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Economics and agronomic performance of maize and soybean intercropping under various tillage and residue levels

Narayan Khatri[1]* and Tika Bahadur Karki[2]

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ABSTRACT

A field experiment was conducted at National Maize Research Program, Rampur, Chitwan, Nepal during rainy season of 2013 to find out the effect of tillage, residue levels and intercropping systems on yield and yield attributing characters of maize and soybean. The results revealed that the grain yield of maize and soybean was significantly influenced by intercropping systems, but not by tillage system and residue levels. The grain yield of maize obtained under sole cropping (4.76 t/ha) was significantly higher than maize + soybean intercropping system (4.27 t/ha). Similarly, the grain yield of sole soybean was significantly higher (1.99 t/ha) than that of maize + soybean intercropping system (1.26 t/ha). There was 10 percent reduction of maize yield as compared to sole maize system due to intercropping systems. Similarly, reduction of seed yield of soybean under maize and soybean intercropping system was 37 % as compared to sole soybean system. Moreover, the total grain yield equivalent of 6.45 t/ha obtained from sole soybean system was significantly higher and was followed by maize and soybean intercropping system with 4.99 t/ha. Significantly, higher Land Equivalent Ratio (1.38) was recorded with maize and soybean intercropping system over sole system (1.0). Maize and soybean intercropping system produced higher gross return, net return and Benefit: Cost ratio. Net returns and Benefit: Cost ratio obtained from maize + soybean intercropping system under zero tillage residue removed condition was higher of NRs. 1,55,478 and 2.77 respectively.

INTRODUCTION

Maize is a traditional crop cultivated for human food, feed and fodder; and for raw material in various poultry and animal feed industries. It is used for hundreds of other industrial purposes because of its broad global distribution, low price as compared to other cereals and diverse grain type having wide range of biological and industrial properties. Maize and soybean intercropping is predominant in western and southwestern hills in relatively dry seasons, to avoid the risk of crop failure. Soybean is considered as an ideal crop for intercropping with maize owing to its comparative tolerance for shade and drought, efficient light utilization and utilizes soil moisture efficiently (Wright et al. 1988).

1-National Wheat Research Program, Bhairahawa, Nepal
2-National Maize Research Program, Rampur, Nepal
*Email: narayan.iaas068@gmail.com

In Nepal, soybean is one of the important leguminous crops selected for production and utilization for human food and feed for poultry (Pandey et al. 2007). It has potential of fixing atmospheric nitrogen besides meeting its own nitrogen requirement and serves as a viable and low cost medium for soil fertility improvement (Muonekeet al. 2007). Soybean has the potential for improving human diet as well as animal feed by supplying high quality protein and serves as a good source of raw material base for agro-industries (Atungwu and Afolabi 2001). Maize based cropping system using high intensive tillage is predominant in the sloping hill terraces. These sloping terraces suffer more soil runoff loss (Lal 1983). Since, the problem of soil loss is partly natural and partly human induced, need of appropriate technological intervention based on land use suitability, have drawn attention of the researchers. Resource conservation technologies, for example, minimum tillage have shown better performance in most part of the world in restoring the organic matter and increasing crop yield in long run (Cassel et al.1995). Decreasing soil fertility, increased soil erosion, poor water infiltration and increased soil compaction are the other major constraints of maize production system brought about by the conventional agricultural practice which is more labor intensive mainly for repeated land preparations and intercultural operations. Conservation agriculture may be a practicalalternative to make maize farming sustainable while conserving the soil.

Reduced tillage, proper crop rotation and the residue management are the three basic working principles of conservation agriculture, which are considered the ultimate components to address the problem of soil degradation, labor scarcity and diminishing return of the maize based system in Nepal. The concept of cereal-legume intercropping is not in vogue in agricultural sciences (Dahlmann and Von Fragstein 2006). Presently, intercropping is gaining popularity day by day among small growers as it provides yield advantage compared to monocropping through yield stability and fulfilling diversified domestic needs (Nazir et al. 2002 and Bhatti et al. 2006). Hence, this experiment was carried out in order to evaluate the effect of tillage, residue levels and intercropping systems on yield and yield attributing characters of maize and soybean.

