STUDIES ON PLANTING PATTERNS OF SORGHUM + SOYBEAN INTERCROPPING SYSTEM

BY

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DISSERTATION

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IN

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CANDIDATE'S DECLARATION

I, hereby declare that this dissertation or part thereof, has not been previously submitted by me for a degree of any University.

Kadam

(G.L. KADAM)

Place : PARBHANI
Date : 23 / 06 /2003

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CERTIFICATE-I

This is to certify that *Shri* **KADAM GAJANAN LAXMANRAO** has satisfactorily prosecuted his course and research for a period of not less than four semesters and that the dissertation entitled **"STUDIES ON PLANTING PATTERNS OF SORGHUM + SOYBEAN INTERCROPPING SYSTEM"** submitted by him is the result of original research work and is of sufficiently high standard to warrant it's presentation to the examination.

I also certify that the dissertation or part thereof has not been previously submitted by him for a degree of any university.

Place : PARBHANI
Date : 23/ 06 /2003

(Dr. G.G. Shinde)
Research Guide

CERTIFICATE-II

This is to certify that the dissertation entitled " **STUDIES ON PLANTING PATTERNS OF SORGHUM + SOYBEAN INTERCROPPING SYSTEM**" submitted by ***Shri*** **KADAM GAJANAN LAXMANRAO** to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRONOMY,** has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.

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INTRODUCTION

Sorghum is an important cereal crop in the world next to wheat, rice and maize. Area covered by sorghum in India is 9.5 to 10.5 Mha. It has the highest average national productivity of 0.7 – 0.85 t/ha (Anonymous, 1999). It ranks third in acreage and production among cereals in India. In Maharashtra, sorghum is grown in *kharif* and *rabi* seasons. Area under sorghum crop in Maharashtra is nearly 55 lakh hectares out of which *kharif* sorghum covers 21.50 lakh ha with production of 39.11 lakh tonnes. Sorghum has special significance in India as, in addition to its importance as one of the major grain crops, it is extensively grown for fodder purpose. It fulfil demands of fodder for cattle of farmers. Sorghum grain is eaten by human beings in India in the form of *Bhakari*. Ethanol also prepared from sorghum grain. Sorghum is important source of protein and carbohydrates.

The soybean is now becoming one of important field crops in Maharashtra with increasing of the cultivation area of this crop. In Marathwada region, area under soybean crop is 63,300 ha (2000-01). Soybean is one of the *kharif* legume crop. Legumes have well recognized role in restoring soil fertility and improving soil physical properties. They are valued (Legumes) for protein rich food, feed and fodder and therefore have been rightly described as unique jewels of Indian crop husbandry (Swaminathan, 1981).

Soybean is assuming it's importance due to high protein content (40 – 42 per cent) especially lycine, edible oil (20 per cent) and

other industrial uses. Soybean is supplementing the edible oil needs of the country and therefore gaining much importance in these days. In India, soybean occupies an area of about 6.8 million ha. with total annual production of 6.84 Mt and 10.05 q/ha productivity in 1999-2000 (Anonymous, 2000).

The area under the *kharif* sorghum is gradually declining due to it's low demand for food, low produce price relative to oilseeds and pulses and lagging productive growth. The grain quality is also affected due to grain mold incidence in *kharif.* The net returns from the competing crops suitably grown in the same agro-ecology is much higher due to higher market price. Thus the *kharif* sorghum is being replaced by soybean, sunflower, groundnut, cotton and other high value crops. The weakening competitiveness of sorghum is also due to Government Policies being less favorable to sorghum, such as minimum support price (MSP) and absence of procurement of sorghum grain when price falls in market below minimum support price (MSP). Though productivity of *kharif* sorghum in addition to it's fodder even under low management is higher than competing crops. But higher market prices for competing crops allure to sorghum grower to opt for cultivation of these high return crops.

The profitability of *kharif* sorghum can further be increased by the introduction of grain mold resistant hybrid sorghum with high value leguminous crop such as arhar, soybean, etc. Intercropping of soybean and sorghum to improve soil condition and productivity is good source. Intercropping has got importance and wide popularity resulting in benefits in dryland farming.

Regions with rainfall range 600 to 900 mm the land and other resources of crop production can be utilized to the fullest extent by adopting sorghum + soybean intercropping, thus increasing the monetary returns per unit area.

Suitability and feasibility of intercropping of prosperity of Indian farmers have been comprehensively reviewed by Aiyer (1949). The beneficial effects and advantages of intercropping have been recorded by many research workers. Tarahalkar (1976), Umrani *et al.* (1981), Lomte and Dabhade (1990), Solunke *et al.*(1990) and Kachapur *et al.* (1992) and Wanjari *et al.* (1994).

Studies on the intercropping systems under the sorghum project involved the development of suitable genotypes, which offer the least competition and result in the development of suitable cropping patterns so as to identify remunerative intercropping systems. Sorghum + Pigeonpea, Sorghum + Soybean, Sorghum + groundnut and a few other mixtures have been found to be remunerative. Legume as intercrop not only enhance the income but also provide much needed protein to supplement farmer's predominantly cereal diet (Anonymous, 2001).

An increase in the length and thickness of sorghum earhead in association with legumes observed by Jaganathan *et al.* (1974). Sorghum associated with soybean in alternate rows gave higher grain weight per plant and 1000 grain weight than sorghum in pure stand (Ghatol, 1970).

Planting alternate rows of sorghum and soybean in 2:2 proportion was the best way of intercropping at both Indore and Sehore (Hegde and Pandey, 1992). In pure sorghum, the yield of grain recorded was 3593 kg/ha. In 1:2 and 3:3 ratio sorghum grain yield realised was 86

per cent and 79 per cent of pure crop respectively. (Anonymous, 1996-97). Total productivity and economic returns per unit area were found to be increased by intercropping soybean + sorghum in 2:1 row proportion at Akola (Anonymous, 2002a).

Studies were conducted at Sorghum Research Station, Parbhani from 1975-1980 on intercropping of various legumes. Intercropping of early legumes like green gram, black gram, cowpea and soybean with sorghum in 30/90 cm pairing with 2:2 row proportion in recommended when irrigated wheat or any suitable crop is to be grown, during *rabi* sequence cropping (Anonymous, 1991).

However, at present the sole sorghum in *kharif* is grown at the row spacing of 45 cm by majority of the farmers. In past the experiments were conducted on additive series at the row spacing of 30 cm and pairing of 30-60 cm and 30-90 cm. In sole *kharif* sorghum soybean can be introduced by replacing sorghum lines by adopting some definite row proportions.

Taking into account above points, it was felt necessary to introduce soybean as an intercrop in *kharif* sorghum with different row proportions and to conduct the experiment entitled "Studies on planting pattern of sorghum + soybean intercropping", with the following objectives.

1) To study the total productivity and profitability of sorghum with soybean as an intercrop compared to sole crops.

2) To find out suitable sorghum + soybean row proportion for intercropping in Vertisol.

Review of Literature

Chapter-II

REVIEW OF LITERATURE

A brief account of the research work done in the past on the aspect of present study is reviewed in this chapter.

During last some decade, several researchers have undertaken studies on intercropping of cereals and legume with cereal as base crop in the country or vice-versa. So an attempt have been made to present brief review in this chapter.

Importance of Intercropping

The method of intercropping is nothing but growing of two or more crops in different row proportions so that highest yield and net profit may be obtained under varied environmental conditions. If crops with different growth habit are grown together then it may be possible to exploit better plant nutrients and moisture from different soil layers and interception of light, energy can be utilized more efficiently. Further the risk due to diseases and pests may be reduced. Also, the weeds can be controlled more efficiently.

In India intercroppings importance was comphrensively highlighted about four decades ago by Aiyer (1949).

Willey (1979) stated that development and feasibility of economically viable intercropping system depends on the selection of compatible crop. Intercropping is particularly beneficial when it involves

two component crops with different growth pattern for better temporal use of resources.

Growing of two or more different crops necessarily on the same piece of land. base crop necessarily be in distinct row arrangement and recommended plant population of the base crop is suitably combined with appropriate additional plant density of the associated crops. From basic point of view it shows a greater scope for intercropping. Sorghum with soybean crop, past and present research shows that intercropping utilizes resources efficiently and provide advantage over sole crop. Intercropping has become a new way bounty for production per hectare per unit time. Agro-climatic conditions of Marathwada are favorable for growing sorghum and soybean.

2.1 Effect of intercropping on growth characters

Ghatol (1970) reported improvement in girth of stem per plant of sorghum CSH 1 when intercropped with soybean as compared to sole crop of sorghum.

Patil (1970) observed improvement in height, number of leaves. leaf area and dry matter production per plant of sorghum in mixed cropping treatments with 50 per cent or more proportion of green gram.

Chudawant (1971) reported that height of sorghum plant was increased when sown mixed with cowpea as compared to pure crop of sorghum.

Deshpande (1991) recorded plant height, number of functional leaves and dry matter per plant were significantly higher in sole crop of sorghum than other intercropping treatments.

Ibrahim *et al.* (1993) recorded fresh weight, dry weight, plant height, number of tillers, number of internodes and LAI of sorghum all greatest with intercropping. Stem diameter, crude protein, dry matter and ash percentage were highest in single crop of sorghum.

2.2 Effect of intercropping on yield contributing characters

Ghatol (1970) reported improvement in girth, length and weight of panicle and grain weight per plant of sorghum CSH 1 when intercropped with soybean.

Guldekar (1974) recorded the improvement in thickness of cob, weight of cob and grain weight per plant of sorghum due to intercropping of groundnut as compared to sole crop.

Jagannathan *et al.* (1974) noticed an increase in length and thickness of sorghum earhead with associated legumes.

Wahatule (1985) reported all the yield contributing characters viz., length, width of earhead, weight of earhead, weight of grain per earhead and test weight of sorghum were maximum in 3:3 row proportion as compared to 4:2 row proportion and sole cropping of sorghum.

Deshpande (1991) recorded highest length of earhead in sole sorghum whereas weight of earhead and weight of grain per earhead of sorghum was maximum in 1:3 row ratio of sorghum + pigeonpea intercropping compared to sole sorghum.

Gupta (1996) reported that sorghum reduced number of pods/plant and seed weight per plant of blackgram and pigeonpea whereas soybean remained unaffected.

2.3 Effect of intercropping on yield

Rao and Willey (1981) concluded that sorghum, pigeonpea intercropping system is superior to sole cropping at all levels of yields and is widely adaptable.

Giri and Bainade (1981) found that intercropping in sorghum hybrid CSH-6 gave the sorghum grain equivalent 5.58 t/ha compared with 5.08 t/ha for sorghum in pure stands.

Solunke *et al.* (1990) recorded that a paired planting of *kharif* sorghum with pigeonpea, green gram and cowpea for fodder as intercrop increased total productivity and resulted in higher monetary returns when compared with sole sorghum.

Sorghum (CSH 5), pigeonpea (T 21), groundnuts, soybean (Punjab-1) and black gram (Krishna) were grown in Rajesthan in *Kharif* as pure stand or as sorghum + legume intercrops in three different row arrangement. It was observed that pigeonpea and groundnut produced higher yield than other legumes when intercropped. Pigeonpea and groundnut produced higher yield than other legume and when intercropped (Gupta, 1990).

In pure sorghum the yield of grain recorded was 3593 Kg/ha. In 1:2 and 3:3 ratios sorghum grain realised was 86 percent and 79 per cent of the pure crop, respectively. In intercropping as soybean + sorghum, the highest grain equivalent was obtained in 1:2 geometry which was 3824 and the next best equivalent of 3707 was recorded in 3:3. In pure sorghum and soybean the recorded grain equivalents were 3370 and 1512, respectively (Anonymous, 1996-97).

Kushwaha and Chandel (1997) reported that sorghum Cv. SPV 881 was grown alone and or was intercropped with soybean Cv. PK. 472. The highest sorghum grain yields of 3.19 and 3.58 t/ha in 1993 and 1994, respectively were obtained under intercropping.

2.4 Inercropping and Land equivalent ratio

Patra and Chatterjee (1986) reported that the LER value of maize or pigeonpea was higher when soybean was intercropped in 2:2 row proportion than 2:1 row proportion.

Chandel *et al.*, (1987) reported that the maximum LER 1.46 was recorded in paired rows of maize at 30 and 90 cm + 2 rows of soybean.

Tomar *et al.*, (1987) concluded that pigeonpea and soybean in 1:2 row ratio was most productive with LER of 1.43.

Ramteke (1988) found highest LER (1.52) when sorghum was intercropped with pigeonpea followed by sorghum + soybean intercropping (1.44).

Shanthaveerabhadraiah *et al.* (1991) reported that sorghum was intercropped with groundnut or soybean in row ratio of 1:1 or 2:1 row ratio and red gram intercropped with soybean in 1:1 and 2:1 row ratio. The highest land equivalent ratio (1.65) was obtained from red gram / soybean (1:1) intercrop.

Pal *et al.* (1991) found that the sorghum + soybean with 3:3 row ratio gave land equivalent ratio of 1.64 and with 4:2 row ratio it was 1.59.

Raghawanshi *et al.* (1993) reported that sorghum and soybean were grown in pure stands and intercropped. Land equivalent ratio was

highest (1.10 in 1988-89 and 1.16 in 1989-90) from intercrops in which the recommended fertilizer rates were applied to both crops.

Pal *et al.* (1993) concluded that the sorghum/soybeans intercrops which had LER upto 1.40 in 1986 and 1.35 in 1987 were more productive than soybean/maize intercrops with maximum LER of 1.28 and 1.34 in 1986 and 1987, respectively.

Soybean intercropped with pigeonpea corn and sorghum gave LER ranging from 1.25 to 1.70 or even higher, (Anonymous, 2002b)

2.5 Different planting pattern for intercropping

The results of intercropping experiment conducted at Parbhani with sorghum showed no significant reduction in yield of sorghum in paired row compared to uniform rows, higher yield and returns were obtained in paired rows of sorghum intercropped with greengram, soybean, groundnut and pigeonpea. (Anonymous, 1975-76).

The experiment conducted at Sorghum Research Station Parbhani revealed that growing of soybean with sorghum in 2:2 proportion was found beneficial as compared to sole sorghum, (Anonymous, 1991).

Solunke *et al.* (1990) recorded that a paired planting of *kharif* sorghum with pigeonpea, greengram and cowpea for fodder as intercrop increased total productivity and resulted in higher monetary returns when compared with sole sorghum.

Hedge and Pandey (1992) reported that planting alternate rows of sorghum and soybean in 2:2 proportion was the best way of intercropping at both Indore and Sehore. At Parbhani a row of mungbean could be introduced between rows of normally planted sorghum further

they observed that intercropping increased the productivity of sorghum by about 5 per cent.

Kolhe (1992) observed that sorghum based intercropping system with pigeonpea and soybean under protective irrigation was more productive and economical than under rainfed condition further observed that 3:3 proportion was economically viable than sole sorghum.

Pal *et al.* (1993) observed that among the intercrop combination sorghum grown in 4:2 row combination gave higher grain yield than that grown in 3:3 row combination with the pigeonpea, sunflower, soybean because of higher plant population of former.

Dubey *et al.* (1995) found that sorghum when intercropped with the legumes (pigeonpea and soybean) gave higher yield than grown as mixture or broadcast with sorghum. The intercropping with 2:2 row ratio recorded highest sorghum grain equivalent, net profit, cost benefit ratio as compared to 1:1 ratio.

Danawade and Shinde (1996) concluded that inclusion of pigeonpea as a base crop in intercropping system with soybean in 2:1 row proportion was found to be most advantageous.

From the experiments conducted at various locations in India it was concluded by NRCS, Hyderabad, that soybean + sorghum with 6:3 and 4:2 row ratio, the highest returns were obtained in 6:3 row combination, (Anonymous, 1997-98).

2.6 Economics of sorghum + legume intercropping

Lingegouda *et al.* (1972) stated that higher monetary returns were obtained through mixed cropping of groundnut and sorghum in the ratio of 3:1 and 4:1

Roy *et al.* (1981) stated that intercropping of pigeonpea with maize, groundnut, soybean, ragi and green gram produced highest income as compared to sole crop.

Verma *et al.* (1983) reported increased net profit by intercropping pigeonpea or soybean with sorghum in alternate row of 30 cm apart.

Patra and Chatterjee (1986) reported that the highest monetary advantages of Rs. 4289 to Rs. 5792 per hectare were obtained when soybean and maize intercropped in 2:2 alternated paired rows.

