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Influence of Maize-Cowpea Intercropping System on Growth, Productivity and Competitive Ability of Crops Cultivated Under South Odisha Conditions

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ABSTRACT

Being a widely row-spaced crop, maize (*Zea mays* L.) offers ample scope for adoption of intercropping systems with other crops. In maize-based intercropping system, legumes are preferred worldwide. Among different legumes, cowpea (*Vigna unguiculata* L.) is an important crop that is fit to *kharif* and other seasons. Based on the above facts, the present study was conducted during *kharif* season of 2019 in P.G. Research Farm of M.S. Swaminathan School of Agriculture, Centurion University of Technology Management, Odisha. The treatments were laid out in randomized block design with four replications. The experiment consists of six treatments, namely, maize + cowpea (1:1), maize + cowpea (2:1), maize + cowpea (1:2), maize + cowpea (3:3), sole maize and sole cowpea which were replicated for four times. The results of the study revealed that the plant height and number of leaves of both crops were not influenced significantly; however, there was significant difference among the treatments in dry matter accumulation per unit area. Yield attributes of maize and cowpea did not show any significant difference among the intercropping treatments. The maximum grain yield, stover yield and biological yield of maize and cowpea were recorded in sole maize and sole cowpea respectively. Among various competition functions, the combined LER, the treatment maize + cowpea (1:1) registered the greater value of 1.18. In all the intercropping treatments, the ATER was lesser than unity, indicating that the intercropping systems were not advantageous in utilizing area and time. Intercropping maize + cowpea (1:1) resulted in monetary advantage of Rs.7299 ha^{-1}. The study concludes that sole maize showed its superiority over all mixed stands of maize + cowpea under the replacement series of the intercropping system because of decreased plant population in the mixed stands.

Keywords: Maize, Cowpea, Intercropping, Yield, Competition functions

Maize (*Zea mays* L.) is one of leading crops of the world and is widely cultivated under diverse cropping systems that was domesticated first in Central America. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as 'queen of cereals' because of its highest genetic yield potential. Apart from this, maize is an important industrial raw material and provides large opportunity for value addition. Maize

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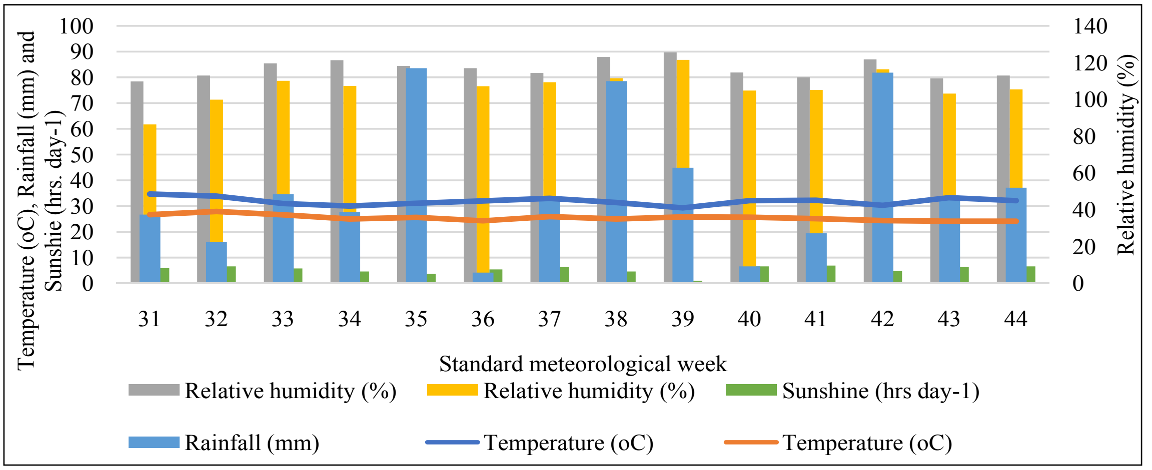
attains third position after rice and wheat in the world and it fits to various agroclimatic regions in different growing seasons. Among the world's maize growing countries, USA is the largest producer of contributes nearly 35% of the total maize produced. Worldwide, maize is grown in 182 m ha with a production of 987 million t and productivity of 5423 kg ha^{-1} (FAOSTAT, 2021). In India, maize had a coverage of 9.18 million ha with a production of 27.23 million t and productivity of 2965 kg ha^{-1} in 2018-19 (ICAR-IIMR, 2019). In Odisha, area grown under maize is 2.69 lakh ha which produces 7.51 m t grain with an average productivity of 2791 kg ha^{-1} (GoO, 2020). Maize contributes nearly 9% in the national food basket and more than 400 billion to the agricultural GDP at current prices (Sairam *et al.* 2023). Maize is primarily used for feed (60 %) followed by human food (24%), industrial (starch) products (14%) beverages and seed (1% each) (Maitra *et al.* 2019a). Being a widely row-spaced crop, maize offers ample scope for adoption of intercropping systems with other crops (Sahoo *et al.* 2023). In maize-based intercropping system, legumes are preferred worldwide.

