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Evaluating the Role of Maize-Soybean Intercropping in Sustainable Maize Production

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Abstract

Continuously rising population along with declining cropped area are alarming to global food security. Between domestic production and demand there is a huge gap. To ensure the food for next generations, there is intensive need to enhance the multiple index of land. Maize–soybean intercropping can be a viable strategy for discoursing the gap between production and demand. A field study was conducted for evaluating the role of soybean intercropping in sustainable maize production at Agronomy Research Area, University of Agriculture, Faisalabad. The experiment was carried out following randomized complete block design (RCBD) with three replications. The treatments were sole maize at 60 cm spaced single row plantation (T_1), sole maize at 90 cm spaced double row strips (T_2), sole maize at 120 cm spaced triple row strips (T_3), maize at 60 cm spaced single rows with alternate row of soybean (T_4), maize at 90 cm spaced double row strips with 2 alternative rows of soybean (T_5) and maize at 120 cm spaced triple row strips with 3 alternate rows of soybean (T_6). Different observations were recorded for both crops (maize and soybean) such as number of plant per sq. m., 1000-grain weight (g), biological yield (t ha^{-1}), grain yield (t ha^{-1}), harvest index (%), number of pod for soybean. Result showed that maximum yield was obtained in 90 cm spaced double row maize strips with 2 row of soybean. Economic analysis showed that benefit cost ratio (BCR) and net income was also higher with the same treatment.
Keywords: Intercropping, maize, soybean, planting geometries.

Introduction

Maize belongs to family poaceae. After wheat and rice, it ranks third globally (Chaudhry et al., 1993). Maize provide 35% of food requirement in most countries (Braun *et al*., 2010). The major maize growing areas in Pakistan are KPK and Punjab providing 99% of the total maize production of country. During 2016-17 maize contributed 2.7% in value addition, 0.5% in GDP with production of 6.130 million tons and cultivated area of 1.334 million hectares (Govt. of Pakistan, 2017). Maize has high nutritional value i.e. 68.5% carbohydrates, 8% fats, 4% ash, 3% crude fiber and 16.5% protein (Ullah et al., 2007). More than 50% of the total maize production is being used as a food in developing countries (Arun-Kumar *et al*., 2008). It has widespread uses in poultry and livestock feed (Witt and Pasuquin, 2007). In Pakistan, different cropping schemes which are being followed in maize growing areas such as maize – wheat, potato – spring maize, maize – barseem, maize – B.T cotton, maize – wheat – maize – barseem and maize – wheat – cotton – barseem. Maize based cropping systems are much exhaustive, continuously depleting the soil fertility badly. Despite having high potential, maize production is very low as compared to other countries. There is need to modernized the conventional cropping system to sustain the production. Inert cropping can be viable strategy to cope with above mentioned problems.

Soybean (*Glycine max* L.) native to East Asia belongs to family fabaceae. It is an important leguminous crop in the world. It has widespread uses in poultry meal, animal feed as well as in human food. It is also used in medicine to cure the various chronic diseases such as cancer, heart attack. It contains 20% oil and 40% protein (Graham and Vance 2003). From Agronomic point of view, soybean is most important because of its high economic value, protein, oil contents and uses in poultry feed. It is also considered as an ecofriendly crop (Popovic *et al.*, 2013). As a leguminous crop, it can fix the atmospheric nitrogen through root nodules in its roots which can address the nutrient depletion problem and is also being used as a biofuel recently. Soybean inclusion in maize intercropping would be a viable technique for fulfillment of huge gap between the production and demand of oil seed crops (Sanginga *et al.*, 2003). In Pakistan, soybean was introduced as an oil seed crop but it has poor adoptability in the field. Very low yield, poor germination, deterioration of seed viability, climatic hazards and marketing problems are main constrains for soybean in Pakistan (Yari *et al.*, 2010).

Pakistan is still facing scarcity of edible oil. The domestic production is only 0.446 million tons while the oil seed import bill is Rs.152.514

billion (July 2016-March 2017). There is a wide gap between the domestic production and demand (Govt. of Pakistan, 2017). Pakistan is not able to attain the self-sufficiency in oil seed production due to its fixed conventional cropping systems which do not permit the cultivation of oil seed crops on a large area. Similarly, on the other hand traditional oil seed cultivars are unable to fulfill the demand of oil in Pakistan (Khan *et al*., 2012).

