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Competitive functions, pest dynamics and bio-economic analysis in traditional maize and legumes intercropping systems under rainfed situation of South India

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The investigation encompassing traditional maize and legume intercropping systems in various patterns was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India and revealed that the maize equivalent yield was significantly higher in maize + blackgram (1:1) with 75 cm × 20 cm spacing (7330 kg ha^{-1}). Also higher LER (1.4) and ATER (1.2) were recorded in maize + blackgram (1:1) with 90×20 cm spacing. Whereas significantly higher system productivity index was observed in maize + greengram (1:1) with 75 cm × 20 cm spacing (431.4). Further, lower aggressivity (-1.2) and higher relative crowding co-efficient (4.3) of intercrops were noticed in maize + blackgram (1:1) with 90 cm × 20 cm spacing. Competitive ratio of intercrops was higher in maize + cowpea (1:2) (1.27) with wider spacing of 90 cm × 20 cm. In a 1:1 row ratio of 90 cm 20 cm spacing, the lower light transmission ratio values were observed. At a 1:2 row ratio and 90 cm 20 cm spacing, maize and cowpea intercropping produced significantly less weed and dry matter. There was least fall armyworm infestation under maize + greengram at 1:2 row ratio in 90 cm × 20 cm spacing (1.7 %) which followed maize + greengram in 75 cm x 20 cm spacing at a 1:1 row ratio (1.9 %).The study concluded that values of most of the intercropping indices were favourable under maize + blackgram and maize + greengram with alternate row at spacing of 75 × 20 cm and hence, it would be most advantageous for maize-legume cropping system in terms of land utilization and sustainable maize production with least pest effect.

Keywords: Competitive functions, Economics, FAW control, Intercropping, Weed suppression, Yield

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Maize (*Zea mays* L.) is called "Queen of cereals" and one of the most widely-grown cereal crop which stand first with respect to global production. In India, it stands third after rice and wheat in cereal production. It contributes about 9.1% of total food grain production in the country. Maize grain contains 4%-5% oil, 10% protein, 71.8 g carbohydrate, 2.2 g fiber, 348 mg phosphorous, 286 mg potassium, 114 mg sulphur, 0.12 mg vitamin C and 1.78 mg amino acids. More than 63% of the maize produced in India is being utilized for cattle and poultry feed. And about 22% and 9% is used in the starch industry and food, respectively. In the world, it is cultivated on an area of 184.3 million ha with an annual production of 1041.7 million metric tonnes with a productivity of 5742 kg ha^{-1}[1]. In India, currently, it is grown in an area of 9.38 million ha with a production of 28.76 million metric tonnes with productivity of 3065 kg ha^{-1}[2]. In Karnataka state, maize is grown in an area of 1.31 million ha with a production of 3.85 million metric tonnes and a productivity of 2,948 kg ha^{-1}[3]

Pulses are indispensable food as they are rich in proteins and found to be the main source of protein for vegetarian people of India. Malnutrition of the vulnerable sections of our society is originated due to the unavailability of pulses. Nutritionists assess the supplementation of pulses with cereal based food as one of the perfect possible alternatives to reduce the difficulty associated with protein malnourishment. Indian Council of Medical Research (ICMR) recommended 56-80 g per person per day of pulses to meet the protein requirement. But, the present per capita availability of pulses in India is 43.9 g. To overcome this, pulse production has to be expanded from the present 22 million tonnes to 28-30 million tonnes. One of the decisions to improve the pulse

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Abbreviations: FAW-Fall armyworm; LER-Land equivalent ratio; ATER-Area-time equivalent ratio; SPI-System productivity index; RCC-Relative crowding co-efficient; CR- Competitive ratio production is to augment the area under pulses. The area under legumes increased by different farming systems, sequence and intercropping strategies.

Planting two crops in a row system in a same field is a traditional method of obtaining diverse food crops. The main idea is to improve productivity per unit time and area, land resources and farm inputs. One of the key reasons for higher yields in intercropping is that the component crops can use natural resources in different ways, resulting in a greater overall use of natural resources than if they were grown separately[4]. Crops having divergent growth habits can decrease the mutual competition for growth factors. Cowpea, green gram and black gram, because of short duration, grow complementary with maize crop and fit capably as intercrops in maize. As these crops have divergent growth pattern and rooting habit, there is a healthy competition between them. Since maize is a broadly spaced crop, inter-row space could profitably be utilized by legumes. Maize-legume intercropping system, besides increasing productivity and profitability, also improves soil health, conserves soil moisture and increases total out turn[5]. The maximum nutrient demand for green gram or black gram or cowpea is at 30 DAS and in maize it is at 60 DAS. Hence crops like maize can be conveniently intercropped to utilize the natural resources more efficiently. This study examined the effects of maize intercropping with green gram, black gram and cowpea on maize productivity and system sustainability.

Materials and Methods

Experimental materials

A field trial was conducted at MAR, Dharwad (15^0 12' N, 74^0 59' E), during *Kharif* 2018-19. The climatic mean maximum (28.2°C) and minimum temperature (19.5°C) and average rainfall (347.4 mm) with 36 rainy days, mean maximum relative humidity (87.5%) and minimum (65.5%) were registered during July to October, which was optimum for crop performance.

