



Productivity, profitability and soil biochemical properties in maize (*Zea mays*) and soybean (*Glycine max*) intercropping as influenced by population proportion of component crops

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ABSTRACT

A field experiment was conducted during *kharif* 2016 at College of Post Graduate Studies (CAU-Imphal), Umiam, Meghalaya to study the effect of population proportions of component crops on performance of maize (*Zea mays* L.)+ soybean [*Glycine max* (L.) Merr.] intercropping. The experiment was laid out in randomized block design with three replications comprised eight treatments (sole maize, sole soybean and six treatments on maize+soybean intercropping with different population proportion of component crops. Treatment 2:2 paired maize+soybean recorded maximum maize equivalent yield (3.91 t/ha) and land equivalent ratio (1.23) which were at par with intercropping treatments 1:1 Additive, 1:1 Replacement, 2:1 Replacement and 2:1 Additive but significantly higher over the sole maize and 2:1 Paired intercropped treatments. However, maximum net return (₹ 23643/ha) and B: C (1.68) ratio were recorded from 1:1 R maize+soybean which were at par with 2:1 Replacement and 2:2 Paired but significantly higher over sole maize and other intercropping treatments. Introduction of soybean as an intercrop in maize left relatively higher amount of soil available N, P, soil microbial biomass carbon (SMBC) and dehydrogenase activity (DHA) in soil after crop harvest as compared to sole maize. Significantly higher soil available N was recorded from the treatment 1:1 Replacement while significantly higher soil available P, SMBC and DHA were recorded from the treatment 2:2 Paired over sole maize, respectively.

Key words: Land equivalent ratio, Maize+soybean, Maize equivalent yield, Net return, Soil bio-chemical properties

Maize (*Zea mays* L.) is the second major food crop in North Eastern Hill Region (NEH) of India after rice. Its productivity in the region (1.6 t/ha) is much below than the national average of 2.5 t/ha (Anonymous 2012). Among the various factors responsible for poor maize productivity, application of lower doses of fertilizers especially nitrogen (N) is most important.

Being exhaustive crop, maize is very responsive to higher doses of N however; hilly farmers are unable to supply the required amount of N doses in maize due to high cost and poor accessibility of fertilizers. One of the possible ways to increase maize productivity in this region would be to harness the advantage of biological N fixation through intercropping of maize with a N fixing legume like soybean [*Glycine max* (L.) Merr.] as it offers a good scope for crop intensification in space dimension if introduced in wide spaced maize. Maize+soybean intercropping is known to increase the size and stability of yields compared to either of sole crop especially under low input conditions. It also helps to maintain soil fertility as besides giving additional

yields and income, it accumulated 80 to 350 kg/ha of atmospheric N in plant available form in soil (Sanginga and Woomer 2009).

The extent of competition-induced yield losses of component crops in intercropping is likely to depend on their spatial arrangement (Undies *et al.* 2012). Mohta and De (1980) observed that the yields of the cereals were not affected by their intercropping with soybean in either of single or double rows. However, Addo-Quaye *et al.* (2011) reported the best yields of component crops in spatial arrangement of single rows of maize alternating with single rows of soybean. Keeping a view of the above, a field experiment was undertaken to assess the effect of different population proportion of maize and soybean on productivity, profitability and soil biochemical properties in an intercropping system.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* 2016 on experimental farm of College of Post Graduate Studies, CAU, Umiam, Meghalaya. The soil was sandy clay loam, moderately acidic, medium in available N (315.04 kg/ha), P (16.34 kg/ha) and K (196.12 kg/ha) and SMBC (260.32 µg/g soil) and DHA (2.39 µg TPF/hr/g soil) with pH 5.23.

