RESEARCH ARTICLE Legume Research- An International Journal, Volume 46 Issue 12: 1647-1652 (December 2023)

Evaluation of Soybean and Green Gram as Intercrops with Maize under Different Row Proportions in the North-eastern Hill Region, India

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10.18805/LR-4791

ABSTRACT

Background: Intercropping maize with legumes can enhance diversity, stability, complementary sharing of resources, maintain soil fertility, productivity and livelihood of the farmers. The current study was aimed to develop the scientific knowledge of maize and pulse intercropping and their combinations in different planting structures.

Methods: The field experiment consisted of seven treatments *viz*. sole maize, sole soybean, sole green gram and two intercropping ratios of soybean and green gram with maize at 1:1 and 1:2 row ratios and laid out in randomized block design in four replications during 2018-19 at Imphal. The intercropping, economic and competitive efficiency indices were calculated accordingly.

Result: Intercropping of maize either with soybean or green gram in 1:2 ratio gave the best combination based on intercropping and economic efficiencies. Maize + soybean at 1:2 row produced the highest maize equivalent yield (82.65 q ha^{-1}), system productivity (22.60 kg ha^{-1} day^{-1}) and production efficiency (55.84 kg ha^{-1} day^{-1}). Maize + green gram at 1:2 ratio had significantly higher land equivalent ratio (1.7) and land equivalent co-efficient (0.54) whereas maize + soybean at 1:2 ratio produced the highest area time equivalent ratio (1.27). Competition between the crops was higher under maize + green gram at 1:1 ratio.

Key words: Efficiency, Greengram, Intercropping, Maize, Soybean, Yield.

INTRODUCTION

Growing of crops in mixtures is an age old practice in the north-eastern hill region of India. However, due to lack of systematic intercropping knowledge of different crops led to risk of crop failure and instability of crop production. Under this situation, one of the important strategies to increase agricultural output is the development of scientific intercropping system which can enhance diversity and stability of fields, complementary sharing of plant resources, maintain soil fertility, productivity and after all livelihood of the rural poor farmers of the north eastern India.

In north eastern hill state particularly in Manipur, maize (*Zea mays* L.) is the 2nd most important food grain crop grown next to rice occupying an area 0.23 m ha with an average grain productivity of 2.3 t ha^{-1} (Anonymous, 2021). Also, soybean (*Glycine max* L.) and green gram (*Vigna radiata* L.) are the important legume crops because of its adaptability. In intercropping of maize and these pulses some of the important advantages are the differentiating development, growth pattern, stature and rooting behaviour so that this supplements each other instead of going after the resources and make preparations for climate difficulties (Zhang *et al.,* 2011). Intercropping of maize with legumes provides many benefits such as stable yields, efficient use of resources, fix atmospheric N in soil, improve soil quality, reduce crop yield variability and fortify family diets with protein and micronutrients (Layek *et al.,* 2018). It is highly significant when moisture content in soil is limited as a higher amount of available water is being used in intercropping as against sole cropping. Having deep root system, legumes can extract moisture and nutrients from deeper layer and hence does not compete with associated cereals (Das *et al.* 2016).

Different crop combination ratios for intercropping of legumes and cereals have conflicting experimental results on the potential productivity advantage of mixed cropping over monoculture including cereal and legume mixtures. Similarly, the yield advantage of intercropping has not been so marked in several situations possibly due to the use of supra-optimal plant population proportions and, in some cases, to the use of sub-optimal population proportions for component crops (Refay *et al.,* 2013). The present experiment was, therefore, undertaken to examine the feasibility of growing different pulses with maize in different row proportions in north eastern part of India.

MATERIALS AND METHODS

The experiment was conducted during *kharif* season of

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How to cite this article: Singh, S.D., Nongmaithem, N., Konsam, J., Senjam, P. and Singh, N.A. (2023). Evaluation of Soybean and Green Gram as Intercrops with Maize under Different Row Proportions in the North-eastern Hill Region, India. Legume Research. 46(12): 1647-1652. doi: 10.18805/LR-4791.

Submitted: 13-09-2021 **Accepted:** 08-03-2022 **Online:** 25-04-2022

2018-19 at the Andro farm of Central Agricultural University Andro, Imphal East district, Manipur on sandy clay loam soil having 5.79 pH, 1.78% organic carbon, 285 kg ha^{-1} available nitrogen, 22.7 kg ha^{-1} available phosphorus and 143 kg ha^{-1} exchangeable potassium. Total rainfall received during the crops growth was 1374 mm. An average maximum and minimum temperature of 32°C and 19°C was recorded during the entire growing period. Seven treatments *viz.* sole maize, sole soybean, sole green gram, maize+soybean (1:1), maize+green gram (1:1), maize+soybean (1:2), maize +green gram (1:2) were laid out in randomized block design (RBD) in four replications. Maize var. HQPM-5, soybean var. JS-335 and green gram var. HUL-12 were sown on June, 2018 as additive method of intercropping at 70 cm × 20 cm spacing and the recommended doses of N:P:K were applied through urea, single super phosphate and muriate of potash. Observations on growth and yield attributes of both main and intercrops were taken at appropriate time. Economics was calculated according to market price of each crop.

