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Bio-economic assessment of sunflower-mungbean intercropping system at different planting geometry

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A field study to evaluate the bio-economic assessment of sunflower-mungbean intercropping system at different planting geometry was carried out at Agronomic Research Area, University of Agriculture, Faisalabad during spring season 2009. The experiment was laid out in randomized complete block design with factorial arrangement having three replications. Sunflower hybrid (Hysun 33) and mungbean variety Azri-2006 was sown. The experiment was comprising treatment having factor A: planting geometry; P_1(70cm single row planting),P_2(105/35 cm spaced paired row planting), P_3 (175/35 cm four row planting) and factor B; intercropping I_1(sunflower alone),I_2 (sunflower + mungbean. All the growth and yield components were significantly affected by the varying planting patterns and intercropping. Maximum value of achene yield (2891 kg ha^{-1}) in case of intercropping treatments was obtained in the alone sowing of sunflower and in case of planting geometries maximum achene yield (3002 kg ha^{-1}) was obtained in the treatment when sunflower was sown at 175/35 cm four rows apart sowing. The interactive effect of different planting patterns and intercropping show that maximum achene yield (3128 kg ha^{-1}) was obtained in case of P_3I_2.The maximum net benefit of Rs. 95995 (1130$) was obtained from the plots in which sunflower was sown at 175/35 cm four rows apart (P_3I_2).

Keywords: Achene, aggressivity value, intercropping system, planting geometry, relative crowding co- efficient

INTRODUCTION

Sunflower (*Helianthus annuus* L.) an important oilseed crop belongs to the family Compositae. Sunflower oil is quite palatable containing soluble vitamins A, D, E, K and 40 to 47% oil content (Saleem et al., 2003). Its seed contains 23% protein, 40-50 % oil that is free from toxic elements. Its oil contains 110 g kg^{-1} of saturated fatty acids, 4-9% palmitic acid, 1-7% stearic acid, 14-40% oleic acid and 48-74% linoleic acid (Hatim and Abbasi, 1994 and Rodriguez et al., 2002). Its oil is called premium oil because it contains high percentage of polyunsaturated fatty acid (60%) and it has been accepted that higher level of unsaturated fatty acid in the diet reduces the level of blood cholesterol which is responsible for heart disease (Rathore, 2001). The protein content of sunflower cake ranges from 20-40% (Gandhi et al., 2008).

In Pakistan 506 thousand hectares area are under sunflower cultivation. At present, there is a need for production of more pulses as we are deficient in protein in our daily diet. Mungbean *(Vigna radiata L.)* commonly known as green gram and golden gram is consumed as boiled or fried food. It is a drought tolerant, short duration, early maturing legume crop and an important pulse crop in many Asian countries including Pakistan (Naeem et al., 2000; Fraz et al., 2006). Pulses contain 20-25% protein (Khan et al., 2002), 0.6% fat, 0.9% fiber and are known as poor man's meat in the developing countries (Potter and Hotchkiss, 1997). Biological nitrogen fixation is of great importance in pulses (mungbean) since the potential environmental hazards of nitrogenous fertilizers

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have raised ecological concern and also the fertilizers are becoming steadily less economic (Elahi et al., 2004).

The main reasons for low production of sunflower are poor agronomic practices, inadequate pest and disease control, lack of high yielding varieties, decline in soil fertility, shortage of good quality seeds at planting, low producer prices**,** marketing of sunflower, lack of access to credit, non-uniform plant distribution, weak research - extension – farmer linkages and low adoption of developed technologies (Okoko et al., 2008; Qureshi and Memon, 2008).

Sunflower production can be increased by horizontally or by vertically because total crop productivity and net return per unit area are higher in intercropping than sole cropping. In modern agriculture, intercropping is considered to be an effective and most potential way of increasing crop production per unit area particularly on small farms. There is a need to grow more than one crop in a season to satisfy the diversified demands of the farm people. Intercropping is an advance agro-technique and is considered to be an effective and potential mean of increasing crop production per unit area particularly farmers with small holdings (Ali et al., 2000). Farmers in Pakistan are constrained by low crop productivity due to limited land resources. Intercropping is a modern agronomic technique, effective and potential mean of increasing crop production per unit area and time (Ahmad and Anwar, 2001). Ghosh, (2004) stated that intercropping offers to farmers the opportunity to engage nature's principle of diversity at their farms**.** Intercropping is a possible way of increasing the productivity on small farms, as it provides security against potential losses of monoculture. The yield losses of sole crop due to environmental condition may compensate by intercrop (Fukai and Ternbath, 1993).

