Agro-Economic Assessment of Maize-Soybean Intercropping System

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Abstract: Intercropping increases the agronomic productivity along with economical proficiency of any cropping system through efficient utilization of resources compared to monocropping system. Intercropping of soybean in maize improves the net income, benefit cost ratio (BCR) of the system and help to overcome the scarcity of oilseeds in Pakistan as sowing times of both crops coincide. Economic feasibility associated with different maize-soybean intercropping systems has been evaluated by growing soybean as intercropping in maize. Field experiment was directed to assess the impacts of maize and soybean intercropping on its yields and monetary aspects at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during autumn 2014. The trial was organized in a randomized complete Block Design (RCBD) with four replications. Treatments were comprised of sole maize at 60 cm spaced single row, sole soybean at 30 cm spaced single row, sole maize at 90 cm spaced double row strips, maize at 90 cm spaced double row strips + 1 row of soybean, maize at 90 cm spaced double row strips + 2 rows of soybean and maize at 90 cm spaced double row strips + 3 rows of soybean. In crux, maize-soybean intercropping system with double rows strips of maize + 2 rows of soybean performed with maximum net income, benefit-cost ratio (BCR) and land equivalent ratio (LER) associated with all other intercropping treatments.

Key words: Intercropping • Maize-soybean yield • Land equivalent ratio • Economics

INTRODUCTION

The immense rise in human population together with significant decline in cropped area, is posing threat to the global food security. In order to secure food for future generations, there is a dire need to modernize traditional farming system to develop production-oriented and economic-based cropping system practices. Pakistan is facing acute shortage of edible oil, so imports a huge quantity of edible oil and oilseeds to fulfill its requirements [1]. Along with ever increasing population pressure, per unit consumption is also rising but domestic production of edible oilseeds is not sufficient to fill the gap between production and demand [2]. All this requires an urgent attention for improving the miserable situation of this vital sector. Overlapping of growing season of oilseed crops with major field crops is considered the major constraint in this regard. Soybean growing period coincides with autumn maize and farmers remain reluctant for growing soybean instead of maize. Intercropping of oilseeds with major crops could be an acceptable approach. Poly-Culture or Multi-Cropping (developing of two or more than two crops on same area in one year) especially inter-cropping has been demonstrated extremely gainful agro-technique in tropical and subtropical areas of the world. It provides farmers with more benefits and yield stability [3]. Pakistan falls in sub-tropical regions with irrigated agriculture and there is an ample supply of sunlight for plant growth. Therefore, multiple cropping of two or more crops seems to be a better option for small growers in Pakistan regarding system productivity and sustainability [4]. Effective use of solar energy, nutrients and water in intercropping enhances system productivity efficiently [5].

Although, component crop yield decreases in intercropping but system efficiency increases in terms of benefit cost ratio (BCR), net income and land equivalent ratio (LER) [6] because intercropping increases farm income by using land resources efficiently. Individual crops in inter-cropping show different competitive behaviors that can be assessed in terms of competitive
An experiment concerning with agro-economic assessment of maize-soybean intercropping system was conducted on Agronomic Research Area, University of Agriculture, Faisalabad during Autumn 2014 to assess the feasibility of maize-soybean intercropping. Randomized complete block design (RCBD) was used having net plot size of 5.0 m × 3.6 m for each treatment. Treatments were comprised of sole maize at 60 cm spaced single row, sole soybean at 30 cm spaced single row, sole maize at 90 cm spaced double row strips, maize at 90 cm spaced double row strips + 1 row of soybean, maize at 90 cm spaced double row strips + 2 rows of soybean and maize at 90 cm spaced double row strips + 3 rows of soybean. Number of rows of maize was kept constant in sole and intercropping treatments; only row to row distance was decreased to adjust intercrop lines in between the maize strips. Varieties of maize and soybean were DK-919 (Dekalb) and Williams-82, respectively. Sowing was done on July 24-2014 with single row hand drill. Seed rate for maize and soybean was used @ 25 kg ha⁻¹ and 62 kg ha⁻¹, respectively. Sole soybean was sown for determining the land equivalent ratio (LER). Thinning of maize crop was done two times in whole growing period. To free the plot from weeds, two hoeing were done manually. All the cultural operations were kept constant during whole study period. Observations on growth and yield related traits of both the component crops were recorded. The data obtained were analyzed statistically by using Fisher’s analysis of variance technique and differences among treatment’s means were compared by using least significant difference test (LSD) at 5% probability level. Benefit-cost analysis was executed to appraisal the actual economic feasibility associated with diverse maize-soybean intercropping system. The production expenditures associated with maize in addition to soybean involved land preparation, seed, seeding, irrigation, fertilizers and harvesting. This gross income was predicted using the current market prices for both the grain as well as straw of the maize in addition to soybean in Pakistan. Net gain was calculated by means of subtracting total expenses from the gross income while benefit-cost percentage (BCR) was calculated by means of separating the actual gross income along with total expenses.

