J. Agrofor. Environ. 1(2): 53-57, 2007 ISSN 1995-6983

Compatibility analysis of mustard and soybean stands in intercrop association

M.A. Awal, M.H.R. Pramanik and M.A. Hoque
Department of Crop Botany, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.

Abstract: An experiment was conducted to evaluate the co-existence based on the growth and yield performance of different mustard (*Brassica napus* L.) and soybean (*Glycine max* L.) populations in intercrop association. The different plant populations, each with four replications, were sole stand of mustard or soybean crops, single row intercrops (one row of mustard followed by one row of soybean, MS1), and double row intercrops (two rows of mustard followed by two rows of soybean, MS2). The plant height, branch number per plant, leaf area index, total dry matter, grain yield, and harvest index were maximum in sole crops and those were minimum in MS1 intercrops. Mustard seed yields in MS1 and MS2 intercropping were declined by about 17 and 11%, respectively compared to its sole cropping (1.98 t ha^{-1}), and the corresponding seed yields of soybean were decreased by about 14 and 8% compared to its sole stands (1.85 t ha^{-1}). In the spatial associations, performance of mustard and soybean in MS2 intercropping was better than that in MS1 intercropping. The competitive ratio among the partner species in each intercrop approached to unity indicating that the management practices and species used in this study had effectively balanced the competition between them. These results suggest that soybean crop is compatible with mustard stands and may be intercropped with planting two rows of mustard followed by two rows of soybean for their profitable production.

Key words: Intercropping association, Competitive ratio, Mustard, Soybean.

Introduction

Intercropping is an important technique to intensify crop production growing two or more crops simultaneously in the same piece of land (Beet, 1977). It is commonly practiced in the developing countries and is recognized potentially beneficial system of crop production for substantial yield advantages over sole cropping (Singh *et al.*, 1992). However, profitable intercropping system mainly depends on the partner species and their foliage geometry including climatic and edaphic conditions, management practices and local food habit as well as grower’s demand (Connolly *et al.*, 2001).

Mustard (*Brassica napus* L.) is an important oil seed crop in the world. It is also a top ranking edible oil crop in Bangladesh covering about 74% of the total oil seed cropped area and 59% of total oil production (BBS, 2004). Soybean (*Glycine max* L.) is also an important oil seed crop which provides high quantity vegetable oil and plant protein compared to any other legumes. It provides about 60% of the total oil used around the globe (Fehr, 1989) and also enriches soil fertility during adding atmospheric nitrogen in soil through symbiotic association with *Rhizobium*.

The recommended dietary allowance (RDA) is estimated to be 6 g oil $capita^{-1}$ day^{-1} for a diet with 2700 KCal (NNC, 1984). On this RDA basis, Bangladesh requires about 0.31 million ton of oil equivalent to 0.86 million ton of oil seed for nourishing her people. However, our country can produce only about 0.37 million tons of oil seed which covers only about 40% of the total domestic need (Rahman, 2000). Thus, Bangladesh is facing a huge deficit of edible oil and has to import edible oil. Therefore, attention should be given to increase oil seed production to meet the shortage of the cooking oil in Bangladesh. Intensive production of mustard and soybean is an alternative means to alleviate shortage of cooking oil as these crops are well adapted in the agro-climatic condition of Bangladesh. Since the cultivable land areas are gradually squeezing in Bangladesh, therefore, intercropping is an alternative means to boost up mustard and soybean production for increasing the oil seed supply.

Mustard plant is a tall stature crop compared to soybean and they can be cultivated simultaneously in an intercropping system which may provide profitable return to the growers. However, the compatibility of these crops in intercrop association has not yet been evaluated. Therefore, the present research was conducted to evaluate the co-existence of mustard and soybean crops based on their growth and yield performance in intercrop association.

Materials and Methods

The experiment was conducted at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh, during the period from November 2006 to March 2007. The experimental field was a medium low land, fairly levelled and silt loam in texture having a soil pH 6.32.

