

**PERFORMANCE OF SOYBEAN (*Glycine max* L. Merrill)  
GENOTYPES TO PLANTING GEOMETRY**

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GENOTYPES TO PLANTING GEOMETRY**

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**BY**

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**CERTIFICATE**

This is to certify that the thesis entitled "PERFORMANCE OF SOYBEAN (*Glycine max* L. Merrill) GENOTYPES TO PLANTING GEOMETRY" submitted by Mr. LINGARAJ ANGADI for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRONOMY to the University of Agricultural Sciences, Dharwad is a record of research work carried out by him during the period of his study in this University under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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# CONTENTS

Chapter No.	Chapter Particulars
	CERTIFICATE
	ACKNOWLEDGEMENT
	LIST OF TABLES
	LIST OF FIGURES
	LIST OF PLATES
	LIST OF APPENDICES
1.	INTRODUCTION
2.	REVIEW OF LITERATURE
	2.1 Varieties
	2.2 Effect of row spacing
3.	MATERIAL AND METHODS
	3.1 Location of experimental site
	3.2 Soil characteristics of experimental site
	3.3 Climatic conditions
	3.4 Previous cropping history
	3.5 Experimental details
	3.6 Crop management
	3.7 Biometric observations
	3.8 Observations on growth indices
	3.9 Observations on yield and yield components
	3.10 Quality parameters
	3.11 Chemical analysis
	3.12 Economics of the system
	3.13 Statistical analysis and interpretation of data
4.	EXPERIMENTAL RESULTS
	4.1 Plant growth parameters
	4.2 Yield and yield components
	4.3 Economic analysis
5.	DISCUSSION
	5.1 Weather conditions and crop performance
	5.2 Effect of genotypes
	5.3 Effect of planting geometry
	5.4 Economics
6.	SUMMARY AND CONCLUSIONS
	REFERENCES
	APPENDICES

## LIST OF TABLES

Table No.	Title
1.	Physical and chemical properties of the experimental site (0-30 cm soil depth)
2.	Monthly meteorological data during the year 2015 and average of 23 year (1992-2014) at the Agriculture Research Station, Nipani, University of Agricultural Sciences, Dharwad
3.	Plant height (cm) of soybean varieties as influenced by planting geometry
4.	Number of branches plant <sup>-1</sup> of soybean varieties as influenced by planting geometry
5.	Number of tri foliate leaves plant <sup>-1</sup> of soybean varieties as influenced by planting geometry
6.	Dry matter production (g plant <sup>-1</sup> ) of soybean varieties as influenced by planting geometry
7.	Leaf area (dm <sup>2</sup> plant <sup>-1</sup> ) and leaf area index plant <sup>-1</sup> of soybean varieties as influenced by planting geometry
8.	Relative growth rate (g g <sup>-1</sup> day <sup>-1</sup> ) and Net assimilation rate (g dm <sup>2</sup> day <sup>-1</sup> ) of soybean varieties as influenced by planting geometry
9.	Crop growth rate (g dm <sup>2</sup> day <sup>-1</sup> ) and Absolute growth rate (g plant <sup>-1</sup> day <sup>-1</sup> ) of soybean varieties as influenced by planting geometry
10.	Number of root nodules plant <sup>-1</sup> and Nodules dry weight plant <sup>-1</sup> (g) in soybean varieties as influenced by planting geometry
11.	Canopy spread (cm <sup>2</sup> plant <sup>-1</sup> ) in soybean varieties as influenced by planting geometry
12.	Canopy temperature (°C plant <sup>-1</sup> ) in soybean varieties as influenced by planting geometry
13.	Number of pods plant <sup>-1</sup> , seed weight plant <sup>-1</sup> (g) and test weight (g) of soybean varieties as influenced by planting geometry
14.	Seed yield (q ha <sup>-1</sup> ), haulm yield (q ha <sup>-1</sup> ) and harvest index (%) of soybean varieties as influenced by planting geometry
15.	Protein content (%) and protein yield (q ha <sup>-1</sup> ) of soybean varieties as influenced by planting geometry
16.	Oil content (%) and Oil yield (q ha <sup>-1</sup> ) of soybean varieties as influenced by planting geometry
17.	Economic of soybean varieties as influenced by planting geometry

## LIST OF FIGURES

Figure No.	Title
1.	Monthly meteorological data during the year 2015 and average of 23 year (1992-2014) at the Agriculture Research Station, Nipani, University of Agricultural Sciences, Dharwad
2.	Plan of layout of the experiment
3.	Dry matter production ( $\text{g plant}^{-1}$ ) in soybean varieties as influenced by planting geometry
4.	Leaf area ( $\text{dm}^2 \text{ plant}^{-1}$ ) of soybean varieties as influenced by planting geometry
5.	Leaf area index $\text{plant}^{-1}$ of soybean varieties as influenced by planting geometry
6.	Canopy spread ( $\text{cm}^2 \text{ plant}^{-1}$ ) in soybean varieties as influenced by planting geometry
7.	Canopy temperature ( $^{\circ}\text{C plant}^{-1}$ ) in soybean varieties as influenced by planting geometry
8.	Number of pods $\text{plant}^{-1}$ and seed weight ( $\text{g plant}^{-1}$ ) of soybean varieties as influenced by planting geometry
9.	Seed yield ( $\text{q ha}^{-1}$ ) and haulm yield ( $\text{q ha}^{-1}$ ) of soybean varieties as influenced by planting geometry
10.	Economic of soybean varieties as influenced by planting geometry

## LIST OF PLATES

<b>Plate No.</b>	<b>Title</b>
1.	General view of the experimental plot
2.	Performance of soybean genotypes under various planting geometry at 30 DAS
3.	Performance of soybean genotypes under various planting geometry at harvest

## LIST OF APPENDICES

<b>Appendix No.</b>	<b>Title</b>
I.	Prices of inputs and outputs
II.	Treatment-wise details of cost of cultivation (₹ ha <sup>-1</sup> ) of soybean on per hectare basis

# 1. INTRODUCTION

Soybean (*Glycine max* L. Merrill) is an important leguminous crop and able to leave residual N effect for succeeding crop equivalent to 35-40 kg N ha<sup>-1</sup>. It has high nutritive value having 40-42 per cent protein and 20 per cent oil. The crop produces enormous amount of biomass therein enhances the soil organic matter status in soil. It can be grown as a good intercrop or mixed crop with maize, sorghum, pigeon-pea and cotton due to its short duration. It provides a good protective cover to intercept rain and wind therein minimizes soil erosion. Soybean is used in production of beverages, nuggets, chunk and milk.

Soybean is a major oil seed crop of the world, grown on an area of 118.01 million hectare with a production of 315.06 million tonnes and productivity of 2.67 t ha<sup>-1</sup> (Anon., 2015). In the world, it is being cultivated mainly in USA, Brazil, China, Argentina and India. In India, it is grown over an area of 10.02 million hectare with production of 11.64 million tonnes and productivity of 1062 kg ha<sup>-1</sup> (Anon., 2015). Predominant soybean growing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Gujarat. soybean in Karnataka occupies an area of 0.29 million hectare with production of 0.24 million tonnes and productivity of 868 kg ha<sup>-1</sup> (Anon., 2015). Belagavi, Bidar, Dharwad, Haveri and parts of Bagalkot are the major soybean growing districts.

Plant population is an important non-monetary input and an optimum factor for higher realization through light penetration in crop canopy. As seed rate increases plant competition increases, generating stress on the canopy, minimizing the benefit to narrow row spacing, especially when environmental conditions limit plant growth. The optimum plant population according to row spacing has been optimized for soybean crop in Whigham (1998); Whigham and Lundvall (1996). The optimum plant density with proper geometry of planting is prevailing on agro-climatic condition. The row- to- row spacing with plant population should be maintained for getting better growth and yield of crop. The equi-distant plant spacing increase crop growth rate, dry matter accumulation and seed yield (Andrade *et al.*, 2002) Abiotic and biotic stresses can mitigate the yield response of soybean to narrow- row spacing . Moisture stress has been documented to reduce the yield benefit from narrow spacing (Heitholt *et al.*, 2005) Therefore, it is imperative to find out the optimum row spacing for newly released soybean genotypes under different agro-climatic condition to improve yield potential of soybean.

Agronomic research, in general aims at improving cultural practices of crop varieties to realize optimum yield. Row spacing is one of the major factors which plays a major role in growth and yield of soybean. Optimum row spacing ensures proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, land as well as air space and water. There are two general concepts to describe the relationship between plant density and seed yield. Firstly, the plant spacing within and among rows, plant density must be such that the crop develops a canopy that could be able to intercept more than 95 per cent incoming solar radiation during its reproductive growth stages. Secondly, nearly equidistant plant arrangement minimizes interplant competition and produces maximum seed yield. Acko and Tradan (2008) reported that appropriate row spacing and cultivar is necessary for obtaining high yield and quality seeds of soybean. The optimum row spacing for higher seed yield may differ from cultivar to cultivar and location to location. Therefore, the present study was planned to standardize row spacing for achieving maximum seed yield with the following objectives.

1. To standardize the spacing in soybean.
2. To know the impact of spacing on growth, yield and quality of soybean.
3. To work out the economics.

## 2. REVIEW OF LITERATURE

The review of literature on the effect of varieties and planting geometry on growth, growth indices, yield and yield attributes and quality characters of soybean are presented in this chapter.12.02

### 2.1 Varieties

A great role in crop production is played by varieties. The environment set to a variety/genotype determines its yield within its genetic limit. Hence, combination of varieties and environmental factors can bring about increase in production. Difference in yield of genotypes/varieties is attributed to many courses and is the result of complex process in various parts of the plant involving many physiological changes. These physiological changes are influenced in environmental factors prevailing at different stages of crop growth. To understand yield variation among the soybean varieties due to environmental differences and agronomic manipulation, both yield and growth analysis are required.

#### 2.1.1 Growth and growth components

##### 2.1.1.1 Plant height

Rekha and Dhurua (2010) concluded that among three soybean varieties JS-335 (30.6 cm) and MACS-450 (30.2 cm) recorded the significantly higher plant height over variety PK-1029 (25.7 cm).

Vyas and Khandwe (2014) reported that the soybean genotype JS-97-52 recorded significantly higher plant height (83.40 cm) compared to the JS-95-60 genotype (42.80 cm).

Jaybhay *et al.* (2014) reported that the soybean variety RKS-18 showed higher plant height (62 cm) over MAUS-61 variety (60 cm).

Ramgiriy *et al.* (2014) found that the among four soybean varieties, the JS-97-52 showed the higher plant height (68 cm) over JS-95-60 (58 cm), but in case of JS-335 and JS-93-05 on par with each other (61 cm).

Dogra *et al.* (2014) visualized that the soybean genotype SL-958 (80 cm) had attained maximum plant height followed in genotype DS-12-5A (79 cm) and minimum plant height was recorded in genotype SL-688 (52 cm).

Singh *et al.* (2014) visualized that the plant height was significantly higher in SL-958 (102.1 cm) than the other genotypes and SL-744 (92.1 cm) had the lowest plant height.

##### 2.1.1.2 Number of branches per plant

Ramgiriy *et al.* (2014) reported that among four soybean varieties the JS-97-52 showed more number of branches plant<sup>-1</sup> (4.67) over JS-95-60 (3.33), JS-335 (4.22), JS-93-05 (3.67) but number of nodules plant<sup>-1</sup> was non-significant with respect to all the varieties.

Jaybhay *et al.* (2014) reported that the soybean variety RKS-18 showed higher number of branches (3.36) over MAUS-61 variety (2.32).

Vyas and Khandwe (2014) reported that the soybean genotype JS-97-52 recorded significantly higher number of branches (4.94) compared to the JS-95-60 genotype (3.97).

#### 2.1.1.3 Number of trifoliolate leaves

Sheelavantar (1980) from Dharwad reported that out of six varieties tested, davis recorded the highest number of leaves (18.2 to 25.4) plant<sup>-1</sup> at all the stages of crop growth. The lowest number of leaves plant<sup>-1</sup> was recorded in improved pelican (9.4 to 14.2). Similarly, Mohd. Abbas *et al.* (1994) observed significant difference between two plant types with respect to number of leaves plant<sup>-1</sup>. Erect type (JS-75-46) recorded lesser leaves (17.8) compared to spreading (JS-72-44) type (20.8).

#### 2.1.1.4 Root studies (number of nodules and root dry weight)

Mere *et al.* (2013) reported that the variety JS-97-52 showed significant variation from RKS 18 in producing the highest number of nodules (27), nodules dry weight (0.29 g) and highest dry weight plant<sup>-1</sup> at 30 (2.62 g) and 60 (12.51 g) day after sowing.

Vyas and Khandwe (2014) reported that the soybean genotype JS-95-60 recorded significantly higher nodules at 60 day after sowing (52.10) compared to the JS-97-52 genotype (43.60).

#### 2.1.1.4 Growth indices

Sarma and Kalaisalia (1990) observed that the dry matter partitioning was maximum to pods in PK-471 (84.4 %) followed in KHSb-2 (78.5 %) and Hardee (77.9 %) while in LBS- 2 dry matter partitioning was minimum (53 %).

Malek *et al.* (2012) revealed that among the soybean varieties BAU-70 showed the significant higher leaf area plant<sup>-1</sup> (708 cm<sup>2</sup>) over the BAU- 21 and shohag variety.

Malek *et al.* (2012) revealed that among the soybean varieties BAU-70 showed similar total dry matter production, crop growth rate and relative growth rate (15.3 g plant<sup>-1</sup>, 210 mg plant<sup>-1</sup> day<sup>-1</sup> and 17 mg g<sup>-1</sup> day<sup>-1</sup>) with BAU- 21 variety (13.5 g plant<sup>-1</sup>, 167 mg plant<sup>-1</sup> day<sup>-1</sup> and 15.3 mg g<sup>-1</sup> day<sup>-1</sup>).

Mere *et al.* (2013) reported that the varieties did not show significant difference in dry weight plant<sup>-1</sup>. In case of crop growth rate at 30 and 60 DAS, it was found on par with each other in RKS-18 (0.44 and 0.45 g cm<sup>2</sup> day<sup>-1</sup>), JS-9752 (0.273 and 0.282 g cm<sup>2</sup> day<sup>-1</sup>) but the varieties did not register significant difference in relative growth rate at 30 and 60 DAS.

Vyas and Khandwe (2014) reported that the soybean genotype JS-95-60 recorded significantly higher net assimilation rate (0.008 mg cm<sup>-2</sup> day<sup>-1</sup>) at 30-45 DAS compared to the JS-97-52 genotype (0.004 mg cm<sup>-2</sup> day<sup>-1</sup>), but relative growth rate results were non-significant with respect to the genotypes.

#### 2.1.1.5 Yield and yield components

The varieties Puas-40 (2,521 kg ha<sup>-1</sup>) and KB-79 (2,215 kg ha<sup>-1</sup>) recorded significantly higher increase in seed yield of 19 % and 5 %, respectively over the variety JS-335 (Goudreddy *et al.*, 1994).

All India coordinated research project conducted the research on soybean varieties. The variety MAUS-162 recorded 25.2, 49.74 and 9.32 % increase seed yield over local check, MAUS-47 and national check, Bragg and JS-335 respectively (Anon., 2002, 2003 and 2004).

Kumar *et al.* (2005) also reported genotypic differences with respect to pods plant<sup>-1</sup>. Genotypes of soybean did differ in seed yields (Dubey and Billore, 1993 and Billore *et al.*, 2009)

Rekha and Dhurua (2010) concluded that among three soybean varieties, JS-335 recorded the significantly higher seed yield (1,055 kg ha<sup>-1</sup>), number of pods plant<sup>-1</sup> (64) than PK-1029 and MACS-450 variety and the seed index was non-significant with respect to soybean varieties.

Mere *et al.* (2013) reported that the variety JS-9752 produced significantly higher number of pods plant<sup>-1</sup> (52.19), 100 seed weight (14.62 g) and seed yield (1.74 t ha<sup>-1</sup>) compared to RKS-18.

Vyas and Khandwe (2014) reported that the soybean genotype JS-9752 recorded significantly higher number of pods plant<sup>-1</sup>, straw yield (60.1 and 4,132 kg ha<sup>-1</sup>) compared to the JS-95-60 genotype (34.91 and 2,291 kg ha<sup>-1</sup>) and soybean genotype JS-95-60 recorded significantly higher seed yield (2,274 kg ha<sup>-1</sup>), seed index (11.73) and harvest index (51.64) than JS-9752 cultivar (1630 kg ha<sup>-1</sup>, 7.05 g, 29.11 % respectively).

Jaybhay *et al.* (2014) reported that the soybean variety RKS-18 recorded the higher number of pods plant<sup>-1</sup> (40), seed yield (3,062 kg ha<sup>-1</sup>), higher seed index (14.01 g) and harvest index (52.82 %) over MAUS-61 (38, 2560 kg ha<sup>-1</sup>, 13.44 g and 40.60 %) respectively.

Billore *et al.* (2014) reported that in northern plain zone, soybean cultivar SL-525 produced higher seed yield (2,182 kg ha<sup>-1</sup>) compared to PS-1347 (2,056 kg ha<sup>-1</sup>) and northern eastern zone, soybean variety RKS-18 showed its superiority over variety JS-97-52 during two years of the experimentation and produced higher seed yield in (2,044 kg ha<sup>-1</sup>) over JS-97-52 (1,969 kg ha<sup>-1</sup>).

Ramgiriy *et al.* (2014) reported that among different varieties of soybean, the number of seeds pod<sup>-1</sup> was maximum in RVS2007-4 (3.22) and JS-93-05 (3.00), seed index was found high in JS-95-60 (12.83g) followed by RVS2007-4 (12.67 g), seed yield was found high in JS-97-52 (1,560 kg ha<sup>-1</sup>) over JS-93-05 (1,380 kg ha<sup>-1</sup>).

Dogra *et al.* (2014) visualized that the soybean genotype SL-958 produced higher seed yield (2,500 kg ha<sup>-1</sup>), harvest index (42.34%) than genotype SL-983 (2,450 kg ha<sup>-1</sup>,39.04%) and SL-1123 but the genotype SL-983 produced higher 100-seed weight (12.59 g) followed in genotype SL-958 (12.32) than the EC-45716 and SL-688.

Singh *et al.* (2014) reported that, the variety SL-958 produced higher seed yield (2637 kg ha<sup>-1</sup>) than SL-900 (2578 kg ha<sup>-1</sup>) and SL-744. Similar trend was seen with number of pods plant<sup>-1</sup> and seed index.

Pandey *et al.* (2014) reported that the genotypes, JS-20-71, JS-20-87, Bragg, RVS-2001-4, JS-20-50, JS-97-52 recorded more than 1800 kg ha<sup>-1</sup> seed yield over JS-93-05 (1075 kg ha<sup>-1</sup>) genotype both under control and excess moisture conditions

#### 2.1.1.6 Seed quality

Mere *et al.* (2013) observed that the variety JS-9752 produced significantly higher protein yield (721.82 kg ha<sup>-1</sup>) and oil yield (342.02 kg ha<sup>-1</sup>) compared to RKS 18 (669.90 kg ha<sup>-1</sup>, 315.11 kg ha<sup>-1</sup> respectively).

Vyas and Khandwe (2014) reported that the soybean genotype JS-97-52 recorded significantly higher oil content (17.80 %) over JS-95-60 (17.40 %). However, the reverse trend was seen for protein content in JS-95-60 (38.96 %) and JS-97-52 (37.50 %) respectively.