Harvest index (HI) and other competition functions were calculated by the following formulas:

\[
\text{Harvest Index (\%) } = \frac{\text{Grain yield}}{\text{Biological Yield}} \times 100
\]
Land Equivalent Ratio (LER) = LER (Maize) + LER (Soybean)

LER (Maize) = \( \frac{\text{Grain yield of intercrop maize}}{\text{Grain yield of sole maize}} \)

LER (Soybean) = \( \frac{\text{Grain yield of intercrop soybean}}{\text{Grain yield of sole soybean}} \)

Net Return = Total Income - Total Cost

Benefit Cost Ratio (BCR) = \( \frac{\text{Gross income}}{\text{Total expenditure}} \)

RESULTS AND DISCUSSION

Number of Grains per Ear of Maize: The number of grains per ear of maize was differed significantly by various intensities of soybean intercropping. The maximum number of grains per ear of maize (435) was recorded in maize alone grown at 60 cm spaced single rows which was significantly higher than all intercropped maize with soybean treatments. However, the minimum number of grains (380) per ear of maize was found in maize + 3 rows of soybean. Maize + 1 row of soybean produced higher number of grains (401) per ear than rest of intercropping treatments (Table 1). The difference in the number of grains per ear of maize in various treatments happened due to different intercropping intensities of soybean in maize that caused competition between the component crops and ultimately affected the number of grains per ear of maize. These results are in line with those reported by Ullah et al. [16], who conducted experiments on maize-legumes based intercropping system and stated that there was a significant effect in the number of grains per ear of maize. However, Arshad et al. [17] reported the non-significant effect of number of grains per ear of maize in intercropping arrangement.

1000-Grain Weight (g) of Maize: 1000-grain weight of maize under different intensities of soybean intercropping in maize showed significantly affect. The maximum 1000-grain weight (297.50 g) was recorded in maize alone grown at 60 cm spaced single rows, while the minimum 1000-grain weight (259.75 g) was noticed in maize + 3 rows of soybean. However, maize + 1 row of soybean produced 1000-grain weight (269.75 g) while maize + 2 rows of soybean produced 1000-grain weight (265.25 g) (Table 1). Higher 1000-grain weight was observed in sole maize because of competition free environment. These results are in line with those reported by Ehsanullah et al. [18], who stated that there was significant effect in 1000-seed weight of maize in intercropping system. However, Panhwar et al. [19] reported non-significant effect of intercropping on 1000-grain weight of maize.

Biological Yield of Maize (t ha\(^{-1}\)): All intensities of soybean intercropping reduced biomass yield of maize crop as compared to sole maize crop because of simultaneous competition between different intensities of component crop. Significantly maximum biomass (16.18 t ha\(^{-1}\)) was recorded in maize alone at 60 cm spaced single rows which was at par with maize alone grown at 90 cm spaced double row strips (15.05 t ha\(^{-1}\)). The minimum maize biomass (12.54 t ha\(^{-1}\)) was recorded when 3 rows of soybean intercropped in maize (Table 1). Significant reduction in production of maize biomass in different intensities of intercropping compared to sole maize crop was due to direct competition between maize and soybean for different plant growth factors like moisture, nutrient, space and light etc. The maximum biomass was obtained in maize alone due to competition free environment for different input resources. Reduction in biomass yield of base crop due to competitive effect of different intensities of intercrops was also reported by Mandal et al. [20].

