Original Research Article

Response of soybean to integrated nutrient management in cotton and soybean intercropping system

Amit M. Pujar[1*] and V. V. Angadi[2] and Shamarao Jahagirdar[3]

[1]Ph.D. Scholar, Department of Agronomy, UAS, Dharwad, Karnataka, India
[2]Principal Scientist (Agronomy) and Head, AICRP on IFS-OFR scheme, MARS, UAS, Dharwad, Karnataka, India
[3]Professor of Plant Pathology, UAS, Dharwad, Karnataka, India
[*]Corresponding author e-mail: amit4670@gmail.com

ABSTRACT

A field experiment was conducted to study the integrated nutrient management on growth components of soybean, resource use efficiency and economics of cotton and soybean intercropping system. The study was conducted at All India Coordinated Research Project on soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka (India) during *Kharif* 2015 and 2016. The experiment was laid out in a randomised complete block design with three replications and twenty treatments. As per the treatments, the organic manure (FYM) and green leaf manures (gliricidia and pongamia) were applied 15 days before sowing of the crop. Vermicompost was spot applied to soil before dibbling of seeds in cotton and soybean intercropping system in 1:2 row proportion, soybean introduced as intercrop in cotton with row spacing of cotton 120 cm and soybean 30 cm. Results of the study indicated that significantly higher soybean growth attributes were observed in sole soybean than intercropped soybean, except for plant height. Among the intercropping system, T_3 (150 % recommended dose of fertilizer for cotton and soybean) recorded significantly higher number of branches plant, leaf area per plant, leaf area index, dry matter production and the total number of nodules per plant. Intercropping of cotton and soybean resulted in more efficient utilization of resource. Among the intercropping system, T_3 (150 % recommended dose of fertilizer for cotton and soybean) recorded higher biomass and leaf area of cotton and soybean intercropping system. Among the different treatments, significantly higher gross returns and net returns were recorded in T_3 (150 % recommended dose of fertilizer for cotton and soybean) and it was on par with T_2 (125 % recommended dose of fertilizer for cotton and soybean) and T_{17} (T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}) during both years and in pooled data. Among the different treatments, significantly higher benefit cost ratio was recorded in T_{16} (T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}) compared to rest of the intercropping systems and sole cotton and soybean during both years and in pooled data. However, T_{16} was on par with T_2 (125 % recommended dose of fertilizer for cotton and soybean) during 2015-16. Farmers can adopt a fertilizer dose of 125: 62.5: 62.5 N, P_2O and K_2O kg ha^{-1} in cotton and soybean intercropping system or 100: 50: 50 N, P_2O_5 and K_2O kg ha^{-1} along with Gliricidia + Pongamia 2.5 t ha^{-1} each for cotton and soybean intercropping for profitable yields in rainfed situation.

Keywords: Integrated nutrient management; cotton; soybean; economics

1. INTRODUCTION

Agriculture is one of the most vulnerable and adaptation-prone sources of livelihood facing climate change. Among the different field crops, cotton (*Gossypium hirsutum* L.) is one of the most important cash crops that provide fiber to the textile industries around the world. According to the rough estimation regarding the world production of cotton, 80% comes from Brazil, China, India, Pakistan, Turkey, USA, and Uzbekistan. Cotton contributes a major portion to the gross national product (GNP) of many countries. Hence, there is a need for sustainable intensification, i.e., increasing productivity from existing agricultural lands while minimizing the negative environmental effects and ensuring the future needs of food production. This has been proposed as a central means to restrict further land clearing for agriculture and transform agriculture and food systems to operate in a more sustainable way [1]. The approach emphasizes reducing the use of external inputs such as industrial fertilizers and pesticides that further pressurize the environment and climate. It builds on spatio-temporal functional diversification of the agroecosystem and the combination of crop species and traits that support and make better use of ecosystem services [2]. Intercropping represents a within-field diversification strategy that is based on ecological intensification. It refers to the cultivation of two or more crops together in time and space, and it is an ancient practice of cropping that aims to maximize productivity per land area using only a few external inputs. Intercropping helps in the total production of different commodities with higher returns under dryland conditions, besides better utilization of natural and scarce resources per unit time [3]. Soybean, being a short duration and short stature legume, the crop has greater ability to fix atmospheric nitrogen. It occupies prime position in intercropping system. Intercropping of cotton with short duration legume like soybean was found more remunerative than sole cotton [4 and 5]. Application of organic manures along with inorganic fertilizers helps to rejuvenate the degraded soils and ensures sustainability in crop production is known as integrated nutrient management. Suitable management practices like intercropping and judicious combination of organic and inorganic manures are considered ecologically viable, economically feasible and avoid environmental pollution. In addition, combination of organic and inorganic manures works like slow release fertilizers for providing balanced nutrients to plants. Keeping these facts in view, the present study was undertaken with objective to evaluate the sources of nutrients on the performance of soybean in cotton and soybean intercropping system and economics intercropping economics system.

