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GROWTH AND YIELD RESPONSE OF SOYBEAN TO DIFFERENT CROPARRANGEMENTSANDNUTRIENTMANAGEMENTSUNDEROF MAIZE (*ZEA MAYS* L.) - SOYBEAN (*GLYCINE MAX* L.) INTERCROPPING SYSTEM

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Abstract

This field experiment was conducted during the *kharif* season of 2014 and 2015 at the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), India; to find out the appropriate crop arrangement and fertility levels for maize and soybean intercropping system. Treatments comprised of six cropping arrangements *viz*. sole maize (C_1), sole soybean (C_2), two replacement series (2 maize + 2 soybean, C_3 and 2 maize + 4 soybean, C_4), two additive series (two rows (C_5) and one row (C_6) of soybean planted in-between two rows of maize and four fertility levels viz. 125% recommended dose of fertilizer (RDF) (F_1), 100% RDF (F_2), 75% RDF (F_3) and 50% RDF (F_4). Research showed that the sole cropping is more beneficial for the legume component than intercropping as the growth of intercropped soybean get adversely affected by the tall cereal component maize. Except plant height remaining attributes were recorded highest in sole soybean (C_2) and was followed by 2M+4S (C_4) in most of the characters. Minimum value of these characters were observed under maize + soybean additive series C_5 in which two soybean rows were planted in between two rows of maize. Higher fertilizer dose application showed positive influence on growth and so on yield. All the growth attributing characters of soybean showed increasing trend when fertilizer dose was increased from 50% RDF to 125% RDF.

Key words : Soybean, maize, intercropping, crop arrangement, nutrient management.

Introduction

Soybean (*Glycine max* L.) is known as the wonder crop of the twentieth century. It is a cheapest source of vegetable oil and protein. It contains about 40 per cent protein, well balanced in essential amino acids, 20 per cent oil rich with poly unsaturated fatty acids specially Omega 6 and Omega 3 fatty acids, 6-7 per cent total mineral and 5-6 per cent crude fibre (Chauhan *et al*., 1988). Whether soybean is grown under monocropping system or intercropping system, it maintains the soil fertility by fixing nitrogen biologically and enables the farmer to cope with erosion as well as declining level of soil organic matter. Soybean is considered as an ideal crop for intercropping with cereals specially tall statured cereal crop maize; owing to its comparative tolerance for shade and drought, efficient light utilization and less competitiveness for soil moisture (Wright *et al*., 1988). Ijoyah *et al*. (2013) reported in there experiment that competitive pressure of maize and soybean were low, indicating that the crops are complementary and suitable in mixture.

Intercropping of maize with legumes is an alternative to maize monocropping and has a number of advantages compared to monocropping systems (Carruthers *et al*., 2000). For instance, soybean can positively contribute to soil health, human nutrition and health, livestock nutrition, household income, poverty reduction and overall improvements in livelihoods and ecosystem services, than many other leguminous grain crops (Rakasi, 2011). Maize has been intercropped with legumes for conservation agriculture and to inhibit soil degradation and control pests like predatory ants in maize fields (Ngwira *et al*., 2012). Moreover, the use of legumes may also increase the mobility of heavy metals in soils (Li *et al*., 2009). Intercropping of soybean in maize not only gave higher production, but also keep down weed growth, because of its smothering effect.

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But in maize-soybean intercropping system, maize with relatively higher growth rate, highest advantage and a more extensive rooting system is favoured in the competition with associated soybean. The general observations from this are that yields of the legume components are significantly depressed by cereal components in intercropping, which is attributed to reduced photosynthetically active radiation (PAR) that reaches the lower parts of the maize canopy occupied by the soybean crop (Matusso, 2014). This yield reduction of soybean is supported by the improper spatial arrangement and nutrient management under intercropping system. In order to take care of different types of competitions between the intercrops, there is a need for the proper arrangement of component crops and a careful management of all nutrient sources, which includes inorganic fertilizers as well as the biologically fixed nitrogen, so that higher production unit^{-1} of land could be achieved.

