The reduction in yield was gradual in CSH-5 but abrupt in the local (Pacha Jonna).

Simple correlations were computed to test the degree to which sorghum yields were influenced by various environmental parameters during the crop growth period.

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Table 8: Grain yield (t.ha⁻¹) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	4.4	2.0	1.9	1.3		
	Local	2.2	0.2	1.5	1.1	1.8 (W1)	2.1
	Mean	3.3	1.1	1.7	1.2		
Rainfed (W2)	Hybrid	4.3	1.2	1.3	0.5		
	Local	2.7	0.4	1.2	0.3	2.0 (W2)	1.2
	Mean	3.5	0.8	1.2	0.4		
Average		3.4	1.0	1.5	0.8		

Treatments	SEm	CD(5%)
Water (WAT)	0.09ns	-
Sowing dates (SD)	0.08***	0.3
Genotypes (GENO)	0.06***	0.2
WAT x SD	0.13**	0.4
WAT x GENO	0.10**	0.3
SD x GENO	0.12***	0.3
WAT x SD x GENO	0.18ns	-
CV(%)	19.5	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

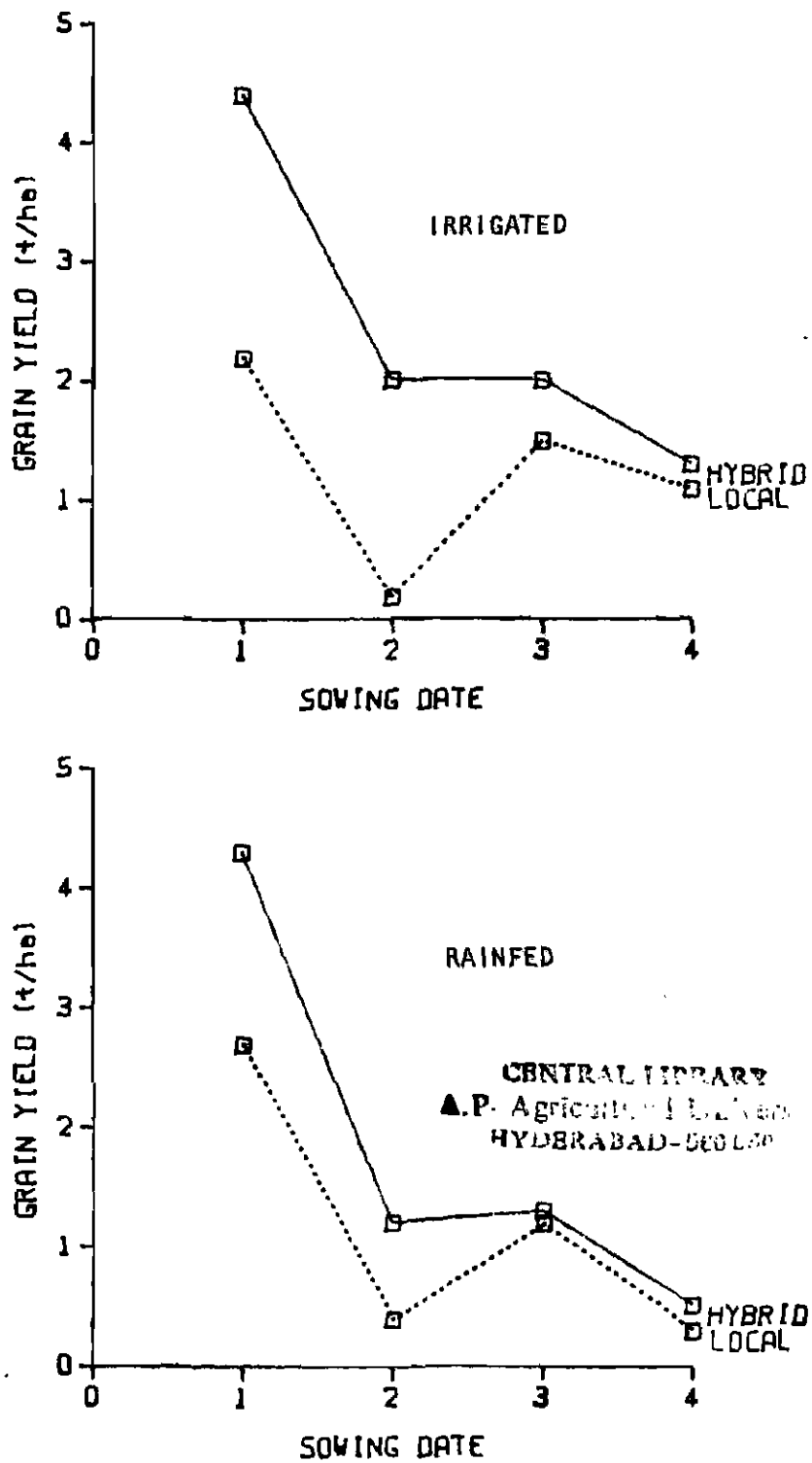


Fig. 14. Grain yield ($t\ ha^{-1}$) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

There was a highly significant correlation among grain yield and the various environmental factors. The negative and significant correlation between grain yields and pan evaporation for the genotypes planted at different periods in the season.

Precipitation, mean relative humidity and the cumulative light interception were significantly and positively correlated with grain yield of the sorghum genotypes (Appendix A.10).

The data presented in Appendix A.10 for the local variety followed similar trends as presented in Appendix A.10, but the level of significance is not as high as in the case of the hybrid. At each observation, the correlation was less compared to the hybrid.

4.3.3. Stover yield and stover per plant

The data of stover yield (t.ha^{-1}) of sorghum grown at four sowing dates and two water regimes are summarized in table 9.

Significant differences were found in the mean stover yields of sorghum genotypes at various planting dates, with higher stover yield when sorghum is planted early. The yield of stover (t.ha^{-1}) declined markedly as plantings were delayed from the second fortnight of June to the last week of July. However, a maximum stover yield of 9.3 t.ha^{-1} was recorded from first sowing date, followed by 6.1 , 3.3 and 3.1 t.ha^{-1} under second, third and fourth sowing dates, respectively. The reduction of stover yield being 66.7 percent was obtained when the sowing were delayed from June 17 to July 30.

-1

Table 9: Stover yield (t.ha⁻¹) as affected by various sowing dates and water regimes during rainy season, 1986

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	8.4	5.8	5.1	4.3		
	Local	11.4	8.2	2.9	3.8	6.2(W1)	5.2
	Mean	9.9	7.0	4.0	4.0		
Rainfed (W2)	Hybrid	7.3	5.2	3.1	2.2		
	Local	10.0	5.1	2.0	1.9	4.6(W2)	5.7
	Mean	8.7	5.2	2.6	2.1		
Average		9.3	6.1	3.3	3.1		

Treatments	SEm	CD(5%)
Water (WAT)	0.15**	0.7
Sowing dates (SD)	0.17***	0.5
Genotypes (GENO)	0.15*	0.5
WAT x SD	0.26ns	-
WAT x GENO	0.22ns	-
SD x GENO	0.28***	0.8
WAT x SD x GENO	0.40*	1.2
CV(%)	16.0	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

The local variety Pacha Jonna yielded more stover yield of 5.7 t.ha^{-1} than the hybrid CSH-5 (5.2 t.ha^{-1}), and their effect was significant (Fig.15).

There was no significant interaction between water regimes and genotypes for stover yield. There was also no appreciable variation in stover yield between water regimes and sowing dates interaction, but very high significant differences were found between sowing dates and genotypes interaction.

With respect to stover yield per plant (g), the data followed similar trends as mentioned in total stover yield (Table 9).

Irrigation increased the stover yield.plant⁻¹ significantly when compared to rainfed treatments. The increase was 15.0 g which was significantly superior over rainfed treatments.

Differences in stover yield per plant due to sowing dates were also highly significant. Maximum stover yield.plant⁻¹ of 79.3 g was secured from date 1, followed by date 2 (77.9 g), date 4 (46.4 g) and date 3 (43.5 g), respectively.

The yield differences due to the effect of genotypes were not significant. However, the respective stover yield per plant recorded under the hybrid and local variety were 61.8 and 61.7 g , respectively (Fig.16).

The only interaction effect observed was between water regimes and sowing dates.

