Plant Archives Vol. 26, No. 1, 2026 pp. 2589-2594 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.359

IMPACT OF MAIZE-LEGUME BASED INTERCROPPING SYSTEMS ON YIELD AND YIELD ATTRIBUTES IN EASTERN INDIA

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(Date of Receiving-13-02-2026; Date of Revision-03-03-2026; Date of Acceptance-16-04-2026)

ABSTRACT

The study was conducted at the research farm ICAR-Indian Agricultural Research Institute, Jharkhand in *kharif*, 2022 to identify the best intercropping system in maize-legume based intercropping systems. The treatments include, T_1: Pure stand of Maize; T_2: Pure stand of Green gram; T_3: Pure stand of Cowpea; T_4: Maize + Green gram (Additive stand) (1:2); T_5: Maize + Green gram (Replacement stand-I) (1:1); T_6: Maize + Green gram (Replacement stand-II) (1:3); T_7: Maize + Cowpea (Additive stand) (1:2); T_8: Maize + Cowpea (Replacement stand-I) (1:1); T_9: Maize + Cowpea (Replacement stand-II) (1:3). Results indicated that, among intercropping systems maize + cowpea (Additive Stand) performed significantly better in terms of maize grain yield (6.96 t/ha) and maize equivalent yield (10.05 t/ha). However, among the intercrops maize + green gram (Replacement stand - II) recorded highest green gram grain yield (0.96 t/ha) and maize + cowpea (Replacement stand - II) recorded highest cowpea gram yield (1.12 t/ha). The study concludes that, maize + cowpea (Additive Stand) can be a better intercropping system for higher productivity in this Eastern India region.

Key words : Additive stand, Equivalent yield, Replacement stand.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops globally and plays a critical role in food security, livestock feed and industrial applications. The maize is cultivated throughout the year in all states of the country for various purposes including grain, fodder, green cobs, sweet corn, baby corn, popcorn in peri-urban areas. (Anonymous, 2012). In India maize has total production of 33.62 million tonnes from the total area of 10.04 million hectares accounting average productivity of 3349 kg/ha (Anonymous, 2022). The world population is apprehended to be increased by 70% in 2050 threatening the global community with the constraint of providing safe and secure food supplies to an increasing number of people (Tian *et al*., 2016). Under these circumstances, the adoption of high intensity cropping systems may be the viable option to increase agricultural productivity and production as a whole (Maitra *et al.*, 2019; Mousavi *et al*., 2011). The combination of short and long duration crops or shallow and deep-rooted crops are preferred. The crops should be selected based on their resource use capability and competitive ability in time or space. Moreover, plant stand and planting geometry also influence resource use efficiency by crops in the mixture (Maitra *et al*., 2021). The proportional row arrangement of different crop components crops in an intercropping system ascertains advantage or disadvantage of intercropping compared to pure stands of the respective crops (Yang *et al*., 2015). Maize–legume intercropping has also been shown to improve yield stability under climatic variability, reducing the risks associated with monocropping systems (Raza *et al*., 2019). Complementary canopy architecture and rooting patterns in maize–legume systems result in more efficient light interception and water utilization, thereby improving overall system productivity (Yu *et al*., 2016). Legume inclusion in intercropping systems significantly improves nitrogen dynamics through biological nitrogen fixation, which can contribute to increased nitrogen availability for the associated maize crop (Jensen *et al.*, 2020; Kebede *et al.*, 2021). The maize productivity is often constrained by declining soil fertility, inefficient nutrient utilization and increasing environmental stresses, particularly in developing regions such as Eastern India. Sustainable intensification of maize-based systems is therefore essential to meet the rising food demand under limited resource availability (Ladha *et al.*, 2022). The present study evaluating the impact of maize-legume based intercropping on yield attributes and yield productivity is crucial for developing region specific recommendations. This study aims to understand the interaction effects among the component crops and to quantify the advantages in terms of yield. The results provide valuable insights for designing resilient cropping systems capable of adapting to climate variability and constrained resource conditions.

Materials and Methods

A field experiment was conducted in *kharif*, 2022 at the research farm ICAR-Indian Agricultural Research Institute, Jharkhand at 24^{o} 28' N and longitude 85^{o} 34' E and an altitude of 395 m above the mean sea level (MSL). The soil is sandy loam, acidic in reaction (*pH* - 5.4), non-saline (EC- 0.74 dS/m), low soil organic carbon (0.29 %), low in available nitrogen (128.4 kg/ha), medium in available phosphorus (6.62 kg/ha) and low in available potassium (135.8 kg/ ha). The experiment was laid out in randomized block design with nine treatments and five replications. Ten plants from each plot were randomly selected from the net plot were tagged and used for recording the observations on different yield attributes. The plants from the plot for each treatment were cut from gross plot area and weighed after sundried for the yield estimation and expressed in t/ha.