2. MATERIAL AND METHODS

Field experiment was carried out to study the integrated nutrient management (INM) practices on growth components of soybean, resource use efficiency and economics of cotton and soybean intercropping system in 1:2 row proportion during *kharif* 2015 and 2016 at plot 101 ‘D’ block, All India Co-ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka (India), which is located at latitude of 15^0 26' N and 75^0 07' E longitude with an altitude of 678 m above mean sea level. The soil was clay with pH 7.3, 0.51% organic carbon, 281 kg ha^{-1} available N, 34 kg ha^{-1} available P_2O_5 and 312 kg ha^{-1} available K_2O and 0.35 dsm^{-1} EC. The experiment was laid out in randomised complete block design with three replications and twenty treatments as given in the tables. Sowing was done by adopting 120 cm x 60 cm row spacing for cotton and soybean introduced as intercrop with 40 cm x 10 cm in 1:2 row proportions during *Kharif* season on June 12th, 2016. Organic manure (FYM) and green leaf manures (gliricidia and pongamia) were applied 15 days before sowing of the crop according to the treatments. Vermicompost was spot applied to soil before dibbling of seeds. RDF was applied to both crops in intercropping system according to population (100:50:50 and 40:80:25 kg N, P_2O_5 and K_2O ha^{-1} for Cotton and Soybean, respectively).

2.1 Growth parameters of soybean

2.1.1 Plant height

The plant height was measured from ground level to the tip of the main shoot and their mean was expressed as plant height in centimetres (cm).

2.1.2 Number of branches per plant

The number of branches per plant was counted from five tagged plants and their mean was recorded as a number of branches per plant.

2.1.3 Leaf area per plant

Leaf area was recorded by leaf area meter. The top, middle and bottom leaves were collected from five selected plants at random from each plot and leaf area was measured by using leaf area meter (LICOR LI 3000A). The leaf area from top, middle and bottom of plant was multiplied by the number of leaves per plant (top, middle and bottom leaves). The leaf area per plant was expressed in decimeter squares (dm^2).

2.1.4 Leaf area index

Leaf area index (LAI) was calculated as per the procedure is given by [6].

2.1.5 Dry matter production

The five randomly selected plants were used to record the dry matter production at harvest. The plants were uprooted and separated into leaves, stem and pods. They were oven dried separately at 70°C for 48 hours and the total dry weight gram per plant (g $plant^{-1}$) was recorded.

2.1.6 Total number of nodules per plant

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

2.2 Resource efficiency of the system

2.2.1 Biomass

It was measured by using the following formula at harvest of cotton and expressed in kilograms per hectare (kg ha^{-1}).

Biomass (kg ha^{-1}) = Summation of dry matter production per plant of both the crops x plant population per hectare of respective crops.

2.2.2 Leaf area

It was measured by using the following formula at harvest of cotton and expressed in centimetre squares per hectare (cm^2 ha^{-1}).

Leaf area (cm^2 ha^{-1}) = Summation of leaf area per plant of both the crops x plant population per ha of respective crops

2.3 Economics of the system

The prices of the inputs that prevailed during experimentation were considered for working out the cost of cultivation.

Gross return (Rs. ha^{-1}) was calculated on the basis of market price of the produce during harvest period. Net return (Rs. ha^{-1}) was calculated by deducting the cost of cultivation (Rs. ha^{-1}) from gross return. Benefit-cost ratio (BC) was worked out as follows.

$$\text{BC ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

2.4 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. The treatment means were compared by Duncan's Multiple Range Test (DMRT) at 0.05 level of probability [7].