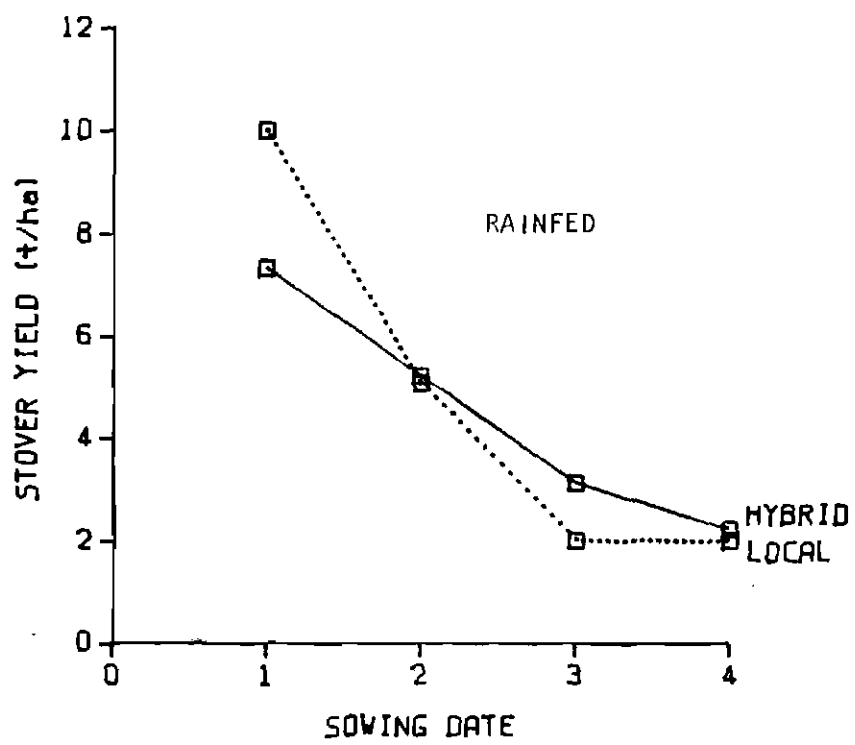
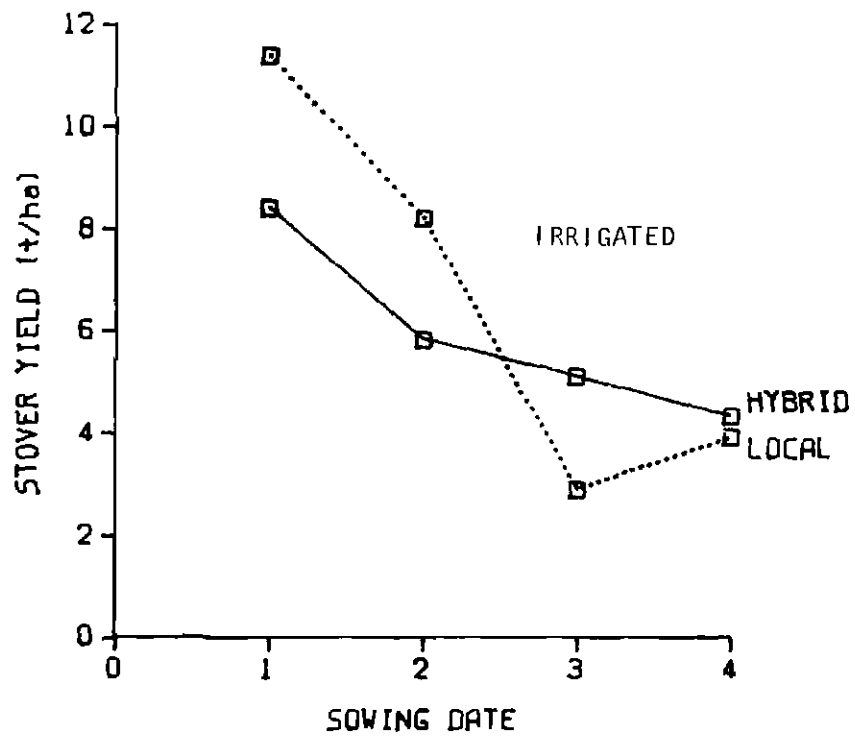


Fig. 15. Stover yield ($t\ ha^{-1}$) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

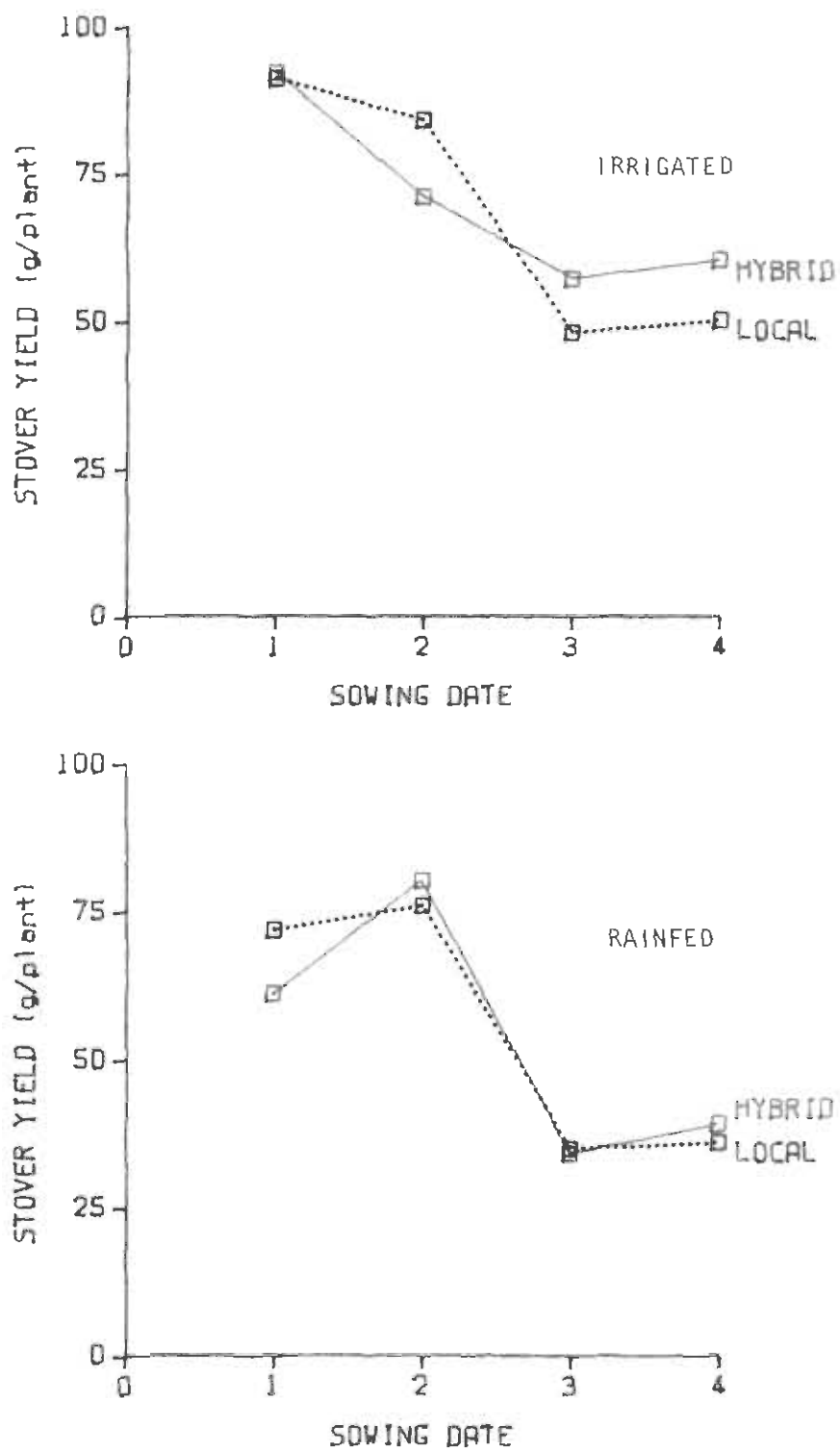


Fig. 16. Stover yield (g plant^{-1}) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

4.3.4. Harvest index and seed weight

The harvest index and 1000 grain weights in different treatments were statistically analysed and the data are presented in tables 10 and 11 and the trends are shown in Figs.17 and 18.

Harvest index and seed weight were unaffected by the two water regimes.

Different sowing dates had significantly influenced the harvest index. Maximum harvest index of 33.8 was recorded in the hybrid at date 1, followed the local variety at date 3 (31.9). The low harvest index from the late plantings were probably due to the greater number of plants which were barren.

The increase in harvest index was influenced with the genotypes in each level of sowing dates and water regimes. The hybrid produced a harvest index of 22.8 which was highly significant over rainfed treatments (17.2).

