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Impact on Maize (*Zea mays*) Productivity and Yield Parameters with Intercropping with French Bean (*Phaseolus vulgaris* L) and Blackgram (*Vigna mungo*)

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ABSTRACT

A field experiment was conducted at Lovely Professional University, Jalandhar, Punjab in *kharif* season in 2022. The experiment had a total of nine treatments with three replications i.e. T_1–Sole maize, T_2–Sole french bean, T_3–Sole blackgram, T_4–Maize+french bean (1:1), T_5–Maize+french bean (1:2), T_6–Maize+french bean (1:3), T_7–Maize+blackgram (1:1), T_8–Maize+blackgram (1:2) and T_9–Maize+blackgram (1:3). In the treatments, rows of legumes were sown in between maize in 1:1, 1:2 and 1:3 ratios. Sole maize and intercropped maize was provided with the recommended dose of fertilizer, while in the sole blackgram and french bean plots, recommended doses of the respective legume was provided. The best results of intercropping were shown by maize+blackgram (1:2) followed by maize+black gram (1:3) and maize+french bean (1:2). The yield assessment function like land equivalent ratio (LER) and maize equivalent yield (MEY) prominently indicated the benefits of maize-legume intercropping system under Punjab region.

Key words: Production, utilization, LER, MEY, yield, intercropping

INTRODUCTION

Maize (*Zea mays*) contributes around 9% to India's food basket and 5% to world food energy. Its production was 25.16 million metric tonnes in 2021-22 (Agricultural Market Intelligence Centre, PJTSAU) in a 9.8-million-hectare area. It was 1.73 million tonnes up from 1950-51. Punjab produces 610 thousand tonnes of maize from 0.165 million hectares. Punjab produces 3697 kg/ha maize (Agricultural Statistics at a Glance, 2020). Due to its C4 metabolism and physiological traits, it has great production potential. However, careful attention should be given which limits yield potential. Globally, extensive cereal mono-cropping has increased crop output but also polluted, over used resources and disrupted the ecological balance (Li *et al.,* 2014; Srivastav *et al.,* 2021). The crop species in intercropping share space, light and inputs, thereby increasing land use (Li *et al.,* 2021). Intercropping allows two or more crops to cohabit for part of their lives, providing many benefits. Legumes grow well with maize, a widely spaced crop that allows intercropping (Panda *et al.,* 2021). Maize and legumes yield a lot and boost nutritional consumption. Legumes fix atmospheric N_2, but maize needs soil nitrogen (Fan *et al.,* 2020).

MATERIALS AND METHODS

The experiment was carried out on sandy loam soil at the field of Lovely Professional University, Phagwara, Punjab. The farm is situated at 31°22′31.81″ North latitude and 75°23′03.02″ East longitude with 252 m average elevation above mean sea level. It is at 350 km distance from the capital of India (Delhi) in Punjab. The climate of the experimental location was subtropical, featuring mild winters, hot summers and a rainy season with an average annual precipitation of 711 mm. Irrigation met the remaining water needs. The study was in a randomized block design with three replicates, and it involved nine interventions and three replications (Table 1). Maize - french bean and a maize - blackgram intercropping schemes were used in the experiments. The soil contained 0.152% organic carbon, 300 kg/ha available nitrogen, 16 kg/ha available

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phosphorus, 125 kg/ha available potassium with 0.370 dS/m electrical conductivity and 7.9 pH. Treatments composition was: T_1–Sole maize, T_2–Sole french bean, T_3–Sole blackgram, T_4–Maize+french bean (1:1), T_5–Maize+french bean (1:2), T_6–Maize+french bean (1:3), T_7–Maize+blackgram (1:1), T_8–Maize+blackgram (1:2) and T_9–Maize+blackgram (1:3).

