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GROWTH RESPONSE OF MAIZE TO DIFFERENT CROP ARRANGEMENTS AND NUTRIENT MANAGEMENTS UNDER MAIZE (*ZEA MAYS* L.) AND SOYBEAN (*GLYCINE MAX* L.) INTERCROPPING SYSTEM

Pragya Pandey* and M. C. Bhambri

Depatment of Agronomy, I.G.K.V., Raipur - 492 001 (Chhattisgarh), India.

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 nutrient management for maize and soybean intercropping system. Six crop arrangements *viz.* sole maize (C_1), sole soybean (C_2), two replacement series (2M + 2S, C_3 and 2M + 4S, C_4) and two additive series {Addition of two rows (C_5) and one row (C_6) of soybean) were combined with four nutrient management *viz.* 125% RDF (F_1), 100% RDF (F_2), 75% RDF (F_3) and 50% RDF (F_4). Intercropping was found more beneficial over sole cropping as light use efficiency, crop growth rate, relative growth rate, net assimilation rate and yield of the maize increased under intercropping. Above all, yield data shows that the intercropping is more advantageous for the cereal component than legume component. Significant higher grain yield was reported in 2M+2S, replacement series in comparison to rest of the crop arrangements. Higher fertilizer dose application showed positive results on growth and so on yield. All the growth attributing characters of maize showed increasing trend when fertilizer dose was increased from 50% RDF to 125% RDF.

Key words : Maize, soybean, crop arrangement, nutrient management, intercropping.

Introduction

In the present scenario, there is less scope for horizontal expansion of agricultural fields hence to meet out the self sufficiency in the food production thrust will be on crop diversification and increasing productivity. Intercropping is a dynamic and sustainable approach to get maximum productivity from every unit of land. This system is a viable agronomic practice for stepping up the production especially in regions where the small farmer intensively utilizes a limited land area (Francis, 1986). Generally, crop yield equivalent from intercropping is higher than the sole cropping.

One of the copping strategies adopted by farmers is intercropping legumes with cereals. Several workers (Matusso *et al*., 2014; Metwally *et al*., 2003 and Metwally *et al*., 2005) observed beneficial effect of legumes when grown in combination with cereals. Legumes become more important and offer an alternative for increasing nitrogen input in various cropping systems and soil management practices because of their ability to fix significant amounts of atmospheric nitrogen (Matusso *et al*., 2014). In cereal + legume intercropping systems, the combination of a tall cereal with an adventitious root system and a short-statured legume with a deep tap root utilizes space and time more efficiently than a sole cereal crop.

Intercropping of maize and soybean is a widely adopted cereal-legume intercropping system. This intercropping not only helps to produce additional food from less expanse of land but also utilises the natural resources more efficiently with minimal adverse effect on the environment in order to meet the increasing population request (Amos *et al*., 2012). Intercropping of legumes with maize is considered to be better way for securing nitrogen economy and increasing yield of maize as well providing bonus yield of soybean. This also enhances the productivity per unit time and space and higher net returns of intercropping system over monoculture (Thayamini and Brintha, 2010).

***Author for correspondence :** E-mail: gyan.pragya89@gmail.com

The system of growing soybean and maize together is less effective for yield of both the crops owing to improper spatial arrangement. Optimum crop arrangement is therefore one of the most important factors for higher productivity, by efficient utilization of ground resources and also harvesting as much solar radiation and in turn better photosynthate formation (Thavaprakaassh, 2005). When crop arrangements are combined with appropriate nutrient levels then desirable yield of intercropping system can be achieved. Sustainable crop production, therefore, requires a careful management of all nutrient sources available in a farm, particularly in maize based cropping systems (Wakene *et al.*, 2007). Therefore, this paper deals with different combinations of different crop geometry and fertility levels to out the best out of them.