Water regimes and sowing dates interaction was found to be significant. Highly significant interaction between sowing dates and genotypes was recorded. However, water regimes and genotypes interaction were not significant.

The greatest and highly significant seed weight of sorghum genotypes was obtained in the first sowing date. The seed weight decreased with the delay in sowings. The weight obtained from plants in the first, second, third and fourth sowing dates apart were 19.1, 13.5, 16.0 and 13.3 g, respectively.

Table 10: Harvest index as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	30.5	22.9	22.8	19.5		
	Local	15.4	2.0	30.7	19.4	20.4 (W1)	22.8
	Mean	22.9	12.4	26.7	19.5		
Rainfed (W2)	Hybrid	33.2	16.1	22.5	15.2		
	Local	20.2	6.6	31.9	11.4	19.6 (W2)	17.2
	Mean	26.7	11.3	27.2	13.3		
Average		24.8	11.9	27.0	16.4		

Treatments	SEm	CD(5%)
Water (WAT)	0.67ns	-
Sowing dates (SD)	0.98***	2.9
Genotypes (GENO)	0.65***	1.9
WAT x SD	1.37*	4.1
WAT x GENO	0.93ns	-
SD x GENO	1.34***	3.9
WAT x SD x GENO	1.88*	5.5
CV(%)	18.2	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Table 11: Thousand seed weight (g) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	19.0	17.3	13.3	11.1		
	Local	16.9	6.7	20.4	19.0	15.4(W1)	13.9
	Mean	18.0	12.0	16.8	15.0		
Rainfed (W2)	Hybrid	17.3	14.9	10.8	7.8		
	Local	23.0	15.2	19.6	15.5	15.5(W2)	17.0
	Mean	20.2	15.1	15.2	11.6		
Average		19.1	13.5	16.0	13.3		

Treatments	SEm	CD(5%)
Water (WAT)	0.67ns	-
Sowing dates (SD)	0.63***	1.9
Genotypes (GENO)	0.38***	1.1
WAT x SD	1.02**	3.0
WAT x GENO	0.77***	2.3
SD x GENO	0.82***	2.4
WAT x SD x GENO	1.27**	3.7
CV(%)	13.8	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

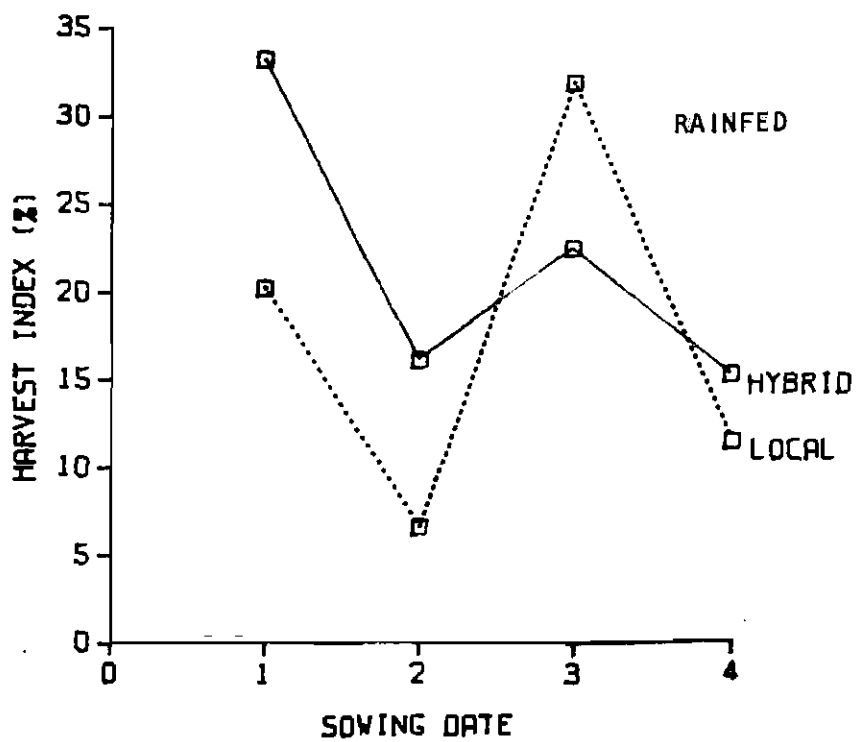
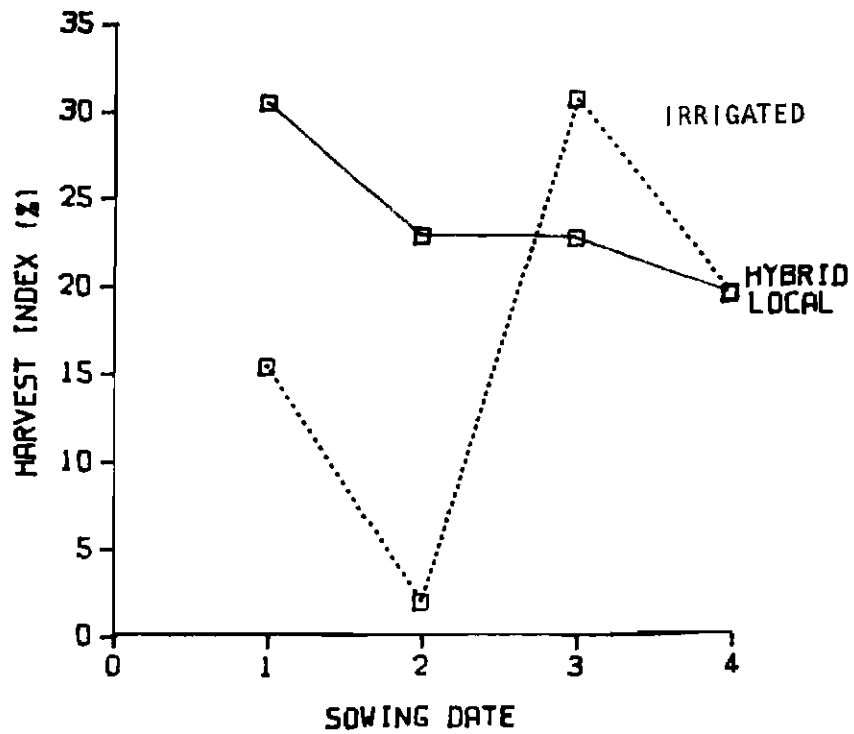


