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Research Paper

Advantage of maize (*Zea mays*)-based intercropping system to different nutrient-management practices

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ABSTRACT

A field experiment was conducted during (*pre-kharif*) (February–May) seasons of 2014 and 2015 at the Instructional Farm, Pundibari, Cooch Behar, West Bengal, to evaluate the effect of maize (*Zea mays* L.) intercropped with cowpea [*Vigna unguiculata* L.) and nutrient-management practices on yield attributes, yield, nutrient uptake and competition indices. Among the cropping system, sole crop resulted in the highest yield attributes, grain yield (3,913 kg/ha), stover yield (6,565 kg/ha), harvest index (37.21%), uptake of nitrogen (101.36 kg/ha), phosphorus (19.80 kg/ha) and potassium (110.90 kg/ha). However, growing of maize as an intercrop with cowpea in a 2 : 2 row ratio resulted in the highest grain yield (3,249 kg/ha), stover yield (5,707 kg/ha) and harvest index (36.19%) than 2 : 4 row ratio combination. Among the nutrient-management practices, 75% recommended dose of fertilizer (RDF) + phosphate-solubilizing bacteria (PSB) + *Azotobacter* + vermicompost (VC) @ 5.0 t/ha resulted in the highest yield attributes, grain yield (3,684 kg/ha), stover yield (6,207 kg/ha), harvest index (37.14%) and NPK uptake. However, productivity system in terms of maize-equivalent yield (MEY), land-equivalent ratio (LER), relative crowding coefficient (RCC), competition index (CI), aggressivity, competition ratio (CR), land-equivalent coefficient (LEC), area time-equivalent ratio (ATER) and monetary advantage was found to be higher in 2 : 2 row ratio, followed by 2 : 4 row ratio combination. Thus, maize intercrop with cowpea in 2 : 2 row ratio combination and supplied with 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t/ha (N_3) improved the productivity of sole crop as well as intercrop system.

Key words : Maize, Cowpea, Competition function, Nutrient uptake, Yield attributes, Yield

Maize is the world's widely grown highland cereal and primary staple food crop in many developing countries (Ram *et al*., 2017). In India, it is the third most important food crop after rice and wheat with a production of about 28.72 million tonnes in 2017 (FAO, 2019) and contributes to the nearly 9% of the national food basket (Jeet *et al*., 2017). In West Bengal, it occupies 0.16 million ha of the area, with a production of 0.72 million tonnes and productivity of 4,615 kg/ha (MoAFW, 2016). In North Bengal, *pre-kharif* (February–May) maize is gaining popularity among the farmers primarily because of the optimum yield potential owing to residual supply of nutrients from previous crops. However, inadequate supply of nutrients during *pre-kharif* season in this region is the major cause for low grain yield. Generally, maize is a heavy feeder crop, requires more amount of nutrients than other crops. In order to meet the nutritional requirements, farmers are applying large quantities of inorganic fertilizers without understanding its negative impact on future soil health as well as environment health. There is some evidence of decline in productivity of *pre-kharif* maize even with the application of recommended dose of fertilizer because soils are deficient in nutrients, especially nitrogen, phosphorus and potassium. Continuous growing of a same crop over the years on the same cultivated area leads to ill soil health. However, to overcome this problem during *pre-kharif* season, introduction of grain legume in cereal-based cropping system aims at increased productivity and profitability to achieve food and nutritional security and sustainability (Swaminathan, 1998). Various intercropping patterns of legumes and non-legumes have been a central feature of many agricultural systems in tropics and subtropics (Willey, 1979; CIAT, 1986). Thus, better management of nutrients is especially important for increasing crop production of maize–cowpea intercropping system in *tarai*

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region (foot-hills) of West Bengal. Hence, this study was carried to find out the effect of nutrient-management practices on yield attributes, yield, NPK uptake and competitive indices in maize and cowpea intercropping system.