Soil was medium black clay in texture (pH- 7.6, EC 0.35 dS m^{-1}, organic C -0.51 % and medium in N (296 kg ha^{-1}) and P (28 kg ha^{-1}) and K (283kg ha^{-1}). Maize variety 'NK-6240', greengram variety 'DGGV-2', blackgram variety 'DBGV-05' and cowpea variety 'DC-47-1' were selected as the experimental material.

Cultivation method

The experiment was conducted in complete block with 3 replications. The treatments included sole maize at 60 cm × 20 cm, sole greengram, blackgram and cowpea at 30 cm × 20 cm planting geometry, maize intercropping with greengram, blackgram and cowpea at 1:1 row ratio of 75 cm × 20 cm spacing and 1:1, 1:2 row ratio in 90 cm × 20 cm spacings. The row proportion followed was 1:1 and 1:2 for replacement series of intercropping systems. The recommended quantity of 7.5 tonnes of FYM was incorporated in to top soil two weeks before planting. Recommended dose of fertilizer was applied for the sole crops of maize (100:50:25 kg N, P_2O_5 and K_2O ha^{-1}, respectively), greengram, blackgram and cowpea. In the intercropping systems the fertilizers were applied proportionate to population of component crops and were placed in furrows opened at 5 cm away from the crop row and covered with soil. For maize crop, 50% of the N and entire phosphorous and potash were placed below the seed in opened furrows at the time of sowing and remaining 50% N was applied in two equal quantities, at first weeding corresponding to knee-high stage and second dose corresponding to tasselling stage. For component crops, full dose of nitrogen, phosphorous and potash were placed below the seed in opened furrows at the sowing time. The other management operations were done as per recommended package of practices for both main and intercrops. Data were recorded on growth and yield performance of crops.

Competitive functions analysis

The efficiency of intercropping systems was assessed based on different parameters, such as maize equivalent yield, land equivalent ratio[4], area-time equivalent ratio[6], system productivity index[4], relative crowding coefficient, aggressivity, competitive ratio[7].

MEY for intercrop = Maize yield + [{pulse yield kg(kg ha^{-1}) × Price of pulse (₹ kg^{-1})} ÷ Maize price (₹ kg^{-1})]

Land equivalent ratio (LER) = [(Yab ÷ Yaa) + (Yba ÷ Ybb)]

System productivity index (SPI) = [(Sa÷ Sb) × (Yb + Ya)]

Aggressivity (Aab) = [Yab ÷ (Yaa× Zab)} – {Y ba ÷ (Ybb×Zba)}]

Relative crowding co-efficient (RCC, Kab) = [(Yab × Zba) ÷ {(Yaa– Yab) × Zab}]

Competitive ratio (CRa) = [(Yab÷ Yaa) × (Ybb÷ Yba)]

Light transmission ratio (LTR %) = [(I ÷ I_0) × 100]

Per cent light interception = (100 – LTR)

Analysis of available nutrients

The methods used to analyse the soil available nitrogen, available phosphorus and available potassium (kg ha^{-1}) were by modified alkaline potassium permanganate method[8], Olsen's method[9] and flame photometry method[10], respectively.

Weed dynamics

Weed population m^{-2} and total dry matter were recorded at 30 and 60 DAS under each treatment in 0.5 m^{-2} quadrat. And data on weed were transformed using square root transformation.

Fall armywarm (*Spodoptera frugiperda*, J. E. Smith) incidence (FAW)

Total number of fall armyworm infected plants was recorded at 30 DAS under each treatment. Fall armyworm (FAW) incidence (%) was computed using the following formula.

FAW incidence (%) = (Total number of FAW infected plants ÷Total number of plants) ×100

Data analysis

The observations collected from trial at various growth periods were subjected to statistical analysis[11]. The stage significance used in 'F' as well 'T' tests was 5%. LSD values were calculated where ever the 'F' test was significant.

Results and Discussion

Effect of maize and legumes intercropping on crop productivity

Sole maize registered higher yield of kernel and stover as compared to its yield in intercropping (Table 1). Intercropping increases land utilisation rate and maintains soil fertility[12]. When comparing maize and cowpea cropping systems, alternate rows at 75 cm 20 cm spacing for maize + blackgram yielded significantly higher kernel and stover yields of maize (5940 and 890 kg ha^{-1}, respectively). However, it was on par with maize + greengram at the same planting geometry. Increase in kernel and stover yield of maize in sole cropping was mainly due to higher plant population. In addition, yield attributing characters viz., cob length, cob girth, grain weight per cob and test weight and growth attributes at harvest were also higher in sole cropping of maize. Further higher light transmission ratio (44% and 24.6% at 30 and 60 DAS, respectively) also contributed to better growth and yield of sole maize. Increased light transmission ratio

Table 1 — Yield performance of maize and short duration legumes under maize and short duration legumes intercropping.