3. RESULTS AND DISCUSSION

3.1.1 Soybean growth attributes

Plant height differed significantly due to integrated nutrient management (INM) treatments during both the years and in pooled data (Table 1). Among the different treatments, T_3 (150 % RDF for cotton and soybean) recorded the highest plant height during both years and in pooled data. The number of branches per plant differed significantly due to INM treatments during both the years and in pooled data (Table 1). Significantly higher number of branches per plant was observed in sole soybean than intercropped soybean. Among the intercropping systems, T_3 recorded the highest number of branches per plant during both years and in pooled data. Leaf area differed significantly due to INM treatments during both the years and in pooled data (Table 1). At 60 DAS, the highest leaf area was observed in sole soybean than intercropped soybean during 2016-17 and in pooled data. At 60 DAS, T_3 (150 % RDF for cotton and soybean) recorded higher leaf area and it was on par with T_2 (125 % RDF for cotton and soybean) and T_{17} (T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}) during 2016-17 and in pooled data. LAI differed significantly due to INM treatments during both the years and in pooled data (Table 2). At 60 DAS, significantly higher LAI was observed in sole soybean than intercropped soybean during both years and in pooled data. Among the intercropping systems at 60 DAS, the highest LAI was observed in T_3 (150 % RDF for cotton and soybean) during both years and in pooled data. Dry matter production differed significantly due to INM treatments during both the years and in pooled data (Table 2). Significantly higher dry matter production was observed in sole soybean than intercropped soybean during both years and in pooled data. Among the intercropping systems, T_3 (150 % RDF for cotton and soybean) recorded the highest dry matter production during both years and in pooled data. The total number of nodules per plant differed significantly due to INM treatments during both the years (Table 2). Among the intercropping treatments at 60 DAS, T_4 recorded higher number of nodules per plant during both years and in pooled data. The results are in agreement with the findings of [8 and 9], who also reported that combined application of organic and inorganic nutrients was superior over inorganic alone. In one of the studies by [10] reported that optimum availability if nutrients through organic manures and favorable soil environment through balanced soil moisture which enhanced N fixation, rate of photosynthesis and consequently lead to better vegetative growth.

3.1.2 Biomass and leaf area of the system

When two or more crops grown together in an intercropping system, the component crop yield may be lower compared to their sole crop yields due to inter-specific competition for growth resources *viz.,* light, moisture, nutrients due to increased population pressure per unit land area or demand exceeding supply or due to both. Biomass differed significantly due to integrated nutrient management (INM) treatments during both the years. At harvest, the highest biomass recorded in T_3 during both years and in pooled data (Table 3). Leaf area differed significantly due to INM treatments during both the years. The similar trend was followed for leaf area of the system. The higher biomass is due to the higher uptake of nutrients by both cotton and soybean along with leaf litter drops from the soybean. The results are in agreement with the findings of [10], who reported that higher biomass yield in the intercropping system was due to higher uptake of nutrients.

3.1.3 Economics of the intercropping system

Gross returns differed significantly due to integrated nutrient management (INM) treatments during both the years and in pooled data (Table 4). Among the different treatments, significantly higher gross returns were recorded in T_3 (150 % RDF for cotton and soybean) and it was on par with T_2 (125 % RDF for cotton and soybean) and T_{17} (T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}) during both years and in pooled data. All the intercropping systems recorded significantly higher gross returns than sole crops in both years and in pooled data. The higher gross returns with these treatments were due to better performance of component crops in terms of yields and also due to higher price of cotton. Net returns differed significantly due to INM treatments during both the years and in pooled data (Table 4). Among the different treatments, significantly higher net returns were recorded in T_2 (125 % RDF for cotton and soybean) and it was on par with T_3 (150 % RDF for cotton and soybean) and T_{16} (T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}) and T_{17} (T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}) during both years and in pooled data and T_{18} (T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}) during 2015-16. All the intercropping systems recorded significantly higher net returns than sole crops in both years and in pooled data. BC ratio differed significantly due to INM treatments during both the years and in pooled data (Table 4). Among the different treatments, significantly higher BC ratio was recorded in T_{16} (T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}) compared to rest of the intercropping systems and sole cotton and soybean during both years and in pooled data. However, T_{16} was on par with T_2 (125 % RDF for cotton and soybean) during 2015-16. The higher BC ratio was due to better performance of component crops, which gave higher productivity and net returns, helping in getting higher BC ratio. The results are in agreement with the findings of [11], where cotton variety Narsimha intercropped with soybean (JS-335) recorded significantly higher seed cotton equivalent yields, maximum net returns and BC ratio. In one of the studies conducted by [13] revealed that higher returns to the rupee invested was found in soybean intercropping system than growing soybean sole crop.