Cowpea (*Vigna unguiculata* L.) is an important legume crop and is grown mainly during summer and kharif seasons (Sudharani *et al*. 2018). The crop is thought to be a native to West Africa and is widely cultivated in warm regions around the world. It is also called black-eyed pea or southern pea used as pulse; however, green pods are consumed as vegetable and whole plant as fodder. In addition to their use as a protein-rich food crop, cowpeas are extensively grown as a hay crop and as a green manure or cover crop. The feeding value of cowpea forage is high and superior to other legumes. Cowpea has around 13- 18% protein, 18-26% crude fiber and 2-3% crude fat. It provides highly pleasant, tasty and quality fodder. (Bisht *et al*. 2001). In this regard, intercropping legumes in maize can be a suitable option to obtain multiple benefits of their association (Panda *et al*. 2021, 2022; Priya *et al*. 2023; Sagar *et al*. 2023). Cereal-legume intercropping plays an important role in subsistence farming among smallholders for production in both undeveloped and developing countries, especially in limited resources conditions (Maitra *et al*. 2021, 2023a). Yields of intercropping are often higher than in sole cropping systems (Lithourgidis *et al*. 2006; Maitra, 2018; Chappa *et al*. 2022). An intercropping system harnesses multifaceted benefits such as stable or more yield (Maitra, 2020), crop diversification, greater ecosystem services and healthy environment (Maitra and Gitari, 2020; Gitari *et al*. 2020), natural insurance against aberrant weather conditions and crop failure (Maitra *et al*. 2019b; Maitra *et al*. 2020), livelihood and food security for smallholders (Manasa *et al*. 2020), soil quality improvement (Praharaj and Maitra, 2020; Jena *et al*. 2022; Maitra *et al*. 2023b) and higher resource use efficiency (Parimaladevi *et al*. 2019; Kumar and Maitra, 2020). Considering the above-mentioned facts, the present study was conducted to assess the influence of maize-cowpea intercropping system on growth, productivity and competitive ability of crops.

MATERIALS AND METHODS

The field experiment was conducted at PG research farm of M.S. Swaminathan School of Agriculture, Centurion University of Technology Management, Paralakhemundi, Gajapati, Odisha, which is geographically located at 23°39′ N latitude and 87°42′ E longitude under typical tropical climatic conditions. During the crop period the mean maximum temperature varied between 28.9°C to 33.3°C. Whereas the weekly mean minimum temperature during this crop period ranged from 23.1°C to 25.7°C (Fig. 1). Mean monthly relative humidity at 7 AM and 2 PM during the crop period was 84.2 % and 80.2%. Rainfall during the cropping period accounted for a total of 989.6 mm. The daily sunshine hour was gradually decreased from July to September, however, from September onwards it was increased. Maximum sunshine hour was noted in July (6.9 hrs. day^{-1}). The mean sunshine hour during crop period was 5.0 hrs. day^{-1}.

The experimental site was uniform and soil type was light textured brown forest soil. The soil samples were drawn from 0-30 cm depth of the experimental field at random. The composite soil sample was analysed for physicochemical properties by following standard procedures and the results indicated that the soil was sandy loam in texture, neutral in pH, medium in organic carbon, low in available nitrogen, medium in available phosphorus and medium in available potassium.



Source: Agro-meteorological observatory, Centurion University, Odisha.

