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Yield and Economics of Maize (*Zea mays*) + Soybean (*Glycin max* L. Merrill) Intercropping System under Different Tillage Methods

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Abstract A study was conducted to determine the most profitable crop arrangements for maize and soybean intercropping system. The effect of tillage {conventional (CT) versus zero tillage (ZT)} and six crop arrangements (sole maize, sole soybean, maize+soybean intercropping at different row ratio arrangements) on grain yield and economics was investigated in Chitwan, Nepal during the summer of 2013. The grain yields of maize and soybean were not affected by tillage methods. However, crop arrangements significantly affect yield component and yield of both maize and soybean. Sole crop of maize and soybean recorded significantly higher grain yield than corresponding yields under intercropping systems. Planting maize+soybean at 1:1 ratio recorded highest maize grain yield (4.58 Mg ha^{-1}) and 2:2 ratio recorded the highest soybean yield (1.70 Mg ha^{-1}). Yield reduction due to intercropping ranged from 21.44% to 31.9% in maize and 22.3% to 53.88% in soybean as compared to their sole cropping. Remarkably higher net return was obtained in ZT (NPRs 110.4 thousands ha^{-1}) than CT (NPRs 105.8 thousands ha^{-1}). Intercropping of maize and soybean at 2:2 ratio recorded maximum benefit (NPRs 132.7 thousands ha^{-1}), maize grain yield equivalent (8.74 Mg ha^{-1}) and land equivalent ratio (1.47) than sole and intercropping treatments. It was found that paired rows of soybean between two rows of maize under ZT system could achieve higher productivity and profitability.

Keywords: *intercropping system, tillage, crop arrangements, yield, economics*

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1. Introduction

Agriculture is the mainstay of Nepalese people. About 65.6% of total population of the country is engaged in agriculture. Nepal has 3,091,000 ha of total cultivated agriculture land [1]. Agriculture sector shares 35.11% of gross domestic product (GDP) [1]. Maize **(***Zea mays***)** is the second most important staple food crop both in terms of area and production, after rice in Nepal. It is grown in 0.871 million hectares of land with a total production of 2,179,414 Mg and productivity of 2.501 Mg ha^{-1} [1]. It occupies about 28.19% of the total cultivated agricultural land. It shares about 23.04% of the total cereal production in Nepal, and therefore plays an important role in national food security. Soybean (*Glycin max* L. Merrill) is a rich source of protein (40%) and essential amino acids, vitamins (B and D) and the important minerals. In Nepal, it is grown in an area of 29,282 ha (8.76% of total area under legume cultivation) with production of 28,270 Mg and productivity 0.97 Mg ha^{-1} [1].

Tillage is one of the important processes in agriculture since it contributes up to 20% of the crop production factors [2]. It also has significant effect on soil properties. The type and intensity of tillage affects the agricultural sustainability through its influence on soil properties [3,4]. Conventional tillage decreases soil compaction and hence provides favorable seed bed preparation, enhances root growth and development, controls weeds, and maintains crop yields [5,6]. However, the practice of repeated ploughing in conventional tillage (CT) is responsible for soil structural degradation, accelerated erosion, loss of soil organic matter (SOM), and disturbs nutrient cycles (Sundermeier et al., 2011). Loose soil, resulting from frequent tillage, is prone to water and wind erosion. Moreover, CT considered as expensive operation in terms of work and fuel consumption. The shift from conventional to conservation tillage methods across the world has occurred due to concerns for soil water conservation, fuel and erosion control [7], without losing significantly on the yield front.

Mixed cropping of cereals and legumes is widespread in the tropics [8] mainly for climatic and socio-economic reasons [9]. Land productivity measured by Land

Equivalent Ratio (LER) and monetary gain proves mixed cropping of cereal and legumes to be advantageous [10]. Maize and soybean may form one of such important cereal legume intercropping system and this system improves the availability of residual nitrogen in the soil. Biological nitrogen fixation (BNF), which enables legumes to use atmospheric N_2, is important in legume-based cropping systems where N is limited. If a legume is grown in association with another crop, commonly a cereal, the N nutrition latter may be improved by direct N transfer from the former to the latter [11]. Therefore, productivity is potentially enhanced by the inclusion of a legume in the cropping system. But the main cause of low production and productivity under intercropping obtained in developing country is due to improper crop arrangements, wrong intra-specific mixture and wasteful use of resources. Arrangement of crops in mixture in conventional farming system in Nepal is random and without any scientific patterns for effective interception of the solar radiation. Spatial arrangement of crops in mixture is an important management practice that can provide complete ground cover and hence improve solar radiation interception. The present experiment was undertaken to determine a suitable arrangement under maize + soybean intercropping system, and under different tillage methods for higher productivity and economic advantage.