Materials and Methods

Field experiment was conducted during the *kharif* season (July to October) of 2014 and 2015 at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur situated in central parts of Chhattisgarh and lies at latitude, longitude and altitude of 21°4' N, 81°35' E and 290.20 metres above mean sea level, respectively. The experimental area consisted of clayey soil with pH 7.5 (neutral) with available 175.61 kg ha^{-1} Nitrogen (Low), 10.752 kg ha^{-1} Phosphorus (Medium) and 330.736 $kgha^{-1}$ Potash (High) at the depth of 0-30 cm. The experiment was laid out in Factorial Randomised Block Design with three replications. Each replication was divided into 24 experimental treatments. Maize and soybean plants were spaced at 60×20 cm^2 and 30×5 cm^2 spacing, respectively. 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) added in-between two rows of maize} and four nutrient management *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 taken for maize was 110:60:40 and for soybean was 20:60:40; N: P_2O_5:K_2O kg N ha^{-1}. Growth attributing characters *viz.* light use efficiency, crop growth rate, relative growth rate and net assimilation rate per plant were recorded at periodic interval of 20 days. These parameters were calculated by the following formulas.

Light use efficiency : The light use efficiency was worked out with the help of following formula :

$$\text{LUE } (\text{ghr}^{-1}) = \frac{\text{Dry matter (g m}^{2})}{\text{Sunshine hours (hr)}}$$

Crop growth rate (CGR) : Crop growth rate (g $plant^{-1}day^{-1}$) is the rate of dry matter production per unit ground area per unit time and was computed between 20-40, 40-60, 60-80 DAS and 80-at harvest by formula given by Watson (1952).

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

Where, W_1 and W_2 are the dry weight per unit area at the time t_1 and t_2, respectively.

Relative growth rate (RGR) : Relative growth rate (g g^{-1} $plant^{-1}$ day^{-1}) is the rate of increase in the dry weight per unit dry weight per unit of time and was calculated at 20-40, 40-60, 60-80 DAS and 80-at harvest by formula given by Watson (1952).

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

Where,

ln = Natural logarithm

W_1 and W_2 = Dry matter production per plant (g) at time t_2 and t_1, respectively.

t_1 and t_2 = time intervals.

Net assimilation rate (NAR) : This is the increase in dry weight of plant per unit of leaf area per unit of time. NAR was calculated as per the formula:

$$\text{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{L_nA_2 - L_nA_2}{A_2 - A_1} (\text{g m}^{-2} \text{ leaf area day}^{-1})$$

Where, W_1 and W_2 are the total dry weight of plant on two successive occasions t_1 and t_2 and A_1 and A_2 are the corresponding leaf area per plant.

Results and Discussion

Light use efficiency (g $plant^{-1}$ hr^{-1})

Light use efficiency (LUE) describes how efficient intercepted radiation was converted to biomass (Robertson *et al.*, 2001). Adding the other crop could increase the radiation use efficiency by increasing the value of the proportional light interception (Vandermeer, 1989; Harris, 1990; Awal *et al.*, 2003 and Jahansooz *et al.*, 2007). Keating and Carberry (1993) assumed that the intercrops are a closer approximation to the randomly distributed leaves required for Beer's law than the sole crops due to greater plant density. Similar result was obtained from this experiment where intercropping more efficiently utilised the intercepted light than sole crops. Figs. 1 and 2 shows that LUE in case of both the factors increased upto 80 DAS followed by a decline till harvest.

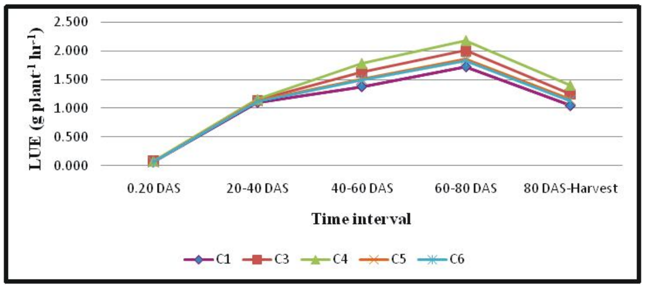

Fig. 1 : Light use efficiency of maize as influenced by crop arrangement under maize + soybean system (Mean).