4. CONCLUSION

Farmers can adopt a fertilizer dose of 125: 62.5: 62.5 N, P_2O and K_2O kg ha^{-1} in cotton and soybean intercropping system or 100: 50: 50 N, P_2O_5 and K_2O kg ha^{-1} along with Gliricidia + Pongamia 2.5 t ha^{-1} each for cotton and soybean intercropping for profitable yields.

ACKNOWLEDGEMENTS

I feel the inadequacy of words to express my deep sense of gratitude and profound indebtedness to Dr. V. V. ANGADI, Principal Scientist (Agronomy) and Head, AICRP on IFS-OFR Scheme, MARS, UAS, Dharwad. He played an important role in my research as the esteemed chairperson of my advisory committee and also to my advisory committee members Dr. J. A. Hosmath, Professor of Agronomy; Dr. Shamarao Jahagirdar, Professor of Plant Pathology; Dr. D. N. Kambrekar, Professor of Agriculture Entomology, UAS, Dharwad, Karnataka, India.

AUTHORS' CONTRIBUTIONS

'Amit M. Pujar' designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. 'Dr. V. V. Angadi and 'Dr. Shamarao Jahagirdar managed the analyses of the study. All authors read and approved the final manuscript."

REFERENCES

1. Garnett T, Appleby MC, Balmford A, Bateman IJ, Benton TG, Bloomer P, Burlingame B, Dawkins M, Dolan L, Fraser D. Sustainable intensification in agriculture: Premises and policies. Science. 2013;34:33–34.
2. Costanzo A, Bàrberi P. Functional agrobiodiversity and agroecosystem services in sustainable wheat production: A review. Agronomy for sustainable development. 2014;34:327-348.
3. Sharma. Intercropping in desi cotton. PKV Research Journal. 2000;18(1):10-12.
4. Salwaru MI, Mahamed HMH. Effect of intercropping cotton with maize under different nitrogen rate and different hill spacing of maize. In: Proceedings of Beltwide Conference, Jan 5th, 8th, San Diego, USA, 1995;570-572.
5. Sarkar RK, Chakraborthy A, Mazumdar RC. Effect of intercropping oilseeds and pulse crops in upland cotton for total productivity and monetary advantage in system. Indian Journal of Agricultural Sciences. 1995;65(4):246-249.
6. Sestak Z, Castsky J, Jarvis, PG. Plant photosynthetic production. In: *Manual of Methods* (Ed.), W. JUNK, N. V., Publications, The Hughus, 1971;343-381.
7. Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research. John Wiley and Sons Publishers, New Delhi, India. 1984: 8-328.
8. Bandyopadhaya KK, Gosh PK, Choudhary RS, Hati KM, Mishra AK. Integrated nutrient management practices in soybean and sorghum in sole and intercropping system in Vertisols. Indian Journal of Agricultural Science. 2004;74(2):55-63.
9. Channagouda RF, Babalad HB. Impact of organic farming practices on quality parameters of cotton. Research on Crops. 2015;16(4):752-756.
10. Naveen BT, Babalad HB. Conservation agriculture to sustain the productivity and soil health in cotton and groundnut intercropping system. 2017; 27(1):24-33.
11. Vidhyavathi, Dasog GS, Babalad HB, Hebsur NS, Gali SK, Patil SG, Alagawadi AR. Influence of nutrient management practices on crop response and economics in different cropping systems in a vertisol. Karnataka J. Agri. Sci. 2011; 24(4):455-460.
12. Rekha MS, Dhurua S. Productivity of pigeonpea + soybean intercropping system as influenced by planting patterns and duration of pigeonpea varieties under rainfed conditions. Legume Research. 2009;32(1):51-54.
13. Manjunath MG, Salakinkop SR. Growth and yield of soybean and millets in intercropping systems. J. Farm Sci. 2017; 30(3): 349-353.