2. Materials and Methods

The experiment was conducted at Rampur (27° 37' N; 84° 25' E), Chitwan, Nepal during the summer of 2013. The soil was sandy loam with a pH of 5.4. The soil was low in soil organic matter content (1.95%), medium in total nitrogen content (0.12%) and available potassium content (159 kg ha^{-1}) but high in available phosphorous content (110 kg ha^{-1}). Treatment combinations were: sole maize (*Zea mays*), sole soybean (*Glycin max* L. Merrill), maize and soybean at 1:1, 1:2, 2:1 and 2:2 row ratios under two tillage system (conventional and zero). Maize variety Manakamana-3 (white flint grain type) and soybean variety Puja (bold grain) were used in the experiment. Plant populations were maintained at 53,333 ha^{-1} and 200,000 ha^{-1} for maize and soybean respectively. An additive or superimposed model was used and plant density of both crops was kept constant in intercrop plot. In all treatments, there were eight rows of maize per plot. On the other hand, the number of soybean rows per plot varied depending upon the row ratio of soybean, but soybean plant per plot was maintained constant by adjusting within row spacing of the companion crop, soybean. Plant to plant distance for maize was equal in all treatments viz., 1:1, 1:2, 2:1, 2:2 and sole crop. However, the row to row distance of maize was varied depending upon row ratio. In sole plot, 1:1 and 1:2 row ratios maize seed were sown maintaining 25 cm distance between plants and 75 cm distance between rows. In 1:1 row ratio plot, one row of soybean was planted at the centre of two maize rows and within row spacing was maintained at 6.6 cm. Likewise, in 1:2 row ratio plot, 2 rows of soybean were sown in between two maize rows at a distance of 25 cm and within row spacing was maintained at 13 cm. Similarly, in 2:2 row ratio paired row of maize and paired row of soybean were sown in alternate fashion and each row was separated by 37.5 cm. Finally, in 2:1 row ratio plot, one soybean row was sown after paired maize row and each of the soybean and maize rows was separated by 50 cm. Within row spacing for soybean was maintained at 6.66 cm for 2:1 and 2:2 row ratio plots but 2 plants per hole was kept in case of 2:1 row ratio plot to maintain constant soybean plant population. Sole soybean was planted at 50 cm × 10 cm spacing.

The experiment was laid out in a randomized strip plot design with three replications. The unit plot size was 6 m × 3 m, maize cv. manakamana-3 and soybean cv. Pooja were used in this experiment. Soybean seeds were sown twenty five days after planting maize. A uniform basal dose of 120:60:30 kg N, P_2O_5 and K_2O for maize and 20:40:20 kg N, P_2O_5 and K_2O for soybean was applied through urea, Diammonium phosphate (DAP) and Murate of Potash (MOP). Glyphosate @ 1.5 kg active ingredient ha^{-1} was applied 15 days before field preparation as a non selective herbicide and Altrazine @ 2 kg active ingredient ha^{-1} was applied just after maize sowing as a pre emergence herbicide. Data on yield components were recorded from randomly selected 10 plants for both the crops. Maize grain yield equivalent (MGEY) was computed by converting yield of intercrops on the basis of prevailing market price of the individuals by the following formula [12].

$$Maizegrainyieldequivalent\left(MGYE\right) = Ym + \frac{Yi \times Pi}{Pm}$$

Where, Ym = yield of maize
Yi = yield of soybean
Pi = Selling price of soybean
Pm = Selling price of maize

Economic analysis was also done to access the economic productivity of the intercropping system.

