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Collaborative Multilocation Sorghum Modeling Experiment

Report for 1980-1981

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
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NOTICE TO THE READER

This is an informal report of the Collaborative Multilocation Sorghum Modeling Experiment for 1980-1981. The report is designed to stimulate thinking and comments from professional colleagues and is not a formal publication bearing the endorsement of the Institute.

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REPORT OF COLLABORATIVE MULTILOCATION SORGHUM MODELING EXPERIMENT

1980-1981

Prepared on behalf of the Cooperators

by

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COLLABORATIVE MULTILOCATION SORGHUM MODELING EXPERIMENT

Introduction

Over the past three years a multilocation collaborative project is being conducted at ICRISAT and at other cooperating centers in the SAT. Scientists from different disciplines are actively involved in collecting congruent data sets on soils, crops, weather and management with the following main objectives:

(i) To develop and test dynamic sorghum simulation models by integrating information on different aspects of crop growth and development.

(ii) To develop a quantitative understanding of crop response to environment.

(iii) To identify areas where quantitative knowledge is lacking and plan a future course of action to fill the gaps in knowledge.

(iv) To use models as research tools in the development and transfer of technology.

Preliminary tests with SORGF (Arkin et al. 1976) showed that several subroutines in the model need modification for its adoption to the SAT regions. These subroutines deal with emergence, soil water, leaf area development, phenology, light interception and drymatter partitioning. Based on limited data sets, some preliminary revisions were made in SORGF during the year 1979-80 (Agroclimatology Report of Work, 1979-80). The revised SORGF model referred to as SORGF-1 showed improvements in simulating sorghum growth and development.

Data collected from the sorghum modeling experiments during the rainy and postrainy seasons of 1979 and 1980 were used to further examine the SORGF model. The revised model is now referred to as SORGF-2. The revisions made and the simulation results from SORGF and SORGF-2 are described in this report.

Experimental Methods

Replicated trials involving two standard sorghum genotypes, CSH-1 and CSH-6 during the rainy season and CSH-8 and M-35-1 during the postrainy season, were conducted at most of the locations. Additional moisture treatments of adequate water and water stress at certain critical stages were included in the postrainy season experiments. Standard data sets on crop, soil, weather and management required to test the model were collected. Details of the nature of data and method of data collection were described by Huda et al. (1980).

Details of Multilocation Trials

The experiments were conducted at ICRISAT Center, Coimbatore, Delhi, Hissar, Parbhani, Pune, Rahuri, and Ludhiana in India and at Khon Kaen in Thailand. Data obtained at each of these locations during the 1980 rainy season, and 1979-80 and 1980-81 postrainy seasons, are given in the appendix tables. A brief description of the trials is given below.

1. ICRISAT Center

a) 1979-80 Postrainy Season

The trials were conducted on both Alfisol (RP-4) and Vertisol (BP-12) soils.

RP-4: The response of two sorghum genotypes CSH-8 and M-35-1 to available soil moisture was studied by creating two levels of soil moisture depletion. The available water holding capacity of the soil is 8.5 cm. Crops were sown on 19 November and the soil was recharged to capacity just after planting. Emergence occurred on 22 November. Two differential moisture regimes were created by giving four supplemental irrigations at 19, 39, 57, and 76 DAE (referred to as treatment A) and only two supplemental irrigations at 39 and 76 DAE (referred to as treatment B). Final plant populations/ha for CSH-8 were 143,000 and 125,000 in treatments A and B respectively and for M-35-1 in both treatments they were 150,000.

BP-12: This experiment involved comparison of five different row spacings of sorghum hybrid CSH-8 i.e., 30-, 60-, 90-, 120-, and 150-cm at two different moisture regimes. The crop was sown on 22 November. After a 'come-up' irrigation of 4-cm on 23 November the emergence occurred on 26 November. The available water holding capacity of the soil is 14 cm. The moisture regimes included three supplemental irrigations measuring 6, 6 and 4.5 cm at 15, 35 and 55 DAE (treatment A) and no supplemental irrigation (treatment B).

b) 1980 Rainy Season

Alfisol (RP-4): Two sorghum hybrids CSH-1 and CSH-6 were tested under supplemental irrigation (treatment A) and under rainfed situation (treatment B). The crops were sown on 19 June and emergence occurred on 23 June. After giving two supplemental irrigations to treatment A at 5 and 28 DAE it was noticed that rains following irrigations led to waterlogging and no further irrigations were given. This waterlogging led to decreased total drymatter and grain yield for CSH-6 as will be discussed later.

Vertisol (BW-3): This trial involved three sorghum genotypes CSH-1, CSH-6 and SPV-351 which were sown on 18 June and emergence occurred on 4 July because of dry seeding. Plant populations at harvest were 117,000, 130,000 and 114,000 for CSH-1, CSH-6 and SPV-351 respectively.

c) 1980-81 Postrainy Season

Experiments were conducted on both Alfisols and Vertisols with the specific objective of quantifying the effect of moisture stress on leaf area development, phenology, drymatter production and its partitioning in various genotypes.

Alfisol (RP-4): Three sorghum genotypes CSH-6, CSH-8, and M-35-1 were grown under two moisture treatments A and B. The crop was sown on 10 October. A common irrigation was given to both treatments on 11 October to recharge the profile. Emergence occurred on 13 October. Treatment A received four supplemental irrigations at 10, 28, 39 and 70 DAE while treatment B was irrigated at 10 and 39 DAE (Plate 1).

A: Well-watered.
Front: CSH-8, Middle: CSH-6, Rear: M-35-1.

B: Stressed
Front: CSH-8, Middle: CSH-6, Rear: M-35-1.

Plate 1: A view of sorghum modeling experiment with three genotypes under two moisture treatments grown at ICRISAT Center on an Alfisol (RF-4) during 1980-81 postrainy season.

Vertisol (BW-3): An unreplicated trial involving four genotypes (CSH-6, CSH-8, M-35-1 and CSV-5) and two moisture treatments A and B was conducted. Sowing was done on 24 November. The entire field was irrigated after sowing to recharge the profile holding 200 mm available water. Treatment A was given irrigations at 36, 65 and 81 DAE while in treatment B no supplemental water was applied to the crop.

2. Coimbatore

Sorghum modeling experiment was initiated in Coimbatore from the 1980-81 postrainy season. CSH-8 was sown on 9 November. The soil contained 6 cm available water at sowing against the capacity to hold 14.4 cm available water. Emergence occurred on 12 November. A total of 205 mm of rainfall was received in this growing season. Five irrigations each of 5 cm were given at 28, 44, 58, 74, and 90 DAE. Population was 140,000/ha.

3. Delhi

At Delhi, both CSH-1 and CSH-6 were sown on 28 June during the 1980 rainy season. The soils at Delhi are recent alluvial soils with a maximum water holding capacity of 18.7 cm. The available soil water at sowing was 8.5 cm. Two irrigations were given on 27 August and 16 September each with 5 cm. This treatment is referred to as A. The other treatment involves growing crops under rainfed situation and is referred to as treatment B.

4. Hissar

In the 1979 rainy season CSH-6 performed considerably better with grain yield of 3590 kg/ha compared to 1580 kg/ha for CSH-1 due to damage caused by shootfly for the later hybrids. Therefore, only CSH-6 was grown in 1980 rainy season with two moisture treatments. The crop was sown on 20 June. In one treatment three additional irrigations each amounting 8 cm were applied on 9 July, 20 July and 16 August (treatment A) and the other treatment involves growing crops under rainfed situation (treatment B).

5. Khon Kaen

Sorghum genotype Hegari was sown on 13 August 1980. The available water at sowing was 11.5 cm indicating the fully recharged profile. Emergence occurred on 16 August. No irrigation was given.

6. Ludhiana

CSH-1 and CSH-6 were sown on 1 July 1980. The soil profile was almost full at the time of sowing. The available water holding capacity of the soil is 12.3 cm. Emergence occurred on 4 July. A total of 74.5 cm rainfall was received during the growing season. The crop was grown in rainfed situation.

7. Parbhani

a) 1979-80 Postrainy Season

CSH-8 and M-35-1 were sown on 7 October. The available water holding capacity was 15 cm at sowing indicating 75 percent recharge of the profile. Emergence

occurred on 12 October. Crops were grown with the residual moisture with 25 mm precipitation received in this growing season.

b) 1980 Rainy Season

CSH-1 and CSH-6 were sown on 23 June. The soil having 20 cm available water holding capacity was about 50 percent recharged at sowing. It took 3 days for emergence. No supplemental irrigation was given.

c) 1980-81 Postrainy Season

CSH-8 and M-35-1 were sown on 20 October. The available soil water at sowing was 16 cm. Emergence occurred on 23 October. Two irrigations each of 5 cm were given on 25 October and 11 November. The stand of M-35-1 was very poor and therefore no data are reported for this variety.

8. Pune

a) 1979-80 Postrainy Season

CSH-1 and M-35-1 were sown on 1 December. The available soil water at sowing was 8.6 cm against the capacity of the soil to hold 12.5 cm available water. Row to row spacing was maintained at 45 cm while this was 75 cm for almost all other locations. Five irrigations each amounting 7 cm were given on 15 November, 12 December, 4 January, 23 January and 7 March.

b) 1980 Rainy Season

CSH-1 and CSH-6 were sown with 45 cm row spacing on 17 July. The available water holding capacity of the soil was 10 cm. An irrigation was given to recharge the profile at sowing.

c) 1980-81 Postrainy Season

CSH-8 and M-35-1 were sown on 16 November with a presowing irrigation after recharging the profile with a capacity to hold 10 cm available water. Emergence occurred on 19 November. Three more irrigations each measuring 10 cm were given on 21 December, 14 February and 4 March. The stand of M-35-1 was not good and therefore data for this genotype were not reported.

9. Rahuri

a) 1980 Rainy Season

CSH-1 and CSH-6 were sown on 12 July. The soil at the time of sowing contained 10 cm available water against its capacity of 12 cm. Emergence occurred on 15 July. There were two moisture treatments. In one treatment 100 mm water was applied through irrigation. This is referred to as treatment A. In treatment B crops were grown under rainfed situation.

b) 1980-81 Postrainy Season

CSH-8 and M-35-1 were sown on 19 October when the available soil water was 10 cm. Two more irrigations each amounting to 10 cm were given on 4 and 6 December.

Results

1. Summary of Weather Data

The normal and seasonal rainfall data along with seasonal potential evaporation at different locations for the 1980 rainy season are given in table 1. Above normal rainfall was received at Delhi, Parbhani and Ludhiana. The seasonal rainfall at ICRISAT Center was normal and was 28 percent higher than the PE requirement. Rainfall at Hissar, Khon Kaen, Pune and Rahuri was below normal. However at Khon Kaen the PE requirements could be adequately met through the seasonal rainfall.

Table 1. Summary of weather data for 1980 rainy season (Sowing to maturity).

Location	Seasonal rainfall	Normal rainfall	Open pan evaporation (Eo)	PE*
	----------	mm	----------	
ICRISAT Center	591	587	658	461
Delhi	724	617	568	398
Hissar	200	304	804	563
Khon Kaen	455	557	392	274
Parbhani	1050	830	698	489
Pune	248	516	500	350
Rahuri	291	538	565	396
Ludhiana	745	528	528	370

*PE = Eo x 0.7

2. Summary of Experimental Results

Detailed data on phenology, maximum and final LAI, total drymatter and grain yield observed for different sorghum genotypes at ICRISAT and the phenological data observed at other cooperating locations are given in the section under simulation results. Summary of genotypic performance under different treatments at each of the locations is given below.

a) ICRISAT Center

(1) 1979-80 Postrainy Season: There was no difference in the days to physiological maturity (PM) between the two moisture treatments A and B for both CSH-8 and M-35-1 in an Alfisol (RP-4) experiment. However, it was observed from other experiments that hastening of the maturity depends on the degree of moisture stress which prevails during the grain filling period. The available

soil moisture at PW in this experiment was 2.0 cm for M-35-1 in both treatments while it was 1.9 and 1.5 cm in treatments A and B for CSH-8. Thus both A and B treatments had the same order of moisture stress during the later part of grain filling period. CSH-8 performed better than M-35-1 under both adequate and limited moisture stiuations.

(II) 1980 Rainy Season: In the trial on the Alfisols (RP-4), total drymatter and grain yield for CSH-6 in treatment A were lower than in treatment B. Observed reductions show that CSH-6 is susceptible to waterlogging in the rainy season. Since total drymatter and grain yield for CSH-1 were higher in treatment A than in B it can be surmised that CSH-1 is tolerant to waterlogging.

In the Vertisol experiment, CSH-6 performed better than CSH-1 and SPV-351, although the leaf area index and total drymatter were maximum in SPV-351. Partitioning of drymatter to grain component which seems to be important here is discussed later.

(III) 1980-81 Postrainy Season: Early maturity because of moisture stress in treatment B was notable for all the three genotypes CSH-6, CSH-8 and M-35-1 tested on the Alfisols (RP-4) in two moisture treatments. Leaf area index, total drymatter and grain yield were maximum in treatment A for all the genotypes (Plate 2). Highest grain yield was recorded for CSH-8 in both treatments. However, under limited water availability in treatment B, M-35-1 was superior in total drymatter production as compared to CSH-8 and CSH-6. Total water use and water use efficiencies for different treatments are shown in table 2.

In the trial on Vertisols (BW-3) early maturity was observed due to the effect of moisture stress. CSH-6 showed early maturity followed by CSV-5, CSH-8 and M-35-1. The performance rankings in terms of grain yield for treatment A is CSH-8 > CSV-5 > CSH-6 > M-35-1 and for treatment B it is CSH-8 > CSH-6 > CSV-5 > M-35-1. Maximum total drymatter in treatment A was recorded for CSH-8 while in treatment B, CSV-5 proved superior.

Results from both the Alfisols and Vertisols show that CSH-8 proved superior to the other genotypes tested.

Table 2. Water use and water use efficiency of three sorghum genotypes grown during the 1980-81 postrainy season at ICRISAT Center.