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The experiment consisted of 8 treatment had sole crops, viz. maize at 60 cm × 20 cm and soybean 30 cm × 10 cm and 6 combination of maize intercropped with soybean in 1:1R (spacing of both the crops are 45 cm to maintain 67% population maize and soybean was grown alternatively with maize for accommodating 33% population of their sole population), 1:1A (single row of soybean between 2 rows of maize at normal spacing 60 cm), 2:1 R (each pair of maize planted at 60 cm in between, alternate with one row of soybean at 45 cm to maintain 83% and 17% of their sole population respectively), 2:1A (single row of soybean between 2 pair of maize at normal spacing 60 cm), 2:1P and 2:2P (one and two rows of soybean between two paired rows of maize, spaced 90 cm apart at 2:1P and 2:2P treatments). The experiment was laid out in randomized block design with 3 replications. The cultivars used in the study were DA-61-A (maize) and JS-335 (soybean). They were sown simultaneously in last weeks of June 2016. The overall rainfall received during the cropping period (June-October) was 1414 mm. Recommended dose of fertilizer of 80-60-40 NPK kg/ha for maize applied As 50% N and full dose of P and K basal dose and remaining 50% N applied as two split 30 and 50 DAS respectively, 20-60-40 NPK kg/ha for soybean applied as full basal dose and for intercropping fertilizer applied on the basis of their plant population. Maize and soybean were harvested in the first and third week of October, respectively. The market price of maize grain (₹ 13 650 t/ha), soybean seed (₹ 27 750 t/ha), maize stover (₹ 1000 t/ha) and soybean straw (₹ 2000 t/ha) were taken for calculating the gross return accrued from the system. Soil samples collected at pre-sowing and post-harvest dates all treatment plots were analyzed for available N, P and K and SMBC and DHA in soil (Jackson 1973).

RESULTS AND DISCUSSION

Maize yield

Sole maize recorded maximum grain yield (3.12 t/ha) which was statistically at par with 2:1A (3.03 t/ha) and 2:1R (2.67 t/ha) but significantly superior over the grain yield recorded from all other intercropping treatments of maize with soybean. Maize grain yield recorded from 2:1A intercropping treatment was also significantly higher over grain yield recorded from all other intercropping treatments except with 2:1R when the difference between the two was at par. The magnitude of yield reduction in various intercropping treatments was in order of 3.0, 14.4, 22.9, 25.1, 27.3 and 39.7% for the treatments 2:1A, 2:1R, 1:1A, 2:1P, 2:2P and 1:1R, respectively in comparison to sole maize due to intercropping effect and reduction in plant population of maize. 1:1R population proportion recorded significantly least maize grain yield because of less plant population as compared to sole maize as well as maize intercropping in additive series. Even though increased yield attributes resulted in more grain weight/plant but this was not sufficient to compensate yield losses due to reduction in plant population of maize. Yogesh *et al.* (2014) also reported reduction in maize yield due to competition

between two intercrops and reduced maize population from 100 to 66%. In 1:1 A planting proportion of component crops, maize recorded significantly least grain yield than sole crop at similar population because of significant reduction in almost all the yield attributes resulted in less grain weight/plant due to greater competition between the component crops. These findings are in conformity with the Undies *et al.* (2012) and Yogesh *et al.* (2014). Maximum biological yield was recorded with sole maize which was at par with 2:1A and 2:1P but significantly superior over the biological yield recorded from remaining intercrop maize treatments. It was because of relatively higher plant population and higher dry matter accumulation in shoots at harvest. Straw yield was also higher in these treatments as it is the result of the differences between biological and grain yield.

Soybean yield

Sole soybean recorded maximum grain yield (1.64 t/ha) which was significantly higher over the soybean grain yield recorded from all the intercropped treatments. Among intercropping, soybean planted in 1:1R treatment recorded higher grain yields which were at par with 2:2P treatment was also significantly higher than the remaining intercropping treatments. A reduction in soybean grain yields for various intercropping treatments was in order of 43.5, 51.5, 56.6, 74.9, 75.6 and 87.0%, for the treatments 1:1R, 2:2P, 1:1A, 2:1R, 2:1P and 2:1A respectively, in comparison to sole soybean. This might be attributed to presence of significantly higher recommended plant population under sole cropping against decreased population under intercropping system. Further, soybean grain yield in 1:1 R planting better because of more number of pods/plant, pods weight/plant and grain weight/plant. However, soybean grain yields in 1:1 A and 2:2 P planting proportion had relatively lesser yield with same plant population of soybean in 1:1 R planting. This was because of probably lower availability of resources particularly light, space and due to shading by tall maize crop. The results on yield attributes and yield of soybean also indicated that whenever soybean was planted with wider row spacing of 45 cm, it maintained relatively higher plant population at harvest due to low mortality. Further, straw and biological yield of soybean recorded significantly higher in sole soybean over all the treatments followed by 1:1R planting population proportion and follow the same trend of grain yield. It was because of more plants per unit area produced more biological yield in these treatment. Since straw yield is the difference between biological and grain yield, it was also higher in these treatments due to high biological yield. Similar finding was also reported by Undie *et al.* (2012) and Yogesh *et al.* (2014).