3. Results and Discussion

3.1. Effect on Maize

Tillage had non-significant effect on yield components of maize. However, most of the yield components of maize were significantly affected when grown in association with soybean under different arrangements (Table 1). Thousand-grain weight did not differ significantly between sole maize and those of intercropped maize. Harvested ear per hectare was significantly higher in maize sole (55.8 thousand ha^{-1}) as compared to intercropped maize. Maize yield was resembled to that number of harvested ears ha^{-1}. Significantly highest grain yield (5.83 Mg ha^{-1}) was obtained from sole maize followed by intercropping system, where maize and soybean were planted in alternate rows. Ennin *et al.* [13], Kumar *et al.* [14] and Meena *et al.* [15] also reported similar results.

3.2. Effect on Soybean

Tillage system had non-significant influence on yield components of soybean. However, most of the components were significantly affected by spatial arrangements. Sole cropping and spatial arrangement under maize and soybean intercropping system had significant effect on pods per plants and grain yield but non-significant effect on number of harvested plants per ha^{-1} and thousand-grain yield. Significantly higher number of pods per plant (68.08) was found in sole soybean, followed by maize and soybean at 2:2 ratio (45.35). The lowest number of pods per plant (32.85) was recorded from maize and soybean at 1:1 ratio and it was similar with maize and soybean at 2:1 and 1:2 ratios. This variation in number of pods per plant was reflected in grain yield. Here significantly highest grain yield (2.19 Mg ha^{-1}) was recorded with soybean sole plot and the lowest with maize and soybean at 2:2 ratio (1.70 Mg ha^{-1}). Ezumal *et al.* [16], Mudita *et al.* [17] and Ofori and Stern [8] observed the similar lower intercrop yield in maize + soybean intercropping system as compared to its sole cropping. Similar findings was also observed by Srarle *et al.* [18] and Siame *et al.* [19] in maize + cowpea intercropping system.

Table 1. Yield attributing characteristics and yield of maize as influenced by tillage methods and spatial arrangements under maize and soybean intercropping system at Rampur, Chitwan, Nepal, 2013

Treatments	Kernels ear^{-1}	Thousand grain weight (g)	Harvested ear ha^{-1} (,000)	Grain yield (Mg ha^{-1})
Tillage				
CT	327.72	300.41	53.14	4.68
ZT	323.6	299.09	53.73	4.577
LSD (P=0.05)	NS	NS	NS	NS
SEm (±)	1.151	4.124	0.209	0.037
Spatial arrangements				
MS	383.9^{a}	308.67	55.80^{a}	5.83^{a}
M+S (1:2)	312.9^{bc}	298.93	52.84^{b}	4.37^{bc}
M+S (2:1)	308.1^{c}	297.37	52.59^{b}	4.34^{c}
M+S (1:1)	330.8^{b}	300.5	52.84^{b}	4.58^{b}
M+S (2:2)	292.6^{c}	293.27	53.09^{b}	3.98^{d}
Grand mean	325.66	299.75	53.43	4.621
LSD (P=0.05)	21.34	NS	1.63	0.219
SEm (±)	6.545	5.282	0.5	0.067
CV, %	3.36	3.4	2.35	4.14

Means followed by common letter (s) in a column are not significantly different based on DMRT at 5% level of significance.

Table 2. Yield attributing characteristics and yield of soybean as influenced by tillage methods and spatial arrangements under maize and soybean intercropping system at Rampur, Chitwan, Nepal, 2013

Factors	Yield attributing characters and yield of soybean			
	No.of harvested plants ha^{-1}	Pods $plant^{-1}$	Thousand grain weight (g)	Grain yield (Mg ha^{-1})
Tillage				
CT	170.66	44.42	128.26	1.55
ZT	170.54	43.51	127.48	1.54
LSD (P=0.05)	NS	NS	NS	NS
SEm (±)	4.08	1.015	0.696	0.004
Spatial arrangements				
SS	165.46	68.08^{a}	129.63	2.19^{a}
M+S (1:2)	173.44	38.55^{c}	127.48	1.51^{c}
M+S (2:1)	173.36	34.98^{c}	127.28	1.31^{d}
M+S (1:1)	170.42	32.85^{c}	126.92	1.01^{e}
M+S (2:2)	170.34	45.35^{b}	128.04	1.70^{b}
Mean	170.60	43.96	127.87	1.54
LSD (P=0.05)	NS	6.451	NS	0.084
SEm (±)	12.465	1.978	2.641	0.027
CV, %	6.07	3.42	6.06	5.76

Means followed by common letter (s) in a column are not significantly different based on DMRT at 5% level of significance.