Chandel *et al.* (1987) reported that the maximum monetary advantage of Rs. 2778 /hectare and net returns Rs. 5087 / hectare were recorded in paired rows of maize + soybean intercropping.

Dhoble *et al.* (1990) reported that intercropping system of sorghum + pigeonpea recorded the highest monetary returns of Rs. 12565 / hectare as compared with cotton + blackgram, cotton + soybean, pearlmillet + pigeonpea intercropping under dryland condition in Marathwada region.

Pal *et al.* (1991) observed that the highest monetary returns were recorded by sorghum + soybean intercropping with 3:3 ratio (Rs. 4508/ha) as compared to 4:2 ratio (Rs.4362/ha) and sole sorghum (Rs.3573/ha).

Dhope *et al.* (1992) observed from the experiment conducted at Akola in Maharashtra, that sorghum intercropped with soybean in 3:3 row ratio gave higher financial returns than sorghum alone, while legume alone grown produced substantially lower returns than any intercrop.

Gode and Bobde (1993) reported that the highest net profit was obtained by intercropping sorghum with soybean in 1:1 row proportion.

Wanjari *et al.* (1994) reported maximum production and net monetary returns from intercropping with 3:3 row proportion. Highest monetary returns were recorded from sorghum + green gram (Rs. 11346 /ha) followed by sorghum + soybean (Rs. 11098 /ha)

Dubey *et al.* (1995) found that gross income and net profit were highest with sorghum + soybean in paired rows.

Mahakulkar (1995) reported that sorghum intercropped with greengram gave highest net monetary returns.

The experiments conducted at the locations of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and Agricultural Research Station, Indore in *kharif* seasons of 1999-2000 and 2000-2001 observed that sorghum + soybean intercropping system increased productivity through adoption of hybrids technology helps target desired yields, and provides an opportunity to part replace sorghum with highly profitable crops like soybean. Replacement proportions in the ratio of one thirds to two thirds has been found to be ideal, depending on the priorities of the end user. Inercropping system of sorghum and soybean provides increased monetary returns as compared to either of the sole crops. Soil related beneficial effects through inclusion of legume also helps sustain the soil health (Anonymous, 2002c).

Soil related beneficial effects through inclusion of legume also helps sustain the soil health.

2.7 Intercropping for stability

There are convincing evidences, showing greater stability of yield due to intercropping (Aiyer, 1949), yield stability is one of the feature that has been claimed for traditional intercropping system.

Reddy *et al.* (1985) the most universally applicable mechanism of intercropping is that if one crop fails to grow poorly the other can compensate, such compensation clearly can not occur when crops grown separately.

Lomte and Dabhade (1990) concluded that sorghum + pigeonpen intercropping was more profitable than sorghum + blackgram and sorghum + sunflower intercropping.

2.8 Intercropping of cereals and legumes

Non-legume base crop was largely benefited by nitrogenous material derived from legumes, sorghum is extensively grown under dryland conditions and has been intercropped (mix cropped) with legumes.

Sharma (1976) opined that the importance of legume in mixed cropping can not be ignored particularly in a country like India where the majority of people are vegetarian and their daily diet is deficient in protein.

Morchan *et al.* (1977) reported that cereal legume intercropping reduced fertilizer dose cost by improving soil fertility.

Materials and Methods

Chapter-III

MATERIAL AND METHODS

The details of the material used and the technique followed during the experimentation are given in the chapter under following heads.

3.1 Experimental site

The experiment was carried out at Sorghum Research Station, Marathwada Agricultural University, Parbhani during *Kharif* 2002-2003. Prior to fertilizer application and sowing of experimental crop, soil samples from 0-30 cm depth were taken from each net plot and the composite sample was analysed for physico-chemical properties of the soil. Mechanical analysis was done by international pipette method. Nitrogen was estimated by Kjeldahl's method (Piper, 1966). Available phosphorus was determined by Olsen's method. Estimation of total K_2O was done by Walkley and Back's method and pH by Backman's glass electrode pH meter (Jackson, 1958).

Data obtained on composition of soil are given in Table 1.

Table 1. Mechanical and chemical composition of soil from experimental plot.

Sr.No.	Particulars	Results
A]	**Mechanical**	
1.	Coarse sand (%)	10.40
2.	Fine sand (%)	13.20
3.	Silt (%)	20.50
4.	Clay sand (%)	55.00
5.	Textural class	Clayey
B]	**Chemical**	
1.	Total nitrogen (%)	0.023
2.	Available phosphate (kg/ha)	16.00
3.	Available potash (kg/ha)	392.00
4.	Organic carbon (%)	0.49
5.	pH	8.15
6.	EC dSm^{-1}	1.32

3.2 Cropping history

The previous cropping history of the experimental plot from 1998-99 onwards is presented in Table 2.

Table 2. Cropping history

Year	Crops	
	Kharif	*Rabi*
1999-2000	Sorghum	--
2000-2001	Sorghum	--
2001-2002	Fallow	Safflower
2002-2003	Present experiment	--

3.3 Climate and weather condition :

Parbhani is situated in subtropical belt on latitude 19°16' North and longitude of 96°41' East having an elevation of 408.5 m above the mean sea level.

The meteorological data for 2002-2003 recorded at the meteorological observatory, Sorghum Research Station, Parbhani are presented in Table 3.

Climate of Parbhani is characterized by cool winter and dry summer. The regular monsoon started from second week of June 2002 (i.e. 23rd meteorological week). The rainfall received during experimental period was (June to Oct. months). 740.4 mm distributed in 35 rainy days. The total annual rainfall received during monsoon period of 2002 was 826.4 mm.

The monsoon started in second fortnight of June but only 75 mm rains received upto 19th June with this amount of rainfall sowing of experiment was done but very good rain were received 24th, 25th and 26th June amounting to 241 mm. Then there was dry spell of about 6 days from 2 to 8 July and again rains were started which help for growth of sorghum crop.

In the month of August about 260.2 mm rain received which were beneficial for growth and development of sorghum crop. In first week of September there was about 68 mm rainfall, it was useful for grain development and from second week of September, the monsoon was withdrawn.

Table 3 : Meteorological data, recorded at Meteorological Observatory, Sorghum Research Station, MAU, Parbhani, 2002-2003.

MW	Dates	Rainfall (mm)	Rainy days	Temperature (^{o}C)		RH (%)	
				Max.	Min	AM	PM
19	May 7-13	0.0	0	42.3	27.3	52	20
20	May 14-20	11.2	2	41.2	26.4	63	31
21	May 21-27	10.1	2	40.6	26.6	62	28
22	May 28-03	1.4	0	40.6	26.6	57	27
23	June 4-10	17.2	1	38.2	25.0	67	36
24	June 11-17	23.7	2	36.8	23.6	78	43
25	June 18-24	34.0	3	34.3	23.8	85	56
26	June 25-1	241.5	4	28.6	21.8	89	72
27	July 2-8	0.0	0	33.5	23.0	77	47
28	July 9-15	1.7	0	34.9	23.2	75	43
29	July 16-22	12.4	1	32.1	22.9	81	57
30	July 23-29	68.3	5	30.9	21.6	86	65
31	July 30-5	44.7	3	31.5	22.6	83	69
32	Aug. 6-12	39.1	4	28.3	21.8	86	79
33	Aug. 13-19	5.8	1	29.6	22.1	88	66
34	Aug. 20-26	112.4	2	27.7	21.6	90	77
35	Aug. 27-02	58.2	3	29.0	21.9	89	74
36	Sept. 3-9	68.4	4	28.6	21.1	86	72
37	Sept. 10-16	3.2	1	31.8	20.3	87	53
38	Sept. 17-23	8.4	1	32.1	21.1	85	55
39	Sept. 24-30	0.0	0	34.1	21.1	79	43
40	Oct. 1-7	0.0	0	35.8	18.0	76	34
41	Oct. 8-14	0.0	0	33.5	20.6	75	45
42	Oct. 15-21	0.0	0	31.8	19.9	89	50
43	Oct. 22-28	0.0	0	33.3	44.4	73	26
44	Oct. 29-Set 5	0.0	0	32.4	11.5	71	27

There was slight attack of shootfly and aphids which was controlled by spraying insecticide endosulfan. Incidence of grain mold was not observed due to withdrawal of monsoon in second week of September, therefore grain quality was good.

Mean maximum temperature between June and Oct. month varied from the (i.e. from 22 MW to 43 MW was) 27.7^{O}C to 40.O^{O}C, where as mean minimum temperature was between 14.4^{O}C to 26.0^{O}C

Relative humidity observed was at morning varied from 57 to 90 per cent and relative humidity at evening was observed varied from 26 to 79 per cent.

3.4 Experimental details

3.4.1 Design and treatments

Design : Randomised block design

Replication : Three

Treatments : Eight

A. Treatment details :

Row proportion

1. T_1 Sorghum + Soybean (2:1) (66:33)
2. T_2 Sorghum + Soybean (3:3) (50:50)
3. T_3 Sorghum + Soybean (4:2) (66:33)
4. T_4 Sorghum + Soybean (2:4) (33:66)
5. T_5 Sorghum + Soybean (6:3) (66:33)
6. T_6 Sorghum + Soybean (3:6) (33:66)
7. T_7 Sorghum sole
8. T_8 Sole soybean.

Bracket values indicates percentage of the respective crop plant population

Other details :

1. Plot size : Gross : 6.30 m x 5.0 m

   Net : 4.05 m x 4.0 m (9 lines) for T_5 and T_6

   5.40 m x 4.0 m (12 lines) for $T_1, T_2, T_3, T_4, T_7, T_8$.

2. Variety : (a) Sorghum : PVK 801

   (b) Soybean : JS 335

3. Spacing : Sorghum : 45 cm x 12.5 cm

   Soybean : 45 cm x 5 cm

Characteristics of genotypes of sorghum and soybean

Sorghum : PVK 801.

- It is selection from GDLP –34–5–5–3
- It is highly tolerant to grain mold and lodging
- It is multiple disease resistant
- It is more responsive to applied fertilizer
- It requires 72 to 74 days for 50 per cent flowering.
- It matures with 108-110 days.
- Average grain yield is 33 to 38 q/ha and fodder yield 100 to 105 q/ha.
- Good Bhakari making quality, fodder is nutritious and more palatable
- It is released at state level for cultivation in May, 1999.

Soybean JS 335

- It is high yielding variety

- Suitable for Marathwada region
- It requires 32-36 days for 50 per cent flowering
- It matures within 95-98 days.
- Average grain yield is 22 to 28 qt/ha
- Good protein quality content.

3.4.2 Layout

The experimental field was laid out as per plan after preparatory cultivation before sowing.

The layout consisted of 24 experimental units in three replication having eight (8) unit each. The plan of layout for all treatments is given in figure 1.

The treatments were allotted randomly to various plots restricting randomization in each replication.

3.5 Cultivation

The schedule of cultural operation is given in Table 4.

3.5.1 Preparatory tillage

The land was ploughed 0-30 cm deep with tractor plough after harvest of previous crop. Loose friable and fine seed bed was prepared by subsequent harrowing with blade harrow. The stubbles and previous crop residues were collected and plot was cleaned. Lastly fine and compact seed bed was prepared by giving one harrowing by heavy inverted harrow.

3.5.2 Fertilizer application

In Sorghum + soybean intercropped plot recommended dose of sorghum 80 Kg N + 40 kg P_2O_5 + 40 Kg K_2O per ha was given to all intercropped plots according to plot size in two splits. At the time of sowing

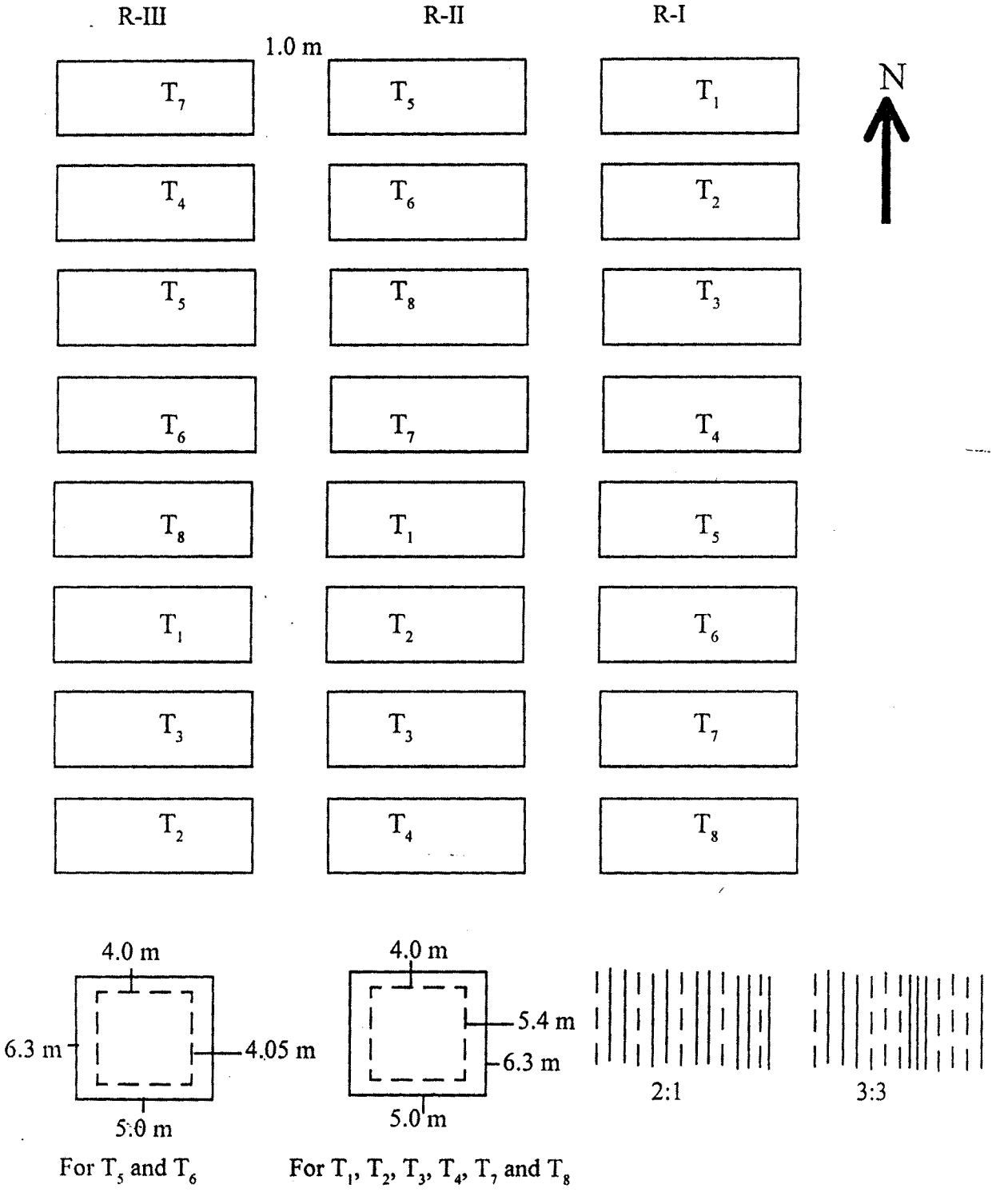

Fig. 1. PLAN OF LAYOUT

Sorghum | Soybean

Rows at both the ends indicates border line.

basal dose was given to sorghum + soybean intercropped plot. After one month remaining half dose of nitrogen was applied to only rows of sorghum in the intercropped plots depending on area of sorghum crop.

For sole sorghum half dose of 'N' and full dose of P_2O_5 and K_2O was applied at sowing and remaining half dose of N was applied 32 days after sowing through urea.

For the sole soybean recommended dose of NPK @ 30:60:30 kg N, P_2O_5 and K_2O per hectare was given according to plot size and area at the time of sowing.

3.5.3 Seed sowing, gap filing and thinning

The seeds of sorghum PVK 801 and Soybean JS 335 were used for sowing.

Three to four seeds of sorghum and two to three seeds of soybean (JSS-335) were dibbled at each hill in their respective rows in experimental field at moist zone (4-5 cm depth) on 21 June 2002. The gap filling was done 8 days after sowing to ensure the required plant population. The thinning was done 14 days after sowing and only one healthy and vigorous seedling was kept at each hill.

