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Effect of Integrated Nutrient Management Practices on Maize (*Zea mays* L.) Based Intercropping System under *Terai* Region of West Bengal

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To increase the area of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) Walp. intercropping system and also to create the awareness about the integrated nutrient management practices in intercropping system of farmers of this region.
Study Design: Split –plot design with three replications.
Place and Duration of Study: Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar during *pre kharif* season of 2014-2015.
Methodology: Four levels of cropping system C1- sole maize, C2-sole cowpea, C3-maize + cowpea (2:2) and C4- maize + cowpea (2:4) were assigned to main plots and four levels of integrated nutrient management N_1: 100% RDF (recommended dose of fertilizers) 80:40:40 kg ha^{-1} of N: P_2O_5: K_2O, N_2:100% RDF + phosphate solubilising bacteria (PSB) + *Azotobacter*, N_3:75% RDF + PSB+ *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} and N_4: 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t ha^{-1} for sub plot.

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Results: Among the cropping systems, yield attributes, yield and harvest index was recorded highest under sole crop of maize but when maize grown as intercrop 2:2 row ratio combinations produced highest yield attributes, yield and harvest index as compare to 2:4 row ratio combination. In case of integrated nutrient management, treatment supplied with 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} (N_3) produced highest yield attributes, yield and harvest index was recorded under 100% RDF + PSB + *Azotobacter* (N_2). However, the productivity of system in terms of LER, relative crowding co-efficient (RCC), competition ratio (CR) and aggressivity was found to be higher with 2:2 row ratio combination followed by 2:4 row ratio combination. Among the integrated nutrient management, the productivity of system in terms of LER, relative crowding co-efficient (RCC), competition ratio (CR) and aggressivity found to be higher under 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} (N_3).

Conclusion: It may be concluded that integrated nutrient management practices increases the yield attributes, yield, harvest index and competition function of maize and cowpea intercropping system and supplied with 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} (N_3) overall gain on sustainable basis.

Keywords: Cowpea; competition function; maize; yield attributes; yield.

1. INTRODUCTION

Maize (*Zea mays* L.) is an annual C_4 plant belonging to the grassy family Poaceae, with its origin in Central America. In West Bengal, maize is cultivated in an area of 128.7 thousand hectares with a production of 522.4 thousand tons [1]. In North Bengal, p*re kharif* maize are gaining popularity among the farmers primarily because of the optimum yield potential owing to residual supply of nutrients from previous crops.

Maize, in general being a heavy feeder, requires much more nutrients than compared to other crops and in order to meet those nutritional requirements the farmers are applying large quantities of inorganic fertilizers without understanding its negative impact in the fertility status of the soil as well as the concerned environment. However, continuously growing of a same crop over years in the same cultivated area leads to ill health of the soil, increases various pest and diseases and decline in productivity that can overcome by following alternate methods such as intercropping, relay cropping and mixed cropping. Introduction of grain legume in cereal based cropping system aims at increased productivity and profitability to achieve food and nutritional security and sustainability [2]. Various intercropping patterns of legumes and non-legumes have been a central feature of many agricultural systems in tropics and subtropics [3 and 4]. Intercropping or mixed cropping plays an important role in agriculture because of the effective utilization of resource, significantly enhancing crop productivity compare with that monoculture [5] and intercropping is widely accepted as a sustainable practice due to its yield advantage, high utilization efficiency of light, water and pest and diseases suppression [6].

Among different maize based cropping system, maize-cowpea is emerging as potential maize based cropping system in India. This cropping system practices increased, because of its value addition in food and it fits well in the intercropping system compare to green gram [7], it is also tolerant to abiotic and biotic stress. After certain period nutrition requirement by maize become more and waste material of pulses remains (after harvest) can be used as manure for maize. Thus, intercropping improves the utilization of available researches, root yield advantages and increases yield stability. Considering the above mentioned reason, this study was carried out to find out the effects of maize based intercropping as influenced by integrated nutrient management on yield attributes, yield and competitive function.