Conventional cropping systems of Pakistan are much exhaustive and depleting the soil badly. These cropping systems are not fulfilling the requirements of farmers (Marer *et al*., 2007). Cultivable land is decreasing due to urbanization and industrialization (Awal *et al*., 2006). Conventional planting geometry of crops does not facilitate the intercropping. Current system of mono cropping is not able to keep pace with increasing demands of farmer. The urgent attention is required to modernize the present mono-cropping to poly-crop culture which can be an acceptable approach for the enhancement of production per unit area, judicious use of land resources, time and increasing income (Dolijanvic *et al.*, 2009). According to current situation of small land holding, enlarged families, matching of growing seasons, low yield and subsistence farming, multiple cropping could be beneficial approach especially at small farmer level in Pakistan (Ali *et al*., 2000). Multiple cropping could be efficient and economically viable because it increases the production per unit area, saves time and ensures judicious use of resources with increased farmers' economy. The urgent need to develop such type of pattern facilitates intercropping (Khan *et al*., 2012). There is dire need to adopt the economically viable solution of above said problem. Intercropping of soybean with maize could be the best economically viable approach to resolve the problems.

Maize-soybean intercropping can fulfil the gap between oilseed productions and demand (Sanginga, 2003). The leguminous crops fix atmospheric nitrogen via nodule formation (Popovic *et al.,* 2013). Benefit cost ratio (BCR) increases in intercropping but the component crop yield remains low because multiple cropping enhances the productivity by efficient utilization of resources (Banik *et al*., 2006). Cereal and legume poly-cultures increase nitrogen supply and may decrease pest pressure (Farooq *et al*., 2011). Hence intercropping may enhance productivity by efficient utilization of resources with additional benefits of improved soil health and reduced cost of production.

Keeping in view the above mentioned facts, the current study was conducted to evaluate maize-soybean intercropping under different planting geometries for the promotion of poly culture in the agro climatic conditions of Faisalabad district.

Materials and Methods

The study pertaining to evaluate the role of maize-soybean intercropping for sustainable maize production was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (Pakistan) during autumn 2017 (31^o North latitude and 73^o East longitudes). The general elevation of land is about 188.4 m above sea level. Soil sampling was done before sowing and after harvesting in all the treatments. Soil samples from depth of 15 cm were collected with spade. Soil analysis was conducted in Ayyub Agriculture Research Institute (AARI) Faisalabad. The experiment was carried out following randomized complete block design (RCBD) with three replications. The net plot size was kept 5m × 3.6 m. The treatments were sole maize at 60 cm spaced single row (T_1), sole maize at 90 cm spaced double row strips (T_2), sole maize at 120 cm spaced triple row strips (T_3), maize at 60 cm spaced single rows with alternate row of soybean (T_4), maize at 90 cm spaced double row strips with 2 alternative rows of soybean (T_5) and maize at 120 cm spaced triple row strips with 3 alternate rows of soybean (T_6). Fertilizers (Urea, DAP and MOP) were applied to full fill the recommended dose of Nitrogen (N), Phosphorous (P) and Potassium (K) (250, 125 and 125 kg ha^{-1} respectively). Whole of the phosphorus and potassium were applied at the time of sowing while the nitrogen was applied in 3 splits (at sowing, at knee height and at flowering). The first irrigation was applied 20 days after sowing while subsequent irrigations were adjusted according to the need of the crops. Total seven irrigations were applied during the growing period of the crops until crop reached physiological maturity. Thinning of maize and soybean were performed before 1st irrigation to maintain plant to plant distance (according to the treatments). The crop was kept weed free by tillage operations in order to avoid weed crop competition. All other agronomic practices such as insecticides application etc. were kept normal and uniform for all the treatments. Both maize and soybean was harvested manually in last week of November, 2017. After harvesting, the maize plants were left in field for four days for sun drying and there after tied into bundles. Then cobs were separated from the stalks and allowed drying in sunshine for five days before shelling. The data were collected on the desired parameters of component crops per treatment using standard procedures. To determine the plant population per square meter for both crops (maize and soybean) total number of plants in each row and plot were counted and with the help of unit method total numbers of plants per square meter were calculated. To determine the number of pod per plant for soybean, pods of ten randomly selected tagged plants were counted and then averaged. Weight of 1000 seeds for both crops (maize and soybean) was recorded by taking three representative samples each of 1000 seeds from each treatment, then weighing them on electrical balance and converted to average 1000 seed weight in grams**.** Biological yield for both crops (maize and soybean**)** was also calculated on dry weight basis. The biological yield obtained from each plot was recorded in kg and then converted in to tons per hectare. To determine the grain yield for both crops (maize and soybean) at maturity, plants from each plot were harvested, sun dried and threshed manually and seed yield was recorded in kg per plot and then converted in to tons per hectare. Harvest index (HI) for both crops (maize and soybean) was calculated as the ratio of grain yield to biological yield and then expressed in percentage.

$$\text{Harvest index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Results and discussion

Parameters for maize (Main crop)

Number of plants (m^{-2})

The results related to optimum plant population are presented in the table-2. It was found that plant population was non-significantly affected by all the treatments under studied. Optimum plant population is necessary to assure the optimum crop stand. Good crop stand leading towards high potential of yield. Similar plant population in all treatments was due equal number of rows in all planting geometries. The results were opposite to those reported by Matusso *et al.* (2013) and Kebebew *et al.* (2014) concluded that plant population was significantly affected in various planting geometries of intercropping.