Table 1: Plant height, number of branches per plant at harvest and leaf area per plant at 60 DAS of soybean as influenced by INM in cotton and soybean intercropping system

Treatments	Plant height (cm)			Number of branches per plant			Leaf area plant^{-1} (dm^2) at 60 DAS		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1: 100 % RDF for cotton and soybean	33.8hi	36.2ef	35.0h	5.21k	5.10h	5.15g	11.9g	11.0i	11.4f
T_2: 125 % RDF for cotton and soybean	33.8hi	38.0a	35.9ef	6.42c	6.73bc	6.58b	13.2bc	13.4b	13.3b
T_3: 150 % RDF for cotton and soybean	38.1a	38.1a	38.1a	6.51b	6.74bc	6.62b	13.4b	13.4b	13.4b
T_4: 100 % FYM and RDF for cotton and soybean (RC)	36.9b	37.8ab	37.3b	6.34d	6.46d	6.40c	13.2bc	12.9c-f	13.0b-d
T_5: T_1 + FYM 2.5 t ha^{-1}	34.2gh	32.1h	33.1i	5.52h	5.80g	5.66f	12.7d-f	12.3gh	12.5e
T_6: T_1 + FYM 5 t ha^{-1}	34.3f-h	36.1f	35.2gh	5.56g	6.17ef	5.86de	12.6ef	12.5f-h	12.6de
T_7: T_1 + Gliricidia 2.5 t ha^{-1}	34.7e-g	36.9cd	35.8fg	5.33j	6.33e	5.83ef	12.6ef	12.7d-g	12.6de
T_8: T_1 + Gliricidia 5 t ha^{-1}	34.2gh	37.2bc	35.7fg	5.42i	6.45d	5.94de	12.6ef	12.8c-f	12.7c-e
T_9: T_1 + Pongamia 2.5 t ha^{-1}	33.9h	36.5d-f	35.2gh	5.22k	6.11f	5.66f	12.5f	12.6e-h	12.6de
T_{10}: T_1 + Pongamia 5 t ha^{-1}	34.1gh	36.8c-e	35.5	5.26j	6.20ef	5.73f	12.6ef	12.7d-g	12.6de
T_{11}: T_1 + Vermicompost 1.25 t ha^{-1}	34.9d-f	36.2ef	35.5f-h	5.81f	6.05f	5.93de	12.8c-f	12.5f-h	12.6de
T_{12}: T_1 + Vermicompost 2.5 t ha^{-1}	35.1c-e	36.3d-f	35.7fg	5.84f	6.20ef	6.02d	12.7d-f	12.6b-d	12.7c-e
T_{13}: T_1 + FYM 2.5 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	35.4cd	37.9a	36.7b-d	6.20e	6.65bc	6.43c	13.0b-e	13.1b-d	13.1bc
T_{14}: T_1 + FYM 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	35.3c-e	37.9a	36.6cd	6.17e	6.63cd	6.40c	12.9c-f	13.1b-e	13.0b-d
T_{15}: T_1 + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1}	35.5cd	37.8ab	36.7b-d	6.23e	6.57cd	6.40c	13.1b-d	13.0b-d	13.0b-d
T_{16}: T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	35.1c-e	37.9a	36.5de	6.16e	6.70cd	6.43c	12.9c-f	13.1bc	13.0b-d
T_{17}: T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	36.4b	38.0a	37.2bc	6.32d	6.77b	6.55bc	13.1b-d	13.2bc	13.2b
T_{18}: T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}	35.6c	38.0a	36.8b-d	6.28d	6.75b	6.52bc	13.1b-d	12.2h	12.6de
T_{20}: Soybean sole crop (100 % RDF and FYM)	33.2i	34.1g	33.6i	6.92a	7.20a	7.06a	14.3a	14.9a	14.6a
Mean	**34.9**	**36.9**	**35.9**	**5.93**	**6.40**	**6.17**	**12.9**	**12.8**	**12.8**
S.Em. $\pm$	**0.21**	**0.21**	**0.44**	**0.03**	**0.05**	**0.09**	**0.13**	**0.12**	**0.28**
C.V. (%)	**5.22**	**6.74**	**5.35**	**8.53**	**7.64**	**8.12**	**11.6**	**12.5**	**11.4**