The recommended dose of fertilizer used was 50 kg/acre N, 24 kg/acre P_2O_5 and 12 kg/acre K_2O. Urea was applied in split doses, half as basal dose, one-fourth dose at knee high stage and the final dose at the pre-tasselling stage. Line sowing was done as per the package of practices of Punjab Agricultural University. Plots were regularly irrigated at intervals of 7-10 days with a flood irrigation system. Five healthy plants were tagged and marked for taking readings from each plot to record growth parameters like plant height with the help of a measuring scale, number of leaves, chlorophyll index with the help of SPAD meter. The number of rows/cob, number of cobs/plant, number of grains/row/cob, length of cob and cob diameter were manually counted when the crop was harvested at maturity. An electronic weighing scale was used to measure the yield characteristics, including seed index, grain yield and stover yield. The plant samples were dried in the sun for three days and then dried in an oven for 72 h at 60°C to measure dry matter. Grain and stover yield were calculated at physiological maturity. The harvest index was calculated as economic yield/biomass yield. Land equivalent ratio and maize equivalent yield were calculated after harvesting. ANOVA was carried out using SPSS 22 software. Tukey and Duncan homogeneity of variance was adapted to express as means ± standard deviation with P<0.05.

RESULTS AND DISCUSSION

Intercropping maize with legumes had a significant impact on agronomic indices as compared to sole maize. Plant height was maximum 212.23 cm at harvest in (T_8) maize + blackgram (1:2) followed by 206.63 cm in (T_9) maize+blackgram (1:3) and 202.63 cm in (T_5) maize+french bean (1:2). Sole maize had minimum 189.20 cm height at the time of harvest among all other treatments (Table 1). Under the legume intercropping system, maize plants had grown taller, this might be because they had to compete with other crops for light. Additionally, the favourable microclimate that the legume crops created and the improved availability of nitrogen to cereal crop plants may be responsible for the increase in plant height of cereal components (Alla *et al.,* 2015; Ginwal *et al.,* 2019). When the plant started reaching maturity, the number of leaves decreased. The number of leaves (Table 1) were maximum 13.97 in (T_8) maize+blackgram (1:2) followed by 13.57 in (T_9) maize+black gram (1:3) and 13.07 in (T_5) maize+french bean (1:2). Intercropping with legumes produced more leaves/plant than mono-cropping maize (Wangiyana *et al.,* 2021). SPAD's (chlorophyll index) value increased when maize reached its maturity. The maximum 41.20 SPAD (chlorophyll index) reading was seen in (T_8) maize+blackgram (1:2) intercropping, followed by 40.23 in (T_9) maize+blackgram (1:3) and 39.07 in (T_5) maize+french bean (1:2). It is evident from Table 1 that sole maize had the lowest (35.25) SPAD (chlorophyll index) reading. Compared to monocrop, the SPAD (chlorophyll index) reading of intercropped maize was more (Ren *et al.,* 2021). For maize, the SPAD value in all treatments displayed a trend that increased initially, peaked and then began to

Table 1. Effect of legumes-based intercropping on plant height, number of leaves, leaf area, dry weight and chlorophyll index (SPAD) in maize

Treatment	Plant height (cm)	No. of leaves	Leaf area (cm^2)	Dry weight (g)	Chlorophyll index (SPAD)
T_1–Sole maize	$189.20^{f}\pm1.26$	$12.10^{d}\pm0.22$	$1022.47^{d}\pm1.8$	$200.10^{e}\pm1.2$	$35.25^{d}\pm1.7$
T_4–Maize+french bean (1:1)	$193.43^{e}\pm0.74$	$12.20^{d}\pm0.28$	$1026.63^{d}\pm1.2$	$202.97^{d}\pm0.9$	$36.83^{cd}\pm0.5$
T_5–Maize+french bean (1:2)	$202.63^{c}\pm1.25$	$13.07^{bc}\pm0.09$	$1046.97^{bc}\pm1.7$	$214.30^{b}\pm1.5$	$39.07^{abc}\pm0.9$
T_6–Maize+french bean (1:3)	$196.97^{d}\pm1.19$	$12.87^{c}\pm0.19$	$1044.83^{bc}\pm2.6$	$207.77^{c}\pm0.6$	$38.90^{abc}\pm1.0$
T_7–Maize+blackgram (1:1)	$196.40^{d}\pm0.94$	$12.53^{cd}\pm0.41$	$1042.50^{c}\pm0.9$	$206.30^{c}\pm0.8$	$37.97^{bc}\pm0.9$
T_8–Maize+blackgram (1:2)	$212.23^{a}\pm1.65$	$13.97^{a}\pm0.21$	$1055.93^{a}\pm2.5$	$218.73^{a}\pm1.1$	$41.20^{a}\pm0.8$
T_9–Maize+blackgram (1:3)	$206.63^{b}\pm1.88$	$13.57^{ab}\pm0.33$	$1048.83^{b}\pm2.7$	$215.63^{b}\pm1.7$	$40.23^{ab}\pm0.9$