Materials and Methods

The two year Field experiment were conducted during the *kharif* season (July to October) of year 2014 and 2015 at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya in Raipur situated in central parts of Chhattisgarh, India. The experiment was laid out in Factorial Randomised Block Design with three replications. Each replication was divided into 24 experimental treatments. Maize seeds were sown at a spacing of 60×20 cm^2 and soybean was spaced at an intra-row spacing of 5 cm with 30 cm inter-row spacing. Treatments comprised of six cropping arrangements viz. sole maize (C_1), sole soybean (C_2), maize + soybean in 2:2 (C_3) and 2:4 (C_4) rows in replacement series and two additive series (two rows of soybean (C_5) and one row of soybean (C_6) planted in-between two rows of maize and 4 fertility levels *viz*. 125% recommended dose of fertilizer (RDF) (F_1), 100% RDF (F_2), 75% RDF (F_3) and 50% RDF (F_4). Recommended dose of fertilizer used for maize was 110 kg N ha^{-1}, 60 P_2O_5 kg ha^{-1} and 40 K_2O kg ha^{-1} and for soybean was 20 N kg ha^{-1}, 60 P_2O_5 kg ha^{-1} and 40 K_2O kg ha^{-1}. Maize was harvested at complete maturity and soybean was harvested when the first pod of the plants fully matured and dried. Seeds were weighed and adjusted to constant moisture levels of 14% and 12% in maize and soybean, respectively. The experimental data were statistically analyzed for analysis of variance and test of significance as described by Gomez and Gomez (1984).

Growth attributing characters of soybean *viz*. height, number of branches, leaf number, leaf area and dry weight per plant were recorded at 20, 40, 60, 80 DAS and at harvest. Number of nodules and nodule weight was taken at 40, 60 and 80 DAS. Leaf area index (LAI) and leaf area duration (LAD) were calculated by the formulas as directed by Watson (1947) and Power *et al*. (1967), respectively.

Results and Discussion

All the growth parameters of maize were significantly influenced by different cropping arrangements and fertility levels.

Plant height (cm)

Plant height of soybean showed increasing trend from 20 DAS to 80 DAS but slightly reduced at the time of harvest in each treatment (table 1). Tallest plants were obtained from additive series C_5 with two rows of soybean planted in between two rows of maize and the shortest plants were observed under sole soybean (C_2), throughout the crop growth period. The competition for light from the greater population of plants in intercropping might have induced taller soybean plants. This reaffirmed the finding of many researchers (Ijoyah *et al*., 2013; Undie *et al*., 2012). Out of four nutrient levels, 125% RDF (F_1) produced tallest plants, which was at par with 100% at all stages except 20 DAS and lowest value of plant height was recorded from 50% RDF (F_4). Increasing nitrogen effects that lead to increase cell division, cell expansion and increase in size of all its morphological parts (Adesoji *et al*., 2013).

Number of the branches

Sole soybean (C_2) produced significantly higher number of branches per plant over rest of the treatments (table 1). Additive series of two rows of soybean planted in between two row of maize (C_5) was the lowest producer of branches, throughout the period of investigation. Without any hindrance of competition from maize under intercropping, sole plantation of soybean might experienced the favourable microclimate for healthier root growth. This helped the crop to acquire more nutrients and water necessary to sustain plant growth. Zhang *et al.* (2015) reported the similar result. Among nutrient management, maximum number of branches were produced from the treatment with 125% RDF (F_1) and this was followed by 100% RDF (F_2), 75% RDF (F_3) and 50% RDF (F_4) in decreasing order. Like the result of the present study, Undie *et al.* (2012) also found significant influence of nitrogen on number of branches per plant in soybean.

Leaf number and leaf area

An increasing trend of leaf number and leaf area

Table 1 : Effect of crop arrangement and nutrient management on plant population, plant height and number of branches of soybean under maize + soybean intercropping system (Mean data of two years).