Table 1: Effect of maize-soybean intercropping on yield and yield component of maize.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Number of grains per ear</th>
<th>1000 grains weight (g)</th>
<th>Biological yield (t/ha)</th>
<th>Grain yield (t/ha)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize alone at 60 cm apart single row</td>
<td>435.00 a</td>
<td>297.50 a</td>
<td>16.18 a</td>
<td>6.4 a</td>
<td>39.99</td>
</tr>
<tr>
<td>Maize alone at 90 cm double row strips</td>
<td>421.50 ab</td>
<td>283.25 ab</td>
<td>15.05 ab</td>
<td>5.9 ab</td>
<td>39.83</td>
</tr>
<tr>
<td>Maize at 90 cm double row strips with 1 row of Soybean</td>
<td>401.25 bc</td>
<td>269.75 bc</td>
<td>14.29 bc</td>
<td>5.6 bc</td>
<td>39.21</td>
</tr>
<tr>
<td>Maize at 90 cm double row strips with 2 rows of Soybean</td>
<td>391.50 bc</td>
<td>265.25 bc</td>
<td>13.20 ed</td>
<td>5.3 ed</td>
<td>38.96</td>
</tr>
<tr>
<td>Maize at 90 cm double row strips with 3 rows of Soybean</td>
<td>380.50 c</td>
<td>259.75 c</td>
<td>12.54 d</td>
<td>4.7 d</td>
<td>37.59</td>
</tr>
<tr>
<td>LSD at (5%)</td>
<td>33.43</td>
<td>22.13</td>
<td>1.23</td>
<td>0.69 d</td>
<td>3.03</td>
</tr>
</tbody>
</table>
Grain Yield of Maize (t ha\(^{-1}\)): Data regarding the final yield of maize as affected by different intensities of soybean intercropping are shown in Table 1. The perusal of the Table indicated that different intensities of soybean intercropping reduced the grain yield of maize as compared to sole maize crop. The maximum grain yield of maize (6.43 t ha\(^{-1}\)) was recorded in maize grown alone at 60 cm spaced single rows which was at par with maize alone grown at 90 cm spaced double rows strips (5.99 t ha\(^{-1}\)). The rest of treatments like maize + 1 row of soybean, maize + 2 rows of soybean and maize + 3 rows of soybean gave 5.60, 5.30 and 4.70 t ha\(^{-1}\) grain yield of maize, respectively. However, the minimum grain yield (4.70 t ha\(^{-1}\)) was recorded when 3 rows of soybean were intercropped in maize. Significant reduction in maize grain yield was accord due to greater inter and intra specific competition for different growth factors like nutrients, moisture, space and light etc. between maize and soybean, which affected different yield contributing component like number of grains per cob and 1000-grain weight of maize etc. (Table 1).

Harvest Index (%) of Maize: The physiological efficiency and ability of a crop plant for converting the total dry matter into economic yield is determined by its harvest index value. Higher the value more will be the physiological efficiency and vice versa. Data regarding the harvest index are presented in Table 1. It is clear from Table 1 that harvest index of maize was not affected by different intensities of soybean intercropping. The maximum harvest index 40.74% was recorded in maize alone grown at 60 cm spaced single rows. While, the minimum harvest index 37.59% was recorded in maize + 3 rows of soybean intercropping system. The harvest index of maize was on an average varied from 40.74 to 37.59% (Table 1). Harvest index of maize showed non-significant effect in intercropping arrangements. The difference between minimum and maximum range was 3.15% which was not significant according to the statistical analysis. The results are supported by the findings of Kebebew et al. [21], who observed non-significant differences in harvest index of maize in intercropping.

Table 2: Effect of intercropping on yield and yield components of soybean intercropped with maize

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant population (m(^{-2}))</th>
<th>100-seed weight (g)</th>
<th>Biological yield (t/ha)</th>
<th>Seed yield (t/ha)</th>
<th>Harvest Index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean alone at 30 cm apart</td>
<td>29.75 a</td>
<td>112.50 a</td>
<td>2.93 a</td>
<td>1.20 a</td>
<td>40.96 a</td>
</tr>
<tr>
<td>Maize at 90 cm double row strips with 1 row of Soybean</td>
<td>9.75 d</td>
<td>102.75 ab</td>
<td>0.97 c</td>
<td>0.34 c</td>
<td>35.22 b</td>
</tr>
<tr>
<td>Maize at 90 cm double row strips with 2 rows of Soybean</td>
<td>16.00 c</td>
<td>97.50 bc</td>
<td>1.22 b</td>
<td>0.46 b</td>
<td>38.07 ab</td>
</tr>
<tr>
<td>Maize at 90 cm double row strips with 3 rows of Soybean</td>
<td>19.75 b</td>
<td>90.50 c</td>
<td>1.30 b</td>
<td>0.51 b</td>
<td>38.82ab</td>
</tr>
<tr>
<td>LSD at (5%)</td>
<td>2.29</td>
<td>9.97</td>
<td>0.21</td>
<td>0.07</td>
<td>3.67</td>
</tr>
</tbody>
</table>

Number of Plants (M\(^{-2}\)) of Soybean: Plant population of a crop is necessary to harvest good yield. Good crop stand ultimately ensures reasonable economic benefits. Plant population of soybean was affected significantly by maize-soybean intercropping system (Table 2). Soybean sole grown at 30 cm spaced single rows exhibited significantly higher plant population (29 plant m\(^{-2}\)) than maize-soybean intercropping. The minimum plant population (9 plant m\(^{-2}\)) was recorded in case of 60 cm spaced double rows strips of maize + two rows of soybean. One of the main reasons for significant plant population results is due to less number of rows per unit area maintained as per treatment.