Different superscripts mean significantly different at P<0.05.

decline as the growth increased (Li *et al.,* 2020).

The microenvironment within a population of plants and their spatial distribution can be impacted by variations in leaf area. Maximum 1055.93 cm^2 leaf area was found in maize + legume combination i.e in (T_8) maize+blackgram (1:2) followed by 1048.83 cm^2 in (T_9) maize+blackgram (1:3) and 1044.883 cm^2 in T_5 maize + french bean (1:2). Leaf area increased significantly till harvest (Table 1), which also increased stover yield. This is a result of nitrogen impact, which caused an increase in cell division and enlargement in all its morphological components (Dwivedi *et al.,* 2016; Nasar *et al.,* 2020). The intercropping system had an impact on the dry matter (g) of maize and legumes, treatment (T_8) maize+blackgram (1:2) recorded significantly higher, 218.73 g dry matter accumulation than any other treatments followed by (T_9) maize+blackgram (1:3 with 215.63 g) and (T_5) maize + french bean (1:2 with 214.30 g). Sole maize had significantly less 200.80 g amount of dry matter than other treatments at the time of harvest. Due to interspecies competition caused by the presence of legumes, there was less variation in dry matter in different treatments of maize with different legume species. This might be due to increase in nitrogen availability in maize due to N fixation by the legume crops which resulted in the increased photosynthesis and metabolism of the maize crop leading to higher dry matter accumulation (Deepak *et al.,* 2019).

The results of the variance analysis showed that there was a significant variation between intercropping treatments and growth stages in terms of CGR and RGR (Table 2) at all the observational stages as compared to maize+legume intercropping. Similar results were found in the studies of Pandey and Bhambri (2017). The treatment (T_8) maize+blackgram (1:2) had the maximum CGR 2.35 g^2/day followed by 2.26 g^2/day in (T_9) maize+blackgram (1:3) and 2.20 g^2/day in (T_5) maize+french bean (1:2). Yavas and Unay (2016) had similar findings. Maximum RGR 0.007072/gg/day was recorded in (T_8) maize+blackgram (1:2) followed by 0.006808/gg/day in (T_9) maize+blackgram (1:3) and 0.006707/gg/day in (T_5) maize+french bean (1:2).

The number of cobs/plant was maximum 2 (Table 3) in T_8 and T_9 intercropping systems followed by T_5 with 1.73. Length of cob was maximum (19.33 cm) in T_8 followed by T_9 with 18.45 cm which was almost similar to 18.36 cm in T_5. Cob diameter had the similar results i.e., it was maximum 8.37 mm in T_8 followed by T_9 with 8.10 mm and T_5 with 8.03 mm.