Tr. No.	Treatment	Maize			Intercrop			
		Cob length (cm)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Pods plant^{-1}	Test weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1	Sole maize (60 cm × 20 cm)	15.9	6810	9230	-	-	-	-
T_2	Sole greengram (30 cm × 10 cm)	-	-	-	34.9	5.7	1010	2020
T_3	Sole blackgram (30 cm × 10 cm)	-	-	-	30.3	6.3	1060	2560
T_4	Sole cowpea (30 cm × 10 cm)	-	-	-	14.3	10.7	1200	3100
T_5	Maize (75 cm × 20 cm) + greengram (1:1)	14.2	5920	8870	24.2	5.0	470	1600
T_6	Maize (90 cm × 20 cm) + greengram (1:1)	15.2	5220	7690	31.6	5.7	550	1640
T_7	Maize (90 cm × 20 cm) + greengram (1:2)	14.3	4880	6920	27.3	5.3	610	1650
T_8	Maize (75 cm × 20 cm) + blackgram (1:1)	14.8	5940	8900	28.2	6.0	520	2180
T_9	Maize (90 cm × 20 cm) + blackgram (1:1)	15.3	5390	7990	30.3	6.3	650	2370
T_{10}	Maize (90 cm × 20 cm) + blackgram (1:2)	14.3	5070	7990	30.2	6.0	700	2430
T_{11}	Maize (75 cm × 20 cm) + cowpea (1:1)	13.6	5440	8330	11.6	9.3	660	2710
T_{12}	Maize (90 cm × 20 cm) + cowpea (1:1)	13.7	4310	6740	12.7	10.7	700	2820
T_{13}	Maize (90 cm × 20 cm) + cowpea (1:2)	12.8	3670	6040	12.3	9.7	800	3070
	S.Em. ±	0.4	37.1	40.2	1.6	0.4	6.1	18.0
	LSD (p = 0.05)	1.1	107.7	117.1	4.6	1.1	17.1	53.3

could have helped towards higher photosynthesis, dry matter accumulation and translocation to reproductive parts. Similarly, sole crops of blackgram (1060 and 2560 kg ha^{-1} respectively), greengram (1010 and 2020 kg ha^{-1} respectively) and cowpea (1200 and 3100 kg ha^{-1} respectively) recorded significantly higher seed and haulm yield compared to their yield in intercropping system. Among the row ratios of 1:1 and 1:2 of maize and intercrop, 1:2 row ratio registered the highest seed yield and haulm of greengram (601 and 1650 kg ha^{-1} respectively), blackgram (700 and 2430 kg ha^{-1} respectively) and cowpea (800 and 3070 kg ha^{-1} respectively) due to higher plant population coupled with better yield attributes at 90 cm × 20 cm spacing (Table 1). However, grain weight per plant and test weight of legumes were higher in 1:1 row proportion at 90 cm × 20 cm spacing due to wider spacing which resulted in lesser competition for natural factors such as solar radiation, soil moisture, air, and essential micronutrients. And there was more light transmission ratio in 90 cm × 20 cm spacing with 1:1 row ratio compared to 1:2 row ratio. Increased light transmission ratio could have helped towards more photosynthesis. Maximum yield loss of intercrops was in 1:1 row ratio due to reduction in plant population and their susceptibility to shading effect. Minimum yield reduction of intercropped legumes was in 1:2 row ratio, which might be due to its elastic response to change in plant population, staggering of peak demands for growth factors, tolerance to shade effect and early maturity of intercrop[13].

Competitive functions

LER greater than one in intercropping showed that it would be most advantageous in terms of land use, profitability and biological efficiency of the system. Intercropping increases land utilisation rate[12]. In present study, LER of intercropping treatments was significantly higher (1.2-1.4) compared to sole crops (Table 2). Maximum LER was registered in maize + blackgram (1:1) with 90 cm × 20 cm spacing (1.4) which was on par with maize + greengram at the same spacing (Table 2). Significantly lower LER was observed with maize + cowpea (1:2) with

Table 2 — Influence of maize and short-duration legumes intercropping on competitive functions

Tr. No.	Treatments	LER	ATER	MEY (kg ha^{-1})	SPI	Aggressivity		RCC		Competitive ratio	
						Maize	Intercrop	Maize	Intercrop	Maize	Intercrop
T_1	Sole maize (60 cm × 20 cm)	1.00	1.00	6810	-	1	-	1	-	1	-
T_2	Sole greengram (30 cm × 10 cm)	1.00	1.00	2870	-	-	1.00	-	1.00	-	1
T_3	Sole blackgram (30 cm × 10 cm)	1.00	1.00	2840	-	-	1.00	-	1.00	-	1
T_4	Sole cowpea (30 cm × 10 cm)	1.00	1.00	2990	-	-	1.00	-	1.00	-	1
T_5	Maize (75 cm × 20 cm) + greengram (1:1)	1.34	1.16	7250	431.4	1.11	-1.11	7.25	2.05	1.87	0.54
T_6	Maize (90 cm × 20 cm) + greengram (1:1)	1.31	1.10	6780	388.4	1.13	-1.13	1.48	2.89	1.41	0.72
T_7	Maize (90 cm × 20 cm) + greengram (1:2)	1.31	1.07	6590	365.8	1.06	-1.06	2.60	1.90	1.25	0.90
T_8	Maize (75 cm × 20 cm) + blackgram (1:1)	1.36	1.21	7330	415.4	1.11	-1.11	3.55	2.28	1.49	0.56
T_9	Maize (90 cm × 20 cm) + blackgram (1:1)	1.41	1.22	7130	389.9	1.17	-1.17	1.89	4.34	1.30	0.78
T_{10}	Maize (90 cm × 20 cm) + blackgram (1:2)	1.41	1.20	6950	371.1	1.11	-1.11	2.44	2.76	1.17	0.76
T_{11}	Maize (75 cm × 20 cm) + cowpea (1:1)	1.34	1.18	7070	345.7	1.01	-1.01	1.72	2.92	1.51	0.68
T_{12}	Maize (90 cm × 20 cm) + cowpea (1:1)	1.21	1.04	6050	284.0	0.93	-0.93	0.73	3.67	1.12	0.92
T_{13}	Maize (90 cm × 20 cm) + cowpea (1:2)	1.20	1.01	5650	253.3	0.80	-0.80	1.03	4.03	0.87	1.27
	S.Em. ±	0.07	0.06	33.1	20.5	0.08	0.07	1.76	0.91	0.16	0.13
	LSD (P = 0.05)	0.20	0.16	97.3	59.9	NS	0.20	NS	2.66	NS	0.39