2. MATERIALS AND METHODS

The field experiment was conducted at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar during *pre kharif* season (early March) of 2014-2015 situated on the 26°19′86″ N and 89°23′53″ E, 43 m above mean sea level. The climatic condition of terai zone is sub-tropical in nature with eminent characteristics of rainfall, high humidity and prolonged winter. The topography of the land where the experiment was undertaken, medium high in situation endowed with good drainage facilities. During the last five years in the experimental field mostly paddy was cultivated in the kharif season and toria in the rabi season and the land is released after the harvesting of toria in the month of middle of January after that the field remained fallow. The soils are mostly sandy to sandy loam in texture, porous and grayish black in color. The bulk density and cation exchange capacity are also low in this region. As the soil is porous in nature, the water holding capacity of soil is very low in this region. The soil had pH 5.10, Organic carbon (0.86%), total nitrogen (210.3%), available phosphorous (17.98 kg/ha) and available potassium (111.85 kg/ha). Sources of nutrients- Nitrogen - as Urea, Phosphorus - as SSP (Single super phosphate), Potassium - as MOP (Muriate of Potash), VC= - vermicompost [N (0.59 & 0.61%), P (0.19 & 0.21%) and K (0.20 & 0.22%)] and bio fertilizers - *Azotobacter* and phosphate solubilising bacteria (PSB). The land was ploughed once by a tractor drawn plough and was followed by power tiller operation to have a loose and friable condition of the soil. Then the field was leveled by bullock drawn wooden ladder followed by removal of stubbles and weeds. After land preparation well decomposed vermicompost was applied as basal as per treatments. Nitrogen, phosphorus and potassium (80, 40 & 40 kg ha^{-1}) in the form of Urea, SSP and MOP was applied respectively to the soil as per the treatments. Half dose of N, full dose of P_2O_5 and K_2O were applied at the time of final land preparation and rest half dose of N was applied as top dressing after completion of the first weeding (25 DAS). Name of cultivar maize composite variety RCM-1 and cowpea cultivar name is Lakki. The experiment was laid out in a split –plot design with three replications. Four levels of cropping system C1- sole maize, C2- sole cowpea, C3-maize + cowpea (2:2) and C4- maize + cowpea (2:4) were assigned to main plots and four levels of integrated nutrient management N_1: 100% RDF (recommended dose of fertilizers) 80:40:40 kg ha^{-1} of N: P_2O_5: K_2O, N_2:100% RDF + phosphate solubilising bacteria (PSB) + *Azotobacter*, N_3:75% RDF + PSB+ *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} and N_4: 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t ha^{-1} for sub plot. 20 kg ha^{-1} seed rate was used for maize. 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 plant to plant 20-25 cm spacing was followed for maize in the North-South direction. 20 kg ha^{-1} seed rate was used for cowpea. 30 cm row to row and plant to plant 10-15 cm spacing with 3-4 cm depth was followed in the north-south direction. The results were analyzed taking consideration of post harvest parameters were number of cobs $plant^{-1}$, number of grain cob^{-1}, 100-grain weight (g), grain yield (q ha^{-1}), stover yield (q ha^{-1}) and harvest index (%). Competition function likes aggressivity [8], competition ratio (CR) [9], relative crowding co-efficient (RCC) [10] and examined in details by Hall [11], LER [12]. The data obtained from two years (2014 and 2015) studies were analyzed statistically following split- plot design as per the procedure given by Gomez and Gomez [13].