The analysis and interpretation of data were done by using the Fisher's method of analysis of variance technique.

RESULTS AND DISCUSSION

Effect of intercropping on soybean and green gram

Plant height

Plant height in intercropped treatments was adversely affected due to competition with main crop. There was reduction in plant height either in soybean or green gram with increase of their row ratios in intercropping with maize (Table 1). Sole soybean recorded the tallest plant (99.00 cm), similarly sole green gram observed the tallest plant (72.25 cm). Similar result of reduced plant height in intercropping treatment was observed by Mohan *et al.* (2005).

Number of pods plant^{-1} and number of seeds pod^{-1}

The highest number of pods plant^{-1} was recorded from sole soybean (238.75) and sole green gram (29.96). Reduction

Intercropping indices such as land equivalent ratio (LER) given by Willey, (1979).

$$LER = \frac{\text{Yield of the main crop in mixture}}{\text{Yield of the main crop in sole}} + \frac{\text{Yield of the intercrop in mixture}}{\text{Yield of the intercrop in sole}}$$

Land equivalent coefficient (LEC) given by Adetiloye and Ezedinma,1983.

$$LEC = \frac{\text{Yield of the main crop in mixture}}{\text{Yield of the main crop in sole}} + \frac{\text{Yield of the intercrop in mixture}}{\text{Yield of the intercrop in sole}}$$

Area time equivalent ratio (ATER) given by Hiebsch and Mc Collum, (1987).

$$ATER = \frac{(\text{Relative yield of main crop} \times \text{Duration of main crop}) \times (\text{Relative yield of intercrop} \times \text{Duration of intercrop})}{\text{Total duration of the intercropping system}}$$

Relative crowding coefficient (RCC) given by Cousens and O' Neill, (1993).

$$RCC = \frac{\text{Relative yield of main crop}}{(1 - \text{Relative yield of main crop})} + \frac{\text{Relative yield of intercrop}}{(1 - \text{Relative yield of intercrop})}$$

Aggressivity given by Mc Gilchrist in 1965.

$$\text{Aggressivity} = \frac{\text{Yield of the main crop in sole}}{\text{Yield of the main crop in mixture} \times \text{Sown proportins of main crop}} - \frac{\text{Yield of the intercrop in sole}}{\text{Yield of the intercrop in mixture} \times \text{Sown proportins of intercrop}}$$

Maize equivalent yield (MEY) was obtained from Anjaneyula *et al.,* 1982.

$$MEY = \frac{(\text{Yield of main crop} \times \text{Price of main crop}) + (\text{Yield of intercrop} \times \text{Price of intercrop})}{\text{Price of main crop}}$$

System productivity and Production efficiency (kg ha^{-1} day^{-1}) were expressed by Gangwar *et al.* (2006).

$$\text{System productivity (kg ha}^{-1}\text{ day}^{-1}\text{)} = \frac{\text{Maize equivalent yield (kg ha}^{-1}\text{)}}{\text{365 Days}}$$

$$\text{Production efficiency (kg ha}^{-1}\text{ day}^{-1}\text{)} = \frac{\text{Maize equivalent yield (kg ha}^{-1}\text{)}}{\text{Total duration of cropping sequence (days)}}$$

in number of pods per plant due to intercropping might be attributed to shorter plant height in intercropping and could utilize lower percentage of incoming solar radiation. Similar results of lower pods plants^{-1} in legumes due to intercropping were observed by Mohan *et al.* (2013) and Kheroar and Patra (2014).

Seed and stover yield

Sole treatments provided the maximum seeds yield of 20.03 q ha^{-1} for soybean and 9.20 q ha^{-1} for green gram. However, among the two different row proportions, seed and stover yield under intercropping of 1:2 row ratio was higher over yield at 1:1 row ratio due to higher planting density of intercrops in 1:2 proportions led to more number of pods and dry matter per unit area. In intercropping of maize due to plant height variation, the legumes could not able to receive the incoming solar radiation efficiently which affected the rate of photosynthesis. Similar results were also obtained by Kheroar and Patra, (2014).

Effect of intercrops on maize

Plant height

The plant height of the maize was higher in sole maize as compared to maize height in intercropping with pulses irrespective of row ratios (Table 2). The shorter plant of maize was found when intercropped at 1:2 row ratio with pulses. This might be due to interspecies and competitive interaction of intercrops with maize for the resources like water, nutrients and light. These results corroborated with the finding of Baldevram *et al.* (2005) and Patel *et al.* (2018).