Intercropping can help in increasing crop productivity particularly at small farms of Pakistan. However, conventional planting geometry does not permit convenient intercropping. There is dire need to search a new pattern of sunflower plantation that can give sunflower yields compatible with that of the conventional plantation and also facilitates intercropping. Non-uniform plant distribution exhibits a remarkable effect on the productivity of the crop. Uniform adjustment of the crop spacing in the field is one of the most important factors for yield and quality of sunflower (Barros *et al.,* 2004). Four plant spacing (20, 25, 30 and 35 cm between hills) in sunflower revealed that plant height, stem diameter, head diameter, number of seeds per head, 1000-seed weight and seed yield (kg ha^{-1}) were significantly affected by plant spacing. Twenty-five cm was observed as suitable plant spacing, whereas higher or lower plant spacing had a negative effect on seed and oil yields ha^{-1} (Thabet, 2006).

The present study was designed to assess the bio-economic advantages of sunflower based intercropping system under agro-climatic condition of Faisalabad, to enhance the area and production of domestic edible oil economically by intercropping and to modify traditional methods of sunflower cultivation.

MATERIALS AND METHODS

A field study was carried out at Agronomic Research Area, University of Agriculture, Faisalabad to evaluate the effect of sunflower-mungbean intercropping at different planting geometry during spring season 2009. The climate of the region is subtropical to semi-arid. The experimental area is located at 73^{O} East longitude, 31^{O} North latitude and at an altitude of 135 meters. The experiment was laid out in randomized complete block design with factorial arrangement having three replications and a net plot size of 5.6 m × 6.0 m. Sunflower hybrid (Hysun 33) and mungbean variety Azri-2006 was sown on 2^{nd} week of February, 2009 and crop was harvested on June 07, 2009. The experiment was comprised of the following treatments: planting geometry:P_1(70cm single row planting),P_2(105/35 cm spaced paired row planting), P_3 (175/35 cm four row planting) and intercropping I_1(sunflower alone),I_2 (sunflower + mungbean).

Sowing was done with the help of single row hand drill keeping row to row distance according to the planting geometry in sunflower. The plant to plant distance of 25 cm and 10 cm was maintained in sunflower and mungbean respectively by thinning at growth stage of 2-4 leaf. . The seed rate for sunflower was 6 kg ha^{-1} and 30 kg $ha^{-1}$for mungbean. The nitrogen phosphorus and potassium applied @ 150-100-0 kg ha^{-1} respectively in the form of urea (46% N) and diammonium phosphate (46 % P). $1/3^{rd}$ nitrogen and full phosphorus dose was applied at sowing while remaining nitrogen with 1^{st} two irrigations. First irrigation was applied about 30 days after sowing, while subsequent irrigations were applied according to the crop need. Plant protection measures were adopted to keep crop free of weeds, insect pests and diseases. All other agronomic practices were kept normal and uniform for all the treatments.

Data regarding all the parameters: plant height at maturity (cm), 1000-achene weight (g) achene yield (kg ha^{-1}), protein content(%), oil content (%), harvest index (%) of sunflower and plant height at maturity (cm), No. of seed per pod, grain yield (t ha^{-1}), 1000-grain wt.(g), harvest index (%), protein content (%),of mungbean and sunflower achene yield equivalent, land equivalent ratio relative crowding co-efficient, competition ratio aggressivity value, of sunflower and, economic analysis were collected using standard procedures and analyzed by using Fisher's analysis of Variance technique. LSD test at 5% probability was used to compare the differences among treatments means (Steel et al., 1997). Grain protein content (%) was determined by Gunning and Hubbard method of sulphuric acid digestion and distillation by Micro-Kjelhhal,s method (Jackson, 1962)

% Crude protein = Nitrogen (%) x 6.25

Oil and protein contents were determined by Soxhlet Fat Extraction method described by Low, 1990.