Means followed by the same letters do not differ significantly (0.05) by DMRT; RC – Recommended Check

Table 2 : Leaf area index at 60 DAS, dry matter production and total number of nodules per plant at harvest of soybean as influenced by INM in cotton and soybean intercropping system

Treatments	Leaf area index at 60 DAS			Dry matter production (g $plant^{-1}$)			Total number of nodules per plant		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1: 100 % RDF for cotton and soybean	2.96e	2.76f	2.86c	5.21k	5.10h	5.15g	21.0f	21.6i	21.3i
T_2: 125 % RDF for cotton and soybean	3.30bc	3.35b	3.33b	6.42c	6.73bc	6.58b	22.3b-e	24.1b-d	23.2b-d
T_3: 150 % RDF for cotton and soybean	3.35b	3.36b	3.36b	6.51b	6.74bc	6.62b	22.5b-e	24.1bc	23.3bc
T_4: 100 % FYM and RDF for cotton and soybean (RC)	3.29bc	3.22cd	3.26b	6.34d	6.46d	6.40c	23.0bc	24.2b	23.6b
T_5: T_1 + FYM 2.5 t ha^{-1}	3.16cd	3.08de	3.12bc	5.52h	5.80g	5.66f	21.9d-f	22.1h	22.0h
T_6: T_1 + FYM 5 t ha^{-1}	3.16cd	3.12de	3.14bc	5.56g	6.17ef	5.86de	22.0d-f	22.1gh	22.10gh
T_7: T_1 + Gliricidia 2.5 t ha^{-1}	3.15de	3.18cd	3.16bc	5.33j	6.33e	5.83ef	21.7ef	22.7f	22.2gh
T_8: T_1 + Gliricidia 5 t ha^{-1}	3.16cd	3.19cd	3.17bc	5.42i	6.45d	5.94de	21.8d-f	22.8f	22.3e-h
T_9: T_1 + Pongamia 2.5 t ha^{-1}	3.13de	3.15cd	3.14bc	5.22k	6.11f	5.66f	21.7ef	22.6fg	22.1gh
T_{10}: T_1 + Pongamia 5 t ha^{-1}	3.14de	3.17cd	3.15bc	5.26j	6.20ef	5.73f	21.7ef	22.6fg	22.1gh
T_{11}: T_1 + Vermicompost 1.25 t ha^{-1}	3.20cd	3.13de	3.16bc	5.81f	6.05f	5.93de	22.1c-e	22.1gh	22.1gh
T_{12}: T_1 + Vermicompost 2.5 t ha^{-1}	3.19cd	3.14de	3.16bc	5.84f	6.20ef	6.02d	22.2b-e	22.3gh	22.2f-h
T_{13}: T_1 + FYM 2.5 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	3.25bc	3.28c	3.27b	6.20e	6.65bc	6.43c	22.6b-e	22.4f-h	22.5d-h
T_{14}: T_1 + FYM 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	3.22cd	3.27c	3.25bc	6.17e	6.63cd	6.40c	22.5b-e	23.4e	22.9b-f
T_{15}: T_1 + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1}	3.27bc	3.25c	3.26b	6.23e	6.57cd	6.40c	22.7b-d	23.4e	23.0b-e
T_{16}: T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	3.22cd	3.29c	3.25b	6.16e	6.70cd	6.43c	22.3b	23.5e	22.9c-g
T_{17}: T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	3.28bc	3.31c	3.29b	6.32d	6.77b	6.55bc	23.1b-d	23.8c-e	23.4bc
T_{18}: T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}	3.27bc	3.04e	3.16bc	6.28d	6.75b	6.52bc	22.8b-d	23.7de	23.2bc
T_{20}: Soybean sole crop (100 % RDF and FYM)	4.77a	4.96a	4.87a	6.92a	7.20a	7.06a	24.4a	25.1a	24.7a
Mean	**3.23**	**3.31**	**3.22**	**5.93**	**6.40**	**6.17**	**22.3**	**23.0**	**22.7**
S.Em. ±	**0.03**	**0.03**	**0.07**	**0.03**	**0.05**	**0.09**	**0.31**	**0.13**	**0.50**
C.V. (%)	**11.1**	**12.9**	**11.6**	**8.53**	**7.64**	**8.12**	**5.92**	**7.82**	**6.800**