3. RESULTS AND DISCUSSION

3.1 Effect of Cropping System and Integrated Nutrient Management on Yield Attributes of Maize

Irrespective of cropping system and integrated nutrient management yield attributes as more in first year than in second year due to more vigorous growth of the crop in second year which was reflected on yield attributes of maize. Among the cropping systems sole crop of maize significantly produced highest yield attributes viz. cob length, cob girth, number of cob $plant^{-1}$, 100 grain weight, number of rows cob^{-1}, number of grains cob^{-1} and grain weight cob^{-1} (Table 1). Among the intercropping cropping system (maize + cowpea) the highest yield attributing was recorded under 2:2 row ratio combination followed by 2:4 row ratio combination (Table 1). The number of cobs $plant^{-1}$ and number of grains cob^{-1} were influenced significantly when maize was intercropped with legume, viz. cowpea and there was an increasing trend with respect to sole maize due to the development of both temporal and spatial complimentarily as a result of which there was no competition for nitrogen and there was a possibility of current transfer of fixed nitrogen to the cereal crop like maize. The highest number of cob $plant^{-1}$ were recorded when maize grown as sole crop but when maize grown as intercrop highest number of cob $plant^{-1}$ were recorded under 2:2 row ratio combination followed by 2:4 row ratio combination (Table 1). The increment of yield in sole maize is only due to less competition for sunlight, space, water and nutrients [14]. Hundred grain weight of maize was significantly influenced due to the practice of its intercropping with others but there was an increasing trend when legumes were intercropped with maize. Singh et al. [15] showed that the legumes when intercropped with maize improve and increased the yield attributes of maize viz. cob length, cob girth, number and grain weight, cobs $plant^{-1}$ and 100 grain weight. The yield attributes viz. length and girth of cob, number and weight of grains cob^{-1}, cob plant^{-1}, number of rows cob^{-1} and 100 grain weight were also increased by intercropping legumes (Table 1).

The influence of integrated nutrient management on yield attributing characters viz. number of rows cob^{-1}, 100 grain weight, number of grain cob^{-1}, length and girth of cob, grain weight cob^{-1} and number of cob plant^{-1} (Tables 1) were recorded highest under treatment receiving 75% RDF in combination with PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} (N_3) when maize was grown as sole crop but when maize grown as intercrop highest yield attributing characters viz. number of rows cob^{-1}, 100 grain weight, number of grain cob^{-1}, length and girth of cob, grain weight cob^{-1} and number of cob plant^{-1} were recorded under 2:2 row ratio combination followed by 2:4 row ratio combination. It might have been owing to better utilization of resources, availability and absorption of nutrient by crop. Rana et al*.* [16] revealed that intercropping systems were superior to sole crop. The maize as well as legumes yield attributes and yields in intercropping systems was higher where 100% of NPK dose was applied compared to 50% NPK dose.

3.2 Effect of Cropping System and Integrated Nutrient Management on Grain Yield, Stover Yield and Harvest Index of Maize

Grain yield of maize was increased when intercropped with legume like cowpea. Similarly stover yield was also increased when legume like cowpea were intercropped both at 2:2 and 2:4 proportions. The highest grain yield and stover yield were recorded under sole maize compared to the intercropping situation this was due to the more number of plant population per unit area. But when maize intercrop with cowpea the highest grain and stover yield were recorded under 2:2 row ratio combination followed by 2:4 row ratio combination (Table 2). Mandal et al*.* [17] also reported that grain yield and stover yield of maize was significantly higher in case of sole crop of maize compared to intercropping systems with legumes (maize with soybean and groundnut intercrops). The yield advantage of maize in intercropping systems with legumes probably occurred from the difference in the timing of utilization of resources by crop from soil layers, especially during peak vegetative and reproductive stages of growth, thus resulting in both temporal and spatial complementarities. Also, the increase in grain yield of maize might be resulted from maize-legume association due to symbiotic nitrogen fixation by legumes and current transfer of nitrogen to the associated maize plants (Table 2). Padhi and Panigrahi [18] reported that maize with soybean and blackgram significantly recorded highest maize grain yield and stover yield. Intercropping of maize with cowpea had significant effects on grain yield, stover yield and improved soil fertility as reported by Dahmardeh, et al*.* [19].

Integrated nutrient management on grain and stover yield of maize significantly increased in treatment receiving 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} (N_3) compared to the other treatments when maize grown as sole crop but when maize grown as intercrop highest grain and stover yield were recorded under 2:2 row ratio combination followed by 2:4 row ratio combination (Table 2). This was due to enhanced yield attributes of maize, available nutrients and improves soil fertility. Misra et al*.* [20] reported that application of 100% recommended dose of fertilizers to intercrop increased significantly maize and lentil yield. Satyajeet et al*.* [21] reported that the pooled grain yield was recorded highest with 100% RDF in conjunction with vermicompost and biofertiliser.