Treatment	Plant population (000'ha^{-1})		Plant height (cm)					Number of branches		
	20 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	40 DAS	60 DAS	80 DAS
Crop arrangement										
C_2	72.64	58.58	13.9	46.8	78.4	103.0	101.8	3.67	5.07	6.02
C_3	26.10	21.05	14.1	46.2	79.4	108.0	106.8	3.01	4.36	5.36
C_4	32.76	26.42	14.2	47.2	80.9	104.8	103.6	3.33	4.68	5.66
C_5	65.52	52.84	15.8	50.8	84.0	117.4	116.1	2.08	3.83	4.54
C_6	32.73	26.40	15.5	48.0	82.6	113.3	112.1	2.28	3.97	4.73
SEm±	0.40	0.33	0.2	0.2	0.3	0.5	0.5	0.10	0.08	0.08
CD (P=0.05)	1.13	0.92	0.5	0.7	0.9	1.5	1.4	0.28	0.24	0.23
Nutrient management										
F_1	45.98	37.08	16.4	51.1	86.1	115.3	114.0	3.41	5.02	5.93
F_2	45.97	37.07	15.1	48.3	81.9	111.3	110.1	3.13	4.68	5.57
F_3	45.95	37.05	14.0	46.6	79.5	107.1	105.9	2.60	4.16	4.98
F_4	45.89	37.01	13.3	45.2	76.8	103.5	102.3	2.35	3.67	4.58
SEm±	0.36	0.29	0.2	0.2	0.3	0.5	0.4	0.09	0.08	0.07
CD (P=0.05)	NS	NS	0.5	0.6	0.8	1.3	1.2	0.25	0.21	0.20

NS- Non significant, C_2-Sole soybean, C_3- Maize + soybean, 2:2, C_4- Maize+ soybean, 2:4, C_5- Two rows of soybean planted in between two rows of maize, C6 - One row of soybean planted in between two rows of maize, F_1 - 125% RDF, F_2 - 100% RDF, F_3 - 75% RDF, F_4 -50% RDF.

was observed in each treatment with the increase in age of the crop (table 2). Highest number of leaves as well as leaf area was recorded in sole soybean treatment. Lowest value of these parameters were observed from the additive series with two rows of soybean were planted in between two rows of maize (C_5). This shows that the soybean was dominated by corn in intercropping system. Among nutrient levels highest values of leaf number and leaf area was recorded from 125% RDF and lowest from 50% RDF. Bannett *et al*. (1989) found that low soil N, significantly reduced leaf area as a result of reduced leaf size.

Leaf area index (LAI) and Leaf area duration (LAD)

Leaf area index and leaf area duration (days) were closely correlated with dry matter production and yield and they proved to be good indicators of onset of competition. These characters are directly related to the sink of the plant i.e. leaves, and so to the photosynthetic rate and efficiency of leaf. Tables 2 and 4 shows an increase in LAI and LAD from 20-40 DAS to 60-80 DAS, respectively. Highest LAI and LAD was recorded under sole soybean (C_2) and lowest from C_5 additive series (two rows of soybean introduced between two rows of maize). When soybean is intercropped with maize, it decreases LAI and LAD possibly due to the shadow effect of the tall maize on soybean. Increase in fertilizer dose exerted positive effect on LAI as well as on LAD. In the treatments with 125% RDF, higher N, P and K dose was applied which helped in achieving reported higher values of these characters over rest of three nutrient levels. Higher amount of nitrogen (Devendra *et al*., 1983; Undie *et al*., 2012), phosphorous (Chen *et al*., 2013) and potash (Tabatabaii Ebrahimi *et al*., 2011) helps in increasing LAI and LAD.

Number and dry weight of nodules plant^{-1}

Number of root nodules and their dry weight (g plant^{-1}) of soybean was recorded at 40, 60 and 80 DAS (table 3). Increase in number of root nodules plant^{-1} was observed up to 60 DAS and then the number declined. Both the characters recorded significant higher values under sole soybean treatment (C_2) over other crop arrangements and the lowest value was registered under

Table 2 : Effect of crop arrangement and nutrient management on number of leaves, leaf area and leaf area index of soybean under maize + soybean intercropping system (Mean data of two years).