Observation	CSH-8		CSH-6		M-35-1	
	A	B	A	B	A	B
1. Water use (mm)	289	210	281	198	291	210
2. Water use efficiency (kg of TDM/ha/mm)	38.6	30.8	32.9	25.3	35.2	32.3

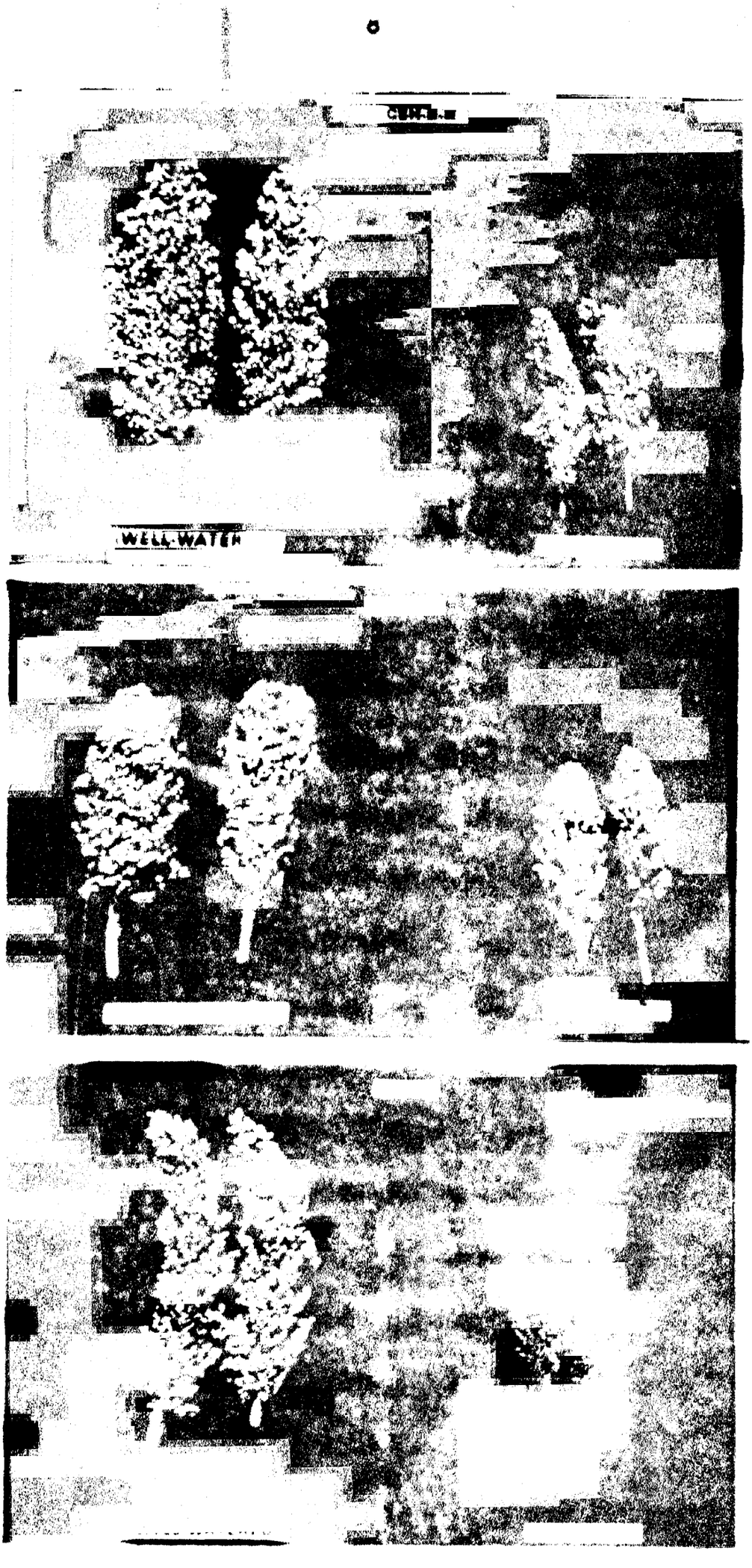

Plate 2: Comparison of heads for three sorghum genotypes grown at ICRISAT Center on an Alfisol (RP-4) during 1980-81 postrainy season.

b) Cooperating Centers

A summary of crop data for all the cooperating centers is given in table 3. The data indicate that during rainy season, CSH-6 performed consistently better than CSH-1 at all locations excepting Rahuri during the 1980 rainy season. Supplemental irrigations given to treatment A totalled 100 mm at Rahuri and this led to waterlogging. CSH-6 yielded less than CSH-1 in treatment A while in treatment B (rainfed), CSH-6 proved superior. This observation confirms the susceptibility of CSH-6 to waterlogging observed in the Alfisol trial at ICRISAT Center during the same season. In the postrainy season at all locations CSH-6 showed its superiority over M-35-1.

Table 3. Summary of crop data collected at cooperating centers.

(1) Delhi (1980 Rainy Season)

	CSH-1 (A)	CSH-1 (B)	CSH-6 (A)	CSH-6 (B)
Final plant population	140,000	140,000	160,000	160,000
Total drymatter (kg/ha)	11,586	9,016	12,810	11,430
Grain yield (kg/ha)	3,850	3,550	4,500	3,900
Maximum LAI	5.92	5.92	5.15	5.15
Final LAI	3.39	1.69	2.49	1.43

ar (1980 Rainy Season)

	CSH-6 (A)	CSH-6 (B)
Final plant population	175,000	167,000
Total drymatter (kg/ha)	23,420	20,316
Grain yield (kg/ha)	3,310	2,756

(3) Ludhiana (1980 Rainy Season)

	CSH-1	CSH-6
Final plant population	80,000	80,000
Total drymatter (kg/ha)	14,200	14,200
Grain yield (kg/ha)	1,437	2,467
Maximum LAI	1.09	1.08
Final LAI	0.54	0.32

(4) Khon Kaen (1980 Rainy Season)

Final plant population	119,000
Total drymatter (kg/ha)	4,750
Grain yield (kg/ha)	950
Maximum LAI	1.04
Final LAI	0.91

Table contd..

(A) Adequate moisture supply
(B) Rainfed

Table 3 Contd.

(5) Coimbatore (1980-81 Postrainy Season)

	CSH-8
Final plant population	140,000
Grain yield (kg/ha)	3,167

(6) Rahiri (1980 Rainy Season)

	CSH-1 (A)	CSH-1 (B)	CSH-6 (A)	CSH-6 (B)
Final plant population	130,000	130,000	140,000	140,000
Grain yield (kg/ha)	3,913	3,203	2,694	3,595

(7) Rahuri (1980-81 Postrainy Season)

	CSH-8	M-35-1
Final plant population	90,000	140,000
Grain yield (kg/ha)	7,158	4,071

(8) Parbhani (1979-80 Postrainy Season)

	CSH-8	M-35-1
Final plant population	70,000	68,000
Total drymatter (kg/ha)	5,800	5,300
Grain yield (kg/ha)	2,000	1,400
Maximum LAI	2.32	1.87
Final LAI	1.59	1.43

(9) Parbhani (1980 Rainy Season)

	CSH-1	CSH-6
Final plant population	112,000	115,000
Total drymatter (kg/ha)	11,240	13,020
Grain yield (kg/ha)	2,800	3,050
Maximum LAI	3.72	3.36
Final LAI	1.4	1.23

(10) Parbhani (1980-81 Postrainy Season)

	CSH-8
Final plant population	92,300
Total drymatter (kg/ha)	5,150
Grain yield (kg/ha)	3,080
Maximum LAI	4.62
Final LAI	1.07

Table contd.

Table 3 Contd.

(11) Pune (1979-80 Postrainy Season)

	CSH-8	M-35-1
Final plant population	180,000	150,000
Total drymatter (kg/ha)	8,657	4,000
Grain yield (kg/ha)	5,360	1,766

(12) Pune (1980 Rainy Season)

	CSH-1	CSH-6
Final plant population	70,000	120,000
Total drymatter (kg/ha)	5,133	8,205
Grain yield (kg/ha)	1,233	2,138

(13) Pune (1980-81 Postrainy Season)

	CSH-8
Final plant population	100,000
Total drymatter (kg/ha)	6,296
Grain yield (kg/ha)	2,759

3. Revised Subroutines in SORGF

a) Phenology

The time from emergence to floral differentiation is computed in the SORGF model as the period midway between the stages when five leaves expanded and when the flag leaf is visible in the whorl; time from emergence to anthesis is calculated as the computed date the flag leaf was expanded plus 0.86 times the computed number of days from differentiation to flag leaf appearance; time from emergence to physiological maturity (PM) is calculated as 1.4 times the computed number of days from emergence to anthesis.

In the revised version of SORGF instead of Accumulated Daily Heat Units, Growing Degree Days (GDD) are used to estimate the phenological events with a base temperature of 7°C and a cutoff temperature of 30°C. Data collected at ICRISAT Center show that 390 GDD are required to reach panicle initiation (PI) for hybrids like CSH-1, CSH-6 and CSH-8. GDD for varieties like SPV-351 and M-35-1 are 420 which is a little higher. These values are referred to as base GDD for PI. Emergence to anthesis is computed as 2.68 times GDD required for PI. Similarly emergence to physiological maturity is computed as GDD required for PI times 4.15.

The simplicity of the method of GDD computation may cause errors in calculating GDD. Some criticisms of calculating GDD using maximum and minimum temperatures with base and cutoff temperature are as follows:

- The threshold temperatures are not constant but change with advancing age of the plant (Wang, 1960); the narrower the range between daily maximum and minimum, the faster the development rate is at the same average temperature (Arnold 1971); and

- the day length bias is also incorporated in computing GDD in a north-south direction (Newman 1971). Stapper and Arkin (1980) used a day length correction factor for computing GDD to determine the phenology of corn.

It is suggested that these points be considered and a sound method of GDD computations be evolved in due course of time. However, the following correction factor is used in the revised version for computing phenology.

$$\text{GDD for PI} = \text{Base GDD } (1-(13-\text{Day length}) \times .2)$$

A base day length of 13 hours was chosen because the average day length for the emergence to PI in the rainy season is 13 hours at ICRISAT Center. Emergence to anthesis and PM for other locations is computed in a similar manner for ICRISAT Center.

b) Leaf Area

Total number of leaves and maximum area for individual leaf are two of the input data requirements for driving SORGF model. The number of leaves given as input data for a genotype determine its maturity duration depending on the environmental condition. It needs 50 HU above 7°C base temperature for a new leaf to emerge and then attainment of its maximum area is also a function of temperature. It is assumed that in the present model each leaf will achieve its maximum area irrespective of water stress. Also it is assumed that senescence will start after 11th leaf fully expands. These are some of the limitations in the computation of leaf area index.

It would be useful to simulate area for each leaf using environmental information instead of using them as input data. Data collected from ICRISAT indicate that senescence occurs after seventh leaf has expanded. So this information is included in the revised version. It is also assumed that the final LAI at PM will be 0.5 of its maximum under no moisture stress situation; 1/3 under mild water stress conditions (at WATSCO -- ratio of current available water and water holding capacity -- between 1.0 and 0.5). In severe moisture situation (WATSCO < 0.5) the final LAI will be nearly zero. Critical evaluation of the effect of moisture stress on leaf development is presently underway. Reasonable estimation of leaf area index is important because this information is used in other subroutines like light interception and soil water.

c) Light Interception

The light interception portion of the model simulates the relative quantum flux intercepted by a single plant. Intercepted Photosynthetically Active Radiation (PAR) is calculated on an hourly basis following a Beer's law relationship using solar radiation and light transmission values. Hourly solar radiation is computed from the input solar radiation and by accounting for the number of hours of sunlight for any day which is calculated as a sine function of the local solar time and day length. Examination of our data show that model computation of solar declination and day length are quite accurate resulting in sufficiently accurate estimation of hourly solar radiation. The quantum flux density (PAR) in Einsteins m^{-2} day^{-1} is estimated in SORGF from the energy flux density (RS) in cal $cm^{-2}day^{-1}$ as

$$PAR = RS\ (0.121)$$

However our results indicate that the constant relating PAR to solar radiation (RS) should be altered. In the revised version, PAR is thus calculated as 0.09 times RS.

Light transmission is calculated from the relationship of extinction coefficient and maximum light transmission using information on row spacings and LAI. An examination of the computed and measured light transmission for different row spacings showed that the model was overestimating light-transmission, especially at low levels of canopy light transmission. The model breaks down for row spacings greater than 137 cm because the computed light transmission exceeds 100 percent. Thus the functions for estimating extinction coefficient (X2) and maximum light transmission (X1) were revised. These are:

$$X2 = 0.0065 * \text{Row spacing} - 0.6469$$

$$X1 = 0.4711 * \text{Row spacing} + 67.2642$$

$$\text{Light transmission} = X1 * \text{Exp}\ (X2 * \text{DLAI}\ (I))$$

Both SORGF and the revised equations simulate light transmission within 15 percent of observed light transmission, with the revised equations performing better for wider row spacings. This indicates scope for further improvement of this subroutine.

d) Soil Water

Daily available water for the entire soil profile (single layered) is computed after Ritchie (1972) using information on initial available soil water, available water holding capacity, rainfall/irrigation, and evaporative demand. Potential evaporation below a plant canopy (Eos) is calculated after computing potential evaporation from bare soil (Eo) and using LAI values. Eo is calculated in the model using the Priestley-Taylor (1972) equation which requires net radiation as input data. Net radiation is computed from albedo, maximum solar radiation reaching the soil surface (Ro), and sky emissivity. Ro is calculated using a site-specific sine function as follows for ICRISAT Center:

$$Ro = 616 + 103 * (Sin (0.0172 * (I-80))$$

and Ro is not allowed to exceed 690 cal $cm^{-2} day^{-1}$

However, results indicate that Eo is underestimated. It may be useful to include open pan data as an input requirement of the model so that by multiplying these data with a suitable constant PE could be estimated. In the revised version open pan data times 0.7 has been included to compute PE.

However, several other subroutines of soil water are available in the literature. At present an exercise is underway to compare the performance of these subroutines. The subroutine giving accurate estimates of available soil water will be included in the model. These subroutines are:

(i) Ritchie model (1972) with appropriate modification for computing ET.

(ii) Ritchie model (1972) with the procedure developed by Williams and Hann (1978) to account for an effective rooting depth and consider a multi-layered profile.

(iii) ICSWAB (Reddy, 1979).

Reasonably accurate computation of soil water is important because it determines the moisture stress index which influences LAI, phenology, drymatter and its partitioning.

e) Drymatter and its Partitioning

In SORGF potential photosynthate is calculated from intercepted PAR. Net photosynthate is computed after accounting for the water and temperature stress as well as for respiration. At ICRISAT Center we do not have facilities to study the photosynthesis and respiration in detail. So it was felt that it would be desirable to develop a relationship between total drymatter (TDM) and intercepted PAR. Our data indicate that 3 gm of drymatter is produced per MJ of PAR absorbed when water and temperature stress do not occur. From the daily potential drymatter, actual drymatter increase is estimated as a function of temperature and water stress using the TEMPCO and WATSCO coefficients. This has been included in the revised version of the model.

The average harvest index was found to be 0.50 for the hybrids like CSH-1, CSH-6 and CSH-8; and 0.36 for varieties like M-35-1 and SPV-351 under no moisture stress conditions. However, these values were lower depending on the degree of moisture stress. In the revised version the harvest index used was 0.40 for hybrids and 0.26 for varieties under moisture stress conditions. Assumptions are made that HI per day holds a linear relationship from anthesis to PM. Further examination of the data is required to come up with a more satisfactory partitioning coefficients.

4. Summary of Simulation Results

The revised SORGF version is referred to as SORGF-2. The following comparision of SORGF and SORGF-2 results are made with the observed data.

a. Phenological events.
b. Leaf area index as a function of time.
c. Drymatter and its partitioning to grain yield.
d. Statistical analysis.

a) Phenological Events

Observed and simulation results for the days required from emergence to anthesis and PM for different genotypes, locations, seasons and treatments are compared in tables 4 and 5. Observed data indicate that rainy season hybrids like CSH-1 and CSH-6 took about 52-56 DAE to reach anthesis and 85-88 DAE to reach PM, while SPV-351 took about 62-63 DAE to reach anthesis and about 90-95 DAE to reach maturity. In early October plantings during the postrainy season CSH-8 matured a little earlier than M-35-1. It took about 60-66 DAE to reach anthesis and 98-106 DAE to reach PM. M-35-1 reached anthesis by 67-71 DAE and PM by 105-113 DAE. When plantings were delayed till late November on deep Vertisols days to anthesis and PM were extended for CSH-8. M-35-1 also took longer to reach anthesis (80 DAE) and PM (115 DAE).

