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Interspecific competition, growth and productivity of maize and pea in intercropping mixture

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Key words: Competitive ratio, dry matter accumulation, land equivalent ratio, intercropping.

Abstract

A field trial was conducted to study the interspecific competition, growth and productivity of maize and pea in intercropping mixture in the department of Crop Botany, Bangladesh Agricultural University from November 2009 to April 2010. In this intercrop association, maize was considered as main crop and pea as intercrop. The experiment comprised of four treatments namely, (i) sole maize, (ii) sole pea, (iii) single row intercropping mixture (1M:1P i.e. single row of maize followed by single row of pea), and (iv) double row intercropping mixture (1M:2P i.e., single row of maize followed by double rows of pea). Dry matter accumulation in cob/pod of each population plants was the maximum in sole cropped plants while that was found minimum in 1M: 2P intercropped plants especially for pea while 1M: 1P intercropped plants ranked intermediate. The 1M:2P combined maize and pea mixture produced maximum seed yield (7.82 t ha^{-1}) which was about 10, 28 and 47% higher yield than the yield obtained from 1M:1P combined mixture stands (7.04 t ha^{-1}), sole maize (5.65 t ha^{-1}) and sole pea (4.15 t ha^{-1}), respectively. The single and double row combined intercropping mixtures gave the highest land equivalent ratio (1.31 and 1.47) and area time equivalent ratio (1.33 and 1.25, respectively). In both 1M: 1P and 1M: 2P intercropping mixtures, maize population exhibited strongly higher competition over pea. The 1M: 1P and 1M: 2P intercropping mixtures generated 1.44 and 1.71-fold higher maize equivalent yield as compared to the yield obtained from maize alone.

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Introduction

Maize (*Zea mays* L.) ranks after rice and wheat as the third most important cereal in Bangladesh. It is the highest grain-yielding crop having multiple uses as every part of the plant or its product is used in one form or the other. Grain can be used for human consumption in various ways, such as corn meal, fried grain, roasted cob or popped and corn flour. Maize starch can be compared with rice and wheat nutritionally, is used in the food, chemical, textile, paper and plastic industries. Green maize plants are grown mainly as fodder and its grains are used for human consumption and as dairy and poultry feed in many areas in Bangladesh (Awal and Khan, 2004). The production areas of maize are increasing day by day due to increase in poultry and dairy farms in the country. The farmers are also interested to grow it, so the maize crop has been included in the crop diversification programme in Bangladesh (Bhuiya *et al.*, 2005). Pea (*Pisum sativum* L.) is an important leguminous crop and has a tremendous value in agriculture as a good source of plant protein. It is used both as pulse and vegetable. Pea can play an important role in agro-economy and national health of Bangladesh. Pea seeds contain about 3-4 times as much protein and 2-3 times as much mineral as rice. It provides an important source of protein to human diets (Martin *et al.,* 1976). It can also be used as green fodder for animals. As legume, growing pea crops add substantial amount of atmospheric nitrogen to the soil by Biological Fixation System through *Rhizobium* bacteria in root nodules. Therefore, cultivation of maize and pea could mitigate carbohydrate, protein and other nutritional deficiencies in Bangladesh. Cultivation of maize and pea as sole crops require separate lands and/or, times which are critical as the arable land is gradually decreasing in Bangladesh. However, cultivation of these two crop species in intercropping mixture may save the land and time substantially. Intercropping is proved to be an excellent technique to increase total yield, higher monetary return, and greater resource utilization and fulfil the diversified needs of the farmers (Singh *et al.,* 1986). Although some cereal/legume intercrop associations are tested elsewhere (Ofori and Stern, 1987) but no study is yet to be reported on maize/pea intercropping under the agro-climatic conditions of Bangladesh. Crop compatibility is the most essential factor for a feasible intercropping system. Thus, the success of any intercropping system depends on the proper association of crop species where competition between them for natural resources is minimum (Awal *et al.,* 2006). Competition in intercropping can be reduced considerably through either judicious selection of crop species or by changing plant population i.e., spatial orientation of row spacing (Rahman *et al*., 2009). A careful selection of crop species could reduce the competition to a considerable extent (Singh, 1983). Maize is a tall stature cereal whereas pea is a short stature legume crop and in intercrop mixture they may also provide profitable return to the farmers. Therefore, the present study was undertaken to assess the suitability of pea plants as intercrop with maize stands and to find out the competition between maize and pea stands, and their growth and productivity in intercropping mixture as compared to their sole crops.