MATERIALS AND METHODS

A field experiment was conducted during *pre-kharif* seasons February to May of 2014 and 2015 at the Instructional Farm, Uttar Banga Krishi Vishavidyalaya, Pundibari, Cooch Behar (26°19’86" N and 89°23’53" E, 43 m above mean sea-level), West Bengal. The climatic condition of *tarai* zone is sub-tropical, with eminent characteristics of rainfall, high humidity and prolonged winter. The soils are mostly sandy to sandy loam in texture, porous and greyish black, having sand (64.19%), silt (20.47%) and clay (15.34%) organic carbon (0.85%), total nitrogen (211.5), available phosphorus (19.2) and available potassium (112.9) with *p*h. The experiment was laid out in a split-plot design with 3 replications. Four levels of cropping system [sole maize, sole cowpea, maize + cowpea (2 : 2 replacement series) and maize + cowpea (2 : 4 replacement series)] were assigned to main plots and 4 levels of nutrient management, viz. 100% recommended dose of fertilizer (RDF) 80 : 40 : 40 kg/ha of N: P_2O_5: K_2O, 100% RDF + phosphate-solubilizing bacteria (PSB) + *Azotobacter*, 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t/ha and 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha), in subplots. In maize composite variety ‘RCM’ and seed rate 20 kg/ha were used. Sowing was done in the lines with the help of tyne by opening a shallow furrow at uniform depth (3–5 cm), 45 cm row-to-row and 20–25 plant-to-plant spacing. In case of cowpea 20 kg/ha seed rate Lakki variety were used, adopting 30 cm row-to-row spacing, 10–15 cm plant-to-plant spacing and 3–4 cm depth. The results were analysed taking consideration of post-harvest parameters such as cob girth (cm), cob length (cm), cobs/plant, 100-grain weight (g), grain rows/cob, grains/cob, grain weight/cob (g), grain yield (kg/ha), stover yield (kg/ha), harvest index (%), nitrogen, phosphorus and potassium uptake (kg/ha). However, for cowpea pods/plant, seeds/pods, 1,000-seed weight, seed yield (kg/ha), stover yield (kg/ha) and harvest index (%).

Maize-equivalent yield (MEY) was calculated as:

$$\text{Maize-equivalent yield} = \frac{\text{Yield of cowpea} \times \text{price of cowpea/kg}}{\text{Price of maize/ kg}}$$

Land-equivalent ratio (LER), relative crowding co-efficient (RCC), competition index (CI), aggressivity, competitive ratio (CR), area-time equivalent ratio (ATER) and land-equivalent coefficient (LEC) were calculated as per Willy and Osiru (1972), Dewit (1960), Donald (1963), Mc Gilchrist (1965), Willey and Rao (1980), Heibsch (1980) and Adetiloye and Ezedinma (1983) respectively.

Monetary advantage (MA) was calculated as per the suggestion of Willey, (1979)

The data obtained from 2 years (2014 and 2015) studies were analysed statistically following split-plot design as per the procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield components of maize

The data on pooled basis revealed that, yield attributes of maize such as cob length, cob girth, 100-grain weight, cob/plant, grain/cob, rows/cob and grain weight/cob were significantly influenced by intercropping systems and nutrient-management practices (Table 1). Among the cropping systems, sole crop of maize revealed significantly higher values of yield attributes such as cob length cob girth cob/plant 100-grain weight rows/cob grains/cob and grain weight/cob than the other intercropping systems. Intercropping of maize with cowpea in 2 : 2 row ratio resulted in higher yield-attributing characters over 2 : 4 row ratio combination (Table 1). The increase of yield attributes in intercropping system might be owing to development of both temporal and spatial complimentarily because of which there was no competition for nitrogen and there was a possibility of current transfer of fixed nitrogen to the crop. The highest number of cob/plant was recorded when maize grown as sole crop but when maize grown as an intercrop, highest number of cob/plant was recorded under 2 : 2 row ratio combination followed by 2 : 4 row ratio combination (Table 1). Our findings are in close conformity with those of Singh *et al.,* (2000) and Shivay *et al.,* (2002). The nutrient-management practices were significantly influenced the yield attributing characters. From the pooled data, it was pertinent that the sole crop of maize produced highest cob length, cob girth, cob/plant, 100-grain weight, rows/cob, grains/cob and grain weight/cob under treatment receiving 75% RDF+ PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3) than the other treatments (Tables 1). Increase in yield attributes under nutrient-management practices might be owing to better utilization of applied nutrients through different source of nutrients by crop. According to Yadav *et al*. (2016), increase yield parameters of maize might be owing to inclusion of organic sources of nutrient such as vermicompost, *Azotobacter*, phosphate-solubilizing bacteria along with chemical fertilizers.