Maize equivalent yield

The economic yield of the soybean was converted into equivalent grain yield of maize (MEY) based on the minimum support price (MSP) for grains of maize and soybean declared by Government of India for the *khariif*

Table 1 Effect of population proportion of component crops on yield attributes and grain and biological yields of maize and soybean

Treatment	Yield attributes						Yields (t/ha)			
	Maize			Soybean			Maize		Soybean	
	Cob weight (g/plant)	No. of grains/cob	Grain weight (g/cob)	No. of pods/plant	Pod weight/plant	Grain weight/plant	Grain yield (t/ha)	Biological yield (t/ha)	Grain yield (t/ha)	Biological yield (t/ha)
SM	134.40	343.39	85.01				3.12	8.10		
SS				53.80	12.42	8.68			1.64	6.62
1:1R	123.54	333.95	72.60	62.87	15.86	11.04	1.88	4.65	0.94	2.85
1:1A	73.90	258.96	49.56	47.73	11.00	7.69	2.44	6.07	0.72	2.37
2:1R	111.23	338.43	76.95	56.53	15.02	10.65	2.67	6.55	0.42	1.23
2:1A	80.53	281.57	61.51	38.87	9.79	6.96	3.03	7.56	0.22	0.71
2:1P	92.61	314.76	68.33	52.07	13.81	9.64	2.34	6.88	0.42	1.30
2:2P	93.21	322.20	61.81	54.73	14.85	10.60	2.26	6.09	0.81	2.42
CD (P=0.05)	22.69	55.92	21.36	11.89	2.37	1.87	0.67	1.33	0.15	0.40

SM, Sole maize; SS, Sole soybean; R, Replacement; A, Additive; P, Paired

Table 2 Effect of population proportion of component crops on MEY, LER, economics of maize and available N, P, K, SMBC and DHA maize and soybean

Treatment	MEY (t/ha)	LER	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	SMBC (µg/g soil)	DHA (µg TPF/hr/g soil)
SM	3.12	1.00	47656	12246	1.35	5.12	1.17	302.89	13.61	179.76	232.80	2.69
SS	3.33	1.00	55455	22563	1.69	5.22	1.02	342.66	20.45	182.37	359.79	5.32
1:1R	3.80	1.18	58222	23643	1.68	5.33	1.03	326.11	16.06	174.67	310.41	3.06
1:1A	3.88	1.22	59440	10215	1.21	4.98	1.00	309.45	16.95	189.67	363.00	6.41
2:1R	3.53	1.13	53347	18365	1.52	4.90	1.01	315.69	16.04	162.68	245.05	2.97
2:1A	3.38	1.08	51623	10621	1.26	5.44	1.01	320.30	18.82	171.36	342.25	2.77
2:1P	3.17	1.00	50441	9440	1.23	5.10	1.14	309.79	17.28	179.01	328.04	4.40
2:2P	3.91	1.23	61697	15433	1.33	5.14	0.91	316.99	17.94	196.93	313.93	6.98
CD (P=0.05)	0.55	0.17	8537	8537	0.22	NS	NS	22.29	3.15	NS	57.04	0.63
Initial soil status						5.23	1.02	315.04	16.34	196.12	260.32	2.39

SM, Sole maize; SS, Sole soybean; R, Replacement; A, Additive; P, Paired, MEY, Maize equivalent yield; LER, Land equivalent ratio; NS, Non-significant; SMBC, Soil microbial biomass carbon; DHA, Dehydrogenase activity

2016. All the intercropped treatments recorded relatively higher MEY over the sole maize even the intercropped maize grain yield was lower in some of intercropped treatments in comparison to sole maize. It was possible due to loss of maize grain yields were adequately compensated by additional yields of soybean which was accompanied with very high MSP as compared to maize. The significant difference was observed in MEY where maximum MEY was recorded in 2:2P intercropped maize which was at par with 1:1A, 1:1R, 2:1 R and 2:1 A but significantly superior over the other treatments. The higher MEY was probably also due to N fixing behavior of soybean and higher canopy cover resulting in the reduced evapo-transpiration and

encouraging the maize and intercropped soybean to use the natural resources especially light more efficient than other population proportions. These results confirm with the finding of Padhi and Panigrahi (2006).