The experiment comprised of the treatments viz., sole stand of mustard or soybean crops, single row intercrops (one row of mustard followed by one row of soybean, MS1), and double row intercrops (two rows of mustard followed by two rows of soybean, MS2). The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The unit plot size was 4m×4m. For all the sole and intercropped plots, row to row and plant to plant distances in a row were 25 and 5 cm, respectively. Seeds of mustard (cv. BINA Sorisha-4) and soybean (cv. Shohag) were sown as per treatments by hand on 16 November 2006 in north to south (N-S) rows orientation. The basal fertilizers of urea, triple super phosphate and muriate of potash, gypsum, zinc and boron were applied during the final land preparation corresponding to 250, 180, 70, 150, 5 and 1.5 kg ha^{-1}, respectively. Irrigation, pest control and other intercultural practices were performed as and when necessary to optimise growth and development of the crops.

The destructive samplings were furnished at 10 days interval from 35 days after sowing (DAS) and continued till maturity of mustard (75 DAS) or soybean (95 DAS) crops for collecting required data. At each sampling time, five plants were harvested from each plot. The selected plants were uprooted carefully in order to ensure maximum root to be retained. The morphological data were recorded on plant height, number of branches per plant and leaf area. The leaves, stems and roots of the harvested plants were separated and area of the separated leaves was measured with an electronic area meter (LI 3000, USA) and then their corresponding dry weight was recorded after drying at 80°C until constant weight. Finally, the leaf area index (LAI) was calculated as the leaf area/ground area ($m^2\,m^{-2}$) based on spacing of the harvested plants. At the end of the experiment, plants were harvested and their yield was calculated on whole plot harvest basis. The competitive ratio (CR) between mustard and soybean was calculated following Willey and Rao (1980):

$$\mathrm{CR} = \left(\frac{I_\mathrm{M}/S_\mathrm{M}}{I_\mathrm{S}/S_\mathrm{S}}\right)\left(Q_\mathrm{S}/Q_\mathrm{M}\right) \qquad (1)$$

where,

I_M and I_S are the yields of mustard and soybean in intercropping, and that of S_M and S_S are the corresponding yields in sole cropping, respectively. The term Q_M is the relative space occupied by mustard and that of Q_S by soybean in the intercrop association.

The collected data were statistically analyzed and the analyses of variances (ANOVA) were calculated using computer software programme MSTAT-C (Russell, 1986). The mean differences were evaluated by least significant difference (LSD) or Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

Results

Micrometeorological parameters: A summary of the micrometeorological parameters during the study period from November 2006 to March 2007 is presented in Table 1. After seed sowing in the middle of November, both air and soil temperatures steadily decreased till January followed by gradual increase towards harvest of the crops. However, one way gradual decrease, from sowing to crop harvest, was noticed for relative humidity. In the experimental site, there was scanty or no rainfall occurred until the end of January. In January, the plants received minimum sunshine hour which gradually increased towards maturity of the crops.

Plant stature: The above ground vertical development was expressed as plant height and the data are presented in Fig. 1. Plants in mustard population had the stature which was about the double of that in soybean plants resulting distinctly two vertical tiers of combined intercrop canopy. Initial shorter plant height in all the treatments gradually increased towards maturity on 75 DAS for mustard, and on 95 DAS for soybean. Both the mustard and soybean plants grown in sole condition exhibited some what taller stature than the plants grown with intercrop association.

Number of branches/plant: Initially there were few branches in each plant of mustard or soybean which steadily increased with the advancement of growing season (Table 2). Mustard plants produced about three folds greater number of branches compared to soybean plants. Sole mustard or soybean plants produced the greater number of branches than the plants grown with intercrops.

Leaf area index (LAI): Initial low LAI of mustard and soybean plants was rapidly increased to maximum on 55 DAS in mustard and 85 DAS in soybean (Fig. 2). The LAI in mustard plant quickly declined after reaching the peak. Mustard plants grown in sole, MS2 intercrop and MS1 intercrop treatments respectively evolved maximum, middle and minimum LAIs throughout their growth period. Soybean plants grown under different treatments also showed monotonic pattern of LAI development as that of the LAI evolved by the mustard plants.