Number of cobs per plant

Intercropping of either soybean or green gram in maize could not bring more number of cobs per plant as compared to sole maize. The data in Table 2 showed that increase in row ratios of pulse led to decrease in number of cobs per plant. The result of higher number of maize cobs in sole maize as compared to intercropping is in conformity with the findings of Patel *et al.* (2018).

Number of grain rows per cob and number of grains per row

Sole maize produced the highest number of grain rows per cob (15.60) and number of grains per row (32.23). Lower values of yield attributes under intercropping treatments might be due to the suppressing effect of fast growing, vigorous growth of broad leaved canopied intercrop (Patel *et al.,* 2018). This result was validated by the findings of Kaushal *et al.* (2015).

Maize grain and stover yield

Sole maize recorded the highest maize grain yield (54.68 q ha^{-1}) and stover yield (86.28 q ha^{-1}) as compared to intercropping treatments (Table 2). There was reduction in yield with increase of row ratios which was in conformity with the findings of Baishya *et al.* (2021). The reduction in grain yield of maize under intercropping treatments could be assigned to lower values of yield attributes under intercropping treatments resulting from poor plant growth due to competition effect between maize and intercrops (Patel *et al.,* 2018). Reduction in seed yield of maize owing to pulse intercropping was also reported by Kaushal *et al.* (2015).

Intercropping efficiencies and competitive abilities

Land equivalent ratio

All the intercropping treatments have higher and better land resource utilization in terms of LER relative to the corresponding sole crops (Table 3). Intercropping of maize

Table 1: Performance of soybean and green gram in intercropping with maize.

	Height (cm)	Nos. of pods plant^{-1}	Nos. seeds pod^{-1}	Seed yield (q ha^{-1})	Stover yield
Sole soybean	99.00	238.75	2.10	20.03	58.49
Sole green gram	72.25	29.96	10.18	9.20	31.03
Maize + Soybean (1:1)	90.00	167.75	2.10	9.92	26.78
Maize + Green gram (1:1)	60.84	25.43	8.98	4.69	12.81
Maize + Soybean (1:2)	87.25	173.88	2.20	13.07	37.73
Maize + Green gram (1:2)	54.94	21.76	8.19	6.20	20.78
Sem (±)	2.55	6.39	0.28	0.26	0.50
CD (p=0.05)	7.69	34.30	0.85	0.77	1.51

Table 2: Performance of maize in intercropping with soybean and green gram in different row ratios.

	Height (cm)	Nos. of cobs plant^{-1}	Nos. of grain rows cob^{-1}	Nos. of grains row^{-1}	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})
Sole maize	198.75	1.72	15.60	32.23	54.68	86.28
Maize + Soybean (1:1)	169.50	1.14	13.65	26.95	45.58	73.33
Maize + Green gram (1:1)	181.75	1.21	14.40	28.63	48.70	76.75
Maize + Soybean (1:2)	163.00	0.98	12.35	24.80	41.70	67.93
Maize + Green gram (1:2)	165.50	1.09	13.00	25.60	43.28	71.73
Sem (±)	2.43	0.04	0.16	0.52	0.06	0.09
CD (p=0.05)	7.48	0.13	0.51	1.61	1.81	2.77

with green gram at 1:2 row proportion registered the highest LER (1.47). Maize is a wide spaced crop with slower growth during early stage. Besides, higher row planting provided enough scope to the legumes to grow, which was expressed by Liang *et al.* 2017; Manassa *et al.* 2018.

Land equivalent coefficient

Higher value of LEC in 1:2 row ratio than 1:1 ratio showed more potential in mixture productivity of 1:2 ratio and their interaction to their components planted on per unit area productivity (Table 3). The highest LEC was recorded in maize+green gram at 1:2 ratio (0.54) followed by maize+ soybean at 1:2 ratio (0.50). This result of increasing LEC value with increase of row ratios is supported by findings of Parimaladevi *et al.* (2019).

Area time equivalent ratio

The highest ATER value was observed under maize+ soybean at 1:2 ratio (1.27) followed maize+green gram at 1:2 ratio (1.23), maize + green gram at 1:1 (1.22) and maize +soybean at 1:1 (1.22) (Table 3). The lowest value of ATER in sole green gram is due to short duration of land occupied in the system. However, higher value of ATER in higher row proportion than lower row proportion was in accordance with the findings of Parimaladevi *et al.* (2019) in intercropping of maize with different legumes.

Relative crowding coefficient

RCC shows the competitive ability of a crop in mixture. The results in the Table 3 revealed that intercropping of maize with green gram have higher potential mixture than intercropping of soybean in terms of RCC irrespective of row ratios. The highest RCC was recorded in maize+green gram at 1:1 ratio (11.67) followed maize+green gram at 1:2 (8.81), maize+soybean at 1:2 ratio (7.19) and maize+ soybean at 1:1 ratio (6.20), respectively.