3.5.4 Crop protection measures :

For the control of shootfly and stem borer incidence on sorghum three sprayings of endopsulfan 35 EC @ 1075 ml/ha (0.05 per cent) was undertaken. For soybean two to three sprayings were undertaken to control pest and insects.

3.5.5 Cultural operation

The date-wise schedule of important cultural operation carried out in experimental plot during the season are presented in Table 4.

3.5.6 Harvesting and threshing

The variety of sorghum matured at about 120 days and that of soybean at about 95 days. The border strips were harvested first and then harvesting of five observation plant was done and then harvesting of net plot was done, respectively. The produce was sundried and weighed.

3.6 Biometric observations

3.6.1 Sorghum

The details in respect of various biometric observations recorded are presented in Table 5.

3.6.1.1 Sampling technique

Various observations on growth studies were taken on five randomly selected plants of sorghum and soybean from each crop and each net plot. The selected plants were labelled and all the biometric observations were recorded on them.

3.6.1.2 Pre-harvest studies

3.6.1.2.1 Emergence count

Emergence count was taken on the 15^{th} day after sowing. The gaps if any were filled to maintain the required plant population. The final emergence count was taken on 19^{th} day after sowing.

Table 4.Schedule for cultural operations performed in experiment plot

Sr. No.	Field Operation	Freq.	Date
A]	**Pre-sowing**		
1.	Ploughing	1	20-5-02
2.	Harrowing with blade harrow	2	26-5-02
			30-5-02
3.	Cleaning of field	1	4-6-02
4.	Experimental layout	1	16-6-02
B]	**Sowing**		
1.	Seed treatment of sorghum with carbofuran	1	20-6-02
2.	Seed treatment of soybean with *rhizobium* culture	1	20-6-02
3.	Dibbling of crops	1	21-6-02
C]	**Fertilizer application**		
1.	Basal application as per treatment	1	21-6-02
2.	Top dressing as per treatment	1	23-7-02
D]	**Post sowing operations**		
1.	Gap filling	1	29-6-02
2.	Thinning	1	5-7-02
3.	Weeding : Hand weeding I	3	28-6-02
	Hand weeding II		29-7-02
	Hand weeding III		19-8-02
4.	Hand hoeing	2	4-7-02
			21-7-02
5.	Spraying	3	2-7-02
			18-7-02
			10-8-02
6.	Harvesting of sorghum	1	20-10-02
7.	Threshing and Winnowing of sorghum	1	30-10-02
8.	Harvesting of soybean	1	25-9-02
9.	Threshing and winnowing of soybean	1	4-10-02

3.6.1.2.2 Height of plant

The plant height was measured in cm from the base of the plant to the legule of fully opened leaf.

3.6.1.2.3 Number of functional leaves

Total number of fully opened green leaves per plant was recorded.

3.6.1.2.4 Leaf area per plant

Maximum length and breadth in cm of all the fully opened green leaves were measured and area per leaf was calculated by using formula given by Stickler and Pauli (1961). The total leaf area per plant was calculated by summation of individual leaf area per leaf.

Leaf area/leaf = (Maximum length) X (Maximum breadth) X (0.747)

3.6.1.2.5 Dry matter accumulation studies

For the dry matter accumulation studies one plant from each net plot was selected at random at every stage of sampling. The plants so selected were supported and it's roots were removed. The aerial portion of plant was divided into various plant parts like stem, leaves and earhead according to stage of growth. These separated plant parts were collected in separate brown paper bags properly labelled, air dried first and then dried in hot air oven at 60°C until constant weight was obtained and then weighed. The final constant weight was recorded as the dry matter weight in grams per plant.

3.6.2 Soybean

3.6.2.1 Emergence count and final plant stand

Emergence count was taken 15 days after sowing from each net plot. The data given in Table 6, similarly the final plant stand from each net plot was recorded at harvest.

3.6.2.2 Height of plant

The Height of plant was measured from the ground level of the plant to the base of apical bud of the main shoot with an interval of 20 days.

3.6.2.3 Number of functional leaves per plant

The progressive number of functional leaves i.e., fully opened green leaves per plant was counted at 20 days interval. In case of soybean trifoliate was considered as one leaf.

3.6.2.4 Leaf area per plant

Leaf area was calculated by using the plant uprooted for dry matter accumulation studies from each net plot periodically. All the leaves were detached and grouped in three groups viz., small, medium and big. The gradewise leaves were counted and their frequency was recorded. The maximum length and breadth of two average sized leaves from each group was measured and then mean was worked out. The leaf area was calculated by using the following formula for each grade.

$$A = L \times B \times K \times N$$

Where,

A = Leaf area in cm^2 under particular group.

L = Maximum length of leaf in cm

K = Leaf area constant for soybean (0.6889, Pawar, 1978).

N = Number of leaves under particular group.

The summation of leaf area of all the three grades in cm^2 per plant was calculated.

3.6.2.5 Number of branches per plant

Number of branches per plant arising from the main shoots were recorded at 60, 80 and at harvest after sowing

.2.6.2.6. Dry matter accumulation per plant

One plant from each net plot was selected at random at every stage of observation. The selected plants were uprooted and roots were removed. The aerial part was air dried first and then dried in hot air oven at 60°C until the constant weight was obtained. The oven dried material then weighed separately and final constant weight was obtained. The oven dried material then weighed separately and final constant weights were recorded in (g).

3.7 Growth analysis (Sorghum and Soybean)

Data on growth characters viz., weight, leaf area, dry matter per plant for sorghum were further analysed for working out the growth functions. AGR,RGR and LAI. These physiological determinations of plant growth as affected by treatments reflect the plant yield. Hence, these physiological constants were worked out in present study.

3.7.1 Absolute growth rate (AGR)

Absolute growth rate is the total gain in height or weight by plant within a specific time interval. It is generally expressed as cm per day

in case of plant height and grams per day in case dry matter production per plant and is calculated by using formula :

$$AGR = \frac{(H_2 - H_1)}{(t_2 - t_1)} = \text{for height} \quad \text{---------- 1}$$

$$AGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} = (\text{for weight}) \quad \text{---------- 2}$$

Where ,

H_2 and H_1 refer to plant height

W_2 and W_1 refer to dry matter weight of plant and

t_2 and t_1 refer as time

3.7.2 Relative growth rate (RGR)

According to Blackman (1919) the increase in dry matter of plant is of continuous compound interest where in the increment in any interval adds to the capital for subsequent growth. The rate of increment is known as RGR. This growth constant was worked out by using the formula given by Fisher (1921).

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

Where,

W_2 and W_1 refer to dry matter weights of plant and

t_2 and t_1 refer as time

RGR is expressed as g/g/day

Log_e = natural log (2.3026).

The RGR is a joint function of the phytosynthetic efficiency of leaves, known as net assimilation rate (NAR)

Table 5 : Details of bio-metric observation :

Sr. No	Particulars	Frequency	Days from sowing	No. of plants observed.
A]	**Sorghum**			
a)	**Pre-harvest studies**			
1.	Emergence count	1	19	All net plots
2.	Height of plant (cm)	5	40,60, 80, 100, at harvest	5
3.	Number of functional leaves /plant	5	40,60, 80, 100, at harvest	5
4.	Leaf area per plant (cm^2)	5	40,60, 80, 100, at harvest	5
5.	Dry matter per plant (g)	5	40,60, 80, 100, at harvest	1
b)	**Post harvest studies**			
1.	Length of earhead (cm)	1	At harvest	5
2.	Weight of earhead (g)	1	At harvest	5
3.	Weight of grains per earhead (g)	1	At harvest	5
4.	Test weight (1000 grains) (g)	1	At harvest	Plot-wise sample
5.	Total earhead per net plot (kg)	1	At harvest	All net plots
6.	Yield of grain per net plot (kg)	1	At harvest	All net plots
7.	Yield of bhoosa per net plot (kg)	1	At harvest	All net plots
8.	Yield of fodder per net plot (kg)	1	At harvest	All net plots
B]	**Soybean :**			
a)	**Pre-harvest**			
1.	Emergence count	1	15	All net plots
2.	Plant height (cm)	5	20, 40, 60, 80 , at harvest	5
3.	Number of functional leaves	4	20, 40, 60, 80	5
4.	Leaf area (dm^2)	4	20, 40, 60, 80	5
5.	No. of branches	3	60, 80 , at harvest	5

Table 5 : Contd....

Sr. No	Particulars	Frequency	Days from sowing	No. of plants observed.
6.	Total dry matter/plant	5	20, 40, 60, 80 , at harvest	5
b)	**Post-harvest :**			
1.	Number of pods per plant	3	60, 80, at harvest	5
2.	Weight of grain per plant	1	At harvest	5
3.	Test weight (100seed)	1	After harvest	Plot wise
4.	Straw yield (kg)	1	At harvest	All net plots
5.	Grain yield (kg)	1	At harvest	All net plots

3.7.3. Leaf area index (LAI)

It is the ratio of leaf area per plant to the land area expressed in the same unit. The LAI was worked out using the formula given by Wastson (1947).

$$LAI = \frac{\text{Leaf area per plant } cm^2}{\text{Land area per plant } cm^2}$$

3.8 Post – harvest studies

3.8.1 Sorghum

3.8.1.1 Weight of earhead

Earhead from five randomly selected plants were harvested and after drying their weight was recorded in gram and mean weight per earhead was calculated

3.8.1.2 Weight of grains per plant

The earheads of five selected plants were threshed, winnowed and grain weight was recorded in gram and mean weight per plant was calculated.

3.8.1.3 Test weight :

Grains obtained from each net plot were used for test weight (1000 grains) studied by random sampling. Thousand grains were counted and weighed in grams.

3.8.1.4 Grain yield :

At maturity, the net plots were marked and all the plants from each net plot were harvested and kept for sun-drying for eight days, except the five sample plants which were harvested separately for individual plant yields. The earheads were cut, weighed, threshed with wooden hand thresher and grains were cleaned with hand winnowing. The yield of the clean grains per net plot was recorded in kg and was converted to kg/ha. The weight of five observation plants added to this.

3.8.1.5 Yield of *bhoosa*

The *bhoosa* yield was calculated by deduction of grain yield from the weight of earheads and then converted into kg/ha.

3.8.1.6 Fodder yield

After harvest, sorghum plants were sun-dried for about 20 days and their weights were recorded treatment-wise on the spring balance and the corresponding fodder yields were calculated on hectare basis.

3.8.1.7 Grain to fodder ratio

This was computed from the yield of grains and fodder obtained from each net plot. The yield of *bhoosa* not added in fodder.

3.8.1.8 Grain to *bhoosa* ratio

This was calculated from the weight of grain and *bhoosa* obtained from each net plot of treatments.

3.8.1.9 Land equivalent ratio (LER)

From studying the best utilization of land, the land equivalent ratio for various treatments were calculated by using the following formula,

$$LER = \frac{\text{(Yield of main crop in intercropping)}}{\text{(Yield of main crop in sole crop)}} + \frac{\text{(Yield of intercrop in intercropping)}}{\text{(Yield of intercrop in sole crop)}}$$

3.8.2 Sorghum grain equivalent

For comparing sole cropping with intercropping system the sorghum equivalent was calculated.

$$\text{Sorghum grain equivalent} = \text{Sorghum yield} + \frac{\text{Monetary value of intercrop / ha}}{\text{Selling price of sorghum}}$$

3.8.2.1 Harvest index

It was calculated from economic yield and biological yield of crop by formula,

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.9 Soybean

3.9.1 Number of pods per plant

The number of pods from five observation plants were counted and average per plant was workout.

3.9.2. Weight of pods per plant

The dry weight (g) of pods per plant was recorded from the five sampled plants by working out their mean weight.

3.9.3 Grain weight per plant

The weight of grains per plant was taken after threshing five sample plants by calculating the mean of same plants.

3.9.4 Test weight

Weight of 100 grains from produce of each net plot was recorded in gm as test weight. The grain of bold size taken 100 and grain of small size taken 1000 for test weight (Reddy and Reddi, 1995).

3.9.5 Straw yield

After separation the pods from the plants, the straw of the net plot was weighed and yield per plot was recorded in kg and then converted into kg/ha.

3.9.6 Grain yield per plot

All the plants from each net plot were harvested and kept for sundrying. Then produce was threshed by beating with wooden stick because of which grains were separated from pods. The threshed material was winnowed for separating grains from *bhoosa* by hard winnowing. The weight of clean grains was recorded in kg/plot and then it was converted into kg/ha.

3.9.6 Biological yield

It is calculated with the summation of grain + straw yield in case of soybean.

3.9.7 Gross monetary returns

The gross monetary return (Rs/ha) for the intercropping system were worked out with prevailing market prices of both the component crops and subjected to statistical analysis.

3.9.8 Net returns

The net returns were calculated by deducting the cost of cultivation from the gross income.

3.9.9 General analysis

The statistical analysis of the data was done by the analysis of variance method (Panse and Sukhatme, 1967). The Null Hypothesis was tested by 'F' test of significance to know whether observed treatment effects were real or not from the data in which the treatment effects were significant. The appropriate standard error (SE) and critical difference (CD) at 5 per cent level of probability were calculated. Data graphically illustrated at appropriate places.

3.9.9.1 Multiple regression

The sorghum equivalents and yields of sorghum so also soybean were defined as the function of dynamics of row proportion of sorghum and soybean. To ascertain the influence of row proportion on yield following type of multiple regression model (Snedecor and Cochran, 1980) was adopted.

$$Y = b_o + b_1x_1 + b_2x_2$$

Where,

Y = sorghum grain equivalent kg/ha

b_1 = slope of sorghum row proportion

b_2 = slope of soybean row proportion

x_1 = proportion of sorghum rows (%)

x_2 = proportion of soybean rows (%)

Experimental Findings

Chapter-IV

EXPERIMENTAL FINDINGS

The experimental data, statistical parameters and results are presented in this chapter.

4.1 Sorghum

4.1.1 Pre-harvest studies

4.1.1.1 Emergence count and final plant stand of sorghum as influenced by various treatments

The data regarding emergence count at 20 days after sowing and final stand at harvest expressed in arcsin value of various treatments are presented in Table 6.

Table 6. Emergence count and final stand of sorghum as influenced by various treatments.

Treatments	Emergence count (Arcsin value)	Final plant stand (Arcsin value)
T_1 (2:1)	62.63	55.27
T_2 (3:3)	65.00	55.93
T_3 (4:2)	65.72	53.51
T_4 (2:4)	66.52	53.32
T_5 (6:3)	66.91	56.81
T_6 (3:6)	63.45	58.01
T_7 Sole sorghum	63.52	59.80
S.E. $\pm$	1.27	1.81
C.D. at 5%	NS	NS
G. mean	64.82	56.09

Data presented in above Table 6 showed that there were no significant difference among various treatments in respect of emergence count and final plant stand.

The different row ratios were designed to represent the following component proportions. T_1, T_3 and T_5 sorghum (66 %), soybean (33 %) while T_4 and T_6 represents the reverse (33 and 66 %) and T_2 equal proportion (50:50).

The data presented in Table 6 gives the actual plant stand of sorghum crops. The actual plant population of the sorghum crop in the various treatments was less by 6 to 13 % as compared to normal population to be maintained in the various row proportions.

4.1.1.2 Height of plant

Data in respect of plant height (cm) as influenced periodically by various treatments are presented in Table 7.

Table 7. Sorghum plant height as influenced by various treatments (cm/plant)

Treatments	Days after sowing				
	40	60	80	100	At harvest
T_1 (2:1)	48.50	126.00	171.24	172.80	173.20
T_2 (3:3)	55.14	137.55	181.00	182.14	183.00
T_3 (4:2)	42.10	117.68	160.00	164.00	164.74
T_4 (2:4)	48.10	126.24	169.32	172.65	173.18
T_5 (6:3)	41.00	116.00	159.24	162.24	164.45
T_6 (3:6)	55.27	138.40	181.57	182.80	183.64
T_7 Sole sorghum	40.00	110.08	158.00	160.72	162.80
S.E. ±	1.71	2.75	3.08	2.78	2.68
C.D. at 5%	5.13	8.26	9.25	8.34	8.04
G. mean	47.15	124.56	168.62	171.05	172.14

The data presented in Table 7 clearly indicated that the mean plant height of sorghum increased continuously upto maturity. This increase was very fast upto 60 days, fast in between 60 and 80 days and thereafter it was slow.

In general in all treatments the height increased rapidly about 60 days after sowing.