#### 2.1.1.7 Economics

Singh *et al.* (2014) visualized that the variety SL-958 gave the maximum gross return (₹ 67,523 ha<sup>-1</sup>), net return (₹ 48,476 ha<sup>-1</sup>) and B:C (3.54) but the differences were non – significant.

Vyas and Khandwe (2014) reported that the soybean genotype JS-95-60 recorded significantly higher net returns (₹ 38,577 ha<sup>-1</sup>) with B:C ratio of 4.37 than JS-97-52 cultivar.

## 2.2 Effect of row spacing

### 2.2.1 Growth and growth components

#### 2.2.1.1 Plant height

Bullock *et al.* (1997) reported that soybean sown in row widths of 38, 76, and 114 cm, shown a linear decrease in plant height (99, 96, 93 cm) with increasing row width respectively.

Pedersen and Lauer (2003) reported that plant height increased slightly with increase in planting density in soybean

Mehmet (2008) reported that the maximum plant height (96.9 cm) of soybean was recorded at row spacing of 70 x 5 cm against at 70 x 20 cm row spacing (67.4 cm).

Singh *et al.* (2009) reported that planting geometry of 30 x 5 cm or 15 x 10 cm (0.66 million plants/ha) significantly increased the soybean plant height compared to 30 x 10 cm or 20 x 15 cm, These observations confirmed the results of Halvankar *et al.* (1999)

Singh (2011) reported that the row spacing of soybean at 22.5 cm recorded the higher plant height (26.8 cm) than 45 cm row spacing but it was on par with 30 cm row spacing (26.8 cm).

Ibrahim (2012) visualized that decreased plant spacing in soybean generally resulted in an increase in plant height. Increase in plant height might have resulted due to competition for sunlight than those of plants grown in lower population density. Similar results have been reported by Khan (2007).

Malek *et al.* (2012) visualized that soybean plant height increased with decreasing row spacing. The tallest plant (60 cm) was observed at 25 cm row spacing followed in 30 cm row spacing (57 cm). In contrast, the widest row spacing of 35 cm had the shortest plant (56 cm).

Ibrahim (2012) revealed that significantly higher plant height observed at 4 cm plant spacing (69.6 cm) compared to 8 cm, 16 cm, 20 cm plant spacing of soybean.

Bhagirath *et al.* (2013) visualized that significantly higher plant height of soybean (94 cm) at 20 × 5 cm spacing than those at 20 × 10 (89 cm), 40 × 10 (72.2 cm) and 40 × 5 (80.2 cm).

Doyle *et al.* (2014) revealed that among two row widths of soybean, 38.1 cm (narrow row) and 76.2 (wider row) the narrow row spacing increased plant height (46.7 cm) compared to the wider row spacing (47.6 cm).

Jaybhay *et al.* (2014) reported that the row spacing of 30 cm recorded significantly higher plant height (62 cm) compared to 45 cm row spacing.

#### 2.2.1.2 Number of branches

Mehmet (2008) revealed that number of branches significantly varied among plant densities. Maximum number of branches (7.9 plant<sup>-1</sup>) was produced at row spacing of 70 x 20 cm, followed by 70 x 15 cm row spacing (7.1 plant<sup>-1</sup>). The least value was recorded at 70 cm x 5 cm (5.5 plant<sup>-1</sup>). Similar findings have been obtained by Yilmaz, 2003.

Singh *et al.* (2009) concluded that the soybean recorded significantly higher number of branches plant<sup>-1</sup> (6.2) when the crop was sown at 30 x 10 cm row spacing than other spacing, though being statistically on par with 20 x 15 cm (5.8).

Malek *et al.* (2012) visualized that the highest number of branches plant<sup>-1</sup> in soybean (2.18) was observed in wider row spacing of 35 cm and were statistically similar to 30 cm row spacing and the lowest was recorded in narrow spacing of 25 cm.

Rahman and Hossain (2013) reported that, the soybean sowing in wider row spacing (50 cm) recorded significantly higher branches plant<sup>-1</sup> (2.51) over the narrow row spacing 20 and 30 cm.

Mondal *et al.* (2014) reported that reduction in number branches plant<sup>-1</sup> in closer spacing might be due to increased number of plants unit<sup>-1</sup> area leading to intra plant competition. On the other hand, many workers reported that plant morphological characters increased with increasing plant spacing except plant height (Babalald *et al.*, 2005; Mondal *et al.*, 2012, Malek *et al.*, 2012).

Jaybhay *et al.* (2014) reported that the row spacing of 30 cm recorded significantly higher number of branches per plant (3.36) compared to 45 cm row spacing.

#### 2.2.1.3 Root studies (root dry weight and number of root nodules)

Amongst planting geometry of soybean, significantly higher number of nodules/plant and its dry weight were recorded at wider row spacing of 30 x 10 or 20 x 15 cm compared to narrow spacing of 30 x 5 or 5 x 10 cm. In general, the number of nodules and dry weight of nodules plant<sup>-1</sup> increased up to 65 days of crop growth and thereafter decreased. This can be attributed to the fact that, with the age of the crop, the nodules degenerate (Pandey *et al.*, 1995).

Singh *et al.* (2009) concluded that significantly higher number of nodules plant<sup>-1</sup> (24.7) was obtained when the crop was sown in 30 x 10 cm planting geometry than other spacing, though being statistically on par with 20 x 15 cm (22.3).

Malek *et al.* (2012) visualized that the highest nodules plant<sup>-1</sup> (20.4) was observed in wider row spacing of 35 cm and were statistically on par with 30 cm row spacing and the lowest was recorded in narrow spacing of 25 cm.

Rahman and Hossain (2013) reported that, the soybean sown in row spacing of 40 cm recorded significantly higher root nodules (13.12) over the 30, 20 and 50 cm row spacing.

#### 2.2.1.4 Number of trifoliolate leaves

Bhagirath *et al.* (2013) reported that in soybean the highest numbers of trifoliolate leaves (24 plant<sup>-1</sup>) were observed at 40 x 10 cm spacing and they were significantly higher than those at other spacings 20 x 10 cm (17.5 plant<sup>-1</sup>), 20 x 5 cm (12.6 plant<sup>-1</sup>) and 40 x 5 cm (16.2 plant<sup>-1</sup>).

Mondal *et al.* (2014) visualized that the significantly higher number of leaves plant<sup>-1</sup> (17.20) was observed at the wider spacing of 30 x 20 cm followed by spacing of 30 x 15 cm. In contrast, the lowest number of leaves was recorded in the plant spacing of 30 x 5 cm.

#### 2.2.1.5 Growth indices

Bullock *et al.* (1997) reported that, soybean sown in row widths of 38, 76, and 114 cm had higher crop growth rate with decreasing row width.

The leaf area development with closer spacing of soybean contributed to high total dry matter production due to higher solar radiation interception that contributed to higher yield production (Ball *et al.*, 2000a).

Several researchers reported that the genotypes which produced greater total dry matter production also showed higher yield due to large root system and leaf area (Manral and Saxena, 2005; Mondal *et al.*, 2012; Markos *et al.*, 2002).

Singh *et al.* (2009) visualized that among cropping geometries of soybean, 30 x 5 cm spacing recorded maximum leaf-area index and was on par with 15x10 cm spacing at vegetative and flowering stages in both the years except at peak flowering stage in the first year. This might be due to the higher crop density as reported in Singh and Gopaldaswamy (1991).

Reduction in leaf area plant<sup>-1</sup> and total dry matter plant<sup>-1</sup> in closer spacing might be due to increased number of plants unit<sup>-1</sup> area and their inter competition (Babalald *et al.*, 2005; Mondal *et al.*, 2012, Malek *et al.*, 2012).

Singh *et al.* (2009) concluded that in soybean significantly higher dry matter production (4,192 kg ha<sup>-1</sup>) was obtained when the crop was sown at 30 x 10 cm planting geometry than other spacing, though being statistically at par with 20 x 15 cm (4,082 kg ha<sup>-1</sup>).

Malek *et al.* (2012) observed the highest leaf area ( $662 \text{ cm}^2 \text{ plant}^{-1}$ ), total dry matter production ( $15.8 \text{ g plant}^{-1}$ ), absolute growth rate ( $212 \text{ mg p}^{-1}\text{d}^{-1}$ ) and relative growth rate ( $17.4 \text{ mg g}^{-1}\text{d}^{-1}$ ) in soybean sown under wider row spacing of 35 cm and they were statistically on par with 30 cm row spacing and the lowest was recorded in narrow spacing of 25 cm. However, the highest leaf area index was recorded in narrow spacing of 25 cm (4.89) and the lowest was seen in wider spacing of 35 cm (3.95).

Rahman and Hossain (2013) reported the highest leaf area index and total dry matter when soybean was grown at 20 cm row spacing, The highest values of leaf area index and total dry matter were (2.14 and  $381.91 \text{ g m}^{-2}$  respectively) at 20 cm row spacing which decreased with increased row spacing. The lowest values were (1.16 and  $3.39 \text{ g m}^{-2}$  respectively) at 50 cm row spacing.

Mondal *et al.* (2014) visualized that the significantly higher leaf area  $\text{plant}^{-1}$  ( $629 \text{ cm}^2$ ) was observed at the wider spacing of 30 cm  $\times$  20 cm followed in spacing of 30 cm  $\times$  15 cm. In contrast, the lowest leaf area  $\text{plant}^{-1}$  was recorded in the plant spacing of 30 cm  $\times$  5 cm.

#### 2.2.1.6 Yield and yield components

The plant density can be varied with planting geometry in changing the inter and intra row spacing. Significantly higher soybean yield was recorded with intra row spacing of 10 cm ( $1.59 \text{ t ha}^{-1}$ ) over 15 cm and 20 cm ( $1.52$  and  $1.49 \text{ t ha}^{-1}$  respectively) as opined in Lokars and Tiwari (1973).

A closer row spacing of 45 cm produced a higher seed yield over wider row spacing of 60 cm (Kacha *et al.*, 1990)

The plant geometry of 45 cm  $\times$  15 cm was found to be the most optimum and recorded significantly higher yield at Hyderabad on medium black soil (Rami Reddy *et al.*, 1990).

Board *et al.* (1990) reported that early season light interception was the reason for higher seed yields in soybean sown in narrow rows than those grown in wide rows. In narrow rows, increased light interception led to more pods  $\text{plant}^{-1}$  and seeds  $\text{plant}^{-1}$  which provided the yield advantage in narrow row spaced soybean.

Duraisingh and Gopalswamy (1991) obtained a significant increase in number of pods  $\text{plant}^{-1}$ , seed  $\text{pod}^{-1}$  and 100 seed weight at 30  $\times$  10 cm spacing than 30  $\times$  5 cm spacing.

Manjappa *et al.* (1991) recorded the highest seed yield of soybean at higher plant population of 4.4 lakh plants  $\text{ha}^{-1}$  compared to 2.2 and 3.3 lakh plants  $\text{ha}^{-1}$ .

Aslam *et al.* (1993) concluded that the soybean row spacing of 30 cm significantly recorded the higher seed yield ( $2,485 \text{ kg ha}^{-1}$ ) but the 45 cm ( $2,030 \text{ kg ha}^{-1}$ ) and 60 cm ( $1,923 \text{ kg ha}^{-1}$ ) row spacing were on par with each other. However, the number of pods  $\text{plant}^{-1}$  was higher in 60 cm row spacing compared to the 30 cm and 45 cm row spacing.

Jadhav *et al.* (1994) reported that yield attributes were significantly increased under narrow row spacing of 30 cm resulting in significant improvement in seed yield ( $32.06 \text{ q ha}^{-1}$ ) and straw yield ( $59.43 \text{ q ha}^{-1}$ ) compared to other wider row spacing of 45 cm.

Aralikatti (1996) reported that the plant population of 6.6 lakh plants ha<sup>-1</sup> resulted in significantly higher seed yield (27.92 t ha<sup>-1</sup>) over the other plant population levels (4.4 and 3.3 lakh plants ha<sup>-1</sup>) during summer.

Row spacings of 70 x 5 cm and 70 x 10 cm in soybean produced similar harvest index (50.8 and 50.4%). The lowest harvest index (48.8%) was observed at 70 x 20 cm row spacing. Some researchers obtained similar findings (Bullock *et al.*, 1997; Ball *et al.*, 2000b).

Bullock *et al.* (1997) reported that, Soybean sown in row widths of 38,76 and 114 cm, showed a linear decrease in seed yield (3497, 3250 and 2920 kg ha<sup>-1</sup>), number of pods per plant (93, 89 and 85) and harvest index (33, 31 and 30) with increasing row width.

Plant density of 0.45 million plants ha<sup>-1</sup> recorded significantly higher yield (2543 kg ha<sup>-1</sup>) compared to 0.3 million plants ha<sup>-1</sup> and further increase in plant density to 0.6 million plants ha<sup>-1</sup> did not increase yield significantly. However, the interaction of varieties and plant density was significant and determinate, short duration and compact varieties (JS-335 and Monetta) responded significantly up to 0.6 million plants ha<sup>-1</sup> (Anon., 1997).

Seed yield of soybean was significantly higher in narrow rows (25 and 51 cm) than in the wide rows (76 cm) with the 25-cm row spacing averaging 10% higher than the 76-cm row spacing (Ethredge *et al.*, 1998).

Ball *et al.* (2000a) concluded that increasing plant population of soybean reduced yield of individual plants but increased yield per unit area. Similar findings have also been reported in other research (Asanome and Ikeda, 1998 and Bowers *et al.*, 2000).

The highest seed yield in the lowest spacing could have been achieved in early canopy closure in the narrowest rows that facilitated high total dry matter production. The leaf area development with closer spacing contributed to high total dry matter production due to higher solar radiation interception that contributed to higher yield production (Ball *et al.*, 2000a).

Kumar and Badiyala (2002) reported that 30 cm row spacing resulted in significantly higher number of pods per plant. It may be due to lower number of plants per unit area under 30 cm row spacing.

Caliskan *et al.* (2004) reported that row spacing had a significant effect on plant height, number of nodes per plant, main-stem pod, seed number, branch pod and seed number and seed yield in both cropping systems. The highest seed yield (4,142 kg ha<sup>-1</sup>) averaged over years was obtained from 50-cm row width in full season soybean cropping, whereas a 30-cm row width had the highest seed yield (3,241 kg ha<sup>-1</sup>) in double-cropped soybean.

The authors observed that seed yield increased with increasing plant spacing to certain levels and thereafter decreased. Although number of pods plant<sup>-1</sup> was the lowest in closer spacing but seed yield m<sup>-2</sup> was the highest due to increase in plant population in closer spacing than that of wider spacing. Similar result was reported by many workers in soybean (Ball *et al.*, 2000b; Gratero and Montilla, 2003; Babalald *et al.*, 2005; Acko and Tradan, 2008).

The seed yield of soybean varieties was higher in closer plant spacing than wider plant spacing and this might be due to increased number of plants unit area<sup>-1</sup>. Similar result was also reported by many workers (Ball *et al.*, 2000b; El-Douin *et al.*, 2002; Singh *et al.*, 2013; Babalald *et al.*, 2005; Khan 2007). They observed that grain yield increased with increasing plant density up to certain levels.

Ahmad *et al.* (2007) revealed that significant differences were observed for soybean pods plant<sup>-1</sup> among different varieties. Highest number of pods (26.3) and highest pod yield (3738 kg ha<sup>-1</sup>) were recorded in SP-2000, while the lowest number of pods plant<sup>-1</sup> (18.3) and pod yield of (2010 kg ha<sup>-1</sup>) were recorded in SP-96 genotypes.

Mehmet (2008) reported that maximum seed yield of soybean was realized at 70 x 5 cm (2,623 kg ha<sup>-1</sup>) and 70 x 10 cm (2,451 kg ha<sup>-1</sup>) row spacings. The lowest plant population (70,143 plant ha<sup>-1</sup>) produced the lowest yield (1957 kg ha<sup>-1</sup>). An increase in seed yield per hectare in response to plant density due to increased number of plants per unit area. Christmas (2002), Berglund and Helms (2003) and Yilmaz (2003) have also reported similar results.

Lone *et al.* (2009) visualized that the highest number of pods plant<sup>-1</sup> (75.23) and 1000 seed weight (111.18 g) of soybean was recorded in plants sown at wider row spacings of 60 cm compared to other two spacings of 30 cm and 45 cm.

Lone *et al.* (2009) visualized that row spacing of soybean at 45 cm resulted in significantly superior seed (22.57 q ha<sup>-1</sup>) and straw yield (39.74 q ha<sup>-1</sup>) over 30 cm and remained at par with 60 cm for seed and straw yield. The extent of increase in seed yield at 45 cm row to row spacing was 13.14 % higher when compared to 30 cm row to row spacing.

Singh *et al.* (2009) concluded that significantly higher pods per plant<sup>-1</sup> (34.3), 100 seed weight (14.16 g) and seed yield (1312 kg ha<sup>-1</sup>) was obtained when the crop was sown at 30 x 10 cm planting geometry than other spacing, except at 20 x 15 cm in soybean.

Walker *et al.* (2010) investigated the response of soybean to various row spacings 38 (1, 92, 800 plants ha<sup>-1</sup>) and 76 cm (92, 100 plants ha<sup>-1</sup>). Narrow row spacing (4,906 kg ha<sup>-1</sup>) produced yields higher than or equal to those obtained from wide row spacing (4,400 kg ha<sup>-1</sup>).

Zhou *et al.* (2010) concluded that the seed yield of soybean at 18 x 18 cm (2,615 kg ha<sup>-1</sup>) and 27 x 12 cm (2,668 kg ha<sup>-1</sup>) row spacing was significantly higher than that of 54 x 6 cm (2,196 kg ha<sup>-1</sup>).

Ram *et al.* (2011) revealed that in soybean row spacing of 30 and 45 cm did not influence any of the plant character, yield attributes, biological yield, seed yield and harvest index significantly.

Rahman *et al.* (2011) reported increase in soybean seed yield up to plant population of 0.8-1.0 million plants ha<sup>-1</sup> and then decreasing trend at 1.2 million plants ha<sup>-1</sup>. Higher seed yield at the highest population level was due to better plant growth, more pods per unit area and higher biological yield.

Singh (2011) reported that in soybean the row spacing of 45 cm recorded significantly higher seed yield (2,796 kg ha<sup>-1</sup>), biological yield (8,427 kg ha<sup>-1</sup>) pod plant<sup>-1</sup> (58.5) compared to the 22.5 cm and 30 cm row spacing.

Ibrahim (2012) revealed that decreasing plant spacing has generally resulted in an increase in soybean seed yield in 4 cm (2,192 kg ha<sup>-1</sup>) compared to 8 cm (1,472 kg ha<sup>-1</sup>), 16 cm (1,279 kg ha<sup>-1</sup>) and 20 cm (1,189 kg ha<sup>-1</sup>) plant spacing in soybean.

Malek *et al.* (2012) recorded the highest seed yield of soybean (3.28 t ha<sup>-1</sup>) in row spacing of 30 cm that was statistically on par with 25 cm row spacing (3.20 t ha<sup>-1</sup>).