Fig. 17. Harvest index (%) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

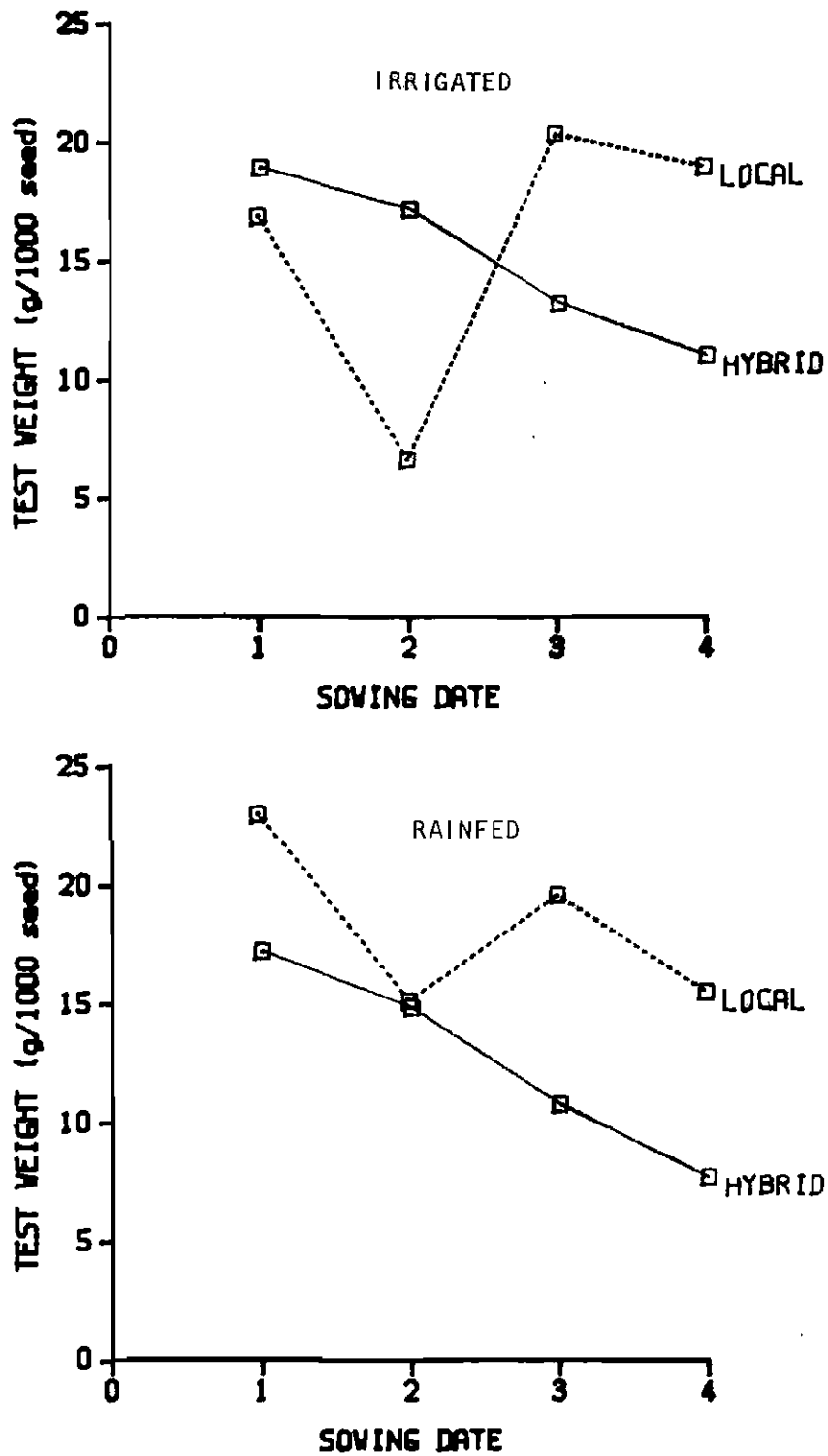


Fig. 18. Test weight ($\text{g } 1000 \text{ seed}^{-1}$) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

The weight differences between the seeds produced by the genotypes at various sowing dates and water regimes were found to be highly significant.

Very highly significant interaction between water regimes x sowing dates, water regimes x genotypes, sowing dates x genotypes and water regimes x sowing dates x genotypes were observed.

4.3.5. Threshing percentage

The average threshing percentage of the two genotypes planted under four sowing dates and two water regimes are presented in table 12 and the trends are shown in Fig.19.

There was no significant difference in the threshing percent between irrigation and rainfed treatments as well as between genotypes.

Threshing percentage decreased significantly from the first sowing to the fourth sowing dates. A general trend of decrease in threshing percent was observed with a delay in sowing. The threshing percentage were 76.1, 44.6, 62.9 and 55.5 g for first, second, third and fourth sowing dates, respectively.

The interaction of sowing dates x genotypes was found to be significant. The genotypes responded differently to the sowing dates. Local variety produced more threshing percent at first sowing date. The hybrid was not effected much by changes in sowing dates.

Table 12: Threshing percentage as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	72.8	67.2	55.2	56.4		
	Local	75.1	18.8	73.4	66.7	60.7 (W1)	59.9
	Mean	73.9	43.0	64.3	61.6		
Rainfed (W2)	Hybrid	76.0	52.8	51.8	47.3		
	Local	80.7	39.6	71.2	51.6	58.9 (W2)	59.6
	Mean	78.3	46.2	61.5	49.4		
Average		76.1	44.6	62.9	55.5		

Treatments	SEm	CD(5%)
Water (WAT)	0.64ns	-
Sowing dates (SD)	1.28***	3.8
Genotypes (GENO)	0.98ns	-
WAT x SD	1.69***	5.0
WAT x GENO	1.17**	3.4
SD x GENO	1.89***	5.5
WAT x SD x GENO	2.59***	7.6
CV(%)	9.3	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

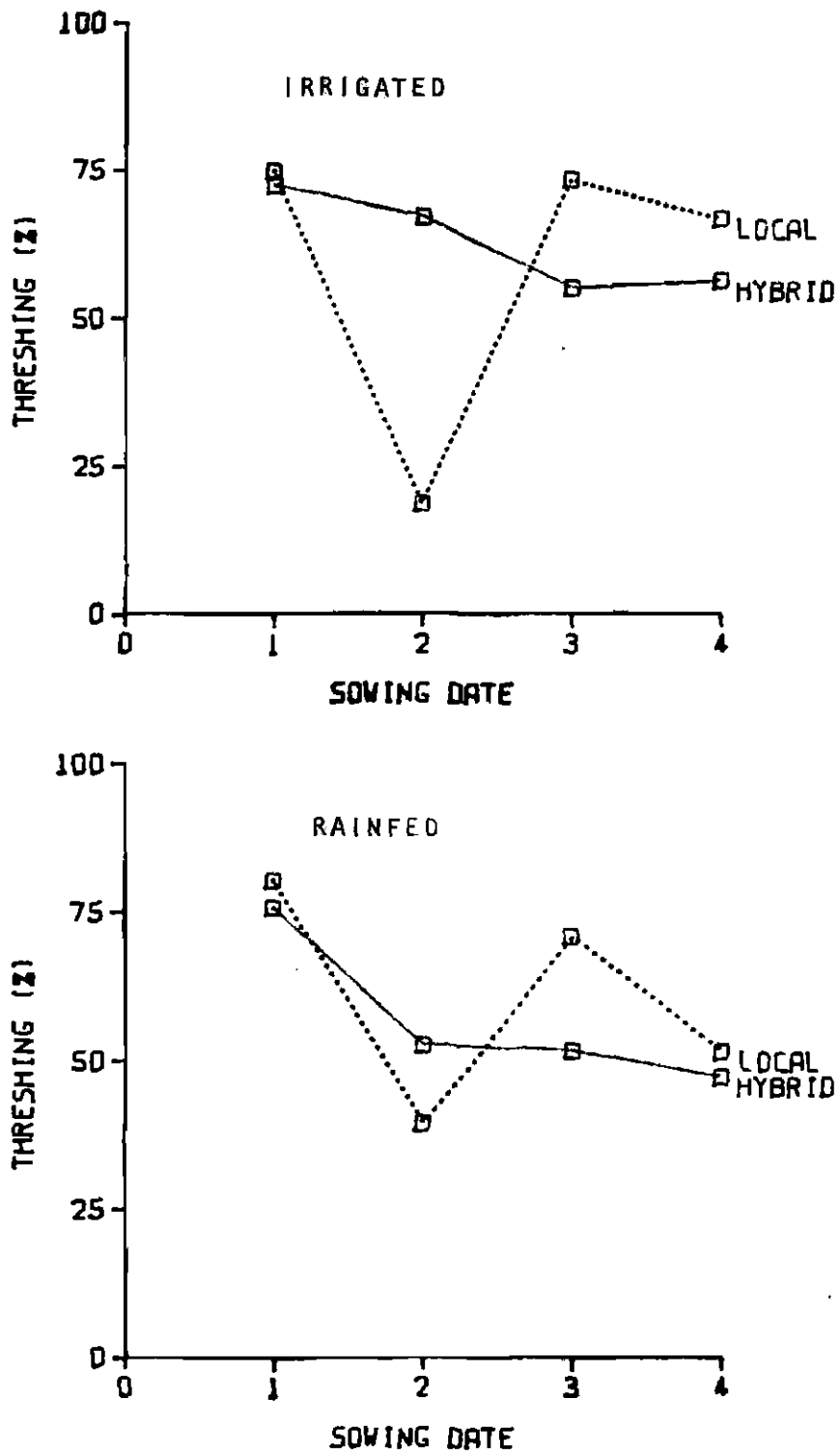


Fig. 19. Threshing (%) of two sorghum genotypes planted at four dates during rainy season of 1986 at ICRISAT Center.

Water regimes x sowing dates, water regimes x genotypes and water regimes x sowing dates x genotypes were found to be highly significant.

**DISCUSSION
AND
CONCLUSION**

V

DISCUSSIONS AND CONCLUSIONS

Sorghum is famous for its ability to produce satisfactory yields under conditions of limited moisture and it is also able to produce very high yields under favorable moisture regimes. The yields obtained with irrigation can be high and compete favorably with those of irrigated corn (Bielorai *et al.*, 1964). Irrigation of sorghum has become a widespread practice and has contributed considerably to the increase of the grain yields in various parts of the world (Arnon *et al.*, 1962). Grain yields of sorghum can vary between 300 and 3000 kg.ha⁻¹ under rainfed conditions and can exceed 6000 kg.ha⁻¹ with irrigation (Gibbon and Pain, 1985).