Maize equivalent yield

MEY was calculated as below,

Table 1 : Treatment details.

Treatment	Details
T_1	Pure stand of Maize
T_2	Pure stand of Green gram
T_3	Pure stand of Cowpea
T_4	Maize + Green gram (Additive stand) (1:2)
T_5	Maize+Green gram (Replacement stand-I) (1:1)
T_6	Maize+Green gram (Replacement stand-II) (1:3)
T_7	Maize + Cowpea (Additive stand) (1:2)
T_8	Maize + Cowpea (Replacement stand-I) (1:1)
T_9	Maize + Cowpea (Replacement stand-II) (1:3)

$$MEY\ (Crop\ a) = \frac{Yield(Crop\ a) \times Price(a)}{Price\ of\ base\ crop}$$

Where,

Yield (a) is the yield of individual crop (a)

Price (a) is the price of crop (a) and market price of base crop.

Results and Discussion

Yield attributes of maize

Results revealed that there was no significant difference in yield attributes of maize (Table 2). The number of cobs per plant average across the treatments showed the variation between 1.55 to 1.72 cobs per plant. Cob length (20.86 cm) and cob girth (17.54 cm) was the highest with pure stand of maize. The number of grains per cob was observed highest with maize + cowpea (AS) (686.7). The highest test weight was observed with pure stand of maize (171.9 g) (Table 2). The non-significant variation in yield attributes across treatments can also be attributed to several agronomic factors. First, the availability of sufficient nutrients in the soil might have minimized interspecific competition, allowing maize plants in both sole and intercropping systems to access adequate nutrients for growth and reproductive development. Second, effective moisture availability during the crop growth period could have reduced competition for water between component crops, thereby maintaining stable yield attributes. Additionally, the complementary growth pattern of the legume may have played a role. Moreover, biological nitrogen fixation by the legume might have contributed marginally to the nitrogen economy of the system, indirectly supporting maize growth without creating measurable differences in yield attributes. Another possible reason is that ensuring the individual maize plant with similar spatial conditions and resource availability showed no significant variations in growth behaviour and subsequent development so there was no significant difference among yield attributes. These results are in agreement with the findings of Fu *et al.* (2023), Nasar *et al.* (2024) and Kaushal *et al.* (2015).

Yield of maize

Grain and stover yields were determined on area basis, thus showing significant differences on account of variation in plant population under different cropping systems. Results revealed that grain and stover yields of maize were significantly influenced with different intercropping systems. Significantly among intercropping systems higher grain yield (6.96 t/ha) and stover yield (8.89 t/ha) was observed with maize + cowpea (AS).

Table 2 : Effect of intercropping system on yield attributes of maize.

Treatment	Cobs/ plant (No.)	Cob length (cm)	Cob girth (cm)	Grains/ cob	Test weight (g)
T_1: Pure stand of Maize	1.72	20.86	17.54	685.6	171.9
T_4: Maize + Green gram (AS)	1.66	20.62	17.46	684.5	170.1
T_5: Maize + Green gram (RS-I)	1.61	20.49	17.43	676.8	168.8
T_6: Maize + Green gram (RS-II)	1.55	20.18	17.39	672.4	167.8
T_7: Maize + Cowpea (AS)	1.68	20.67	17.47	686.7	170.4
T_8: Maize + Cowpea (RS-I)	1.63	20.51	17.45	679.3	166.4
T_9: Maize + Cowpea (RS-II)	1.58	20.23	17.41	674.2	168.3
SEm ±	0.04	0.82	0.70	17.59	6.47
LSD (P=0.05)	NS	NS	NS	NS	NS

Table 3 : Effect of intercropping system on grain, stover and biological yield parameters of maize.