Fig. 1: Standard week wise meteorological data during the crop growth period

The experiment was laid out in a randomized block design (RBD) with six treatments and each treatment was replicated for four times. The experiment consisted of six treatments, namely, maize + cowpea (1:1), maize + cowpea (2:1), maize + cowpea (1:2), maize + cowpea (3:3), sole maize and sole cowpea. Maize hybrid Ganga-2 and cowpea variety CO 6 were chosen for the experiment. The field was laid out into plots and all the plots were micro levelled manually before sowing in main field. The fertilizers, namely, nitrogen, phosphate and potash (N, P_2O_5 and K_2O) were applied as per recommended dose which were for sole maize: 120-60-40 kg ha^{-1}, for sole cowpea 20-40-20 kg ha^{-1} and for maize + legume: 120-60-40 kg ha^{-1} of N-P_2O_5-K_2 respectively. The spacing for hybrid maize (under both sole and intercropping) adopted was 60 cm × 25cm, whereas, the pure stand of cowpea was maintained at a spacing of 60 cm x 15 cm row to row and plant to plant respectively. The growth and yield attributes of maize and yield of both the crops were recorded by adopting the standard procedures. The competitive functions such as Land equivalent ratio, area time equivalent ratio, monetary advantage and maize equivalent yield were calculated by considering the concept and formulas given by Willey and Osiru (1972), Hiebsch (1978), Willey (1979) and De Wit (1960) respectively. The statistical analysis of the experimental data was processed by considering the concept of Gomez and Gomez (1984). The analysis of variance (ANOVA), the standard error of means (S.Em. ±) and critical difference (C.D.) at 5% probability level of significance was analysed through Excel software, Microsoft Inc., Redmond, Washington, USA.

RESULTS AND DISCUSSION

The data on plant height and number of leaves of maize measured at harvest showed a non-significant difference among the intercropped treatments (Table 2). However, the sole maize registered a marginally higher plant height and number of leaves. Among the intercropping treatments, maize + cowpea (1:1) registered marginally taller plants than other intercropped treatments. The results are in conformity with the findings of Iderawumi (2014), Mandal *et al.* (2014) and Prakash *et al.* (2019). In case of dry matter accumulation of maize at harvest, there was significant difference among treatments. Sole maize registered the highest dry matter accumulation (1315 g m^{-2}) and it remained significantly superior to all other intercropped treatments. Further, dry matter production by intercropped maize with cowpea (2:1) was significantly higher than maize + cowpea with row proportion of 1:2 and 1:1 respectively. Such results were obtained because of variation in plant stand of maize in different cropping systems under replacement series of study. In the treatment maize + cowpea (1:2), maize population was less (22,000 ha^{-1}), whereas, plant population in sole maize was higher with a total plant of 66,666 ha^{-1}, which may result in more biomass production. The results corroborate with the findings of Mandal *et al.* (2014), Kumar *et al*. (2018) and Manasa *et al*. (2018).

Table 1: Effect of maize-cowpea intercropping system on growth attributes of crops

Treatments	Plant height at harvest (cm)		Dry matter at harvest (g m^{-2})		Number of leaves at harvest	
	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea
Maize + Cowpea (1:1)	204.0	94.3	757	189.3	9.3	83.4
Maize + Cowpea (2:1)	201.2	90.2	900	128.1	8.4	79.61
Maize + Cowpea (1:2)	200.8	86.6	545	311.5	9.3	85.4
Maize + Cowpea (3:3)	204.3	92.3	730	175.6	9.0	86.4
Sole Maize	209.5	—	1315	—	10.1	—
Sole Cowpea	—	96.5	—	437.9	—	87.4
S.Em. (±)	6.16	2.4	32.3	8.9	0.24	2.3
C.D. (at 5%)	NS	NS	148.9	41.4	NS	NS

NS=Non-significant.

Table 2: Effect of maize-cowpea intercropping system on yield attributes of crops

Treatments	Yield attributes of maize				Yield attributes of cowpea		
	Number of cobs plant $^{-1}$	Number of seeds row^{-1}	Number of rows cob^{-1}	100 grain weight (g)	Number of pods plant^{-1}	Number of grains pod^{-1}	100 grain weight (g)
Maize + Cowpea (1:1)	1.46	19.2	14.3	22.5	18.3	11.0	10.7
Maize + Cowpea (2:1)	1.43	18.8	14.3	22.1	17.9	10.8	10.4
Maize + Cowpea (1:2)	1.48	19.4	14.3	22.7	18.6	11.5	10.9
Maize + Cowpea (3:3)	1.45	19.0	14.3	22.4	18.1	11.2	10.6
Sole Maize	1.42	18.5	14.0	22.3	—	—	—
Sole Cowpea	—	—	—	—	18.7	10.5	11.0
S.Em. (±)	0.05	0.67	0.48	0.89	0.56	0.36	0.28
C.D. (at 5%)	NS	NS	NS	NS	NS	NS	NS

NS= Non-significant.