Biomass production: Biomass production, expressed as total dry matter (TDM) accumulation per unit of land area of mustard or soybean plants, was significantly affected by the different intercropping systems (Fig 3). For both of mustard and soybean plants, there was minimum TDM accumulation at initial stage which gradually increased with time. However, the time-function of TDM accumulation was faster in mustard than that of soybean crops. Mustard or soybean plants grown with sole and MS1 treatments respectively accumulated maximum and minimum amount of biomass while the plants under MS2 intercrop association ranked intermediate.

Yield components, yield and harvest index: The value of all yield components like number of siliqua or pod plant^{-1}, number of seed pod^{-1} or siliqua^{-1}, 1000-seed weight and seed weight plant^{-1}, and seed yield and harvest index was found relatively higher in the mustard or soybean plants grown under sole condition than the same species grown with intercrop association (Table 3). For example, seed yield declined by only about 17 and 11% in the mustard crops grown with single row (MS1) and double row (MS2) intercropping, respectively than that of sole crop, and corresponding seed yield reductions for soybean MS1 and MS2 intercrops were 14 and 8% as compared to their sole stands. Similarly, harvest index declined by about 11 (8) and 6 (4)%, respectively for mustard and soybean plants grown with MS1 (MS2) intercrop treatments as compared to their respective sole treatments.

Competitive ratio (CR): The CR, based on seed yield and space of all the partner stands in this study approached unity (Fig. 4). Both of partner species had higher CR in MS2 intercropped plants than that of the plants grown with MS1 intercropping system. However, there was no significant variation of CR among the associated populations in any of the intercropping systems.

Table 1. Monthly mean micrometeorological parameters at the onsite agricultural weather station during the growing period from November 2006 to March 2007

Months	Air temperature (ºC)			Soil temperature[1] (ºC)	Relative humidity (%)	Rainfall[2] (mm)	Sunshine duration[2] (hrs)
	Max	Min	Mean				
Nov., 2006	28.9	18.3	23.6	25.2	86.1	0.20	153.8
Dec., 2006	26.2	13.5	19.9	22.1	85.2	0.00	129.4
Jan., 2007	23.6	10.8	17.2	19.2	82.9	0.00	115.0
Feb., 2007	25.4	15.7	20.6	22.0	81.1	55.2	148.4
Mar., 2007	34.5	22.0	28.3	24.6	75.4	18.5	218.2
Mean	27.7	16.1	21.9	22.6	82.1	73.9[3]	764.8[3]

[1]Average value from 5, 10 and 15 cm soil depths.
[2 & 3] Monthly and seasonal totals, respectively.

Table 2. Seasonal time-course of number of branches plant^{-1} of (a) mustard, (b) soybean plants under different cropping systems

Cropping systems	Number of branches plant^{-1} at different days after sowing						
	35	45	55	65	75	85	95
(a) Mustard plants (M)							
Sole crop	3.3 a	15.7 a	18.0 a	19.5 a	22.8 a		
MS1 intercrop	2.3 b	12.2 b	12.7 b	14.4 b	19.4 b		
MS2 intercrop	2.5 b	12.5 b	12.9 b	15.3 b	20.3 b		
(b) Soybean plants (S)							
Sole crop	2.1 a	4.4 a	4.7 a	4.8 a	6.1 a	6.2 a	6.3 a
MS1 intercrop	1.4 b	3.2 b	3.6 b	3.8 b	5.5 b	5.4 c	5.4 b
MS2 intercrop	1.5 b	3.2 b	3.6 b	3.8 b	5.3 b	5.8 b	5.4 b

In a column, figures for each group either soybean or mustard, having common letters do not differ significantly at 5% level of probability.