Yield components of cowpea

Pods/plant, seeds/pod and 1,000-seed weight were significantly reduced due to intercropping system compared to sole crop (Table 2). However, sole crop of cowpea more pods/plant, seeds/pods and 1,000-seed weight than the other treatments. Cowpea intercropped with maize in 2 : 4 row ratio recorded higher number of pods/plant, seeds/pods and 1,000-seed weight than 2 : 2 row ratio combination (Table 2). Cowpea intercrops with maize were shorter and could utilize lower percentage of incoming solar radiation. Cowpea was adversely affected in 2 : 2 row ratio combinations probably due to short stature of the crop and experienced shading effect of maize in the early stages of crop growth. As a result, decreasing trend was noticed for pods/plant, seeds/pods and 1,000-seed weight in 2 : 2 row ratio (Table 2). Patra *et al*., (2000) revealed that, the intercropping system recorded the lower number of pods/plant and seeds/pod as compared to sole crop. Cowpea and blackgram intercrop with maize in paired row (2:2) ratio combination significantly increased the yield attributes as reported by Naresh *et al,* (2014). Pods/plant, seeds/pod and 1,000-seed weight were significantly influenced by nutrient management practices (Table 2). Treatment received 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3) recorded maximum pods/plant, seeds/pod and 1,000-seed weight in sole crop of cowpea. However, lowest values of pods/plant (22.86), seeds/pod (17.25) and 1,000-seed weight (125.79 g) was recorded under 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha (N_4). This might be due to the proper utilization of space, nutrient, moisture and light or shading effect by main crop. Meena *et al.,* (2006) reported that application of 75% recommended dose of fertilizer to maize and 50% to soybean significantly increased the yields over 50% RDF in maize and no fertilizer in soybean.

Grain yield, stover yield and harvest index of maize

Grain and stover yield of maize decrease significantly when cowpea was intercropped with maize in 2 : 2 and 2 : 4 proportions. The highest grain (3,913 kg/ha) and stover yield (6,565 kg/ha) were recorded under sole maize than intercropping situation, which was owing to the more plant population per unit area. However, when maize intercropped with cowpea, the highest grain (3,249 kg/ha) and stover yield (5,707 kg/ha) were recorded under 2 : 2 row ratio than 2 : 4 row ratio (Table 2). The increase in grain and stover yields of maize under intercropping systems might be owing to favourable microclimate and biological nitrogen fixation process in cowpea. Our results confirm with the findings of Mandal *et al.,* (2014) and Devi Moirangthem and Singh (2018) in maize–legume intercropping systems. Application of 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3) significantly resulted in higher grain (3,684 kg/ha) and stover yield (6,207 kg/ha) in sole crop of maize than the other treatments. This was owing to the enhancement of yield attributes of maize, availability and absorption of applied nutrients and improved soil fertility. This result also confirm the findings of Majhi *et al.* (2018). Satyajeet *et al.* (2007) reported that, the application of 100% RDF in conjunction with vermicompost and biofertilizers significantly increased grain and stover yield of maize.