1000-grain weight (g)

Table-2 revealed significant difference in 1000-grain weight of maize under the treatments. Maximum 1000-grain weight (325.67 g) was recorded in T_2 (90 cm spaced double row sole maize strips) while minimum 1000-grain weight (243.67 g) was recorded in T_6 (120 cm spaced triple row maize strips with 3 alternate rows of soybean). 1000-grain weight represents the seed development as well as seed quality. It is most valuable component of grain yield in maize. It is controlled by genetics as well as by environment of specific area. The difference in 1000-grain weight was due to various types of competitions in different planting geometries. These results are in line with those reported by Ullah *et al*. (2007) and Ehsanullah *et al*. (2011) who stated that there was substantial effect on 1000-grain weight of maize in intercropping system. However, Panhwar et al. (2005) found non-significant effect of intercropping on 1000-grain weight of maize in intercropping treatments.

Biological yield (t ha^{-1})

Results presented in Table-2 indicated that biological yield of maize was significantly affected by the treatments under studied. Maximum biological yield (18 t ha^{-1}) was obtained with T_2 (90 cm spaced double row sole maize strips). However, minimum biological yield (12.66 t ha^{-1}) was recorded in T_6 (120 cm spaced triple row maize strips with 3 alternate rows of soybean) due to more competition for resources. Biological yield is an indication of total dry matter produced during total growth period of crop. It represents the total growth and development of crop during the crop duration. Reduction in biomass yield of base crop was due to the competitive effect of different intensities of intercrops. These results are in line with Matusso, 2013 who also reported that decline in biological yield of maize in case of its intercropping in comparison to sole maize plantation.

Grain yield (t ha^{-1})

All the treatments significantly affected the parameter under studied (Table-2). Maximum grain yield (6.29 t ha^{-1}) was observed in T_1 (60 cm spaced monoculture maize) which was statistically at par with T_2 (90 cm double row monoculture maize strips) due to less competition for resources. Lowest grain yield (4.10 t ha^{-1}) of maize was recorded in T_6 (120 cm spaced triple row maize strips with 3 alternate rows of soybean). It is most valuable factor and is a combination of various yield components. Grain yield reduction in maize-soybean intercropping as compared to sole cropping was due to presence of competition for growth resources. These results were also in accordance with the findings of Addo-Quaye, 2011.

Harvest index

Data related to harvest index is presented in the table-2 which showed non-significant effect of all the treatments for this parameter. Harvest index represents capability of crops to convert the total dry matter into economic yield as well as represents physiological efficiency of crop. The results are supported by the findings of Ehsanullah (2011) who observed non-significant differences in harvest index of maize in intercropping.

Parameters for soybean (intercrop)

Number of pods per plant

Table-3 revealed that all the treatments significantly affected the parameter under study. Maximum number of pod per plant (128.33) were observed in T_5 (90 cm apart double row maize strips with 2 alternate rows of soybean) which was statistically at par with T_6 (120 cm apart triple row maize strips with 3 alternate rows of soybean) while minimum number of pod per plant (93) were observed in T_4 (60 cm apart single row maize with

1 alternate row of soybean). It is yield contributing parameter as well as deciding the yield potential of crop. The variations in number of pods per plant were due to competition among the crop plants and dominant effect of maize. The results were in line with Kebebew *et al*, (2014) and Aziz *et al.* (2012) who also reported that different planting arrangements had significant effect on the number of pod per plant.

1000-seed weight (g)

Results presented in Table-3 indicated that various planting geometries had significant effect on 1000-seed weight of soybean. Maximum 1000-seed weight (140 g) was observed in T_5 (90 cm apart double row maize strips with 2 alternate rows of soybean) while minimum 1000-seed weight (111.33 g) was observed in T_4 (60 cm apart single row maize with 1 alternate row of soybean). 1000-seed weight is most valuable indicator for enhancement in grain yield. The difference in 1000-seed weight was due to presence of various types of competition among the planting geometries in intercropping. These results were in match with Aziz *et al*, (2012) who concluded that various planting arrangements had the significant effect on 1000-seed weight of soybean in intercropping. However, Kebebew *et al*, (2014) found that various planting arrangements had non-significant effect on 1000-seed weight of soybean in intercropping.