Ether Extract (%) = W_2*-*W_1 *X 100/Wt. of the sample*

While on the other hand Land equivalent ratio was computed using the formula described by Willey (1979), Relative crowding co-efficient (Dewit, 1960), Aggressivity Value (McGilchrist ,1965) and Competition ratio (Willey et al., 1980).

RESULTS AND DISCUSSIONS

Sunflower

Plant Height (Cm) At Harvest

The data in Table 1 shows the effect of planting geometry, intercropping and interaction of planting pattern and intercropping on plant height and it was found to be non-significant. The maximum plant height was measured (151.48 cm) in case of intercropping of sunflower with mungbean and minimum height of 149.74 cm in sunflower alone; however, these differences could not reach to the level of significance. Regarding planting geometry the maximum plant height of 151cm was measured in 105/35 cm spaced paired row planting (P_2) and minimum height of 149 cm in 175/35 cm four row planting (P_3). The possible reason for almost same height in all the treatment is that all the plants have an equal opportunity of the resources especially of light in intercropping. Another important reason for these types of results is that sunflower plant height is mainly controlled and regulated by the genetic rather than various intercropping and planting technique. The results are in line with Sultana (2007) and Ahmad et al. (2001) who also reported non-significant differences among planting geometry for plant height. The results are in contrast with Panhwar (2004) who reported significant differences for maize plant height among maize-soybean intercropping and plant spacing. Bhatti (2005) also observed significant effect of sesame plant height in case of sesame-soybean intercropping under different plant spacing. The differences in the results can be attributed to the differences in the genetic makeup of the crop plants (Maize and sunflower) and intercrop used.

1000-Achene Weight (G)

Among the various yield contributing factors 1000-achene weight is one of the remarkable factors that play an important role in the final yield of a crop. The data related to sunflower 1000- achene weight is presented in Table 1. It shows significant effect of planting patterns on 1000-achene weight and no mean differences was observed in case of intercropping and interaction of planting pattern and intercropping. The maximum 1000- achene weight of 61.82 g was measured when sunflower was sown at 175/35 cm four apart four rows planting (P_3) while minimum achene weight (60.13 g) was observed where sunflower sown at 105/35 cm apart paired row planting (P_2). The maximum 1000-achene weight (64.87 g) was found when sunflower sown alone with minimum of 63.71 g in intercropping of sunflower with mungbean. As far as interaction of both the factors is concerned maximum weight was taken (68.50 g) when sunflower planted at 175/35 cm apart four rows planting (P_3I_1) and minimum 1000-achene weight of 59.53 g was observed where sunflower sown at 105/35 cm apart paired row planting (P_2I_1). Malik et al. (1992) findings are similar with this result who found significant effect of row spacing on sesame grain weight. The result is in contrast with Saleem et al. (2003) who found no differences among the mean of weight in case planting patterns. The differences in the results can be attributed to differences in the climatic condition, fertility status of soil and genetic makeup of crop plants.

Achene Yield (Kg Ha^{-1})

Achene yield is the main and ultimate objective of the sunflower crop. This factor is related to many factors such as plant population, 1000-achene weight, number of achene per head, head diameter as well as agronomic practices that are practiced during the production of a crop. So any decrease or increase in any above mentioned factors must affect the final yield of a crop. The data related to achene yield is presented in the Table 1. Achene yield was significantly affected by the intercropping, planting pattern and the interaction of planting pattern and intercropping. In case of intercropping greater achene yield of 2891kg ha^{-1} was obtained in case of alone sunflower followed by the yield of intercrop that is 2603kg ha^{-1}. The reduction of yield in intercropping probably may be due to inter and intra-specific competition for light, moisture, space and nutrients etc. As far as planting pattern is concerned the maximum yield (3002 kg ha^{-1}) was obtained in case 175/35 cm four rows apart planting (P_3) while minimum yield of 2808 kg ha^{-1} at 105/35 cm spaced paired row planting (P2). However, the interaction between planting pattern and intercropping was also statistically significant. The maximum yield of 3071 kg ha^{-1} was at 70cm single row alone planting (P_1I_1) which was statistically at par with (3128 kg ha^{-1}) at 175/35 cm four rows apart alone planting (P_3I_1) while the minimum achene yield was obtained at 105/35 cm spaced paired row planting in combination with mungbean (P_2I_2) (2389 kg ha^{-1}) which is statistically at par with 105/35 cm spaced paired row alone planting (P_2I_1) and 70cm single row planting in mungbean combination (P_1I_2) but higher than that of 105/35 cm spaced paired row planting in combination with mungbean (P_2I_2). Variations among the yield in different planting patterns may be due to severe intra-specific competition in sunflower plants. The maximum