100-Seed Weight (G) of Soybean: 100-seed weight of soybean was significantly affected by maize-soybean intercropping system (Table 2). All intercropping treatments caused significant reduction in 100 seeds weight of soybean compared with soybean alone. Reduction in 100-seed weight of soybean grown in association with maize was probably due to the aggressive nature of maize which resulted in intense intercrop competition. Aziz et al. [22] reported the significant effect of intercropping on 100-seed weight of soybean.

Biological Yield of Soybean (t ha\(^{-1}\)): Data regarding the biological yield of soybean are presented in Table 2. It is clear from the Table 2 that the biomass yield per hectare of soybean was reduced in different intensities of intercropping as compared to sole soybean crop because of simultaneous competition between different intensities of component crops. Significantly maximum biomass (2.93 t ha\(^{-1}\)) was recorded in soybean alone grown at 30 cm spaced single rows followed by maize + 3 rows of soybean and maize + 2 rows of soybean. However, the minimum biomass (0.97 t ha\(^{-1}\)) was found in case of 1 row of soybean when it was intercropped in maize (Table 2). Significant reduction in the production of soybean biomass at different intensities of intercropping was observed due to competition between the component crop for plant growth factor like moisture and nutrient etc. The maximum biomass was found in soybean alone due to competition free environment.
Seed Yield of Soybean (t ha\(^{-1}\)): Data pertaining the final seed yield of soybeans affected by different intensities of intercropping under study are presented in Table 2. It is clear that different intensities of intercropping affected seed yield significantly of soybean. The maximum seed yield of soybean (1.20 t ha\(^{-1}\)) was recorded in sole soybean crop followed by maize + 3 rows of soybean and maize + 2 rows of soybean giving 0.51 t ha\(^{-1}\) and 0.46 t ha\(^{-1}\) seed yield, respectively. The minimum seed yield (0.34 t ha\(^{-1}\)) was recorded in case of maize + 1 row of soybean.

It was further observed that there was a progressive increase in the soybean seed yield with increasing the intensities of intercropping of soybean in maize so the maize + 3 rows of soybean intercropping system produced the higher soybean seed yield than all other intercropped soybean treatments. The results led to the conclusion that sowing of maize at 90 cm spaced double rows strips with intercropping of 3 rows of soybean was most suitable intercropping system for having better seed yield of intercropped soybean. The higher seed yield of soybean was found when soybean grown alone due to competition free environment. The intercrop (soybean) yield get decreased in intercropping treatments as compare to sole cropping of soybean might be due to the interspecific competition among the intercrop components for light, water, air and nutrients and also the aggressive effects of maize (C4 species) on soybean, a C3 species [23]. The shading effect of maize plants (taller) on soybean may also cause to decline in photosynthetic rate of (lower plants) soybean and thereby yield of intercrop reduced in intercropping arrangements. This reduction in seed yield due to intercropping was ascribed to low plant density in addition to fewer number of pods per plant, number of seeds per pod and 100-seed weight of intercropping soybean. Findings of these results are in quiet agreement with those reported by Muneer et al. [24], who studied the effects of different maize-soybean intercropping on yield and its economics and also concluded that there is increment in soybean seed yield with increasing the intensities of soybean intercrop in maize.

Harvest Index (%) of Soybean: Data regarding the harvest index are presented in Table 2 it is clear that harvest index value of soybean was significantly affected when it was intercropped in maize. The maximum harvest index value 38.82% was recorded in maize + 3 rows of soybean followed by maize + 2 row of soybean. However, the minimum harvest index value 35.22% was recorded in maize + 1 rows of soybean intercropping system. Significantly higher value of harvest index was noted in sole soybean grown at 30 cm spaced single rows. The reduction of harvest index of intercrop might be due to the maize shading effects on soybean which caused the legume component to allocate its photosynthates to vegetative growth and height increasing for competing with taller maize.