Harvest index reflects the partitioning of photosynthetic between the grain and the vegetative plant, and improvement in the harvest index emphasizes the importance of

Table 1. Effect of cropping system and nutrient management on yield attributes and yield of maize (pooled data of 2 years)

Treatment	Cob length (cm)	Cob girth (cm)	Cobs/ plant	100-grain weight (g)	Grains rows/cob	Grains/cob	Grain weight/cob (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Cropping system (C)										
C_1	15.54	14.84	1.53	33.02	14.72	294.27	76.64	3913	6565	37.31
C_3	15.05	13.81	1.49	31.56	13.88	279.31	73.24	3249	5707	36.19
C_4	13.84	13.10	1.38	29.80	12.92	245.50	70.07	2761	5179	34.65
SEm±	0.45	0.59	0.07	0.53	0.64	3.43	0.79	61.17	56.61	0.43
CD P=0.05)	1.58	1.72	NS	2.06	NS	13.39	3.09	179.5	221.0	1.68
Nutrient management (N)										
N_1	14.07	14.37	1.39	30.37	13.42	268.37	72.41	3188	5696	35.73
N_2	15.05	13.34	1.47	32.39	14.20	276.62	74.88	3394	5910	36.33
N_3	15.83	15.86	1.58	34.14	15.13	288.74	78.19	3684	6207	37.14
N_4	14.30	12.08	1.40	28.93	12.59	258.38	67.79	2964	5454	35.01
SEm±	0.46	0.09	0.03	0.50	0.41	3.70	0.87	70.63	115.4	0.78
CD (P=0.05)	1.38	0.34	0.10	NS	1.23	11.01	2.57	207.2	342.8	NS

C_1, Sole maize; C_2, sole cowpea; C_3, maize + cowpea (2 : 2); C_4, maize + cowpea (2 : 4); N_1, 100% recommended dose of fertilizer (RDF) 80 : 40 : 40 kg/ha of N: P_2O_5: K_2O; N_2,100% RDF + phosphate- solubilizing bacteria (PSB) + *Azotobacter;* N_3, 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t/ha; N_4, 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha carbon allocation for grain production. Among the cropping systems, the highest harvest index of maize was recorded under sole maize but when maize was intercropped with cowpea, higher harvest index of maize was recorded under 2 : 2 and 2 : 4 row ratios (Table 1). The pooled data showed that nutrient-management practices significantly influenced the harvest index of maize. Among the nutrient-management practices, the highest harvest index of maize was recorded in 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3). The lowest harvest index of maize (35.01%) was recorded under 50% RDF + PSB + *Azotobacter* + 50% vermicompost 2.5 t/ha (N_4) (Table 1).

Yield of cowpea

The highest seed (941 kg/ha) and stover yield (1429 kg/ha) were recorded under sole crop. However, cowpea intercropped with maize, the highest seed yield (763 kg/ha and 666 kg/ha) and stover yield (1207 kg/ha and 1007 kg/ha) were recorded under 2 : 4 row ratio combination followed by 2 : 2 row ratio combination (Table 2). Actual yield was slightly higher at 2 : 4 proportion of sowing than 2 : 2 proportion owing to receipt of higher amount of solar radiation. Tall-growing maize plants shaded the cowpea and the main reason for reduction in yield was probably due to the receipt of lower amount of incoming solar radiation which affected the rate of photosynthesis and thereby translocation of photosynthesis from source to sink. Decrease in yield of cowpea also occurred due to intercropped with maize as also reported by Patra *et al.,* (2000). Among the nutrient-management practices, the highest seed yield (835 kg/ha) and stover yield (1354kg/ha) were recorded under treatment which received 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3) but highest harvest index (40.15%) was recorded under 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5t/ha (N_4). This might be owing to application of organic and inorganic source of nutrients improved the physiochemical properties of soil, better utilization and movement of applied nutrients by crop. Our findings confirm those of Selim (2018).