Means followed by the same letters do not differ significantly (0.05) by DMRT; RC – Recommended Check

Table 3: Biomass and leaf area of cotton and soybean at harvest as influenced by INM in cotton and soybean intercropping system

Treatments	Biomass (kg ha^{-1})			Leaf area (cm^2 ha^{-1})		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
T_1: 100 % RDF for cotton and soybean	1,045n	1,046i	1,046h	17,922j	18,249l	18,086j
T_2: 125 % RDF for cotton and soybean	1,152bc	1,225b	1,188b	18,729b-d	20,396b	19,562b
T_3: 150 % RDF for cotton and soybean	1,160b	1,215b	1,187b	18,780b-d	20,170c	19,475bc
T_4: 100 % FYM and RDF for cotton and soybean (RC)	1,136de	1,171de	1,153cd	18,827bc	19,136h	18,982ef
T_5: T_1 + FYM 2.5 t ha^{-1}	1,081j-l	1,120h	1,100g	18,175hi	18,645k	18,410i
T_6: T_1 + FYM 5 t ha^{-1}	1,084jk	1,137f-h	1,111fg	18,308f-h	18,949ij	18,629h
T_7: T_1 + Gliricidia 2.5 t ha^{-1}	1,066m	1,152e-g	1,109fg	18,082ij	19,382fg	18,732gh
T_8: T_1 + Gliricidia 5 t ha^{-1}	1,075k-m	1,165de	1,120fg	18,185g-i	19,629e	18,907fg
T_9: T_1 + Pongamia 2.5 t ha^{-1}	1,066m	1,146e-g	1,106g	18,037ij	19,094hi	18,565hi
T_{10}: T_1 + Pongamia 5 t ha^{-1}	1,069lm	1,162d-f	1,116fg	18,082ij	19,415f	18,749gh
T_{11}: T_1 + Vermicompost 1.25 t ha^{-1}	1,091ij	1,130gh	1,110fg	18,375fg	18,893j	18,634h
T_{12}: T_1 + Vermicompost 2.5 t ha^{-1}	1,103hi	1,152e-g	1,128ef	18,445ef	19,239gh	18,842fg
T_{13}: T_1 + FYM 2.5 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	1,106gh	1,180d	1,143de	18,653cd	19,692e	19,172d
T_{14}: T_1 + FYM 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1,118fg	1,186cd	1,152cd	18,583de	19,866d	19,224d
T_{15}: T_1 + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1}	1,127ef	1,168de	1,148d	18,690cd	19,616e	19,153de
T_{16}: T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1,133de	1,205bc	1,169bc	18,584de	20,022cd	19,303cd
T_{17}: T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	1,141cd	1,207bc	1,174b	18,899b	20,043c	19,471bc
T_{18}: T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1,133de	1,212b	1,172b	18,751b-d	20,099c	19,425bc
T_{19}: Cotton sole crop (100 % RDF and FYM)	1,677a	1,731a	1,704a	25,689a	27,462a	26,575a
T_{20}: Soybean sole crop (100 % RDF and FYM)	-	-	-	-	-	-
Mean	**1,078**	**1,195**	**1,164**	**17,889**	**19,894**	**19,363**
S.Em. ±	**4.30**	**7.95**	**6.41**	**63.7**	**58.2**	**61.0**
C.V. (%)	**12.3**	**11.2**	**11.4**	**9.23**	**9.45**	**9.10**

Means followed by the same letters do not differ significantly (0.05) by DMRT; RC – Recommended Check

Table 4: Economics as influenced by INM in cotton and soybean intercropping system