Rahman and Hossain (2013) reported that soybean row spacing of 20 cm recorded higher seed yield (133.75 g m<sup>-2</sup>) compared to 50 cm row spacing but 30 cm (119.02 g m<sup>-2</sup>) and 40 cm (117.3 g m<sup>-2</sup>) row spacing were at par with each other and number of pods plant<sup>-1</sup> was highest in 40 cm row spacing (19.86) compared to others.

Meena *et al.* (2013) reported that soybean variety JS-9752 at 30 cm row spacing with 75 kg ha<sup>-1</sup> seed rate, gave significantly higher yield, net return and benefit cost ratio compared to other varieties, row spacing and seed rate respectively.

Mondal *et al.* (2014) visualized that the highest seed yield was recorded at the closer spacing of 30 × 5 cm (278 g m<sup>-2</sup>) followed by the spacing of 30 cm × 10 cm (249 g m<sup>-2</sup>). The lowest seed yield was recorded in wider spacing of 30 cm × 20 cm (166 g m<sup>-2</sup>).

Doyle *et al.* (2014) revealed that, two row spacings 38.1 cm and 76.2 cm for narrow row and wider row spacing, the smaller-seeded genotypes had a small numerical (< 1.0 %) yield advantage when planted with narrow row spacing (2,663 kg ha<sup>-1</sup>) compared to the wider row spacing (2,100 kg ha<sup>-1</sup>) in soybean.

Awasmal, *et al.* (2014) reported that the row spacing of 45 cm recorded the highest seed yield (2,138 kg ha<sup>-1</sup>) and was significantly superior to 75 cm (1,809 kg ha<sup>-1</sup>) but on par with the 60 cm (2,068 kg ha<sup>-1</sup>). Similar results were reported in Deshmukh *et al.* (1997) and Kacha *et al.* (1990) and Tourino *et al.* (2002).

Vyas and Khandwe (2014) reported that the row spacing of 45 cm recorded the highest seed yield (2,022 kg ha<sup>-1</sup>), and it was on par with the 60 cm row spacing (1,967 kg ha<sup>-1</sup>).

Jaybhay *et al.* (2014) reported that the row spacing of 30 cm recorded the significantly higher number of pods plant<sup>-1</sup> (40), 100 seed weight (14.01 g) and seed yield (3062 kg ha<sup>-1</sup>) compared to 45 cm row spacing.

#### 2.2.1.7 Quality parameters

Sharma and Sharma (1993) found to be non-significant with respect to oil content with increased plant densities of soybean. Similar results confirmed in (Jadhav *et al.*, 1994).

Singh *et al.* (2009) concluded that the soybean planting pattern of 30 × 5 cm recorded maximum oil yield being at par with 15 × 10 cm and was significantly higher than other planting geometries. Oil content (%) did not differ significantly among the planting geometries. These results are in conformity with those of Halvankar *et al.* (1999).

#### 2.2.1.8 Economics

Vyas and Khandwe (2014) reported that the soybean genotype JS-95-60 recorded significantly higher net returns at 30 cm row spacing (₹ 41,014 ha<sup>-1</sup>) than 45 (₹ 38,376 ha<sup>-1</sup>) and 60 cm row spacing (₹ 36,341 ha<sup>-1</sup>), whereas genotype JS-97-52 recorded significantly higher seed yield (1,630 kg ha<sup>-1</sup>) at 45 cm row spacing (₹ 27,708 ha<sup>-1</sup>) than 30 (₹ 18,260 ha<sup>-1</sup>) and 60 cm (₹ 27,333 ha<sup>-1</sup>) row spacing.

## 3. MATERIAL AND METHODS

A field experiment was conducted during *kharif* 2015 to study the “Performance of soybean genotypes to planting geometry” at Agricultural Research Station (ARS), Nipani under rainfed condition. The details of the materials used and the methods adopted during the course of investigation are presented in this chapter.

### 3.1 Location of experimental site

The experiment was conducted in plot No 8 of ARS Nipani (16.2°N latitude and 74.2° E longitudes with an altitude of 610 m above mean sea level). Nipani comes under Northern Transitional Zone (Zone-8) of Karnataka, which lies between the Western Hilly Zone (Zone-9) and Northern Dry Zone (Zone-3).

### 3.2 Soil characteristics of experimental site

The experiment was conducted on medium black soil. Composite soil sample was collected from the experimental site before sowing and was analyzed for physical and chemical properties and the results are presented in Table 1.

### 3.3 Climatic conditions

Agricultural Research Station Nipani receives rainfall from both South-West and North-East monsoons, which is well distributed from June to November. The mean monthly meteorological data on rainfall, temperature and relative humidity during the period of experimentation (2015) and the average data for the past 23 years (1992-2014) are presented in Table 2 and Fig. 1. The rainfall received during the year of experimentation (2015) was 788.9 mm in 40 rainy days, it was 12.02 per cent lower than the average of past 23 years (896.7 mm). The major portion of rainfall was received from May to October with two peaks in the month of June (183 mm) and October (196.6 mm). Mean monthly maximum temperature ranged from 29°C (July and August 2015) to 36.1°C (April 2015). While, the minimum temperature ranged from 12.4°C (January 2015) to 21.3°C (May 2015). The mean monthly relative humidity ranged from 48 per cent in April to 78 per cent in June, July, and August months. The rainfall during cropping period was 391.3 mm well distributed during crop growth period. The mean maximum temperature during the period of experimentation ranged from 29.0°C (July) to 32.4 °C (October), while the minimum temperature ranged from 20.2°C (July) to 20.4 °C (October). Both minimum and maximum temperatures were favorable for normal growth and development of the crop.

### 3.4 Previous cropping history

During 2014-15, soybean in *kharif* and wheat in *rabi* were grown.

### 3.5 Experimental details

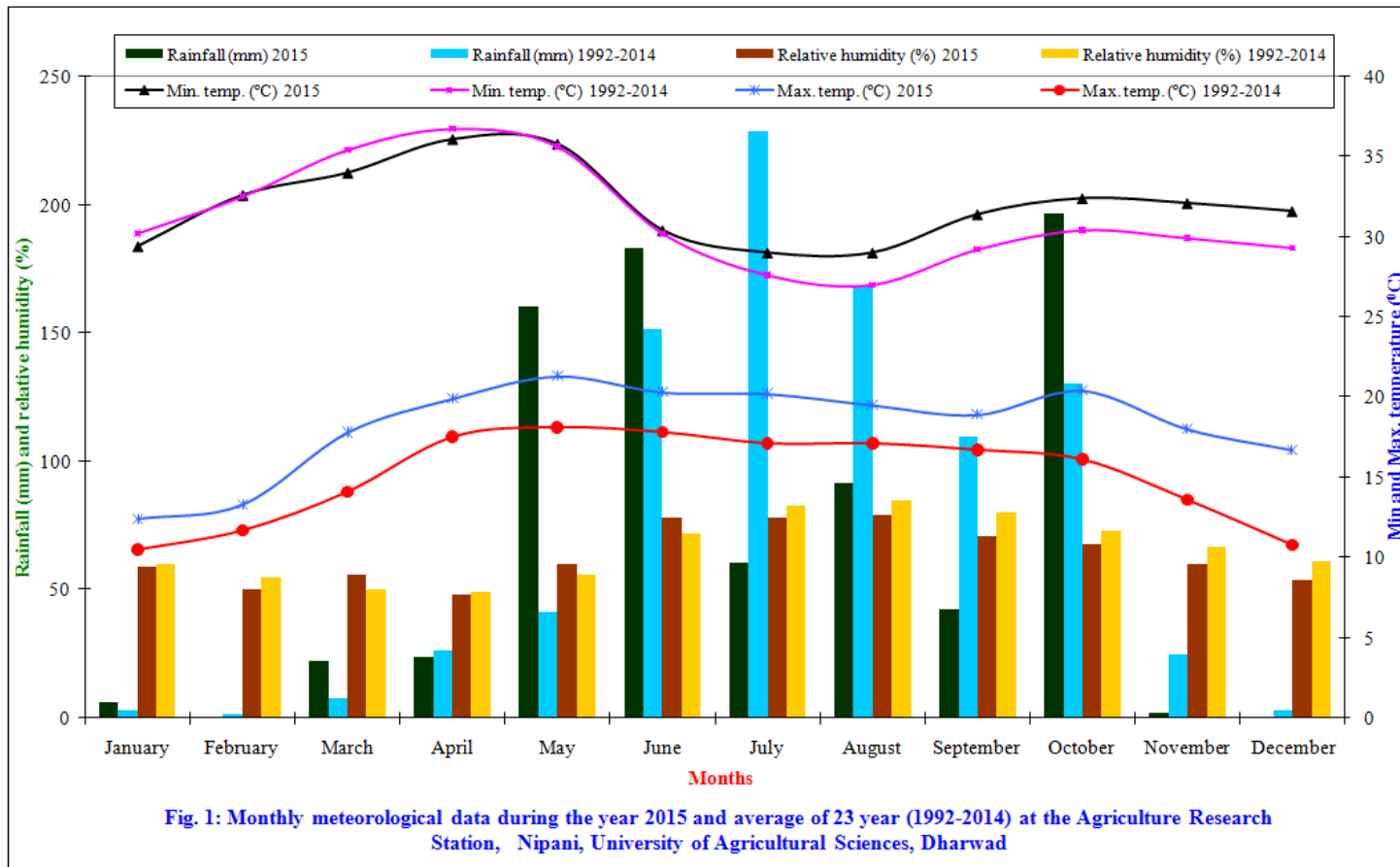
The details of the experiment conducted during 2015-16 at ARS, Nipani are given below.

**Table 1: Physical and chemical properties of the experimental site (0-30 cm soil depth)**

Sl. No.	Particulars	Values	Method adopted
<b>A. Physical properties</b>			
1.	Particle size analysis		International pipette method (Piper, 1966)
	a) Sandy (%)	31.70	
	b. Silty (%)	7.98	
	c. Clayly (%)	60.40	
	d. Textural class	Clayey	
<b>B. Chemical properties</b>			
	1. Organic carbon (%)	0.63	Walkley and Black wet oxidation method (Jackson, 1967)
	2. pH (1:2.5 soil: water suspension)	7.51	Buckman'S pH meter (Piper, 1966)
	3. EC (1:2.5 soil: water suspension) (ds m <sup>-1</sup> )	0.25	Conductivity bridge (Piper, 1966)
	4. Available nitrogen (kg ha <sup>-1</sup> )	145.6	Alkaline permanganate method (Subbiah and Asija. 1956)
	5. Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	31.00	Olsen's method (Jackson. 1967)
	6. Available K <sub>2</sub> O (kg ha <sup>-1</sup> )	457.20	Flame photometer method (Jackson, 1967)

**Table 2: Monthly meteorological data during the year 2015 and average of 23 year (1992-2014) at the Agriculture Research Station, Nipani, University of Agricultural Sciences, Dharwad**

Months	2015					1992-2014 (Average of last 23 years)				
	Rainfall (mm)	Rainy days	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Rainy days	Temperature (°C)		Relative humidity (%)
			Max	Min				Max	Min	
January	6.4	1	29.4	12.4	59	3.3	0.2	30.2	10.5	60
February	0.0	0	32.6	13.3	50	1.6	0.1	32.5	11.7	55
March	22.0	2	34.0	17.8	56	7.6	0.7	35.4	14.1	50
April	23.8	1	36.1	19.9	48	26.5	2.3	36.7	17.5	49
May	160.2	5	35.8	21.3	60	41.3	2.2	35.6	18.1	56
June	183.0	13	30.4	20.3	78	151.7	10.1	30.2	17.8	72
July	60.6	7	29.0	20.2	78	228.7	16.3	27.6	17.1	83
August	91.7	7	29.0	19.5	79	168.2	13.7	27.0	17.1	85
September	42.4	2	31.4	18.9	71	109.6	8.3	29.2	16.7	80
October	196.6	2	32.4	20.4	68	130.4	7.7	30.4	16.1	73
November	2.2	0	32.1	18.0	60	24.9	1.7	29.9	13.6	67
December	0.0	0	31.6	16.7	54	2.9	0.3	29.3	10.8	61
<b>Total</b>	<b>788.9</b>	<b>40</b>				<b>869.7</b>	<b>63.7</b>			



**Fig. 1: Monthly meteorological data during the year 2015 and average of 23 year (1992-2014) at the Agriculture Research Station, Nipani, University of Agricultural Sciences, Dharwad**

### 3.5.1 Design and layout

The experiment was laid out in Factorial Randomized Block Design with 12 treatments combination as detailed below with four replications. The plan of layout is given in Fig. 2 and the general view of the experiment is given in Plate 1.

### 3.5.2 Treatment details

Factor – I - Varieties

$V_1$  = JS-9305

$V_2$  = Dsb-21

Factor - II – Row Spacing (cm)

$S_1$  = Farmer practice (90 × 5 cm) (540 plant population)

$S_2$  = 60 × 7.5 cm (1,080 plant population)

$S_3$  = 30 × 15 cm (1,080 plant population)

$S_4$  = 22.5 × 20 cm (1,080 plant population)

$S_5$  = 45 × 10 cm (1,080 plant population)

$S_6$  = 30 × 10 cm (1,620 plant population)

### 3.5.3 Other details

Crop : Soybean

Variety : JS-9305, Dsb-21

Replications : Four

Treatments : Twelve

Gross plot size : 9 m x 5.4 m

Net plot size : 7.2 m x 5.2 m (90 x 5 cm), 7.8 m x 5.25 m (60 x 7.5),

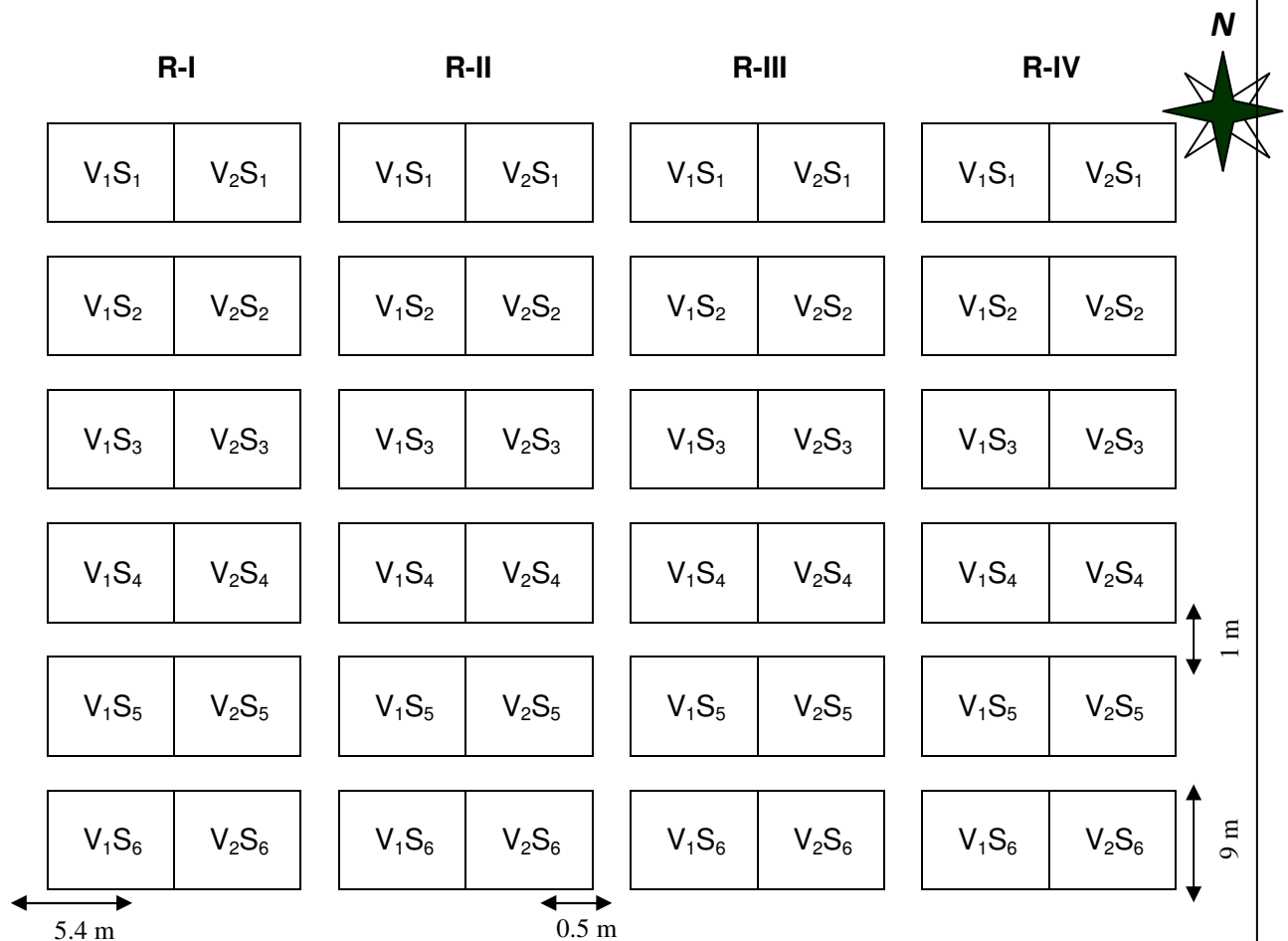
8.4 m x 5.1 m (30 x 15), 8.55 m x 5.0 m (22.5 x 20),

8.1 m x 5.2 m (45 x 10), 8.4 m x 5.2 m (30 x 10).

Spacing : As per treatments

Season : *Kharif-2015*

Situation : Rainfed



Varieties - V<sub>1</sub> – JS-9305 V<sub>2</sub> – Dsb-21

Row Spacings- S<sub>1</sub> – 90 x 5 cm row spacing S<sub>2</sub> - 60 x 7.5 cm row spacing

S<sub>3</sub> - 30 x 15 cm row spacing S<sub>4</sub> - 22.5 x 20 cm row spacing

S<sub>5</sub> - 45 x 10 cm row spacing S<sub>6</sub> - 30 x 10 cm row spacing

**Fig. 2: Plan of layout of the experiment**



**At 30 DAS**



**At 60 DAS**

**Plate 1: General view of the experimental plot**

### 3.5.4 Description of the variety: Dsb-21

a	Plant height	60-65 cm
b	Distinguishing morphological characters	i) Purple flowers characters ii) Pubescence- almost absent on stem, leaves and pods. iii) Semi- determinate habit iv) Yellow seed coat and Brown hilum
c	Maturity	90-95 day
d	Days to 50% flowering	38-42 day
e	Maturity group	Medium
f	Reaction to major diseases	Both under field and controlled conditions, it is highly resistant to soybean rust compared to JS-335 which is highly susceptible.
g	Reaction to major pests	Under field conditions, it is moderately resistant to pod borer compared to JS-335.

### 3.5.5 Description of the variety: JS-9305

a	Plant height	55-60 cm
b	Distinguishing morphological characters	i) Violet flowers characters ii) Pubescence- almost absent on stem leaves and pods. iii) Semi- determinate habit iv) Yellow seed coat and Brown hilum
c	Maturity	80-85 day
d	Days to 50% flowering	38-40 day
e	Reaction to major diseases	Both under field and controlled conditions, it is highly susceptible to soybean rust and it is resistant to purple seed strain disease.
f	Reaction to major pests	Under field conditions, it is susceptible to pod borer.

## 3.6 Crop management

### 3.6.1 Land preparation

The land was ploughed, harrowed and brought to fine tilth, FYM was added (6 tons per hectare) and the plots were laid out as per the plan of layout of the experiment.