Simulation results indicated that SORGF underestimated the maturity duration while the estimation by the revised version was reasonably close to the observed data.

b) Leaf Area Index as a Function of Time

Data on leaf area index were collected at 7-10 days interval in all the treatments for every experiment conducted at ICRISAT Center. Simulation results are compared with the observed data, and the maximum LAI and final LAI at PM for all these experiments are given in table 6. Seasonal changes in LAI for selected experiments are shown in Figures 1 to 4.

Results indicate that both SORGF and SORGF-2 overestimate the maximum LAI. Suggestions are made in the preceding section regarding future revisions in computing LAI in the early growth stages. Modifications made so far in this regard account for leaf senescence after the expansion of the 7th leaf (instead of after the 11th leaf as is done in SORGF) and include the effect of moisture stress in the grain filling period. The revised version of SORGF improved the computation of LAI in the grain filling period. However, further improvements are envisaged in the overall leaf area development computation.

c) Drymatter and its Partitioning to Grain Yields

Total drymatter (kg/ha) and grain yields (kg/ha) for all experiments conducted at ICRISAT Center are compared with simulation results (table 7), and seasonal patterns in observed and simulated drymatter and grain yield for selected genotypes are shown in Figures 5 to 8.

Observed and simulated drymatter and grain yield pooled over all the treatments are shown in Figures 9 and 10 to examine the degree of correspondence between observed and simulated results. Results indicate that some improvements in simulating TDM and grain yields were achieved through revisions and considerable scope exists for further improvement.

Table 4. Observed and Simulated Phenological Events at ICRISAT Center.

Location	Season	Genotype/ Treatment	Days from emergence to Anthesis			Days from emergence to PM		
			O	S_1	S_2	O	S_1	S_2
RP-4	1979 Rainy	CSH-1	56	54	53	87	76	83
		CSH-6	55	54	53	85	76	83
BW3-A	1979 Rainy	CSH-6	52	62	53	81	76	82
		SPV-351	63	54	57	89	76	88
RP-4	1979-80 Post-rainy	CSH-8 A	60	69	72	98	97	103
		CSH-8 B	62	69	72	97	97	103
		M-35-1 A	67	69	76	105	97	109
		M-35-1 B	69	69	76	105	97	109
RP-4	1980 Rainy	CSH-1 A	52	51	54	88	76	85
		CSH-1 B*	52	51	54	88	76	85
		CSH-6 A	53	51	54	86	76	85
		CSH-6 B*	53	51	54	86	76	85
BW3-A	1980 Rainy	CSH-1	54	51	57	87	80	87
		CSH-6	54	51	57	84	79	87
		SPV-351	62	52	61	94	73	94
RP-4	1980-81 Post-rainy	CSH-8 A	66	56	66	106	80	108
		CSH-8 B	64	56	66	102	80	108
		M-35-1 A	71	64	72	113	87	116
		M-35-1 B	70	64	72	111	87	116
BW3-A	1980-81 Post-rainy	CSH-8 A	73	74	74	110	104	104
		CSH-8 B	73	74	74	107	104	104
		M-35-1 A	80	75	78	115	106	110
		M-35-1 B	80	75	78	111	106	110

O = Observed
S_1 = SORGF
S_2 = SORGF-2
A = Adequate moisture supply
B = Limited moisture supply
PM = Physiological maturity
* = Rainfed

Table 5. Observed and simulated phenological events for cooperating centers

Location	Season	Genotype	Days from emergence to Anthesis			Physiological Maturity		
			O	S_1	S_2	O	S_1	S_2
Parbhani	1979-80 Postrainy season	CSH-8	56	54	60	96	76	101
		M-351	66	54	64	106	76	106
Pune	" "	CSH-8	61	75	79	111	105	112
		M-351	69	75	82	114	105	117
Delhi	1980 Rainy season	CSH-1	58	49	62	99	69	95
		CSH-6	56	49	62	95	69	95
Parbhani	" "	CSH-1	58	53	53	88	75	84
		CSH-1	54	53	53	86	75	84
Khonkaen	" "	Hegari	52	38	52	92	54	80
Parbhani	1980-81 Postrainy season	CSH-8	59	56	69	111	79	115
Coimbatore	" "	CSH-8	58	55	61	96	76	93
Rahuri	" "	CSH-8	59	56	68	91	79	115
		M-351	63	61	73	96	86	121

O = Observed

S_1 = SORGF

S_2 = SORGF-2

PM = Physiological Maturity

Table 6. Observed and Simulated Maximum and Final Leaf Area Index

Location	Season	Genotype/ Treatment	Maximum LAI			Final LAI		
			O	S_1	S_2	O	S_1	S_2
RP-4	1979 rainy	CSH-1	2.86	2.98	2.86	2.05	2.98	1.08
		CSH-6	2.70	3.29	2.86	1.93	3.29	1.11
BW3-A	1979 rainy	CSH-6	3.47	3.38	3.07	1.40	3.37	1.58
		SPV-351	3.46	3.38	3.04	1.83	3.34	1.55
RP-4	1979-80 post-rainy	CSH-8A	2.74	3.64	3.14	1.10	3.59	0.95
		CSH-8B	2.25	3.18	2.74	0.42	3.14	0.25
		M-35-1A	3.04	3.74	3.20	0.92	3.69	0.76
		M-35-1B	2.29	3.74	3.20	0.27	3.69	0.23
RP-4	1980 rainy	CSH-1A	2.93	3.88	3.13	1.23	3.81	1.61
		CSH-1B*	3.06	4.40	3.57	1.77	4.32	1.82
		CSH-6A	3.54	4.53	3.94	0.96	4.53	2.01
		CSH-6B*	3.52	4.53	3.94	1.57	4.53	2.01
BW3A	1980 rainy	CSH-1	2.83	3.93	3.12	1.07	3.87	1.60
		CSH-6	2.76	3.63	3.12	1.52	3.59	1.60
		SPV-351	3.50	3.64	3.30	1.10	3.64	1.69
RP-4	1980-81 post-rainy	CSH-8A	2.96	4.98	4.48	1.92	4.97	1.45
		CSH-8B	2.58	3.81	3.36	0.46	3.80	0.23
		M-35-1A	2.86	3.95	3.53	0.84	3.92	1.03
		M-35-1B	2.02	2.80	2.50	0.45	2.78	0.17
BW3A	1980-81 post-rainy	CSH-8A	3.88	4.12	3.63	1.98	4.12	1.68
		CSH-8B	3.16	4.12	3.63	0.79	4.12	0.33
		M-35-1A	3.71	4.04	3.44	2.77	4.04	1.46
		M-35-1B	2.35	3.50	2.98	0.61	3.47	0.28

O = Observed
S_1 = SORGF
S_2 = SORGF-2
A = Adequate moisture supply
B = Limited moisture supply
* = Rainfed

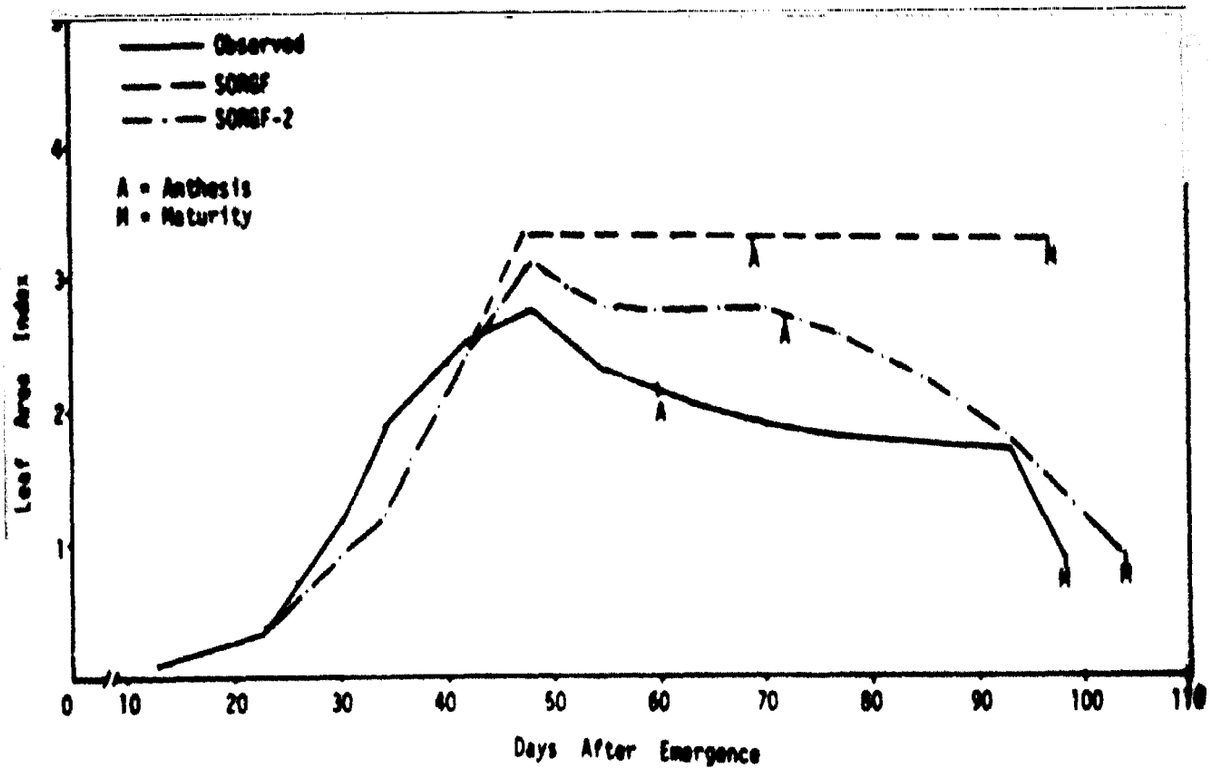

Figure 1. Observed and simulated leaf area index for sorghum hybrid CSH-6 grown under adequate water supply (Trt.A) during the 1979-80 post-rainy season on Alfisol at ICRISAT Center.

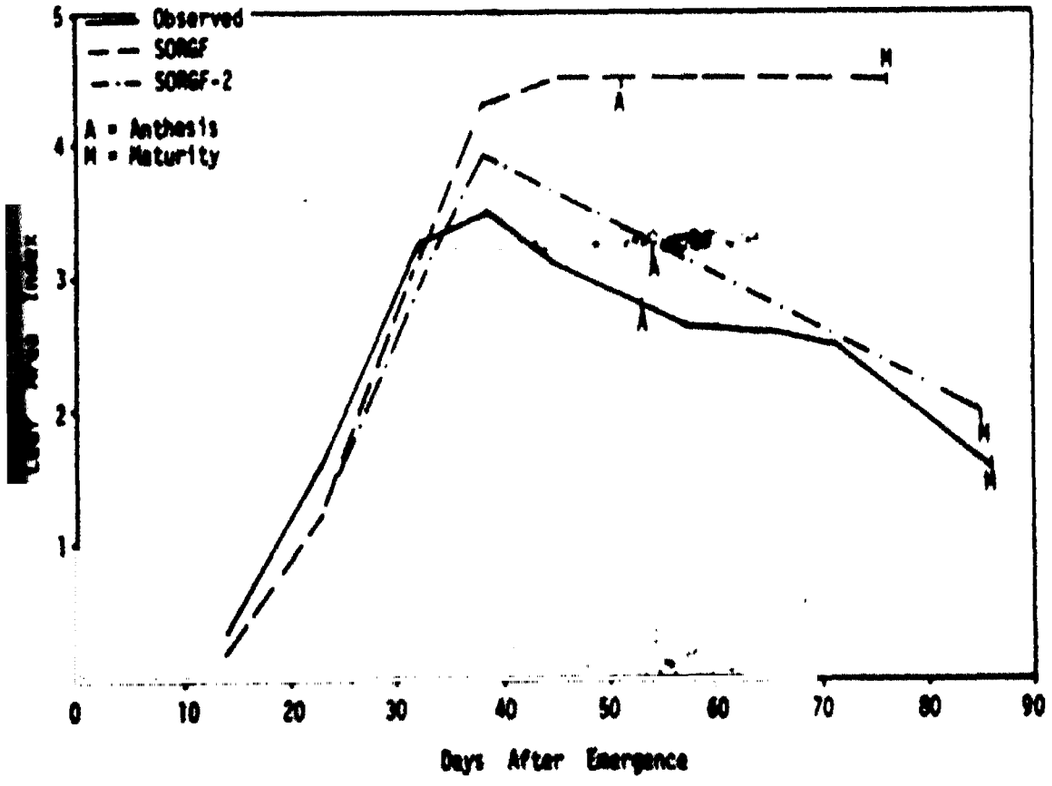

Figure 2. Observed and simulated leaf area index for sorghum hybrid CSH-6 grown under rainfed situation (Trt.B) during the 1980 rainy season on Alfisol at ICRISAT Center.

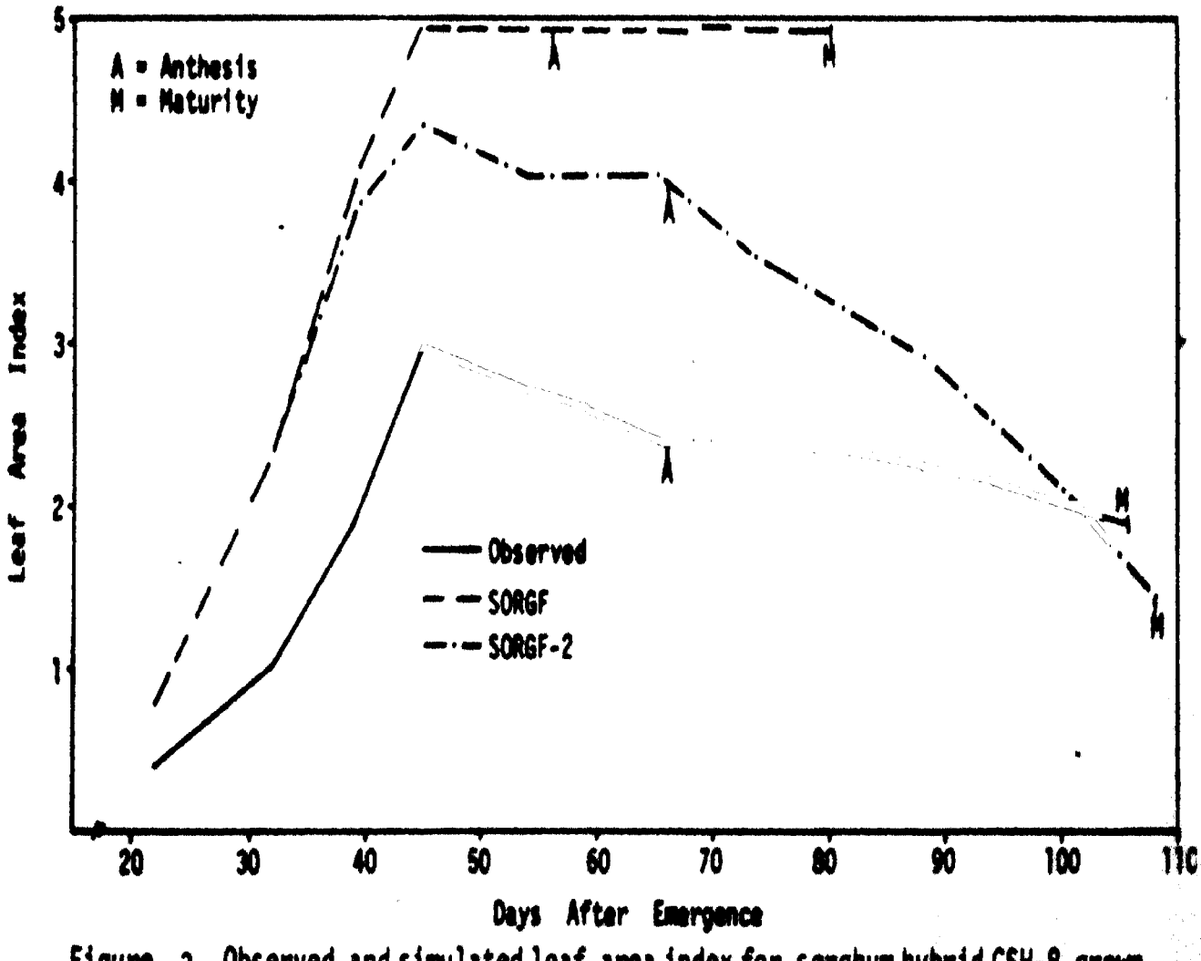

Figure 3. Observed and simulated leaf area index for sorghum hybrid CSH-8 grown under adequate water supply (Trt.A) during the 1980-81 postrainy season on an Alfisol at ICRISAT Center.