Treatments	Gross returns (Rs. ha^{-1})			Net returns (Rs. ha^{-1})			Benefit-cost ratio		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1: 100 % RDF for cotton and soybean	1,21,920j	1,66,669h	1,44,294h	76,839f	1,13,497hi	95,168g	2.70g-i	3.13f	2.92fg
T_2: 125 % RDF for cotton and soybean	1,41,035a	1,78,396ab	1,59,716ab	93,917a	1,23,188a	1,08,553a	2.99a	3.23bc	3.11b
T_3: 150 % RDF for cotton and soybean	1,41,647a	1,79,743a	1,60,695a	92,492a	1,22,498ab	1,07,495ab	2.88bc	3.14ef	3.01cd
T_4: 100 % FYM and RDF for cotton and soybean (RC)	1,39,328a-c	1,73,358c-e	1,56,343c-e	83,247c	1,09,187j	96,217fg	2.48k	2.70j	2.59j
T_5: T_1 + FYM 2.5 t ha^{-1}	1,27,645g-i	1,69,431g	1,48,538g	80,064de	1,13,760h	96,912fg	2.68hi	3.04g	2.86h
T_6: T_1 + FYM 5 t ha^{-1}	1,28,601gh	1,69,823fg	1,49,212fg	78,520ef	1,11,652i	95,086g	2.57j	2.92i	2.74i
T_7: T_1 + Gliricidia 2.5 t ha^{-1}	1,26,983hi	1,72,440fg	1,49,712fg	81,202c-e	1,18,569de	99,886de	2.77ef	3.20cd	2.99de
T_8: T_1 + Gliricidia 5 t ha^{-1}	1,27,950g-i	1,73,059fg	1,50,504fg	82,869cd	1,19,888cd	1,01,378cd	2.84cd	3.25b	3.05c
T_9: T_1 + Pongamia 2.5 t ha^{-1}	1,25,143i	1,70,733g	1,47,938g	79,362ef	1,16,862ef	98,112ef	2.73f-h	3.17d-f	2.95ef
T_{10}: T_1 + Pongamia 5 t ha^{-1}	1,26,609hi	1,71,555g	1,49,082g	81,528c-e	1,18,384de	99,956de	2.81de	3.23bc	3.02cd
T_{11}: T_1 + Vermicompost 1.25 t ha^{-1}	1,30,276fg	1,70,050fg	1,50,163fg	82,695cd	1,14,379gh	98,537ef	2.74fg	3.05g	2.90f-h
T_{12}: T_1 + Vermicompost 2.5 t ha^{-1}	1,32,789f	1,70,607f	1,51,698f	82,708cd	1,12,436hi	97,572e-g	2.65i	2.93i	2.79i
T_{13}: T_1 + FYM 2.5 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	1,35,897de	1,74,188de	1,55,042de	88,316b	1,18,517de	1,03,416c	2.86cd	3.13f	2.99de
T_{14}: T_1 + FYM 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1,35,586e	1,74,068e	1,54,827e	88,005b	1,18,397de	1,03,201c	2.85cd	3.13f	2.99de
T_{15}: T_1 + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1}	1,37,632b-e	1,73,994de	1,55,813de	87,551b	1,15,823fg	1,01,687cd	2.75fg	2.99h	2.87gh
T_{16}: T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1,36,430c-e	1,75,901c-e	1,56,166c-e	91,349a	1,22,730a	1,07,040ab	3.03a	3.31a	3.17a
T_{17}: T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	1,39,500ab	1,77,830a-c	1,58,665a-c	91,919a	1,22,159ab	1,07,039ab	2.93b	3.19cd	3.06bc
T_{18}: T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1,38,751a-d	1,76,283b-d	1,57,517b-d	91,170a	1,20,612bc	1,05,891b	2.92b	3.17d-f	3.04cd
T_{19}: Cotton sole crop (100 % RDF and FYM)	95,493k	1,28,495i	1,11,994i	54,094g	88,026k	71,060h	2.31l	3.18de	2.74i
T_{20}: Soybean sole crop (100 % RDF and FYM)	89,802l	1,01,350j	95,576j	52,860g	64,408l	58,634i	2.43k	2.74j	2.59j
Mean	**1,28,950**	**1,67,398**	**1,50,943**	**81,285**	**1,12,498**	**98,905**	**2.71**	**3.05**	**2.90**
S.Em. ±	**953**	**631**	**808**	**953**	**631**	**808**	**0.02**	**0.01**	**0.01**
C.V. (%)	**10.4**	**11.3**	**10.5**	**13.7**	**12.0**	**11.7**	**7.12**	**7.35**	**6.41**

Means followed by the same letters do not differ significantly (0.05) by DMRT; RC – Recommended Check;
Market price: Cotton : 5000 and 4700 Rs. q^{-1} during 2015-16 and 2016-17, respectively; soybean : 3500 and 2750 Rs. q^{-1} during 2015-16 and 2016-17, respectively.