Treatment	Number of leaves				Leaf area (cm^2 $plant^{-1}$)				Leaf area index			
	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS
Crop arrangement												
C_2	4.32	8.36	12.58	13.16	124.64	502.04	876.67	981.19	0.69	2.79	4.87	5.51
C_3	4.23	8.13	12.13	12.85	118.47	443.62	814.31	944.90	0.66	2.46	4.52	5.25
C_4	4.29	8.23	12.45	12.87	120.16	453.26	846.22	979.39	0.67	2.52	4.70	5.44
C_5	4.13	7.62	11.83	12.21	111.36	397.22	772.58	891.16	0.62	2.21	4.29	4.95
C_6	4.12	7.96	11.92	12.57	116.27	408.75	785.67	912.01	0.65	2.27	4.36	5.07
SEm±	0.06	0.17	0.16	0.20	2.64	15.89	25.43	23.70	0.02	0.09	0.15	0.14
CD (P=0.05)	NS	0.47	0.45	0.55	7.39	44.50	71.20	66.36	0.04	0.26	0.41	0.39
Nutrient management												
F_1	4.43	8.55	12.89	13.19	129.74	532.95	933.44	1014.38	0.72	2.96	5.19	5.67
F_2	4.24	8.23	12.25	12.78	118.35	430.80	844.33	965.78	0.66	2.39	4.58	5.32
F_3	4.14	7.81	11.85	12.59	114.24	418.49	765.32	911.25	0.63	2.32	4.36	5.12
F_4	4.07	7.65	11.73	12.37	110.38	381.68	733.27	875.51	0.61	2.12	4.07	4.86
SEm±	0.06	0.15	0.14	0.18	2.36	14.22	22.74	21.20	0.01	0.08	0.13	0.12
CD (P=0.05)	0.16	0.42	0.40	0.49	6.61	39.80	63.68	59.35	0.04	0.23	0.37	0.34

C_2- Sole soybean, C_3- Maize+soybean, 2:2, C_4- Maize+soybean, 2:4, C_5- Two rows of soybean planted in between two rows of maize, C_6 - One row of soybean planted in between two rows of maize, F_1 - 125% RDF, F_2 - 100% RDF, F_3 - 75% RDF, F_4 - 50% RDF.

additive series (C_5) with two rows of soybean planted in between two rows of maize. Mandal *et al.* (2014) and Ijoyah (2013) also reported that the same. Number of the nodules and their dry weight $plant^{-1}$ decreased as the fertility level declined from 125% RDF to 50% RDF. This result is in close agreement with the findings of Singh and Kumar (2012).

Dry matter accumulation (g $plant^{-1}$)

Dry matter production (g $plant^{-1}$) by soybean increased progressively from 20 DAS till 80 DAS and then decreased marginally at harvest (table 4). Among different crop arrangements, sole soybean (C_2) produced the maximum dry matter $plant^{-1}$, which was reported at par with 2M+4S (C_4) during the course of investigation. However, additive series with two rows of soybean planted in-between two rows of maize (C_5) produced the minimum dry matter and remain comparable with treatment C_6 (one row of soybean planted between two rows of maize) at all the observational stages. Above ground and below ground biomass of soybean was probably get adversely affected by depressing effect of high population of maize (Overcrowding of both species in $meter^2$ area) under additive series. Reduction in the leaf number, leaf area and LAI in intercropping directly contributed to the lower dry matter production of soybean plants. Issahaku (2010) also reported the same under maize + soybean intercropping. Dry matter accumulation was also increased with increase in fertility level from 50% to 125% RDF. The reason for the this may be attributed to the fact that of more photosynthetic activity of the plant on the account of adequate supply of nutrients (NPK). Iqbal *et al.* (2006) also indicated higher dry matter production with higher dose of fertilizers.

Seed yield (q ha^{-1})

Data related to seed yield of soybean are presented in table 4. Out of six crop arrangements, sole soybean (C_2) produced significantly higher seed yield over rest of the crop arrangements and it was followed by C_4,C_3,C_5 and C_6 in descending order. Greater number of branches and leaves could have influenced the monocropped soybean to produce greater number of pods $plant^{-1}$ as well as higher seeds pod^{-1} (Data is not presented here) leading to higher seed yield (Ijoyah *et al.*, 2010; Kebebew *et al.*, 2014). However, the two additive series produced comparable seed yield of soybean. Among nutrient management 125% RDF produced the highest seed yield

Table 3 : Effect of crop arrangement and nutrient management on number of nodules and dry weight of nodule of soybean under maize + soybean intercropping system (Mean data of two years).