The mean plant height in cm per plant was influenced significantly due to various planting patterns of sorghum + soybean intercropping at all the stages of crop growth and at harvest. At all the stages of crop growth, the highest plant height was observed in 3:3 planting pattern (T_2) which was at par with 3:6 (T_6) and significantly superior over rest of the planting patterns. Further, it was observed that the planting pattern of 2:1 and 2:4 were at par and significantly superior than planting pattern of 4:2 (T_3), 6:3 (T_5) and sole sorghum (T_7), the later three being at par with each other at the same stage.

4.1.1.3 Mean number of functional leaves per plant

Data on mean number of functional leaves per plant as influenced by various treatments are given in Table 8.

Table 8. Mean number of functional leaves as influenced by various treatments

Treatments	Days after sowing				
	40	60	80	100	At harvest
T_1 (2:1)	3.61	7.86	6.78	3.98	1.92
T_2 (3:3)	3.78	8.61	7.47	4.87	2.40
T_3 (4:2)	3.44	7.18	6.00	3.30	1.20
T_4 (2:4)	3.58	7.80	6.70	4.15	1.72
T_5 (6:3)	3.41	7.00	5.92	3.45	1.20
T_6 (3:6)	3.80	8.65	7.54	5.11	2.45
T_7 Sole sorghum	3.37	6.94	5.75	3.20	1.00
S.E. $\pm$	0.55	0.18	0.22	0.16	0.15
C.D. at 5%	NS	0.57	0.68	0.49	0.46
G. mean	3.57	7.72	6.60	4.00	1.70

Mean number of functional leaves per plant increased upto 60 DAS and thereafter decreased till maturity. At 40 DAS the mean number of functional leaves/plant were found to be non-significant, whereas at rest of the stages it was significant.

At 60, 80, 100 and at harvest the 3:3 (T_2) planting pattern produced more number of functional leaves per plant which was comparable with 3:6 planting pattern (T_6) and both were significantly superior than the remaining treatments. Further, it is observed that the 2:1 and 2:4 planting patterns were at par and significantly superior than T_3 (4:2), T_5 (6:3) and T_7 (sole sorghum) treatments in recording mean number of functional leaves per plant. The treatment of 4:2, 6:3 and sole sorghum were at par with each other.

4.1.1.4 Mean leaf area per plant (cm^2)

Data regarding leaf area in cm^2/plant of sorghum are presented in Table 9 and graphically presented in Fig. 2.

Table 9. Mean leaf area of sorghum as influenced by various treatments (cm^2/plant)

Treatments	Days after sowing			
	40	60	80	100
T_1 (2:1)	1265	3451	2572	1685
T_2 (3:3)	1419	5200	3668	2464
T_3 (4:2)	1179	2650	2243	1310
T_4 (2:4)	1237	3388	2536	1632
T_5 (6:3)	1145	2608	2187	1240
T_6 (3:6)	1412	5058	3703	2382
T_7 Sole sorghum	1162	2672	2170	1183
S.E. ±	100.97	234	93.84	98.19
C.D. at 5%	NS	705	282	294.57
G. mean	1281	3575	2725	1699

Data given in Table 9 indicated that leaf area per plant was less at 40 DAS increased at faster rate upto 60 DAS and decreased thereafter upto harvest. It was maximum at 60 DAS in all the treatments.

Leaf area in cm^2 per plant was influenced significantly due to various treatments at all the growth stages except at 40 DAS. At 60, 80 and 100 DAS the leaf area in cm^2 per plant recorded by 3:3 (T_2) and 3:6 (T_5) planting pattern was at par and significantly superior than rest of the treatments. Further, it is observed that 2:1 (T_1) and 2:4 (T_4) planting patterns were at par and significantly superior to 4:2, 6:3 and sole sorghum treatments, the later three being at par with each other in recording leaf area per plant.

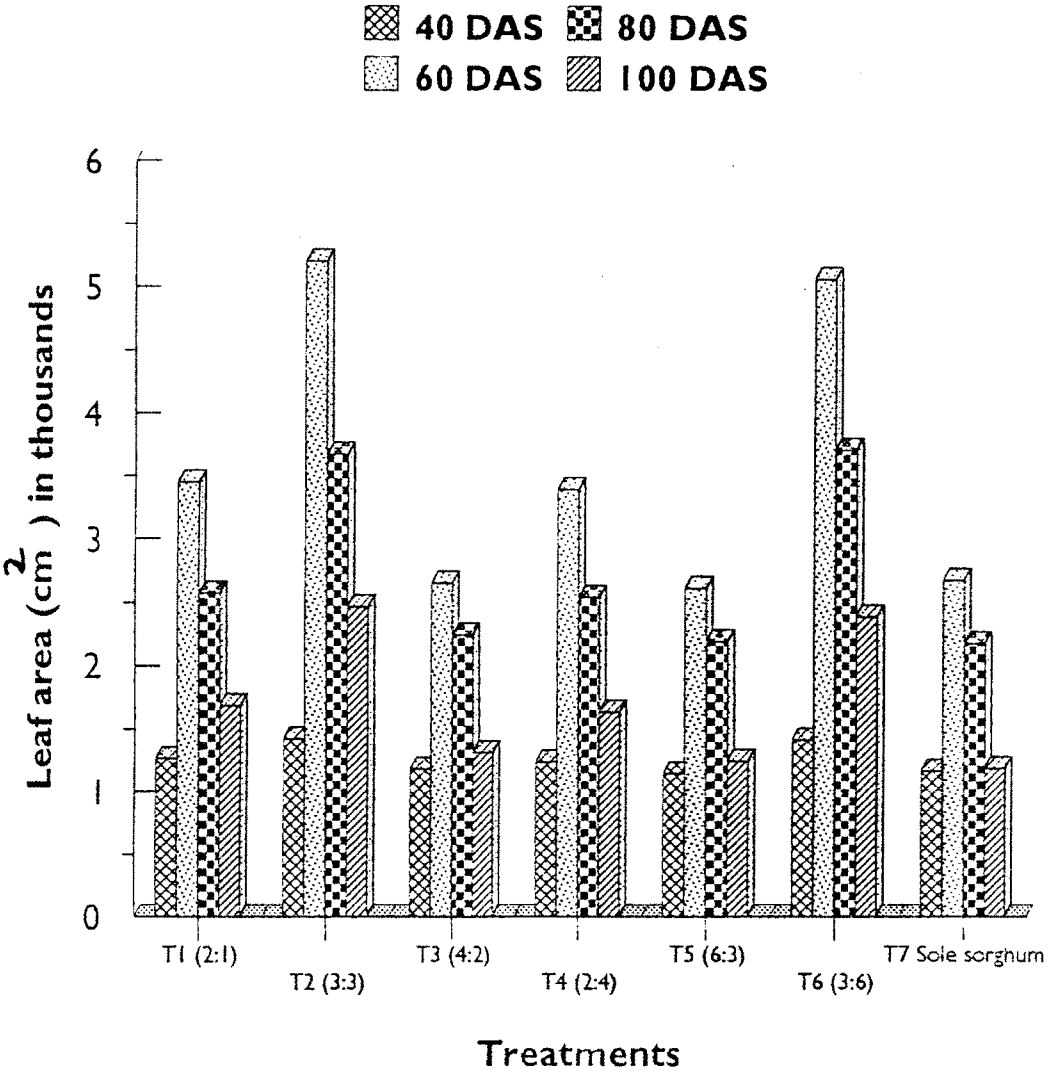

Fig. 2. Mean leaf area of sorghum as influenced by various treatments (cm^2/ plant)

4.1.1.5 Dry matter accumulation per plant (g)

Data in respect of total dry matter accumulation per plant as affected periodically by various treatments are presented in Table 10 and depicted in Fig. 3.

Table 10. Total dry matter accumulation per plant of sorghum as influenced by various treatments (g/plant)

Treatments	Days after sowing				
	40	60	80	100	At harvest
T_1 (2:1)	7.80	31.48	95.64	137.24	146.10
T_2 (3:3)	9.45	40.84	108.85	150.43	161.64
T_3 (4:2)	5.80	23.64	84.92	125.10	134.14
T_4 (2:4)	7.64	31.00	96.70	136.84	145.45
T_5 (6:3)	5.84	22.80	82.14	123.40	132.18
T_6 (3:6)	10.24	42.71	110.55	151.14	162.38
T_7 Sole sorghum	5.62	22.41	80.80	122.54	133.10
S.E. $\pm$	0.41	2.03	3.12	3.43	3.65
C.D. at 5%	1.26	6.10	9.38	10.33	11.04
G. mean	7.48	30.69	94.22	135.24	145.00

The data on total dry matter accumulation/plant indicated that it was slow upto 40 DAS and increased at faster rate from 60 days onwards upto harvest. In general the total dry matter in g/plant was maximum in T_6 (3:6) and T_2 (3:3) treatments at all the growth stages.

The total dry matter accumulation in g/plant was highest in 3:6 (T_6) planting pattern which was at par with 3:3 (T_2) planting pattern and both treatments recorded significantly superior total dry matter in g/plant over remaining treatments at all the growth stages.

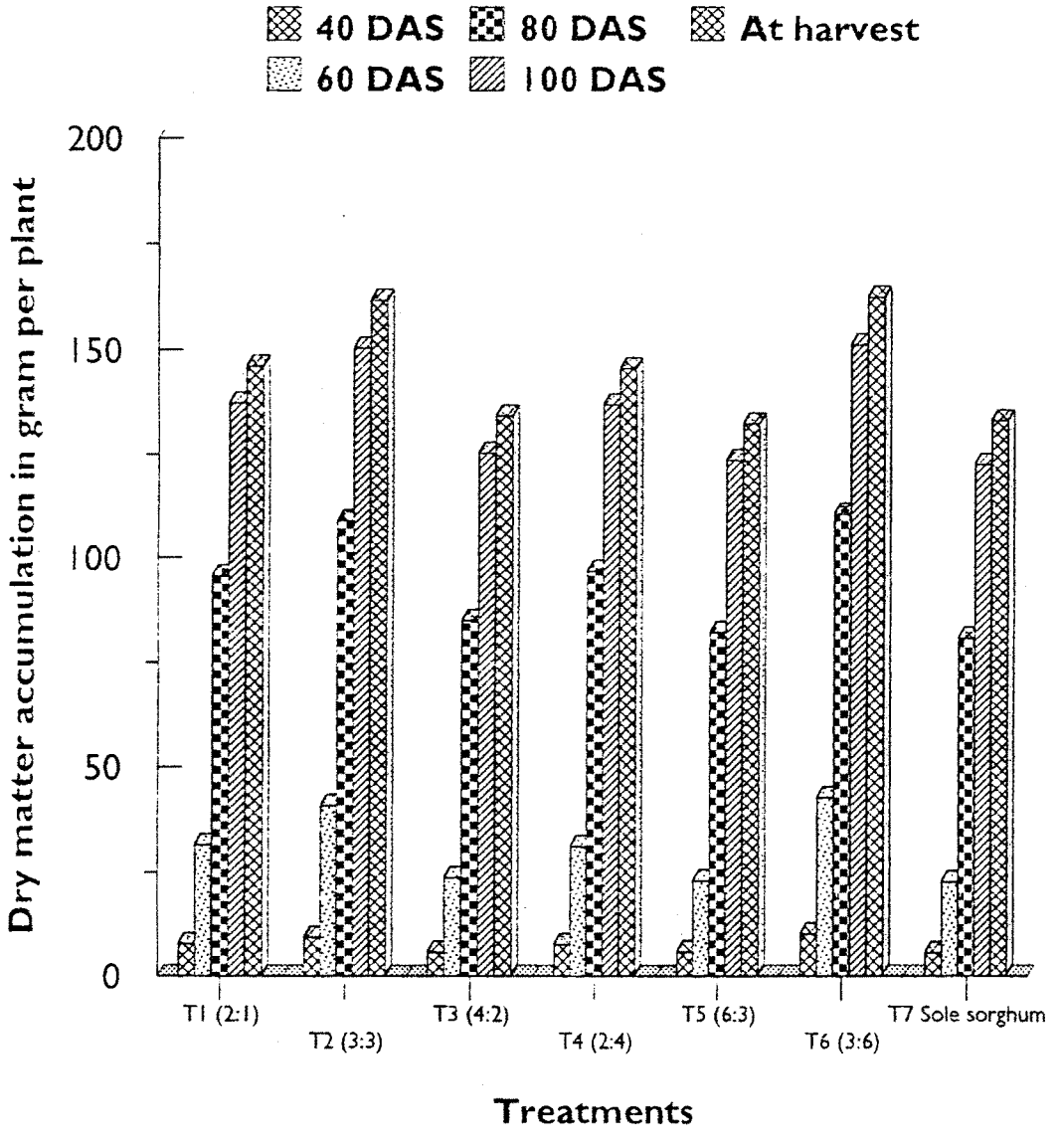

Fig. 3. Total dry matter accumulation per plant of sorghum as influenced by various treatments (g/plant)

The planting pattern of 2:1 (T_1) and 2:4 (T_4) were at par and significantly superior to 4:2, 6:3 and sole sorghum treatments at all the stages of crop growth. Further, it was observed that 4:2 (T_3), 6:3 (T_5) and sole sorghum were comparable with each other in recording total dry matter at all the growth stages.

4.1.1.6 Growth function

Data on AGR, RGR, 50 per cent flowering in days and LAI as influenced by various treatments were not analysed statistically. The inferences are drawn on the basis of mean value.

4.1.1.6.1 Absolute growth rate for height (cm/plant/day)

Data regarding AGR for height is presented in Table 11.

Data on AGR for height indicated that maximum AGR was in between 41-60 days, it was moderate between 61-80 days and decreased thereafter at harvest.

AGR for height in between 41-60 DAS was highest in the treatments of 3:6 and 3:3 planting patterns. Thereafter trend in AGR for height between various treatments was inconsistent.

Table 11. Mean absolute growth rate for plant height of sorghum as influenced by various treatments (cm/plant/day).

Treatments	Days after sowing			
	41-60	61-80	81-100	101-harvest
T_1 (2:1)	3.87	2.26	0.078	0.020
T_2 (3:3)	4.12	2.17	0.057	0.043
T_3 (4:2)	3.77	2.11	0.200	0.037
T_4 (2:4)	3.90	2.15	0.166	0.026
T_5 (6:3)	3.75	2.16	0.150	0.110
T_6 (3:6)	4.15	2.15	0.061	0.042
T_7 Sole sorghum	3.50	2.39	0.136	0.104
G. mean	3.86	2.19	0.121	0.054

4.1.1.6.2 Absolute growth rate for dry matter (g/plant/day)

Values relevant to AGR for dry matter (g/plant/day) computed from data of total dry matter are presented in Table 12.

Table 12. Mean absolute growth rate for total dry matter of sorghum as influenced by various treatments (g/plant/day).

Treatments	Days after sowing			
	41-60	61-80	81-100	101-harvest
T_1 (2:1)	1.18	3.20	2.08	0.443
T_2 (3:3)	1.56	3.40	2.07	0.560
T_3 (4:2)	0.89	3.06	2.00	0.450
T_4 (2:4)	1.16	3.28	2.00	0.430
T_5 (6:3)	0.84	2.96	2.06	0.439
T_6 (3:6)	1.62	3.39	2.02	0.562
T_7 Sole sorghum	0.83	2.91	2.08	0.528
G. mean	1.15	3.17	2.04	0.487

Data on AGR for total dry matter g/plant/day indicated that it was less between 41-60 DAS maximum between 61-80 days and decreased thereafter upto harvest.

The treatment of 3:6 and 3:3 planting patterns recorded maximum AGR for total dry matter per plant as compared to other treatments. From 60 days onwards the various treatments did not differ much in recording AGR for total dry matter.

4.1.1.6.3 Relative growth rate for dry matter (g/g/day).

The data pertaining to RGR for total dry matter/plant are given in Table 13.

Table 13. Mean relative growth rate of sorghum for total dry matter as influenced by various treatments (g/g/day).

Treatments	Days after sowing			
	41-60	61-80	81-100	101-harvest
T_1 (2:1)	0.069	0.055	0.018	0.0031
T_2 (3:3)	0.073	0.049	0.016	0.0035
T_3 (4:2)	0.070	0.063	0.019	0.0034
T_4 (2:4)	0.070	0.056	0.017	0.0031
T_5 (6:3)	0.068	0.064	0.020	0.0034
T_6 (3:6)	0.071	0.047	0.015	0.0035
T_7 Sole sorghum	0.069	0.06	0.020	0.0041
G. mean	0.070	0.056	0.017	0.0034

Values of RGR for dry matter computed from data of total dry matter indicated that it was higher in between 41-60, moderate between 61-80 days and decreased thereafter till harvest. Various treatments did not differ much in recording RGR for total dry matter.