Among the cropping systems, the highest harvest index of maize (36.96 and 37.56) was recorded under sole crop of maize but when maize intercropped with cowpea, higher harvest index of maize (35.68 and 36.71) was recorded under 2:2 row ratio combination followed by 2:4 (33.97 and 35.32) row ratio combination(Table 2). Among the integrated nutrient management practices, highest harvest index of maize (36.43 and 37.85) was recorded in 75% RDF + PSB + *Azotobacter* + vermicompost (VC) @ 5.0 t ha^{-1} (N_3). The lowest harvest index of maize (34.73 and 35.29) was recorded under 50% RDF + PSB + *Azotobacter* + 50% vermicompost 2.5 t ha^{-1} (N_4) (Table 2).

3.3 Effect of Cropping System and Integrated Nutrient Management on Competition Functions

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 (Figs. 1 and 2). Between the two spatial arrangements,

Table 1. Effect of cropping system and integrated nutrient management on yield attributes of maize

Treatments	Cob length (cm)		Cob girth (cm)		Cob plant^{-1}		100-grian weight (g)		Rows cob^{-1}		Grain cob^{-1}		Grain weight cob^{-1}	
Cropping system (C)	**YI**	**YII**	**YI**	**YII**	**YI**	**YII**	**YI**	**YII**	**YI**	**YII**	**YI**	**YII**	**YI**	**YII**
C1	15.45	16.18	14.36	15.38	1.47	1.56	32.70	33.74	14.20	15.23	292.38	296.16	75.11	78.04
C3	14.25	15.36	13.31	14.27	1.41	1.48	30.96	31.96	13.19	14.56	276.97	281.66	71.49	74.44
C4	13.50	14.31	12.49	14.01	1.35	1.42	29.49	30.48	12.25	13.58	242.77	248.23	68.97	71.59
S. Em(±)	**0.35**	**0.72**	**0.26**	**0.94**	**0.06**	**0.14**	**0.58**	**0.72**	**0.75**	**0.89**	**4.50**	**5.34**	**1.74**	**1.73**
C.D. (0.05)	**1.38**	**2.15**	**1.02**	**2.92**	**NS**	**0.48**	**2.29**	**2.16**	**NS**	**2.66**	**17.60**	**20.88**	**NS**	**5.14**
Integrated nutrient management (N)														
N1	14.11	14.84	12.94	14.14	1.38	1.44	30.19	31.42	12.93	13.91	266.57	270.18	73.58	72.41
N2	14.71	15.69	13.83	14.93	1.43	1.50	31.61	32.77	13.53	14.88	273.86	279.37	75.71	74.88
N3	15.33	16.57	14.29	15.71	1.50	1.60	33.97	34.65	14.46	15.80	286.01	291.47	79.13	78.19
N4	13.45	14.03	12.49	13.43	1.32	1.40	28.42	29.40	11.93	13.24	256.39	260.38	70.34	67.79
S. Em(±)	**0.93**	**0.53**	**0.82**	**0.61**	**0.11**	**0.09**	**1.00**	**0.90**	**0.80**	**0.26**	**2.93**	**6.74**	**0.61**	**0.87**
C.D. (0.05)	**NS**	**1.60**	**NS**	**2.15**	**NS**	**0.25**	**NS**	**NS**	**NS**	**1.01**	**8.70**	**20.05**	**2.38**	**2.57**

YI=2014 and YII= 2015, C_1: sole maize, C_3: maize +cowpea (2:2), C4: maize + cowpea (2:4), N_1: 100% RDF 80:40:40 kg/ha of N: P_2O_5: K_2O, N_2:100% RDF + phosphate solubilising bacteria (PSB) + Azotobacter, N_3:75% RDF + PSB + Azotobacter + vermicompost (VC) @ 5.0 t ha^{-1}, N_4:50% RDF + PSB + Azotobacter + 50% vermicompost @ 2.5 t ha^{-1}