MATERIALS AND METHODS

This study was conducted at National Maize Research Program farm, Rampur, Chitwan during summer season from May 2013 to November 2013. The experiment was laid out in strip- split design with twelve treatments and three replications. Treatments consisted of two different tillage methods namely conventional tillage and zero tillage as vertical factor, two different levels of residue (residue kept and residue removed) as horizontal factor and three different levels of cropping systems namely sole maize, sole soybean and maize + soybean intercropping system as sub plot factor. Manakamana-3 and Puja were the variety of maize and soybean used for the experiment respectively. Row to row spacing for each plot was maintained at 100 cm so that every plot received 6 rows of maize where two outer rows were marked as boarder rows, next two rows were for destructive sampling and two inner rows were net plot. The number of rows of maize was fixed as six in each treatment and plant to plant spacing was of 50 cm and 2 plants per hill were maintained. On the other hand, the number of rows per plot of soybean was varied depending upon the row ratio of soybean and sole planting. It was 10 rows for 1:2 and 12 rows for sole planting. The spacing for both 1:2 ratios and sole planting was 50 × 10 cm^2 fixed in all treatments. The net plot of maize consisted of two central rows (8 m^2) and in case of soybean; it was 4 rows in both 1:2 ratio and sole crop. However, the net harvesting area of soybean in all treatments was the same (8 m^2). The obtained data were analysed by using MSTAT-C Package and SPSS software.

RESULTS AND DISCUSSION

Grain and Stover yield (t/ha) of maize

Tillage system and residue levels had no significant effect on grain yield of maize (Table 1). However, grain yield of maize was found higher in conventional tillage (4.53 t/ha) as compared to zero tillage (4.49 t/ha).Mashingaide et al. (2009) also reported that residue retention did not significantly increase maize and sorghum yields. Lower yield in residue kept plot might be due to the lodging of more number of plants caused by termite attack and infection on cob. This finding is also in line with Casa et al. (2003). Barzegar et al.(2003) reported that under a wide range of environment conditions

Table 1. Effect of tillage, residue and intercropping systems on grain yield, stover yield and harvest index of maize

Treatments	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index
Tillage			
Conventional	4.53	7.28	0.39
Zero	4.49	6.21	0.42
SEm±	0.08	0.32	0.01
LSD	ns	ns	ns
Residue levels			
Residue removed	4.62	6.46	0.43
Residue kept	4.42	7.03	0.39
SEm±	0.14	0.51	0.02
LSD	ns	ns	ns
Intercropping system			
Sole maize	4.76[a]	7.11	0.41
Maize + soybean	4.27[b]	6.38	0.40
SEm±	0.12	0.47	0.02
LSD	0.40	ns	ns
CV%	9.46	24.18	17.22
Grand mean	4.52	6.75	0.41

Non-significant (ns).Means followed by the common letter within each column are not significantly different at 5% level of significance by DMRT crop yield obtained by no-till, reduced tillage, and stubble retention systems were equivalent or even a higher than thoserecorded under conventional tillage.

Intercropping system had a significant effect on grain yield of maize (Table 1). Significantly higher grain yield of maize (4.76 t/ha) was obtained in sole maize system as compared to the intercropping system (4.27 t/ha). Under maize and soybean intercropping system, there was 10 percent reduction of maize yield as compared to sole maize system. Silwana and Lucas (2002) recorded 15 % yield decrease in the maize crop while growing as intercropping, whereas Ofori and Stern (1987) found 11 % declines in maize yield under intercropping system. Lower yield under intercropping system might be due to inter and intra specific competition for moisture, light, space and nutrients(Izaurralde et al. 1990).Tillage system as well as residue and intercropping systems showed non- significant difference on stover yield of maize (Table 1). The average mean of Stover yield was 6.75 t/ha.

Harvest index (HI) of maize

Harvest index of maize was not significantly influenced by tillage, residue and intercropping systems (Table 1). The average HI of the experiment was 0.41.

Yield and yield attributing characters of soybean

1000 seed weight (g)

Thousand-seed weight is an important yield contributing parameter that directly affects the seed yield of soybean. There was a significant effect of intercropping system on 1000- grain weight of soybean (Table 2). Higher value of 1000 seed weight was recorded under sole cropping of soybean (132.67 g) as compared to maize and soybean intercropping system (131.08 g). Increments in 1000-seed weight of soybean in sole cultivated pot are attributed to favorable growing conditions, which improved nutrient and water uptake. Undie et al. (2012) found similar results. But tillage management and residue levels had no significant effect on 1000-seed weight of soybean.