Several workers have reported the major influence of planting dates on limiting production of sorghum (Srivastava *et al.*, 1981 and Ogunlela, 1985). Delay in sowing reduced the grain yield markedly. The late sown crop during rainy season affected severely by shoot fly at seedling stage and midge at grain formation stage (Singh *et al.*, 1976). Therefore, its time of planting should be adjusted so that the variety passes through its life cycle at the most optimum environmental conditions for growth and development. This being a crop of rainfed areas in India and Africa, soil moisture and rainfall pattern are the important considerations for deciding the time of planting (Singh *et al.*, 1976).

The present study showed that plant height was significantly affected by the two water regimes and with taller plants were recorded under irrigated treatments (200 cm). Consequently, the irrigation treatment which produced the taller plants gave higher yields of stover and total dry matter. These results confirmed the findings of Poehlman (1959) and Chaudhary (1964) who reported that plant height is one of the major components of stover yields of sorghum. The irrigated sorghum plants were taller than non-irrigated sorghum plants (Sivakumar *et al.*, 1979).

The large differences of height among sowing dates resulted primarily from the effect of genotypes which interacted significantly with the amount and distribution of precipitation and irrigation rates.

The significant effects of sowing date x water regime and sowing dates x genotypes interaction on height resulted primarily from differential response of sorghums to the water regimes. Similar results were obtained by Mirhadi and Kobayashi (1981) and Salgado (1984) who stated that plant height increased in irrigated plots compared to non-irrigated plots at all planting dates and also reported that plant height was less at the later sowing dates.

The number of leaves and panicle weight were unaffected by water regimes but were influenced by sowing date. Many researchers reported the advantage of early sowing over later in producing more leaves. Schaffer (1981) studied the effect of planting date and environment on the phenology of grain sorghum

(*Sorghum bicolor* (L.) Moench) and reported that early planting of sorghum increased the number of leaves a plant produced but had little effect on the duration of panicle development. Conversely, later plantings of sorghum were subjected to high temperatures during early growth and hastened vegetative development with a reduction in the number of leaves produced. Generally, the later sown plants produced fewer leaves in many studies (Sieglinger, 1936; Peck and Weibel, 1973; and Kassam and Andrews, 1975).

Plant population was not significantly affected by water regimes. Both irrigated and non-irrigated plots had the same stand at all planting dates. In contrast, delays in planting have a major effect in plant population because it declined by 11% as plantings were delayed from June 17 to July 1. The decline with successive planting dates was probably due to increased mortality of seedlings, caused by shoot fly. This infestation of shoot fly resulted in poor establishment and growth of the crop late in the season. Subsequently, the yields of the genotypes were affected much more with the decrease in stand.

Again, the number of heads per unit area was not affected significantly by water regime treatments, but significantly reduced by late sowing. The water regimes x genotypes interaction was not significant. In both genotypes, the number of fertile heads was reduced as plantings were delayed and more barren heads were recorded. Consequently, yields of grain per unit area was influenced with the decreased number of heads when

sorghum was planted late. Observations to this effect have been made by Arnon and Blum (1965). They reported that the effect of the larger number of heads produced under the more favorable conditions of early sowing and were significantly reduced by late sowing.

The number of grains per panicle was not affected by the two water regimes but it declined when sowing was delayed beyond June 17, with a maximum reduction of 56% due to the delay in sowing date 2. These results reflect the final number of fertile heads produced under the more favorable conditions of early sowing and high water regimes. Most of the yield differences were associated with differences in grain number and hence with preanthesis environmental conditions. There was a significant dates x genotype interaction. At the early sowing date, the hybrid produced more seeds, approximately double of the local variety in both irrigated and non-irrigated treatments. The effect of genotypes was not consistent at all planting dates, but was consistent with the observation made by Ogunlela (1985).

Total shoot dry matter production were always greater under irrigated treatments, at all planting dates consistent with those of non-irrigated sorghum plants as reported by Sivakumar *et al.* (1979).

Total dry matter production declined significantly as planting dates were delayed from June 17 through July 30. Even a delay in two weeks substantially reduced the total dry matter. The reduction was 43.1% due to the first delay in sowing, but the

next delay resulted in very high depression in yield of dry matter (50%). Further delay reduced the dry matter markedly (68%). These reductions in dry matter matched the reduction in plant heights, number of leaves, grain yield and finally stover yield. Observations of this effects clearly confirm the findings of Ghadekar *et al.* (1986) who reported that the total dry matter, plant height, stover and grain yield were significantly more when sorghum was sown on June 28 and decreased with delay in sowing. The lowest values were recorded when the crop was sown on July 26. Kudasmanavar *et al.* (1984) reported similar observations to the findings of this study. The influence of planting dates on the genotypes were also measured in the above study. Genotype x planting date interaction was found to be highly significant.

Regarding grain yield, the water regime treatments did not affect significantly the grain yield of sorghum genotypes. This is in agreement with the findings of Dhonde *et al.* (1985) indicating that the grain yield of sorghum was not influenced significantly due to different water regimes. However, the response of grain sorghum genotypes to irrigation showed not only a beneficial effect on some agronomic characteristics but also reduced shoot fly (*Atherigona soccata* R.) damage compared with non-irrigated treatments at later planting dates. Observation to this effect have been made by Vithaya (1982).

The highest grain yield was obtained from the first sowing date and the yield declined sharply as sowing was delayed from June 17 through July 30. The difference in the grain yield from

the first and the last sowing date was 2.6 t.ha⁻¹. The reduction in yield was associated with the high incidence of shoot fly at seedling stage and by head bug (*Calocoris angustatus* Lath.) at grain formation stage and severe drought from weeks 38 through 42. These results are in agreement with those reported by Masood Ali *et al.* (1981), Ogunlela (1985), Muchow *et al.* (1986), Srivastava *et al.* (1981) and Subbian *et al.* (1983) who reported that late sown sorghum showed a marked reduction in grain yield. The vegetative growth of late sown sorghum was also extremely poor. A similar record on a millet crop has been made by Balyan *et al.* (1982). The late sown crop during the rainy season was affected severely by shoot fly at seedling stage and midge at grain formation stage (Singh *et al.*, 1976).

The significant interaction between the genotypes and sowing dates illustrates the differential response of the genotypes to the variation in sowing dates. The hybrid CSH-5 yielded twice as much as did the local Pacha Jonna when planted early but yields decreased when sowings were delayed (Table 8).

Water regimes, mean relative humidity and solar radiation were significantly and positively correlated with grain yield in both the genotypes. The character most negatively correlated with grain yield in both the genotypes was evaporation. The respective correlation coefficient (r) values were -0.96*** and -0.88** for the hybrid CSH-5 and the local variety Pacha Jonna respectively. The mean relative humidity was significantly and negatively correlated with evaporation. The respective

correlation coefficient (r) value was -0.99^{**} for both the genotypes.

The stover yield of sorghum was high in irrigated treatments compared to non-irrigated ones at all planting dates. Their effect was significantly different at $P < 0.01$ level of significance. This might be due to more heights and number of leaves. The highest stover yield which amounted to 6.22 t.ha^{-1} was achieved under irrigation. While the lowest of 4.62 t.ha^{-1} of stover was recorded from the non-irrigated plots. The results obtained under the condition of this experiment are in agreement with the findings of several other investigators (Chaudhary, 1964; Muhammed Rashid, 1964 and Bond *et al.*, 1964).

Significant differences were found in the mean stover yield of the genotypes due to various planting dates. The data showed a trend of higher stover yield in early planting; however, with further delays in planting from mid-June to end of July, the mean stover yields of the genotypes decreased significantly. The high stover yields obtained from June 17 plantings indicate the ability of the genotypes to utilize the growing season most effectively when planted early. Umrani (1983); Itnal *et al.* (1986); Surender Reddy *et al.* (1974) at the Agricultural Research and Education Centers, India, reported that stover yield of sorghum was reduced with each delay in sowings.

The highly significant interaction of genotypes with sowing dates indicated a differential response of varieties to the variation in sowing dates.

The local variety produced more stover than the hybrid in the first two sowings; however, with further delay in sowing, the hybrid produced more stover than the local.

Thousand grain weight was generally not affected by water regimes planted at different sowing dates. The influence of planting date on 1000 grain weight studied in this experiment indicate that the cultivar x planting date interactions were found to be highly significant (Table 11). Planting date had a greater effect on seed weight. The delay in planting beyond the normal date, affected markedly the seed weight of the genotypes. Date 3 was less affected than others, while dates 2 and 4 were more significant. In both the genotypes, the average seed weight declined as planting was delayed from June 17 through July 30. A delay of 45 days in planting reduced seed weight by almost 32% (19.1 vs 13.3 g.1000⁻¹ grains). A significant portion of the yield reduction may be related to decline in seed weight. This may reflect the combined effect of the adverse environment and the infestation of insect pests on the influence of late planting on seed weight. Grain weight is often regulated by environmental conditions from flowering to maturity (Murry *et al.*, 1984). Plants in this study flowered and matured about the same time. This suggests that 1000 grain weight may be the most important yield components to examine in identifying genotype differences in grain yield along the sowing dates.