Table 2. Effect of cropping system and integrated nutrient management on yield of maize

Treatments	Grain yield (q ha^{-1})		Stover yield (q ha^{-1})		Harvest index (%)	
Cropping system (C)	**YI**	**YII**	**YI**	**YII**	**YI**	**YII**
C1	37.7	40.5	64.4	66.9	36.96	37.65
C3	31.2	33.8	56.0	58.1	35.68	36.71
C4	26.3	28.9	50.9	52.7	33.97	35.32
S. Em(±)	**1.19**	**1.33**	**1.15**	**1.09**	**0.64**	**0.63**
C.D. (0.05)	**3.53**	**3.95**	**4.51**	**4.28**	**NS**	**NS**
Integrated nutrient management (N)						
N1	30.3	33.4	55.9	58.1	35.04	36.40
N2	32.8	35.1	58.1	60.1	35.95	36.70
N3	35.4	38.3	61.5	62.6	36.43	37.84
N4	28.4	30.9	52.8	56.2	34.73	35.29
S. Em(±)	**0.74**	**0.63**	**1.42**	**1.28**	**0.99**	**0.99**
C.D. (0.05)	**2.89**	**2.46**	**4.24**	**3.79**	**NS**	**NS**

YI=2014 and YII= 2015, C_1: sole maize, C_3: maize +cowpea (2:2), C4: maize + cowpea (2:4), N_1: 100% RDF 80:40:40 kg/ha of N: P_2O_5: K_2O, N_2:100% RDF + phosphate solubilising bacteria (PSB) + Azotobacter, N_3:75% RDF + PSB + Azotobacter + vermicompost (VC) @ 5.0 t ha^{-1}, N_4:50% RDF + PSB + Azotobacter + 50% vermicompost @ 2.5 t ha^{-1}

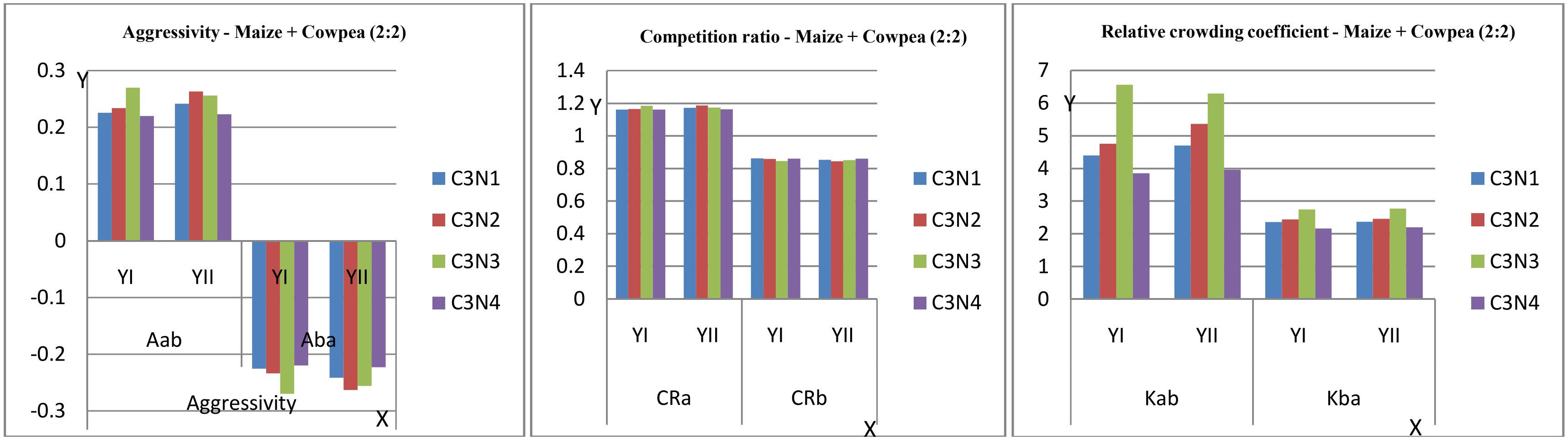

Fig. 1. Effect of cropping system and nutrient management on aggressivity, competition ratio and relative crowding coefficient