The maximum number of grains/row/cob 484.33 was noticed in (T_8) intercropping system followed by T_9 with 479.00 and T_5 with 476.67. The lowest (455.67) number of grains/row/cob was recorded in sole maize. In general, intercropping beneficial impacts on growth and yield were mostly attributable to the efficient use of resources e.g. water, light and nutrients (Gao *et al.,* 2014; Raza *et al.,* 2019). In the latest research, intercropping was found to be superior to mono-cropping in terms of the physio-agronomic characteristics of maize. Most likely, the nitrogen fixation, which aids in improving plant growth and development, was responsible for this (Liu *et al.,* 2018). The number of rows/cob was found maximum 18.33 in T_8 followed by maize+blackgram (1:3) with 17.27) and T_5 with 16.80. The cob length, cob weight, number of rows/cob, 100-grain weight, stover production and grain yield of the maize crop were more in maize legume intercropping system as compared to sole cropping (Boregowda, 2015). It's because sufficient N fixation helped to increase the amount of enzymes, enzyme activities and chlorophyll in

Table 2. Effect of legumes-based intercropping on growth analysis parameters in maize

Treatments	CGR (g^2/day^{-1})	RGR (gg/day)
T_1–Sole maize	2.06^{d}±0.042	0.006203^{e}±0.0001158
T_4–Maize+french bean (1:1)	2.11^{cd}±0.021	0.006311^{de}±0.0001008
T_5–Maize+french bean (1:2)	2.20^{bc}±0.058	0.006707^{ab}±0.0001462
T_6–Maize+french bean (1:3)	2.16^{c}±0.023	0.006505^{bcd}±0.0001818
T_7–Maize+blackgram (1:1)	2.13^{cd}±0.031	0.006434^{cde}±0.0001915
T_8–Maize+blackgram (1:2)	2.35^{a}±0.043	0.007072^{a}±0.0002567
T_9–Maize+blackgram (1:3)	2.26^{b}±0.034	0.006808^{ab}±0.000173

Different superscripts mean significantly different at P<0.05.

Table 3. Effect of legumes-based intercropping on yield parameters of maize

Treatment	No. of cobs/ plant	Length of cob (cm)	Cob diameter (cm)	No. of rows/ cob	No. of grain rows/cob	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Seed index (g)
T_1–Sole maize	1.00^{c}±0.00	16.70^{d}±0.12	7.37^{e}±0.2	14.33^{d}±0.47	455.67^{e}±3.7	5434.5^{e}±37.16	6597.10^{f}±38.62	43.78^{d}±0.05	20.8^{d}±0.4
T_4–Maize+french bean (1:1)	1.17^{c}±0.24	17.03^{cd}±0.17	7.67^{d}±0.1	15.33^{c}±0.47	465.33^{d}±3.4	5629.33^{d}±18.01	7150.40^{e}±16.51	43.93^{cd}±0.02	22.9^{c}±1.4
T_5–Maize+french bean (1:2)	1.73^{a}±0.21	18.36^{b}±0.24	8.03^{bc}±0.1	16.80^{b}±0.43	476.67^{bc}±2.5	5776.33^{b}±22.40	7328.40^{c}±27.53	44.15^{bc}±0.04	26.1^{b}±0.6
T_6–Maize+french bean (1:3)	1.67^{ab}±0.24	18.17^{b}±0.12	7.93^{bc}±0.0	16.30^{bc}±0.42	474.00^{bc}±0.8	5723.00^{c}±8.29	7274.33^{cd}±59.00	44.03^{bcd}±0.02	25.7^{b}±0.4
T_7–Maize+blackgram (1:1)	1.33^{bc}±0.24	17.5^{c}±0.23	7.82^{cd}±0.1	15.67^{c}±0.47	471.33^{c}±0.9	5696.33^{c}±12.71	7223.00^{de}±27.86	43.99^{cd}±0.05	23.3^{c}±0.9
T_8–Maize+blackgram (1:2)	2.00^{a}±0.00	19.33^{a}±0.39	8.37^{a}±0.1	18.33^{a}±0.47	484.33^{a}±1.7	5911.50^{a}±35.72	7519.00^{a}±43.23	45.17^{a}±0.31	28.4^{a}±1.0
T_9–Maize+blackgram (1:3)	2.00^{a}±0.00	18.45^{b}±0.19	8.10^{b}±0.1	17.27^{b}±0.25	479.00^{b}±2.2	5805.50^{b}±19.93	7414.67^{b}±17.00	44.30^{b}±0.10	27.3^{ab}±0.2

Different superscripts mean significantly different at $P<0.05$.

plant leaves, and also improved light absorption (Raza *et al.,* 2019). Additionally, the intercropping process below-ground rhizospheric interaction improved Fe nutrition and hence increased the chlorophyll concentration (Nasar *et al.,* 2020). The higher production of dry matter, cobs/plant, grains/cob, seed index and cob yield were promoted by higher CGR and RGR (Boregowda, 2015).