Materials and methods

Site and soil

The experiment was conducted at the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University (BAU), Mymensingh, during the period from November 2009 to April 2010. Soil of the experimental field was more or less neutral with a pH value of 6.7, low in organic matter and fertility level. The land type was medium high with silty loam texture.

Climate and weather

The region belongs to sub-tropical humid climate. Weather conditions during experimental periods are presented in Fig. 1.

Planting materials

A tall stature maize variety, BM-7 (BARI Maize-7) was used as dominant/principal crop while a short stature pea variety, BARI Pea-3 (Ashuri) was used as subordinate/companion crop in the intercropping system.

Experimental treatments and design

The experiment comprised of four treatments namely, (i) sole maize, (ii) sole pea, (iii) single row intercropping mixture (1M:1P i.e. single row of maize followed by single row of pea), and (iv) double row intercropping mixture (1M:2P i.e., single row of maize followed by double rows of pea). The experiment was laid out following randomized complete block design (RCBD) replicated thrice. Row to row distance was 100 cm for SM and 50 cm for SP. In 1M: 1P, row to row distance of maize was 100 cm where companion pea row were grown in between the maize row. The size of each unit plot was 5m×4m.

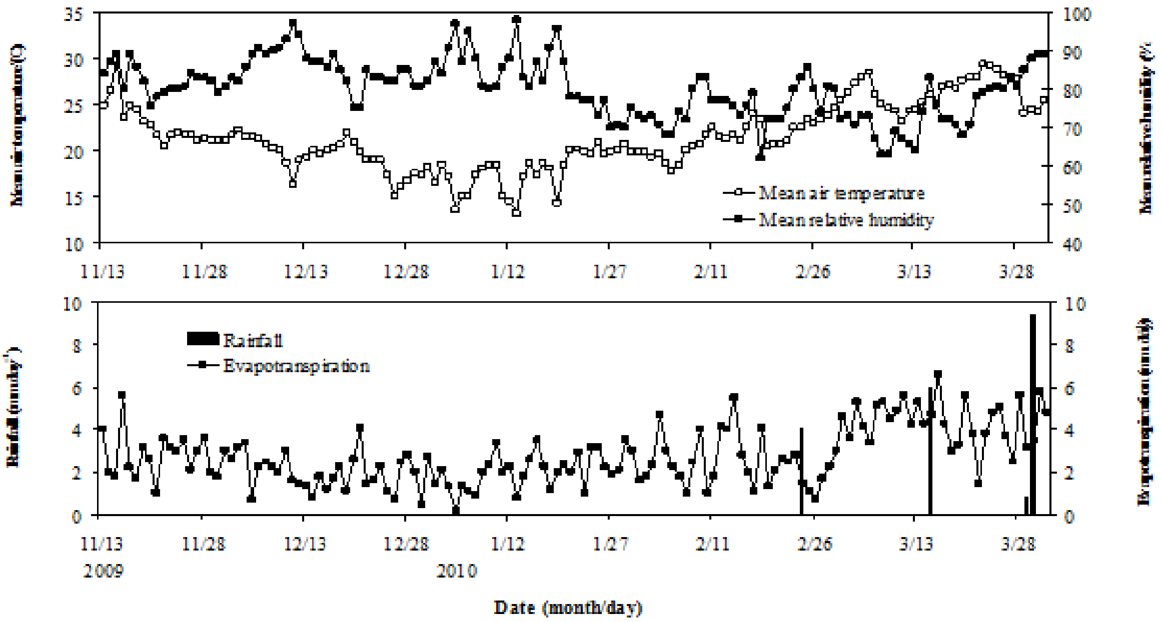

Fig. 1. Daily record of mean air temperature, relative humidity, total rainfall and evapotranspiration during the experimental period

Fertilizer management

The cowdung and the fertilizers of urea, triple super phosphate (TSP) muriate of potash (MOP), gypsum, zinc sulphat ($ZnSO_4$) and boric acid were applied in the plots corresponding to 217, 6.52, 9.73, 6.18, 0.608 and 0.434 kg/ha, respectively. At the time of final land preparation the total amount of cowdung, half of amount of total urea and entire dose of other fertilizers were mixed to the soil. Rest half of amount of the total urea was applied with two equal splits at 25 and 45 days after sowing (DAS).

Destructive sampling and data collection

The first sampling for recording data on different growth parameters was started at 30 DAS and continued at an interval of 10 days till maturity of pea on 80 DAS or maize on 140 DAS. The harvested plants were oven dried at 80±2°C till constant weight and their dry weight was recorded with an electronic balance. The data on growth, yield components and yield of the crops were collected.