90 cm × 20 cm spacing (1.2) due to competition of cowpea for growth factors. Higher LER value (2.3 and 2.1, respectively) was seen in Tur and urdbean and pigeonpea + maize intercropping[14]. Similarly, LER of 1.9 in maize + pigeonpea at 45 cm × 75 cm spacing was recorded[15].

Area time equivalent ratio (ATER) of intercropping systems were significantly higher (1.0-1.2) compared to sole crops. ATER values were greater than one in all the systems studied. Similar to LER, ATER was higher in maize and pulse mixtures. The disadvantage of calculating LER is that it doesn't take into account cropping duration. To correct these disadvantages, the LER was revised to consider the period of cropping right from seeding to crops maturity[16]. At 1:1 row ratio of maize + blackgram in 90 cm × 20 cm spacings, significantly higher ATER values (1.2) was recorded due to better land use efficiency and spatial and temporal complementarities under this system (Table 2). Hence an intercropping system was found advantageous in comparison to monoculture. The present results are in line with findings in maize and tur intercropping at 4:2 ratio which revealed higher ATER value (1.2) compared to other intercropped treatments[13]. There was increased area time equivalent ratio (1.66) with intercropping of rice bean and corn at 1:2 row ratio[16].

Aggressivity (A) of maize did not alter due to intercrops and their geometry of sowing. Positive value of aggressivity of maize showed dominance of the main crop over intercrop and vice versa in case of negative values[26]. Greater values indicate a wider difference of competitiveness of component crops. Significantly lower aggressivity of intercrops was noticed in maize + blackgram (-1.2) and the highest aggressivity of intercrops in maize + cowpea (-0.8) at 1:2 row ratio with 90 cm × 20 cm spacing (Table 2). Row ratio of 1:2 of maize + cowpea showed dominance of cowpea over other intercrops. This may be because cowpea's efficient resource utilisation resulted in high vegetative growth with less intraspace and shading impact, resulting in an increase in cowpea's dominance capacity. Similar findings were seen in maize and legumes intercropping system[1,16]. Higher aggressivity (-1.09) for black cowpea in maize + black cowpea intercropping was obtained in 2:2 row ratio[17].

The relative crowding co-efficient (RCC) for maize was significantly higher (1.0) than for legume crops, suggesting that maize was the dominant crop and yielded significantly more than expected. Under intercropping systems, the highest RCC value suggests greater compatibility and a clear yield advantage[17]. Significantly higher RCC of intercrops was noticed in maize + blackgram (1:1) (4.3) with 90 cm × 20 cm which was at par with maize and cowpea (1:2) (4.0) at wider spacing of 90 cm × 20 cm (Table 2). RCC specified that it was beneficial to grow blackgram as intercrop with maize, which was further proved by better product of RCC values. The higher plant population, better land utilization efficiency and mutual co-operation between the intercrops. Similarly higher RCC was obtained in maize and pigeon pea intercropping system[20]. Relative higher RCC values in fodder jowar and tur (15.1) and 1:1 (9.2) than rest of intercropping systems[21].

Competitive ratio (CR) was calculated to indicate optimum competitive balance between the component crops. Significantly higher CR of intercrops was noticed in maize + cowpea (1:2) (1.27) with wider spacing of 90 cm × 20 cm. Higher CR co-efficient indicates dominant companion in the intercropping (Table 2).

Light transmission ratio (LTR) measurements revealed that component crops were making efficient use of light resources. Lower LTR was observed with 90 cm × 20 cm spacing which implies the highest light use efficiency compared to 75 cm × 20 cm spacing in 1:1 row ratio and (Fig. 1). Spatial spread of leaf canopy helped for efficient use of light. Further deep root proliferation into soil profile made better spatial use of water and nutrients. Similar results were obtained in maize and legumes intercropping in 1:2 row proportion[16].

Weed density and weed dry matter

Grassy weeds were the most prevalent weed flora in the experimental area. Viz., *Cynodon dactylon* L., *Dinebra retroflexa.* Among broad leaf weeds (BLWs), *Amaranthus retroflexus, Mollugo disticha*, *Digera arvensis*., *Corchorus trilocularis*, *Portulaca oleracea* L., *Parthenium hysterophorous*, *Commelina benghalensis* L., *Euphorbia geniculata*, *Alternanthera sessilis* L., *Convolvulus arvensis* L., *Conyza ambigua* and *Leucas aspera* were dominant. Among sedges, *Cyperus rotundus* was noticed. Similar weed spectrum was noticed[22].