The maximum grain yield (5911.50 kg/ha) was recorded in T_8 maize+blackgram (1:2) followed by (T_9) maize+blackgram (1:3) with 5805.50 kg/ha and (T_5) maize + french bean (1:2) with 5776.33 kg/ha (Table 3). Similarly, stover yield was also noted maximum 7519.00 kg/ha in (T_8) maize+blackgram (1:2) followed by (T_9) maize+blackgram (1:3) with 7414.67 kg/ha and (T_5) maize+french bean (1:2) with 7328.40 kg/ha. This was due to the fact that intercropping increased the total biomass produced resulting in higher yields. It also improved the soil fertility through the addition of nitrogen-fixing legumes which increased the soil nitrogen for better nutrient uptake by the maize. Intercropping of maize and legumes had considerable impact on harvest index and seed index in maize (Table 3). It was seen that other treatments with legumes had an almost similar reading, but the maximum seed index 28.40 g was found in T_8 followed by (T_9) 27.30 and (T_5) 26.10 g. Similarly, maximum harvest index 45.17% was recorded in (T_8) followed by T_9 44.30% and T_5 44.15%.

Number of pods/plant, seeds/pod, test weight and seed yield of black gram and french bean directly influenced the yield. Different intercropping treatments caused significant variations in yield parameters of blackgram and french bean (Table 4). The number of pods/plant were maximum in pure stands of blackgram 32.17 and french bean 29.00. Seeds/pod were also recorded best in mono crop for both blackgram 7.33 and french bean 6.73. Likewise, seed yield was also maximum in pure stand of legumes. The maximum 2317.133 kg/ha seed yield was obtained from sole blackgram plot as compared to sole french bean 2148.700 kg/ha. The test weight was maximum in sole plots of blackgram 36.17 g and french bean 257.90 g. Gohain and Puchno (2017), Mansa *et al.,* (2018) and Ezung *et al.* (2022) had also similar findings.

Increased intra-specific and inter-specific competition for growth resources may have

Table 4. Effect of intercropping on yield parameters of pulses and yield assessment studies

Treatment	No. of pods/ plant	Seeds/pod	Seed yield (kg/ha)	Test weight (g)	LER	MEY (kg/ha)
T_1–Sole maize	-	-	-	-	$1.00^{e}\pm0$	$5434^{e}.50\pm37.16$
T_2–Sole french bean	$29.00^{b}\pm0.82$	$6.73^{ab}\pm0.377$	$2216.27^{b}\pm15.61$	$257.90^{a}\pm3.34$	$1.00^{e}\pm0$	-
T_3–Sole black gram	$32.17^{a}\pm1.03$	$7.33^{a}\pm0.471$	$2317.13^{a}\pm28.38$	$36.17^{d}\pm0.28$	$1.00^{e}\pm0$	-
T_4–Maize+french bean (1:1)	$20.67^{d}\pm0.47$	$5.67^{b}\pm0.471$	$1851.83^{e}\pm24.82$	$230.10^{c}\pm1.39$	$2.11^{d}\pm0$	$7916.26^{d}\pm45.99$
T_5–Maize+french bean (1:2)	$25.67^{c}\pm1.25$	$6.33^{ab}\pm0.471$	$2020.37^{d}\pm17.45$	$245.13^{b}\pm2.55$	$2.16^{c}\pm0.01$	$8536.81^{c}\pm104.58$
T_6–Maize+french bean (1:3)	$28.10^{b}\pm0.94$	$6.67^{ab}\pm0.471$	$2111.90^{c}\pm41.55$	$258.13^{a}\pm2.07$	$2.16^{c}\pm0.03$	$8165.19^{d}\pm57.53$
T_7–Maize+blackgram (1:1)	$25.53^{c}\pm0.34$	$5.97^{b}\pm0.818$	$1984.97^{d}\pm24.28$	$33.37^{d}\pm0.66$	$2.11^{d}\pm0.03$	$10969.55^{b}\pm134.18$
T_8–Maize+blackgram (1:2)	$28.00^{b}\pm0.82$	$6.33^{ab}\pm0.471$	$2028.80^{d}\pm9.68$	$34.95^{d}\pm0.31$	$2.23^{a}\pm0.01$	$11671.03^{a}\pm229.67$
T_9–Maize+blackgram (1:3)	$28.13^{b}\pm0.34$	$6.67^{ab}\pm0.471$	$2148.70^{c}\pm12.48$	$35.28^{d}\pm0.09$	$2.19^{b}\pm0.01$	$11165.18^{b}\pm96.44$