4.1.1.6.4 Studies on 50 per cent flowering

Data regarding 50 per cent flowering of sorghum is presented in Table 14.

Table 14. Days required to 50 per cent flowering as influenced by various treatments in sorghum.

Treatments	Days to 50 per cent flowering
T_1 (2:1)	74
T_2 (3:3)	70
T_3 (4:2)	73
T_4 (2:4)	72
T_5 (6:3)	74
T_6 (3:6)	71
T_7 Sole sorghum	72
G. mean	72.28

Mean number of days required for 50 per cent flowering was 72.28 days after sowing. The treatment of 3:3 and 3:6 planting pattern took about 70-71 days for flowering which was earlier by 2-3 days as compared to other treatments.

4.1.1.6.5 Leaf area index (LAI) per plant

Data of LAI periodically recorded are presented in Table 15.

In general, the leaf area index (LAI) increased upto 60 DAS and thereafter it declined.

The data on LAI recorded periodically indicated that the mean LAI was small at 40 days, it was maximum at 60 days, moderate at 80 DAS and decreased thereafter at harvest.

The treatment of 3:3 and 3:6 planting patterns recorded maximum LAI, which was more as compared to various intercropping treatments as well as sole sorghum at all the growth stages of crop.

Table 15. Leaf area index/plant (LAI) as influenced by various treatments.

Treatments	Days after sowing			
	40	60	80	100
T_1 (2:1)	2.24	6.13	4.57	2.99
T_2 (3:3)	2.70	9.24	6.52	4.38
T_3 (4:2)	2.09	4.71	3.98	2.32
T_4 (2:4)	2.19	6.02	4.50	2.90
T_5 (6:3)	1.95	4.63	3.88	2.20
T_6 (3:6)	2.68	8.99	6.58	4.23
T_7 Sole sorghum	2.06	4.75	3.85	2.10
G. mean	2.27	6.35	4.84	3.01

4.1.2 Post harvest studies

4.1.2.1 Length, girth and weight of earhead, weight of grain per earhead and test weight

Data on yield contributing characters are presented in Table 16.

Table 16. Mean length girth, weight of earhead, weight of grain per earhead and test weight of sorghum as influenced by various treatments

Treatments	Length of earhead (cm)	Girth of earhead (cm)	Weight of earhead (g)	Weight of grain per earhead (g)	Test weight (1000 grain) (g)
T_1 (2:1)	24.15	13.94	38.10	29.48	34.12
T_2 (3:3)	26.20	15.58	45.26	32.21	33.10
T_3 (4:2)	22.47	11.35	30.50	25.28	32.70
T_4 (2:4)	24.07	13.76	37.80	29.01	34.33
T_5 (6:3)	22.15	11.58	29.58	24.95	32.04
T_6 (3:6)	26.37	15.64	46.03	32.32	34.39
T_7 Sole sorghum	21.94	11.20	29.09	24.78	34.15
S.E. ±	0.29	0.18	2.15	0.79	1.83
C.D. at 5%	0.87	0.56	6.48	2.40	NS
G. mean	23.88	13.28	36.62	28.29	33.54

In general, there were significant differences in all the yield contributing characters due to various treatments.

Length of earhead

The highest length of earhead (26.37 cm) was recorded by 3:6 (T_6) planting pattern which was at par with 3:3 planting pattern and both were significantly superior to remaining treatments in recording length of earhead per plant. The planting pattern 2:1 and 2:4 were at par and significantly superior to 6:3 (T_5), 4:2 (T_3) and sole sorghum (T_7) in recording length of earhead, the later three treatments (T_3, T_5 and T_7) were at par with each other.

Girth of earhead

The maximum girth of earhead was recorded in 3:6 and 3:3 planting pattern which was at par and significantly superior to other treatments. Further, it is observed that the 2:1 and 2:4 planting pattern were at par and significantly superior than 4:2, 6:3 and sole sorghum in recording girth of earhead per plant, the later three (4:2, 6:3 and sole sorghum) being at par with each other.

Weight of earhead

The data indicated that the weight of earhead in g per plant was highest in 3:6 planting pattern (46.03 g) which was at par with 3:3 and both the planting patterns were significantly superior over remaining treatments. The treatment of 2:1 and 2:4 planting patterns were at par and significantly superior than 4:2, 6:3 and sole sorghum treatments in recording weight of earhead per plant. The 4:2, 6:3 and sole sorghum planting patterns were at par with each other in recording weight of earhead per plant.

Weight of grain per earhead

The 3:6 planting pattern recorded highest grain yield per earhead (46.03 g) which was at par with 3:3 planting pattern and significantly superior to remaining treatments.

The planting pattern of 2:1 and 2:4 were at par and found to be significantly superior to 4:2, 6:3and sole sorghum planting patterns in recording weight of grain per earhead. Further, it was observed that treatments 4:2, 6:3 and sole sorghum were at par with each other.

Test weight

Test weight of the grain recorded in various treatments was non significant.

In general, all yield contributing characters were significant under intercropping as compared to sole sorghum crop.

4.1.2.2 Grain, fodder and *bhoosa* yield (kg/ha)

Data regarding grain, fodder and *bhoosa* yield are presented in Table 17 and graphically represented in Fig. 4.

Table 17. Grain, fodder, *bhoosa* yield (kg/ha), grain recovery of sorghum as influenced by various planting patterns

Treatments	Yield (kg/ha)			Grain recovery (%)
	Grain	Fodder	*Bhoosa*	
T_1 (2:1)	3397	8650	867	84.12
T_2 (3:3)	2295	5694	602	56.83
T_3 (4:2)	2769	6442	728	68.57
T_4 (2:4)	1781	4695	471	44.10
T_5 (6:3)	3364	8878	862	83.30
T_6 (3:6)	1876	4149	488	46.00
T_7 Sole sorghum	4038	9226	1019	--
S.E. ±	76.64	221.66	39.42	--
C.D. at 5%	230	665	122	--
G. mean	2788	6819	719	63.82

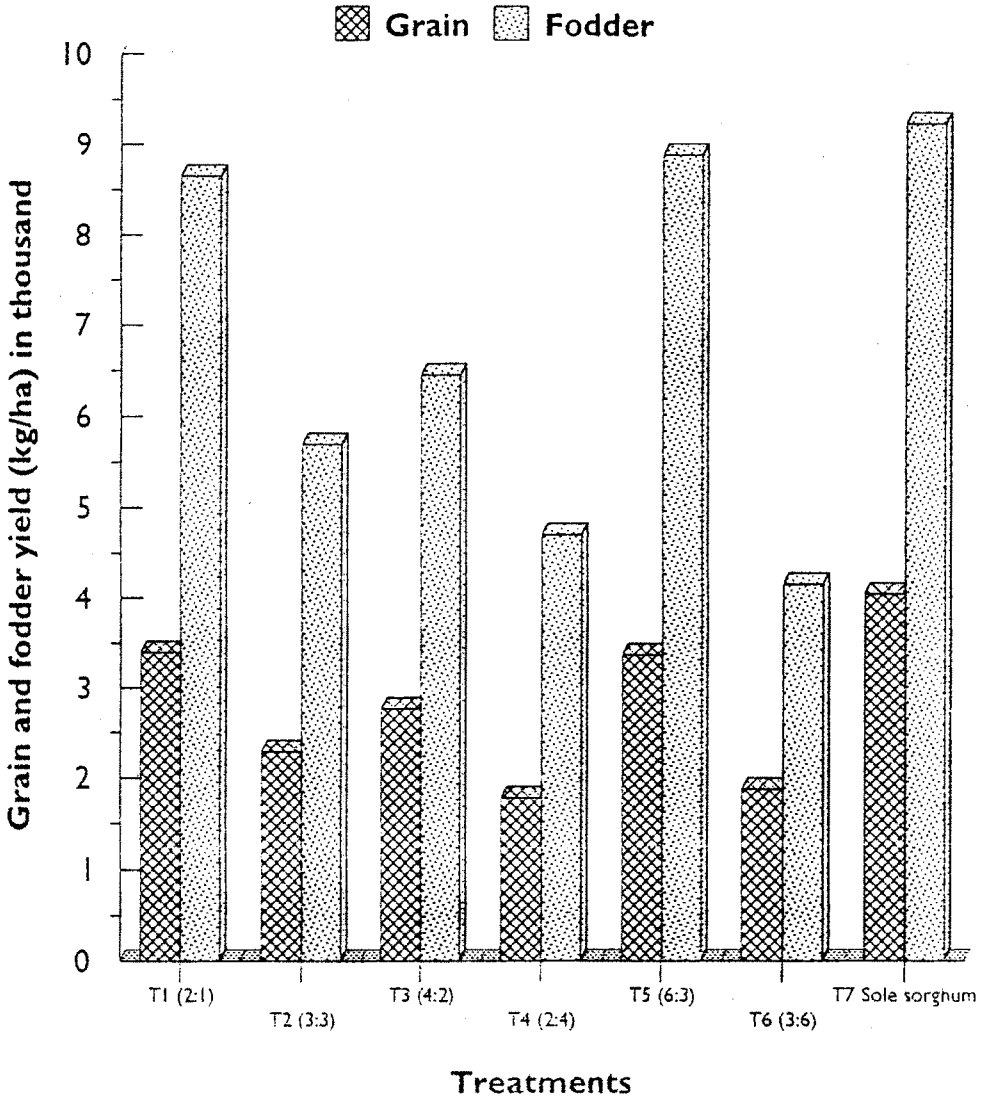

Fig. 4. Grain and fodder yield of sorghum as influenced by various treatments (kg/ha)

Grain yield

The highest grain yield of 4038 kg/ha was given by the sole sorghum which was significantly superior over all the intercropping treatments. Among the various intercropping treatments the planting pattern of 2:1 recorded highest grain yield 3397 kg/ha which was at par with 6:3 planting pattern and both these two treatments were significantly superior as compared to remaining treatments in recording grain yield per hectare.

The planting pattern of 4:2 (T_3) was significantly superior to 3:3 (T_2) and both were significantly superior over 3:6 and 2:4 planting pattern in recording grain yield per hectare. The later two treatments (3:6 and 2:4) being at par with each other.

Fodder yield

Fodder yield in kg/ha was influenced significantly due to various planting patterns of intercropping. The highest fodder yield was given by sole sorghum (9226 kg/ha) which was at par with 6:3 and 2:1 planting pattern and significantly superior to rest of the intercropping treatments. Further it was noticed that 4:2 planting pattern was significantly superior to 3:3 and both these treatments were significantly superior than 2:4 and sole sorghum (T_7) in recording fodder yield.

***Bhoosa* yield**

The highest *bhoosa* yield was recorded by sole sorghum (1019 kg/ha) which was significantly superior over all the intercropping treatments. Among various intercropping treatments the 2:1 planting pattern recorded highest *bhoosa* yield (867 kg/ha) which was at par with 6:3 planting patterns (862 kg/ha) and both these were significantly superior to remaining treatments.

The planting pattern 4:2 was significantly superior to 3:3 and both were significantly superior over 3:6 and 2:4 planting pattern. Later two treatments (3:6 and 2:4) being at par with each other.

Grain recovery

The data on grain yield recovery in percentage in various intercropping treatments as compared to sole sorghum indicated that maximum grain yield recovery was in 2:1 (84 per cent) planting pattern and 6:3 planting pattern (83 per cent), where the 66 per cent plant population was maintained. The planting pattern of 4:2 and 3:3 sorghum + soybean intercropping recorded about 68 and 56 per cent grain yield recovery as compared to sole sorghum, where 66 per cent and 50 per cent sorghum plant population was maintained in these ratios. In 3:6 and 2:4 planting pattern where 33 per cent plant population of sorghum was maintained grain yield recovery was about 46 and 44 per cent as compared to sole sorghum.

4.1.2.3 Land equivalent ratio and sorghum grain equivalent

Data on land equivalent ratio and sorghum grain equivalent are presented in Table 18.

Table 18. Land equivalent ratio and sorghum grain equivalent (kg/ha) as influenced by various treatments.

Treatments	Land equivalent ratio (%)	Sorghum grain equivalent (kg/ha)
T_1 (2:1)	1.26	6720
T_2 (3:3)	1.09	5852
T_3 (4:2)	1.04	5540
T_4 (2:4)	1.13	6053
T_5 (6:3)	1.29	6884
T_6 (3:6)	1.17	6240
T_7 Sole sorghum	--	5326
T_8 Sole soybean	--	6743
S.E. ±	--	123.33
C.D. at 5%		370
G. mean	1.16	6169

Land equivalent ratio

The data presented on land equivalent ratio in Table 18 revealed that highest land equivalent ratio was obtained in 6:3 planting pattern (1.29) followed by 2:1 planting pattern (1.26). The lowest land equivalent ratio was recorded in 4:2 planting pattern (1.04).

Grain equivalent

The highest sorghum grain equivalent yield was given by 6:3 ratio (6884 kg/ha) which was at par with sole soybean and 2:1 planting pattern and these three treatments were significantly superior over rest of the planting patterns. Further it is observed that planting patterns of 3:6 (T_6) was at par with 2:4 but significantly superior than 3:3, 4:2 and sole sorghum treatments. The planting pattern of 2:4 was at par with 3:3 but significantly superior as compared to (4:2) and sole sorghum in recording sorghum grain equivalent yield.

The 3:3 and 4:2 ratios were at par but 3:3 ratio was significantly superior than sole sorghum whereas 4:2 and sole sorghum were at par with each other in producing sorghum grain equivalent yield.

4.1.2.4 Grain to *bhoosa* and grain to fodder ratio

Data pertaining to grain to *bhoosa* and grain to fodder ratio as influenced by various treatments are presented in Table 19.

Table 19. Grain to *bhoosa* ratio and grain to fodder ratio of sorghum as influenced by different treatments.

Treatments	Grain to *bhoosa* ratio	Grain to fodder ratio
T_1 (2:1)	3.91	0.39
T_2 (3:3)	3.81	0.40
T_3 (4:2)	3.80	0.42
T_4 (2:4)	3.78	0.37
T_5 (6:3)	3.90	0.37
T_6 (3:6)	3.84	0.45
T_7 Sole sorghum	3.96	0.43
G. mean	3.85	0.40

Data regarding grain to *bhoosa* ratio and grain to fodder ratio were not analysed statistically inferences are drawn on the basis of mean values. The mean values for grain to *bhoosa* and grain to fodder ratio were 3.85 and 0.40, respectively.

Grain to *bhoosa* ratio was highest in sole sorghum (3.96) and lowest in 4:2 planting pattern (3.80).

In grain to fodder ratio it was highest in the 3:6 (0.45) planting pattern and lowest in 2:4 and 6:3 planting pattern.

4.1.2.5 Harvest index

Data relevant to harvest index in various treatments are presented in Table 20. Data were not statistically analysed. Inferences are based on mean values. The mean value of harvest index of sorghum was 0.26.

Table 20. Harvest index of sorghum as influenced by different treatments.

Treatments	Harvest index
T_1 (2:1)	0.26
T_2 (3:3)	0.26
T_3 (4:2)	0.27
T_4 (2:4)	0.25
T_5 (6:3)	0.25
T_6 (3:6)	0.28
T_7 Sole sorghum	0.28
G. mean	0.26

In PVK 801 under intercropping treatments (3:6) row proportions recorded maximum harvest index (0.28) followed by 4:2 row proportion (0.27) compared to remaining treatments of row proportion.

In case of sole crop treatment the harvest index recorded was 0.28 which was highest as compared to all the intercropping treatments.

4.2 Soybean

4.2.1 Pre-harvest studies

4.2.1.1 Emergence count and final plant stand

The data regarding emergence count and final plant stand at harvest expressed in arcsin values of various treatments are presented in Table 21.

Table 21. Emergence count and final stand of soybean as influenced by various treatments.

Treatments	Emergence count (Arcsin value)	Final plant stand (Arcsin value)
T_1 (2:1)	70.17	64.16
T_2 (3:3)	71.23	62.94
T_3 (4:2)	71.00	62.37
T_4 (2:4)	70.98	64.22
T_5 (6:3)	74.84	59.58
T_6 (3:6)	70.38	63.24
T_8 Sole soybean	68.23	64.70
S.E. $\pm$	2.41	2.14
C.D. at 5%	NS	NS
G. mean	70.97	63.30

Data presented in Table 21 revealed that there were no significant differences among various treatments in respect of emergence count and final plant stand. However, the actual plant population in various treatments was less by 10 % as compared to normal plant population to be maintained.