Sole maize recorded higher weed density (38.90 and 52.13 m^{-2} at 30 and 60 days after planting (DAP, respectively) and dry weight of weeds (26.57 and 42.10 g/m^2 at 30 and 60 DAP, respectively). Red rot weed suppressed the sole maize[23]. Significantly lower

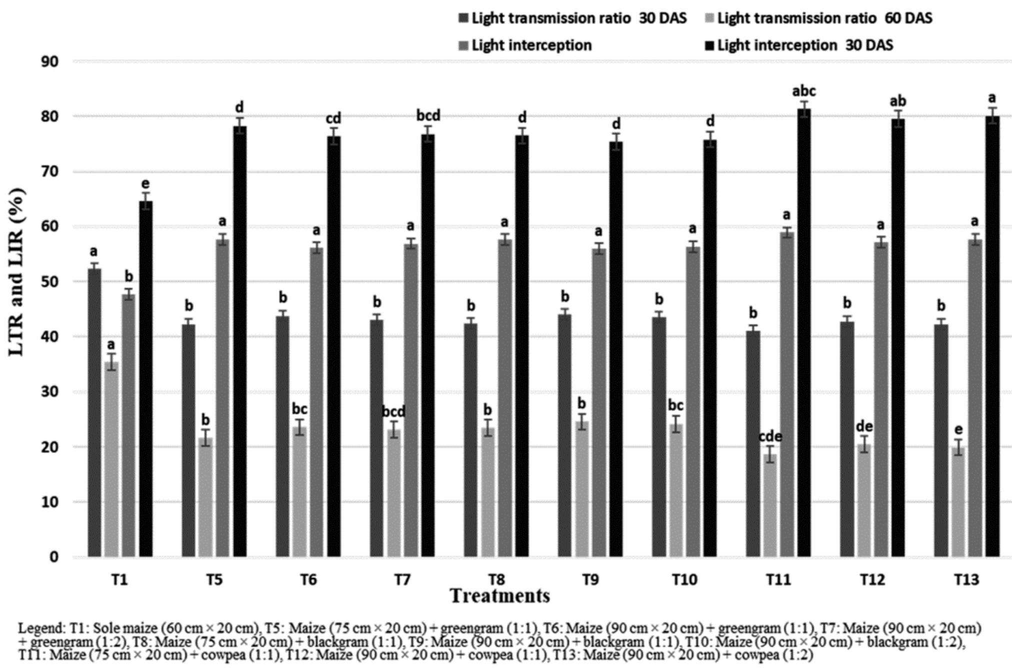


Fig. 1 — Light transmission ratio (LTR) and Light interception (%) of maize at different growth stages as influenced by maize and kharif pulses intercropping. *Bar show mean ± S.E values with same letter are not significantly differ at 5 % level of significance.

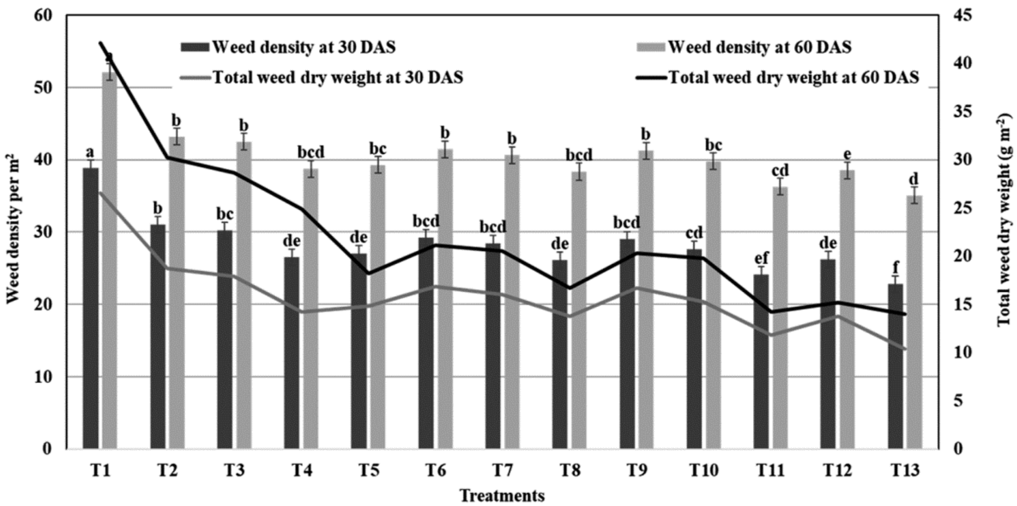
weed population of 22.83 and 35.10 m^{-2} at 30 DAS and 60 DAS, respectively, and their dry matter was recorded in maize and cowpea intercropping (Fig. 2). Similarly weed suppressing the ability of cowpea in maize crop was recorded[24]. Cowpeas high weed smothering capacity may be attributed to its early canopy growth and trailing ability, which results in less available space and light, resulting in a lower weed population and, as a result, lower weed dry weight in intercropping. These findings are in conformity with those reported[25].