Table 7. Observed and simulated total dry matter (kg/ha) and grain yield (kg/ha)

Location	Season	Genotype/ Treatment	Total dry matter			Grain yield		
			0	S_1	S_2	0	S_1	S_2
RP-4	1979 Rainy season	CSH-1	9490	9145	7415	3490	4133	3497
		CSH-6	10440	9631	7630	4100	4333	3599
BW3-A	1979 Rainy season	CSH-6	11730	10892	10013	4190	5148	5007
		SPV-351	11660	10916	10665	4220	5135	3839
RP4	1979-80 post-rainy season	CSH-8 A	7650	11958	9378	3830	6086	4220
		CSH-8 B	4700	9257	5191	2080	3807	2093
		M-351 A	8330	12212	9226	2100	6128	2734
		M-351 B	4950	10130	5108	1300	4125	1328
RP4	1980 Rainy season	CSH-1 A	11300	9829	8784	5540	4365	4392
		CSH-1 B*	10585	9662	8595	5110	4483	4297
		CSH-6 A	11937	10374	9403	5640	4665	4701
		CSH-6 B*	12510	9726	8842	5880	4616	4421
BW3-A	1980 Rainy season	CSH-1	10430	11019	9891	4545	5244	4945
		CSH-6	11290	10471	9768	5310	4983	4884
		SPV-351	12348	9440	11928	4260	4393	4294
RP-4	1980-81 post-rainy season	CSH-6 A	9259	5800	8730	4693	2389	4063
		CSH-6 B	5008	5454	5067	2276	2268	2027
		CSH-8 A	11149	9534	9497	6118	3772	4330
		CSH-8 B	6464	8508	4977	2495	3406	1991
		M-351 A	10234	9250	8568	3948	3988	2645
		M-351 B	6780	7678	4458	1691	3183	1159
BW3-A	1980-81 post-rainy season	CSH-6 A	11143	7746	12700	5345	4138	6350
		CSH-6 B	6590	7555	7146	2992	4026	2907
		CSH-8 A	12631	13944	13487	6136	7606	6564
		CSH-8 B	7452	12767	6365	3115	6452	2579
		M-351 A	12150	14548	14013	3801	7607	4738
		M-351 B	6767	12564	6573	2543	6065	1750

0 = Observed
S_1 = SORGF
S_2 = SORGF-2
A = Adequate moisture supply
B = Limited moisture supply
* = Rainfed

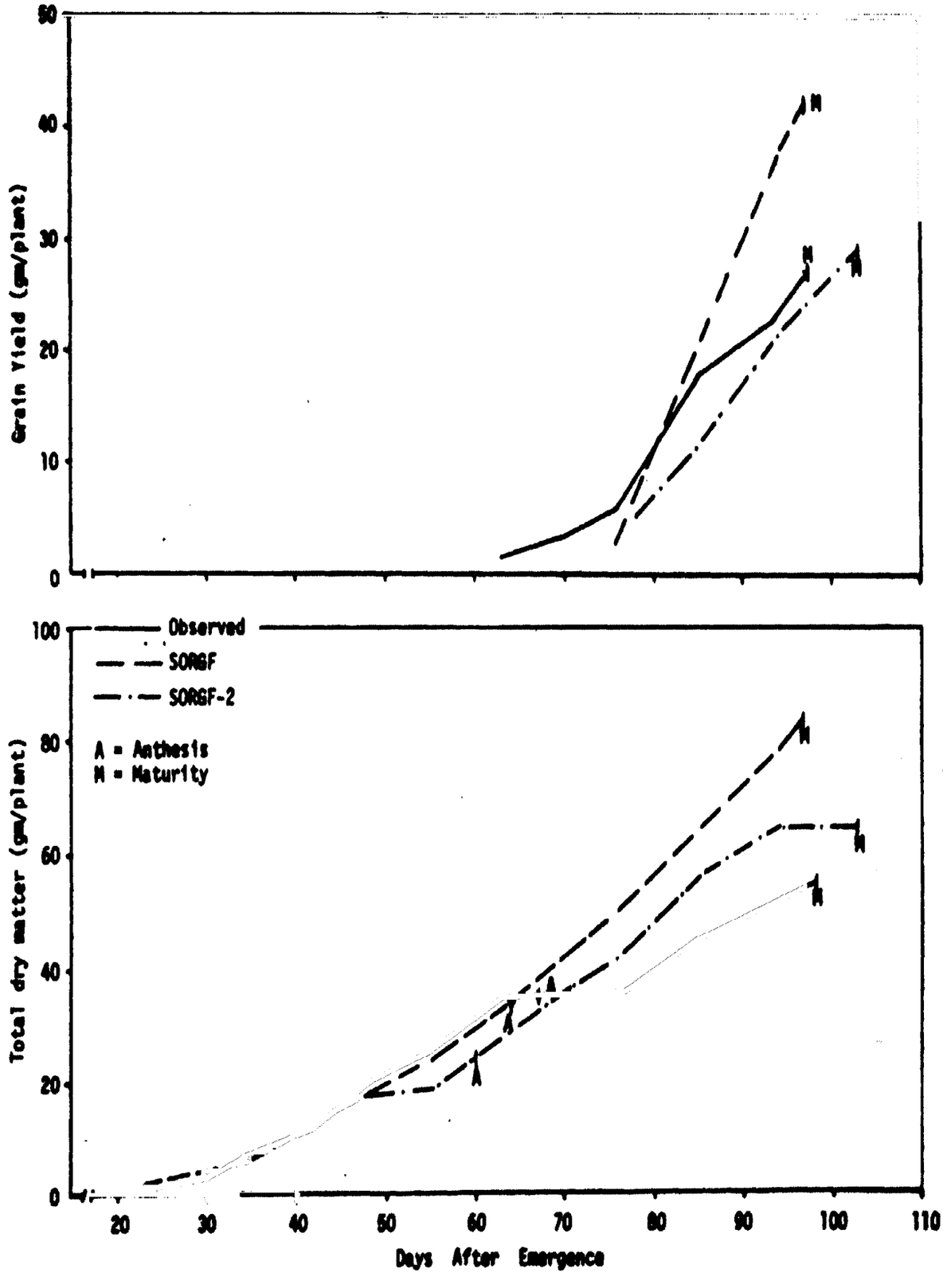

Figure 5. Observed and simulated total dry matter and grain yield for sorghum hybrid CSH-8 grown under adequate water supply during the 1979-80 postrainy season on an Alfisol at ICRISAT Center.

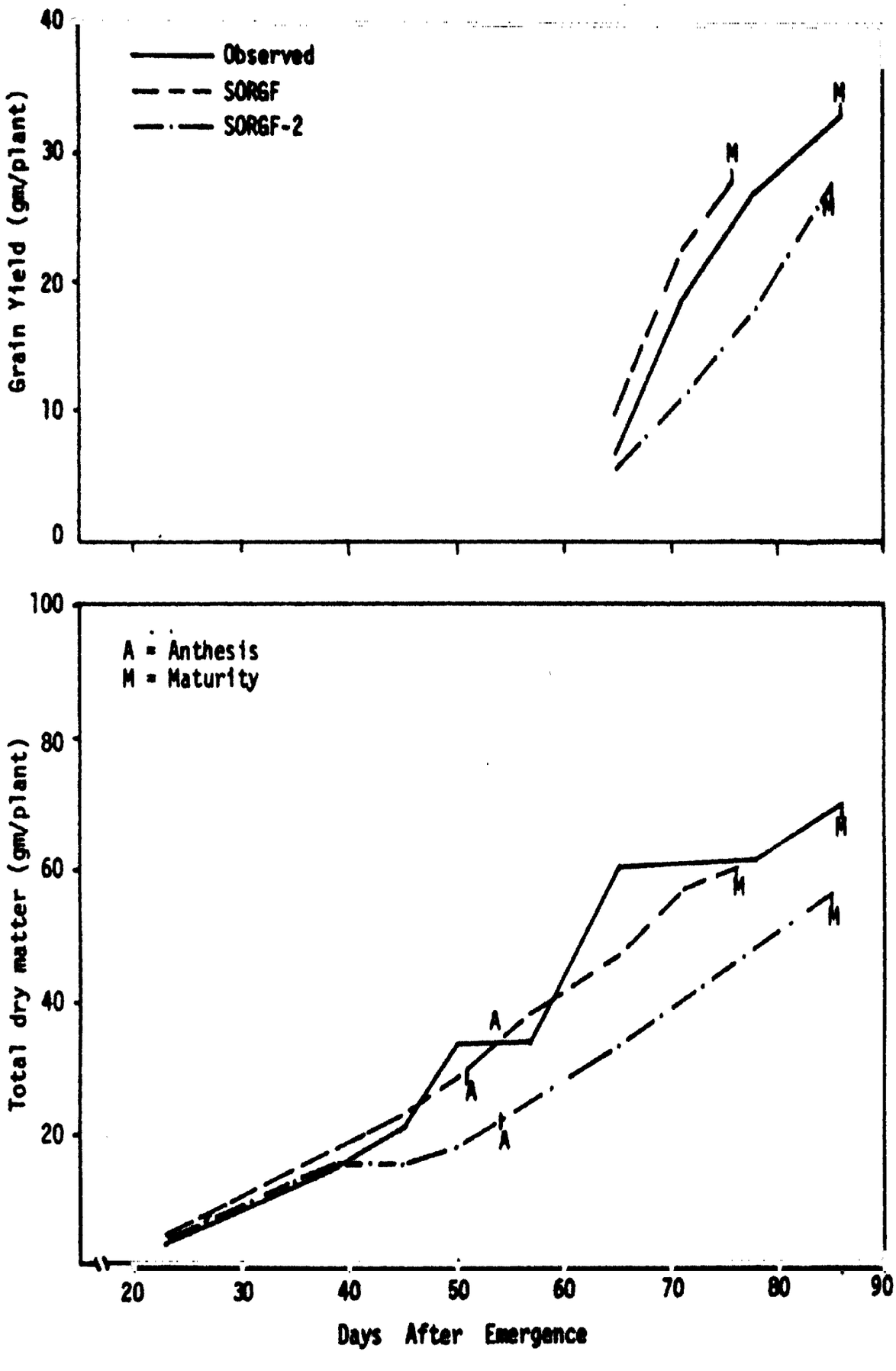

Figure 6. Observed and simulated total dry matter and grain yield for sorghum hybrid CSH-6 grown under rainfed situation (Trt.B) during the 1980 rainy season on an Alfisol at ICRISAT Center.

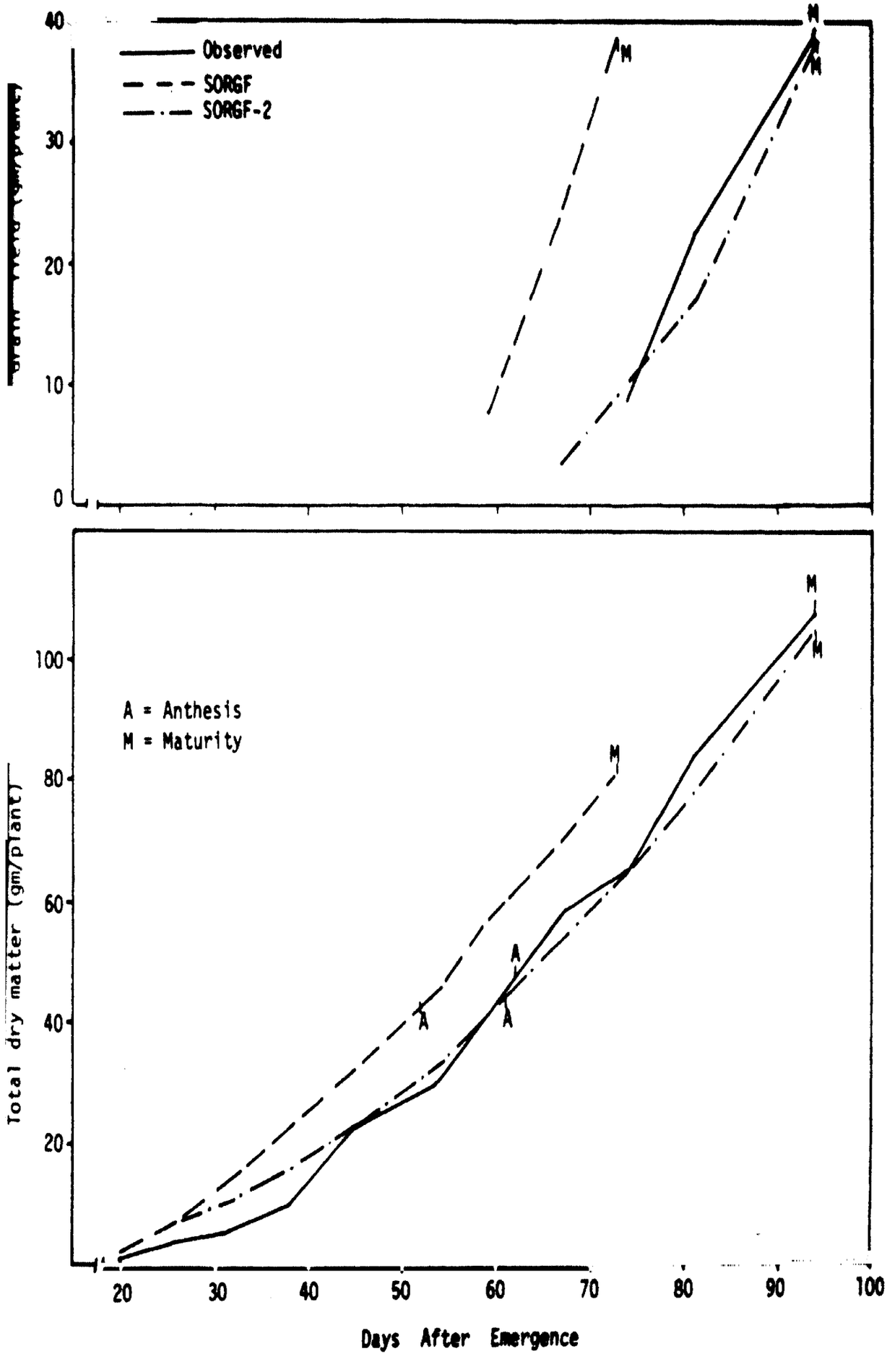

Figure 7. Observed and simulated total dry matter and grain yield for sorghum variety SPV-351 grown under rainfed situation on a deep Vertisol at ICRISAT Center.