Table 1. Influence of planting geometry and intercropping systems on yield and quality of sunflower

Planting Geometry	Plant height	1000-Achene weight (g)	Achene yield kg ha^{-1}	Harvest index (%)	Protein content (%)	Oil content (%)
P_1(70cm single row planting)	149.567	64.92 ab	2808. b	29.083	20.583	39.83 b
P_2(105/35 cm spaced paired row planting)	151.383	60.13 b	2431. c	27.800	20.150	41.43 a
P_3 (175/35 cm four rows apart planting)	150.867	67.82 a	3002. a	29.217	19.850	40.80 ab
LSD VALUE	NS	0.5130	111.6	NS	NS	0.9881
I_1(sunflower alone)	149.733	64.867	2891. a	29.78 a	19.58 b	42.31 a
I_2(sunflower + mungbean)	151.478	63.711	2603. b	27.62 b	20.81 a	39.07 b
LSD VALUE	NS	NS	91.14	1.885	1.106	0.8068
P_1 I_1	148.400	66.567	3071. a	31.033	19.900	41.333
P_1 I_2	150.733	63.267	2546. c	27.133	21.267	38.333
P_2 I_1	152.633	59.533	2473. c	28.000	19.933	42.600
P_2 I_2	150.133	60.733	2389. c	27.600	20.367	40.267
P_3 I_1	148.167	68.500	3128. a	30.300	18.900	43.000
P_3 I_2	153.567	67.133	2876. b	28.133	20.800	38.600
LSD VALUE	NS	NS	157.9	NS	NS	NS

Note: Mean sharing common letters do not differ significantly at 5 % probability level

yield at 175/35 cm four rows apart alone planting (P_3) may be due to better weed control, better utilization of water. The results are in line with that of Zaman and Maity (1988), Faiz (1990) , Khan *et al*. (1994) and Khan (2001). The present results are in consistent with the results of Panhwar (2004) who found significant effect of maize grain yield in case of maize-soybean intercropping under different plant spacing and nitrogen levels. Bhatti (2005) also found mean differences among intercropping, planting geometry and their interaction in sesame-legume intercropping under different planting geometry. The data Ullah (2007) indicated significant differences among various planting patterns, intercropping system and treatment combinations. Khakwani (2001) revealed that relaying of canola in sunflower did not affect sunflower yield significantly.

Oil Content (%)

Oil content is an important component for which the sunflower is mostly grown. Sunflower variety giving more oil content at the given system of crop production is considered more efficient. The oil content data of sunflower is shown in Table 1 which reveals that oil content was significantly affected by the intercropping and planting pattern but non-significantly in case of intercropping and planting geometry interaction. In case of intercropping factor more oil content (42.31 %) was found in the treatment where the sunflower sown alone and less oil content in intercropping of sunflower with mungbean. In planting pattern 41.43 % oil content was measured at 105/35 cm paired row apart planting (P_2) and minimum oil content of 39.83 % at 70 cm apart single row (P_1) which was statistically at par with P_3 (175/35 cm four rows ap**a**rt planting) treatment. As far as interaction is concerned maximum oil content of 43.00 % was observed at 175/35 cm four rows apart alone planting (P_3I_1) and minimum oil content at 70 cm apart single row in mungbean intercropping (P_1I_2). The results are not similar with those of Sultana (2007) and Saleem et al. (2003) with any effect on oil content of sunflower in intercropping system under different planting pattern.