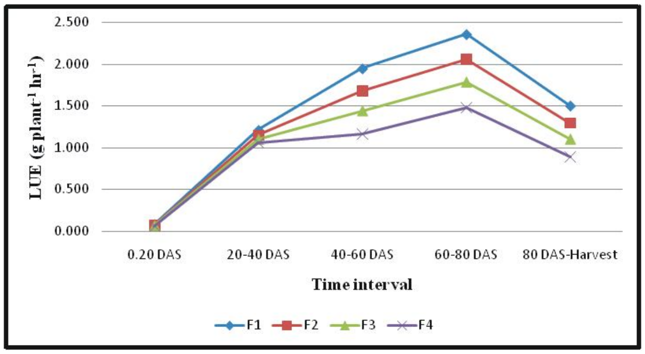

Fig. 2 : Light use efficiency of maize as influenced by nutrient management under maize + soybean system (Mean).

Highest LUE was recorded at 60-80 DAS regarding crop arrangement as well as nutrient management. Differences among LUE obtained from different crop arrangements were very low during first 40 DAS but at later stages a clear difference can be seen owing to better canopy development and increased leaf area index. Maize + soybean, 2:4 crop arrangement (C_4) had given the highest value of LUE till harvest and this treatment was followed by maize + soybean, 2:2 row ratio (C_3) at all the observational stages. While, sole maize (C_1) reported the lowest LUE throughout the crop life. Due to the better canopy development and more number of leaves per plant maize based intercropping facilitated the higher light interception and so the higher LUE. Among four nutrient management highest and lowest LUE was obtained from F_1 (125% RDF) and 50% RDF (F_4), respectively, at all the observational stages. This was due to the higher leaf area index values from highest fertilizer dose applied and that helped the plant to increase the LUE (Shamim *et al*., 2015).

Crop growth rate (g plant^{-1} day^{-1})

Crop growth and biomass is determined by the quantity of radiation intercepted and utilized by the crop canopy (Oyewole, 2010). All the crop arrangements except 2 maize + 4 soybean replacement series (C_4), showed a decreasing trend of crop growth rate (CGR) upto 80 DAS followed by either a plateau or a slight increase (Fig. 3). However, maximum CGR value was noticed between knee height stage to flowering phase (40-60 DAS). CGR under 2:4 replacement series (C_4) was almost two-fold higher than the sole maize which is showing the lowest CGR. C_4 was followed by 2:2 replacement series (C_3). Better root growth with higher root volume and root weight (Data is not given) in comparison to the rest of crop arrangements under 2M+4S, led to better growth of the plant. Mandal *et al.* (2014) and Zhang *et al.* (2015) also reported the similar result. Regarding nutrient management (Fig. 4) a general trend of decrease in CGR followed by a plateau was observed except in case of highest fertility level (F_1). 125% RDF (F_1) recorded an increase upto flowering phase (60 DAS) and then showed a rapid decrease till harvest, perhaps due to the senescence and shading of old leaves leading to lower photosynthesis. The effects of nutrient levels were clear on CGR values as 125% RDF (F_1) showed the highest rate of crop growth whereas 50% RDF (F_4) showed the lowest rate.