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
T_1: Pure stand of Maize	7.03	8.92	44.1
T_4: Maize + Green gram (AS)	6.93	8.87	43.9
T_5: Maize + Green gram (RS-I)	3.63	5.82	38.4
T_6: Maize + Green gram (RS-II)	3.51	5.63	38.4
T_7: Maize + Cowpea (AS)	6.96	8.89	43.9
T_8: Maize + Cowpea (RS-I)	3.83	5.95	39.2
T_9: Maize + Cowpea (RS-II)	3.68	5.75	39.0
SEm ±	0.11	0.16	1.30
LSD (P=0.05)	0.33	0.48	NS

The harvest index of maize was not significantly influenced by intercropping systems. Although, the HI was highest with pure stand of maize (44.1%) and the lowest HI (38.4%) was observed with maize + green gram (RS-II) (Table 3). The significant improvement in grain and stover yields of maize under the maize + cowpea (additive series) system can be attributed to enhanced resource-use efficiency and complementary interactions between component crops. In additive series intercropping, the maintenance of full maize population along with the addition of a legume results in greater total plant density, which enhances light interception and overall system productivity. This increased canopy coverage improves photosynthetically active radiation (PAR) utilization, leading to higher biomass accumulation and ultimately greater grain and stover yields. These findings are in accordance with experimental results of Manasa *et al*. (2020), Bhatnagar *et al*. (2012), and Kheroar and Patra (2014) and Kermah *et al*. (2017).

Yield attributes of green gram

The number of pods per plant was significantly higher in the pure stand of green gram (27.4 pods / plant) (Table 4). There was no significant difference among the treatments regarding number of seeds per pod and test weight. The higher seeds per pod (9.4 seeds / pod) and test weight (37.5 g) were in pure stand of green gram (Table 4). Possible reason for higher pods per plant in sole green gram plots might be attributed to less inter specific competition and better utilization of nitrogen being fixed by root nodule. Possible reason for higher pods per plant in sole green gram plots might be attributed to less inter specific competition and better utilization of nitrogen being fixed by root nodule. The results are in line with findings of Khan *et al*. (2012) and Asim *et al*. (2006). The non-significant variation in number of seeds per pod and test weight can be attributed to the availability of sufficient nutrients in the soil might have minimized interspecific competition. These results were supported by Khan *et al*. (2012).

Yield of green gram

Grain and stover yield was significantly influenced with intercropping systems. Significantly among intercropping systems higher grain yield (0.96 t/ha) and stover yield (2.12 t/ha) was recorded with maize + green gram (RS-II). The harvest index of green gram was not significantly influenced with intercropping systems (Table 5). The highest HI was observed with pure stand of green gram (32.1%) and the lowest HI was observed with maize + green gram (AS) (29.8%) (Table 5). This improvement in yield under the replacement series may be attributed to reduced interspecific competition due to lower maize plant population, which allows better availability of light, nutrients, and moisture for green gram. In intercropping systems, yield performance of the intercrop is often enhanced when competition from the main crop is minimized, particularly under replacement series arrangements. The improved performance of green gram in the RS-II system can also be linked to better light interception and canopy exposure. Reduced shading from maize likely enhanced photosynthetic activity in green gram, leading to higher dry matter accumulation and yield.

Table 4 : Effect of intercropping system on yield attributes of green gram.

Treatment	No. of pods/ plant	No. of seeds/ pod	Test weight (g)
T_2: Pure stand of Green gram	27.4	9.4	37.5
T_4: Maize + Green gram (AS)	20.0	8.7	33.5
T_5: Maize + Green gram (RS-I)	20.3	8.9	34.6
T_6: Maize + Green gram (RS-II)	23.8	9.1	36.4
SEm ±	0.6	0.3	1.1
LSD (P=0.05)	2.0	NS	NS

Table 5 : Effect of intercropping system on grain, stover and biological yield of green gram.

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
T_2: Pure stand of Green gram	1.32	2.79	32.1
T_4: Maize + Green gram (AS)	0.73	1.72	29.8
T_5: Maize + Green gram (RS-I)	0.82	1.78	31.5
T_6: Maize + Green gram (RS-II)	0.96	2.12	31.2
SEm ±	0.03	0.06	1.2
LSD (P=0.05)	0.11	0.2	NS

Table 6 : Effect of intercropping system on yield attributes of cowpea.

Treatment	No. of pods/ plant	No. of seeds/ pod	Test weight (g)
T_3: Pure stand of Cowpea	29.7	14.1	93.4
T_7: Maize +Cowpea (AS)	23.1	12.2	88.4
T_8: Maize +Cowpea (RS-I)	24.7	12.9	89.7
T_9: Maize +Cowpea (RS-II)	27.3	13.1	91.7
SEm ±	0.6	0.37	2.95
LSD (P=0.05)	2.06	NS	NS

These results were supported by Lithourgidis *et al.* (2011) and Chen *et al.* (2017).