Land equivalent ratio

LER is the total of partial LER of all the component crops in an intercropping system. LER value above one (1.0) indicated an advantage in land use efficiency in an intercropping system and in present investigation all intercrop treatments recorded LER above 1.00 except 2:1P intercropping treatment. LER followed the trend of MEY and varied significantly due to population proportion of

component crops. Maximum LER was recorded from 2:2P planting of maize-soybean while in treatment 2:1P, LER was observed only 1.0, means there was no loss or gain in yield due to intercropping of maize with soybean. This LER value was a result of significant reduction in maize grain yield due to closer planting in paired rows at 45 cm which was equally compensated by soybean grain yield in terms of MEY. The reason for greater LER in other intercropping treatments was because of higher MEY due to maximum complementary use of available resources in intercropping treatments by the component crops. These results were in agreement with that of Mandal *et al.* (2014).

Economic analysis

The cost of cultivation was considerably high in intercropping system than sole cropping. It was result of additional input and laborer's requirement for intercrop soybean in addition to maize crop accompanied with much higher costs of legume seeds than maize seeds. All intercropped treatments gave higher gross return over sole maize. Treatment 2:2P planting proportion gave relatively higher gross return over other sole crops and intercrop treatments. However, soybean intercropped with maize at 2:1A and 2:1P planting of maize yielded relatively lower net return than sole maize. As net return is the product of subtraction of cost of cultivation from gross return, higher treatment cost of all intercropped treatment than sole maize was the reason for less net return from some of the intercropped maize treatments as compared to sole maize. Sole soybean and 1:1R planting of maize gave higher net return over the other treatments because of least cost of cultivation and more grain yield of soybean. Treatments 1:1R, sole soybean, 2:1R and 2:2 P recorded 93.07, 84.25, 49.96 and 26.02% higher net return over the sole maize, respectively because of relatively lower cost of cultivation in these treatments even though the gross return in these treatments were relatively lower. However, intercropping with 2:1P, 2:1A and 1:1A population treatments recorded 56.79, 22.91 and 13.27 % lesser net return respectively as compared to sole maize even though the gross return in these treatments was much higher than sole maize. But relatively higher cost of cultivation was responsible for actual low return from these treatments. B:C ratio also followed the trend of net return sole soybean has higher B:C ratio followed by 1:1R and 1:1A. The results confirm the finding of Padhi and Panigrahi (2006) and Yogesh *et al.* (2014).

Soil biochemical properties

The residual effect of various population proportions of component crops in maize-soybean intercropping on soil fertility was studied on chemical (soil pH, organic carbon and available N, P and K) and biological (SMBC and DHA) properties after harvest as compared to initial status. For available N and P, sole soybean recorded significantly higher over the other treatments. Higher fixation of atmospheric N through BNF coupled with significantly higher leguminous population in sole soybean and better availability of growing

environment. Although other treatments recorded more available P than its initial soil status, sole maize recorded decline in P status. Maximum P solubilisation was also reported from sole soybean and relatively higher soil available P was analyzed in maize-soybean intercropping treatments than the sole maize. This was due to positive leguminous effect of soybean on soil microbial properties. SMBC was recorded significantly higher in 2:1R and sole maize treatment but at par with all other remaining treatments. Maximum DHA recorded from 2:2P treatment which was at par with 1:1A but significantly superior over all the sole and intercropped treatments. The significance of higher SMBC and DHA in intercropped treatments was the result of positive leguminous effect on soil properties which resulted in higher microbial population and their greater activities due to presence of higher amount of nitrogen rich organic matter in soil. Highest availability of K in sole soybean was because of low uptake in comparison to sole maize and other intercropped treatments. Similar results of maize-soybean intercropping on soil biochemical properties were also observed by Padhi and Panigrahi (2006) and Mandal *et al.* (2014).

Thus raising of one row of maize alternate with one row of soybean in replacement planting of maize, spaced 45 cm apart, under rainfed condition during *kharif* proved most compatible, economically viable and superior to other intercropping treatments. On the basis of present investigation it was observed that treatment 1:1R was a better alternate for maize-soybean intercropping as it gave significantly higher MEY, LER, net return and B:C ratio over sole maize. This treatment also recorded higher available N in soil over sole maize after crop harvest.

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