Table 3. Yield contributing characters, yield and harvest index of mustard and soybean crops at physiological maturity under different cropping systems

Cropping systems	No. of pod or siliqua plant^{-1}	No. of seed pod^{-1} or siliqua^{-1}	Seed weight plant^{-1} (g)	1000-seed wt (g)	Seed yield (t ha^{-1})	Harvest index (%)
Mustard crops (M)						
Sole crop	156.7 a	24.4 a	6.6 a	4.2 a	1.98 a	37.1 a
MS1 intercrop	128.9 b	21.0 b	4.9 c	3.1 c	1.65 c	32.9 b
MS2 intercrop	135.8 b	21.6 b	5.7 b	3.8 b	1.77 b	34.1 b
Soybean crops (S)						
Sole crop	59.0 a	2.8 a	5.5 a	101.0 a	1.85 a	42.3 a
MS1 intercrop	47.4 c	2.5 b	5.0 ab	92.0 b	1.59 b	39.8 c
MS2 intercrop	52.0 b	2.6 b	5.2 a	91.5 b	1.70 b	40.8 b

In a column, figures for each group either soybean or mustard, having common letters do not differ significantly at 5% level of probability.

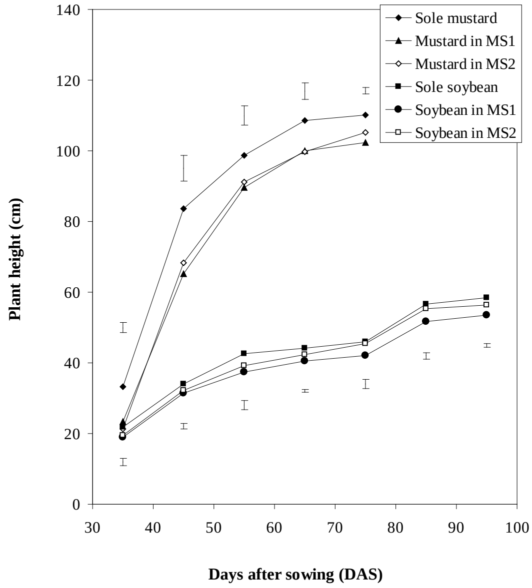

Figure1. Seasonal time-course of height of mustard soybean stands under different cropping systems. Vertical bars (upper bars for mustard and lower bars for soybean) indicate the LSD at 0.05 level

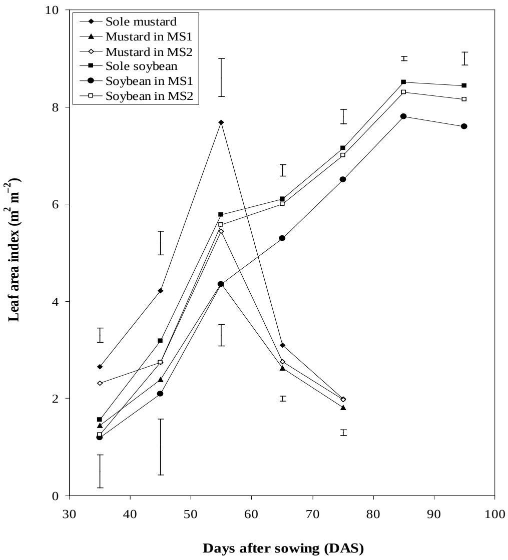

Figure 2. Seasonal time-course of leaf area index (LAI) of mustard and soybean as affected by different cropping systems. Vertical bars (upper bars for soybean and lower bars for mustard) indicate the LSD at 0.05 level.

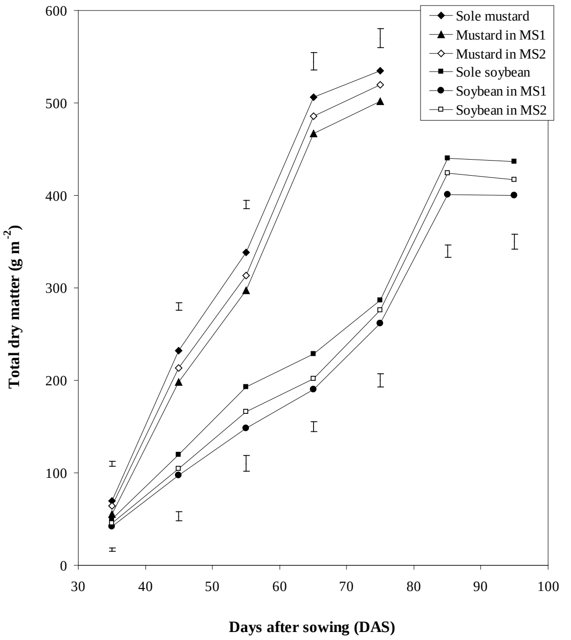

Figure 3. Seasonal time-course of total dry matter accumulation in mustard and soybean as affected by different cropping systems. Vertical bars (upper bars for mustard and lower bars for soybean) indicate the $LSD_{0.05}$ of treatment means.