Protein Content (%)

Protein content is also an important factor of sunflower with reference to nutrition. The data related to the protein content is presented in Table 1. The table shows that protein content of sunflower is significantly affected by the intercropping of sunflower with mungbean legume and not affected by the planting pattern and interaction between intercropping and planting geometry. The higher protein content of 20.81 % was measured in case of sunflower intercropping with mungbean and lower protein content in the treatment when sunflower sown alone. In case of planting pattern factor more protein content of 20.58 % found at 70 cm apart single row (P_1) and minimum at 175/35 cm four rows apart planting (P_3) that is 19.85 %. As far as interaction is concerned maximum protein of 21.27 % was taken P_3I_1 (175/35 cm four rows

Table 2. Effect of planting geometry and intercropping systems on yield and quality of mungbean

Planting Geometry	Plant height (cm)	No. of Seed per Pod	1000-Grain wt.(g)	Grain yield (t ha^{-1})	Harvest index (%)	Protein Content (%):
P1(70cm single row planting)	32.567b	10.80bc	60.01 b	0.89 bc	22.83 a	16.477 a
P2(105/35 cm spaced paired row planting)	35.900b	9.92c	60.88 ab	0.85 c	22.48 a	17.153 a
P3 (175/35 cm four row planting)	35.400b	11.93b	61.36 a	0.91 b	21.90 a	16.390 a
Mungbean alone at 30 cm	49.967a	14.38a	61.52 a	1.12 a	22.24 a	17.757 a
LSD value	4.54	1.52	1.23	0.044	0.9678	1.42

Note: Mean sharing common letters do not differ significantly at 5 % probability level

Table 3 . Sunflower achene yield equivalent (kg ha^{-1}) as affected by intercropping and different planting geometry

TREATMENTS	Sunflower yield (kg ha^{-1})	Mungbean yield (kg ha^{-1})	Sunflowe achene yield equivalent (kg ha^{-1})	Total Sunflower achene yield equivalent (kg ha^{-1})	% increase over control yield (kg ha^{-1})
Sunflower alone	3071.21	–	–	3071.21	-
P_1 (70cm single row planting)	2545.47	885.46	1106.83	3652.30	18.92%
P_2 (105/35 cm spaced paired row planting)	2389.10	847.05	1058.80	3447.79	13.24%
P_3 (175/35 cm four rows apart planting)	2875.48	909.52	1136.90	4012.38	30.64 %

Table 4. Land Equivalent Ratio (LER) as affected by intercropping an different planting geometry

TREATMENTS	Sunflower	Mungbean	LER VALUE
P_1 (70cm single row planting)	0.83	0.81	1.64
P_2 (105/35 cm spaced paired row planting)	0.97	0.77	1.74
P_3 (175/35 cm four rows apart planting)	0.92	0.83	1.75

Table 5. Relative Crowding Coefficient as affected by intercropping and different planting geometry

TREATMENTS	SUNFLOWER K_S	MUNGBEAN K_M	SYSTEM $K = K_S \times K_M$
P_1 (70cm single row planting)	1.29	0.45	0.58
P_2(105/35 cm spaced paired row planting)	1.74	0.62	1.08
P_3(175/35 cm four rows apart planting)	1.42	0.45	0.64

K_S = Coefficient of Sunflower
K_M= Coefficient of Mungbean
K = Product of Coefficients

Table 6. Competitive Ratio (CR) as affected by intercropping and different planting geometry

TREATMENTS	SUNFLOWER CR_S	MUNGBEAN CR_M
P_1 (70cm single row planting)	1.03	0.98
P_2 (105/35 cm spaced paired row planting)	1.26	0.80
P_3 (175/35 cm four rows apart planting)	1.11	0.90

CR_S = Competitive Ratio of Sunflower
CR_M = Competitive Ratio of Mungbean

Table 7. Aggressively value (A) for the component crops as affected by intercropping and different planting geometry

TREATMENTS	SUNFLOWER A_S	MUNGBEAN A_M
P_1 (70cm single row planting)	0.02	– 0.02
P_2 (105/35 cm spaced paired row planting)	0.27	– 0.27
P_3 (175/35 cm four rows apart planting)	0.09	– 0.09

A_S = Aggressivity value of sunflower
A_M = Aggressivity value of mungbean

Table 8: Effect of Planting geometry and intercropping on net income (Rs. ha^{-1}) of sunflower and mungbean production

Treatment	Expenditure (Rs ha^{-1})	Gross income (Rs ha^{-1})	net income (Rs ha^{-1})	Benefit cost ratio
P_1I_1	59100	122848	63748	51 %
P_1I_2	64500	146092	81592	55 %
P_2I_1	59100	98915	39815	40 %
P_2I_2	64500	137917	73417	53 %
P_3I_1	59100	125112	66012	53 %
P_3I_2	64500	160495	95995	60 %

apart planting with mungbean intercropping) and minimum at 175/35 cm four rows apart alone planting (P_3I_1) with the value of 18.90 %.