Nutrient uptake

Nutrient uptake by maize and cowpea was influenced by the combination and proportion of intercropping situation (Table 2). The highest uptake of nitrogen, phosphorus and potassium was recorded under sole crop of maize compared to the intercropping systems. However, when maize was intercropped with cowpea the highest uptake of nitrogen, phosphorus and potassium were recorded under 2 : 4 than 2 : 2 row ratio (Table 2). This might be owing to the higher biomass and grain yield, as the uptake is the resultant of higher dry-matter content and percentage of nutrients content in crop. The increase of NPK uptake might be owing to the better utilization and supply of nitrogen by the cowpea intercropped with maize. Our result also support the findings of Pandey and Tiwary (2017) and Yamuna *et al*., (2017). The nutrient-management practices, significantly influenced the uptake of nitrogen, phosphorus and potassium (Table 2). The highest uptake of nitrogen, phos-

Table 2. Effect of cropping system and nutrient management on yield attributes and yield of cowpea and nitrogen, phosphorus and potassium uptake (pooled data of 2 years)

Treatment	Pods/ plant	Seeds/ pods	1000-seed weight (g)	Seeds yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Cropping system (C)									
C_1	-	-	-	-	-	-	101.36	19.80	110.90
C_2	29.17	22.11	131.94	941	1429	40.03	-	-	-
C_3	24.57	18.89	127.59	666	1007	39.80	91.77	16.38	103.89
C_4	26.39	20.56	129.39	763	1207	38.91	97.59	17.62	106.79
SEm±	0.54	0.93	0.59	0.06	0.55	0.95	0.52	0.29	0.93
CD (P=0.05)	2.09	2.85	2.31	0.22	2.14	NS	2.04	1.13	3.68
Nutrient management (N)									
N_1	25.83	19.48	128.50	778	1166	40.07	92.89	17.04	104.96
N_2	28.16	21.19	130.63	806	1237	39.57	98.29	18.37	108.88
N_3	30.01	23.49	133.63	835	1354	38.52	106.71	20.68	112.69
N_4	22.86	17.25	125.79	740	1100	40.15	89.75	15.65	102.25
SEm±	0.70	0.52	0.75	0.07	0.25	0.46	0.97	0.35	1.27
CD (P=0.05)	2.09	2.14	2.24	0.20	0.76	NS	2.90	1.04	3.77

C_1, sole maize; C_2, sole cowpea; C_3, maize + cowpea (2 : 2); C_4, maize + cowpea (2 : 4); N_1, 100% recommended dose of fertilizer (RDF) 80:40:40 kg/ha of N: P_2O_5: K_2O; N_2,100% RDF + phosphate-solubilizing bacteria (PSB) + *Azotobacter;* N_3, 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t/ha; N_4, 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha phorus and potassium was recorded with the treatment receiving 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3) than the other treatments (Table 2). Higher uptake of NPK might be owing to the combined application of organic and inorganic nutrients supplied which improved the soil fertility that increase the availability and better utilization of applied nutrients by the crops. Application of recommended dose of fertilizers in an integrated manner significantly influenced the higher uptake of primary nutrients in baby corn and horsegram intercropping system as reported by Sinha (2017).

Aggressivity

The maize and cowpea intercropping system revealed the highest aggressivity values under 2 : 4 row ratio combination. Aggressivity values were positive (+ve) in maize which obviously indicated that maize was the dominant crop, whereas the associated intercrops appeared to be the dominated ones having negative (-ve) values (Table 3). Between the 2 spatial arrangements, 2 : 4 proportion of intercropping resulted in higher values of aggressivity, which denoted higher interspecific competition (Table 3). Maize intercropped with cowpea and rice bean (2:1) was found to be a compatible intercropping system with lower values of aggressivity (0.01) (Sharma *et al.,* 2006).