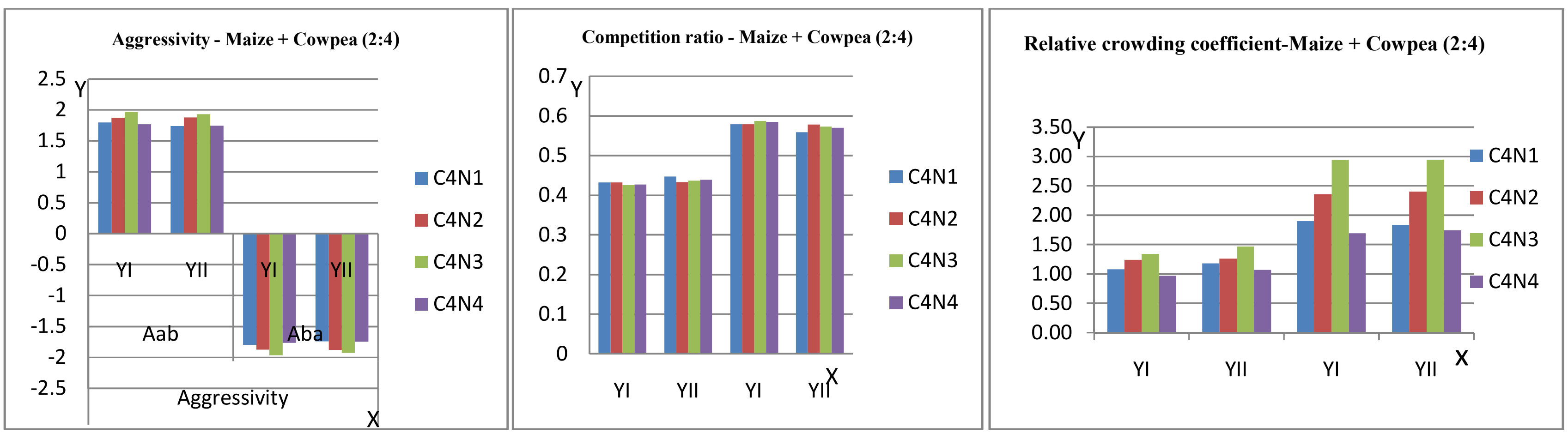

Fig. 2. Effect of cropping system and nutrient management on aggressivity, competition ratio and relative crowding coefficient