These results indicate that grain weight is extremely sensitive to planting date and could account for some of the decline in seed yield experienced in most later planted sorghums.

These results are in close agreement with the findings of Hume and Kebede (1981) and Singh *et al.* (1976) who reported that delay in sowing reduced the grain yield by decreasing the number of seeds per panicle and seed weight.

CONCLUSIONS

From this experiment, it can be concluded that earlier planting of sorghum under both irrigated and rainfed conditions increased grain yield due to more favorable environmental conditions early in the season. Irrigation of sorghum should be considered, although this crop is well known for its tolerance to drought conditions.

The most optimum sowing time for rainfed sorghum during rainy season in India appeared to be at the onset of first monsoon showers. Progressive delays of 15, 20 or 45 days not only decreased the yield and yield components but also increased the incidence of pest damage but less in irrigated treatments.

It would be of interest to pursue this study in more detail for a number of years to arrive at more definite conclusions and suggestions.

SUMMARY

VI
SUMMARY

A field experiment was conducted at the center of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, on Alfisol during the rainy season of 1986 to assess the effect of different planting dates and water regimes on the growth, grain yield and yield components of sorghum genotypes. Grain sorghums, (*Sorghum bicolor* (L.) Moench) hybrid CSH-5 and Local Pacha Jonna were planted on June 17, July 1, 15 and 30. Irrigation treatments received water once at fortnightly intervals during the growing season were taken as main plots.

The results of the experiment are summarised below:

1. There was a remarkable increase in the growth characters like plant height, number of leaves per plant, and plant stand in irrigated treatments compared with rainfed treatments at all planting dates.

2. Panicle length, grain weight per panicle, number of grains per panicle and panicle weight were significantly influenced by water regimes at all planting dates.

3. Irrigation significantly increased the grain yield, stover yield and total dry matter at all planting dates.

4. The grain yield and yield components were reduced significantly with a delay in sowing partly due to shoot-fly damage at seedling stage and head bug damage at grain formation stage.

5. Early planting resulted in higher grain and stover yields compared with later planting in both irrigated and rainfed treatments.

6. Interaction between water regimes and sowing dates had an additive effect on yield. The patterns have shown that adequate moisture supply and early sowing of the sorghum genotypes resulted in significant yield increase.

**LITERATURE
CITED**

VII

LITERATURE CITED

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APPENDICES

Appendix I: Standard week weather data from Jun. 15 to Nov. 15 for the year 1986.

STD WEEK	MONTH	RAIN mm	EVAP mm	MAX. TEM	MIN. TEM	R.HU 0717	R.HU 1417	SOL. RADIATION (LY/DAY)
24	JUN	73.8	54.5	33.7	23.5	85.9	54.0	343
25		33.3	50.7	30.8	23.2	87.3	57.3	345
26		8.9	43.8	30.3	23.0	83.9	53.0	262
27	JUL	7.0	68.9	34.2	24.2	73.3	38.1	489
28		20.1	53.7	31.9	23.9	74.4	50.4	354
29		93.6	35.8	27.9	21.9	90.1	72.9	261
30		2.3	41.1	29.6	21.7	86.6	59.4	378
31		58.0	38.3	29.9	21.9	93.0	63.6	432
32	AUG	107.8	28.2	27.5	21.9	93.7	81.6	315
33		69.2	29.7	27.0	21.3	91.4	76.0	339
34		4.1	34.0	29.1	21.4	88.7	61.4	460
35		0.0	43.1	31.4	22.3	81.7	49.1	544
36	SEP	49.2	44.4	31.4	22.3	81.4	57.7	459
37		4.4	33.2	30.3	22.3	88.4	56.7	424
38		2.3	40.8	33.0	22.2	90.4	46.7	520
39		1.4	41.2	33.2	21.8	89.3	43.6	476
40	OCT	0.0	40.5	32.1	21.2	90.6	48.6	423
41		0.0	42.1	34.1	20.3	81.6	33.6	438
42		0.0	47.8	33.6	19.6	81.1	28.1	441
43		0.0	45.0	31.6	16.3	81.7	28.9	464
44		4.6	30.3	29.6	20.2	90.0	51.7	325
45	NOV	32.6	30.3	29.8	20.0	92.6	52.4	343
46		0.0	34.2	31.7	17.8	87.7	32.7	416

Please note that rainfall and evaporation data are totals not means

STD WEEK = Standard Week.

RAIN = Rainfall (mm).

EVAP = Evaporation (mm).

MAX. TEM = Maximum Temperature (°C).

MIN. TEM = Minimum Temperature (°C).

R.HU 0717 = Relative Humidity (%) at 0717h.

R.HU 1417 = Relative Humidity (%) at 1417h.

SOL. RADIATION = Solar Radiation (LY/DAY).

(LY/DAY)

Appendix A.1 - Days to 50% flowering of sorghum at various sowing dates and water regimes during rainy season, 1986.

WATER REGIMES	S01		S02		S03		S04		GENOTYPE				
	HYBRID	LOCAL	HYBRID	LOCAL	HYBRID	LOCAL	HYBRID	LOCAL	HYBRID	LOCAL			
IRRIGATED	58	65	62	58	63	61	54	62	58	59	56	62	59
RAINFED	58	65	62	58	64	61	54	63	59	57	56	63	59
MEAN	58	65	62	58	64	61	54	63	58	56	56	63	59

S01 = first sowing date (June 17, 1986)

GENO = Genotype;

S02 = Second sowing date (July 1, 1986)

Hybrid ; CSH-5

S03 = third sowing date (July 15, 1986)

Local ; Pochha Jamma

S04 = Fourth Sowing date (July 30, 1986)

Appendix A.2 - Days to physiological maturity of sorghum at various sowing dates and water regimes during rainy season 1986.

WATER REGIMES	SD1		SD2		SD3		SD4		GENOTYPE	
	HYBRID	LOCAL	HYBRID	LOCAL	HYBRID	LOCAL	HYBRID	LOCAL	HYBRID	LOCAL
IRRIGATED	101	101	100	100	98	98	97	97	99	99
RAINFED	101	101	99	99	98	98	97	97	99	99
MEAN	101	101	100	100	98	98	97	97	99	99

SD1 = first sowing date (June 17, 1986)

GENO = Genotype

SD2 = Second sowing date (July 1, 1986)

Hybrid ; CS+5

SD3 = Third sowing date (July 15, 1986)

Local ; Pochha Janna

SD4 = Fourth sowing date (July 30, 1986)

Appendix A.3: Plant stand (x1000) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	72.1	66.4	64.3	63.5		
	Local	71.3	63.9	64.3	65.1	66.4 (W1)	66.2
	Mean	71.7	65.1	64.3	64.3		
Rainfed (W2)	Hybrid	72.1	63.5	64.6	63.5		
	Local	72.2	66.0	64.9	63.3	66.3 (W1)	66.4
	Mean	72.2	64.7	64.7	63.4		
Average		71.9	64.9	64.5	63.9		

Treatments	SEm	CD(5%)
Water (WAT)	0.53ns	-
Sowing dates (SD)	0.92***	2.7
Genotypes (GENO)	0.75ns	-
WAT x SD	1.25ns	-
WAT x GENO	0.92ns	-
SD x GENO	1.40ns	-
WAT x SD x GENO	1.95ns	-
CV(%)	6.4	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix A.4: Total number of heads (x 1000) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	71.3	64.4	55.4	39.0		
	Local	70.0	57.7	50.2	39.8	56.0 (W1)	56.0
	Mean	70.6	61.0	52.8	39.4		
Rainfed (W2)	Hybrid	70.4	57.5	49.4	44.4		
	Local	71.7	35.4	44.2	43.3	53.5 (W2)	51.0
	Mean	71.0	46.5	46.8	43.8		
Average		70.8	53.8	49.8	41.1		