Available nutrient status in soil

Maize intercropping with legumes increased the soil nitrogen content and decreased both phosphorous and potassium (Fig. 3). Sole maize cultivation resulted in soil erosion and associated nutrients[26]. In the intercropping system, higher the legume density (1:2 row ratio), greater was the available soil N content. Intercropping of maize with legumes facilitated both maize growth and yield. Significantly higher available nitrogen content in the soil was in sole cowpea (300.5 kg ha^{-1}). It was on par with sole greengram (295.7 kg ha^{-1}) and sole blackgram (293.6 kg ha^{-1}) compared intercropping systems. In sole maize, there could be a competition for the same nutrients. Intercropping maintains soil fertility[12]. Generally, indiscriminate use of agriculture chemicals and fertilizers reduces soil fertility, and ultimately crop yield. The amount of available phosphorus and potassium in the soil did not differ significantly. However, the single crop of cowpea (28.2 kg ha^{-1}) and maize + cowpea had higher usable phosphorous content in the soil (27.8 kg ha^{-1}). Rhizobia developed in root nodules of pulses absorb free nitrogen present in the atmosphere and transfer it to available form to corn growth and further improve productivity of corn. Thus, intercropping corn with pulses reduces the amount of nitrogen requirement apart from sustaining soil fertility. On the contrary rotation of maize with soybean or groundnut found better than their relay cropping in Ghana for improving soil fertility and crop productivity[5]

Fall armyworm (*Spodoptera frugiperda,* J. E. Smith) incidence

Fall armyworm (FAW) is polyphagous pest native to tropical and subtropical regions of the Americas[3,12,27]. It can feed on about 80 different plant species and cereal crops such as corn, rice, small millets, sugarcane and sorghum are preferred hosts for this pest. It can also feed on soybean, cotton and vegetable crops[9]. FAW incidence was higher on entire sole maize crop (5.7 %) as compared to the intercropping system. When plants were infested between the first and second weeks after germination, yield reductions of up to 22.6% were observed[28]. Crop



Legend: T1: Sole maize (60 cm × 20 cm), T2: Sole greengram (30 cm × 10 cm), T3: Sole blackgram (30 cm × 10 cm), T4: Sole cowpea (30 cm × 10 cm), T5: Maize (75 cm × 20 cm) + greengram (1:1), T6: Maize (90 cm × 20 cm) + greengram (1:1), T7: Maize (90 cm × 20 cm) + greengram (1:2), T8: Maize (75 cm × 20 cm) + blackgram (1:1), T9: Maize (90 cm × 20 cm) + blackgram (1:1), T10: Maize (90 cm × 20 cm) + blackgram (1:2), T11: Maize (75 cm × 20 cm) + cowpea (1:1), T12: Maize (90 cm × 20 cm) + cowpea (1:1), T13: Maize (90 cm × 20 cm) + cowpea (1:2)

Fig. 2 — Weed density per m^2 and weed dry matter (g m^{-2}) at different growth stages as influenced by maize and *kharif* pulses intercropping. *Bar show mean ± S.E values with same letter are not significantly differ at 5 % level of significance.