### 3.6.2 Seeds and sowing

Seeds were treated with Carbendizum (fungicide) @ 3 g per kg of seeds as a precautionary measure against fungal diseases. Two seeds per hill were dibbled at 5 cm depth in furrows on 8<sup>th</sup> July 2015 with a seed rate of 62.5 kg per hectare.

### 3.6.3 Fertilizer application

Recommended dose of N (40 kg), P<sub>2</sub>O<sub>5</sub> (80 kg) and K<sub>2</sub>O (25 kg) per ha in the form of Urea, DAP (Di ammonium Phosphate) and MOP (Muriate of Potash) respectively were applied at the time of sowing along with Zinc sulphate @ 12 kg per ha.

### 3.6.4 Gap filling and thinning

Gaps were filled and excess seedlings were thinned at twenty days after sowing to maintain optimum plant population.

### 3.6.5 Plant protection and aftercare

Soon after sowing the land was sprayed with pre- emergent herbicide *i.e.*alachlor @ 3.3 ml/ litre of water followed by hand weeding and one inter-cultivation at 25 days after sowing. The crop was sprayed with profinophos (@ 2 ml/ lit) and Hexaconazole (@ 1 ml/ lit) to control spodoptera and rust respectively.

## 3.7 Biometric observations

Five plants from net plot area were randomly selected and observations on the following growth parameters were recorded at 30 DAS, 60 DAS and at harvest.

### 3.7.1 Plant height (cm)

The plant height was measured from ground level to the tip of the main shoot for five plants and the mean was expressed as plant height in centimeters (cm).

### 3.7.2 Number of branches plant<sup>-1</sup>

The Number of branches per plant was counted from five tagged plants and their mean was recorded as number of branches per plant at 30 DAS, 60 DAS and at harvest.

### 3.7.3 Number of trifoliate leaves plant<sup>-1</sup>

The number of trifoliate leaves present in each plant was counted from five tagged plants and their mean was recorded as number of trifoliate leaves per plant at 30 DAS and 60 DAS.

### 3.7.4 Number of root nodules plant<sup>-1</sup>

The number of effective root nodules was counted at 30 and 60 DAS in randomly selected five plants. The plants were carefully uprooted from the soil without damaging and roots were dipped gently in a bucket containing tap water to remove the adhering soil and nodules were then counted.

### 3.7.5 Canopy spread (cm<sup>2</sup>)

The canopy spread per plant at 30 DAS and 60 DAS was calculated by multiplying the maximum spread of the plant in two directions perpendicular to each other *i.e.*, N-S and E-W by placing centimeter tape and the observation were recorded for five plants and the average was calculated and expressed in square centimeter.

### 3.7.6 Canopy temperature (°C)

Canopy temperature was measured during mid- day using an infrared thermometer. It was measured by pointing the infrared thermometer to the canopy at a height of 30 cm from the canopy and the values were averaged as the canopy temperature for each plant.

### 3.7.7 Dry weight of nodules plant<sup>-1</sup>

Root nodules per plant were oven dried at 70°C for two days and dry weight was recorded and expressed as g plant<sup>-1</sup>.

### 3.7.8 Leaf area plant<sup>-1</sup>

Leaf area was measured by disc method as suggested in Vivekanandan *et al.* (1972). The leaflets were separated from petiole. Fifty discs of known size were obtained through cork bore from randomly selected 25 leaves from five plants. The discs and the remaining leaf blades were oven dried at 70°C to a constant weight and leaf area was calculated at 30 and 60 DAS.

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

Where,

LA = Leaf area (dm<sup>2</sup> plant<sup>-1</sup>)

Wa = oven dry weight of all leaves (inclusive of 50 discs) in g.

Wd = oven dry weight of 50 discs

A = Area of 50 discs in dm<sup>2</sup>

The mean of five plants was recorded as leaf area plant<sup>-1</sup>.

### 3.7.9 Leaf area index (LAI)

It is defined as assimilatory surface per unit area of land (Sestak *et al.*, 1971). Leaf area index was worked out at 30 and 60 DAS by dividing the leaf area per plant by land area occupied by the plant.

$$\text{LAI} = \frac{\text{Leaf area per plant (dm}^2\text{)}}{\text{Land area occupied in the plant (dm}^2\text{)}}$$

### 3.7.10 Dry matter production plant<sup>-1</sup> (g)

The five randomly selected plants were used to record the dry matter production at 30 and 60 DAS and at harvest. The plants were uprooted and separated into leaves, stem and reproductive parts. They were oven dried separately at 70°C for 48 hours and the dry weight (g plant<sup>-1</sup>) was recorded.

### 3.7.11 Harvesting and threshing

Crop was harvested at 95 DAS (01-10-2015). The plants in each net plot were kept in a heap for drying and dried plants were threshed. Seed and haulm weight per net plot was recorded after complete drying.

## 3.8 Observations on growth indices

### 3.8.1 Absolute growth rate (AGR)

The absolute growth rate was calculated by using the formula of Radford (1967) and expressed in g plant<sup>-1</sup> day<sup>-1</sup>.

$$\text{AGR} = \frac{(W_2 - W_1) \text{ (g plant}^{-1} \text{ day}^{-1}\text{)}}{t_2 - t_1}$$

Where,

$W_1$  and  $W_2$  = Total dry weights of plants at time  $t_1$  and  $t_2$  respectively.

### 3.8.2 Crop growth rate (CGR)

The Crop growth rate was calculated by using the formula of Watson (1952) and expressed in g dm<sup>2</sup> day<sup>-1</sup>.

$$\text{CGR} = \frac{(W_2 - W_1) \times 1}{(t_2 - t_1) \times P}$$

Where,

$W_1$  and  $W_2$  = Total dry weights of plants at time  $t_1$  and  $t_2$  respectively.

$P$  = Ground area covered in plant in dm<sup>2</sup>

### 3.8.3 Relative growth rate (RGR)

Relative growth rate is the increase in dry weight per unit dry weight per unit time and is expressed as g g<sup>-1</sup> day<sup>-1</sup> and calculated by the formula of Radford (1967) as follows.

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

Where,

$W_1$  and  $W_2$  = Total dry weights of plants at time  $t_1$  and  $t_2$  respectively.

### 3.8.4 Net assimilation rate (NAR)

Net assimilation rate is the rate of increase in dry weight per unit leaf area per unit time (Watson, 1952) and is expressed as  $\text{g dm}^2 \text{ day}^{-1}$ . It was calculated by the formula of Radford (1967) as follows.

$$\text{NAR} = \frac{(W_2 - W_1) (\log_e L_2 - \log_e L_1) \text{ (g dm}^2 \text{ day}^{-1}\text{)}}{(t_2 - t_1) (L_2 - L_1)}$$

Where,

$L_1$  and  $W_1$  = leaf area ( $\text{dm}^2$ ) and dry weight (g) of plant respectively at time  $t_1$

$L_2$  and  $W_2$  = leaf area ( $\text{dm}^2$ ) and dry weight (g) of plant respectively at time  $t_2$

## 3.9 Observations on yield and yield components

The plants selected for growth studies were utilized for recording the observations on the yield components.

### 3.9.1 Number of pods plant<sup>-1</sup>

The pods of individual plants were counted and average of five plants was recorded as number of pods plant<sup>-1</sup>.

### 3.9.2 Test weight (g)

The weight of hundred seeds (g) was recorded from the seed samples drawn from net plot of each treatment and is called as test weight.

### 3.9.3 Seed weight per plant (g)

The pods from randomly selected five plants were harvested, threshed and weighed separately and the average seed yield plant<sup>-1</sup> was expressed in grams.

### 3.9.4 Seed yield (q ha<sup>-1</sup>)

Harvested from net plot were dried and weighed. On the basis of seed weight per net plot, the seed yield per ha was computed and expressed in  $\text{kg ha}^{-1}$  and convert to  $\text{q ha}^{-1}$ .

### 3.9.5 Haulm yield (q ha<sup>-1</sup>)

The total biological portion from above ground portion from net plot at harvest was weighed after complete sun drying and haulm yield  $\text{ha}^{-1}$  was worked out in deducting the seed yield.

### 3.9.6 Harvest index

Harvest index is defined as the ratio of economic yield to biological yield and expressed in percentage. Harvest index was estimated as per the formula suggested by (Donald, 1962)

$$\text{HI (\%)} = \frac{\text{Economic yield (q ha}^{-1}\text{)}}{\text{Biological yield (q ha}^{-1}\text{)}} \times 100$$

## 3.10 Quality parameters

### 3.10.1 Protein content (%)

The nitrogen percentage in soybean seeds was estimated by modified Kjeldahl's method (Jakson, 1967). The protein content was calculated by multiplying the nitrogen percentage with factor 6.25 (Raghuramulu *et al.*, 1983).

### 3.10.2 Protein yield ( $\text{q ha}^{-1}$ )

Protein yield was worked out by multiplying the protein content with seed yield  $\text{ha}^{-1}$

$$\text{Protein yield (q ha}^{-1}\text{)} = \frac{\text{Protein content\%}}{100} \times \text{Seed yield (q ha}^{-1}\text{)}$$

### 3.10.3 Oil content (%)

Determined by Nuclear Magnetic Resonance (NMR) spectrometer against a standard reference sample.

### 3.10.4 Oil yield ( $\text{q ha}^{-1}$ )

$$\text{Oil yield (q ha}^{-1}\text{)} = \frac{\text{Oil content \%}}{100} \times \text{Seed yield (q ha}^{-1}\text{)}$$

## 3.11 Chemical analysis

### 3.11.1 Soil chemical analysis

The soil samples at initial stage were collected and shade dried and it was powdered with pestle and mortar and passed through 2 mm sieve. The sieved samples were used for the estimation of nitrogen, phosphorus and potassium content in soil.

#### 3.11.1.1 Available nitrogen ( $\text{kg ha}^{-1}$ )

Available nitrogen content was determined in alkaline permanganate method as described by Subbiah and Asija (1956).

#### 3.11.1.2 Available phosphorus (kg ha<sup>-1</sup>)

Available phosphorus content was determined by Olsen's method as outlined in Jackson (1967).

#### 3.11.1.3 Available potassium (kg ha<sup>-1</sup>)

Available potassium content was determined by extracting soil with neutral normal ammonium acetate solution and using flame photometer as outlined in Jackson (1967).

### 3.12 Economics of the system

#### 3.12.1 Cost of cultivation

Cost of cultivation or production cost of crop was calculated by considering the cost of all inputs and operations involved in successful growing of the crop and expressed as Cost of cultivation ha<sup>-1</sup> (₹ ha<sup>-1</sup>).

#### 3.12.2 Gross returns (₹ ha<sup>-1</sup>)

The income from main product (seed) and by-product (haulm) of soybean was considered for accounting gross returns. The minimum support price prevailed at the time of selling seed (₹ 3,900 q<sup>-1</sup>) and haulm (₹ 750 tonn<sup>-1</sup>) and UAS, Dharwad rate were considered to calculate the gross returns.

#### 3.12.3 Net returns (₹ ha<sup>-1</sup>)

Net returns were calculated by subtracting the cost of cultivation (₹ ha<sup>-1</sup>) from the gross returns (₹ ha<sup>-1</sup>).

#### 3.12.4 Benefit cost ratio

The ratio of Gross returns and cost of cultivation was worked out for each treatment and was given as benefit cost ratio (B: C) to compare the performance of different treatments.

$$B: C = \frac{\text{Gross return (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

### 3.13 Statistical analysis and interpretation of data

Statistical analysis was carried out based on mean values obtained. The level of significance used in 'F' and 'T' test was P= 0.05 (Gomez and Gomez, 1984).

## 4. EXPERIMENTAL RESULTS

### 4.1 Plant growth parameters

#### 4.1.1 Plant height (cm) (Table 3)

The impact of varieties on plant height at 30 DAS was non-significant, however at 60 DAS and at harvest, significantly higher plant height was recorded in JS-9305 (61.23 cm and 62.05 cm) compared to Dsb-21 (58.56 cm and 59.43 cm) variety.

Significantly higher plant height at 60 DAS and at harvest was recorded at 22.5 x 20 cm (63.49 cm and 64.33 cm) and lower plant height was recorded at 90 cm (57.11 cm and 57.89 cm).

The interaction effect on plant height was non-significant at 30 DAS. At 60 DAS and at harvest significantly higher plant height was recorded in JS-9305 when sown at 22.5 x 20 cm (65.28 cm and 66.23 cm) compared to other treatments.

#### 4.1.2 Number of branches plant<sup>-1</sup> (Table 4)

Varieties did not differ significantly in number of branches plant<sup>-1</sup> at 30 DAS. At 60 DAS and at harvest significantly higher number of branches plant<sup>-1</sup> were recorded in Dsb-21 (5.96 and 6.31) compared to the JS-9305 (5.28 and 5.69).

Among the row spacings, number of branches plant<sup>-1</sup> were on par at 30 DAS. significantly higher number of branches plant<sup>-1</sup> were recorded at 90 x 5 cm (6.65 and 6.95) and lower number of branches plant<sup>-1</sup> recorded at 22.5 x 20 cm (4.73 and 5.13) at 60 DAS and at harvest.

Among the interaction, effect on number of branches plant<sup>-1</sup> was non-significant at 30 DAS. Significantly higher number of branches plant<sup>-1</sup> at 60 DAS and at harvest was recorded in Dsb-21 when sown at 90 x 5 cm (7.18 and 7.45) compared to other treatments.

#### 4.1.3 Number of trifoliolate leaves plant<sup>-1</sup> (Table 5)

Varieties did not differ significantly with respect to number of trifoliolate leaves plant<sup>-1</sup> at 30 DAS. At 60 DAS, Significantly higher Number of trifoliolate leaves plant<sup>-1</sup> (10.99) were recorded in Dsb-21 compared to JS-9305 (9.09).

Among the different row spacings, number of trifoliolate leaves plant<sup>-1</sup> at 30 DAS were found to be non- significant. At 60 DAS significantly higher number of trifoliolate leaves plant<sup>-1</sup> were recorded at 90 x 5 cm (10.88) and lower number of trifoliolate leaves plant<sup>-1</sup> were recorded at 22.5 x 20 cm (9.40) compared to other spacings.

Non-significant interaction effect in case of number of trifoliolate leaves plant<sup>-1</sup> at 30 DAS, significantly higher number of trifoliolate leaves plant<sup>-1</sup> at 60 DAS were recorded in Dsb-21 when sown at 90 x 5 cm (11.73) compared to other treatments.

**Table 3: Plant height (cm) of soybean varieties as influenced by planting geometry**

Treatments	30 DAS			60 DAS			At harvest		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	20.03	20.00	<b>20.01</b>	58.30	55.93	<b>57.11</b>	59.10	56.68	<b>57.89</b>
S <sub>2</sub> - 60 x 7.5 cm	21.48	20.38	<b>20.93</b>	58.36	57.03	<b>57.69</b>	59.28	57.50	<b>58.39</b>
S <sub>3</sub> - 30 x 15 cm	21.03	20.83	<b>20.93</b>	61.37	59.20	<b>60.29</b>	62.50	60.40	<b>61.45</b>
S <sub>4</sub> - 22.5 x 20 cm	22.19	21.55	<b>21.87</b>	65.28	61.70	<b>63.49</b>	66.23	62.43	<b>64.33</b>
S <sub>5</sub> - 45 x 10 cm	20.89	20.45	<b>20.67</b>	61.60	58.16	<b>59.88</b>	62.08	58.88	<b>60.48</b>
S <sub>6</sub> - 30 x 10 cm	21.35	21.03	<b>21.19</b>	62.50	59.38	<b>60.94</b>	63.13	60.68	<b>61.90</b>
<b>Mean</b>	<b>21.16</b>	<b>20.70</b>		<b>61.23</b>	<b>58.56</b>		<b>62.05</b>	<b>59.43</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.30	0.51	0.72	0.18	0.30	0.43	0.15	0.26	0.37
C.D. at 5 %	NS	NS	NS	0.51	0.88	1.24	0.43	0.75	1.05

**Table 4: Number of branches plant<sup>-1</sup> of soybean varieties as influenced by planting geometry**

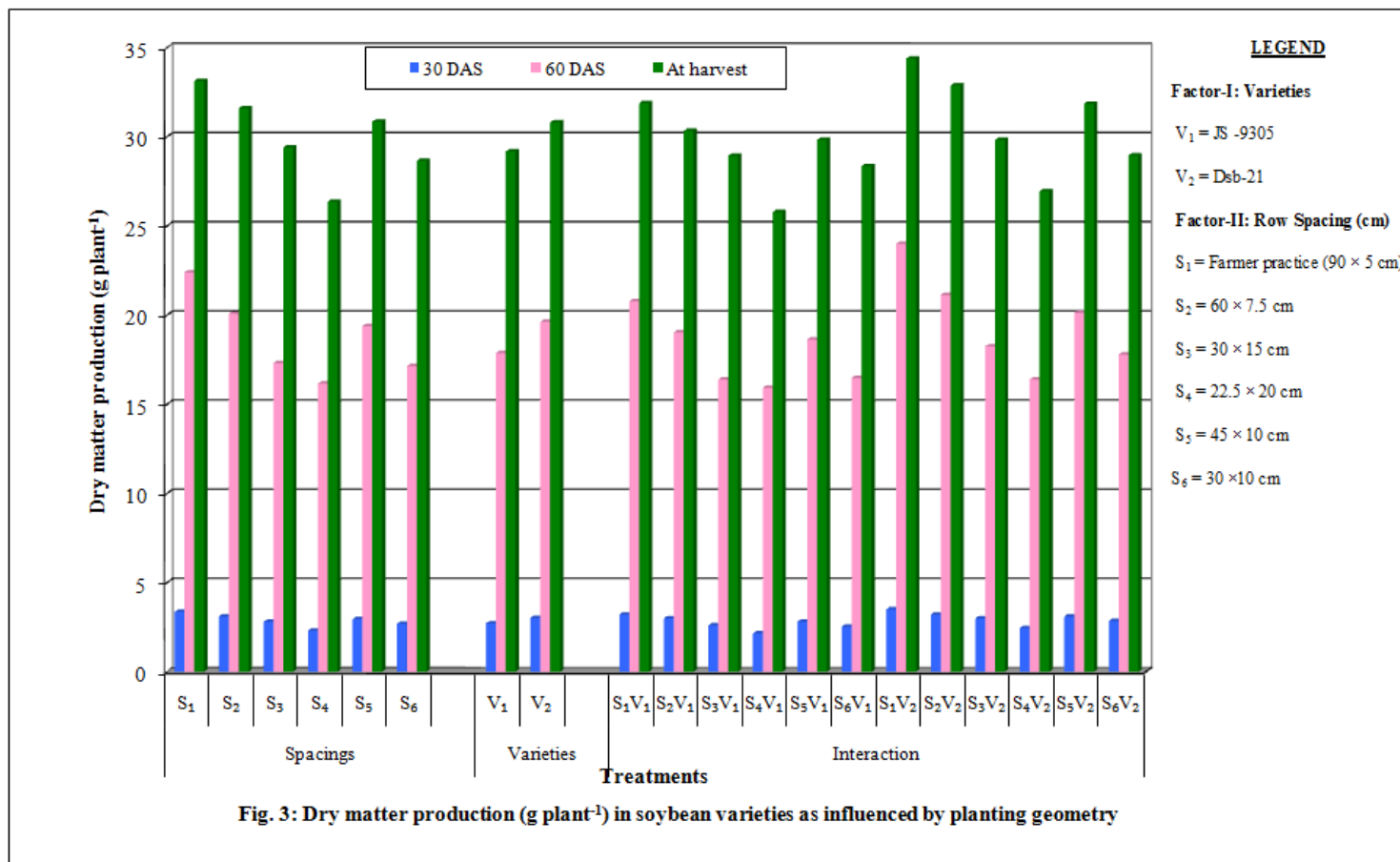
Treatments	30 DAS			60 DAS			At harvest		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	3.13	3.15	<b>3.14</b>	6.13	7.18	<b>6.65</b>	6.45	7.45	<b>6.95</b>
S <sub>2</sub> - 60 x 7.5 cm	3.00	3.03	<b>3.01</b>	5.80	6.43	<b>6.11</b>	6.33	6.68	<b>6.50</b>
S <sub>3</sub> - 30 x 15 cm	2.74	2.93	<b>2.83</b>	5.13	5.69	<b>5.41</b>	5.53	6.09	<b>5.81</b>
S <sub>4</sub> - 22.5 x 20 cm	2.75	3.13	<b>2.94</b>	4.45	5.00	<b>4.73</b>	4.85	5.40	<b>5.13</b>
S <sub>5</sub> - 45 x 10 cm	2.94	3.16	<b>3.05</b>	5.18	5.90	<b>5.54</b>	5.58	6.30	<b>5.94</b>
S <sub>6</sub> - 30 x 10 cm	2.71	2.81	<b>2.76</b>	5.00	5.58	<b>5.29</b>	5.40	5.98	<b>5.69</b>
<b>Mean</b>	<b>2.88</b>	<b>3.03</b>		<b>5.28</b>	<b>5.96</b>		<b>5.69</b>	<b>6.31</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.06	0.11	0.15	0.03	0.06	0.08	0.04	0.07	0.11
C.D. at 5 %	NS	NS	NS	0.09	0.16	0.23	0.12	0.21	0.30