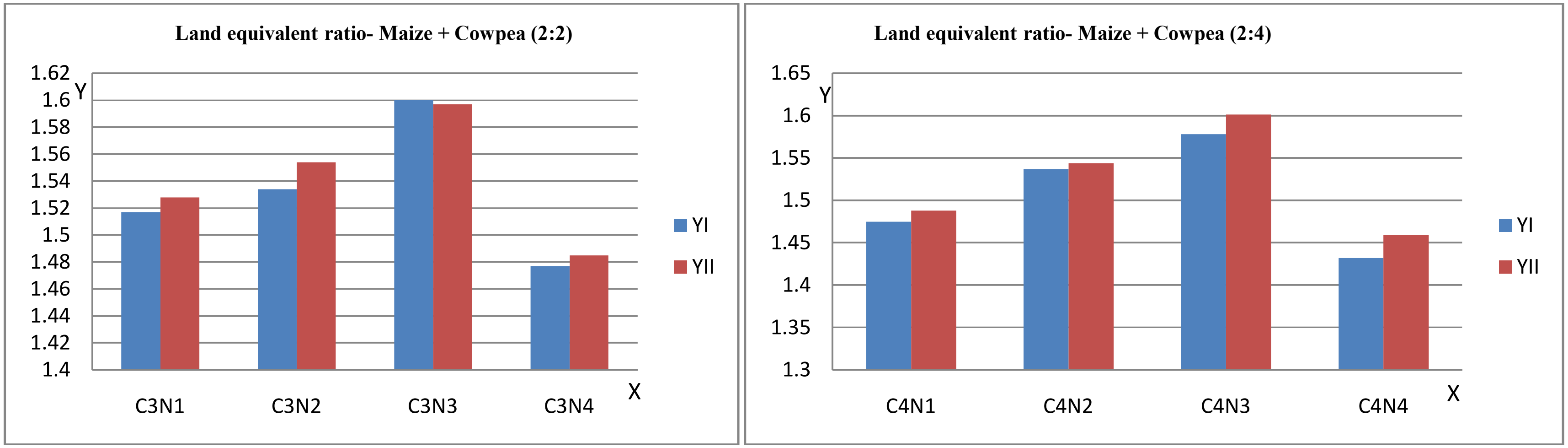

Fig. 3. Effect of cropping system and integrated nutrient management on land equivalent ratio

2:4 proportion of intercropping resulted in higher values of aggressivity which denoted higher interspecific competition (Fig. 1 and 2). However, it was reported from other instances that increase in dry matter occurred when corn was released from self competition and bordered by the competitive crop [22]. Sharma et al. [23] also reported that maize intercropped with cowpea and rice bean both (in row proportion 2:1) was found to be a compatible intercropping system with lower values of aggressivity (0.01).The highest aggressivity values were recorded for maize + cowpea (2:4 row ratio combination) intercropping system (Figs. 1 and 2).

Competitive ratio (CR) for maize was always higher compared with the associated intercrops and higher competitive ratio of maize was observed at 2: 2 proportion of intercropping than 2: 4 proportions (Fig 1and 2). So, maize (being a C_4 plant) appeared to be more competitive and the subsidiary intercrops were found to be less competitive with respect to utilization of available resources. Takim [24] reported that competitive ratio was higher in maize and the CR value increased with an increased A value of maize. This indicated that maize was more competitive than cowpea in all mix-proportions. Padhi and Pangrahi, [18] reported that maize was more competitive with legumes viz. groundnut and soybean having higher values of competition ratios but it was less competitive with blackgram in different row ratios. However, increased 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 superior to grain yield and parameters related to competitive ability than 2:4 row ratio combinations (Fig 1 and 2). The highest competitive ratio was recorded in 2:2 row ratio (maize + cowpea) intercropping system. Groundnut intercropped with pigeon pea in 5:2 or 4:2 row ratio combinations was most remunerative in respect of competitive ratio as reported by Dutta and Bandhopadyay [25].

Relative crowding co-efficient values of maize were found to be greater than unity indicating that species produced more yield than expected. However, the actual yield of cowpea was less than expected in two 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 (Figs. 1 and 2). This result is in conformity with Dhima et al. [26] in cereal-vetch intercropping.

The LER values in different intercropping systems were always greater than unity indicating yield advantages from intercropping systems. Yield advantages occurred due to the development of both temporal and spatial complementarities between maize and cowpea. Similar observations were also made by Ghanbari et al., [27]. Among the intercropping systems, maize + cowpea recorded the highest LER values under 2:2 row ratio combination (LER 1.600, C3N3) in first year but in second year the highest LER values were recorded under C4N3 (1.601) i.e. 2:4 row ratio combination indicating a considerable increase in resource use efficiency at a higher dose of fertilizers (Fig 3). This was due 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. Similar observations made by Sharma & Behera [28] and Meena et al. [29]. This results also corroborated by in maize and soybean intercropping system with different fertility levels. Kumar et al. [30] indicated that the land equivalent ratio more than 1 in all intercropping system and maximum LER in maize + cowpea (2:2) intercropping system compare to the 1:1 and 1:2 ratio. However, maize intercropped with French bean in 2:2 row ratio recorded the highest LER (1.35) followed by maize + cowpea in 1:1 row ratio (1.18) and established their superiority to the monocultures of component crops with 35 and 18 per cent more land use efficiency (Padhi) [31].

4. CONCLUSION

It may be concluded that maize grown as intercrop with cowpea in 2:2 row ratio combinations and supplied with 75% RDF + PSB + *Azotobecter* + vermicompost @ 5.0 t/ha (N_3) is best for obtaining overall gain.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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