Aggressivity

The positive value of aggressivity in maize showed the dominance of maize as compared to soybean or green gram in the intercropping system under different row ratios (Table 3). The highest aggressivity of maize was recorded in intercropping with green gram at 1:1 ratio (0.48) followed by maize+green gram at 1:2 (0.46), maize+soybean at 1:2 (0.44) and maize+soybean at 1:1 ratio (0.34), respectively. The result of dominancy of maize in intercropping with legumes was in conformity with the finding of Manassa *et al.* (2018).

Economic efficiencies

Maize equivalent yield

All the intercropping treatments provided higher MEY than the sole maize. The result also revealed that intercropping of maize with legumes in higher intercrop row ratios produced more equivalent yield than the intercropping with lesser row ratios (Table 4). The highest MEY (82.65 q ha^{-1}) was obtained in maize+soybean at 1:2 ratio followed by

Table 3: Intercropping efficiencies of maize legumes intercropping in different row ratios.

	LER	LEC	ATER	RCC	Aggressivity	
					Maize	Intercrop
Sole maize	1.00	-	1.00	-	-	-
Sole soybean	1.00	-	0.77	-	-	-
Sole green gram	1.00	-	0.64	-	-	-
Maize + Soybean (1:1)	1.33	0.42	1.22	6.20	0.34	-0.34
Maize + Green gram (1:1)	1.41	0.43	1.22	11.67	0.48	-0.48
Maize + Soybean (1:2)	1.42	0.50	1.27	7.19	0.44	-0.44
Maize + Green gram (1:2)	1.47	0.54	1.23	8.81	0.46	-0.46
Sem (±)	0.01	0.01	0.01			
CD (p=0.05)	0.04	0.03	0.04			

Table 4: Economic efficiencies of maize legumes intercropping in different row ratios.

	MEY (q/ha)	System productivity (kg ha^{-1} day^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Net return (Rs. ha^{-1})	B:C
Sole maize	54.68	14.98	36.94	43202	2.19
Sole soybean	42.86	11.74	35.72	32512	2.14
Sole green gram	35.98	9.86	37.88	24116	1.89
Maize + Soybean (1:1)	75.90	20.79	51.28	58927	2.56
Maize + Green gram (1:1)	73.03	20.01	49.34	58061	2.49
Maize + Soybean (1:2)	82.65	22.60	55.84	62270	2.63
Maize + Green gram (1:2)	78.92	21.62	53.32	60324	2.61
Sem (±)	0.74	0.21	0.54	1036	0.03
CD (p=0.05)	2.19	0.60	1.62	3076	0.09

maize+green gram at 1:2 ratio (78.92 q ha^{-1}). Similar results of higher MEY in higher row proportions than the sole crops were reported by Parimaladevi *et al.* (2019).

System productivity

System productivity was highest in intercropping treatments than sole crops (Table 4). Among the intercropping ratios, higher intercropped row ratios of 1:2 provided higher system productivity than less row proportion. The highest system productivity of 22.60 kg ha^{-1} day^{-1} as recorded from maize+ soybean at 1:2 followed by maize+green gram at 1:2 ratio (21.62).

Production efficiency

Intercropping treatments provided the higher production efficiency than the sole crops. Higher row ratio of 1:2 either with soybean or green gram has higher production efficiency than lesser row proportion (Table 4). The highest production efficiency of 55.84 kg ha^{-1} day^{-1} as recorded from maize+ soybean at 1:2 ratios.

Net return and B:C ratio

Net return and B:C increase due to intercropping of legumes as compare to sole crops. The highest net return (Rs 62270/- ha^{-1}) and B:C (2.63) was recorded from maize+soybean at 1:2 ratios followed by maize+green gram at 1:2 ratio. The result in the Table 4 clearly depicted that higher row proportion of intercrops in intercropping with maize provided maximum monetary return than intercropping in lesser row ratio. Similarly, higher net return and B:C in higher row proportion in intercropping of maize with legumes was obtained by Parimaladevi *et al.* (2019).

CONCLUSION

Soybean as row intercrop with maize grown in 1:2 row proportion at Imphal of north-eastern hill region, India produced higher maize equivalent yield (82.65 q ha^{-1}), system productivity (22.60 kg ha^{-1} day^{-1}), production efficiency (55.84 kg ha^{-1} day^{-1}) and assured more income (Rs. 62270/- ha^{-1}) while, maize+green gram at 1:2 ratios had significantly higher land equivalent ratio (1.47) and land equivalent co-efficient (0.536). The intercropping of maize either with soybean or green gram in 1:2 row proportion gave the best combination based on intercropping efficiencies and economic efficiencies.

Conflict of interest

All authors declare there is no conflict of interest. All the co-authors have seen an agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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