Statistical analysis

The collected data on various parameters were compiled and statistically analyzed. Analysis of variance was calculated using the computer software program MSTAT-C (Russell, 1986). The mean differences were evaluated by LSD or Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

Results and discussion

Leaf area index (LAI)

The variation in LAI of maize and pea for different cropping systems has been presented in Figs. 2-3. Initial low LAI in all the treatment plants rapidly increased to a maximum at about 80 DAS in maize and 60 DAS in pea followed by a sharp decline with the advancement of maturity. Maize and pea plants in sole cropping maintained higher LAI throughout the growth period. The variation of LAI among the treatments could mainly be attributed for the variation of number of branches/plant. The initial slow rate of vegetative growth resulted little LAI which showed insignificant variation among the treatments. Subsequent reduction in LAI after vigorous growth was due to the abscission of leaves and senescence of older leaves in lower tiers (Watson, 1958). The result is supported by Uddin, 2008 in mustard/soybean intercropping.

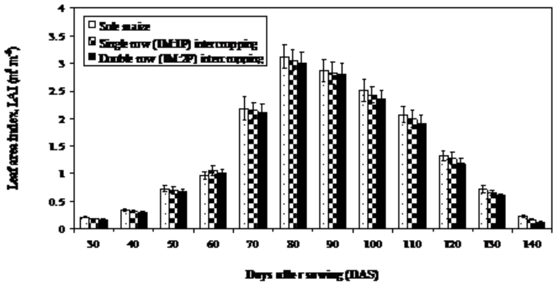

Fig. 2. Leaf area index of maize crop with time grown with sole and intercrop mixtures.

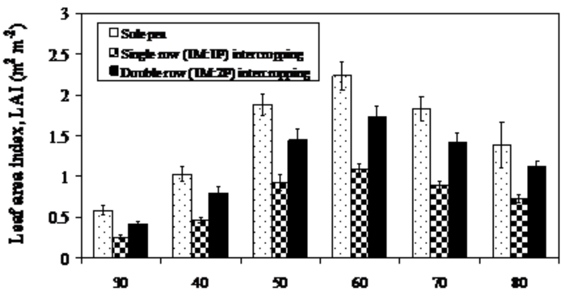

Fig. 3. Leaf area index (LAI) of pea crop with time grown with sole and intercrop mixtures.

Cob dry matter accumulation in maize

The cob dry matter was significantly affected by the various cropping systems (Fig. 4). Cob dry matter accumulation of maize increased exponentially throughout the grain filling period. At 140 DAS, sole maize crop produced maximum cob dry matter (517 g m^{-2}) followed by the cob DM of maize plants grown with single (504 g m^{-2}) and double row intercropping (481 g m^{-2}) mixtures, respectively. That is sole maize produced only about 2 and 7 % higher cob dry matter than that of the maize plants with single and double row intercropping, respectively. This result may be matched with the result of Hoque, (2007) in mustard/soybean mixture.

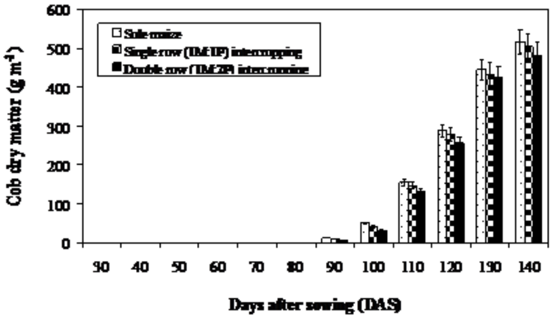

Fig. 4. Cob dry matter of maize crop with time grown with sole and intercrop mixtures.

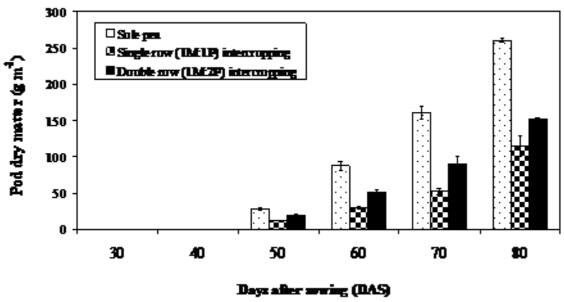

Fig. 5. Cumulative pod dry matter of pea crop with time grown with sole and intercrop mixtures.