Relative growth rate (g g^{-1} plant^{-1}day^{-1})

Relative growth rate (RGR) of maize was recorded higher under intercropping system in comparison to sole cropping. RGR of maize (Figs. 5 and 6) decreased up to 60-80 DAS and after that till harvest either the rate remained same or decreased. Sharp decline in RGR after knee height stage was probably due to increased demand of assimilate during reproductive phase and for growing seed fraction. In case of both the factors applied maximum rate of relative growth was seen during first 40 DAS. The intercropped system increased the variable considered, although the statistical comparisons are not presented here. C_4 (2M + 4S) during major growth period between 40 DAS to 80 DAS showed the highest rate of relative growth whereas sole maize (C_1) recorded the lowest rate of growth. This result is in line with Tripathi (2004). Stimulating effect of fertility levels on RGR could also be seen as the graph of 125% RDF (F_1) and 50% RDF (F_4) showed higher and lower RGR values respectively, in comparison to rest of the fertility levels during major growth period of maize. Since, nitrogen increases photosynthetic tissues thus the treatment with higher nitrogen fertilizer had higher RGR (Azarpour *et al*., 2014). Nitrogen due to the having a role in production and translocation of cytokinin from the root to the shoots increases cell division rate and so the growth rate of plant (Marschner, 1995 and Dasilva and Stutte, 1981).

Net assimilation rate (g m^{-2} leaf area day^{-1})

Data on net assimilation rate (NAR) were calculated for 20-40, 40-60 and 60-80 DAS and presented in Fig 7

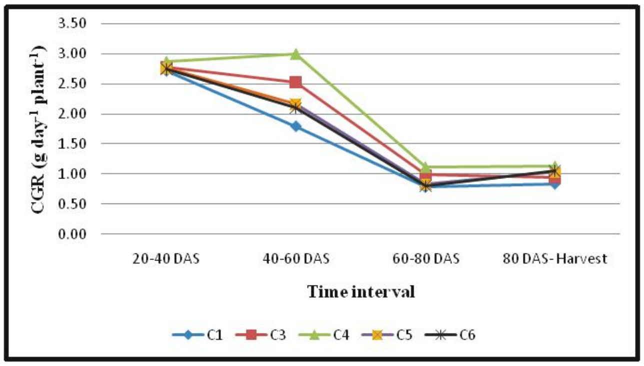

Fig. 3 : Crop growth rate of maize as influenced by crop arrangement under maize - soybean intercropping system (Mean).

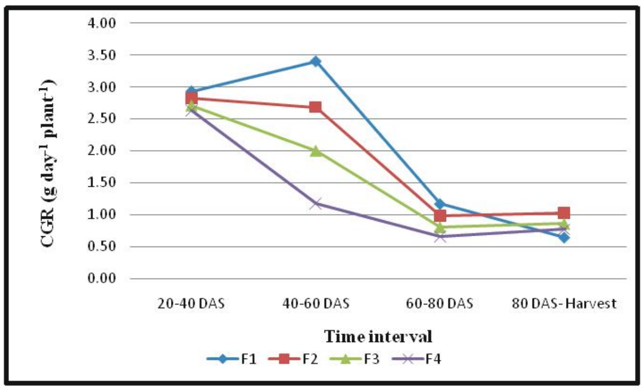

Fig. 4 : Crop growth rate of maize as influenced by nutrient management under maize-soybean intercropping system (Mean).

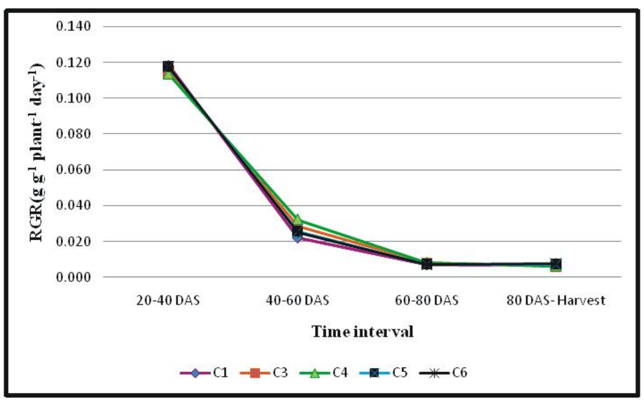

Fig. 5 : Relative growth rate of maize as influenced by crop arrangement under maize - soybean intercropping system (Mean).