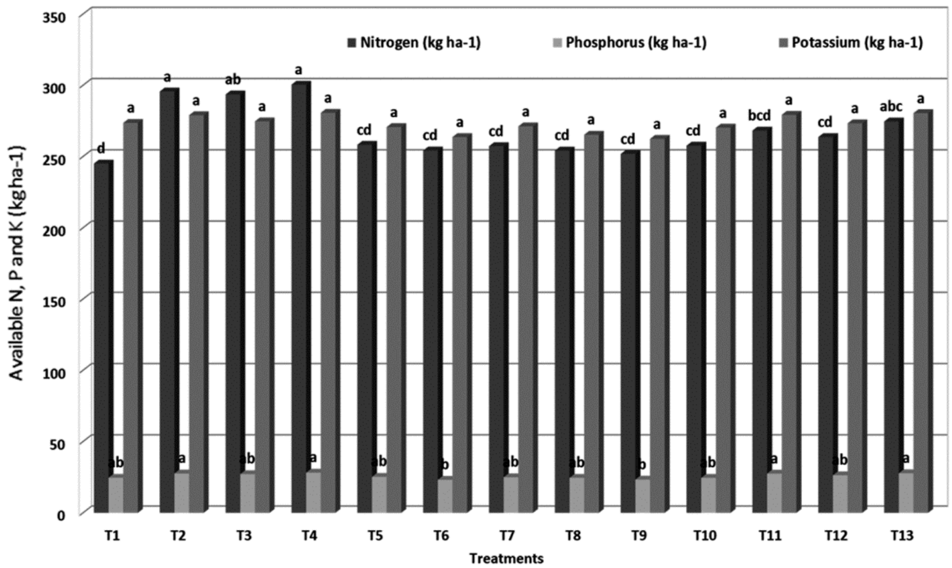


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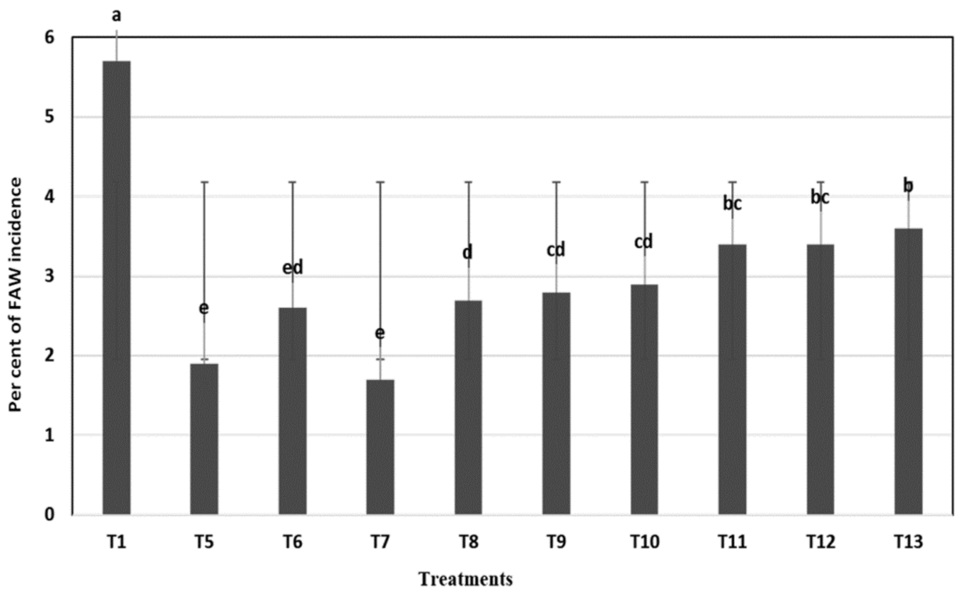
Fig. 3 — Available nitrogen, phosphorous and potassium in soil after harvest of crop as influenced by maize and short duration legumes intercropping. *Bar show mean ± S.E values with same letter are not significantly differ at 5 % level of significance.

yields were very poor when infestation occurs at 3 and 4 weeks after germination[28]. FAW is also a highly destructive and economically significant pest in maize in Brazil, with an estimated annual loss of $400 million due to its attack[29]. The FAW was first observed in India's maize-growing states of Karnataka during 2016, causing farmers to become concerned[30]. Since the invasive crop-eating pest is highly likely to spread further from India, the FAW could jeopardize the food security and livelihoods of majority of maize growing farmers.

Among the intercropping system, FAW least infestation was noticed under maize + greengram at 1:2 row ratio in 90 cm × 20 cm spacing (1.7 %) and maize + greengram at 1:1 row ratio in 75 cm × 20 cm spacing (1.9 %) (Fig. 4). Crop diversity on farm reduced FAW infestation and they support natural enemies by providing resources such as dwelling



Legend: T1: Sole maize (60 cm × 20 cm), T5: Maize (75 cm × 20 cm) + greengram (1:1), T6: Maize (90 cm × 20 cm) + greengram (1:1), T7: Maize (90 cm × 20 cm) + greengram (1:2), T8: Maize (75 cm × 20 cm) + blackgram (1:1), T9: Maize (90 cm × 20 cm) + blackgram (1:1), T10: Maize (90 cm × 20 cm) + blackgram (1:2), T11: Maize (75 cm × 20 cm) + cowpea (1:1), T12: Maize (90 cm × 20 cm) + cowpea (1:1), T13: Maize (90 cm × 20 cm) + cowpea (1:2)

Fig. 4 — Fall armyworm (FAW) incidence at 30 days after sowing as influenced by maize and short duration legumes intercropping. *Bar show mean ± S.E values with same letter are not significantly differ at 5 % level of significance.

habitat, shade, nectar and water. FAW moths prefer to lay eggs under sole corn. When maize is in intercropped with legumes, moths lay egg neither on maize nor legumes and prefer to fly away to boarders. These results are in conformity with recommendation made by Food and Agriculture Organization of the United Nations Rome[31]. It is essential to combine traditional and scientific knowledge, which necessitates collaboration between local farmers and researchers in the region. Crop diversity such as legumes and cereal crops mix in the same land confuses the moths and difficult for FAW to find its preferred host maize and thus damages would be very less as it lays fewer eggs in sporadic manner. Further legumes emit volatile compounds which respell female FAW moth. These volatile compounds act as a "push" effect in push-pull systems, which "push" pest species away from legume plants while they are "pulled" to boarder may be covered with grasses. Volatile compound released by these grass family are similar to chemicals released by maize plant and they make FAW more attractive. And hence mortality of pest occurs due to poor nutrition. Push-pull effect of legume based intercropping in maize plant not only reduces FAW incidence but it also improves soil fertility and crop health. Pesticides offer a good financial return, but they are not environmentally friendly or ecologically sustainable in the long run[8]. Integration of cultural practices such as early planting, intercropping, crop rotation, use of predators, pheromone traps, parasitoides and green pesticides is a novel approach towards sustainable management of FAW in maize cultivation.

Economic analysis

Maize equivalent yield (MEY): When more than one species is intercropped, comparing the economic produce of different species becomes extremely difficult. Individual crop yields in a system are translated into equivalent maize crop yields based on their economic value in order to express the yield advantage[33]. Higher MEY in the intercropping system could be credited to yield advantages attained. Significantly more MEY was obtained in maize + blackgram (1:1) with 75 cm × 20 cm spacing (7330 kg ha^{-1}). Whereas, MEY was lower with maize and cowpea (1:2) with 90 cm × 20 cm spacing (5650 kg ha^{-1}) (Table 2). Similar findings were obtained in maize + soybean[34]. Higher MEY recorded in 1:1 row proportion with 75 cm × 20 cm spacing was due to consequence of differences in the maize yield, component crop yield and price of individual component crop coupled with better use of natural resources by the component crops. These results are in conformity with paired row maize intercropping with soybean at 30 × 90 cm spacing[15]. Intercropping leguminous crops with corn boosts corn yield[35,3].