Treatments	SEm	CD(5%)
Water (WAT)	2.55ns	-
Sowing dates (SD)	2.43***	7.23
Genotypes (GENO)	0.96***	2.79
WAT x SD	3.92*	11.65
WAT x GENO	2.72ns	-
SD x GENO	2.78**	12.52
WAT x SD x GENO	4.36ns	-
CV(%)	10.0	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix A.5: Grain weight per panicle (g) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	76.1	34.3	46.2	28.1		
	Local	26.6	2.4	30.9	23.3	33.5 (W1)	39.6
	Mean	51.3	18.4	38.5	25.7		
Rainfed (W2)	Hybrid	62.3	24.2	27.3	18.2		
	Local	30.6	11.1	22.7	12.0	26.0 (W2)	19.9
	Mean	46.4	17.6	25.0	15.1		
Average		48.9	18.0	31.7	20.4		

Treatments	SEm	CD (5%)
Water (WAT)	2.72ns	-
Sowing dates (SD)	2.22***	6.6
Genotypes (GENO)	1.20***	3.5
WAT x SD	3.84ns	-
WAT x GENO	2.97**	8.7
SD x GENO	2.80***	8.2
WAT x SD x GENO	4.53ns	-
CV (%)	22.9	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix A.6: Number of grains per panicle as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	3996	1911	3483	2528		
	Local	1571	346	1525	1211	2071(W1)	2744
	Mean	2783	1128	2504	1870		
Rainfed (W2)	Hybrid	3599	1615	2518	2298		
	Local	1336	715	1128	762	1746(W2)	1073
	Mean	2468	1165	1823	1530		
Average		2625	1147	2164	1700		

Treatments	SEM	CD(5%)
Water (WAT)	105.6ns	-
Sowing dates (SD)	97.4***	289
Genotypes (GENO)	71.8***	210
WAT x SD	159.3ns	-
WAT x GENO	127.7ns	-
SD x GENO	140.7**	411
WAT x SD x GENO	214.4ns	-
CV(%)	21.3	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

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Appendix A.7: Total panicle weight t.ha as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	6.1	2.9	3.5	2.3		
	Local	2.9	1.0	2.1	1.6	2.8 (W1)	3.0
	Mean	4.5	1.9	2.8	1.9		
Rainfed (W2)	Hybrid	5.6	2.3	2.5	1.1		
	Local	3.3	1.0	1.7	0.6	2.5 (W2)	1.8
	Mean	4.5	1.6	2.1	0.8		
Average		4.5	1.8	2.4	1.5		

Treatments	SEm	CD(5%)
Water (WAT)	0.13ns	-
Sowing dates (SD)	0.12***	0.3
Genotypes (GENO)	0.06***	0.2
WAT x SD	0.19*	0.6
WAT x GENO	0.14**	0.4
SD x GENO	0.14***	0.4
WAT x SD x GENO	0.22ns	-
CV(%)	13.0	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix A.8: Panicle weight per plant (g) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	92.7	47.7	64.7	45.1		
	Local	36.4	12.6	42.8	33.1	46.9 (W1)	55.1
	Mean	64.5	30.1	53.7	39.1		
Rainfed (W2)	Hybrid	74.9	39.6	41.8	34.1		
	Local	36.5	26.2	33.5	20.7	38.4 (W2)	30.2
	Mean	55.7	32.9	37.6	27.4		
Average		60.1	31.5	45.7	33.2		

Treatments	SEm	CD(5%)
Water (WAT)	2.88ns	-
Sowing dates (SD)	2.67***	7.9
Genotypes (GENO)	1.37***	4.0
WAT x SD	4.35ns	-
WAT x GENO	3.19**	9.3
SD x GENO	3.30***	9.6
WAT x SD x GENO	5.14ns	-
CV(%)	18.2	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix A.9: Total dry matter per plant (g) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	184.6	119.0	121.6	105.4		
	Local	127.8	96.7	90.5	83.3	116.1(W1)	116.8
	Mean	156.2	107.9	106.0	94.3		
Rainfed (W2)	Hybrid	135.7	119.5	75.9	72.8		
	Local	108.9	102.3	68.6	56.8	92.6(W2)	91.9
	Mean	122.3	110.9	72.2	64.8		
Average		139.2	109.4	89.1	79.6		

Treatments	SEM	CD(5%)
Water (WAT)	2.95*	13.3
Sowing dates (SD)	4.34***	12.9
Genotypes (GENO)	2.84***	8.3
WAT x SD	6.08*	18.1
WAT x GENO	4.10*	12.0
SD x GENO	5.92ns	-
WAT x SD x GENO	8.33ns	-
CV(%)	15.7	

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix A.10 - Correlation coefficient (N = 8) between grain yield (t.ha⁻¹) of Hybrid CSH-5, water regimes (mm), evaporation (mm), mean relative humidity (mm) and cumulative light interception (Mj m²) during kharif season, 1986.

	Water	Evap.	Mean RH	Cum. Light Int.
Yield	0.976***	-0.959***	0.969***	0.911***
Water		-0.887**	0.902**	0.933***
Evap.			-0.996***	-0.830*
Mean RH				0.817*

Note : see next table footnote for explanation.

Appendix A.11 - Correlation coefficient (N = 8) between grain yield (t.ha⁻¹) of local variety water regimes (mm), evaporation (mm), mean relative humidity (mm) and cumulative light interception (Mj m²) during kharif season, 1986.

	Water	Evap.	Mean RH	Cum. Light Int.
Yield	0.784*	-0.884**	0.854**	0.874*
Water		-0.887**	0.902**	0.933***
Evap.			-0.996***	-0.830*
Mean RH				0.817*

, **, ** = Values are significantly correlated at 0.05, 0.01 and 0.001 levels of probability, respectively.

Cum. Light Int. = cumulative light interception (MJ m⁻²).

RH = relative humidity (%).

Evap. = Evaporation (mm).

Appendix A.12: Stover yield per plant (g) as affected by various sowing dates and water regimes during rainy season, 1986.

Water Regimes	GENO	SOWING DATES				AVERAGE	
		SD1	SD2	SD3	SD4	Water	Geno
Irrigated (W1)	Hybrid	91.9	71.4	56.9	60.3		
	Local	91.4	84.1	47.6	50.2	69.2 (W1)	61.8
	Mean	91.7	77.7	52.3	55.3		
Rainfed (W2)	Hybrid	60.8	80.0	34.0	38.8		
	Local	72.4	76.2	35.1	36.2	54.2 (W2)	61.7
	Mean	66.6	78.1	34.6	37.5		
Average		79.1	77.9	43.5	46.4		
Treatments		SEm	CD(5%)				
Water (WAT)		1.77**	8.0				
Sowing dates (SD)		2.83***	8.4				
Genotypes (GENO)		2.22ns	-				
WAT x SD		3.89*	11.6				
WAT x GENO		2.85ns	-				
SD x GENO		4.23ns	-				
WAT x SD x GENO		5.91ns	-				
CV(%)		20.4					

ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix B.1: Mean sum squares from analysis of variance of plant stand number of heads and barren plants of sorghum genotypes.

Source of variation	DF	Plant stand MS	No. of heads MS	Barren plants MS
Rep stratum	3	2.243E 7	8.720E 6	89.87
Rep water stratum				
Water	1	1.736E 5ns	2.474E 8ns	535.96ns
Residual	3	9.137E 6	2.078E 8	321.56
Total	4	6.896E 6	2.177E 8	375.16
Rep water SD stratum				
SD	3	2.268E 8***	2.424E 9***	3044.58***
Water x SD	3	1.807E 6ns	2.767E 8*	609.58*
Residual	18	1.360E 7	9.464E 7	200.33
Total	24	3.877E 7	4.086E 8	607.02
Rep water SD geno stratum				
Geno	1	3.086E 5ns	3.876E 8***	907.01**
Water x Geno	1	4.938E 6ns	5.470E 7ns	231.26ns
SD x Geno	3	8.616E 5ns	1.825E 8**	407.56ns
Water x SD x Geno	3	8.115E 6ns	6.425E 7ns	234.59*
Residual	24	1.798E 7	2.930E 7	87.44
Total	32	1.449E 7	5.893E 7	161.36
Grand Total	63			
Grand mean	20.0			
Total number of observations	64			

* Significant at $P < 0.05$
 ** Significant at $P < 0.01$
 *** Significant at $P < 0.001$
 ns Not significant
 SD = Sowing dates
 Geno = Genotypes

Appendix B.2: Mean sum squares from analysis of variance of plant height, number of leaves and grain weight per plant of sorghum genotypes.