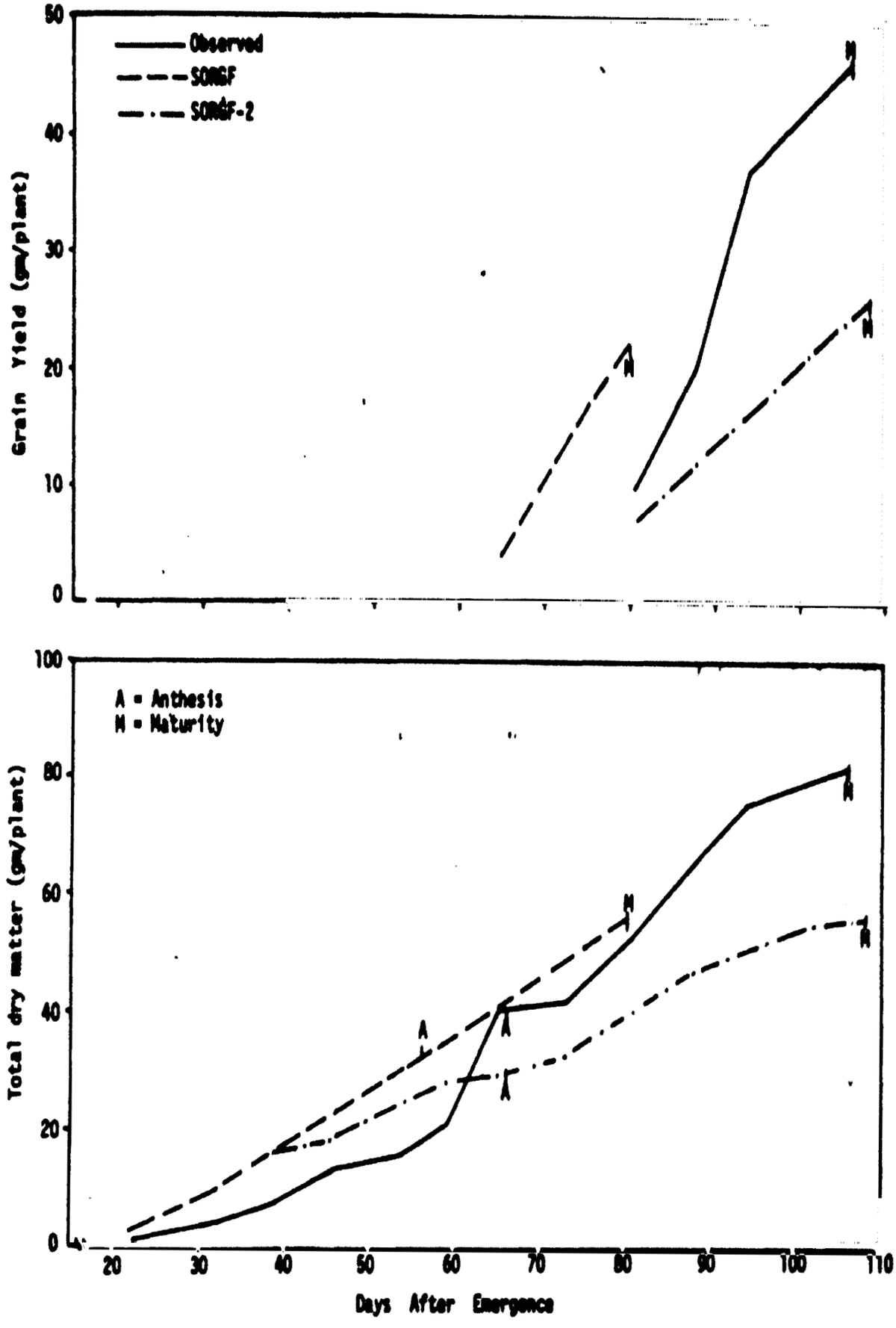

Figure 8. Observed and simulated total dry matter and grain yield for sorghum hybrid CSH-8 grown under adequate water supply (Trt.A) during the 1980-81 postrainy season on an Alfisol at ICRISAT Center.

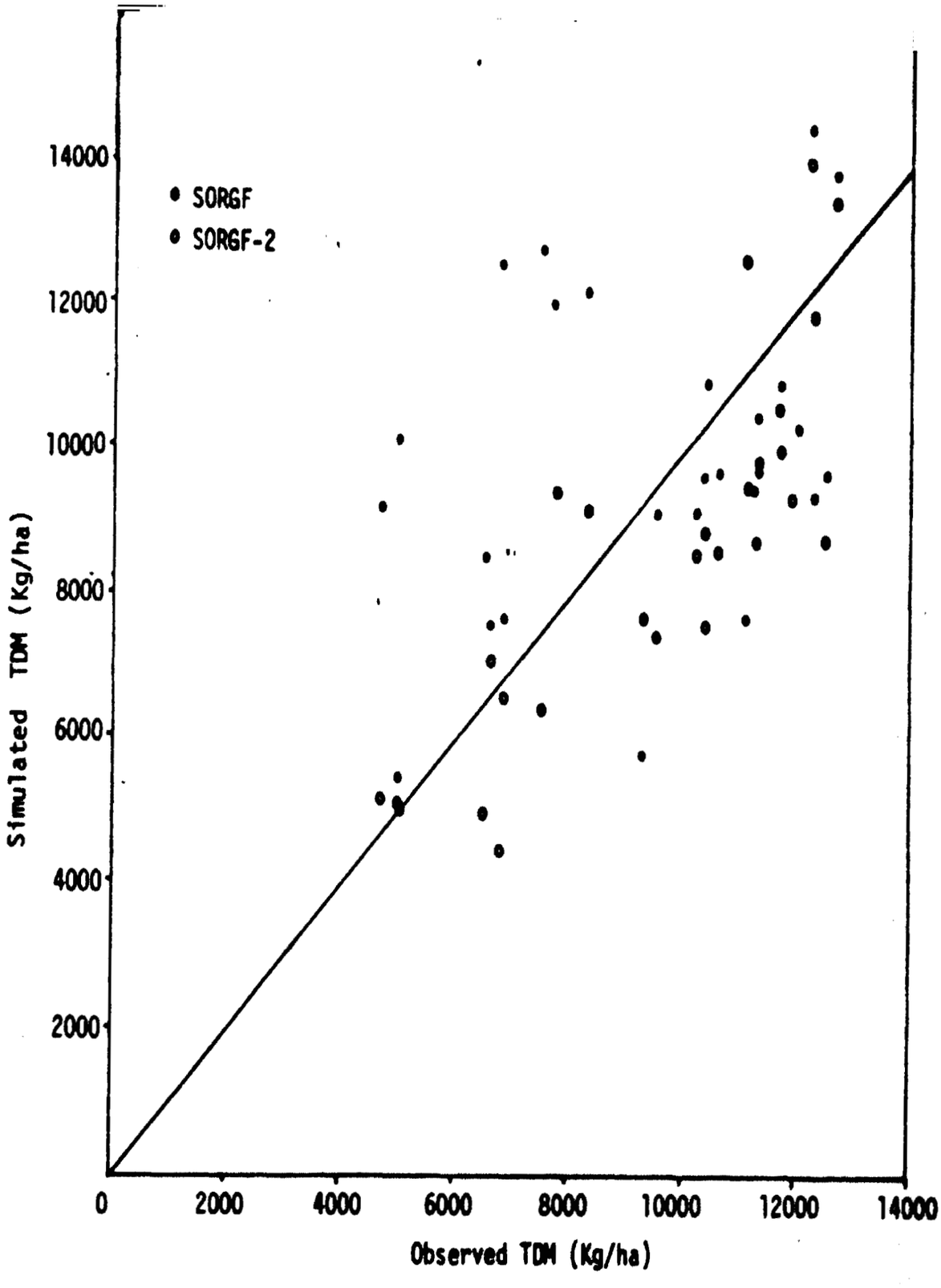

Figure 9. Correspondence between observed and simulated total dry matter (data pooled over all experiments).

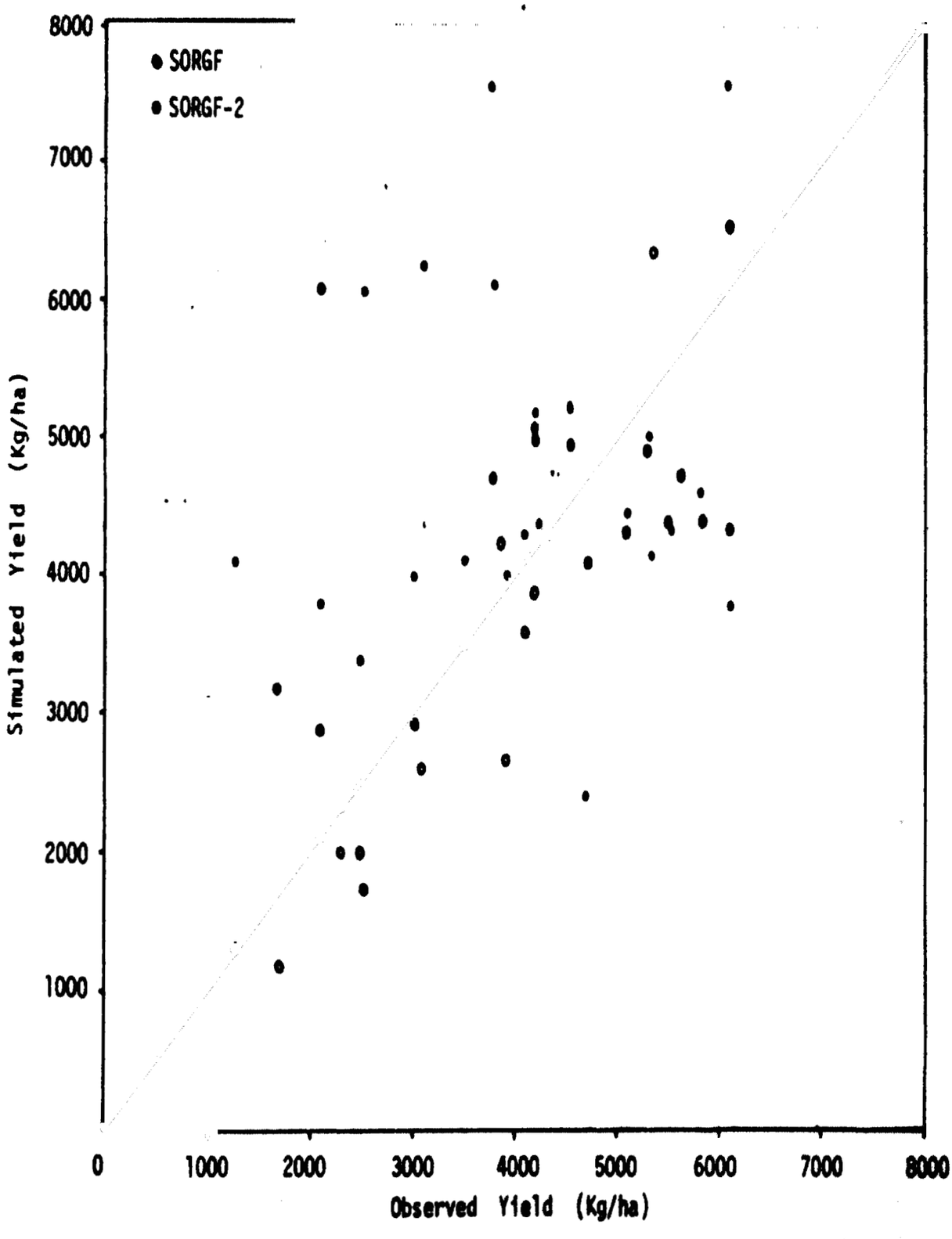

Figure 10. Correspondence between observed and simulated grain yield (data pooled over all experiments).

e) Statistical Analysis of Simulation Results

Selected crop data pooled over 27 data sets were used to compare the performance of SORGF and SORGF-2 models (table 8). The observed TDM (kg/ha) ranged from 4950 for the genotype M-35-1 grown under moisture stress to 12510 for CSH-6 grown in rainy season. Grain yields (kg/ha) ranged from 1300 for M-35-1 under moisture stress to 6136 for CSH-8 under adequate moisture supply treatment in the postrainy season. Simulation results show that SORGF model overestimated particularly the grain yields at both the highest and lowest ends. SORGF-2 improved the simulation.

Table 8. Statistical analysis of simulation results (n = 27)

(a) Highest, mean and lowest response of observed and simulated data

Crop data	Observed			SORGF			SORGF-2		
	Highest	Mean	Lowest	Highest	Mean	Lowest	Highest	Mean	Lowest
Total drymatter (kg/ha)	12510	9444	4950	14548	10000	5454	14013	8645	4458
Grain yield (kg/ha)	6136	3954	1300	7607	4687	3183	6564	3680	1159
Physiological maturity (DAE)	115	97	81	106	85	76	116	98	83
Maximum LAI	3.88	2.89	1.73	4.98	3.68	2.28	4.48	3.2	2.14
Final LAI	2.77	1.24	0.27	4.97	3.65	2.28	2.01	1.12	0.13

(b) Correlation coefficient

	SORGF	SORGF-2
Total drymatter	0.32	0.83
Grain yield	0.17	0.87

(c) Root mean square error (RMSE)

Total drymatter (kg/ha)	2779	1619
Grain yield (kg/ha)	1886	766
Physiological maturity (DAE)	13	3

It can be noted that the data represent genotypes with a range of maturity duration from 81-115 DAE. SORGF underestimated maturity duration while SORGF-2 estimated closely for the entire range of duration. No major change has yet been made in computing maximum LAI which is evident from the overestimation of the data by both models. The effect of moisture stress factors on leaf expansion and senescence should be further examined and incorporated in the model in computing the daily LAI. The observed final LAI data range between 0.27 to 2.77 while SORGF model overestimated final LAI, SORGF-2 improved the estimates.

Correlation coefficient between observed and simulated results (table 8) show that revisions in the model resulted in improved estimates of TDM and grain yield. SORGF could explain only 4 percent variation associated with grain yields in the present data set while SORGF-2 could explain 76 percent variation.