Similar to maize, the plant height and number of leaves of cowpea also found a non-significant effect with implementation of different intercropping treatments (Table 1). The plant height and number of leaves of cowpea at harvest registered its highest values in sole cowpea. However, it remained statistically at par with all other intercropping treatments. This might be due to the complementarity interaction among crops that helped cowpea to flourish uniformly under various spatial arrangements. Earlier, Iderawumi (2014) and Ginwal *et al*. (2019) reported the similar findings. The dry matter accumulation at harvest of cowpea was significantly influenced due to various cropping systems. Sole cowpea produced significantly higher dry matter than other intercropped treatments. Intercropping maize + cowpea with 1:2 row ratio remained significantly inferior to sole cowpea; however, registered significantly higher dry matter accumulation than remaining intercropping treatments, namely, maize + cowpea (1:1), maize + cowpea (2:1) and maize + cowpea (3:3). The superiority of sole cowpea was recorded because of the population of the treatment as it was with 100% plant stand of cowpea. Further, reduction of population decreased the dry matter production per unit area. The results corroborate the findings of Singh *et al*. (2004;2008) and Jan *et al*. (2016).

Yield attributes

The yield attributes of maize such as number of cobs plant^{-1}, number of seeds row^{-1}, number of rows cob^{-1} and 100 grain weight were measured after harvest recorded non-significant difference among different intercropping treatments (Table 2). Maize + cowpea (1:2) produced marginally higher yield attributes and it was closely followed by maize + cowpea (1:1), maize + cowpea (3:3), maize + cowpea (2:1). Earlier, Kheroar and Patra (2013), Jan *et al*. (2016) and Manasa *et al*. (2020) recorded a similar type of observation. Similarly, the yield attributes of cowpea showed a non-significant difference among cropping systems (Table 2). The results are in conformity with the findings of Iderawumi (2014) and Jan *et al*. (2016).

Yield

The grain yield, stover yield and biological yield of maize registered a significant difference among the cropping systems studied. The grain, stover and biological yield of maize recorded the highest values in sole maize (Table 3). Further, the sole maize treatment remained significantly superior to all intercropping treatments. Among the intercropping treatments, maize + cowpea (2:1) recorded the highest grain, stover and biological yield of maize and this treatment remained statistically at par with maize + cowpea (1:1) and maize + cowpea (3:3). Moreover, maize + cowpea (2:1) intercropping was significantly superior to maize + cowpea (1:2). Such results were recorded because of reduction of plant population of maize in mixed stand as the intercropping was studied in a replacement series. The results corroborate with the findings of Kumar *et al*. (2018), Panda *et al*. (2021) and Nandi *et al*. (2022).

The grain yield, stover yield and biological yield of cowpea differed significantly among treatments and sole cowpea registered its significant superiority over intercropped cowpea in maize because of the variation in plant population (Table 3). The reduction of plant population in the mixed stand resulted in decrease of grain, stover and biological yield of cowpea. The treatment with maize + cowpea (1:2) produced grain yield of 733 kg ha^{-1} and it produced significantly higher grain yield of cowpea than other intercropped cowpea treatments. The treatment with maize + cowpea (1:2) had the population density of 66.6% of sole cowpea. Further reduction of cowpea population in mixed stand (i.e., 50%) also reduced grain yield as it was noted under maize + cowpea (1:1) and maize + cowpea (3:3) with grain yield values of 580 and 493 kg ha^{-1}. The treatment with maize + cowpea (2:1) yielded lowest productivity of cowpea and it remained significantly inferior to all the cowpea intercropped treatments as in this case cowpea population was only 33.3%. Earlier Kakon *et al*. (2007) and Dahmardeh *et al*. (2009) observed a similar result where sole cowpea yielded more than intercropped cowpea in a replacement series of experiment.

Competition functions

The land equivalent ratio (LER) of the treatment maize + cowpea (1:1) showed the greatest LER value of 1.18 which was closely followed by maize + cowpea (1:2), maize + cowpea (2:1) and maize + cowpea (3:3) (Table 4). The combined LER values of all the intercropping treatments were more than one, indicating that intercropping gave a yield benefit. Earlier, Jan *et al*. (2016) found that maize and black cowpea intercropping system showed LER values more than unity indicating yield advantage in the intercropping system. The area time equivalent ratio (ATER) calculated for the intercropping treatments showed that the ATER was lesser than unity, indicating that the intercropping system were not advantageous in utilizing area and time (Table 4). In general, the LER over-estimates the efficiency of an intercropping system; however, ATER under-estimates by considering the time factor (Sarkar *et*