Harvest Index (%)

The efficiency of a crop to convert the dry matter into the economic yield is determined with the help of harvest index value. More the value of harvest index of a variety more is the efficiency of the variety to convert the dry matter into the economic part of the crop.The data depicting the harvest index of sunflower is given in Table 1 which shows that intercropping has significant effect on the harvest index but planting geometry and interaction of both the factors have non- significant effect on harvest index. Greater harvest index of 29.78 % was obtained when sunflower sown alone and lower harvest index of 27.62 % in case of sunflower intercrop with mungbean. As far as planting pattern is concerned it showed no effect on the harvest index of sunflower. However maximum harvest index 29.22 % was found at 175/35 cm four rows apart planting (P_3) treatment while minimum (27.80 %) at 105/35 cm paired row planting (P_2). When we look at the interaction of both the factors maximum harvest index (31.03 %) was taken at 70 cm alone apart single planting (P_1I_1) and minimum (27.13) at the treatment of 70 cm apart single planting in mungbean intercropping (P_1I_2). The results are in line with the results of Saleem *et al.* (2003) who found significant effect of both these factors on harvest index. Bhatti (2005) however showed no effect of intercropping and row spacing on sesame harvest index.

Mungbean

Performance of Mungbean In Sunflower-Mungbean Intercropping Under Different Planting Patterns

Plant Height (Cm)

Plant height is an important yield component specially in case of forage crops. The results of mungbean plant height were showed in Table 2. It shows significant effect of planting patterns and intercropping on the plant height. The higher plant height (49.97 cm) was found when mungbean was sown alone at 30 cm spacing in case of intercropping. But in case of planting patterns maximum plant height (35.90 cm) was measured in 105/35 cm spaced paired row planting (P_2I_2) which was statistically at par with P_3I_2 (175/35 cm spaced four rows apart planting) and 70/35 cm spaced single row planting (P_1I_2) which gave the minimum plant height. The results were similar to those of Bhatti (2005) who found significant effect of intercropping and planting patterns on plant height but Khan (2000) narrated non-significant results of plant height in case of cotton-mungbean intercropping.

Number of Seed per Pod

Number of seeds per pod is one of the main yield contributing parameters in case of legumes. The data related to mungbean number of seeds per pod was presented in Table 2. Significant effect of planting patterns and intercropping on the number of pods per plant was depicted by the table. The greater number of seeds per pod (14.38) was found when mungbean was sown alone at 30 cm spacing in case of intercropping. As far as planting patterns is concerned maximum number of seeds per pod (11.93) was measured in P_3I_2 when sunflower was sown at 175/35 cm four rows apart planting followed by (10.80) 70 cm single row apart planting, P_1I_2 which was statistically at par with P_2I_2 (9.92). The results are contrary to Bhatti (2005) where intercropping of sesame with mungbean under different planting spacing showed non-significant effect on seeds per pods.

Grain Yield (T Ha^{-1})

Grain yield is the ultimate aim of every crop sown for seed in case of seed crops. It is the result of many factors which ultimately related to produce the seed. The data regarding to mungbean grain yield was presented in Table 2. Data show highly significant effect of planting patterns and intercropping on the grain yield. Maximum grain yield 1.12 t ha^{-1} was found when mungbean was sown alone at 30 cm spacing in case of intercropping. But as far as planting patterns is concerned maximum grain yield of 0.91 t ha^{-1} was measured in P_3I_2 (175/35 cm four rows apart planting) followed by P_1I_2 0.89 t ha^{-1} (sunflower sowing at 70 cm single row planting in mungbean intercropping) while the minimum grain yield was measured in case of P_2I_2 0.85 t ha^{-1} (105/35 cm spaced paired rows sunflower planting in mungbean combination). The reasons of reduction in the intercropped mungbean yield may be lower number of pods per plants, number of seeds per pods, 1000-grain weight. Different suppressive effects of intercropping on various yield components of mungbean grown under different planting patterns may be due to shading effects of sunflower on lower canopy of legume and interspecific competition between mungbean and sunflower. Similar type of results were described by Sultana (2007) where higher seed yield was found mungbean alone cultivation in case of intercropping and maximum grain yield in P_1 (70cm single row planting) and minimum in P_2 (105/35 cm spaced paired row planting) in case of planting geometry. Ahmad and Rao (1982) and Vyas *et al.* (1995) narrated significant effect of seed yield of intercrops. Bhatti (2005), Khan (2000) and Rao (1991) also described the significant effect of intercropping on mungbean grain yield.