Treatment	Leaf area duration (Days)			Number of nodules			Weight of nodule (g plant^{-1})		
	20 DAS	40 DAS	60 DAS	40 DAS	60 DAS	80 DAS	40 DAS	60 DAS	80 DAS
Crop arrangement									
C_2	34.8	76.6	103.8	42.92	87.76	37.46	0.545	0.933	0.237
C_3	31.2	69.9	97.7	34.33	70.84	28.74	0.451	0.869	0.171
C_4	31.9	72.2	101.4	38.97	73.83	32.19	0.476	0.898	0.194
C_5	28.3	65.0	92.4	22.00	48.49	19.71	0.344	0.810	0.106
C_6	29.2	66.4	94.3	32.25	58.06	24.48	0.367	0.857	0.123
SEm±	0.9	2.3	2.7	0.21	0.23	0.11	0.007	0.006	0.005
CD (P=0.05)	2.6	6.4	7.6	0.59	0.64	0.30	0.018	0.017	0.015
Nutrient management									
F_1	36.8	81.5	108.5	49.05	84.43	32.80	0.644	1.030	0.313
F_2	31.8	72.0	100.7	36.95	71.46	29.86	0.523	0.895	0.209
F_3	28.3	64.6	93.1	26.82	61.18	26.14	0.332	0.797	0.084
F_4	27.3	61.9	89.4	23.55	54.12	25.26	0.247	0.772	0.058
SEm±	0.8	2.0	2.4	0.19	0.20	0.10	0.006	0.005	0.005
CD (P=0.05)	2.3	5.7	6.8	0.52	0.57	0.27	0.017	0.015	0.014

C_2-Sole soybean, C_3-Maize+ soybean, 2:2, C_4-Maize+ soybean, 2:4, C_5- Two rows of soybean planted in between two rows of maize, C_6 -One row of soybean planted in between two rows of maize, F_1- 125% RDF, F_2 - 100% RDF, F_3 -5% RDF, F_4 - 50% RDF.

Table 4 : Dry matter production and seed yield of soybean as influenced by the crop arrangement and nutrient management under maize + soybean intercropping system (Mean data of two year).

Treatment	Dry matter production (g plant^{-1})					Seed yield (q ha^{-1})
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	
Crop arrangement						
C_2	0.76	2.24	8.81	18.27	20.64	14.41
C_3	0.64	2.00	7.50	16.18	18.28	1.70
C_4	0.70	2.13	7.99	17.88	20.13	2.88
C_5	0.49	1.61	6.07	12.41	14.43	1.07
C_6	0.53	1.74	6.56	13.62	15.12	0.93
SEm±	0.02	0.06	0.26	0.53	0.59	0.12
CD (P=0.05)	0.06	0.18	0.73	1.48	1.66	0.34
Nutrient management						
F_1	0.90	2.58	10.23	23.28	25.35	4.96
F_2	0.66	2.06	8.21	17.13	19.28	4.41
F_3	0.49	1.65	6.15	12.37	14.56	3.39
F_4	0.44	1.49	4.96	9.91	11.68	3.49
SEm±	0.02	0.06	0.23	0.47	0.53	0.11
CD (P=0.05)	0.05	0.16	0.65	1.32	1.48	0.30

C_2-Sole soybean, C_3-Maize+ soybean, 2:2, C_4-Maize+ soybean, 2:4, C_5- Two rows of soybean planted in between two rows of maize, C_6 -One row of soybean planted in between two rows of maize, F_1-125% RDF, F_2 - 100% RDF, F_3 -5% RDF, F_4 - 50% RDF.

and the lowest producer was F_4 *i.e.* 50% RDF. Increasing levels of fertility in intercrop soybean significantly increases the seed yield of soybean (Meena *et al*., 2006). As soybean respond well to the more phosphorous application so the highest value for all the parameters *viz.*, dry matter accumulation, pods/plant, number of seeds per plant, test weight and seed yield were highest with 75 kg P_2O_5 (applies under 125% RDF) than 30 kg P_2O_5 (Applied under 50% RDF).

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