Table 3: Effect of maize-cowpea intercropping system on yield of crops

Treatments	Yield of maize (kg ha^{-1})			Yield of cowpea (kg ha^{-1})		
	Grain yield	**Stover yield**	**Biological yield**	**Grain yield**	**Stover yield**	**Biological yield**
Maize + Cowpea (1:1)	3123	4504	7510	580	1291	1871
Maize + Cowpea (2:1)	3752	5163	8941	335	870	1205
Maize + Cowpea (1:2)	2072	3278	5376	723	2343	3066
Maize + Cowpea (3:3)	2927	4326	7268	493	1226	1719
Sole Maize	5056	7646	13114	—	—	—
Sole Cowpea	—	—	—	1031	3293	4324
S.Em. (±)	183.5	513.7	422.7	22.6	100.3	97.7
C.D. (at 5%)	845.4	2367.4	1947.9	104.4	362.5	410.2

Table 4: Effect of maize-cowpea intercropping system g on land equivalent ratio (LER), area time equivalent ratio (ATER) and relative crowding coefficient (RCC)

Treatments	Land Equivalent Ratio (LER)			Area Time Equivalent Ratio (ATER)	Relative Crowding Coefficient (RCC)		
	Maize	Cowpea	Total LER		Maize	Cowpea	Product of RCC
Maize + Cowpea (1:1)	0.62	0.56	1.18	0.93	1.21	1.12	1.36
Maize + Cowpea (2:1)	0.74	0.33	1.07	0.92	1.12	0.96	1.08
Maize + Cowpea (1:2)	0.41	0.70	1.11	0.89	1.28	1.27	1.63
Maize + Cowpea (3:3)	0.58	0.48	1.06	0.91	1.21	0.96	1.16

Table 5: Aggressivity, actual yield loss and monetary advantage index of maize-cowpea intercropping system

Treatments	Aggressivity		Actual yield loss (AYL)			Monetary advantage ₹ ha^{-1}
	Maize	Cowpea	Maize	Cowpea	Total	
Maize + Cowpea (1:1)	0.06	-0.06	-0.38	-0.44	-0.82	7299
Maize + Cowpea (2:1)	1.16	-1.16	-0.63	-0.67	-1.30	2851
Maize + Cowpea (1:2)	-0.99	0.99	-0.59	-0.65	-1.24	3869
Maize + Cowpea (3:3)	0.30	-0.30	-0.81	-0.84	-1.65	2200

al. 2000; Maitra *et al.* 2021). As per the expression of ATER, none of the intercropped treatments were advantageous. The results showed that the product of RCC (K) was always more than 1, indicating a definite yield advantage with all the intercropping treatments in the study (Table 4). This might be due to complementary effects between the two crops species considered in the study and as the study was conducted in a replacement series, less competition as well as more complementarity effect was recorded with cropping systems adopted.

The highest combined K value was obtained with intercropping 1 row of maize with two rows of cowpea (1.63) which indicated higher yield advantages than other treatments. In terms of RCC, the above treatment was closely followed by maize + cowpea (1:1), maize + cowpea (3:3) and maize + cowpea (2:1). The results corroborate with the findings of Jan *et al*. (2016) and Nandi *et al*. (2022). The aggressivity of maize showed positive values with all intercropping treatments except maize + cowpea (1:2) where cowpea population was more in the mixed stand (Table 5). The positive value of aggressivity indicated maize as dominant crop and cowpea as dominated crops in the said treatments. Comparatively higher value of aggressivity noted with maize + cowpea (2:1) indicated greater difference in competitive ability between the competitive crops, resulting in wide variation between the actual and expected yield. Such increase in aggressivity in maize + cowpea (2:1) was probably because of more population (66.6%) of maize in the mixed stand with a replacement series of planting geometry. The results are in conformity to the findings of Khonde *et al*. (2018). The actual yield loss (AYL) index gives precise information on inter and intraspecific competition in an intercropping system as well as the nature of component crops (Banik *et al.* 2000). In the study, both the crops as well as their submission showed the negative values of AYL indicating the combinations or proportions considered disadvantageous (Table 5).

Such results were obtained probably because of replacement series of experiment where widely spaced rows were considered in the study with inappropriate proportion (Alla *et al.* 2015). Monetary advantage varied markedly by different intercropping systems (Table 5). Intercropping maize + cowpea (1:1) resulted in monetary advantage of ₹ 7299 ha^{-1} and the lowest monetary advantages was recorded in maize + cowpea (3:3) with a value of ₹ 2200 ha^{-1}. All intercropping combinations of maize and cowpea registered monetary advantage; however, the figures were not attractive (Choudhary, 2014).

CONCLUSION

The productivity of cropping systems showed the superiority of sole maize and sole cowpea treatments. The superiority of sole cropped treatments of maize and cowpea was due to the replacement series of the intercropping system which clearly revealed that the decrease in the plant population in the mixed stands reduced yields. Based on the study, it can be concluded that sole maize can be grown in south Odisha conditions rather choosing an intercropping system under the replacement series.

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