Pod dry matter accumulation in pea

Pod DM accumulation was significantly affected by various intercropping systems (Fig. 5). Pod dry matter of pea rapidly increased throughout the pod filling period. At 80 DAS, sole pea plants accumulated maximum amount of pod dry matter (261 g m^{-2}) followed by double row (114 g m^{-2}) and single row intercropped plants (153 g m^{-2}). That is sole pea plants produced about 42 and 56% higher pod dry matter than that of the pod DM of pea plants grown with single row and double row intercropping, respectively.

Yield and Yield components

Number of cob plant^{-1} or pod plant^{-1}

Table 1. Yield contributing characters of maize crop at final harvest or physiological maturity under different cropping systems.

Cropping system	Yield components of Maize					Yield components of pea				
	No. of cob plant^{-1}	No. of seeds cob^{-1}	100-seed weight (g)	Seed yield (t ha^{-1})	Biological yield (t ha^{-1})	No. of pod plant^{-1}	No. of seed pod^{-1}	100-seed weight (g)	Seed yield (t ha^{-1})	Biological yield (t ha^{-1})
Sole cropping	1.74 a	415.40	16.82	5.65 a	17.25 a	16.67 a	4.05 a	57.54 a	4.15 a	10.54 a
Single row (1M:1P) intercropping	1.72 b	414.63	16.71	5.57 a	17.04 ab	14.52 ab	3.73 ab	55.7 c	1.47 b	5.73 b
Double row (1M:2P) intercropping	1.71 c	411.99	15.41	5.43 b	16.76 b	12.75 b	3.16 b	51.75 b	2.39 b	5.03 c
$S\bar{x}$	0.11	1.32	0.27	0.14	0.26	0.54	0.27	0.73	0.99	0.75
$LSD_{0.01}$	0.072	NS	NS	0.072	0.227	2.415	0.755	0.372	0.97	2.567

In a column, figures having common letter (s) do not differ significantly at 1% level of probability, and NS = not significant at 5% level of probability.

Table 2. Land equivalent ratio (LER), area time equivalent ratio (ATER) and competitive ratio (CR) of the partner stands of the intercrop or combined intercrop.

Crops in intercrop mixture	Single row (1M:1P) intercropping system			Double row (1M:2P) intercropping system		
	LER	ATER	CR	LER	ATER	CR
Maize (*Zea mays* L.)	0.98 b	0.98 b	3.26 a	0.96 b	0.96 b	3.88 a
Pea (*Pisum sativum* L.)	0.33 c	0.19 c	0.34 b	0.51 c	0.29 c	0.26 b
Combined intercrop	1.31 a	1.33 a	-	1.47 a	1.25 a	-
$S\bar{x}$	0.46	0.58	1.23	0.43	0.47	1.41
$LSD_{0.01}$	0.052	0.186	0.549	0.082	0.052	0.654

In a column, figures having dissimilar letters differ significantly at 1% level of probability

Table 3. Maize equivalent yield (MEY) of different intercropping systems.

Intercropping systems	Maize equivalent yield, MEY (t ha^{-1})
Sole maize (SM)	5.65 b
Singe row (1M:1P) combined intercropping	8.16 a
Double (1M:2P) combined intercropping	9.65 a
$S\bar{x}$	0.14
$LSD_{0.01}$	0.174

Within column, figures having dissimilar letters differ significantly at 1% level of probability.

The number of cob/plant or pod/plant is an important yield attribute in maize or pea crop. The highest number of cob/plant (1.74) was produced by sole cropped maize and lowest (1.71 cob/plant) by the double row intercropped (1M: 2P) plants (Table 1). The plants under single row intercropping mixture ranked intermediate. The pea plants grown under sole cropping produced highest number of pod (16.67) per plant and lowest (12.75/plant) by the double row intercropped (1M:2P) plants with the pod produced by the plants grown with single row intercropping system ranked in middle (Table 1). It might be caused due to less competition for nutrients, air, light, space and other components for the plants under sole cropping, which produced healthy plants along with more number of cob/plant or pod/plant.

Number of seed cob^{-1} or seed pod^{-1}

Sole maize plants produced maximum (415.40) number of seed per cob while minimum (411.99) was produced by the double row intercropped (1M: 2P) plants (Table 1). The plants under single row intercropping ranked intermediate. Similarly, in pea, sole pea plants produced (4.05) maximum number of seed/pod and minimum seed/pod (3.16) by the double row intercropped (1M: 2P) plants. Reduction in this yield attributes in mixture compare to sole cropping, especially in soybean, was expected and might be as a result of intra-and inter specific shading. Our results are supported by Awal *et al.* (2007a) in mustard/soybean intercropping and Rahman *et al.* (2009) in mustard/lentil intercropping.