4.2.1.2 Mean height of soybean per plant (cm)

The mean height of soybean in cm/plant as influenced by different treatments at various stages of crop growth are given in Table 22.

Table 22. Mean plant height of soybean (cm/plant) as influenced by various treatments

Treatments	Days after sowing				
	20	40	60	80	At harvest
T_1 (2:1)	9.83	17.00	24.80	27.10	27.54
T_2 (3:3)	10.29	21.20	32.80	34.42	35.10
T_3 (4:2)	9.66	16.45	24.18	25.10	25.70
T_4 (2:4)	11.43	26.31	41.52	43.24	44.65
T_5 (6:3)	10.14	20.82	31.84	33.20	33.20
T_6 (3:6)	12.06	25.81	39.84	45.10	47.10
T_8 Sole soybean	13.77	30.60	47.64	52.84	54.64
S.E. ±	1.21	1.24	1.95	1.98	1.88
C.D. at 5%	NS	3.76	5.89	6.03	5.70
G. mean	11.02	22.59	34.66	37.28	38.27

The data presented in Table 22 revealed that mean plant height increased continuously and reached to its maximum at the time of maturity.

The rate of increase in plant height was slow upto 20 days, it was fast in between 20-40 and 40-60 days and decreased thereafter and remained constant at maturity. The mean plant height in cm per plant was influenced significantly at all the stages of crop growth except at 20 DAS. At 40, 60, 80 and harvest the sole soybean recorded maximum plant height which was significantly superior than rest of the treatments. The treatments of 2:4 and 3:6 planting patterns were at par and significantly superior as compared to T_2 (3:3), T_5 (6:3), T_1 (2:1) and T_3 (2:4) treatments. Similarly, T_2 (3:3) and T_5 (6:3) were at par and significantly superior than T_1 and T_3 (2:1 and 4:2) treatments in recording plant height, the later two i.e. T_1 and T_3 were at par.

4.2.1.3 Mean number of functional leaves per plant

Data regarding mean number of functional leaves of soybean per plant as influenced by various treatments are presented in Table 23.

Table 23. Mean number of functional leaves of soybean as influenced by various treatments

Treatments	Days after sowing			
	20	40	60	80
T_1 (2:1)	2.0	6.1	9.92	8.1
T_2 (3:3)	2.4	6.4	16.10	13.75
T_3 (4:2)	1.9	6.0	9.8	7.84
T_4 (2:4)	2.6	7.6	23.00	18.50
T_5 (6:3)	2.2	6.3	14.24	12.24
T_6 (3:6)	2.7	7.6	24.20	19.20
T_8 Sole soybean	3.1	8.3	28.60	23.66
S.E. $\pm$	0.61	0.64	1.39	1.27
C.D. at 5%	NS	NS	4.22	4.10
G. mean	2.41	6.90	17.98	14.77

The data on mean number of functional leaves of soybean per plant indicated that increase in leaf number was slow upto 20 DAS, it was fast between 20-40 and 40-60 days and decreased thereafter upto harvest.

Mean number of leaves per plant were influenced significantly at 60 and 80 DAS whereas 20 and 40 DAS it was not significant. At 60 and 80 DAS, the sole soybean produced maximum number of leaves per plant which was significantly superior than rest of the treatments. Further it is observed that the 3:6 and 2:4 planting patterns were at par and significantly superior to 3:3, 6:3, 2:1 and 4:2 ratios in producing number of leaves per plant. Similarly, the treatments of 3:3 and 6:3 planting pattern were at par and significantly

superior over 2:1 and 4:2 ratios in recording number of leaves. Later two ratios i.e. 2:1 and 4:2 were at par with each other.

4.2.1.4 Mean leaf area per plant (dm^2)

The data regarding leaf area per plant (dm^2) as influenced by various treatments are presented in Table 24.

Table 24. Mean leaf area (dm^2) of soybean as influenced by various treatments

Treatments	Days after sowing			
	20	40	60	80
T_1 (2:1)	1.39	5.96	6.24	2.14
T_2 (3:3)	1.62	6.69	9.04	4.10
T_3 (4:2)	1.34	6.05	6.10	2.28
T_4 (2:4)	1.83	7.46	12.00	6.45
T_5 (6:3)	1.55	6.22	8.95	3.84
T_6 (3:6)	1.85	7.50	12.14	6.72
T_8 Sole soybean	1.91	8.30	15.10	8.37
S.E. $\pm$	0.36	0.64	0.71	0.43
C.D. at 5%	NS	NS	2.23	1.37
G. mean	1.64	6.88	9.93	4.84

The data presented in Table 24 shows that mean leaf area per plant progressively increased upto 60 DAS and declined thereafter.

The mean leaf area (dm^2) per plant was small at 20 days, increased at faster rate upto 60 days and decreased thereafter. It was maximum at 60 DAS. Mean leaf area (dm^2/plant) was influenced significantly at 60 and 80 days whereas at 20 and 40 DAS it was not significant.

At 60 and 80 DAS, the sole soybean produced highest leaf area per plant which was significantly superior than all other remaining treatments.

Further, it is observed that the treatments of 3:6 and 2:4 planting patterns were at par and significantly superior to 3:3, 6:3, 2:1 and 4:2 planting pattern. Similarly, 3:3 and 6:3 treatments were at par and significantly superior than 2:1 and 4:2 row proportions treatments, whereas later two ratio 2:1 and 4:2 were at par with each other.

4.2.1.5 Total dry matter accumulation per plant (g)

Data on total dry matter accumulation per plant (g) as influenced by various treatments are presented in Table 25.

Table 25. Total dry matter accumulation per plant of soybean as influenced by various treatments (g/plant)

Treatments	Days after sowing				
	20	40	60	80	At harvest
T_1 (2:1)	1.05	7.74	14.60	19.20	16.42
T_2 (3:3)	1.15	9.24	18.70	22.00	19.74
T_3 (4:2)	1.00	7.84	15.00	18.40	15.62
T_4 (2:4)	1.28	11.09	23.40	24.10	22.10
T_5 (6:3)	1.14	9.00	17.28	21.42	18.80
T_6 (3:6)	1.30	11.44	24.00	25.98	23.50
T_8 Sole soybean	1.40	13.61	26.33	28.60	26.93
S.E. $\pm$	0.21	1.29	0.73	0.68	0.69
C.D. at 5%	NS	NS	2.21	2.10	2.11
G. mean	1.18	9.99	19.44	22.81	20.44

Data on total dry matter accumulation in g/plant of soybean crop indicated that the total dry matter accumulation was very slow at initial stage, it increased slowly upto 20 days, it was fast upto 40 days, it was very fast upto 60 days, slow upto 80 days and decreased thereafter.

Total dry matter accumulation in g/plant was influenced significantly at 60, 80 and at harvest, whereas at 20 and 40 days it was not significant.

At 60, 80 and at harvest the sole soybean crop produced maximum total dry matter per plant which was significantly superior than rest of the treatments.

Further it was observed that treatments T_6 (3:6) and T_4 (2:4) were at par and significantly superior to planting patterns of 3:3, 6:3, 2:1 and 4:2 in producing total dry matter. Similarly the treatments of 3:3 and 6:3 planting patterns were at par and significantly superior to 2:1 and 4:2, the later two at par with each other in producing dry matter (g) per plant.

4.2.1.6 Mean number of branches per plant

The data regarding mean number of branches of soybean/plant recorded at various growth stages are presented in Table 26.

Table 26. Mean number of branches per plant of soybean as influenced by various treatments

Treatments	Days after sowing		
	60	80	At harvest
T_1 (2:1)	2.0	3.0	3.0
T_2 (3:3)	2.2	3.2	3.2
T_3 (4:2)	2.0	3.0	3.0
T_4 (2:4)	2.6	3.2	3.2
T_5 (6:3)	2.1	3.1	3.1
T_6 (3:6)	2.4	3.3	3.3
T_8 Sole soybean	2.7	3.4	3.4
S.E. $\pm$	0.59	0.24	0.24
C.D. at 5%	NS	NS	NS
G. mean	2.28	3.17	3.17

The data on mean number of branches per plant given in Table 26 indicated that the number of branches were less at 60 DAS, increased slowly upto 80 DAS and remained constant at harvest.

The mean number of branches per plant of soybean crop were not influenced significantly due to various treatments.

4.2.1.7 Mean number of pods per plant

The data on mean number of pods per plant of soybean are presented in Table 27.

Table 27. Mean number of pods per plant of soybean as influenced by various treatments

Treatments	Days after sowing		
	60	80	At harvest
T_1 (2:1)	14.10	17.00	19.28
T_2 (3:3)	24.10	28.00	31.20
T_3 (4:2)	12.45	15.84	17.24
T_4 (2:4)	31.80	36.42	38.52
T_5 (6:3)	21.62	24.14	28.62
T_6 (3:6)	32.32	38.24	40.14
T_8 Sole soybean	38.56	45.17	48.46
S.E. $\pm$	1.56	1.86	2.04
C.D. at 5%	4.75	5.62	6.15
G. mean	25.00	29.25	31.92

The data given in Table 27 indicated that the mean number of pods per plant at 60, 80 DAS and at harvest were 25, 29.25 and 32, respectively.

The mean number of pods per plant were influenced significantly due to various treatments at all the stages of crop growth. The highest number of pods per plant were recorded by the treatment of sole soybean which was

significantly superior over rest of the treatments of intercropping. Among the various intercropping treatments T_6 (3:6) recorded highest number of pods/plant which was at par with T_4 (2:4) treatment and both these treatments were significantly superior over 3:3, 6:3, 2:1 and 4:2 planting patterns at all the stages.

Similarly the planting patterns of 3:3 and 6:3 were at par and both were significantly superior to 2:1 and 4:2 planting patterns at all stages, the later two treatments (2:1 and 4:2) being at par with each other.

4.2.1.8 Growth function

Data on AGR, RGR, 50 per cent flowering and LAI as affected by various treatments were not statistically analysed. The inferences are drawn on the basis of mean values.

4.2.1.8.1 Absolute growth rate for height (cm/plant/day)

Data regarding AGR for height are presented in Table 28.

Table 28. Mean absolute growth rate for plant height of soybean as influenced by various treatments (cm/plant/day).

Treatments	Days after sowing			
	21-40	41-60	61-80	81-harvest
T_1 (2:1)	0.358	0.390	0.115	0.020
T_2 (3:3)	0.545	0.580	0.081	0.045
T_3 (4:2)	0.339	0.386	0.046	0.040
T_4 (2:4)	0.744	0.760	0.099	0.094
T_5 (6:3)	0.534	0.551	0.068	0.000
T_6 (3:6)	0.687	0.701	0.263	0.133
T_8 Sole soybean	0.841	0.851	0.260	0.120
G. mean	0.578	0.602	0.133	0.065

The data indicated that the mean absolute growth rate for height was higher in 21-40 and 41-60 DAS and further it was declined till harvest.

At 21-40 DAS and 41-60 DAS sole soybean showed higher AGR than rest of the intercropping treatments and among intercropping treatments 3:6 and 2:4 showed higher AGR than remaining intercropping treatments. At 61-80 DAS and at harvest the AGR for height was highest in T_6 (3:6) and T_8 (Sole soybean) treatments.

4.2.1.8.2 Absolute growth rate for total dry matter (g/plant/day)

Data regarding AGR for total dry matter (g/plant/day) are presented in Table 29.

Table 29. Mean absolute growth rate for total dry matter of soybean as influenced by various treatments (g/plant/day).

Treatments	Days after sowing			
	21-40	41-60	61-80	81-harvest
T_1 (2:1)	0.334	0.358	0.215	-0.185
T_2 (3:3)	0.404	0.473	0.165	-0.150
T_3 (4:2)	0.342	0.358	0.170	-0.185
T_4 (2:4)	0.490	0.615	0.035	-0.133
T_5 (6:3)	0.393	0.414	0.207	-0.174
T_6 (3:6)	0.507	0.628	0.099	-0.165
T_8 Sole soybean	0.610	0.636	0.113	-0.111
G. mean	0.440	0.497	0.143	-0.157

The data on AGR for total dry matter indicated that in general during first 60 days from sowing AGR for dry matter increased steadily and declined thereafter.

At 21-40 and 41-60 days sole soybean and 3:6 planting pattern recorded higher AGR for total dry matter as compared to rest of the treatments.

At 61-80 DAS higher AGR was seen in 2:1 and 6:3 treatments whereas at harvest it was maximum in 2:1, 4:2 and 3:6 planting patterns.

4.2.1.8.3 Relative growth rate for total dry matter (g/g/day)

The values of RGR for total dry matter (g/g/day) computed from the data of total dry matter is given in Table 30.

Table 30. Mean relative growth rate for total dry matter of soybean as influenced by various treatments (g/g/day).

Treatments	Days after sowing			
	21-40	41-60	61-80	81-harvest
T_1 (2:1)	0.099	0.032	0.126	-0.0103
T_2 (3:3)	0.104	0.035	0.008	-0.0072
T_3 (4:2)	0.102	0.032	0.010	-0.0109
T_4 (2:4)	0.107	0.037	0.001	-0.0057
T_5 (6:3)	0.103	0.032	0.010	-0.0086
T_6 (3:6)	0.108	0.037	0.003	-0.0066
T_8 Sole soybean	0.113	0.034	0.004	-0.0040
G. mean	0.119	0.034	0.006	-0.0076

The data on RGR for total dry matter indicated that it was higher between 21-40 DAS and decreased thereafter till harvest.

At 21-40 DAS RGR for total dry matter was highest in sole soybean followed by 3:6 planting patterns. At 41-60 DAS it was highest in 3:6 and 2:4 planting patterns. At 61-80 DAS it was highest in 2:1 ratio. At harvest it was negative in all the treatments.

4.2.1.8.4 Studies on 50 per cent flowering

Data on 50 per cent flowering of soybean are presented in Table 31.

Table 31. Days required to 50 per cent flowering as influenced by various treatments in soybean

Treatment	Days to 50 per cent flowering
T_1 (2:1)	34
T_2 (3:3)	35
T_3 (4:2)	36
T_4 (2:4)	38
T_5 (6:3)	34
T_6 (3:6)	40
T_8 Sole soybean	39
G. mean	36

The data recorded on 50 per cent flowering revealed that the mean number of days required for 50 per cent flowering were 36 days after sowing. The early flowering in 34 days was noticed in the treatments of 2:1 and 6:3 planting pattern as compared to other treatments.

4.2.1.8.5 Leaf area index (LAI) per plant

Data regarding leaf area index as influenced by various treatments are presented in Table 32.

Table 32. Leaf area index per plant as influenced by various treatments

Treatments	Days after sowing			
	20	40	60	80
T_1 (2:1)	0.617	2.648	2.773	0.955
T_2 (3:3)	0.720	2.973	4.017	1.822
T_3 (4:2)	0.595	2.688	2.711	1.013
T_4 (2:4)	0.813	3.315	5.333	2.866
T_5 (6:3)	0.688	2.764	3.977	1.706
T_6 (3:6)	0.822	3.333	5.395	2.986
T_8 Sole soybean	0.848	3.688	6.711	3.720
G. mean	0.729	3.058	4.416	2.152

Data presented on leaf area index in Table 32 showed that the leaf area index of soybean increased progressively from sowing to 60 DAS and decreased thereafter. It was small at 20 DAS, increased steadily at 40 DAS and maximum at 60 DAS and decreased at harvest.

At 20, 40 and 60 DAS the maximum LAI was noticed in sole soybean, 3:6, 6:3 and 2:1 planting patterns. At 80 DAS maximum LAI was observed in sole soybean followed by 3:6 and 2:4 planting patterns.

4.2.2 Post harvest studies

4.2.2.1 Number of pods per plant, grain weight per plant and test weight (100 grain)

Data regarding the number of pods per plant, grain weight per plant and test weight (100 grains) are presented in Table 33.

Table 33. Mean number of pods per plant, grain weight per plant and test weight of soybean as influenced by various treatments.