and 8. Among crop arrangements, upto the flowering phase of maize (60 DAS) the NAR either increased (C_4 and C_3) or remain same (C_5 and C_6) or decreased (C_1) followed by a general decline till harvest. upto 40-60 DAS and decreased then after upto 60-80 DAS. Although 2M + 4S (C_4) had given the lowest rate of increase in NAR of maize during 20-40 DAS, but after that there was a sudden increase was observed and this treatment remain

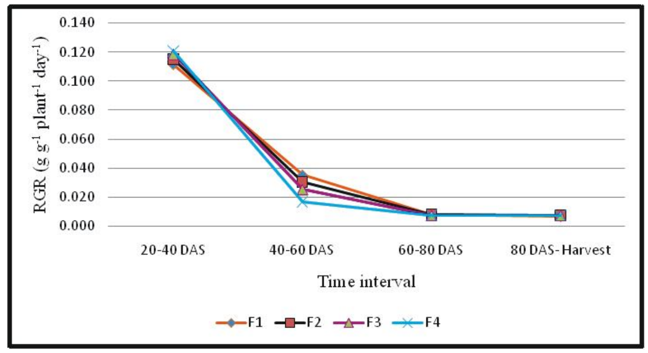

Fig. 6 : Relative growth rate of maize as influenced by nutrient management under maize - soybean intercropping system (Mean).

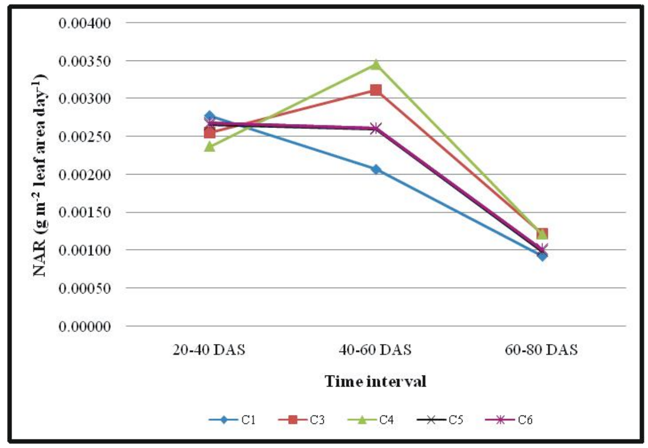

Fig. 7 : Net assimilation rate of maize as influenced by crop arrangement under maize + soybean intercropping system (Mean).

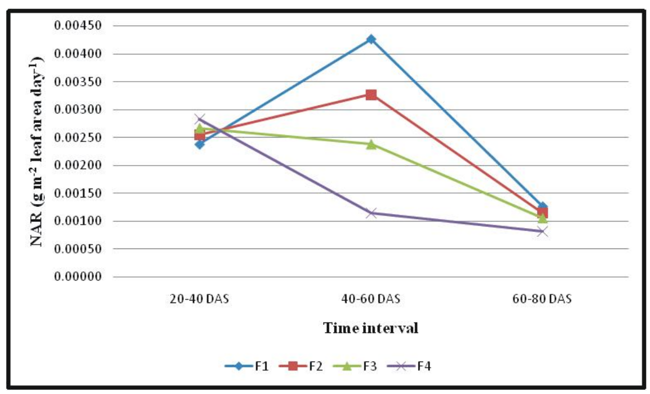

Fig. 8 : Net assimilation rate of maize as influenced by nutrient management under maize + soybean intercropping system (Mean).

the highest producer of NAR till harvest. In variance, sole maize (C_1) produced the lowest NAR at all the observational stages except 20-40 DAS. Two additive series C_5 (Two rows of soybean added between two row of maize) and C_6 (One row of soybean added between two rows of maize) showed comparable values of NAR. Similar to the crop arrangement, the NAR of

Table 1 : Effect of cropping effect of cropping arrangements and nutrient management on grain yield and stover yield under maize + soybean intercropping system.