**Table 5: Number of tri foliate leaves plant<sup>1</sup> of soybean varieties as influenced by planting geometry**

Treatments	30 DAS			60 DAS		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	3.91	4.81	<b>4.36</b>	10.03	11.73	<b>10.88</b>
S <sub>2</sub> - 60 x 7.5 cm	3.88	4.71	<b>4.30</b>	9.48	11.28	<b>10.38</b>
S <sub>3</sub> - 30 x 15 cm	3.41	4.21	<b>3.81</b>	8.70	10.83	<b>9.76</b>
S <sub>4</sub> - 22.5 x 20 cm	3.21	4.01	<b>3.61</b>	8.39	10.41	<b>9.40</b>
S <sub>5</sub> - 45 x 10 cm	3.51	4.31	<b>3.91</b>	9.32	10.93	<b>10.13</b>
S <sub>6</sub> - 30 x 10 cm	3.41	4.21	<b>3.81</b>	8.62	10.80	<b>9.71</b>
<b>Mean</b>	<b>3.55</b>	<b>4.38</b>		<b>9.09</b>	<b>10.99</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.40	0.50	0.60	0.07	0.12	0.17
C.D. at 5 %	NS	NS	NS	0.20	0.35	0.49

**Table 6: Dry matter production (g plant<sup>-1</sup>) of soybean varieties as influenced by planting geometry**

Treatments	30 DAS			60 DAS			At harvest		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	3.20	3.50	<b>3.35</b>	20.78	24.0	<b>22.39</b>	31.88	34.38	<b>33.13</b>
S <sub>2</sub> - 60 x 7.5 cm	3.00	3.20	<b>3.10</b>	19.03	21.13	<b>20.08</b>	30.33	32.88	<b>31.60</b>
S <sub>3</sub> - 30 x 15 cm	2.60	3.00	<b>2.80</b>	16.38	18.25	<b>17.31</b>	28.93	29.83	<b>29.40</b>
S <sub>4</sub> - 22.5 x 20 cm	2.15	2.45	<b>2.30</b>	15.93	16.40	<b>16.16</b>	25.78	26.95	<b>26.36</b>
S <sub>5</sub> - 45 x 10 cm	2.80	3.10	<b>2.95</b>	18.63	20.13	<b>19.38</b>	29.83	31.85	<b>30.84</b>
S <sub>6</sub> - 30 x 10 cm	2.53	2.85	<b>2.69</b>	16.48	17.80	<b>17.14</b>	28.35	28.95	<b>28.65</b>
<b>Mean</b>	<b>2.71</b>	<b>3.02</b>		<b>17.87</b>	<b>19.62</b>		<b>29.17</b>	<b>30.80</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.02	0.04	0.06	0.12	0.21	0.29	0.07	0.12	0.17
C.D. at 5 %	0.07	0.12	0.17	0.34	0.59	0.84	0.20	0.35	0.50



**Fig. 3: Dry matter production (g plant<sup>-1</sup>) in soybean varieties as influenced by planting geometry**

#### 4.1.4 Total dry matter production ( $\text{g plant}^{-1}$ ) (Table 6)

Significantly higher dry matter production  $\text{plant}^{-1}$  was recorded in Dsb-21 (3.02, 19.62 and 30.80 g respectively) compared to the JS-9305 (2.71, 17.87 and 29.17 g respectively) at all the growth stages of crop.

Among the different row spacings, significantly higher dry matter production  $\text{plant}^{-1}$  at 30, 60 DAS and harvest was recorded at 90 x 5 cm (3.35, 22.39 and 33.13 g respectively) and lower dry matter production  $\text{plant}^{-1}$  was recorded at 22.5 x 20 cm (2.30, 16.16 and 26.36 g respectively) compared to other spacings.

The interaction effect of varieties and row spacings on dry matter production  $\text{plant}^{-1}$  was significant at 30 DAS, 60 DAS and at harvest. Significantly higher dry matter production  $\text{plant}^{-1}$  was recorded in Dsb-21 (3.50, 24.00 and 34.38) when sown at 90 x 5 cm row spacing compared other treatments.

#### 4.1.5 Leaf area ( $\text{dm}^2 \text{ plant}^{-1}$ ) (Table 7)

Significantly higher leaf area  $\text{plant}^{-1}$  was recorded at 30 and 60 DAS in Dsb-21 (5.72  $\text{dm}^2$  and 12.69  $\text{dm}^2$ ) compared to JS-9305 (5.12  $\text{dm}^2$  and 11.56  $\text{dm}^2$ ).

With respect to different row spacings the leaf area  $\text{plant}^{-1}$  was significant at 30 and 60 DAS. Significantly higher leaf area  $\text{plant}^{-1}$  was recorded at 90 x 5 cm (6.29 and 14.22  $\text{dm}^2$ ) and lower leaf area  $\text{plant}^{-1}$  was recorded at 22.5 x 20 cm (4.49 and 10.68  $\text{dm}^2$ ).

Significantly higher leaf area  $\text{plant}^{-1}$  was recorded in Dsb-21 when sown at 90 x 5 cm row spacing at 30 and 60 DAS (6.69 and 15.36  $\text{dm}^2$ , respectively) compared to other treatments.

#### 4.1.6 Leaf area index (Table 7)

Significantly higher leaf area index was recorded at 30 DAS and 60 DAS in Dsb-21 (1.37 and 3.03) compared to the JS-9305 (1.22 and 2.77) variety.

Different row spacings showed significant impact on leaf area index  $\text{plant}^{-1}$  at 30 and 60 DAS, Significantly higher leaf area index  $\text{plant}^{-1}$  was recorded at 30 x 10 cm (1.70 and 3.72) and lower leaf area index  $\text{plant}^{-1}$  was recorded at 22.5 x 20 cm (1.00 and 2.37).

Interaction effect at 30 and 60 DAS was recorded significantly higher leaf area index  $\text{plant}^{-1}$  (1.82 and 3.86, respectively) in Dsb-21 when sown at 30 x 10 cm row spacing compared to other treatments.

#### 4.1.7 Relative growth rate (Table 8)

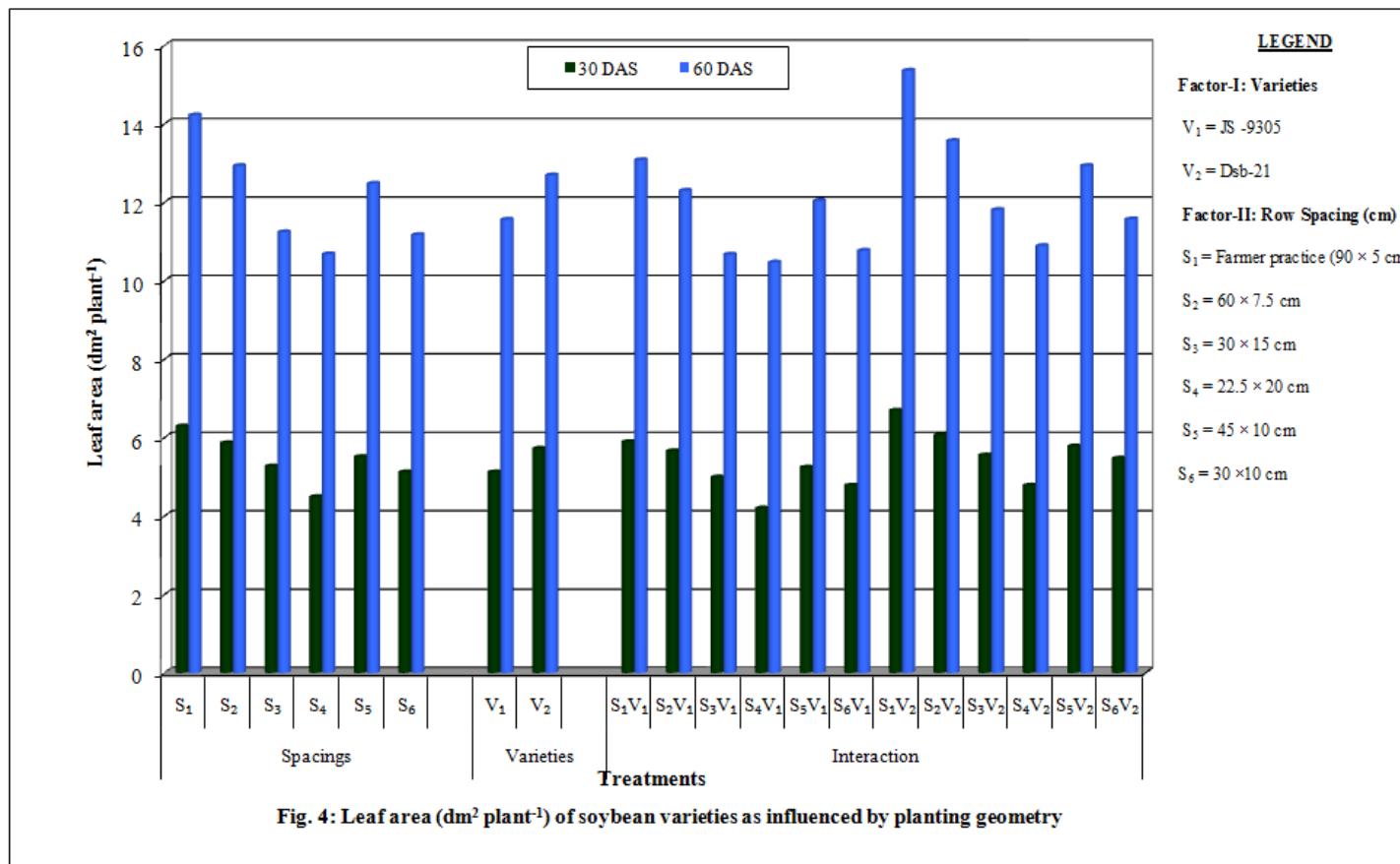
Significantly higher relative growth rate was recorded in JS-9305 (0.0071  $\text{g g}^{-1} \text{ day}^{-1}$ ) compared to the Dsb-21 (0.0066  $\text{g g}^{-1} \text{ day}^{-1}$ ) variety during 60-90 DAS. Non-significant difference with respect to crop growth rate during 30-60 DAS.

**Table 7: Leaf area (dm<sup>2</sup> plant<sup>-1</sup>) and leaf area index plant<sup>-1</sup> of soybean varieties as influenced by planting geometry**

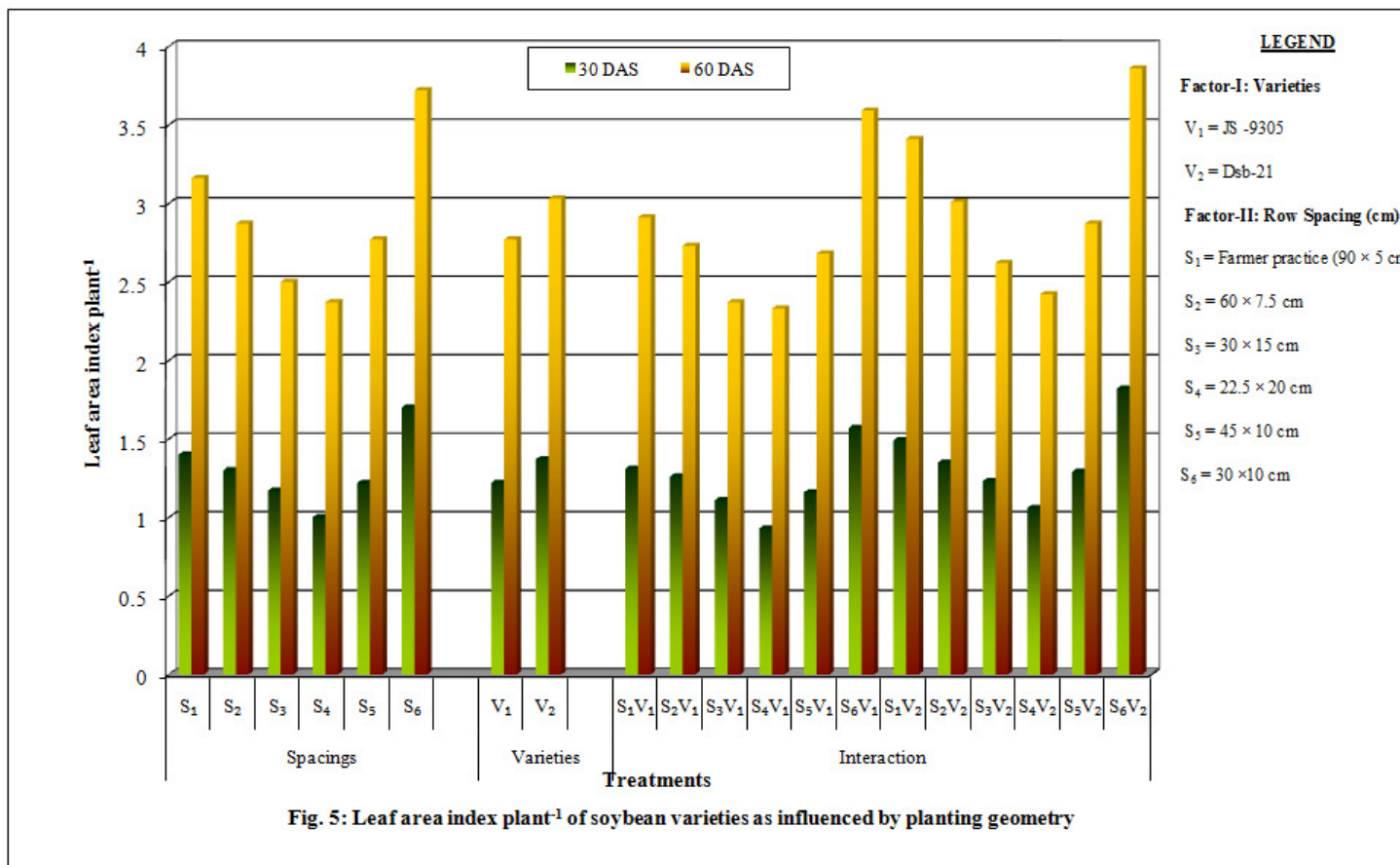
Treatments	leaf area (dm <sup>2</sup> plant <sup>-1</sup> )						leaf area index					
	30 DAS			60 DAS			30 DAS			60 DAS		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	5.89	6.69	<b>6.29</b>	13.08	15.36	<b>14.22</b>	1.31	1.49	<b>1.40</b>	2.91	3.41	<b>3.16</b>
S <sub>2</sub> - 60 x 7.5 cm	5.66	6.06	<b>5.86</b>	12.30	13.57	<b>12.93</b>	1.26	1.35	<b>1.30</b>	2.73	3.01	<b>2.87</b>
S <sub>3</sub> - 30 x 15 cm	4.99	5.55	<b>5.27</b>	10.67	11.81	<b>11.24</b>	1.11	1.23	<b>1.17</b>	2.37	2.62	<b>2.50</b>
S <sub>4</sub> - 22.5 x 20 cm	4.20	4.78	<b>4.49</b>	10.47	10.89	<b>10.68</b>	0.93	1.06	<b>1.00</b>	2.33	2.42	<b>2.37</b>
S <sub>5</sub> - 45 x 10 cm	5.24	5.78	<b>5.51</b>	12.04	12.93	<b>12.48</b>	1.16	1.29	<b>1.22</b>	2.68	2.87	<b>2.77</b>
S <sub>6</sub> - 30 x 10 cm	4.78	5.47	<b>5.12</b>	10.77	11.57	<b>11.17</b>	1.57	1.82	<b>1.70</b>	3.59	3.86	<b>3.72</b>
<b>Mean</b>	<b>5.12</b>	<b>5.72</b>		<b>11.56</b>	<b>12.69</b>		<b>1.22</b>	<b>1.37</b>		<b>2.77</b>	<b>3.03</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.05	0.09	0.12	0.09	0.15	0.22	0.01	0.02	0.03	0.02	0.04	0.05
C.D. at 5 %	0.14	0.99	0.35	0.26	0.44	0.63	0.04	0.06	0.09	0.06	0.11	0.15

**Table 8: Relative growth rate ( $\text{g g}^{-1} \text{day}^{-1}$ ) and Net assimilation rate ( $\text{g dm}^2 \text{day}^{-1}$ ) of soybean varieties as influenced by planting geometry**

Treatments	RGR (30-60 DAS)			RGR (60-90 DAS)			NAR (30-60 DAS)		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	0.0271	0.0279	<b>0.0275</b>	0.0062	0.0052	<b>0.0057</b>	0.028	0.028	<b>0.028</b>
S <sub>2</sub> - 60 x 7.5 cm	0.0267	0.0273	<b>0.0270</b>	0.0068	0.0064	<b>0.0066</b>	0.027	0.028	<b>0.028</b>
S <sub>3</sub> - 30 x 15 cm	0.0266	0.0262	<b>0.0264</b>	0.0070	0.0072	<b>0.0071</b>	0.027	0.027	<b>0.027</b>
S <sub>4</sub> - 22.5 x 20 cm	0.0290	0.0275	<b>0.0283</b>	0.0082	0.0071	<b>0.0077</b>	0.029	0.027	<b>0.028</b>
S <sub>5</sub> - 45 x 10 cm	0.0274	0.0271	<b>0.0273</b>	0.0068	0.0067	<b>0.0067</b>	0.027	0.028	<b>0.028</b>
S <sub>6</sub> - 30 x 10 cm	0.0271	0.0265	<b>0.0268</b>	0.0079	0.0070	<b>0.0075</b>	0.028	0.027	<b>0.027</b>
<b>Mean</b>	<b>0.0273</b>	<b>0.0271</b>		<b>0.0071</b>	<b>0.0066</b>		<b>0.028.</b>	<b>0.027</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. $\pm$	0.0001	0.0003	0.0004	0.0001	0.0002	0.0003	0.001	0.002	0.0005
C.D. at 5 %	NS	0.0007	0.0007	0.0003	0.0005	0.0007	NS	NS	NS



**Fig. 4: Leaf area (dm<sup>2</sup> plant<sup>-1</sup>) of soybean varieties as influenced by planting geometry**



**Fig. 5: Leaf area index plant<sup>-1</sup> of soybean varieties as influenced by planting geometry**

Significantly higher relative growth rate was recorded during 30-60 and 60-90 DAS when sown at 22.5 x 20 cm (0.0283 and 0.0077 g g<sup>-1</sup> day<sup>-1</sup>) during 30-60 and 60-90 DAS compared to other row spacings.