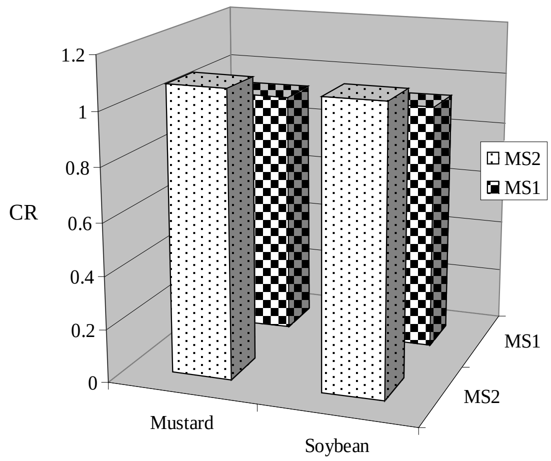

Figure 4. Competitive ratio (CR) of mustard and soybean plants under single row (MS1) and double row (MS2) intercropping systems.

Discussion

Lack of sufficient horizontal expansion of crop foliage is one of the major limiting factors of plant growth in the crop field especially for densely populated stands or intercropping mixtures. In such cases, interplant competition not only occurs in the above ground foliages but also for below ground root networks (Ofori and Stern, 1987). Recommended plant population in sole crops may ensure minimum intra-species competition. Even strong interplant competition may occur in the densely spaced sole crops, but it exerts almost homogeneous effect for the stand grown in all parts of the field. In contrast, the inter-species competition in intercrop association poses heterogeneous effect through capturing most of available resources by the strong partner (Mandimba *et al.*, 1993). Such heterogeneity may acute if the partner species are of different morphological characteristics: stature is one of decisive characters (Keating and Carberry, 1993.). The variation in plant height of mustard or soybean under different cropping systems might be attributed for the differential availability of primary requirements like nutrient, moisture, light, space etc (Bray, 1954; Wahua, 1983; Shackel and Hall, 1984). Generally such resources are acquired homogeneously by the recommended spaced sole crop plants thus minimum inter-plant competition is created compared to the plants grown under single or double row intercropping. In contrast, heterogeneous competition is common for intercrop association thereby some requirements may become acute for both species resulting little shorter height than their respective sole crops. Similarly, less number of branches/plant in intercrop stands might be due to the lack of available space for horizontal spreading of the canopy foliages along with competition for nutrients, moisture and light and our results are supported well by the findings of Awal *et al.* (2007) in barley/peanut intercropping. Additionally, they may grow in a compatible manner which ensured the efficient utilization of natural resources favouring crop growth.

Ontogenetically, crop stands have few LAI following seedling emergence (Awal and Ikeda, 2003). With the development of branches and expansion of new leaves, LAI increases and reached to the maximum potential at 55 DAS in mustard and at 85 DAS in soybean. The variation of LAI among the treatments would mainly be attributed due to the variation of number of branches per plant. Leaf area development and dry matter accumulation at the middle layer of intercropped mustard stands might be affected by the broad-leaved soybean foliage. As leaf is the principal photosynthetic organ of any crop stand, poor LAI in intercrop soybean along with shade offered by the dominate mustard has resulted lower amount of dry matter production. Less amount of dry matter accumulation along with lower harvest index in intercrop stands than sole crop stands has contributed to formulate lower seed yield. The unsatisfactory photosynthate partitioning to the harvestable organ in shaded canopy species has resulted poor harvest index and the result is in good agreement with the findings of Awal *et al.* (2006) for maize/peanut intercrop canopy.