Competitive ratio

Competitive ratio (CR) for maize was always higher compared with the associated intercrops and highest CR was recorded under 2 : 2 row ratio combination than 2 : 4 proportion (Table 3). Therefore, maize appeared to be more competitive and the subsidiary intercrops were found to be less competitive with respect to utilization of available resources. Competitive ratio was higher in maize and the CR value increased with an increase in competitive value of maize (Takim, 2012). This indicated that maize was more competitive than cowpea in all mix-proportions. However, increase in competitive ability of maize did not necessarily mean a decrease in competitive ability of legumes. Maize was found to be most competitive one when grown with cowpea at lower level of fertility. Maize + cowpea in 2 : 2 row ratio combinations were found superior to grain yield and parameters related to competitive ability than 2:4 row ratio combinations (Table 3).

Relative crowding coefficient (RCC)

Relative crowdung coefficient (RCC) values of maize were than unity indicating that species produced more yield than expected. However, the actual yield of cowpea was less than expected in 2 different row ratios. It was due to the less plant population and shading effect compared to the monocrop and different level of fertilizers. All the intercropping systems, by far, were found to be advantageous as the product values (k) were always greater than unity in 2 : 2 row ratio combination than 2 : 4 row ratio combination (Table 3). Our result support the findings of Dhima *et al.* (2007) in cereal-vetch intercropping.

Land-equivalent ratio

Among the intercropping systems, maize + cowpea recorded the highest land-equivalent ratio (LER) values under 2 : 2 row ratio combination, followed by 2 : 4 row ratio combination, indicating a considerable increase in resource- use efficiency at a higher dose of fertilizers (Table 3). The LER values in different intercropping systems were always greater than unity, indicating yield advantages from intercropping systems. Yield advantages occurred owing to the development of both temporal and spatial complementarities between maize and cowpea. This was owing to the better utilization of special and temporal utilization of land and natural resources in intercropping with additional advantage of cowpea and higher market price of cowpea, compared to sole cropping of maize and cowpea. Land-equivalent ratio was found more than 1 in all intercropping systems and the maximum LER in maize + cowpea (2 : 2) intercropping system compared to the 1 : 1 and 1 : 2 ratio as also reported by Kumar *et al.* (2005). However, LER did not reflect absolute level of yield but it was considered as an important variable for the yield target of an intercropping study (Sharma and Behera, 2009).

Monetary advantage

Intercropping system showed higher monetary advantage (MA) as compared to sole crop. The 2 : 2 proportion of intercropping fetched higher monetary advantage than 2 : 4 row ratio of maize + cowpea intercropping system. Row ratio of 2 : 4 sowing indicated less interspecific competition than 2 : 2 row ratio combinations (Table 3). As a whole, intercropping systems showed higher monetary advantage as compared to sole crops both in 2 : 2 (₹1,638) and 2 : 4 (₹1,456) row ratios. This result also confirm the findings of Kumar *et al.* (2005).

Area time equivalent ratio

The values of area time equivalent ratio (ATER) were also greater than unity in all the cases of intercropping systems. The 2 : 2 row ratio combination of sowing recorded the highest ATER values, which appeared to be advantageous and indicated higher productivity in comparison to monoculture (Table 3). This was owing to the greater resource use and resource complementarily when 2 species are grown together. The highest ATER value of the system established that growth requirement of both the component crops differs in time, resulting in higher per day yield of the

Table 3. Effect of cropping system and nutrient management on different competition indices, monetary advantage and maize-equivalent yield (pooled data of 2 years)