3.3. Maize Grain Yield Equivalent

Marked variation in maize grain yield equivalent (MGYE) was observed in different intercropping systems (Table 3). Intercropping system provides higher MGEY over sole cropping. Two rows of soybean grown in paired rows of maize resulted in the highest MGEY of 8.74 Mg ha^{-1} and it was 49.91% higher over sole maize. The increase in MGEY was mainly due to higher return from soybean. Here higher MGEY in intercropping system was also supported by Quayyum *et al.* [20] in maize and black gram.

3.4. Land Equivalent Ratio

Land equivalent ratio (LER) was more than unity in all intercropping systems indicating the greater biological efficiency and yield advantage over sole cropping (Table 3). Amongst different intercropping systems, two rows of soybean in maize paired row produced the highest LER (1.47), which was at par with maize and soybean at 1:2 and 2:1 ratio. The higher LER might be due to better utilization of growth resources, such as soil moisture, light and nutrients by component crops in intercropping systems. The results are similar with the observation of Muoneke *et al.* [21] and Addo-Quaya *et al.* [22] in maize + soybean intercropping system.

3.5. Monetary Advantage

Economic analysis revealed that adoption of zero tillage was more profitable than conventional tillage, since it provided higher net return (NPRs 110.4 thousand ha^{-1}) and B: C ratio (2.47), however, gross return in zero tillage was lower (NPRs 185.1 thousand ha^{-1}) than in conventional tillage (NPRs 189.7 thousand ha^{-1}).

Table 3. Maize grain yield equivalent, land equivalent ratio and economics as affected by tillage methods and spatial arrangements under maize and soybean intercropping system at Rampur, Chitwan, Nepal, 2013

Treatments	MGYE (Mg ha^{-1})	LER	GR NRs ha^{-1} ('000)	NR NRs ha^{-1} ('000)	B:C ratio
Tillage					
CT	7.55^{a}	1.25	189.7^{a}	105.8^{b}	2.257^{b}
ZT	7.36^{b}	1.27	185.1^{b}	110.4^{a}	2.473^{a}
LSD (P=0.05)	0.176	NS	4.352	4.352	0.045
SEm (±)	0.029	0.024	0.715	0.715	0.007
Spatial arrangements					
MS	5.83^{e}	1.00^{c}	147.4^{d}	83.47^{e}	2.304^{c}
SS	6.13^{d}	1.00^{c}	153.2^{d}	90.19^{d}	2.436^{b}
M+S (1:2)	8.60^{a}	1.46^{a}	216.3^{a}	126.6^{a}	2.412^{b}
M+S (2:1)	8.00^{b}	1.36^{ab}	201.3^{b}	115.8^{b}	2.356^{bc}
M+S (1:1)	7.42^{c}	1.27^{b}	186.8^{c}	99.92^{c}	2.151^{d}
M+S (2:2)	8.74^{a}	1.47^{a}	219.6^{a}	132.7^{a}	2.530^{a}
Mean	7.45	1.26	187.42	108.12	2.37
LSD (P=0.05)	0.24	0.14	6.13	6.13	0.08
SEm (±)	0.08	0.04	1.94	1.94	0.03
CV, %	2.77	9.66	2.75	4.77	2.95

MGYE= Maize grain yield equivalent; LER= land equivalent ratio; GR= Gross return; NR=Net return; Means followed by common letter (s) in a column are not significantly different based on DMRT at 5% level of significance.

The experimental results also revealed that intercropping was more profitable than sole maize (Table 3). Two rows of soybean intercropped with two rows of maize contributed the highest gross return (NPRs 219.6 thousand ha^{-1}), net return (NPRs 132.7 thousand ha^{-1}) and B: C ratio (2.53) over sole cropping. The results are in agreement with the findings of Kumar *et al.* [23] and Mudita *et al.* [17]

4. Conclusion

The yield and yield attributing traits of maize and soybean were drastically reduced under maize and soybean intercropping as compared to their sole cropping. However, intercropping recorded significantly higher economic advantage over sole cropping. In addition, LER and MGYE were also higher in intercropping. Therefore, we would recommend the farmers of sub-tropical region of western Chitwan, Nepal to superimpose (100:100) sole crop population of soybean on maize at the spacing of two rows of maize to two rows of soybean for the extra benefits associated with this system.

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