Error analysis of the simulation results indicates that RMSE for TDM, grain yields and PM was reduced due to revisions in the model (table 8).

Conclusions and Future Plans of Work

Revisions in the model did show some improvement in simulation results. Systematic examination of the data is underway not only to improve the predictive nature of the model but also to investigate reasons why in certain individual cases the model performance was poor. At the end of the 1981 rainy season there will be multilocation data sets from five seasons representing various genotypes grown under different treatments. Critical examination of half of the data sets will be undertaken to revise the model and the other half would be used to validate the revised model.

Collaborative work with the soil fertility group is underway to develop a nutrient subroutine for inclusion in the model. It is difficult to develop pest and disease subroutines. However, in the 1981 rainy season an experiment is taken up in the unsprayed plots at ICRISAT Center with five genotypes (CSH-1, CSH-5, CSH-6, CSH-8 and SPV-351) with 40 kg N/ha to evaluate the model performance under medium fertility and no pest and disease control conditions.

Experiments on three pearl millet genotypes (BJ-104, WC-C75 and ICMS-7703) have been taken up from 1981 rainy season to collect standard data sets to develop a dynamic simulation model for pearl millet.

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APPENDIX

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: ICRISAT **Season: 1979-80 postrainy**

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	01 Nov-10 Nov	62.0	29.5	19.6	24.5	406	4.7
2	11 Nov-20 Nov	10.0	27.8	19.8	23.8	360	3.9
3	21 Nov-30 Nov	8.1	29.0	18.8	23.9	362	3.7
4	01 Dec-10 Dec	0.0	27.8	15.3	21.5	442	4.3
5	11 Dec-20 Dec	0.0	28.1	16.2	22.1	348	4.4
6	21 Dec-30 Dec	0.0	27.4	13.5	20.4	416	4.7
7	31 Dec-09 Jan	0.0	28.4	16.0	22.2	402	4.6
8	10 Jan-19 Jan	0.0	28.2	13.8	21.0	451	5.7
9	20 Jan-29 Jan	0.0	30.0	15.2	22.6	439	5.6
10	30 Jan-08 Feb	0.0	30.4	16.7	23.5	468	6.5
11	09 Feb-18 Feb	0.0	31.8	17.8	24.8	475	7.1
12	19 Feb-28 Feb	0.0	34.1	18.3	26.2	489	7.6
13	29 Feb-09 Mar	4.0	35.4	18.6	27.0	515	8.7
14	10 Mar-19 Mar	8.6	33.8	19.6	26.7	533	8.8
15	20 Mar-29 Mar	0.0	37.0	21.3	29.1	513	10.8
	Seasonal total:	92.7					911.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: ICRISAT Season: 1980 rainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	01 Jun-10 Jun	29.8	34.7	23.9	29.3	428	8.5
2	11 Jun-20 Jun	106.2	32.4	23.5	27.9	433	6.4
3	21 Jun-30 Jun	4.9	33.6	24.1	28.9	381	10.6
4	01 Jul-10 Jul	33.1	30.9	22.9	26.9	381	7.0
5	11 Jul-20 Jul	12.8	31.9	23.4	27.7	372	7.1
6	21 Jul-30 Jul	80.9	28.4	22.1	25.3	291	3.7
7	31 Jul-09 Aug	62.2	27.7	21.9	24.8	329	4.0
8	10 Aug-19 Aug	148.8	29.8	22.3	26.0	378	3.9
9	20 Aug-29 Aug	95.1	28.1	21.6	24.8	377	3.6
10	30 Aug-08 Sep	91.5	28.3	21.6	25.0	359	4.1
11	09 Sep-18 Sep	38.9	29.8	21.5	25.6	444	4.9
12	19 Sep-28 Sep	22.8	31.0	22.1	26.5	470	4.4
13	29 Sep-08 Oct	0.0	32.6	19.5	26.0	544	6.0
	Seasonal total:	727.0					742.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: ICRISAT **Season:** 1980-81 postrainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	09 Oct-18 Oct	6.3	32.7	18.6	25.6	488	6.8
2	19 Oct-28 Oct	0.0	30.8	18.5	24.7	468	5.1
3	01 Nov-10 Nov	0.0	30.8	14.4	22.6	496	6.6
4	11 Nov-20 Nov	0.3	29.1	20.2	24.6	340	4.4
5	21 Nov-30 Nov	0.0	29.5	14.7	22.1	458	5.7
6	01 Dec-10 Dec	0.0	28.2	13.5	20.9	430	5.7
7	11 Dec-20 Dec	0.0	29.4	10.9	20.1	479	5.8
8	21 Dec-30 Dec	2.0	27.5	16.9	22.2	354	4.7
9	31 Dec-09 Jan	0.0	28.2	12.8	20.5	440	5.2
10	10 Jan-19 Jan	15.6	24.1	14.5	19.3	340	4.4
11	20 Jan-29 Jan	0.0	28.2	14.9	21.6	464	5.2
12	30 Jan-08 Feb	0.0	30.7	14.6	22.7	511	6.9
13	09 Feb-18 Feb	0.0	32.6	14.8	23.7	531	8.1
14	19 Feb-28 Feb	0.0	33.8	18.1	25.9	531	8.8
15	01 Mar-10 Mar	0.0	34.8	17.7	26.3	574	10.6
16	11 Mar-20 Mar	39.2	32.7	20.1	26.4	519	9.0
17	21 Mar-30 Mar	37.6	33.3	21.0	27.2	553	8.2
	Seasonal total:	101.0					1112.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Coimbatore **Season:** 1980-81 Postrainy

Period	Dates	Rain (mm)	Temperature °C			Solar radiation (ly)	Evaporation (mm)
			Max.	Min.	Mean		
1	09 Nov-18 Nov	125.9	28.6	20.9	24.8	328	3.6
2	19 Nov-28 Nov	3.7	28.8	19.8	24.3	397	3.4
3	29 Nov-08 Dec	6.4	29.4	19.2	24.3	406	4.1
4	09 Dec-18 Dec	0.0*	30.3	19.4	24.8	372	4.5
5	19 Dec-28 Dec	1.2*	29.1	18.7	23.9	330	3.7
6	29 Dec-07 Jan	0.0	30.2	18.4	24.3	405	4.7
7	08 Jan-17 Jan	0.2*	30.1	18.1	24.1	406	4.8
8	18 Jan-27 Jan	0.0*	30.0	19.1	24.5	374	4.4
9	28 Jan-06 Feb	0.0	31.4	15.9	23.7	452	5.6
10	07 Feb-16 Feb	0.0*	32.5	19.7	26.1	445	5.9
11	17 Feb-26 Feb	0.0	32.3	15.3	23.8	514	7.0
	Seasonal total:	137.4					517.0

*Irrigation

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Delhi Season: 1980 rainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	28 Jun-07 Jul	147.6	35.6	26.3	31.0	445	4.5
2	08 Jul-17 Jul	118.1	31.4	25.6	28.5	343	3.0
3	18 Jul-27 Jul	200.8	33.3	26.3	29.8	450	4.3
4	28 Jul-06 Aug	115.3	31.7	26.1	28.9	284	3.5
5	07 Aug-16 Aug	58.1	34.0	25.3	29.6	442	4.3
6	17 Aug-26 Aug	0.4	36.2	25.8	31.0	463	5.7
7	27 Aug-05 Sep	24.6[1]	35.4	25.8	30.6	422	5.8
8	06 Sep-15 Sep	37.6	33.7	24.9	29.3	440	5.0
9	16 Sep-25 Sep	0.0[1]	35.0	23.2	29.1	421	6.0
10	26 Sep-05 Oct	0.0	36.3	20.3	28.3	470	7.0
11	06 Oct-15 Oct	4.0	33.4	20.0	26.7	386	5.5
	Seasonal total:	706.5					546.0

[1]Irrigation

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Hissar Season: 1980 rainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	20 Jun-29 Jun	8.0	38.3	28.2	33.2	508	11.0
2	30 Jun-09 Jul	21.0*	37.4	27.4	32.4	518	8.5
3	10 Jul-19 Jul	25.6	34.6	26.8	30.7	419	5.9
4	20 Jul-29 Jul	58.1*	35.2	26.4	30.8	424	5.3
5	30 Jul-08 Aug	40.7	33.8	26.7	30.3	405	4.4
6	09 Aug-18 Aug	38.9*	36.1	26.0	31.1	544	6.5
7	19 Aug-28 Aug	0.0	37.4	25.7	31.6	562	6.7
8	29 Aug-07 Sep	0.0	36.0	24.6	30.3	512	6.9
9	08 Sep-17 Sep	0.0	35.7	23.6	29.7	485	6.2
10	18 Sep-27 Sep	0.0	36.8	21.3	29.0	497	5.9
11	28 Sep-07 Oct	0.0	37.8	18.2	28.0	465	7.5
	Seasonal total:	192.3					748.0

* = Irrigation

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Khon Kaen **Season:** 1980 rainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	13 Aug-22 Aug	29.5	32.2	24.4	28.3	416	4.1
2	23 Aug-01 Sep	49.5	31.2	24.0	27.6	371	3.6
3	02 Sep-11 Sep	132.7	30.4	23.7	27.0	355	3.2
4	12 Sep-21 Sep	136.5	30.5	23.5	27.0	297	2.4
5	22 Sep-01 Oct	34.3	31.3	23.5	27.4	456	3.7
6	02 Oct-11 Oct	29.5	31.6	23.9	27.7	442	3.7
7	12 Oct-21 Oct	3.1	32.4	24.1	28.2	414	4.8
8	22 Oct-31 Oct	39.5	29.2	21.7	25.5	296	3.1
9	01 Nov-10 Nov	0.0	30.9	21.3	26.1	335	4.0
10	11 Nov-20 Nov	0.0	30.5	20.6	25.6	358	5.1
	Seasonal total:	454.6					377.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Ludhiana **Season:** 1980 Rainy

iod	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	01 Jul-10 Jul	37.5	36.8	26.4	31.6		7.3
2	11 Jul-20 Jul	404.0	33.0	25.7	29.4		4.0
3	21 Jul-30 Jul	111.3	32.8	25.4	29.1		4.1
4	31 Jul-09 Aug	67.8	32.1	25.4	28.8		3.8
5	10 Aug-19 Aug	56.8	33.4	23.2	28.3		4.1
6	20 Aug-29 Aug	8.0	35.3	25.0	30.2		4.8
7	30 Aug-08 Sep	19.6	33.7	23.1	28.4		4.4
8	09 Sep-18 Sep	13.8	34.5	22.8	28.7		4.5
9	19 Sep-28 Sep	0.0	35.0	20.8	27.9		4.5
10	29 Sep-08 Oct	0.0	35.4	19.4	27.4		4.6
11	09 Oct-18 Oct	25.8	31.6	19.1	25.4		3.5
12	19 Oct-28 Oct	0.0	31.9	15.2	23.6		3.1
	Seasonal total:	744.6					527.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Parbhani Season: 1979-80 Postrainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	09 Oct-18 Oct	0.0	34.9	20.6	27.7	463	7.1
2	19 Oct-28 Oct	0.0	33.6	19.6	26.6	426	7.7
3	29 Oct-07 Nov	2.6	31.9	19.3	25.6	330	6.3
4	08 Nov-17 Nov	6.8	31.0	17.8	24.4	363	6.1
5	18 Nov-27 Nov	2.8	31.5	19.6	25.5	327	5.7
6	28 Nov-07 Dec	0.2	29.8	14.4	22.1	409	5.7
7	08 Dec-17 Dec	11.4	29.3	17.2	20.7	409	5.7
8	18 Dec-27 Dec	1.4	29.1	13.5	21.3	406	6.5
9	28 Dec-06 Jan	0.0	30.0	13.4	21.7	404	5.0
10	07 Jan-16 Jan	0.0	30.0	13.1	27.0	410	4.4
11	17 Jan-26 Jan	0.0	31.6	12.9	22.3	437	5.3
12	27 Jan-05 Feb	0.0	31.1	14.1	22.6	429	5.8
13	06 Feb-15 Feb	0.0	32.7	17.1	24.9	445	7.0
	Seasonal total:	25.2					784.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Parbhani **Season:** 1980 rainy

Period	Dates	Rain (mm)	Temperature °C			Solar radiation (ly)	Evaporation (mm)
			Max.	Min.	Mean		
1	23 Jun-02 Jul	153.0	33.1	24.1	28.6	317	7.1
2	03 Jul-12 Jul	23.2	31.8	23.7	27.8	363	6.3
3	13 Jul-22 Jul	9.4	33.6	23.6	28.6	343	6.5
4	23 Jul-01 Aug	72.4	29.3	22.5	25.9	263	5.2
5	02 Aug-11 Aug	82.2	28.8	22.6	25.7	261	3.9
6	12 Aug-21 Aug	131.2	30.7	23.1	26.9	326	4.3
7	22 Aug-31 Aug	40.8	29.8	21.6	25.6	354	4.4
8	01 Sep-10 Sep	88.2	30.4	22.0	25.7	385	7.0
9	11 Sep-20 Sep	12.8	33.2	23.0	28.6	460	6.1
10	21 Sep-30 Sep	1.0	34.7	23.0	28.8	444	5.7
	Seasonal total:	614.2					565.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Parbhani Season: 1980-81 postrainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	20 Oct-29 Oct	0.0*	34.6	18.3	26.4	471	9.1
2	30 Oct-08 Nov	0.0	33.6	16.7	25.1	442	6.9
3	09 Nov-18 Nov	0.0*	31.2	19.7	25.4	364	6.4
4	19 Nov-28 Nov	0.0	32.0	15.6	23.8	403	6.5
5	29 Nov-08 Dec	0.0	29.5	11.4	20.5	402	5.6
6	09 Dec-18 Dec	0.0	29.9	9.0	19.4	410	4.9
7	19 Dec-28 Dec	0.4	29.0	13.2	21.1	323	4.7
8	29 Dec-07 Jan	38.4	27.4	12.9	20.2	385	3.9
9	08 Jan-17 Jan	4.8	24.0	9.7	16.9	359	4.2
10	18 Jan-27 Jan	44.8	26.9	11.5	19.2	402	3.9
11	28 Jan-06 Feb	0.0	30.8	12.2	21.5	452	5.8
12	07 Feb-16 Feb	0.0	32.4	10.9	21.7	484	6.6
	Seasonal total:	88.4					685.0

*Irrigation

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Pune Season: 1979-80 postrainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	12 Dec-21 Dec	0.0*	28.9	12.4	20.7	392	3.4
2	22 Dec-31 Dec	0.0	28.7	11.4	20.1	405	3.8
3	01 Jan-10 Jan	0.0*	28.7	12.6	20.7	386	3.3
4	11 Jan-20 Jan	0.0	30.1	11.8	21.0	422	3.4
5	21 Jan-30 Jan	0.0*	29.9	10.0	20.0	465	4.2
6	31 Jan-09 Feb	0.0	29.9	10.8	20.3	479	4.7
7	10 Feb-11 Feb	0.0*	32.7	12.3	22.5	513	5.4
8	20 Feb-29 Feb	0.0	34.8	13.2	24.0	523	6.3
9	01 Mar-10 Mar	0.0*	33.7	12.6	23.1	568	8.0
10	11 Mar-20 Mar	1.2	34.4	14.9	24.7	552	7.7
11	21 Mar-30 Mar	0.7	36.7	16.9	26.8	567	8.9
	Seasonal total:	1.9					591.0