Land Equivalent Ratio (LER): The land equivalent ratio is the relative area of a sole crop required to produce the yield achieved in intercropping. If LER value is equal to one, it means that there is no yield advantage but when LER value is more than one then there is yield advantage. Data regarding LER of different maize-soybean intercropping systems are presented in Table 3 which indicated that LER values were greater than one in all the intercropping treatments and the range of yield advantage over sole cropping was between 21 to 27% with the highest in case of maize + 2 rows of soybean (27%) followed by maize + 1 row of soybean (22%). However, the minimum LER was recorded in maize + 3 rows of soybean (21%). It means that there should be required 0.27 units more area to produce the same yield of maize as produced by maize + 2 rows of soybean intercropping. Higher LER in intercropping treatments compared with monocropping of maize ascribed to better resources utilization (land, light) and added resources (fertilizer, water). Higher LER in intercropping compared to mono cropping was also reported by Raji et al. [25].

Economic Analysis: The economic analysis of the experiment is done to look into experimental results from farmer’s point of view as they are mainly interested in benefits and cost of a certain technology and also they like to know about risks involved in the adoption of new practices. The efficiency of an intercropping system is determined either by the net income per unit area in a specified period of time, or benefit cost ratio (BCR). Data regarding economic analysis are presented in Table 4. In this analysis prices of inputs prevailing in the local market were used to calculate the economic analysis of different intercropping systems. A glance at the Table 4 indicated that maize + 2 rows of soybean gave the highest net income of Rs. 88681 per hectare. In term of benefit cost ratio (BCR) as shown in Table 4, the highest value of 1.90 was recorded in case of maize + 2 row of soybean, followed by 1.89 in case of barley + 1 rows of soybean. The minimum BCR value of 1.77 was recorded when maize was grown with 3 rows of soybean. The higher output of intercropping system compared to the mono cropping system may have caused from complementary and...
Table 3: Effect of Maize-Soybean Intercropping System on Land Equivalent Ratio (LER)

<table>
<thead>
<tr>
<th>Intercropping system</th>
<th>Maize (M)</th>
<th>Soybean (S)</th>
<th>Intercrop System (M+S)</th>
<th>Yield advantage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize + 1 row of Soybean</td>
<td>0.94</td>
<td>0.28</td>
<td>1.22</td>
<td>22</td>
</tr>
<tr>
<td>Maize + 2 rows of Soybean</td>
<td>0.89</td>
<td>0.38</td>
<td>1.27</td>
<td>27</td>
</tr>
<tr>
<td>Maize + 3 rows of Soybean</td>
<td>0.79</td>
<td>0.42</td>
<td>1.21</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 4: Effect of maize-soybean intercropping system on BCR

<table>
<thead>
<tr>
<th>Intercropping system</th>
<th>Maize value (Rs.)</th>
<th>Intercrop value (Rs.)</th>
<th>Stover value (Rs.)</th>
<th>Gross Income (Rs.)</th>
<th>Total cost (Rs.)</th>
<th>Net income (Rs.)</th>
<th>BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sole maize</td>
<td>149750</td>
<td>-</td>
<td>9000</td>
<td>158750</td>
<td>94394</td>
<td>64356</td>
<td>1.68</td>
</tr>
<tr>
<td>Sole Soybean</td>
<td>-</td>
<td>120000</td>
<td>-</td>
<td>120000</td>
<td>85234</td>
<td>34766</td>
<td>1.41</td>
</tr>
<tr>
<td>Maize+1 row Soybean</td>
<td>140000</td>
<td>34000</td>
<td>8700</td>
<td>182700</td>
<td>96619</td>
<td>86081</td>
<td>1.89</td>
</tr>
<tr>
<td>Maize+2 rows Soybean</td>
<td>132500</td>
<td>46000</td>
<td>8600</td>
<td>187100</td>
<td>98419</td>
<td>88681</td>
<td>1.90</td>
</tr>
<tr>
<td>Maize+3 rows Soybean</td>
<td>117500</td>
<td>51000</td>
<td>7800</td>
<td>176300</td>
<td>99469</td>
<td>76831</td>
<td>1.77</td>
</tr>
</tbody>
</table>

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

CONCLUSION

Grain yield of maize was reduced in intercropping system; however, losses were compensated through additional economic benefits obtained through soybean. It is concluded that maize plus two rows of soybean is more feasible and economical intercropping system under agro-ecological conditions of Faisalabad, Pakistan. It gave high net benefits and proved better for resource utilization. Farmers can get reasonable amount of edible oil for their household and contributes a lot to fulfill oil requirement of the country by following this intercropping technique without sacrificing their major field crop like maize.

REFERENCES