Table 3 — Cost of production, gross returns, net returns and B-C ratio of maize and short duration legumes intercropping

Treatment No.	Treatments	Cost of production (₹. ha^{-1})	Gross returns (₹. ha^{-1})	Net returns (₹. ha^{-1})	B-C ratio
T_1	Sole maize (60 cm × 20 cm)	57932	132415	74483	2.29
T_2	Sole greengram (30 cm × 10 cm)	34091	55479	21388	1.63
T_3	Sole blackgram (30 cm × 10 cm)	32501	55582	23081	1.71
T_4	Sole cowpea (30 cm × 10 cm)	35825	58952	23127	1.65
T_5	Maize (75 cm × 20 cm) + greengram (1:1)	56664	142139	85475	2.51
T_6	Maize (90 cm × 20 cm) + greengram (1:1)	54449	132731	78282	2.44
T_7	Maize (90 cm × 20 cm) + greengram (1:2)	54871	129050	74179	2.35
T_8	Maize (75 cm × 20 cm) + blackgram (1:1)	55848	144516	88668	2.59
T_9	Maize (90 cm × 20 cm) + blackgram (1:1)	54463	140181	85718	2.57
T_{10}	Maize (90 cm × 20 cm) + blackgram (1:2)	54899	137243	82344	2.50
T_{11}	Maize (75 cm × 20 cm) + cowpea (1:1)	56409	139857	83448	2.48
T_{12}	Maize (90 cm × 20 cm) + cowpea (1:1)	54931	120092	65161	2.19
T_{13}	Maize (90 cm × 20 cm) + cowpea (1:2)	55619	112459	56840	2.02
	S.Em. ±	-	6038	6038	0.11
	LSD (P = 0.05)	-	17624	17624	0.32

Note: Sale price of maize ₹. 18.50 kg^{-1}, greengram- ₹. 52.3 kg^{-1}, blackgram- ` ₹. 49.5 kg^{-1} and cowpea - ₹. 46.0 kg^{-1}

System productivity index (SPI): SPI indicates the most productive and stable cropping pattern[36]. SPI values are generally conforming to the LER and RCC values. LER values along with SPI values demonstrated the economic feasibility of cropping systems. Significantly higher SPI was observed in maize + greengram (1:1) with 75 cm × 20 cm spacing (431.4) and lower SPI was observed with maize + cowpea (1:2) with 90 cm × 20 cm spacing (253.3) (Table 2). Higher SPI was in maize + greengram in 1:1 row ratio due to the dominance of maize in most of the intercropping patterns. This could partially be due to the intra-specific competition between maize plants where intercrops suppressed by maize, yet managed to remain the dominant species. In other words, although intercrops were suppressed by maize, its production was still high with respect to its limited land area in this cropping pattern. Similar findings were obtained in barley and medic intercropping[37].

Returns on investment: In a 1:1 row ratio of maize + blackgram, significantly higher gross, net returns and B-C ratio were obtained (₹1,44,516 ha^{-1}, ₹ 88,668 ha^{-1} and 2.59) and it was on par with all other intercropping systems except maize + cowpea (Table 3). The significantly higher gross returns, net returns and B-C ratio were mainly due to better performance of both main as well as intercrops crops[38,15], which have higher equivalent yield and higher market price of maize (₹ 1850 ha^{-1}), greengram (₹ 5229 ha^{-1}) and blackgram (₹ 4955 ha^{-1}). Significantly low economics values were recorded in sole greengram (₹ 55,479 ha^{-1} and ₹ 21,388 ha^{-1}, respectively). The results are corroborated with the findings under clusterbean + cowpea (2:2) intercropping system, where significantly higher gross returns, net returns and B-C ratio were recorded[39]. Among intercropping system maize + rajmash in 1:1 row ratio produced significantly maximum net return (₹ 52,190 ha^{-1}) and B-C ratio (1.9) as compared to maize + rajmash in 2:1 row proportion[40].

Conclusions

Based on the above results it could be inferred that traditional system of intercropping of either greengram or urdbean with corn in alternate row at narrow spacing of 75 × 20 cm under rainfed condition proved very productive, remunerative, compatible and superior to their individual sole planting and other intercropping systems. They recorded significantly higher maize equivalent yield (7330 kg/ ha and 7250 kg/ha, respectively), gross return (₹ 1,44,516 per ha and ₹ 1,42,139 per ha, respectively), net return (₹88,668 per ha and ₹ 85,475 per ha, respectively) and benefit-cost ratio (2.59 and 2.57, respectively). Further these legumes suppressed the weeds and reduced the incidence of recent invasive fall armyworm insect pest. Maize intercropping with legumes increased the nutrients especially nitrogen in soil compared to sole crop of maize so as to sustain soil fertility for succeeding crops.

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Conflict of interest

Both authors certify that there is no conflict of interest in bringing this research paper for publication.

Authors' contributions

H S S: Involved in field experiment, collection, compilation and statistical analysis of data, tabulation, graphs and writing of draft paper; and S R S: Formulated the hypothesis, monitored the collection of data and preparation of final research paper

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