Different superscripts mean significantly different at $P<0.05$.

resulted in a drop in the number of effective branches, which in turn resulted in a decrease in the number of pods/plant in intercrop (Gutu *et al.,* 2015). When intercropped with C_3 species, like the legumes, the crops having C_4 photosynthetic traits, like maize, were competitively dominant in the system. The common bean's poor performance in intercropping with maize may also be due to the legume's shallow root systems and short root systems, which may have diminished the competitive advantage for the growth elements including light, nutrients, water and space (Matusso *et al.,* 2014; Karuma *et al.,* 2016). The test weight revealed that the size of the grains obtained by the various species of legumes varied with the different species, The species providing highest test weight clearly demonstrated the larger size grains quality.

Maize equivalent yield (MEY) and land equivalent ratio (LER) was higher with maize+blackgram intercropping followed by maize+french bean and sole maize. LER showed positive influence on growth and yield of maize and legumes intercrops (LER > 1) in maize+black gram and maize+french bean intercropping. Maximum LER 2.23 was obtained from (T_8) maize+blackgram (1:2). T_5 and T_6 had equal LER 2.16. This indicated that sole maize crop would need 123% (1.23 ha) and 116% (1.16 ha) more land to produce the same amount as an intercropping system. MEY of sole maize was recorded minimum 5434.50 kg/ha and found maximum 11671.03 kg/ha in (T_8) maize+blackgram (1:2). This can be attributed to the nutritive transfer and complementary action of legumes in intercropping systems. Thilakarathna *et al.* (2016) and Khonde *et al.* (2018) yielded comparable outcomes. This may help to explain why both intercropping systems had higher LER and MEY. It is clear that maize is sensitive to intercropping component crops' spatial arrangement, which accounts for the highest significant LER and MEY. Similar results were found in the studies of Kim *et al.* (2018) and Salama *et al.* (2022).

CONCLUSION

Maize intercropping with legumes can provide a number of advantages over monoculture maize production. Intercropping can increase yield and improve soil fertility, as legume crops fix nitrogen from the atmosphere and deposit it into the soil. This can reduce the need for costly synthetic nitrogenous fertilizers. Intercropping can also save time and labour costs, as it requires fewer tillage practices than mono-cropping. Moreover, intercropping can increase farmer income as it can offer greater market value and/or greater yields than mono-cropping maize. In conclusion, maize+blackgram (1:2) showed the best results followed by maize+black gram (1:3) and maize+french bean (1:2) in growth and yield parameters of maize. In case of legumes sole crops, the best results in yield parameters were shown because of more plant population in sole plots and also due to less inter-specific competition between maize and legumes. As indicated by LER, sole maize would need 123% (1.23 ha) and 116% (1.16 ha) more land to produce the same amount of yield as in intercropping system. Hence, one can conclude that intercropping is beneficial.

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