*Irrigation

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Pune Season: 1980 rainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.		Solar radiation (ly)	Evaporation (mm)
1	17 Jul-26 Jul	14.0	27.8	21.4	24.6	343	4.2
2	27 Jul-05 Aug	63.9[1]	26.5	21.1	23.8	294	2.7
3	06 Aug-15 Aug	22.5	27.5	18.8	23.1	383	3.4
4	16 Aug-25 Aug	47.6	27.4	21.2	24.3	367	2.9
5	26 Aug-04 Sep	16.6	26.4	21.0	23.7	338	3.3
6	05 Sep-14 Sep	0.0	28.6	18.6	23.6	457	4.5
7	15 Sep-24 Sep	33.4[1]	30.5	19.8	25.1	510	4.7
8	25 Sep-04 Oct	54.0	31.6	20.6	26.1	410	3.6
9	05 Oct-14 Oct	0.6	34.5	18.4	26.5	524	5.6
10	15 Oct-24 Oct	0.0	32.9	15.2	24.0	509	5.3
11	25 Oct-03 Nov	0.0	32.8	15.2	24.0	455	5.5
	Seasonal total:	252.6					457.0

[1]Irrigation

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Pune **Season: 1980-81 Postrainy**

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	14 Nov-23 Nov	27.5	28.8	19.2	24.0	259	3.0
2	24 Nov-03 Dec	0.0	29.1	10.9	20.0	430	3.6
3	04 Dec-13 Dec	0.0	28.5	9.8	19.2	403	2.8
4	14 Dec-23 Dec	2.8*	29.3	7.7	18.5	405	2.9
5	24 Dec-02 Jan	0.0	26.6	10.6	18.6	384	2.8
6	03 Jan-12 Jan	0.0	27.4	8.3	17.9	436	2.7
7	13 Jan-22 Jan	2.3	26.3	10.0	18.1	440	2.7
8	23 Jan-01 Feb	0.0	29.6	10.3	19.9	497	3.6
9	02 Feb-11 Feb	0.0	30.6	7.8	19.1	508	3.8
10	12 Feb-21 Feb	0.0*	32.0	10.3	21.1	519	4.3
11	22 Feb-03 Mar	0.0	34.3	13.2	23.8	524	4.4
12	04 Mar-13 Mar	0.0*	33.9	12.3	23.1	551	5.7
	Seasonal total:	32.6					423.0

* = Irrigation

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Rahuri **Season:** 1979-80 postrainy

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	18 Oct-27 Oct	5.4	31.4	19.4	25.4	418	
2	28 Oct-06 Nov	23.2	30.9	18.6	24.8	380	
3	07 Nov-16 Nov	30.3	29.4	17.4	23.4	417	
4	17 Nov-26 Nov	3.8	29.7	20.0	24.8	369	
5	27 Nov-06 Dec	71.4	26.6	16.7	21.7	351	
6	07 Dec-16 Dec	0.0	27.8	13.9	20.9	401	
7	17 Dec-26 Dec	0.0	28.6	13.7	21.2	390	
8	27 Dec-05 Jan	0.0	28.5	12.0	20.2	416	
9	06 Jan-15 Jan	0.0	28.9	14.2	21.5	627	
10	16 Jan-25 Jan	0.0	30.0	13.0	21.5	442	
11	26 Jan-04 Feb	0.0	29.2	11.3	20.3	470	
12	05 Feb-14 Feb	0.0	30.7	13.1	21.9	461	
13	15 Feb-24 Feb	0.0	33.2	14.1	23.7	502	
	Seasonal total	134.1					

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Rahuri **Season: 1980 rainy**

Period	Dates	Rain (mm)	Temperature °C Max.	Min.	Mean	Solar radiation (ly)	Evaporation (mm)
1	12 Jul-21 Jul	0.0	30.9	22.8	26.9	422	7.3
2	22 Jul-31 Jul	2.6	30.3	22.7	26.5	320	5.4
3	01 Aug-10 Aug	25.2	28.4	22.2	25.3	280	4.4
4	11 Aug-20 Aug	115.7	29.8	22.0	25.4	321	5.2
5	21 Aug-30 Aug	113.6	28.5	21.0	24.8	341	5.1
6	31 Aug-09 Sep	12.4	29.1	20.8	24.9	410	4.4
7	10 Sep-19 Sep	12.4	31.0	20.5	25.7	454	5.2
8	20 Sep-29 Sep	8.0	32.7	20.8	26.7	449	5.2
9	30 Sep-09 Oct	1.0	33.6	20.9	27.2	471	5.9
10	10 Oct-19 Oct	0.0	35.0	18.7	26.8	492	6.5
	Seasonal total:	290.9					546.0

WEATHER DATA FOR 10 DAY PERIODS FOR DIFFERENT LOCATIONS AND SEASONS
[Except for rainfall, all values are daily averages]

Location: Rahuri Season: 1980 Postrainy

Period	Dates	Rain (mm)	Temperature °C			Solar radiation (ly)	Evaporation (mm)
			Max.	Min.	Mean		
1	13 Oct-22 Oct	0.0	34.5	17.2	25.9	488	6.5
2	23 Oct-01 Nov	0.0	33.3	16.7	25.0	460	5.7
3	02 Nov-11 Nov	0.0	32.2	16.4	24.3	404	5.5
4	12 Nov-21 Nov	25.6	29.9	19.5	24.7	296	4.3
5	22 Nov-01 Dec	0.0	30.7	13.8	22.2	410	4.8
6	02 Dec-11 Dec	0.0*	27.6	11.3	19.5	381	4.6
7	12 Dec-21 Dec	0.0	29.9	9.5	19.7	389	4.5
8	22 Dec-31 Dec	3.1*	26.8	13.0	19.9	329	3.9
9	01 Jan-10 Jan	0.0	27.6	10.5	19.1	393	4.8
10	11 Jan-20 Jan	20.0	24.1	11.3	17.7	329	3.7
11	21 Jan-30 Jan	0.0	29.2	11.9	20.5	438	5.2
12	31 Jan-09 Feb	0.0	31.2	11.0	21.1	460	6.1
13	10 Feb-19 Feb	0.0	31.7	11.7	21.7	476	6.7
	Seasonal total:	48.7					663.0

* = Irrigation

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT-RP-4 Season: 1979-80 Postrainy

a) Phenological data

	Genotype/Treatment			
	CSH-8A*		CSH-8B*	
	Date	DAE	Date	DAE
Sowing	15.11.79		15.11.79	
Emergence	22.11.79		22.11.79	
Fifth leaf				
Panicle initiation	11.12.79	19	11.12.79	19
Flag leaf emergence	05.01.80	44	05.01.80	44
Anthesis	21.01.80	60	23.01.80	62
Physiological maturity	28.02.80	98	27.02.80	97

b) Agronomic data

Depth of sowing (cm)	5.0	5.0
Row spacing (cm)	75	5.0
Initial plant population/ha	180,000	180,000
Final plant population/ha	143,000	125,000
Number of replications	3	3
Maximum number of leaves		
Grain yield (kg/ha)	3832	2080
Total dry matter (kg/ha)	7644	4702

c) Soil data

Available soil water at sowing (cm)	8.5
Maximum available soil water (cm)	8.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm)		Date	Amount (cm)	
	A	B		A	B
19.11.79	8.5	8.5	18.01.80	8.5	8.5
11.12.79	8.5	8.5	06.02.80	8.5	—
31.12.79	8.5	—			

*A = Adequate moisture supply; B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - RP 4 Season: 1979-80 Postrainy

a) Phenological data

	Genotype/Treatment			
	M-35-1 A*		M-35-1 B*	
	Date	DAE	Date	DAE
Sowing	15.11.79		15.11.79	
Emergence	22.11.79		22.11.79	
Fifth leaf				
Panicle initiation	13.12.79	21	11.12.79	19
Flag leaf emergence	7.1.80	46	5.1.80	44
Anthesis	28.1.80	67	30.1.80	69
Physiological maturity	6.3.80	105	6.3.80	107

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	150,000	150,000
Number of replications	3	3
Maximum number of leaves	16	16
Grain yield (kg/ha)	2,100	1,296
Total dry matter (kg/ha)	8,322	4,954

c) Soil data

Available soil water at sowing (cm)	8.5
Maximum available soil water (cm)	8.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm) A	Amount (cm) B	Date	Amount (cm) A	Amount (cm) B
19.11.79	8.5	8.5	18.1.80	8.5	8.5
11.12.79	8.5	8.5	6.2.80	8.5	-
31.12.79	8.5	-			

*A = Adequate moisture supply B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - RP 4 Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-1 A*		CSH-1 B*	
	Date	DAE	Date	DAE
Sowing	19.6.80		19.6.80	
Emergence	23.6.80		23.6.80	
Fifth leaf	7.7.80	14	7.7.80	14
Panicle initiation	11.7.80	18	11.7.80	18
Flag leaf emergence	7.8.80	45	7.8.80	45
Anthesis	14.8.80	52	14.8.80	52
Physiological maturity	19.9.80	88	19.8.80	88

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	150,000	170,000
Number of replications	3	3
Maximum number of leaves	17	17
Grain yield (kg/ha)	5,540	5,110
Total dry matter (kg/ha)	11,300	11,300

c) Soil data

Available soil water at sowing (cm)	3.8
Maximum available soil water (cm)	8.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
28.6.80	8.5		
21.7.80	8.5		

*A = Irrigated B = Rainfed

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - RP 4 Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-6 A*		CSH-6 B*	
	Date	DAE	Date	DAE
Sowing	19.6.80		19.6.80	
Emergence	23.6.80		23.6.80	
Fifth leaf	7.7.80	14	7.7.80	14
Panicle initiation	11.7.80	18	11.7.80	18
Flag leaf emergence	7.8.80	45	7.8.80	45
Anthesis	15.8.80	53	15.8.80	53
Physiological maturity	17.9.80	86	17.9.80	86

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	170,000	170,000
Number of replications	3	3
Maximum number of leaves	17	17
Grain yield (kg/ha)	5,640	5,640
Total dry matter (kg/ha)	11,937	12,510

c) Soil data

Available soil water at sowing (cm)	3.8
Maximum available soil water (cm)	8.5

gation (cm)

Date	Amount (cm)	Date	Amount (cm)
28.6.80	8.5		
21.7.80	8.5		

*A = Irrigated B = Rainfed

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - BW 3 Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment					
	CSH-1		CSH-6		SPV-351	
	Date	DAE	Date	DAE	Date	DAE
Sowing	1.7.80		1.7.80		1. .80	
Emergence	4.7.80		4.7.80		4.7.80	
Fifth leaf						
Panicle initiation	25.7.80	21	24.7.80	20	2.8.80	29
Flag leaf emergence	16.8.80	43	16.8.80	43	25.8.80	52
Anthesis	27.8.80	54	27.8.80	54	4.9.80	62
Physiological maturity	29.9.80	87	26.9.80	84	6.10.80	4

b) Agronomic data

Depth of sowing (cm)	5	5	5
Row spacing (cm)	75	75	75
Initial plant population/ha	180,000	180,000	180,000
Final plant population/ha	117,000	130,000	114,000
Number of replications	3	3	3
Maximum number of leaves	17	17	16
Grain yield (kg/ha)	4,545	5,310	4,260
Total dry matter (kg/ha)	10,430	11.290	12,348

c) Soil data

Available soil water at sowing (cm)	10.2
Maximum available soil water (cm)	20.2

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
NIL			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - RP 4 Season: 1980-81 Postrainy

a) Phenological data

	Genotype/Treatment			
	CSH-6 A		CSH-6 B	
	Date	DAE*	Date	DAE
Sowing	10.10.80		10.10.80	
Emergence	13.10.80		13.10.80	
Fifth leaf	22.10.80	9	22.10.80	9
Panicle initiation	3.11.80	21	3.11.80	21
Flag leaf emergence	19.11.80	37	19.11.80	37
Anthesis	8.12.80	56	9.12.80	57
Physiological maturity	15.1.81	94	9.1.81	88

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	164,000	145,000
Number of replications	3	3
Maximum number of leaves	13	13
Grain yield (kg/ha)	4,693	2,276
Total dry matter (kg/ha)	9,259	5,008

c) Soil data

Available soil water at sowing (cm)	8.5
Maximum available soil water (cm)	8.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm)		Date	Amount (cm)	
	A	B		A	B
10.11.80	8.5	8.5	21.11.80	7.1	8.5
23.10.80	7.5	6.0	22.12.80	8.5	-
10.11.80	7.8	-			

*A = Adequate moisture supply B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - RP 4 Season: 1980-81 Postrainy

a) Phenological data

	Genotype/Treatment			
	CSH-8 A*		CSH-8 B*	
	Date	DAE	Date	DAE
Sowing	10.10.80		10.10.80	
Emergence	13.10.80		13.10.80	
Fifth leaf	22.10.80	9	22.10.80	9
Panicle initiation	4.11.80	22	4.11.80	22
Flag leaf emergence	26.11.80	44	26.11.80	44
Anthesis	18.12.80	66	16.12.80	64
Physiological maturity	27.1.81	106	23.1.81	102

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	132,000	129,000
Number of replications	3	3
Maximum number of leaves	15	15
Grain yield (kg/ha)	6,118	2,495
Total dry matter (kg/ha)	11,149	6,464

c) Soil data

Available soil water at sowing (cm)	8.5
Maximum available soil water (cm)	8.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm)		Date	Amount (cm)	
	A*	B*		A*	B*
11.10.80	8.5	8.	21.11.80	7.1	8.5
23.10.80	7.5	6.0	22.12.80	8.5	-
10.11.80	7.8	-			

*A = Adequate moisture supply B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - RP 4 Season: 1980-81 Post rainy

a) Phenological data

	Genotype/Treatment			
	M-35-1 A*		M-35-1 B*	
	Date	DAE	Date	DAE
Sowing	10.10.80		10.10.80	
Emergence	13.10.80		13.10.80	
Fifth leaf	25.10.80	12	25.10.80	12
Panicle initiation	10.11.80	28	10.11.80	28
Flag leaf emergence				
Anthesis	23.12.80	71	22.12.80	70
Physiological maturity	3.2.81	113	1.2.81	111

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	120,000	85,000
Number of replications	3	3
Maximum number of leaves	16	16
Grain yield (kg/ha)	3,948	1,691
Total dry matter (kg/ha)	10,234	6,710

c) Soil data

Available soil water at sowing (cm)	8.5
Maximum available soil water (cm)	8.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm)		Date	Amount (cm)	
11.10.80	8.5	8.5	21.11.80	7.1	8.
23.10.80	7.5	6.0	22.12.80	8.5	-
10.11.80	7.5	-			

*A = Adequate moisture supply B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - BW 3 Season: 1980-81 Postrainy

a) Phenological data

	Genotype/Treatment			
	CSH-6 A*		CSH-6 B*	
	Date	DAE	Date	DAE
Sowing	24.11.80		24.11.80	
Emergence	30.11.80		30.11.80	
Fifth leaf	26.12.80	26	26.12.80	26
Panicle initiation	27.12.80	27	27.12.80	27
Flag leaf emergence	9.1.81	40	9.1.81	40
Anthesis	4.2.81	66	4.2.81	66
Physiological maturity	6.3.81	96	5.3.81	95