1000-Grain Weight (G)

Among the various yield contributing factors 1000-achene weight is one of the remarkable factors that play an important role in the final yield of a crop. The data related to mungbean 1000-grain weight was presented in Table 2. The table shows significant effect of planting patterns and intercropping on the 1000-grain weight. The higher number of 1000-grain weight (61.52 g) was found when mungbean was sown alone at 30 cm spacing. As far as planting patterns were concerned P_3I_2 (61.36 g) gave the maximum weight in which sunflower was sown at 175/35 cm four rows apart planting while the minimum (60.88 g) 1000-grain weight (60.88 g) was observed in case of 105/35 cm apart paired rows planting (P_2I_2). The results are similar to Sahi (1988) and Nishat (1989) showing significant effect on lentil 1000-grain weight in wheat-lentil intercropping.

Harvest Index (%)

Harvest index value tells the efficiency of a crop to convert the dry matter into the economic yield. More the value of harvest index of a variety more is the efficiency of the variety to convert the dry matter into the economic part of the crop. The data related to mungbean harvest index (%) was presented in Table 2.Data show that planting patterns and intercropping have non-significant effect on harvest index. However the maximum harvest index (22.83%) was found in P_1I_2 when mungbean was sown at 70/35 cm single row spacing and minimum harvest index was measured (21.90 %) when mungbean was sown alone at 175/35 cm four rows apart planting space cm spacing (P_3I_2). The results are in line with Sultana (2007) who found significant of harvest index in sunflower-mungbean intercropping. Bhatti (2005) narrated significant effect of intercropping and planting patterns on mungbean harvest index.

Protein Content (%)

In case of legumes protein content is an important parameter with regards to nutritional value of the legume. The data related to mungbean protein content was presented in Table 2. The table shows non-significant effect of planting patterns and intercropping on protein content. However the greater protein content of 17.75 % was found when mungbean was sown alone at 30 cm spacing in case of intercropping. But in case of planting patterns maximum number of protein content (17.15 %) was measured in P_2I_2 (105/35 cm spaced paired row planting) and minimum protein content (16.39 %) was found in 175/35 cm spaced four rows apart planting. The results are in contrast with Bhatti (2005) who described non-significant effect of sesame-mungbean intercropping under different planting spacing.

Sunflower Achene Yield Equivalent

Sunflower achene yield equivalent was computed by converting the yield of intercrop into the achene yield of sunflower, based on existing market price of each crop (Anjeneyulu *et al*., 1982). It is one of the important criteria used for the assessing the intercropping advantages over monocropping. Sunflower achene yield equivalent of all planting geometry was higher than the yield of sunflower alone (Table 3). Maximum sunflower achene yield (4012.38 kg ha^{-1}) was recorded when sunflower and mungbean sown in association at 175/35 cm apart four rows planting and minimum (3447.79 kg ha^{-1}) sunflower achene yield was measured at 105/35 cm paired row apart planting. The differences in yield were due to the variation between the prices of the crop and their yield at different planting geometry. The results are similar to those of Bhatti (2005) and Sarkar and Chauhdhary (2000), who reported a remarkable increase in Sunflower achene yield equivalent due to intercropping and planting pattern.

Land Equivalent Ratio (LER)

Land equivalent ratio is the relative area of sole crop required to produce the yield achieved in intercropping (Khan *et al.*, 1988). In determining the land equivalent ratio, it is stipulated that management practices for sole and intercropping crops are same.