Treatments	Grain yield ($q\ ha^{-1}$)	Stover yield ($q\ ha^{-1}$)
Crop arrangement		
C_1 (Sole Maize)	60.30	83.70
C_2 (Sole soybean)	27.80	11.20
C_3 (Maize + soybean, 2:2)	71.90	113.70
C_4 (Maize + soybean, 2:4)	49.00	71.70
C_5 (Two row of soybean planted in between two row of maize)	64.60	87.70
C_6 (One row of soybean planted in between two row of maize)	63.20	85.10
S Em ±	0.84	1.16
CD (P=0.05)	2.36	3.26
Nutrient management		
F_1 (125% RDF)	62.50	89.60
F_2 (100% RDF)	59.10	79.20
F_3 (75% RDF)	53.70	71.20
F_4 (50% RDF)	49.20	62.10
S Em ±	0.69	0.95
CD (P=0.05)	1.93	2.66

different fertility levels recorded very close values upto 40 DAS after that either their NAR increased (F_1 and F_2) or decreased (F_3 and F_4). From 40 to 80 DAS, 125% RDF (F_1) showed the highest NAR value while 50% RDF (F_4) recorded the lowest rate of net assimilation. As maize is an exhaustive crop having high nutrition demand, thus under 50% RDF (F_4) due to much lower availability of fertilizer NAR showed a declining trend throughout the crop growth period (Awal and Ikeda, 2003; Moussa and Bersoum, 1995 and Mohsan, 1999).

Grain yield ($q\ ha^{-1}$)

The grain yield was significantly influenced by different crop geometry and nutrient levels. Among crop arrangements C_3, maize + soybean (2:2, replacement series) produced significantly higher grain yield over rest of the crop arrangement (table 1). This was followed by C_5 (Maize planted at 60 cm row to row spacing and two rows of soybean planted in-between, additive series). The significantly lower producer of grain was sole soybean (C_2). Under maize + soybean intercropping systems, soybean yield tends to be lower and maize yield tends to be higher (Ghaffarzaeh *et al*., 1994). This increase in the total grain production in maize + soybean intercropping system obviously was the result of additional yield of soybean as bonus by utilization of inter-row space of maize crop (Singh *et al*., 2005). Regarding nutrient management the grain yield in 125% RDF was highest and significantly superior over rest of the nutrient levels because of the superior yield attributing characters. Higher LUE with higher CGR, RGR and NAR have supported the higher production of dry matter, cobs plant^{-1}, grains cob^{-1}, test weight and cob yield under 125% RDF (F_1). Panhwar *et al*. (2004) concluded that fertilizer levels exhibited highly significant effect on grain yield of maize.

Stover yield ($q\ ha^{-1}$)

Stover yield was significantly influenced by the crop arrangements as well as nutrient management. Significantly higher stover yield was observed in C_3, maize + soybean (2:2, replacement series) than rest of the crop arrangement treatments and it was followed by both additive series (Two rows of soybean, C_5 and one row of soybean C_6 planted in between two rows of maize) and maize + soybean, 2:4 replacement series in descending order (table 1). Both additive series were found comparable while the lowest stover yield was recorded from sole soybean (C_2). 2M + 2S (C_3) exhibited 90.14% higher stover yield over sole soybean . In cereal-legume intercropping, the cereal components usually tend to have greater competitive ability because of their relatively higher growth rate, height advantage and more excessive root system (Ofori and Stern, 1987). The impact of nutrient applied was clearly visible on the stover yield. 125% RDF produced significantly higher stover yield than the remaining three nutrient levels. Treatment 125% RDF (F_1) produced 30.69% higher stover yield over the lowest producer *i.e.* 50% RDF. This was due to the transfer of major amount of photosynthates to seeds resulting lower stover/ straw yield. Similar finding was also reported by Gangwar *et al.* (1994) and Sharma *et al*. (2008).

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