Treatments	Number of pods/plant	Grain weight per plant (g)	Test weight (100 grain) (g)
T_1 (2:1)	19.28	5.42	9.14
T_2 (3:3)	31.20	6.40	9.00
T_3 (4:2)	17.24	5.10	9.10
T_4 (2:4)	38.52	7.34	9.34
T_5 (6:3)	28.62	6.25	9.24
T_6 (3:6)	40.14	7.45	9.18
T_8 Sole soybean	48.46	8.00	9.64
S.E. ±	2.04	0.16	0.51
C.D. at 5%	6.15	0.51	NS
G. mean	31.92	6.56	9.23

There was significant difference in all the yield contributing characters due to various planting patterns.

Number of pods per plant

Mean number of pods/plant at harvest were 31.92/plant. The highest number (48.46 pods/plant) was recorded in treatment of sole soybean (T_8) which was significantly superior to all other intercropping treatments. The pod number reduced when soybean was intercropped with sorghum. Among different intercropping treatments T_6 (3:6) and T_4 (2:4) recorded highest number of pods per plant which were at par with each other and significantly superior than 3:3, 6:3, 2:1 and 4:2 row proportions. Further, it was observed that row proportions of 3:3 and 6:3 were at par and significantly superior to 2:1 and 4:2 row proportions. The lowest number of pods per plant were recorded by 4:2 planting pattern.

Grain weight per plant

The highest grain weight (8.00 g/plant) was recorded in sole soybean which was found to be significantly superior over rest of the intercropping. In intercropping treatments 3:6 and 2:4 row ratios were at par and significantly superior over rest of planting patterns. Lowest pods grain weight per plant was recorded in 4:2 planting pattern.

Test weight

The mean test weight (100 grain weight) of soybean crop was observed to be 9.23 g. The test weight (100 seed weight) was not affected significantly due to various treatments.

4.2.2.2 Seed, straw and biological yield (kg/ha) and harvest index

Data regarding seed, straw and biological yield and harvest index are presented in Table 34 and graphically shown in Fig. 5.

Table 34. Mean seed, straw, biological yield, harvest index and grain recovery as influenced by various treatments

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index	Grain recovery (%)
T_1 (2:1)	664	499	1163	0.57	31.37
T_2 (3:3)	862	669	1531	0.56	40.73
T_3 (4:2)	589	408	997	0.59	27.83
T_4 (2:4)	1135	882	2017	0.56	53.63
T_5 (6:3)	715	578	1293	0.55	33.79
T_6 (3:6)	1186	995	2181	0.54	56.04
T_8 Sole soybean	2116	1667	3783	0.55	100
S.E. $\pm$	52	39	--	--	--
C.D. at 5%	156	120	--	--	--
G. mean	1038	814	1852	0.56	---

Seed yield of soybean

Data presented in Table 34 indicated that the highest seed yield (2116 kg/ha) was given by the treatment of sole soybean which was significantly superior over rest of the treatments of intercroppings.

Among the various planting pattern of intercropping 3:6 and 2:4 planting patterns were at par and found to be significantly superior over rest of the planting patterns in recording grain yield. Further, it is observed that the planting pattern of 3:3, 6:3 were at par and 3:3 was significantly superior to 2:1 and 4:2 planting pattern in giving seed yield.. Similarly row ratio was 6:3 found to be at par with 2:1 and 4:2 planting pattern. Lowest seed yield was recorded by 4:2 planting pattern.

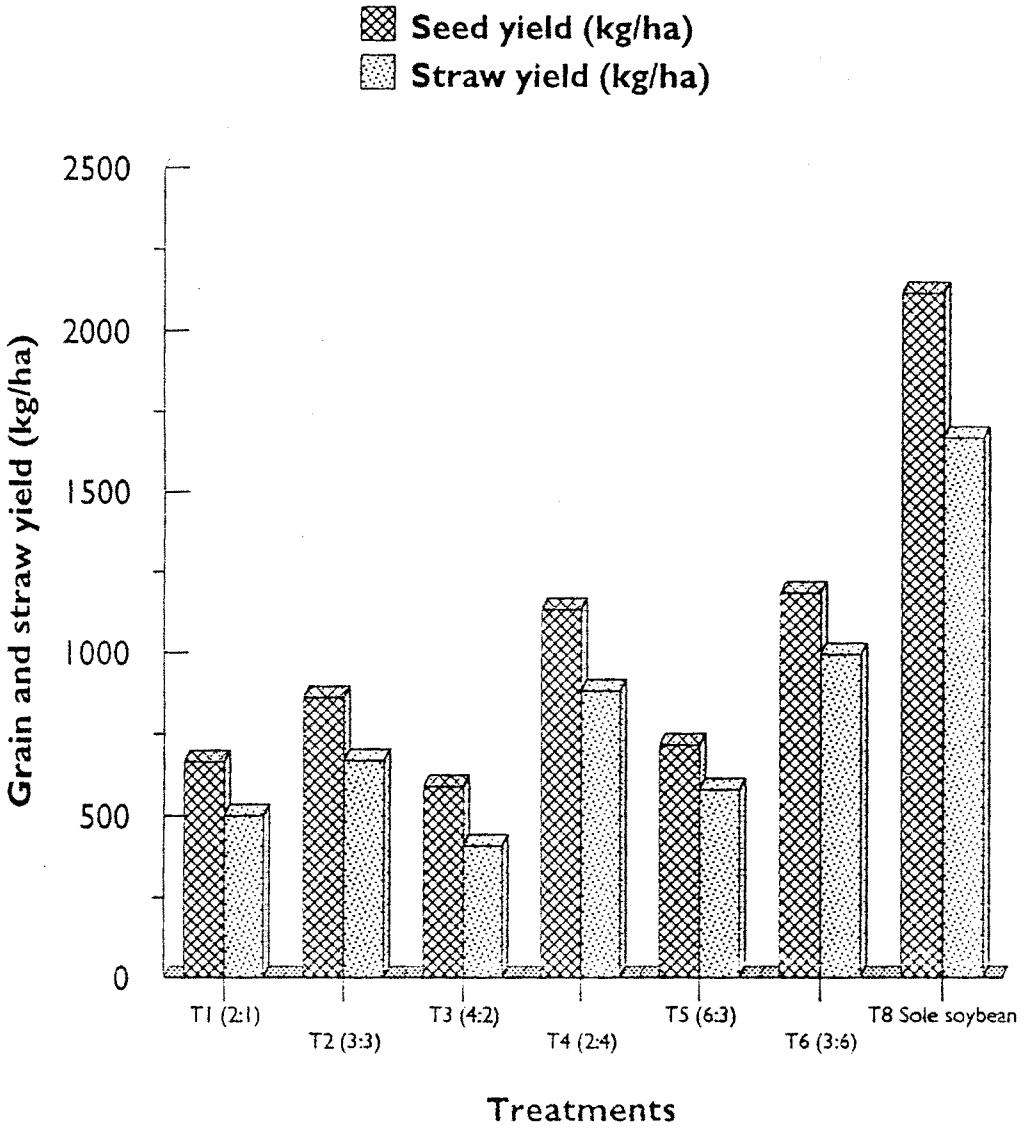

Fig. 5. Grain and straw yield of soybean as influenced by various treatments (kg/ha)

Straw yield

In case of straw yield sole soybean recorded highest yield (1667 kg/ha) which was significantly superior as compared to rest of the treatments.

Among the various intercropping treatments the row proportion of 3:6 and 2:4 recorded highest straw yield which was at par and significantly superior than remaining intercropping treatments. Further, it was observed 3:3 and 6:3 were at par and 3:3 significantly superior than 2:1 and 4:2 planting pattern the later two being at par with each other and 2:1 and 6:3 ratios were also at par with each other.

Biological yield

Data on biological yield indicated that the sole soybean treatment produced highest biological yield as compared to all the remaining treatments.

In case of various planting patterns of intercropping the highest biological yield was recorded in 3:6 followed by 2:4 ratios. Lowest biological yield was recorded in treatment 4:2 planting pattern.

Harvest index

The mean value of harvest index of soybean was 0.56. Maximum harvest index was recorded in T_3 (4:2) followed by 2:1 ratio. The lowest harvest index was noticed in 3:6 row ratio.

Grain recovery

Highest grain recovery was found in 3:6 and 2:4 planting patterns (56 and 53 respectively) where the plant population was 66 per cent maintained compared to sole soybean. Lowest grain recovery was recorded in 4:2 planting patterns (27 per cent) where plant population was 33 per cent.

4.3 Gross monetary return and net return

Data regarding gross monetary returns and net returna (Rs/ha) are presented in Table 35 and depicted in Fig. 6.

Prices of various components of crop in Rs/q.

1. Kharif sorghum grain Rs. 358
2. Kharif sorghum fodder Rs. 50
3. Soybean grain Rs. 1117
4. Soybean straw Rs. 30

Table 35. Gross monetary returns and net returns as influenced by various treatments (Rs./ha)

Treatments	Gross monetary return (Rs/ha)	Net monetary return (Rs/ha)	Cost of cultivation (Rs/ha)	Additional return over sole sorghum (Rs/ha)
T_1 (2:1)	24062	14565	9497	4883
T_2 (3:3)	20893	11410	9483	1728
T_3 (4:2)	19835	10479	9356	797
T_4 (2:4)	21671	12252	9419	2570
T_5 (6:3)	24648	15292	9380	5610
T_6 (3:6)	22344	12925	9419	3243
T_7 Sole sorghum	19070	9682	9388	---
T_8 Sole soybean	24143	14706	9437	---
S.E. $\pm$	470	426	---	---
C.D. at 5 %	1417	1285	---	---
G. mean	22083	12664	9422	2562

Gross monetary returns

Data presented in Table 35 revealed that maximum gross monetary returns (Rs. 24648/ha) were obtained in 6:3 planting pattern which was at par with sole soybean and 2:1 planting pattern and all these three treatments were found to be significantly superior over rest of the planting

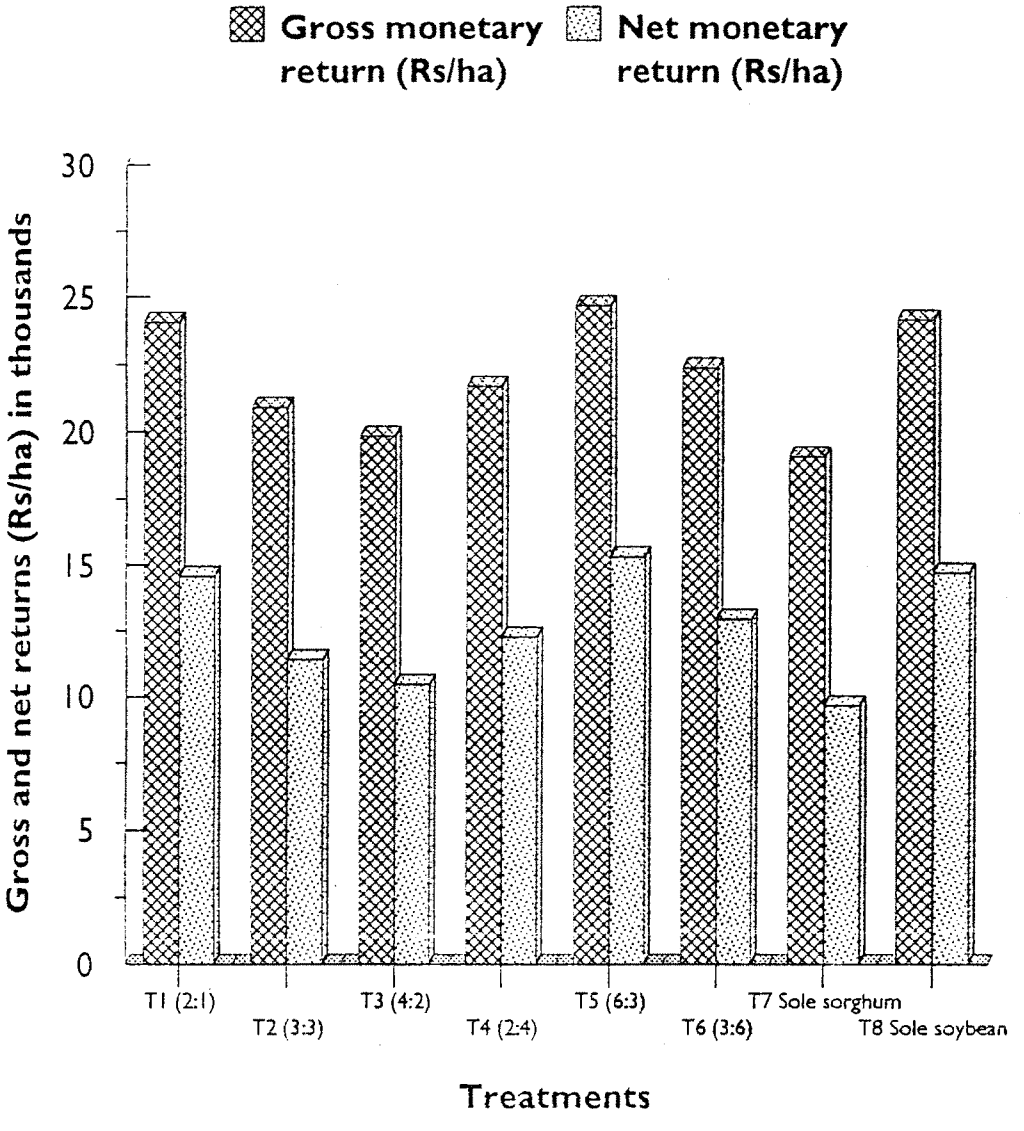

Fig. 6. Gross and net returns (Rs/ha)

patterns. Further it was observed that planting pattern of 3:6 was at par with 2:4 but significantly superior than 3:3, 4:2 and sole sorghum. The planting pattern of 2:4 was at par with 3:3 but significantly superior as compared to 4:2 and sole sorghum in recording gross monetary return.

The treatments of 3:3 and 4:2 planting pattern were at par but 3:3 was significantly superior than sole sorghum whereas 4:2 ratio and sole sorghum were at par with each other.

Net returns

Highest net returns (Rs 15292/ha) were obtained in planting pattern of 6:3 which was at par with sole soybean and 2:1 planting pattern and these three treatments were significantly superior over rest of the planting patterns. Further, it was observed that planting pattern of 3:6 was at par with 2:4 but significantly superior than 3:3, 4:2 ratio and sole sorghum treatments. The planting pattern of 2:4 was at par with 3:3 but significantly superior as compared to 4:2 and sole sorghum in recording net returns.

Treatments of 3:3 and 4:2 planting patterns were at par but 3:3 was significantly superior than sole sorghum whereas 4:2 ratio and sole sorghum were at par with each other.

Additional returns over sole sorghum

Data presented in Table 35 indicated that highest additional returns over sole sorghum was given by 6:3 planting pattern i.e. Rs. 5610/ha followed by 2:1 planting pattern Rs. 4883/ha. Lowest additional returns were from 4:2 planting patterns of Rs. 797/ha.

Multiple regression

Table 36 : Parameters of population dynamics (row proportion) on sorghum equivalent and yield of sorghum and soybean.

Treatments	Sorghum equivalent	Sorghum yield	Soybean yield
Intercept (Bo)	6885.30	5004.12	32.6601
Slope of sorghum row (b_1)	-13.6294	-7.23265	0.90642
Slope of soybean row (b_2)	-2.36108	-47.1197	19.2299
R^2	0.475	0.964	0.971
SEY I	498.638	284.17	122.198

The data on parameters of relation of row proportion dynamics on sorghum equivalent and seed yields sorghum so also soybean presented in Table 36 showed that the row dynamics has shown appreciable influence on the dependent parameters (sorghum equivalent, sorghum and soybean yield). The critical examination of intercept (Bo) showed that intercropping of sorghum + soybean was more use full than its sorghum as well as soybean.

The regression parameters of the said relationship showed that the influence of proportion of rows of sorghum and soybean on sorghum equivalent and yields of respectively crop were different. These data further showed that the effects of row proportion of sorghum on sorghum equivalent were 5.77 times greater than soybean row proportions. On contrary they were 0.15 and 0.04 times in sorghum and soybean yields respectively. From these data it is inferred that the reduction in row proportions of soybean in sorghum + soybean cropping system were less remunerative than sorghum row proportions due to adoption of replacement series. This is because the plant population in an agronomic yield attribute is more important tjam rest of the yield attributes

Further these analysis showed that the competitiveness of either of the crops on each other could not be established due to use of replacement of series in the study. If the additive series would have been use in series then competitiveness and appropriate row proportions for attaining equilibrium in sorghum equivalent would have been possible. Still the use of sorghum + soybean intercropping system would hold good under semi arid environments for insulating risk of failure of either crop due to weather calamities.