Yield attributes of cowpea

The number of pods per plant was significantly higher in the with pure stand of cowpea (29.7 pods / plant) (Table 6). There was no significant difference among the number of seeds per pod and test weight in intercropping systems. But the higher seeds per pod (14.1 seeds / pod) and test weight (93.4 g) was observed in pure stand of cowpea (Table 6). Significant variation in yield attribute like number of pods per plant was may be due to higher dominance of maize crop along with higher crowding effect and plant population density over intercrops resulting less availability of growth resources. The lack of significant variation in the number of seeds per pod and test weight may be attributed to adequate soil nutrient availability, which likely reduced interspecific competition and allowed uniform reproductive development across treatments. These findings were in close conformity with results of Jan *et al.* (2016) and Ramamohan *et al*. (2023).

Yield of cowpea

Grain and stover yield of cowpea was significantly influenced with intercropping systems (Table 7). Significantly higher grain yield (1.12 t/ha) and stover yield (2.52 t/ha) was recorded with maize + cowpea (RS-II)**.** The harvest index of cowpea was not significantly influenced with intercropping systems. Although, the highest value was observed with maize + cowpea (AS) (31.5%) and the lowest value was observed with pure stand of cowpea (30.3%) (Table 7). The improved performance of cowpea under this system may be attributed to reduced interspecific competition due to lower maize plant population, which allowed better availability of growth resources such as light, nutrients and moisture. In replacement series intercropping, reduced dominance of the cereal component often enhances the growth and productivity of the legume intercrop The higher yields may also be associated with improved light interception and canopy exposure of cowpea due to reduced shading from maize. Enhanced access to solar radiation increases photosynthetic efficiency and dry matter accumulation, thereby contributing to higher grain and stover yields. The results are in line with findings of Kermah *et al.* (2017), Tsubo *et al*. (2005) and Lithourgidis *et al*. (2011).

Maize equivalent yield

Maize equivalent yield (MEY) as influenced with different intercropping systems (Fig. 1) that showed significant differences among the cropping systems The highest (10.05 t/ha) maize equivalent yield was obtained

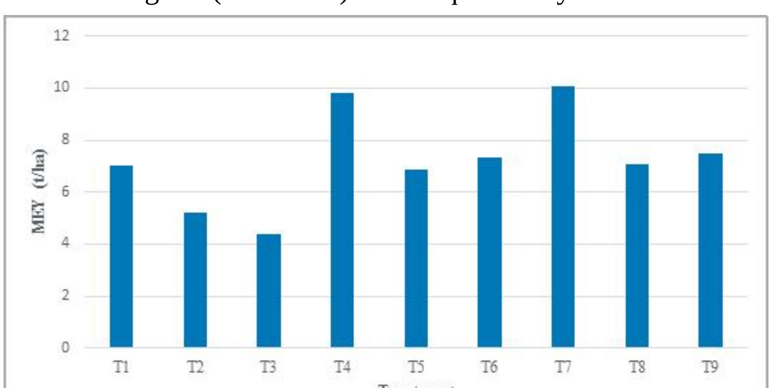

Fig. 1 : Effect of intercropping system on maize equivalent yield (t/ha).

Table 7 : Effect of intercropping system on yield parameters of cowpea.

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
T_3: Pure stand of Cowpea	1.29	2.97	4.26	30.3
T_7: Maize +Cowpea (Additive stand)	0.91	1.98	2.89	31.5
T_8: Maize +Cowpea (Replacement stand-I)	0.95	2.08	3.03	31.4
T_9: Maize +Cowpea (Replacement stand-II)	1.12	2.52	3.64	30.8
SEm ±	0.01	0.07	0.04	0.66
LSD (P=0.05)	0.06	0.24	0.14	NS

with maize + cowpea stands (AS). Higher maize equivalent yield from maize + cowpea stands (AS) is due to the yield advantage from cowpea intercropping treatments over sole maize. Similar observation was also reported by Gaikwad *et al*. (2022) and Patel *et al*. (2018).

Conclusion

The study demonstrated that the maize–legume based intercropping significantly influenced yield and productivity. Among the treatments performance of maize was significantly superior in additive series of maize + cowpea recorded higher maize grain yield and maximum maize equivalent yield due to efficient resource utilization. However, in terms of intercrops replacement series (RS-II) favoured intercrop performance by reducing interspecific competition, enhancing yields of green gram and cowpea. Yield attributes of maize and legumes remained largely stable suggesting balanced resource use. Overall, maize–legume intercropping, particularly maize + cowpea (AS) proved to be a sustainable and efficient production system offering improved yield stability and resource-use efficiency under Eastern Indian agro-ecological conditions. Therefore, it can be recommended as a viable strategy for sustainable intensification in Eastern India.

Competing interests

Authors have declared that no competing interests exist.

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