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	200,000	200,000
Final plant population/ha	199,000	190,000
Number of replications	3	3
Maximum number of leaves	13	13
Grain yield (kg/ha)	5,345	2,992
Total dry matter (kg/ha)	11,143	5,590

c) Soil data

Available soil water at sowing (cm)	20.2
Maximum available soil water (cm)	20.2

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
6.1.81	8.2		
4.2.81	7.0		
22.2.81	7.6		

A = Adequate moisture supply B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - BW 3 Season: 1980-81 post rainy

a) Phenological data

	Genotype/Treatment			
	CSH-8 A*		CSH-8 B*	
	Date	DAE	Date	DAE
Sowing	24.11.80			
Emergence	30.11.80			
Fifth leaf	26.12.80	26	26.12.80	26
Panicle initiation	27.12.80	27	27.12.80	27
Flag leaf emergence	23.1.81	54	23.1.81	54
Anthesis	11.2.81	73	11.2.81	73
Physiological maturity	20.3.81	110	17.3.81	107

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	172,000	172,000
Number of replications	3	3
Maximum number of leaves	16	16
Grain yield (kg/ha)	6,136	3,115
Total dry matter (kg/ha)	12,631	7,452

c) Soil data

Available soil water at sowing (cm)	20.2
Maximum available soil water (cm)	20.2

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
6.1.81	8.2		
4.2.81	7		
20.2.81	7.6		

*A = Adequate moisture supply B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: ICRISAT - BW 3 **Season:** 1980-81 post rainy

a) Phenological data

	Genotype/Treatment			
	M-35-1 A*		M-35-1 B*	
	Date	DAE	Date	DAE
Sowing	24.11.80		24.11.80	
Emergence	30.11.80		30.11.80	
Fifth leaf	26.12.80	26	26.12.80	26
Panicle initiation	6.1.81	37	6.1.81	37
Flag leaf emergence	27.1.81	58	27.1.81	58
Anthesis	18.2.81	80	18.2.81	80
Physiological maturity	25.3.81	115	21.3.81	111

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	180,000	180,000
Final plant population/ha	172,000	149,000
Number of replications	3	3
Maximum number of leaves	16	16
Grain yield (kg/ha)	3,801	2,543
Total dry matter (kg/ha)	12,150	6,767

c) Soil data

Available soil water at sowing (cm)	20.2
Maximum available soil water (cm)	20.2

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
6.1.81	8.2		
4.2.81	7		
20.2.81	7.6		

*A = Adequate moisture supply B = Limited moisture supply

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: COIMBATORE Season: 1980-81 Postrainy

a) Phenological data

	Genotype/Treatment	
	CSH-8	
	Date	DAE
Sowing	07.11.80	
Emergence	12.11.80	
Fifth leaf		
Panicle initiation	02.12.80	20
Flag leaf emergence		
Anthesis	09.01.81	58
Physiological maturity	16.02.80	96

b) Agronomic data

Depth of sowing (cm)	5
Row spacing (cm)	75
Initial plant population/ha	180,000
Final plant population/ha	140,000
Number of replications	
Maximum number of leaves	
Grain yield (kg/ha)	3167
Total dry matter (kg/ha)	

c) Soil data

Available soil water at sowing (cm)	6.0
Maximum available soil water (cm)	14.4

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
10.12.80	5	25.01.81	5
26.12.80	5	10.02.81	
09.01.81	5		

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: DELHI Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-1(A)*&B*		CSH-6(A)*&B*	
	Date	DAE	Date	DAE
Sowing	27.06.80		27.06.80	
Emergence	01.07.80		01.07.80	
Fifth leaf				
Panicle initiation	27.07.80	26	26.07.80	25
Flag leaf emergence				
Anthesis	28.08.80	58	26.08.80	56
Physiological maturity	08.10.80	99	04.10.80	95

b) Agronomic data	CSH-1A	CSH-1B	CSH-6A	CSH-6B
Depth of sowing (cm)	5		5	
Row spacing (cm)	75		75	
Initial plant population/ha				
Final plant population/ha	140,000		160,000	
Number of replications	3		3	
Maximum number of leaves	17		17	
Grain yield (kg/ha)	3850	3550	4500	3900
Total dry matter (kg/ha)	11,586	9016	12810	114 0

c) Soil data

Available soil water at sowing (cm)	8.5	8.5
Maximum available soil water (cm)	18.8	18.8

d) Dates and amount of irrigation (cm)

Date	Amount (cm) (A)	Amount (cm) (B)	Date	Amount (cm)
27.08.80	5	-		
16.09.80	5	-		

*A = Irrigated; B = Rainfed

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: HISSAR Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-6 A*		CSH-6 B*	
	Date	DAE	Date	DAE
Sowing	20.06.80		20.06.80	
Emergence	24.06.80		24.06.80	
Fifth leaf				
Panicle initiation	25.07.80	31	25.07.80	31
Flag leaf emergence	16.08.80		13.08.80	
Anthesis	27.08.80	64	24.08.80	61
Physiological maturity	27.09.80	95	22.09.80	90

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	212,000	214,000
Final plant population/ha	175,000	167,000
Number of replications	3	3
Maximum number of leaves		
Grain yield (kg/ha)	2756	3310
Total dry matter (kg/ha)		

c) Soil data

Available soil water at sowing (cm)	24
Maximum available soil water (cm)	24

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
09.07.80	8.0		
20.07.80	8.0		
16.08.80	8.0		

*A = Irrigated; B = Rainfed

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: KHON KAEN Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment	
	Hegari	
	Date	DAE
Sowing	13.08.80	
Emergence	16.08.80	
Fifth leaf	28.08.80	12
Panicle initiation		
Flag leaf emergence	25.09.80	40
Anthesis	07.10.80	52
Physiological maturity	16.10.80	92

b) Agronomic data

Depth of sowing (cm)	5
Row spacing (cm)	75
Initial plant population/ha	133,333
Final plant population/ha	118,750
Number of replications	4
Maximum number of leaves	17
Grain yield (kg/ha)	950
Total dry matter (kg/ha)	4750

c) Soil data

Available soil water at sowing (cm)	11.5
Maximum available soil water (cm)	11.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
- Nil -			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: LUDHIANA Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-1		CSH-6	
	Date	DAE	Date	DAE
Sowing	30.06.80		30.06.80	
Emergence	04.07.80		04.07.80	
Fifth leaf				
Panicle initiation	11.08.80	38	11.08.80	38
Flag leaf emergence				
Anthesis	15.09.80	72	04.09.80	61
Physiological maturity	07.10.80	95	26.09.80	84

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	83000	83000
Final plant population/ha	80000	80000
Number of replications	3	3
Maximum number of leaves		
Grain yield (kg/ha)	1437	2467
Total dry matter (kg/ha)		

c) Soil data

Available soil water at sowing (cm)	12.3
Maximum available soil water (cm)	12.3

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
- NIL -			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: PARBHANI Season: 1979-80 Postrainy

a) Phenological data

	Genotype/Treatment			
	CSH-8		M-35-1	
	Date	DAE	Date	DAE
Sowing	07.10.79		07.10.79	
Emergence	12.10.79		12.10.79	
Fifth leaf	20.10.79	8	20.10.79	8
Panicle initiation	02.11.79	21	12.11.79	31
Flag leaf emergence	25.11.79	44	05.12.79	54
Anthesis	06.12.79	55	16.12.79	65
Physiological maturity	15.01.80	95	08.02.80	119

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	70333	68300
Final plant population/ha	70000	68000
Number of replications	3	3
Maximum number of leaves		
Grain yield (kg/ha)	2000	1400
Total dry matter (kg/ha)	5800	5300

c) Soil data

Available soil water at sowing (cm)	15.0
Maximum available soil water (cm)	20.0

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
- Nil -			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: PARBHANI Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-1		CSH-6	
	Date	DAE	Date	DAE
Sowing	21.06.80		21.06.80	
Emergence	26.06.80		26.06.80	
Fifth leaf	08.07.80	12	08.07.80	12
Panicle initiation	15.07.80	19	13.07.80	17
Flag leaf emergence	10.08.80	45	07.08.80	42
Anthesis	23.08.80	58	19.08.80	54
Physiological maturity	21.09.80	88	19.09.80	85

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	119,000	121,000
Final plant population/ha	112,000	115,000
Number of replications	3	3
Maximum number of leaves	17	17
Grain yield (kg/ha)	2640	3050
Total dry matter (kg/ha)	11240	13020

c) Soil data

Available soil water at sowing (cm)	10.0
Maximum available soil water (cm)	20.0

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
- Nil -			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: PARBHANI Season: 1980-81 Postrainy

a) Phenological data

Genotype/Treatment

	CSH-8	
	Date	DAE
Sowing	17.10.80	
Emergence	23.10.80	
Fifth leaf	04.11.80	12
Panicle initiation	18.11.80	26
Flag leaf emergence		
Anthesis	21.12.80	59
Physiological maturity	11.02.81	111

b) Agronomic data

Depth of sowing (cm)	5
Row spacing (cm)	45
Initial plant population/ha	92,300
Final plant population/ha	92,300
Number of replications	3
Maximum number of leaves	16
Grain yield (kg/ha)	3080
Total dry matter (kg/ha)	5150

c) Soil data

Available soil water at sowing (cm)	16.0
Maximum available soil water (cm)	20.0

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
25.10.80	5		
10.11.80	5		

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: PUNE Season: 1979-80 Postrainy

a) Phenological data

	Genotype/Treatment			
	CSH-8		M-35-1	
	Date	DAE	Date	DAE
Sowing	26.11.79		26.11.79	
Emergence	04.12.79		15.12.79	
Fifth leaf	20.12.79	16	29.12.79	14
Panicle initiation				
Flag leaf emergence	26.01.80	53	29.01.80	45
Anthesis	03.02.80	61	22.02.80	69
Physiological maturity	25.03.80	114	07.04.80	114

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	45	45
Initial plant population/ha		
Final plant population/ha	180,000	150,000
Number of replications	2	3
Maximum number of leaves		
Grain yield (kg/ha)	5,366	1,766
Total dry matter (kg/ha)	13,100	5,300

c) Soil data

Available soil water at sowing (cm)	8.6
Maximum available soil water (cm)	12.5

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
12.12.79	7.0	12.02.80	7.0
04.01.80	7.0	07.03.80	7.0
23.01.80	7.0		

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: PUNE Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-1		CSH-6	
	Date	DAE	Date	DAE
Sowing	17.07.80		17.07.80	
Emergence	22.07.80		22.07.80	
Fifth leaf	12.08.80	21	10.08.80	19
Panicle initiation				
Flag leaf emergence	30.09.80	70	28.09.80	68
Anthesis				
Physiological maturity	05.11.80	106	03.11.80	105

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	45	45
Initial plant population/ha		
Final plant population/ha	70,000	120,000
Number of replications	3	3
Maximum number of leaves		
Grain yield (kg/ha)	1233	2138
Total dry matter (kg/ha)	5133	8205

c) Soil data

Available soil water at sowing (cm)	10
Maximum available soil water (cm)	10

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
28.07.80			
20.09.80			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: PUNE Season: 1980-81 Postrainy

a) Phenological data

	Genotype/Treatment	
	CSH-8	
	Date	DAE
Sowing	16.11.80	
Emergence	19.11.80	
Fifth leaf		
Panicle initiation		
Flag leaf emergence	26.01.81	68
Anthesis		
Physiological maturity	31.03.81	101

b) Agronomic data

Depth of sowing (cm)	
Row spacing (cm)	
Initial plant population/ha	
Final plant population/ha	100,000
Number of replications	3
Maximum number of leaves	
Grain yield (kg/ha)	2759
Total dry matter (kg/ha)	6296

c) Soil data

Available soil water at sowing (cm)	10
Maximum available soil water (cm)	10

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
12.11.80	10	04.03.81	10
21.12.80	10		
14.02.80	10		

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: RAHURI Season: 1979-80 Postrainy

a) Phenological data

	Genotype/Treatment					
	CSH-6		CSH-8		M-35-1	
	Date	DAE	Date	DAE	Date	DAE
Sowing	18.10.79		18.10.79		18.10.79	
Emergence	23.10.79		23.10.79		23.10.79	
Fifth leaf						
Panicle initiation	06.12.79	44	13.12.79	51	13.12.79	51
Flag leaf emergence						
Anthesis	18.12.79	56	26.12.79	64	30.12.79	68
Physiological maturity	25.01.79	94	09.02.80	109	19.02.80	119

b) Agronomic data

Depth of sowing (cm)	5	5	5
Row spacing (cm)	75	75	75
Initial plant population/ha			
Final plant population/ha	148,700	143,700	147,600
Number of replications			
Maximum number of leaves			
Grain yield (kg/ha)	867	1737	672
Total dry matter (kg/ha)			

c) Soil data

Available soil water at sowing (cm)	10
Maximum available soil water (cm)	12

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
- Nil -			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: RAHURI Season: 1980 Rainy

a) Phenological data

	Genotype/Treatment			
	CSH-1		CSH-6	
	Date	DAE	Date	DAE
Sowing	10.07.80		10.07.80	
Emergence	15.07.80		15.07.80	
Fifth leaf	24.07.80	9	24.07.80	9
Panicle initiation	25.08.80	41	25.08.80	41
Flag leaf emergence				
Anthesis	05.09.80	52	02.09.80	49
Physiological maturity	25.09.80	72	22.09.80	69

b) Agronomic data

Depth of sowing (cm)	4		4	
Row spacing (cm)	75		75	
Initial plant population/ha				
Final plant population/ha	130,000		140,000	
Number of replications				
Maximum number of leaves	A	B	A	B
Grain yield (kg/ha)	3913	3203	2694	3595
Total dry matter (kg/ha)				

c) Soil data

Available soil water at sowing (cm)	10	10
Maximum available soil water (cm)	12	12

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
25.07.80			

CROP AND SOIL DATA FOR DIFFERENT LOCATIONS

Location: RAHURI Season: 1980-81 Postrainy

a) Phenological data

	Genotype/Treatment			
	CSH-8		M-35-1	
	Date	DAE	Date	DAE
Sowing	10.10.80		10.10.80	
Emergence	16.10.80		16.10.80	
Fifth leaf				
Panicle initiation	26.11.80	41	01.12.80	46
Flag leaf emergence				
Anthesis	14.12.80	59	18.12.80	63
Physiological maturity	15.01.80	91	20.01.80	96

b) Agronomic data

Depth of sowing (cm)	5	5
Row spacing (cm)	75	75
Initial plant population/ha	90,000	140,000
Final plant population/ha	90,000	140,000
Number of replications		
Maximum number of leaves		
Grain yield (kg/ha)	7158	4071
Total dry matter (kg/ha)		

c) Soil data

Available soil water at sowing (cm)	10
Maximum available soil water (cm)	12

d) Dates and amount of irrigation (cm)

Date	Amount (cm)	Date	Amount (cm)
04.12.80	10		
26.12.80	10		