Source of variation	DF	Plant height MS	No. of leaves MS	Grain wt. per plant MS
Rep stratum	3	139.5	0.0683	49.56
Rep water stratum				
Water	1	11534.8**	0.0400ns	888.58*
Residual	3	245.8	1.1083	236.50
Total	4	3068.0	0.8413	399.52
Rep water SD stratum				
SD	3	19048.6***	27.5117***	3178.89***
Water x SD	3	545.5*	6.0917***	131.86ns
Residual	18	126.6	0.3844	78.57
Total	24	2544.2	4.5012	472.77
Rep water SD geno stratum				
Geno	1	18509.6***	60.8400***	6168.69***
Water x Gen	1	2425.6***	0.0900ns	526.29**
SDXGeno	3	1921.6***	3.8717**	987.25***
Water x SD x Geno	3	333.6*	0.8350ns	85.99ns
Residual	24	128.3	0.6046	46.42
Total	32	961.9	2.7988	344.65
Grand Total	63			
Grand mean	20.0			
Total number of observations	64			

* Significant at P<0.05
 ** Significant at P<0.01
 *** Significant at P<0.001
 ns Not significant
 SD = Sowing dates
 Geno = Genotypes

Appendix B.3: Mean sum squares from analysis of variance of plant weight per plant, stover yield per plant and panicle length of sorghum genotypes.

Source of variation	DF	Panicle wt/plant MS	Stover y/plant MS	Panicle length MS
Rep stratum	3	97.48	111.3	1.58
Rep water stratum				
Water	1	1149.21ns	3630.1**	9.15***
Residual	3	264.68	100.8	0.06
Total	4	485.81	983.1	2.33
Rep water SD stratum				
SD	3	2809.39*	6047.5***	11.16*
Water x SD	3	260.54ns	468.6*	2.67ns
Residual	18	113.96	128.2	4.05
Total	24	469.21	910.7	4.76
Rep water SD geno stratum				
Geno	1	9880.36***	0.2ns	2505.00***
Water x Geno	1	665.64**	45.6ns	0.09ns
SD x Geno	3	998.29***	144.3ns	65.84ns
Water x SD x Geno	3	101.33ns	180.1ns	2.34ns
Residual	24	59.89	158.3	28.92
Total	32	477.57	150.6	106.37
Grand Total	63			
Grand mean	20.0			
Total number of observations	64			

* Significant at $P < 0.05$
 ** Significant at $P < 0.01$
 *** Significant at $P < 0.001$
 ns Not significant
 SD = Sowing dates
 Geno = Genotypes

Appendix B.4: Mean sum squares from analysis of variance of grain yield, stover yield and total dry matter for sorghum genotypes.

Source of variation	DF	Grain yield MS	Stover yield MS	Total DM MS
Rep stratum	3	87635	214305	556277
Rep water stratum				
Water	1	1876255*	40831352**	72609256**
Residual	3	248218	734110	1995819
Total	4	655227	10758421	19649178
Rep water SD stratum				
SD	3	22907472***	136068048***	274087968***
Water x SD	3	615489**	480612ns	2175233ns
Residual	18	109475	462326	1009061
Total	24	3022476	17415326	35289696
Rep water SD geno stratum				
Geno	1	13690607***	3715615*	17007704***
Water x Geno	1	945202**	648770ns	120403ns
SD x Geno	3	2720639***	14633337***	6061793***
Water x SD x Geno	3	196067ns	2383949*	2190334*
Residual	24	103481	754415	788066
Total	32	808421	2297569	1899940
Grand Total	63			
Grand mean	20.0			
Total number of observations	64			

* Significant at $P < 0.05$
 ** Significant at $P < 0.01$
 *** Significant at $P < 0.001$
 ns Not significant
 SD = Sowing dates
 Geno = Genotypes

Appendix B.5: Mean sum squares from analysis of variance of total dry matter per plant, number of grains per plant and total panicle weight of sorghum genotypes.

Source of variation	DF	Total dry matter/ plant MS	No. of grains/ plant MS	Total panicle weight MS
Rep stratum	3	374.0	195882	87842
Rep water stratum				
Water	1	8864.2*	1690715ns	4541864***
Residual	3	279.2	356803	500918
Total	4	2425.5	690281	1511154
Rep water SD stratum				
SD	3	11131.3***	6414852***	30632408*
Water x SD	3	1278.2*	343075ns	889549ns
Residual	18	301.6	151768	212321
Total	24	1777.4	958567	4099486
Rep water SD geno stratum				
Geno	1	9960.0***	44590012***	36622264***
Water x Geno	1	1059.5*	346068ns	1328150ns
SD x Geno	3	503.6ns	940037**	3229078ns
Water x SD x Geno	3	157.5ns	164230ns	90335ns
Residual	24	258.8	164837	106536
Total	32	600.4	1631405	1577048
Grand Total	63			
Grand mean	20.0			
Total number of observations	64			

* Significant at $P < 0.05$
 ** Significant at $P < 0.01$
 *** Significant at $P < 0.001$
 ns Not significant
 SD = Sowing dates
 Geno = Genotypes

Appendix B.6: Mean sum squares from analysis of variance of Harvest index, test weight and threshing percentage of sorghum genotypes.

Source of variation	DF	Harvest index MS	Test weight MS	Threshing % MS
Rep stratum	3	2.47	0.362	39.73
Rep water stratum				
Water	1	9.67ns	0.065*	54.88ns
Residual	3	14.14	14.541	13.07
Total	4	13.03	10.922	23.52
Rep water SD stratum				
SD	3	804.17***	115.436***	2803.92***
Water x SD	3	68.88*	37.882**	229.26***
Residual	18	15.28	6.248	26.07
Total	24	120.60	23.851	398.70
Rep water SD geno stratum				
Geno	1	508.39***	153.485***	1.65ns
Water x Geno	1	31.17ns	100.591***	269.57**
SD x Geno	3	506.44***	154.245***	1826.18***
Water x SD x Geno	3	40.21*	26.696**	337.98***
Residual	24	13.33	4.569	30.77
Total	32	73.11	28.330	234.45
Grand Total	63			
Grand mean	20.0			
Total number of observations	64			

* Significant at $P < 0.05$

** Significant at $P < 0.01$

*** Significant at $P < 0.001$

ns Not significant

SD = Sowing dates

Geno = Genotypes

Appendix C: Description of genotypes.

	<u>CSH 5</u>	<u>Pacha Jonna</u>
1. Parentage	2077A x CS 3541	G4 (IS 18351)
2. Duration	105-110 days	95 days
3. Grain quality	Spherical cream color	Yellow pericarp
4. Suitability for season	Kharif	Rabi (also grown in Kharif)
5. Disease or pest reaction	Moderate susceptible to shootfly and resistance to all major diseases	
6. Plant height	-	165 cm

VITA

I, Mohamed A. Mao, was born on August 5, 1953 to Halima Sayid and Ahmed Mao, in Merka district at Lower Shebelli region, Somalia.

I was educated at Merka Primary School and completed my secondary school at Mogadishu in 1972. I obtained my B.Sc., degree in 1979 from the Faculty of Agriculture of the "Somali National University" at Afgoi district. I then served as a research officer of Agronomy at Agricultural Research Institute (ARI) with the collaboration of International Development Research Center (IDRC), in Afgoi district.

During the period from 1981 to 1984, I participated in several seminars and workshops of educational and professional interests as follows:

1. India:

a) I attended the FAO/SIDA course on Maize, Sorghum and Millets for Africa and Near East conducted between June and December 1981, at the Indian Agricultural Research Institute (IARI), New Delhi, India (FAO sponsorship).

b) I also had the opportunity to attend the Symposium on "Sorghum in the Eighties", held in November 1981, at the International Crops Research Institute for the Semi-Arid Troics (ICRISAT), Patancheru, A.P., India under the sponsorship of FAO.

2. Kenya:

In June 1982, I attended the FAO/SIDA seminar held at Nairobi, Kenya under the sponsorship of FAO.

3. Zimbabwe:

a) In September 1983, I attended the Farming Systems Workshop Program - Diagnostic phase, held at the University of Zimbabwe, Harare, under the sponsorship of IDRC.

b) In February 1984, the same university held a Farming Systems Workshop Program - Research phase, and I attended it under the sponsorship of CIMMYT, Nairobi.

In 1985 I was admitted into M.Sc. degree program in Agriculture by the International Development Research Center (IDRC) under its East African Program at the Andhra Pradesh Agricultural University (APAU). I carried out the research work at ICRISAT Center, Patancheru, Hyderabad, India, under the guidance of Dr. C.K. Ong, Principal Agronomist, RMP, ICRISAT, and Dr. G.V. Reddy, Professor and Head of Agronomy Department, APAU.

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