Discussion

Chapter-V

DISCUSSION

5.1 Soil, weather and crop growth

Soil analysis data in Table 1 would show that the soil of experiment site was clayey in nature with low in nitrogen and phosphorus and high in organic carbon and potash. The depth of soil was near about 1.5 meters which helped for soil moisture storage.

Weather data given in Table 3 indicated that total rainfall of 740.4mm distributed in 35 rainy days was received during crop growth period. In month June the amount of rainfall received was 316 mm which helped for better establishment of both the crops. In the month of July rainfall about 127.1 mm was received that was beneficial for growth and development of crop. In the month of August there was about 215.5 mm rainfall which helped for grain formation and grain development in both crops. However in the month of September there was about only 80 mm rainfall and the monsoon was withdrawl earlier on 24th September.

The distribution of rainfall was fair. Early withdrawal of monsoon in second week of September had little moisture stress effect on soybean but kept the sorghum crop free from grain mold disease.

The maximum and minimum temperature were in the range of 27.7 to 40.0°C and 14.4 to 26.0°C respectively during the crop growth of sorghum and soybean. Relative humidity in morning hours ranged in between 57 to 90 per cent where as in after noon it was in between 26 to 79.

The temperature and relative humidity observed during the year helped for better growth and yield of both component crops.

The experimental crops viz. sorghum with variety PVK 801 and soybean JS 335 were sown by dibbling method on 21st June 2002. Emergence was satisfactory. Plant stand of both crops was not influenced by various treatments. This revealed that uniform emergence and plant stand was there throughout the period of research and treatment differences under study were the real effects.

5.2 Sorghum

From the data it is seen that the growth of crop in terms of mean height, mean number of functional leaves increased progressively from sowing upto 60 days of crop growth due to active growth of the crop. Also it is seen that the mean height recorded increased till harvest due to panicle development, the maximum increase in height was recorded during 40-60 DAS probably because of active grand growth period.

When sorghum intercropped with soybean (or legumes) there was improvement in height of sorghum crop. Such observation are also reported by Patil (1970) and Chudawant (1971).

The comparison of the sole sorghum and intercropped sorghum in this experiment showed that intercropped sorghum found to be improved in the yield attributing characters like number of leaves, leaf area and dry matter production per plant of sorghum because of complimentary effect in terms of more availability of nitrogen, sunlight and aeration to sorghum. Such results are also reported by Patil (1970).

Accordingly, maximum AGR for height (cm/plant/day) was recorded between 40 to 60 days. At 40 days, the mean number of functional leaves were 3.57/plant and corresponding leaf area observed was 1281 cm^2 reached to its maximum at 60 DAS (7.74 and 3575 cm^2 respectively) and declined thereafter due to drying of leaves. Increase in number of leaves and leaf area was due to grand growth period in sorghum which is observed during 30-70 DAS. But in intercropping treatments the LAI was more because of beneficial or complimentary effects of soybean on sorghum as soybean is a low canopy crop.

Effect of different treatments (planting pattern) on growth characters of sorghum.

The growth of sorghum in respect of plant height, total dry matter production, mean number of leaves and leaf area per plant was influenced significantly due to various planting patterns of sorghum + soybean intercropping. The planting pattern of 3:6 and 3:3 produced significantly more plant height, number of leaves, leaf area and total dry matter/plant as compared to remaining planting patterns, because of complimentary effect was of low canopy crop of soybean on sorghum in terms of more availability of nitrogen, aeration and better penetration of light. This complimentary effect due to both the variation in root habit, duration and developmental stage of sorghum and soybean.

The growth characters like height, number of leaves, leaf area and total dry matter accumulation were significantly higher in 3:6 and 3:3 planting pattern as compared to 2:1, 4:2, 6:3 ratios due to less complimentary effect on sorghum crop as number of soybean lines were

reduced in these ratios. Wahatule (1985), Ibrahim *et al.* (1993) also reported beneficial effects of sorghum + legume intercropping on the growth characters of sorghum.

Yield contributing characters

In the sorghum,yield contributing characters are length, girth and weight of earhead, weight of grain per earhead and test weight which were found maximum under intercropping as compared to sole cropping.

Length of earhead produced in 3:6 and 3:3 planting patterns was maximum compared to sole sorghum and other ratios due to complimentary effect of soybean.

Ghatol (1970), Jagannathan *et al.* (1974) also observed beneficial effect on above characters due to intercropping of legumes in cereals.

In case of girth and weight of earhead it was found to be maximum and significantly superior in 3:3 and 3:6 planting patterns as compared to rest of planting pattern and sole sorghum. These finding are in conformity with the earlier findings reported by Guldekar (1974) and Deshpande (1971).

The thousand seed weight of sorghum was not influenced significantly due to various sorghum + soybean intercropping treatments.

In general the sorghum crop was benefited in improving the yield attributing characters like length, girth and weight of earhead, due to sorghum + soybean intercropping in 3:6 and 3:3 planting patterns as compared to other planting patterns and sole sorghum. This is because of more population of intercrop in these ratios benefited the sorghum crop

through availability of more nitrogen, aeration, penetration of more sunlight and other natural resources. In these two ratios (3:6 and 3:3) there was also less competition among sorghum plant population as compared to sole sorghum and other planting patterns, which resulted in improvement in yield attributes of sorghum.

5.3 Soybean

Effect of different treatments on growth characters of soybean

The height of soybean crop was found to be reduced in all the intercropping treatments because of competitive effect of sorghum crop in the initial stages as the sorghum crop is very fast growing crop and during later stage shade effect might have been reduced the height of soybean. In the sorghum + soybean intercropping treatments of 3:6 and 2:4 of the plant height of soybean is comparatively more as compared to other ratios because less competitive effect of sorghum on soybean. Similar results were reported by Singh *et al.* (1991).

The increase in number of leaves and leaf area was less in initial stages, increased at faster rate during 20 to 40 and 40 to 60 days and decreased thereafter due to less senescence.

The number of leaves, LAI were influenced significantly due to various planting patterns of sorghum + soybean intercropping. Among the intercropping treatment's planting patterns of 3:6 and 2:4 recorded significantly superior number of leaves and leaf area in sq. dm as compared to remaining ratios, indicating thereby that there was less competitive effect on soybean crop as compared to other ratios (2:1, 3:3, 4:2 and 6:3). Chandal *et al.* (1993) also reported similar results.

In case of number of branches per plant they were not influenced significantly due to various treatments of intercropping, which showed that there was no effect of row proportions on number of branches. Singh *et al.* (1991) also observed similar results.

Data on total dry matter in g/plant of soybean crop indicated that total dry matter accumulation was very slow at initial stages, it increased slowly upto 20 days, fast upto 40-60 DAS probably because of active growth period and slow from 80 day to harvest, because of leaf senescence. The total dry matter accumulation was influenced significantly at 60, 80 DAS and at harvest, whereas at 20 and 40 DAS it was not significant. At 60, 80 DAS and at harvest the sole soybean recorded highest total dry matter as compared to rest of intercropping treatments indicating thereby that, there was competitive effect of sorghum on soybean crop in reducing total dry matter per plant. The planting pattern of 3:6 and 2:4 were significantly superior than other ratios in accumulating total dry matter indicating that there was less competitive effect in these ratios as compared to other ratios. These findings are in conformity with Balsubramanium and Venkatashwarlu (1989).

Data on AGR indicated that mean absolute growth rate for height was higher in 41-60 DAS and further it was declined till harvest. At 21-40 DAS and 41-60 DAS sole soybean showed higher AGR than rest of the intercropping treatments and among intercropping treatments 3:6 and 2:4 showed higher AGR than remaining intercropping treatments. At 60-80 DAS and at harvest the AGR for height was highest in 3:6 and sole soybean treatment.

Data on RGR for total dry matter indicated that it was higher at 21-40 DAS and decreased thereafter, RGR was slightly better batter in sole soybean followed by 3:6 planting pattern in initial stages. At later stages it was higher in 2:1 ratio.

Data on LAI showed that it was small at initial and decreased thereafter probably because of leaf senescence. Maximum LAI was observed in sole soybean followed by 3:6 treatment.

Yield contributing characters of soybean

The data on number of pods/plant and grain weight/plant indicated that they were highest and significantly superior in sole soybean as compared to all the planting patterns. Among the different planting patters the ratio of 3:6 and 2:4 recorded maximum number of pods and grain weight per plant as compared to other ratios. This is because of less competitive effect of sorghum on soybean in these treatments. Test weight was not affected significantly due to various treatments.

Yield of sorghum

Grain yield

The grain yield of sorghum crop was highest in sole crop of sorghum (4038 kg/ha) which was significantly superior over all the planting patterns of sorghum + soybean intercropping because of hundred per cent plant population of sorghum. Among various intercropping treatments the planting pattern of 2:1 recorded highest sorghum grain yield of 3397 kg/ha which was at par with 6:3 planting pattern and both were significantly superior as compared to remaining planting patterns. The ratio of 4:2 was significantly superior than 3:3 and both were superior over 3:6 and 2:4

planting pattern whereas later two treatments (3:6, and 2:4) being at par with each other. Though the plant population of sorghum was reduced to 66 per cent in 2:1 and 6:3 planting pattern the grain yield recovery was 83 and 84 per cent respectively as compared to sole sorghum. Similarly, in the planting patterns of 4:2 and 3:3 the grain yield recovery was 68 and 56 per cent, though the sorghum plant population was 66 and 50 per cent as compared to sole sorghum. This increase in grain yield recovery inspite of less population of sorghum is because of complimentary effect of soybean in terms of more availability of nitrogen, better aeration and better penetration of sunlight. Similar findings were reported by Wahatule (1985), Deshpande (1991) and Pal *et al.* (1991).

The fodder yield in kg/ha was influenced significantly due to various planting pattern of intercropping. The highest fodder yield was given by sole sorghum (9226 kg/ha) which was at par with 6:3 and 2:1 planting patterns and significantly superior as compared to rest of intercropping treatments. In planting patterns of 6:3 and 2:1 though the plant population of sorghum was reduced to 66 per cent it has given equivalent fodder yield to that of sole sorghum. This indicated that there is complimentary effect of soybean on sorghum crop.

Yield of soybean

Data in Table 34 indicated that highest seed yield (2116 kg/ha) was given by sole soybean which was significantly superior over rest of treatments of intercropping. The next best treatments were 3:6 and 2:4 planting patterns which were at par and had given significantly superior seed yield than other planting patterns. This is because of the 100 per cent

population in sole soybean, 66 per cent in 3:6 and 2:4 planting patterns where as in rest of planting patterns yield was reduced due to lower population of soybean in 2:1, 3:3, 4:2 and 6:3 ratios (33 %, 50 %, 33 % and 33 % plant population, respectively).

Lowest yield was recorded in 4:2 planting pattern. Similar trend was observed in straw and biological yield of soybean. Whatule, (1985), Pal *et al.* (1993), also reported similar findings.

Net returns

The effect of different treatments on gross and net monetary returns were significant. The intercropping of sorghum with soybean with 6:3 and 2:1 planting pattern recorded maximum net returns of Rs. 15292, and Rs. 14565/ha, respectively which were at par with sole soybean and superior over rest of planting patterns and sole sorghum. This indicated the beneficial effect of including soybean as intercrop in sorghum by replacing one third plant population of sorghum crop in 6:3 and 2:1 ratios. The planting pattern of 6:3 and 2:1 ratio had given additional benefit of Rs. 5610 and Rs. 4883/ha, respectively as compared to sole sorghum.

In general, highest net returns was obtained in intercropping as compared to sole cropping system. These findings are in conformity with those reported by Wahatule (1985), Deshpande (1991), and Dhope *et al.* (1992).

Multiple regression

Data shown in Table 36 indicated that the competitiveness of either of the crops on each other could not be established due to use of replacement series in the study. If the additive series would have been used

in series then competitiveness and appropriate row proportions for attaining equilibrium in sorghum equivalent would have been possible. Still the use of sorghum + soybean intercropping system would hold good under semi arid environments for insulting risk of failure of either crop due to weather calamities (Snedecor and Cochran, 1980).

Summary and Conclusion

Chapter-VI

SUMMARY AND CONCLUSION

An agronomic investigation entitled "Studies on planting pattern of the sorghum + soybean Intercropping system" was carried out at sorghum Research Station, Marathwada Agricultural University, Parbhani during *kharif* 2002-2003 on vertisol to find out suitable cropping system for optimising yield recovery of sorghum and soybean as intercrop.

The experiment was laid out in randomized block design with eight treatments replicated three times. Treatment of sorghum + soybean intercroppings were as in T_1 (2:1), T_2(3:3), T_3 (4:2), T_4 (2:4), T_5 (6:3), T_6 (3:6), T_7 (sole sorghum) and T_8 (sole soybean).

Besides yield data periodical observations were recorded on growth and yield contributing characters of sorghum and soybean to evaluate treatments' effects, some important findings from research are discussed below.

Sorghum

The growth characters viz. plant height, number of leaves, leaf area per plant and total dry matter were found maximum in 3:6 and 3:3 planting pattern and significantly superior as compared to sole sorghum crop.

The growth analysis in terms of AGR, RGR and LAI indicated that the grand growth period of sorghum appeared to be in between 40 to 80 DAS. However, the values of AGR, RGR and LAI were

maximum in 3:6 and 3:3 planting patterns in earlier stages, later on it was inconsistent.

Maximum length of earhead, girth of earhead and weight of earhead was found in 3:6 and 3:3 planting pattern which was found significantly superior over other intercropping treatments as well as sole sorghum.

In general, all the growth characters and yield contributing characters were found maximum in 3:6 and 3:3 row proportions as compared to remaining ratios and sole sorghum.

Maximum grain yield/ha was recorded in sole sorghum as compared to all other treatments. In intercropping 2:1 and 6:3 planting patterns recorded highest and significantly superior grain yield as compared to other row proportions. The grain yield recovery of sorghum was also maximum (84 and 83 per cent respectively) in these two row ratios as compared to other planting patterns.

In case of fodder yield the planting pattern of 2:1, 6:3 and sole sorghum were at par and recorded maximum and significantly superior fodder yield as compared to other planting patterns or treatments.

Soybean

The initial and final plant count was not significantly influenced due to different treatments. Therefore, the differences observed in various treatments were the real treatments effects.

The height of plant was not inlfuenced significant upto 40 DAS and thereafter significant differences in intercropping treatments were observed till harvest. The number of branches were non-significant in all

the treatments. Number of functional leaves differed significantly at 60 and 80 DAS. The highest, leaf area per plant and LAI was recorded in sole soybean followed by 3:6 and 2:4 planting patterns which were at par with each other and significantly superior than remaining intercropping treatments.

In general total dry matter was steadily increased throughout growth period but at harvest it reduced due to leaf senescence. In sole soybean total dry matter accumulation was higher followed by 3:6 planting pattern.

Upto 60 DAS growth function AGR for height and dry matter was highest in sole soybean followed by 3:6 and 2:4 treatments. RGR at initial stages higher in sole soybean and 3:6 planting pattern but at in later stages it was more in 2:1 planting pattern. Maximum LAI was observed in sole soybean followed by 3:6 planting pattern. Test weight was found to be non-significant.

Sole soybean recorded significantly superior grain yield over all treatments followed by 3:6 and 2:4 planting patterns. More or less similar trend was found in respect of straw and biological yield.

Sorghum grain equivalent was recorded maximum in 6:3, sole soybean and 2:1 planting pattern, which were at par with each other and significantly superior over remaining treatments.

Gross monetary returns and net returns

Treatments of 6:3, sole soybean and 2:1 planting pattern recorded maximum gross as well as net returns which were significantly superior than the remaining treatments.

As compared to sole sorghum treatments of intercropping of sorghum with soybean in 6:3 and 2:1 planting pattern was found significantly superior in giving net monetary returns. Therefore, planting pattern of 6:3 and 2:1 of sorghum + soybean intercropping under replacement series at row spacing of 45 cm found to be productive and profitable as compared to sole sorghum.

CONCLUSION

- Planting pattern of sorghum + soybean intercropping at a uniform row spacing of 45 cm in the 6:3 and 2:1 ratio found ideal.
- The overall productivity and profitability was highest in 6:3 and 2:1 planting pattern compared to other treatments and sole sorghum crop at the uniform row spacing of 45 cm.

This conclusion is based on one year experiment hence it needs further experimentation for its confirmation.

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