Interaction effect of the varieties and row spacings on relative growth rate during 30-60 DAS and 60-90 DAS was found to be significant. Significantly higher relative growth rate was recorded in JS-9305 when sown at 22.5 x 20 cm (0.0290 and 0.0082 g g<sup>-1</sup> day<sup>-1</sup>) at 30-60 DAS and 60-90 DAS compared to other treatments.

#### 4.1.8 Net assimilation rate (Table 8)

Soybean varieties, row spacings and their interaction did not show any significant effect on net assimilation rate during 30-60 DAS.

#### 4.1.9 Crop growth rate (Table 9)

Significantly higher crop growth rate was recorded in Dsb-21 (0.132 g dm<sup>2</sup> day<sup>-1</sup>) compared to the JS-9305 (0.121 g dm<sup>2</sup> day<sup>-1</sup>) variety during 30-60 DAS and non-significant difference with respect to crop growth rate during 60-90 DAS.

Different row spacings showed significantly higher crop growth rate during 30- 60 DAS and 60-90 DAS. Significantly higher crop growth rate was recorded at 30 x 10 cm (0.161 g dm<sup>2</sup> day<sup>-1</sup>) and lower crop growth rate was recorded at 22.5 x 20 cm (0.103 g dm<sup>2</sup> day<sup>-1</sup>) during 30-60 DAS. Significantly higher crop growth rate was recorded at 30 x 10 cm (0.128 g dm<sup>2</sup> day<sup>-1</sup>) during 60-90 DAS and lower crop growth rate was recorded at 22.5 x 20 cm (0.076 g dm<sup>2</sup> day<sup>-1</sup>) compared to other row spacings.

Interaction effect of the varieties and row spacings on crop growth rate during 30-60 DAS and 60-90 DAS was found to be significant. Significantly higher crop growth rate was recorded in Dsb-21 when sown at 30 x 10 cm (0.166 and 0.132 g dm<sup>2</sup> day<sup>-1</sup>) at 30-60 DAS and 60-90 DAS.

#### 4.1.10 Absolute growth rate (Table 9)

Soybean variety Dsb-21 recorded significantly higher absolute growth rate (0.553 g plant<sup>-1</sup> day<sup>-1</sup>) compared to the JS-9305 (0.505 g plant<sup>-1</sup> day<sup>-1</sup>) during 30-60 DAS. But the varieties showed non-significant effect on absolute growth rate during 60-90 DAS.

Significantly higher absolute growth rate was recorded at 90 x 5 cm (0.635 g plant<sup>-1</sup> day<sup>-1</sup>) during 30-60 DAS and lower absolute growth rate was recorded at 22.5 x 20 cm (0.462 g plant<sup>-1</sup> day<sup>-1</sup>), absolute growth rate were found to be non- significant during 60- 90 DAS.

Interaction effect of the varieties and row spacings on absolute growth rate significantly higher crop growth rate was recorded in Dsb-21 when sown at 90 x 5 cm (0.683 g plant<sup>-1</sup> day<sup>-1</sup>) at 30-60 DAS and during 60-90 DAS was non-Significant to absolute growth rate.

#### 4.1.11 Number of root nodules plant<sup>-1</sup> (Table 10)

Soybean varieties differed significantly with respect to number of root nodules plant<sup>-1</sup> both at 30 and 60 DAS. The Dsb-21 had significantly higher number of nodules plant<sup>-1</sup> (18.82 and 28.93) compared to JS-9305 (17.98 and 27.67).

**Table 9: Crop growth rate (g dm<sup>2</sup> day<sup>-1</sup>) and Absolute growth rate (g plant<sup>-1</sup> day<sup>-1</sup>) of soybean varieties as influenced by planting geometry**

Treatments	CGR (g dm <sup>2</sup> day <sup>-1</sup> )						AGR (g plant <sup>-1</sup> day <sup>-1</sup> )					
	(30-60 DAS)			(60-90 DAS)			(30-60 DAS)			(60-90 DAS)		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	0.130	0.152	<b>0.141</b>	0.082	0.077	<b>0.079</b>	0.586	0.683	<b>0.635</b>	0.368	0.346	<b>0.357</b>
S <sub>2</sub> - 60 x 7.5 cm	0.119	0.133	<b>0.126</b>	0.084	0.087	<b>0.085</b>	0.534	0.598	<b>0.566</b>	0.377	0.392	<b>0.384</b>
S <sub>3</sub> - 30 x 15 cm	0.102	0.113	<b>0.108</b>	0.093	0.086	<b>0.089</b>	0.459	0.508	<b>0.484</b>	0.418	0.386	<b>0.402</b>
S <sub>4</sub> - 22.5 x 20 cm	0.102	0.103	<b>0.103</b>	0.073	0.078	<b>0.076</b>	0.459	0.465	<b>0.462</b>	0.328	0.352	<b>0.340</b>
S <sub>5</sub> - 45 x 10 cm	0.117	0.126	<b>0.122</b>	0.083	0.087	<b>0.085</b>	0.528	0.568	<b>0.548</b>	0.373	0.391	<b>0.382</b>
S <sub>6</sub> - 30 x 10 cm	0.155	0.166	<b>0.161</b>	0.124	0.132	<b>0.128</b>	0.465	0.498	<b>0.482</b>	0.396	0.372	<b>0.384</b>
<b>Mean</b>	<b>0.121</b>	<b>0.132</b>		<b>0.091</b>	<b>0.090</b>		<b>0.505</b>	<b>0.553</b>		<b>0.377</b>	<b>0.373</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.001	0.002	0.002	0.001	0.002	0.003	0.004	0.007	0.010	0.005	0.008	0.012
C.D. at 5 %	0.003	0.005	0.007	NS	0.006	0.008	0.012	0.021	0.029	NS	NS	NS

**Table 10: Number of root nodules plant<sup>-1</sup> and Nodules dry weight plant<sup>-1</sup> (g) in soybean varieties as influenced by planting geometry**

Treatments	Number of root nodules plant <sup>-1</sup>						Nodules dry weight plant <sup>-1</sup> (g)					
	30 DAS			60 DAS			30 DAS			60 DAS		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	16.20	17.48	<b>16.84</b>	27.00	27.50	<b>27.25</b>	0.21	0.23	<b>0.22</b>	0.50	0.50	<b>0.50</b>
S <sub>2</sub> - 60 x 7.5 cm	18.98	19.35	<b>19.16</b>	29.48	29.48	<b>29.48</b>	0.25	0.26	<b>0.25</b>	0.53	0.53	<b>0.53</b>
S <sub>3</sub> - 30 x 15 cm	18.48	18.58	<b>18.53</b>	26.50	28.30	<b>27.40</b>	0.25	0.25	<b>0.25</b>	0.50	0.51	<b>0.51</b>
S <sub>4</sub> - 22.5 x 20 cm	15.80	17.74	<b>16.77</b>	25.15	27.99	<b>26.57</b>	0.20	0.24	<b>0.22</b>	0.47	0.51	<b>0.49</b>
S <sub>5</sub> - 45 x 10 cm	20.43	20.98	<b>20.70</b>	31.30	31.70	<b>31.50</b>	0.26	0.29	<b>0.27</b>	0.54	0.58	<b>0.56</b>
S <sub>6</sub> - 30 x 10 cm	17.99	18.78	<b>18.38</b>	26.57	28.65	<b>27.61</b>	0.23	0.26	<b>0.24</b>	0.49	0.52	<b>0.51</b>
<b>Mean</b>	<b>17.98</b>	<b>18.82</b>		<b>27.67</b>	<b>28.93</b>		<b>0.23</b>	<b>0.25</b>		<b>0.51</b>	<b>0.53</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.E.m. ±	0.06	0.10	0.14	0.08	0.14	0.20	0.001	0.003	0.004	0.003	0.006	0.008
C.D. at 5 %	0.16	0.28	0.39	0.93	1.61	0.57	0.004	0.007	0.010	0.010	0.017	0.024

Various row spacings showed significant impact on number of nodules per plant at 30 and 60 DAS. Significantly higher number of nodules was recorded when sown at 45 x10 cm (20.70 and 31.50) compared to other row spacings.

The interaction effect of varieties and row spacings on number of nodules per plant was significant both at 30 and 60 DAS. Significantly higher number of nodules plant<sup>-1</sup> were produced in Dsb-21 (20.98 and 31.70) when sown at 45 x 10 cm row spacing.

#### 4.1.12 Nodules dry weight plant<sup>-1</sup> (Table 10)

Soybean varieties differed significantly with respect to nodules dry weight plant<sup>-1</sup> both at 30 and 60 DAS. The Dsb-21 had significantly higher to nodules dry weight plant<sup>-1</sup> (0.25 g and 0.53 g) compared to JS-9305 (0.23 g and 0.51 g).

Various row spacings showed significant impact on nodules dry weight plant<sup>-1</sup> at 30 and 60 DAS. Significantly higher to nodules dry weight plant<sup>-1</sup> was recorded when sown at 45 x10 cm (0.27 g and 0.56 g) compared to other row spacings.

The interaction effect of varieties and row spacings on nodules dry weight plant<sup>-1</sup> was significant both at 30 and 60 DAS. Significantly higher to nodules dry weight plant<sup>-1</sup> were produced in Dsb-21 (0.29 g and 0.58 g) when sown at 45 x 10 cm.

#### 4.1.13 Canopy spread (cm<sup>2</sup>) (Table 11)

Significantly higher canopy spread plant<sup>-1</sup> at 30 DAS and 60 DAS was recorded in Dsb-21 (507.7 cm<sup>2</sup> and 2027.7 cm<sup>2</sup>) compared to the JS-9305 (471.9 cm<sup>2</sup> and 1716.5 cm<sup>2</sup>) variety.

With regard to different row spacings, the canopy spread plant<sup>-1</sup> was significant at 30 and 60 DAS. Significantly higher canopy spread plant<sup>-1</sup> was recorded at 90 x 5 cm (637.5 cm<sup>2</sup> and 2266.3 cm<sup>2</sup>) and lower canopy spread plant<sup>-1</sup> was recorded at 22.5 x 20 cm (397.3 cm<sup>2</sup> and 1615 cm<sup>2</sup>) compared to other spacings.

The interaction effects was found to be significant in canopy spread plant<sup>-1</sup> at 30 and 60 DAS. Significantly higher canopy spread plant<sup>-1</sup> was recorded in Dsb-21 when sown at 90 x 5 cm (657.5 cm<sup>2</sup> and 2477.5 cm<sup>2</sup>) and lower canopy spread plant<sup>-1</sup> was recorded in JS-9305 at 22.5 x 20 cm (380.9 cm<sup>2</sup> and 1478.5 cm<sup>2</sup>) compared to other treatments.

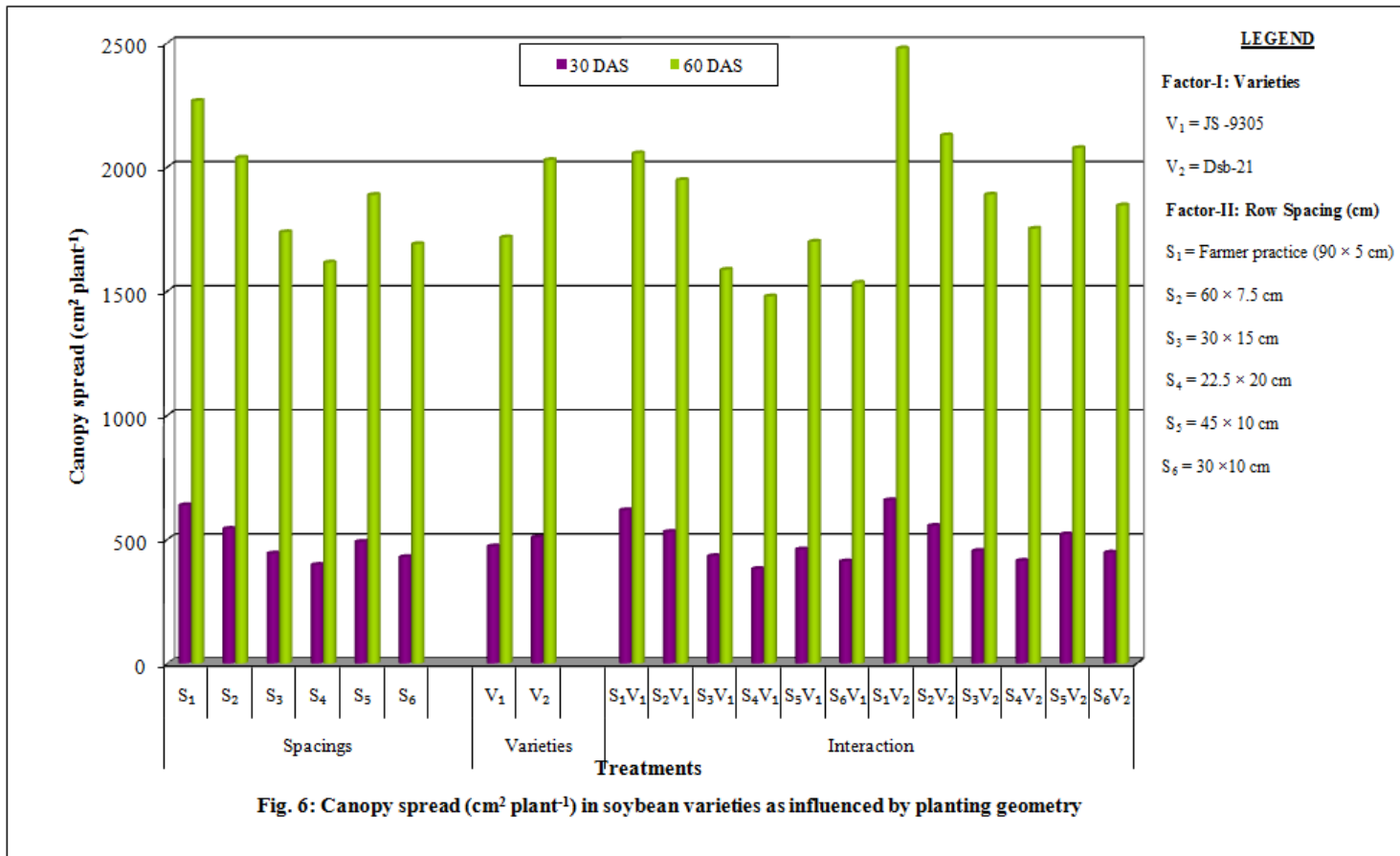
#### 4.1.14 Canopy temperature (°C) (Table 12)

Canopy temperature in different varieties varied significantly at 30 and 60 DAS. The Dsb-21 recorded significantly higher Canopy temperature plant<sup>-1</sup> (27.7 °C and 24.2 °C) compared to the JS-9305 (26.6 °C and 23.3 °C).

Among the different row spacings, significantly higher Canopy temperature plant<sup>-1</sup> was observed at 30 and 60 DAS. significantly higher Canopy temperature plant<sup>-1</sup> was recorded at 90 x 5 cm (28.2 °C and 24.6 °C) and lower Canopy temperature plant<sup>-1</sup> was recorded at 22.5 x 20 cm (26.5 °C and 23.1 °C).

**Table 11: Canopy spread (cm<sup>2</sup> plant<sup>-1</sup>) in soybean varieties as influenced by planting geometry**

Treatments	30 DAS			60 DAS		
	Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21
S <sub>1</sub> - 90 x 5 cm	617.5	657.5	<b>637.5</b>	2055.0	2477.5	<b>2266.3</b>
S <sub>2</sub> - 60 x 7.5 cm	530.0	554.8	<b>542.4</b>	1947.5	2127.5	<b>2037.5</b>
S <sub>3</sub> - 30 x 15 cm	432.4	453.5	<b>442.9</b>	1585.9	1888.8	<b>1737.3</b>
S <sub>4</sub> - 22.5 x 20 cm	380.9	413.7	<b>397.3</b>	1478.5	1751.5	<b>1615.0</b>
S <sub>5</sub> - 45 x 10 cm	459.5	520.3	<b>489.9</b>	1698.8	2076.0	<b>1887.4</b>
S <sub>6</sub> - 30 x 10 cm	411.3	446.7	<b>429.0</b>	1533.3	1845.1	<b>1689.2</b>
<b>Mean</b>	<b>471.9</b>	<b>507.7</b>		<b>1716.5</b>	<b>2027.7</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.73	1.27	1.80	2.02	3.50	4.96
C.D. at 5 %	2.11	3.65	5.17	5.82	10.08	14.26