Almost similar degree of competitive ratio among the partner stands in each association indicates that the species *Brassica napus* and *Glycine max* are compatible and co-existed, and intercropping cultural practices effectively balanced the competition between the species and the result is supported well by Mason *et al.* (1986) in cassava/legume intercropping.

It is concluded that mustard and soybean stands are found to be compatible in intercrop association. Subordinate soybean crop co-exists with dominate mustard stands both in single row (one row of mustard followed by one row of soybean) and double row (two rows of mustard followed by two rows of soybean) intercropping systems. In terms of growth and yield potentials, double row intercropping system is more profitable than single row system. Further intercropping study is necessary for these species to use the land economically without hampering their production potentials.

References

Awal, M.A. and Ikeda, T. 2003. Effect of elevated soil temperature on radiation-use efficiency in peanut stands. Agric. For. Meteorol. 118: 63-74.

Awal, M.A., Koshi, H. and Ikeda, T. 2006. Radiation interception and use by maize/peanut intercrop canopy. Agric. For. Meteorol. 139: 73-84.

Awal, M.A., Pramanik, M.H.R. and Hossen, M.A. 2007. Interspecies competition, growth and yield in barley-peanut intercropping. Asian J. Plant Sci. 6: 577-584.

BBS. 2004. Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics (BBS). Statistics Division, Ministry of Planning, Govt. People's Repub. Bangladesh, Dhaka.

Beet, W.C. 1977. Multiple cropping of maize and soybean under levels of crop management. Netherland J. Agric. Sci. 25(2): 95-102.

Bray, R.H. 1954. A nutrient mobility concept of soil-plant relationships. Soil Sci. 78: 9-22.

Connolly, J., Goma, H.C. and Rahim, K. 2001. The information content of indicators in intercropping research. Agric. Ecosys. Environ. 87: 191–207.

Fehr, W.R., 1989. Soybean. *In*: Oil crops of the world. Robbelin, G., Downey, R.K. and Ashri, A. (eds.). McGraw-Hill Pub. Co., London. p. 58.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. Int'l. Rice Res. Inst., John Wiley & Sons, New York. pp. 139-240.

Keating, B.A. and Carberry, P.S. 1993. Resource capture and use in intercropping: solar radiation. Field Crops Res. 34: 273-301.

Mandimba, G.R., Galandzou, C. and Guenguie, N. 1993. Effect of plant population densities on the growth of *Zea mays* L. and *Arachis hypogaea* in intercropping systems. Biol. Agric. Hort. 10: 141-154.

Mason, S.C., Leihner, D.E. and Vorst, J.J. 1986. Cassava-cowpea and cassava-peanut intercropping. I. yield and land use efficiency. Agron. J. 78: 43-46.

NNC. 1984. Nutrition Policy and Programme for Bangladesh. National Nutrition Council (NNC), Bangladesh. pp. 28-29.

Ofori, F. and Stern, W.R. 1987. Cereal-legume intercropping systems. Adv. Agron. 41: 41-90.

Rahman, H. 2000. Studies on the integrated management of Alternaria blight of mustard. Ph.D. Thesis, Bangladesh Agril. Univ., Mymensingh. pp. 1-3.

Russell, D.F. 1986. MSTAT-C Package Programme. Crop and Soil Sci. Dept., Michigan State Univ., U.S.A.

Shackel, K.A. and Hall, A.E. 1984. Effect of intercropping on the water relations of sorghum and cowpea. Field Crops Res. 8: 381-387.

Singh, S.B., Singh, B.N. and Maura, M.L. 1992. Comparative performance of mixed and intercropping systems with different winter crops under dry land conditions. Indian J. Agron. 37(1): 40-43.

Wahua, T.A.T. 1983. Nutrient uptake by intercropped maize and cowpeas and a concept of nutrient supplementation index (NSI). Exp. Agric. 19: 263-275.

Willey, R.W. and Rao, M.R. 1980. A competitive ratio for quantifying competition between intercrops. Exp. Agric. 16: 117-126.