Biological yield (t ha^{-1})

Results showed that biological yield significantly affected by various planting geometries in intercropping (Table-3). It was concluded that maximum biological yield (2.98 t ha^{-1}) was observed in T_5 (90 cm apart double row maize strips with 2 alternate rows of soybean) and minimum biological yield (1.65 t ha^{-1}) was observed in T_4 (60cm apart single row maize with 1 alternate row of soybean). Biological yield determines the growth as well as development during the life span of crop. The difference in biological yield was due to competitive environment among the crop plants and suppressive effect of maize on soybean. These results were in accordance with the findings of Matusso *et al.* (2013) who concluded that various planting arrangements had significant effect on the biological yield of both crops in intercropping.

Grain yield (t ha^{-1})

Data related to grain yield of soybean in intercropping is given in the table-3. It is concluded that various planting arrangements had significant effect on grain yield of soybean in intercropping. Maximum grain yield (0.55 t ha^{-1}) was recorded in T_5 (90 cm apart maize strips with 2 alternate rows of soybean) followed by T_6 (120 cm apart maize strips with 3 rows of soybean) while minimum grain yield (0.33 t ha^{-1}) was recorded in T_5 (60 cm apart maize rows with 1 alternate row of soybean). Grain yield is collective effect of yield components. Variations in grain yield among different planting geometries were due to presence of various types of competitions among the crops plants (Egbe *et al*., 2010). The shading effect of maize may lower the photosynthetic efficiency of soybean (Muneer *et al*., 2004). These results supported the results reported by Matusso *et al*, (2013) who reported that various intercropping arrangements had significant effect on grain yield of soybean. Moreover, if number of rows of soybean increase in intercropping with maize then increment in grain yield was observed in same planting geometry.

Harvest index (%)

Results presented in table-3 indicated that all treatments had non-significant effect on the harvest index of soybean in intercropping. Harvest index is important factor which determine how much dry matter was converted into economic yield. More the dry matter converted into economic yield more will be the economic benefit. The difference in harvest value in different planting geometries was due to shading effect of maize on soybean.

Conclusion

Yield of main crop (maize) decreased in intercropping because of competitive environment but loss in main crop was fulfilled by additional yield of intercrop (soybean). It was investigated that maize with s2 alternate rows of soybean offer best performance than other planting arrangements in intercropping. It was more economically feasible especially for small farmers. It provides the farmer additional intercropped yield without sacrificing the maize. It provides more benefit by judicious utilization of resources as well as plays a significant role in fulfilling the gap between domestic production and oil requirements of Pakistan.

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Table: 1- Benefit cost ratio and net benefits of intercropping system over monocropping system.

Intercropping system	Maize value (RS.)	Intercrop value (RS.)	Stover value (RS.)	Gross income (RS.)	Total cost (RS.)	Net income (RS.)	BCR
Sole Maize at 60 cm spaced single row	157250	-	10000	167250	90785	76465	0.84
Sole maize at 90 cm spaced double row strips	156250	-	9100	165350	93945	71405	0.76
Sole maize at 120 cm spaced triple row strips	124500	-	8900	133400	94675	38725	0.40
Maize + 1 row of soybean	154250	33000	8700	195950	96519	99431	1.03
Maize + 2 row of soybean	143500	55000	8300	206800	98478	108322	1.09
Maize + 3 row of soybean	102500	39000	7900	149400	99467	49933	0.50

Price of maize = Rs. 25 / kg, Price of maize straw = Rs. 1000/ t, Price of soybean = Rs. 100

Table: 2-Individual means comparison for some yield components of maize

Intercropping system	No. of Plant (m^{-2})	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
Sole Maize at 60 cm spaced single row	8	325.67 a	16.00 c	6.29 a	38.00
Sole maize at 90 cm spaced double row strips	7.66	281.67 c	18.00a	6.25 a	37.00
Sole maize at 120 cm spaced triple row strips	8.00	268.33 d	13.66e	4.98d	37.5
Maize + 1 row of soybean	8.00	256.67 e	14.66d	6.17b	37.00
Maize + 2 row of soybean	8.00	301.33 b	17.00b	5.74c	37.23.
Maize + 3 row of soybean	7.66	243.67 f	12.66f	4.10e	37.33
HSD	NS	10.41	0.89	0.04	NS

Table: 3- Individual means comparison for some yield components of soybean

Intercropping system	No. of pod per plant	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
Maize + 1 row of soybean	93b	111.33c	1.65c	0.33c	38.66
Maize + 2 row of soybean	128.33a	140.00a	2.98a	0.55a	38.00
Maize + 3 row of soybean	119.33a	126.00b	2.52b	0.39b	38.33
HSD	21.54	12.50	0.06	0.04	NS