The LER values for different planting geometries (Table 4) show that land equivalent ratio values are higher than one in all planting patterns which indicate the advantages of intercropped over the sole cropping of sunflower. The maximum LER value of 1.75 was obtained when sunflower sown at 175/35 cm apart four rows planting with mungbean (P_3I_2) which showed 75 % yield advantages. In other words it is possible to harvest the sunflower yield from one hectare of intercropping that is harvestable from 1.75 hectare of sunflower alone cultivation. The minimum LER value (1.64) was obtained at 70 cm single row sunflower sowing with mungbean intercropping. Higher land equivalent ratio in intercropping at various planting patterns was described by the utilization of the natural (light, land) and added (fertilizer, water) resources. Bhatti (2005), Sarkar and Chakraborty (2000) and Sarkar and Sanyal (2000) also reported the higher LER value for intercropped than sole cropping in sesame intercropping with mungbean.

Competition Functions

Competition behaviour of component crops across various planting patterns in intercropping was determined by relative crowding coefficient, competitive ratio and aggressivity.

Relative Crowding Co-Efficient (K)

Relative crowding co-efficient (K) was proposed by Dewit (1960). Relative crowding coefficient (RCC) plays an important role in determining the competition effects and advantages of intercropping. Willey (1979) described that each crop in intercropping system each crop has its own RCC (K). The crop with high value of “K” is dominant over the crop having lower value of “K”. If the product of two values of K of two different crops is greater than 1, it means that intercropping system has advantages, disadvantages in case of value less than 1 and it is equal to 1, it means that intercropping has no advantages.

Table 5 shows that sunflower intercropping has yield advantages at 105/35 cm apart paired sowing with mungbean while other planting treatments have no advantages in mungbean intercropping. The results are in contrast with Bhatti (2005), Sarkar and Chakraborty (2000).

Competition Ratio (Cr)

Competition ratio is an important competitive function to determine the degree with one crop competes with other crop..The Table 6 shows the CR value of sunflower under different planting patterns. The higher CR value for sunflower in all planting patterns showed that sunflower is more competitive than mungbean in all planting geometries. The highest CR value was observed at 105/35 cm apart paired rows sunflower sowing with mungbean followed by 175/35 cm four rows apart sunflower sowing in association with mungbean. It is similar to the results of Bhatti (2005), El-Edward *et al.*, (1985) and Sarkar and Chakraborty (2000).

Aggressivity Value

Table 7 shows the degree of dominance of one crop over the other when sown together. It is an important value to determine the competitive ability of a crop growing in association with each other. If value of aggressivity is zero, then it means that cops have no competition for each other. In case of any value, both the crops have the numerical value with opposite sign. Positive sign shows the dominancy or vice versa. The greater the numerical value bigger will be the differences in crops competition and higher will be differences in expected and actual yield.

Sunflower did not compete equally with mungbean under different planting patterns. Regardless of the planting patterns, the positive sign of sunflower for A values indicated the dominant behaviour of sunflower over mungbean in all treatments. The minimum value of 0.02 in 70 cm single row sunflower planting with mungbean showed that sunflower at this planting geometry had less competition with mungbean. Sarkar et al., (2001), Bhatti et al., (2006) and Sarkar and Chakraborty (2000) also reported similar type of results.

Benefit Cost Ratio

Different planting geometry and intercropping resulted in different net benefit cost ratio. Maximium benefit cost ratio was obtained in P_3I_2 (60%) and minimum benefit cost ratio in case of P_2I_1 (40%) as indicated in the table 8.

Economic Analysis (%)

The details of sunflower production under local conditions are given in the given Table 8 Different planting geometry and intercropping resulted in different net income (Rs. ha^{-1}) as indicated in the table. Treatment in which sunflower was sown at 175/35 cm apart four rows spacing (P_3I_2) resulted in highest net income of Rs. 95995, while 105/35 cm apart paired rows (P_2I_1) giving the minimum net income of Rs. 39815.

The maximum net benefit of Rs. 95995 was obtained from the plots in which sunflower was sown at 175/35 cm four rows apart (P_3I_2).

CONCLUSION

On the basis of studies it was concluded that maximum value of achene yield (2891 kg ha^{-1}) in case of intercropping treatments was obtained in the alone sowing of sunflower and in case of planting geometries maximum achene yield (3002 kg ha^{-1}) was obtained in the treatment when sunflower was sown at 175/35 cm four rows apart sowing. The interactive effect of different planting patterns and intercropping show that maximum achene yield (3128 kg ha^{-1}) was obtained in case of P_3I_2. The maximum net benefit is of Rs. 95995 was obtained from the plots in which sunflower was sown at 175/35 cm four rows apart (P_3I_2).

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