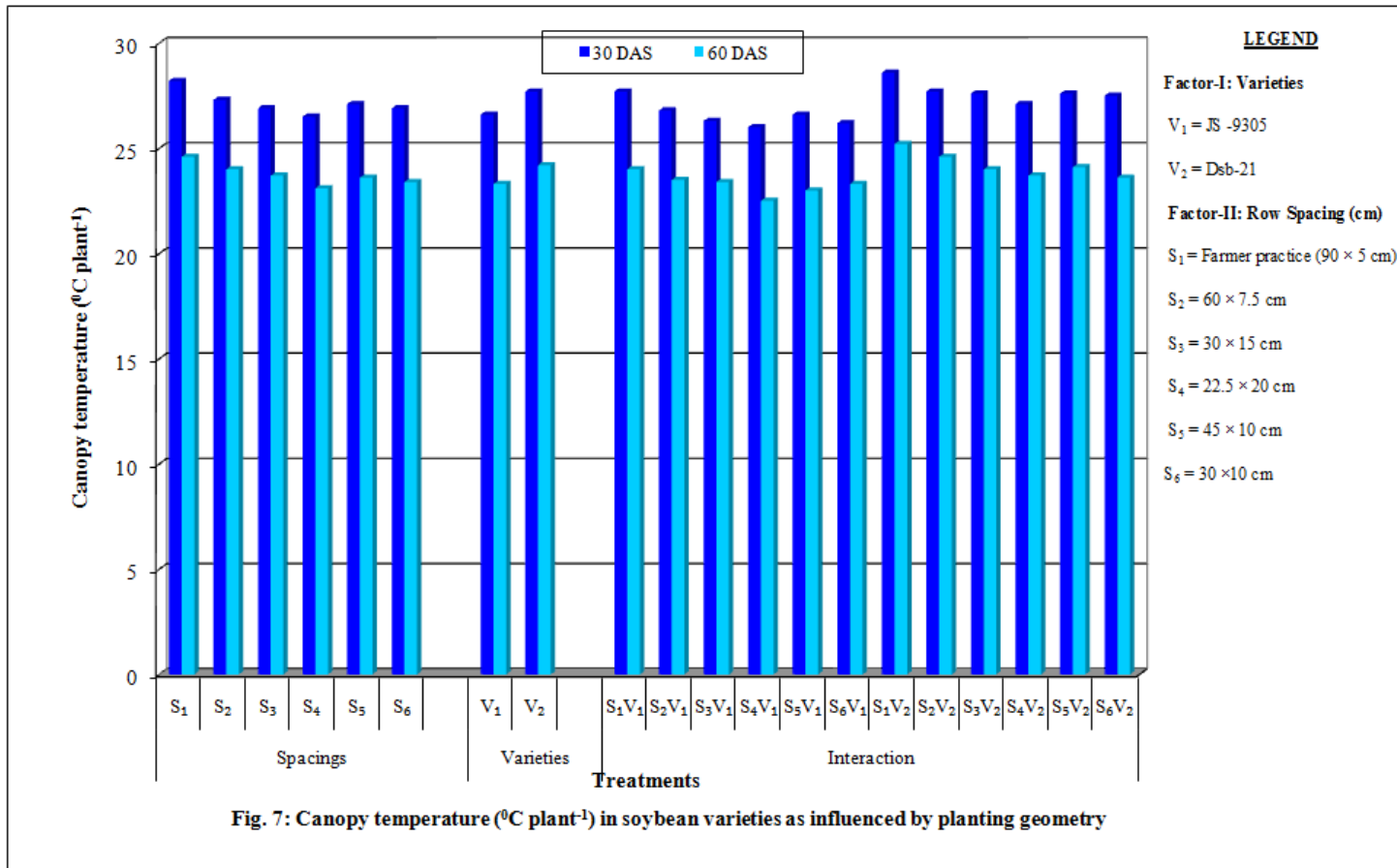


**Fig. 6: Canopy spread (cm<sup>2</sup> plant<sup>-1</sup>) in soybean varieties as influenced by planting geometry**

**Table 12: Canopy temperature ( $^{\circ}\text{C plant}^{-1}$ ) in soybean varieties as influenced by planting geometry**

<b>Treatments</b>	<b>30 DAS (<math>^{\circ}\text{C plant}^{-1}</math>)</b>			<b>60 DAS (<math>^{\circ}\text{C plant}^{-1}</math>)</b>		
<b>Spacing</b>	<b>JS-9305</b>	<b>Dsb-21</b>	<b>Mean</b>	<b>JS-9305</b>	<b>Dsb-21</b>	<b>Mean</b>
S <sub>1</sub> - 90 x 5 cm	27.7	28.6	<b>28.2</b>	24.0	25.2	<b>24.6</b>
S <sub>2</sub> - 60 x 7.5 cm	26.8	27.7	<b>27.3</b>	23.5	24.6	<b>24.0</b>
S <sub>3</sub> - 30 x 15 cm	26.3	27.6	<b>26.9</b>	23.4	24.0	<b>23.7</b>
S <sub>4</sub> - 22.5 x 20 cm	26.0	27.1	<b>26.5</b>	22.5	23.7	<b>23.1</b>
S <sub>5</sub> - 45 x 10 cm	26.6	27.6	<b>27.1</b>	23.0	24.1	<b>23.6</b>
S <sub>6</sub> - 30 x 10 cm	26.2	27.5	<b>26.9</b>	23.3	23.6	<b>23.4</b>
<b>Mean</b>	<b>26.6</b>	<b>27.7</b>		<b>23.3</b>	<b>24.2</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. $\pm$	0.07	0.12	0.16	0.07	0.12	0.16
C.D. at 5 %	0.21	0.37	0.52	0.19	0.33	0.47

30 DAS – August and 60 DAS – September



**Fig. 7: Canopy temperature (°C plant<sup>-1</sup>) in soybean varieties as influenced by planting geometry**

Among the interaction effects, significantly higher canopy temperature was recorded in Dsb-21 when sown at 90 x 5 cm row spacing (28.6 and 25.2 °C, respectively) at 30 and 60 DAS compared to other treatments.

## 4.2 Yield and yield components

### 4.2.1 Number of pods plant<sup>-1</sup> (Table 13)

Among the varieties, significantly higher number of pods plant<sup>-1</sup> of soybean was recorded with Dsb-21 (49.18) compared to the JS-9305 (41.67).

Significantly higher number of pods plant<sup>-1</sup> of soybean was recorded at 45 x 10 cm (53.70) and lower number of pods per plant of soybean was recorded at 90 cm (37.88) compared to other spacings.

Within the interaction, Significantly higher number of pods plant<sup>-1</sup> were recorded in Dsb-21 when sown at 45 x 10 cm (56.95) and lower number of pods plant<sup>-1</sup> (36.52) were recorded in JS-9305 at 90 cm spacing compared to other spacings.

### 4.2.2 Seed weight plant<sup>-1</sup> (g) (Table 13)

Significantly higher seed weight plant<sup>-1</sup> of soybean was recorded in Dsb-21 (19.45 g) compared to the JS-9305 (15.92 g) variety.

Among the different spacings, significantly higher seed weight plant<sup>-1</sup> was recorded at 45 x 10 cm (21.31 g) and lower soybean seed yield was recorded at 90 cm (13.24 g) compared to other spacings.

Among the interaction, significantly higher seed weight plant<sup>-1</sup> was recorded with Dsb-21 when sown at 45 x 10 cm (23.48 g) and lower seed weight plant<sup>-1</sup> (12.53 g) was recorded with JS-9305 at 90 cm spacing compared to other spacings.

### 4.2.3 Test weight (g) (Table 13)

Among the varieties significantly higher test weight was recorded in JS-9305 (13.12 g) compared to the Dsb-21 (12.40 g).

With respect to spacings and interaction, impact due to treatments was found to be non-significant.

### 4.2.4 Seed yield (q ha<sup>-1</sup>) (Table 14)

Significantly higher soybean seed yield was recorded in Dsb-21 (22.20 q ha<sup>-1</sup>) compared to the JS-9305 (17.86 q ha<sup>-1</sup>).

Among the different spacings, significantly higher soybean seed yield was recorded at 45 x 10 cm (24.37 q ha<sup>-1</sup>) and lower soybean seed yield was recorded at 90 cm (14.43 q ha<sup>-1</sup>) compared to other spacings.

**Table 13: Number of pods plant<sup>-1</sup>, seed weight plant<sup>-1</sup> (g) and test weight (g) of soybean varieties as influenced by planting geometry**

Treatments	Number of pods plant <sup>-1</sup>			Seed weight plant <sup>-1</sup> (g)			Test weight (g)		
	Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21
S <sub>1</sub> - 90 x 5 cm	36.52	39.25	<b>37.88</b>	12.53	13.95	<b>13.24</b>	13.03	12.31	<b>12.67</b>
S <sub>2</sub> - 60 x 7.5 cm	39.13	42.15	<b>40.64</b>	13.22	17.85	<b>15.54</b>	13.15	12.48	<b>12.82</b>
S <sub>3</sub> - 30 x 15 cm	42.14	53.08	<b>47.61</b>	17.85	20.95	<b>19.40</b>	13.13	12.33	<b>12.73</b>
S <sub>4</sub> - 22.5 x 20 cm	40.00	51.48	<b>45.74</b>	15.73	19.95	<b>17.84</b>	13.03	12.41	<b>12.72</b>
S <sub>5</sub> - 45 x 10 cm	50.45	56.95	<b>53.70</b>	19.15	23.48	<b>21.31</b>	13.23	12.49	<b>12.86</b>
S <sub>6</sub> - 30 x 10 cm	41.80	52.20	<b>47.00</b>	17.04	20.53	<b>18.78</b>	13.18	12.38	<b>12.78</b>
<b>Mean</b>	<b>41.67</b>	<b>49.18</b>		<b>15.92</b>	<b>19.45</b>		<b>13.12</b>	<b>12.40</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.12	0.21	0.29	0.09	0.16	0.22	0.05	0.08	0.11
C.D. at 5 %	0.34	0.60	0.85	0.26	0.45	0.63	0.13	NS	NS

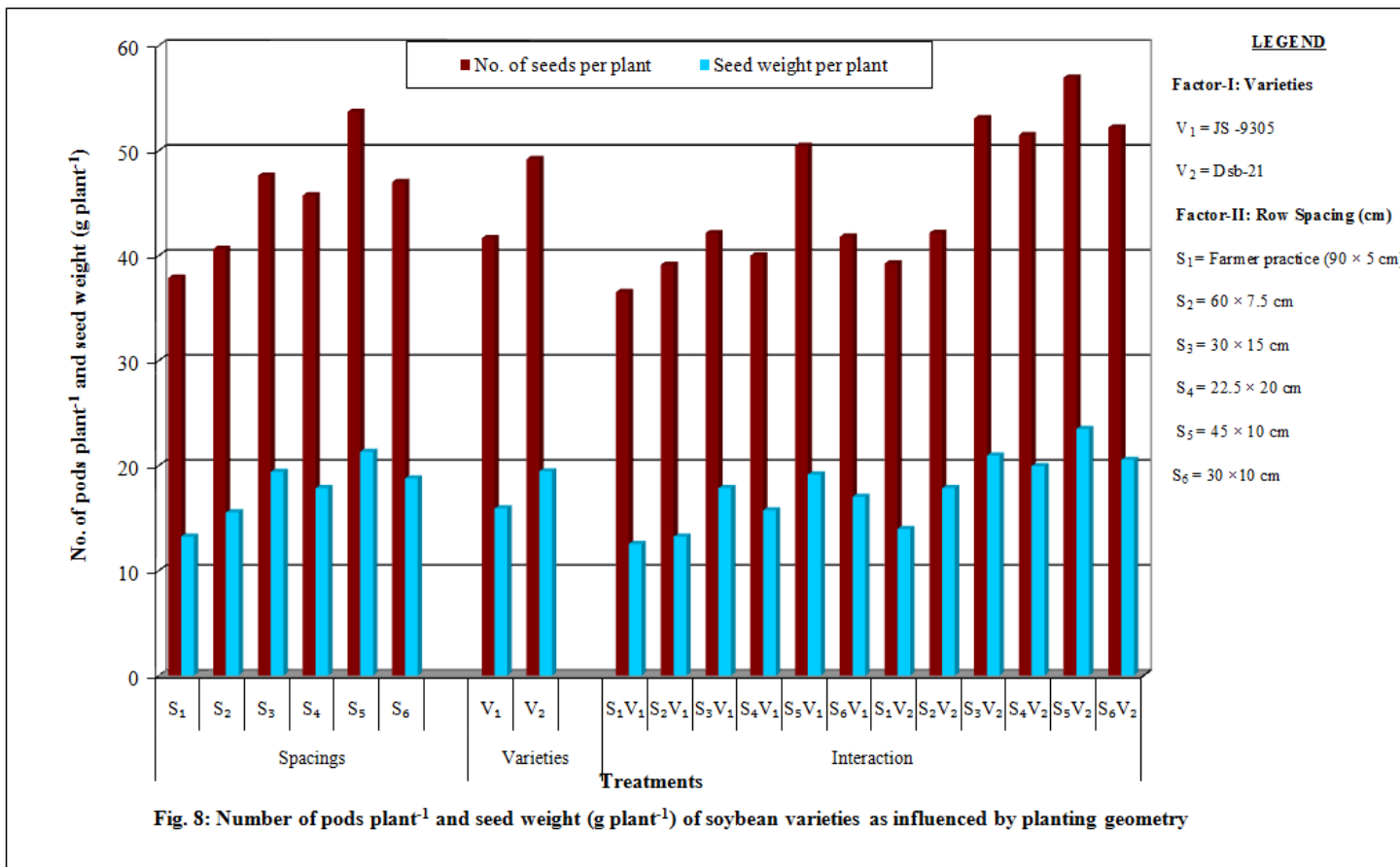


Fig. 8: Number of pods plant<sup>-1</sup> and seed weight (g plant<sup>-1</sup>) of soybean varieties as influenced by planting geometry

Fig. 8: Number of pods plant<sup>-1</sup> and seed weight (g plant<sup>-1</sup>) of soybean varieties as influenced by planting geometry

Significantly higher soybean seed yield ( $26.98 \text{ q ha}^{-1}$ ) was recorded when Dsb-21 was sown at  $45 \times 10 \text{ cm}$  spacing and lower soybean seed yield ( $13.91 \text{ q ha}^{-1}$ ) was recorded with JS-9305 at  $90 \text{ cm}$  spacing compared to other spacings.

#### 4.2.5 Haulm yield ( $\text{q ha}^{-1}$ ) (Table 14)

Significantly higher soybean haulm yield was recorded in Dsb-21 ( $24.46 \text{ q ha}^{-1}$ ) compared to the JS-9305 ( $20.49 \text{ q ha}^{-1}$ ).

Among the different spacings, significantly higher soybean haulm yield was recorded at  $45 \times 10 \text{ cm}$  ( $26.49 \text{ q ha}^{-1}$ ) and lower soybean seed yield was recorded at  $90 \text{ cm}$  ( $16.52 \text{ q ha}^{-1}$ ) compared to other spacings.

Significantly higher soybean haulm yield ( $29.10 \text{ q ha}^{-1}$ ) was recorded when Dsb-21 was sown at  $45 \times 10 \text{ cm}$  spacing and lower soybean seed yield ( $16.12 \text{ q ha}^{-1}$ ) was recorded with JS-9305 at  $90 \text{ cm}$  spacing compared to other spacings.

#### 4.2.6 Harvest index (HI) (Table 14)

With regard to varieties, spacings and interaction, impact due to treatments was found to be non-significant.

#### 4.2.7 Protein content (%) (Table 15)

Soybean varieties, row spacings and their interaction effects did not show any significant effect on protein content of soybean.

#### 4.2.8 Protein yield ( $\text{q ha}^{-1}$ ) (Table 15)

Among the varieties, Dsb-21 recorded significantly higher protein yield ( $7.60 \text{ q ha}^{-1}$ ) compared to the JS-9305 ( $6.06 \text{ q ha}^{-1}$ ).

The row spacing at  $45 \times 10 \text{ cm}$  recorded significantly higher protein yield ( $8.33 \text{ q ha}^{-1}$ ) and lower protein yield was recorded at  $90 \text{ cm}$  row spacing ( $4.93 \text{ q ha}^{-1}$ ) compared to other row spacings.

Among the interaction effects Dsb-21 when sown at  $45 \times 10 \text{ cm}$  recorded significantly higher Protein yield ( $9.28 \text{ q ha}^{-1}$ ) and lower Protein yield ( $4.68 \text{ q ha}^{-1}$ ) was in recorded in JS-9305 when sown at  $90 \times 5 \text{ cm}$  compared to other row spacings.

#### 4.2.8 Oil content (%) (Table 16)

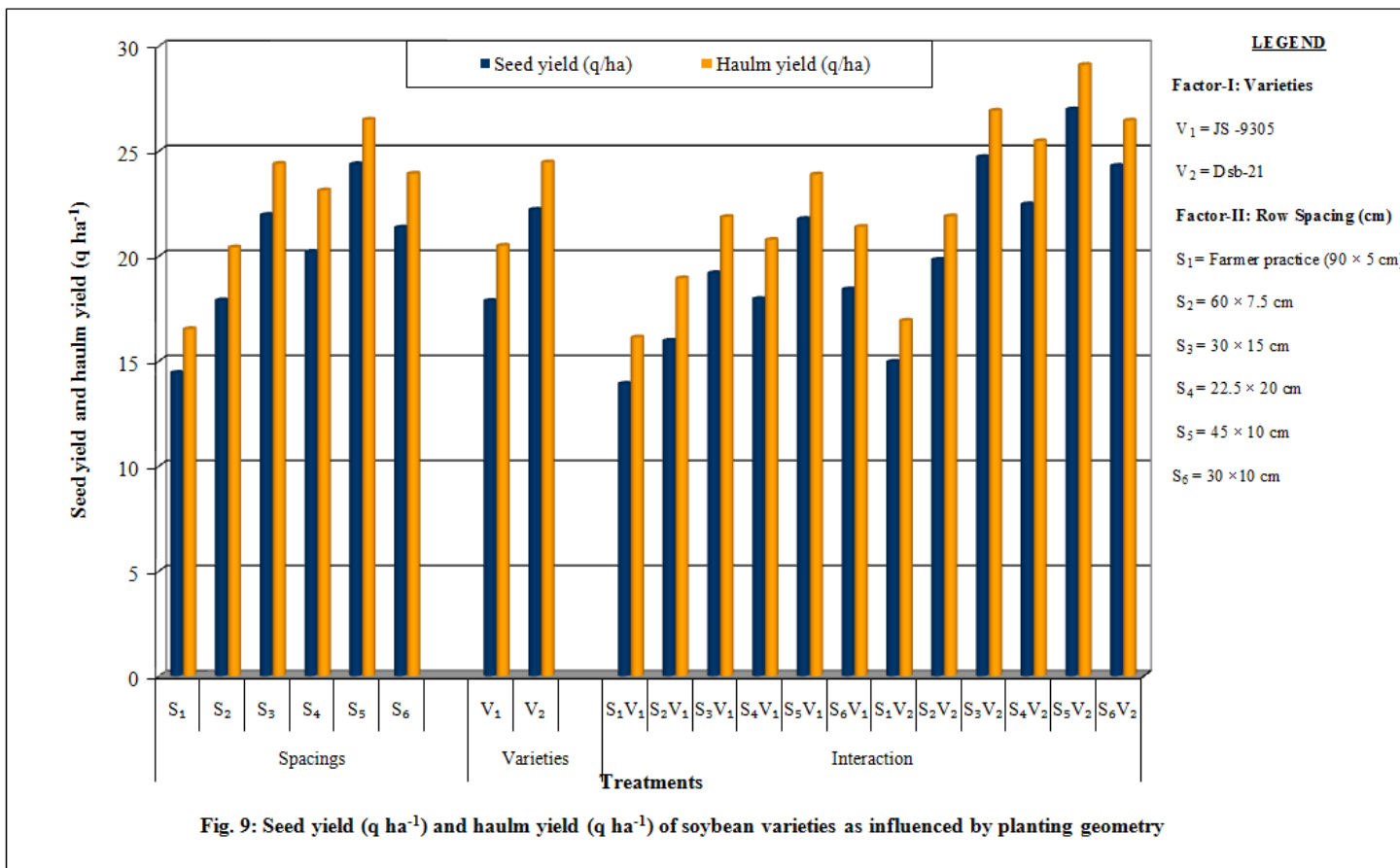
Soybean varieties, row spacings and their interaction effects did not show any significant effect on oil content of soybean.

#### 4.2.9 Oil yield ( $\text{q ha}^{-1}$ ) (Table 16)

Among the varieties, Dsb-21 recorded significantly higher oil yield ( $4.16 \text{ q ha}^{-1}$ ) compared to the JS-9305 ( $3.35 \text{ q ha}^{-1}$ ).