The equation of linear regression analysis (Figure 1) showed the trend of thousands grain weight and grain yield of soybean. It explained the 48 % variation in grain yield of soybean due to thousands grain weight of soybean. The simple linear regression equation was y = 0.204x - 25.25.

Seed and stalk yield (t/ha)

Seed yield of soybean varied significantly in different intercropping systems; but effect of tillage and residue were found insignificant (Table 2).

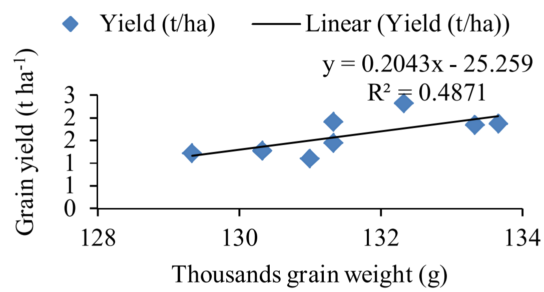

Figure 1.Relationship between grain yield and 1000-grain weight of soybean

Maximum seed yield of soybean (1.99 t/ha) was recorded in plots of sole soybean as compared with maize and soybean intercropping plots (1.26 t/ha). The reduction of seed yield of soybean under maize and soybean intercropping system was about 37 % as compared to sole soybean system.

Thole (2007) also found reduction of soybean yield by 40-69 % under intercropping as compared to sole soybean system. The lower yield of soybean under intercropping might be due to inter specific competition depressive effect of maize, a C_4 species, on soybean, a C_3crop. Similarly, Zhuang, L. and Yu-Bi (2013) reported that shading by the taller plants in mixture could reduce the photosynthetic rate of the lower growing plants and thereby reduce their yields. Stalk yield of soybean was not affected significantly by tillage and residue levels but intercropping systems had significant effect on it (Table 2). Sole soybean system recorded significantly higher stalk yield (3.25 t/ha), whereas maize and soybean intercropping system produced significantly lower stalk yield (2.46 t/ha).

Harvest index

Harvest index of soybean was not significantly influenced by tillage and residue but was affected significantly by intercropping system (Table 2). Sole soybean system recorded higher harvest index (0.38), whereas maize and soybean intercropping system produced significantly lowest harvest index (0.34).

Maize grain yield equivalent (t/ha)

The grain yield of the intercrop converted into equivalent grain yield of any crop based on the existing market price of the produce called grain yield equivalent (Reddy and Reddi 2002).

Maize grain yield equivalent (t/ha) was not significantly affected by tillage system and residue levels (Table 3), but the grain equivalent of the maize varied significantly due to the intercropping systems. Significantly, higher maize grain yield equivalent (6.45 t/ha) was obtained in sole soybean

Table 2. Effect of tillage, residue levels and intercropping systems on seed yield, 1000-seed weight, stalk yield and harvest index of soybean

Treatments	1000 seed wt (gm)	Seed yield (t/ha)	Stalk yield (t/ha)	Harvest index
Tillage				
Conventional	131.92	1.63	2.82	0.36
Zero	131.83	1.62	2.89	0.35
SEm±	0.50	0.10	0.17	0.01
LSD	ns	ns	ns	ns
Residue levels				
Residue removed	132.00	1.64	2.87	0.36
Residue kept	131.75	1.61	2.83	0.33
SEm±	0.18	0.06	0.07	0.005
LSD	ns	ns	ns	ns
Intercropping system				
Sole soybean	132.67[a]	1.99[a]	3.25[a]	0.38[a]
Maize + Soybean	131.08[b]	1.26[b]	2.46[b]	0.34[b]
SEm±	0.42	0.11	0.08	0.01
LSD	1.39	0.26	0.27	0.04
CV%	1.12	16.85	10.18	10.82
Grand mean	131.87	1.63	2.85	0.36

Non-significant (ns).Means followed by the common letter within each column are not significantly different at 5% level of significance by DMRT

system followed by maize soybean intercropping system (4.99 t/ha). It was due to the higher grain yield and higher existing market price of component soybean (Rs. 80 per kg), while the existing market price of maize grain was Rs. 30 per kg. Whereas in sole maize system, significantly lower (3.47 t/ha) grain yield equivalent was recorded.