Seed yield

It is revealed from yield of combined intercropping systems that there was significant variation among the different intercropping systems (Table 1). The double row 1M:2P combined (7.82 t ha^{-1}) or 1M:1P combined (7.04 t ha^{-1}) intercropping system produced maximum seed yield followed by the seed yield obtained from the sole cropped of maize (5.65 t ha^{-1}) or pea (4.15 t ha^{-1}). The 1M: 2P combined mixture stands produced about 28 or 47 % higher seed yield than that of the seed yield harvested from sole crops of maize or pea. In intercropping system, the yield reduction comparing to its sole crop might be attributed due to higher competition for light, space, nutrients and water. The results of combined yield are in full conformity with Awal *et al.* (2007a) in mustard/soybean intercropping, and Rahman *et al.* (2009) in mustard/lentil intercropping.

Biological yield

Different cropping systems showed significant variation in biological yield for maize as well as for pea. The highest biological yield (17.25 t ha^{-1}) was obtained from sole cropped maize which was about only 1 and 3% higher than that of the biological yield obtained from the maize crop grown under 1M:1P and 1M:2P intercropping systems, respectively (Table 1). However, in pea, highest biological yield (10.54 t ha^{-1}) was obtained from sole cropped stands which was about 46 and 52% higher biological yield than the pea grown under 1M:1P and 1M:2P intercropping systems, respectively.

The 1M:2P combined intercropping system produced the maximum biological yield (22.77 t ha^{-1}) which was about 24 and 54% higher biological yield produced by the plants with sole maize and sole pea, respectively. The increased production of biological yield in mixed cropped compared to maize grown alone mainly ascribed to more production of vegetation and biomass of the component crops.

Intercropping indices

Land equivalent ratio (LER)

The land equivalent ratio varied significantly due to the different spatial intercropping in maize with pea (Table 2). In 1M: 1P row intercropping system, combined intercrop results higher LER (1.31) followed by maize (0.98) and pea (0.33) partners i.e., the 1M: 1P combined intercropping mixture showed about 25 and 75% higher LER than that of maize and pea components. In double row intercropping system, combined intercrop also resulted the highest LER (1.47) which was about 35 and 65% higher than that of maize and pea partners, respectively. The 1M: 2P intercropping system was found to be better than 1M: 1P intercropping mixture in response of LER and the result is corroborated with the findings of Dhingra *et al.* (1991) in maize/mungbean intercropping.

Area time equivalent ratio (ATER)

Area time equivalent ratio was significantly affected by different intercropping systems (Table 2). In single row intercropping system, combined intercrop exhibited higher ATER (1.33) which crossed the unity (1.0) and was respectively about 17 and 85% higher than that of ATER from maize and pea partners. In double row intercropping system, combined intercrop mixture also showed highest ATER (1.25) which was about 23 and 77% higher than that of ATER obtained from maize and pea partners, respectively and the result is corroborated with the findings of Awal *et al.* (2007b).

Competitive ratio (CR)

Competitive ratio (CR) of maize and pea under different intercropping systems was calculated and the result is presented in Table 2. In both of intercropping systems, the maize partner strongly dominated over pea. The CR of maize both in 1M:1P (3.26) and 1M:2P row intercropping (3.88) for away even than unity which indicates that the genotypes used and the management practices applied in the experiment effectively favoured to the maize population where pea population was subjected to greatly submissive. The results are very close to the result of Hashem and Moniruzzaman (1986) in maize/cowpea intercrop association.

Maize equivalent yield (MEY)

Maize equivalent yield (MEY) of two intercropping systems is presented in Table 3. The 1M: 1P and 1M: 2P intercropping mixed stands generated about 1.44 and 1.71 folds higher MEY as compared to the yield obtained from sole maize (5.65 t ha^{-1}). The 1M: 2P intercropping mixture gave 9% greater MEY than that of the MEY generated from 1M: 1P planting system. Rana *et al.* (2013) also found the greater equivalent yield from intercropping system especially for double row intercropping mixture.

Conclusion

It can be concluded from the present experiment that maize and pea crops are well compatible in intercrop association, and double row intercropping mixture i.e. single row of maize followed by double row of pea would be better for profitable production of maize and pea crops under the existing agro-ecological conditions of Bangladesh.

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