**Table 14: Seed yield (q ha<sup>-1</sup>), haulm yield (q ha<sup>-1</sup>) and harvest index (%) of soybean varieties as influenced by planting geometry**

Treatments	Yield (q ha <sup>-1</sup> )			Haulm yield (q ha <sup>-1</sup> )			Harvest index (%)		
	Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21
S <sub>1</sub> - 90 x 5 cm	13.91	14.96	<b>14.43</b>	16.12	16.92	<b>16.52</b>	46.32	46.93	<b>46.62</b>
S <sub>2</sub> - 60 x 7.5 cm	15.96	19.82	<b>17.89</b>	18.94	21.89	<b>20.41</b>	45.74	47.52	<b>46.63</b>
S <sub>3</sub> - 30 x 15 cm	19.18	24.71	<b>21.95</b>	21.86	26.92	<b>24.39</b>	46.73	47.86	<b>47.29</b>
S <sub>4</sub> - 22.5 x 20 cm	17.95	22.46	<b>20.20</b>	20.77	25.47	<b>23.12</b>	46.36	46.86	<b>46.61</b>
S <sub>5</sub> - 45 x 10 cm	21.76	26.98	<b>24.37</b>	23.88	29.10	<b>26.49</b>	47.67	48.12	<b>47.90</b>
S <sub>6</sub> - 30 x 10 cm	18.41	24.29	<b>21.35</b>	21.39	26.45	<b>23.92</b>	46.25	47.87	<b>47.06</b>
<b>Mean</b>	<b>17.86</b>	<b>22.20</b>		<b>20.49</b>	<b>24.46</b>		<b>46.51</b>	<b>47.53</b>	
	Spacings	Varieties	Interaction	Spacings	Varieties	Interaction	Spacings	Varieties	Interaction
S.Em. ±	0.10	0.18	0.25	0.10	0.18	0.25	0.38	0.50	0.65
C.D. at 5 %	0.30	0.52	0.73	0.29	0.51	0.72	NS	NS	NS



**Fig. 9: Seed yield (q ha<sup>-1</sup>) and haulm yield (q ha<sup>-1</sup>) of soybean varieties as influenced by planting geometry**

**Table 15: Protein content (%) and protein yield (q ha<sup>-1</sup>) of soybean varieties as influenced by planting geometry**

<b>Treatments</b>	<b>Protein content (%)</b>			<b>Protein yield (q ha<sup>-1</sup>)</b>		
<b>Spacing</b>	<b>JS-9305</b>	<b>Dsb-21</b>	<b>Mean</b>	<b>JS-9305</b>	<b>Dsb-21</b>	<b>Mean</b>
S <sub>1</sub> - 90 x 5 cm	33.64	34.70	<b>34.17</b>	4.68	5.19	<b>4.93</b>
S <sub>2</sub> - 60 x 7.5 cm	33.74	34.32	<b>34.03</b>	5.39	6.80	<b>6.09</b>
S <sub>3</sub> - 30 x 15 cm	34.29	33.88	<b>34.09</b>	6.58	8.37	<b>7.47</b>
S <sub>4</sub> - 22.5 x 20 cm	33.88	33.91	<b>33.90</b>	6.08	7.62	<b>6.85</b>
S <sub>5</sub> - 45 x 10 cm	33.91	34.38	<b>34.15</b>	7.38	9.28	<b>8.33</b>
S <sub>6</sub> - 30 x 10 cm	34.00	34.30	<b>34.15</b>	6.26	8.33	<b>7.29</b>
<b>Mean</b>	<b>33.91</b>	<b>34.25</b>		<b>6.06</b>	<b>7.60</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.13	0.22	0.32	0.04	0.07	0.10
C.D. at 5 %	NS	NS	NS	0.12	0.20	0.29

**Table 16: Oil content (%) and Oil yield (q ha<sup>-1</sup>) of soybean varieties as influenced by planting geometry**

Treatments	Oil content (%)			Oil yield (q ha <sup>-1</sup> )		
Spacing	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	18.89	18.65	<b>18.77</b>	2.63	2.79	<b>2.71</b>
S <sub>2</sub> - 60 x 7.5 cm	19.02	18.94	<b>18.98</b>	3.04	3.75	<b>3.39</b>
S <sub>3</sub> - 30 x 15 cm	18.71	18.90	<b>18.80</b>	3.59	4.67	<b>4.13</b>
S <sub>4</sub> - 22.5 x 20 cm	18.74	18.66	<b>18.70</b>	3.37	4.19	<b>3.78</b>
S <sub>5</sub> - 45 x 10 cm	18.54	18.68	<b>18.61</b>	4.03	5.04	<b>4.54</b>
S <sub>6</sub> - 30 x 10 cm	18.90	18.61	<b>18.75</b>	3.48	4.52	<b>4.00</b>
<b>Mean</b>	<b>18.80</b>	<b>18.74</b>		<b>3.35</b>	<b>4.16</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.Em. ±	0.05	0.08	0.12	0.02	0.03	0.05
C.D. at 5 %	NS	NS	NS	0.06	0.10	0.14

**Table 17: Economic of soybean varieties as influenced by planting geometry**

Treatments	Gross returns (₹ ha <sup>-1</sup> )			Net returns (₹ ha <sup>-1</sup> )			B:C		
Spacings	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean	JS-9305	Dsb-21	Mean
S <sub>1</sub> - 90 x 5 cm	55468	59597	<b>57532</b>	25785	30442	<b>28113</b>	1.87	2.04	<b>1.96</b>
S <sub>2</sub> - 60 x 7.5 cm	63673	78936	<b>71304</b>	33990	49781	<b>41885</b>	2.15	2.71	<b>2.43</b>
S <sub>3</sub> - 30 x 15 cm	76438	98402	<b>87420</b>	46755	69247	<b>58001</b>	2.58	3.38	<b>2.98</b>
S <sub>4</sub> - 22.5 x 20 cm	71562	89493	<b>80528</b>	41879	60338	<b>51109</b>	2.41	3.07	<b>2.74</b>
S <sub>5</sub> - 45 x 10 cm	86638	107407	<b>97023</b>	56955	78252	<b>67604</b>	2.92	3.68	<b>3.30</b>
S <sub>6</sub> - 30 x 10 cm	73396	96705	<b>85050</b>	42063	66197	<b>54130</b>	2.34	3.17	<b>2.76</b>
<b>Mean</b>	<b>71196</b>	<b>88423</b>		<b>41238</b>	<b>59043</b>		<b>2.38</b>	<b>3.01</b>	
	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction	Varieties	Spacings	Interaction
S.E.m. ±	406	704	995	406	704	995	0.01	0.02	0.03
C.D. at 5 %	1169	2025	2864	1169	2025	2864	0.04	0.07	0.10

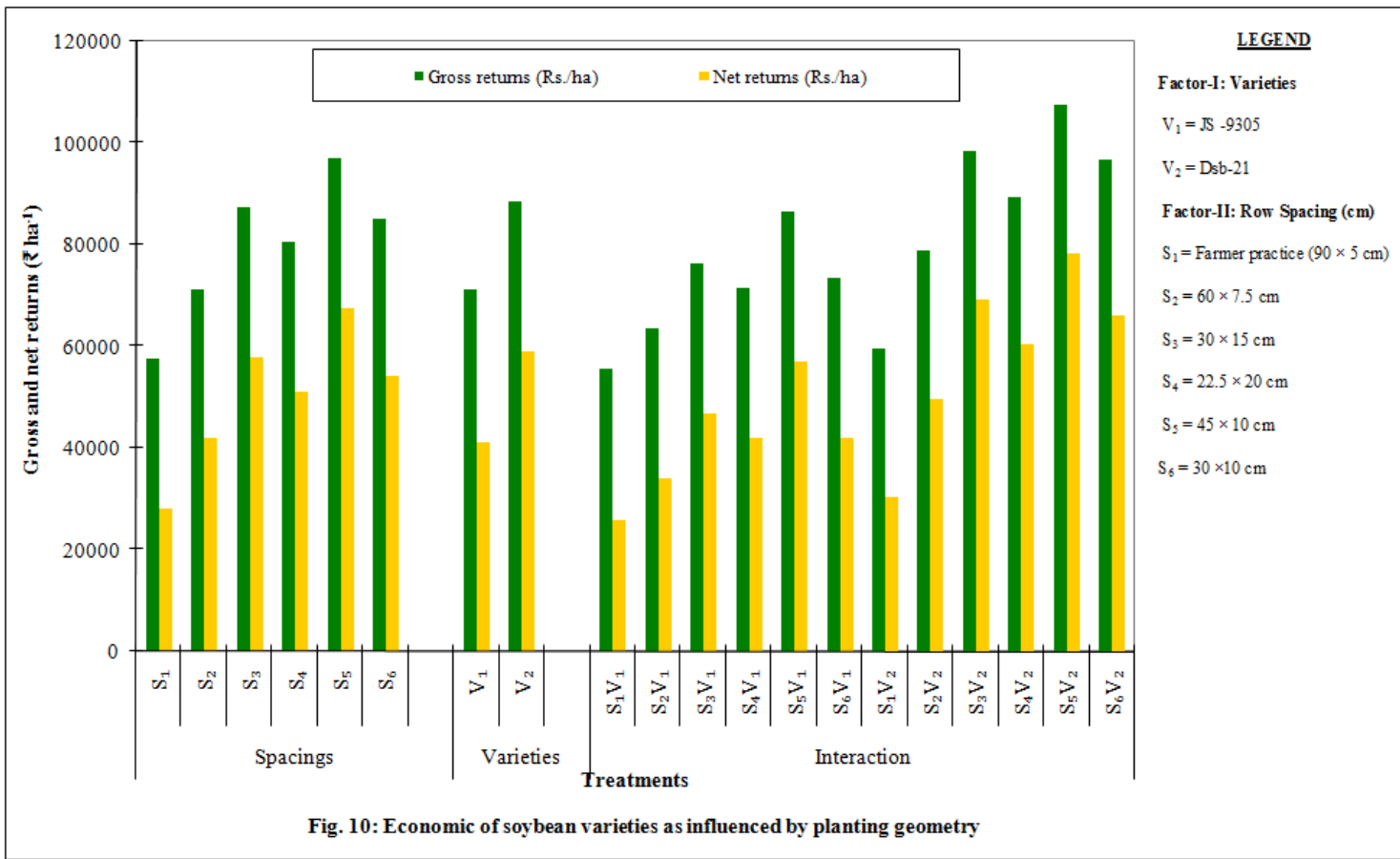


Fig. 10: Economic of soybean varieties as influenced by planting geometry

Fig. 10: Economic of soybean varieties as influenced by planting geometry

The row spacing at 45 x 10 cm recorded significantly higher oil yield (4.54 q ha<sup>-1</sup>) lower oil yield was recorded at 90 cm row spacing (2.71 q ha<sup>-1</sup>) compared to other row spacings.

Among the interaction effects Dsb-21 when sown at 45 x 10 cm recorded significantly higher oil yield (5.04 q ha<sup>-1</sup>) and lower oil yield was in recorded in JS-9305 when sown at 90x 5 cm (2.63 q ha<sup>-1</sup>) compared to other treatments.

### 4.3 Economic analysis (Table 17)

Soybean Dsb-21 recorded significantly higher gross returns (₹ 88,423 ha<sup>-1</sup>), net returns (₹ 59,043 ha<sup>-1</sup>) and B:C ratio (3.01) compared to JS-9305.

Sowing of soybean at 45 x 10 cm recorded significantly higher gross returns (₹ 97,023 ha<sup>-1</sup>), net returns (₹ 67,604 ha<sup>-1</sup>) and B:C ratio (3.30) compared to other row spacings.

Among the interaction effects, significantly higher gross returns (₹ 1,07,407 ha<sup>-1</sup>), net returns (₹ 78,252 ha<sup>-1</sup>) and B: C ratio (3.68) was obtained in Dsb-21 when sown at 45 x10 cm row spacing compared to other treatment combination

## 6. SUMMARY AND CONCLUSIONS

A field experiment was conducted during *Kharif* 2015 at the Agricultural Research Station, Nipani on medium black soil to study the “Performance of soybean genotypes to planting geometry”. The treatments comprised two genotypes (JS-9305 and Dsb-21) and six row spacings (90 x 5 cm, 60 x 7.5 cm, 30 x 15 cm, 22.5 x 20 cm, 45 x 10 cm and 30 x 10 cm). The experiment was laid out in Factorial Randomized Complete Block Design with four replications and 12 treatment combinations. The salient findings of the investigation are summarized below.

- Significantly higher seed yield (22.20 q ha<sup>-1</sup>), haulm yield (24.46 q ha<sup>-1</sup>), number of pods plant<sup>-1</sup> (49.18) and seed weight plant<sup>-1</sup> (19.45 g) were recorded in Dsb-21 compared JS-9305 (17.86, 41.67 and 15.92 g, respectively).
- Significantly higher growth parameters *viz.*, number of branches plant<sup>-1</sup> (6.31) and dry- matter production plant<sup>-1</sup> (30.80 g) at harvest were recorded Dsb-21 compared JS-9305 (5.69 and 29.17 g, respectively).
- Significantly higher plant height at harvest (62.05 cm) was recorded in JS-9305 compared to Dsb-21 (59.43).
- Significantly higher canopy spread (2027.7 cm<sup>2</sup>) and canopy temperature (24.2 °C) at 60 DAS were recorded in Dsb-21 compared to JS-9305 (1716.5 cm<sup>2</sup> and 23.3 °C, respectively).
- Significantly higher numbers of nodules plant<sup>-1</sup> and nodules dry weight plant<sup>-1</sup> were recorded in Dsb-21 (28.93 and 0.53 g) compared to JS-9305 (27.67 and 0.51 g).
- Significantly higher seed yield (24.37 q ha<sup>-1</sup>), haulm yield (26.49 q ha<sup>-1</sup>), number of pods plant<sup>-1</sup> (53.70) and seed weight plant<sup>-1</sup> (21.31 g) were recorded when sown at 45 x 10 cm compared to other row spacings.
- At harvest significantly higher plant height (64.33 cm) were recorded in 22.5 x 20 cm row spacing compared to other row spacings.
- At harvest significantly higher number of branches plant<sup>-1</sup> (6.95) and dry-matter production plant<sup>-1</sup> (33.13 g) were recorded when sown at 90 x 5 cm compared to other row spacings.
- Significantly higher canopy spread (2266.3 cm<sup>2</sup>) and canopy temperature (24.6 °C) were recorded at 90 x 5 cm row spacing compared to other row spacings.
- Significantly higher number of nodules plant<sup>-1</sup> and nodules dry weight plant<sup>-1</sup> (31.50 and 0.56 g) were recorded at 45 x 10 row spacing compared to other row spacings.
- Sowing of Dsb-21 at 45 x 10 cm row spacing were recorded significantly higher seed yield (26.98 q ha<sup>-1</sup>) and haulm yield (29.10 q ha<sup>-1</sup>) compared to other row spacings.
- Significantly higher number of pods plant<sup>-1</sup> (56.95), seed weight plant<sup>-1</sup> (23.48 g) recorded when Dsb-21 was sown at 45 x 10 row spacing compared to other row spacings.

- Total dry-matter production (34.38 g) and number of branches plant<sup>-1</sup> (7.45) at harvest were recorded with Dsb-21 when sown at 90 x 5 cm row spacing compared to other row spacing.
- At harvest, significantly higher plant height (66.23 cm) was recorded with JS-9305 when planted at 22.5 x 20 cm row spacing compared to other treatments.
- Significantly higher canopy spread (2477.5 cm<sup>2</sup>) and canopy temperature (25.2 °C) were recorded in Dsb-21 when sown at 90 x 5 cm row spacing compared to other row treatments.
- Significantly higher numbers of nodules plant<sup>-1</sup> and nodules dry weight plant<sup>-1</sup> (31.70 g and 0.58 g) were recorded in Dsb-21 when sown at 45 x 10 cm row spacing compared to other row treatments.
- Significantly higher protein yield (9.28 q ha<sup>-1</sup>) was recorded in Dsb-21 when sown at 45 x 10 row spacing compared to other treatments.
- Significantly higher oil yield (5.04 q ha<sup>-1</sup>) recorded in Dsb-21 when sown at 45 x 10 row spacing compared to other treatments.
- The higher gross returns (₹ 1,07,407 ha<sup>-1</sup>), net returns (₹ 78,252 ha<sup>-1</sup>) and B:C (3.68) ratio were recorded in Dsb-21 when sown at 45 x 10 row spacing compared to other treatments.
- Based on the results obtained, concluded that Dsb-21 when sown at 45 x 10 row spacing optimum to get higher soybean seed yield (26.98 q ha<sup>-1</sup>) and net returns (₹ 78,252 ha<sup>-1</sup>) with B: C (3.68).

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## Appendix I: Prices of inputs and outputs

Sl. No.	Particulars	Unit	Price (₹)
<b>A) Inputs</b>			
1	Land ploughing		
	Tractor cultivation	Hr	500
	Harrowing (bullock pair)	Day	1,200
2	Seed	Kg	66
3	Seed treatments (Bavistin)	500 ml	359
4	FYM	T	500
5	Fertilizer		
	Urea	Kg	6
	DAP	Kg	25
	MOP	Kg	17.3
	Znso <sub>4</sub>	kg	58
6	Plant protection		
	Flubendiamide (FAME)	50 ml	750
	Nuvan	1000 ml	550
	Contof	1000 ml	590
7	Labour Wages		
	Men	Day	236
	Women	Day	236
<b>B) Outputs</b>			
1	Seed yield	Q	3,900
2	Haulm yield	Q	75



# PERFORMANCE OF SOYBEAN (*Glycine max* L. Merrill) GENOTYPES TO PLANTING GEOMETRY

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2016

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## ABSTRACT

A field experiment was conducted during *kharif* 2015 to study "Performance of soybean (*Glycine max* L. Merrill) genotypes to planting geometry" at Agricultural Research Station (ARS), Nipani under rainfed condition. The experiment was laid out Randomized Complete Block Design with factorial concept and with four replications. There were 12 treatment combinations consisted of two varieties ( JS-9305 and Dsb-21) and six row spacings (90 × 5 cm, 60 × 7.5 cm, 30 × 15 cm, 22.5 × 20 cm, 45 × 10 cm and 30 × 10 cm ).

Soybean variety Dsb-21 produced significantly higher number of pods plant<sup>-1</sup> (49.18), seed weight plant<sup>-1</sup> (19.45 g), seed yield (22.20 q ha<sup>-1</sup>) and haulm yield (24.46 q ha<sup>-1</sup>) compared to JS-9305 variety. Among the different row spacings sowing of soybean at 45 x 10 cm recorded significantly higher number of pods plant<sup>-1</sup> (53.70), seed weight plant<sup>-1</sup> (21.31 g), seed yield (24.37 q ha<sup>-1</sup>) and haulm yield (26.49 q ha<sup>-1</sup>) compared to other treatments.

In interaction effects significantly higher number of pods plant<sup>-1</sup> (56.95), seed weight plant<sup>-1</sup> (23.48 g), seed yield (26.98 q ha<sup>-1</sup>) and haulm yield (29.10 q ha<sup>-1</sup>) were recorded in Dsb-21 when sown at 45 x 10 cm row spacing compared to other treatment combinations. Significantly higher gross returns (₹ 1,07,407 ha<sup>-1</sup>), net returns (₹ 78,252 ha<sup>-1</sup>) and B:C ratio (3.68) obtained in Dsb-21 when sown at 45 x10 cm row spacing compared to other treatment combinations. Sowing of Dsb-21 variety at 45 x 10 cm row spacing is optimum for getting higher soybean seed yield and net returns.