Treatment	Aggressivity		Competition ratio		Relative crowding coefficient		LER	ATER	Competition index	LEC	Monetary advantage (₹)	Maize-equivalent yield
Sole maize												
C_1N_1	–		–		–		–	–	–	–	–	3,805
C_1N_2	–		–		–		–	–	–	–	–	3,995
C_1N_3	–		–		–		–	–	–	–	–	4,246
C_1N_4	–		–		–		–	–	–	–	–	3,646
Sole cowpea												
C_2N_1	–		–		–		–	–	–	–	–	937
C_2N_2	–		–		–		–	–	–	–	–	951
C_2N_3	–		–		–		–	–	–	–	–	968
C_2N_4	–		–		–		–	–	–	–	–	903
Maize + cowpea (2:2)	maize	cowpea	maize	cowpea	maize	cowpea						
C_3N_1	0.234	-0.234	1.167	0.858	4.55	2.37	1.53	1.61	1.616	0.576	1,296	5,860.62
C_3N_2	0.249	-0.249	1.175	0.851	5.06	2.45	1.54	1.64	1.374	0.593	1,413	6,147.18
C_3N_3	0.263	-0.263	1.179	0.849	6.43	2.76	1.61	1.69	0.946	0.635	1,638	6,629.89
C_3N_4	0.223	-0.223	1.162	0.861	3.91	2.18	1.48	1.58	2.025	0.545	1,133	5,444.56
Maize + cowpea (2:4)												
C_4N_1	1.769	-1.769	0.440	0.569	1.13	1.87	1.49	1.56	2.286	0.547	1,098	5,715.13
C_4N_2	1.877	-1.877	0.433	0.579	1.25	2.38	1.54	1.61	1.620	0.591	1,277	6,126.57
C_4N_3	1.946	-1.946	0.431	0.580	1.41	2.95	1.60	1.66	1.182	0.630	1,456	6,575.34
C_4N_4	1.757	-1.757	0.433	0.578	1.02	1.72	1.45	1.52	2.775	0.520	962	5,331.01

LER, Land equivalent ratio; ATER, area-time equivalent ratio; LEC, land-equivalent coefficient; C_1, sole maize; C_2, sole cowpea; C_3, maize + cowpea (2 : 2); C_4, maize + cowpea (2 : 4); N_1, 100% recommended dose of fertilizer (RDF) 80 : 40 : 40 kg/ha of N: P_2O_5 : K_2O; N_2, 100% RDF + phosphate-solubilizing bacteria (PSB) + *Azotobacter*; N_3, 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t/ha; N_4, 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha

system due to temporal complemented effect. Maize + blackgram intercropping system (2 : 2) recorded the highest ATER value that was achieved owing to development of special complementarily as reported by Kheroar and Patra (2014).

Competition index

Competition index (CI) was the highest under 2 : 2 row ratio compared to 2 : 4 row ratio combination. This might be due to more number of maize plants/unit area, and lesser competition for space and nutrients under 2 : 2 row ratio compared to 2 : 4 row ratio which increased the yield of maize under this system (Table 3).

Land-equivalent coefficient

The land-equivalent coefficient (LEC) value was always greater than 0.25, indicating yield advantages in maize–cowpea intercropping system (2 : 2 and 2 : 4). The highest LEC was found under 2 : 2 row ratio combination (0.635) and 2 : 4 row ratio combination (0.630) owing to better spatial complementarily (Table 3). Different row proportion of maize with legumes, the land-equivalent co-efficient was higher in maize + legume in 1 : 2 proportions than in 1 : 1 proportion (Mohan *et al.*, 2005).

Maize-equivalent yield

Maize-equivalent yield (MEY) was higher in all the cases of intercropping than pure stand of maize. However, maximum maize-equivalent yield was recorded under 2 : 2 row ratio than 2 : 4 row ratio combination (Table 3). This might be owing to better utilization of applied nutrients and balanced competition between components crops. Hence, maize intercrop with cowpea, maize yield and extra yield of cowpea helped the increasing maize equivalent yield. Maize-equivalent yield was significantly higher in intercrops than sole crop of maize as also reported by Choudhary *et al.* (2014).

The combined application of organic and inorganic nutrients enhances availability and uptake of nutrients by the crop and significantly increases the productivity of maize and cowpea intercropping system.

From this study, maize–cowpea intercropping system in 2 : 2 row ratio along with 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3) would be the best combination with more productive, remunerative and advantages over sole cropping system as sustainable agriculture in *Tarai* Region of West Bengal.

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