Land equivalent ratio (LER)

The average LER recorded in the experiment was 1.19 and varied from 1.0 to 1.38. Intercropping system had significant effect on LER (Table 3). Significantly, higher LER was recorded from intercropping system (1.38) where as sole maize and sole soybean recorded only 1.0 LER.

The average total land equivalent ratio was more than 1.0 in intercropping treatment (1.38), indicating that intercropping of maize and soybean was advantageous over sole crops alone. Similarly, Ramakrishna and Ong, (1994) reported that intercropping increased the total amount of radiation intercepted due to rapid establishment of ground cover by the combine canopies of the component crops. Researchers like Agbaje et al. (2002) achieved higher land equivalent ratios in intercropping with maize. Efficient use of land resource, where land shortage inclines the farmers to grow many crops on small piece of land is one of the rationales of intercropping in the traditional farming systems.

Combined effect of treatments on economy of maize and soybean intercropping system

Among different intercropping systems, maize and soybean intercropping system produced higher gross return, net return and Benefit: Cost ratio. Net returns obtained from maize + soybean under Zero Tillage residue removed condition was higher of NRs. 1,55,478 than the other combination. Similarly, maize and soybean intercropping system produced higher B: C ratio under zero tillage (ZT) and no residue used condition (2.77) followed by ZT with residue used condition (2.53) (Table 4). Under conventional tillage (CT) with residue kept condition, B: C ratio was found lowest (2.19). Whereas under sole maize system, B: C ratio was found highest in ZT + residue removed plot (RR) (2.46), but in CT, residue removed plot produced lowest B: C ratio (2.09). Similar results were also found in case of sole soybean. Hence, we can conclude that in all intercropping systems, highest B: C ratio was found under ZT residue removed plot followed by ZT with residue kept (RK) plot followed by CT residue removed plot and then lowest was found in case of CT with residue kept plot.

Table 3. Effect of tillage, residue levels and intercropping systems on maize grain yield equivalent and land equivalent ratio.

Treatments	Maize grain yield equivalent (t/ha)	Land equivalent ratio (LER)
Tillage		
Conventional	4.97	1.14
Zero	4.96	1.12
SEm±	0.23	0.01
LSD	NS	NS
Residue levels		
Residue removed	5.03	1.13
Residue kept	4.91	1.12
SEm±	0.10	0.02
LSD	NS	NS
Intercropping systems		
Sole Maize	3.47[c]	1.0[b]
Sole Soybean	6.45[a]	1.0[b]
Maize + Soybean	4.99[b]	1.38[a]
SEm±	0.19	0.01
LSD	0.57	0.04
CV%	13.34	4.93
Grand mean	4.97	1.13

Non-significant (NS).Means followed by the common letter within each column are not significantly different at 5% level of significance by DMRT

Table 4. Combined effect of treatments on economy of maize and soybean intercropping system

Particulars	Treatments	Cultivation practices			
		CT+RK	CT+RR	ZT+RK	ZT+RR
Total cost (NRs/ha)	1. Sole maize	77065	69515	68815	61265
	2. Sole soybean	79905	72355	64655	64105
	3. Maize + soybean	103470	96270	95220	88020
Gross returns (NRs/ha)	1. Sole maize	154743	145607	149070	150870
	2. Sole soybean	187947	151575	149636	151266
	3. Maize + soybean	227061	233342	241027	243498
Net returns (NRs/ha)	1. Sole maize	77678	70692	80255	89605
	2. Sole soybean	108042	79220	84981	87161
	3. Maize + soybean	123591	137072	145807	155478
B: C ratio	1. Sole maize	2.01	2.09	2.17	2.46
	2. Sole soybean	2.35	2.09	2.31	2.36
	3. Maize + soybean	2.19	2.42	2.53	2.77

Note:CT+RK=Conventional Tillage+Residue Kept, CT+RR=Conventional Tillage+Residue Removed, ZT+RK=Zero Tillage+Residue Kept, ZT+RK=Zero Tillage+Residue Removed

CONCLUSION

Our findings indicated that maize and soybean intercropping system in rainy season could be grown successfully and found more profitable over sole cropping system of either crop in Chitwan. Cost of cultivation under zero tillage was found lower than conventional tillage system. Similarly, net returns and Benefit: Cost ratios were found higher under zero tillage maize and soybean intercropping system. This study need to be further tested for one more season taking into account the overall qualities of soil along with growth and yield parameters of both the component crops in order to have the robust findings and recommendations to the farmers.

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