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Research Paper

Performance of maize (*Zea mays*)-based intercropping systems and their residual effect on wheat (*Triticum aestivum*) + lentil (*Lens culinaris*) intercropping system under organic conditions

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ABSTRACT

A field experiment was conducted on a silty clay loam soil of Palampur during 2011–12 and 2012–13, to study performance of maize (*Zea mays* L.)-based intercropping systems and their residual effect on wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] + lentil (*Lens culinaris* Medikus) intercropping under organic conditions. Growth, yield attributes, grain and stover yields of maize were more in sole stand. Intercropping systems resulted in significantly higher grain-maize-equivalent yield than sole stand. Maize + soybean (*Glycine max*) in both additive and paired series resulted in higher maize-equivalent yield than the other intercrops and resulted in better yield of both maize and soybean crops and proved to be the best intercropping system with a net returns of ₹68,807 and ₹65,078 and net returns/rupee invested of ₹1.13 and ₹1.08 respectively. However, wheat and lentil on residual basis showed more yield on intercropping treatment than sole maize. Wheat recorded the highest yield when sown under soybean and ricebean treatment both in additive and paired series, whereas lentil recorded the highest grain yield when sown under asparagus bean (*Vigna unguiculata sesquipedalis*) additive series and was statistically at par with cowpea [*Vigna unguiculata* (L.) Walp.] in paired series. The highest available nitrogen was recorded in maize + soybean in paired and additive series, whereas the lowest available nitrogen in sole maize. Among the intercrops, soybean fixed more N followed by ricebean (*Vigna umbellata*), cowpea (*Vigna unguiculata*) and asparagus bean (*Vigna unguiculata sesquipedalis*). Higher values of available Phosphorus (10.5 kg/ha) and Potassium (228.1 kg/ha) was recorded in sole maize.

Key words **:** Crop productivity, Intercropping, Legumes, Maize–wheat, Organic conditions

Maize–wheat is the dominant cropping system in the sub-mountainous western Himalayan region of India. This system contributes 36.5% of wheat (93.90 mt) and 8.4% of maize (21.57 mt) into Indian food basket (MoA, New Delhi, 2012). Most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops. Moreover, intercropping improves soil fertility through biological nitrogen fixation. Use of legumes increases soil conservation through greater ground cover than sole cropping, and provides better lodging resistance for crops susceptible to lodging than when grown in monoculture.

Of the 2 types of intercropping, additive series is growing of intercrop between the rows of main crop without any adjustment in the spacing of the main crop whereas in paired series, the spacing of the main crop is reduced and equal opportunity is given to the intercrop for better growth. The crops are grown in pair of 2 in case of paired series. Legumes are known to fix atmospheric nitrogen, thus enriching soil fertility and helping to meet the N needs of cereals (Manna *et al*., 2003). Intercropping of maize with different legumes improves the fertility status of the soil which is beneficial to succeeding wheat and lentil intercropping. The beneficial effect of organic sources applied in preceding crop was recorded in succeeding wheat crop (Yadav *et al*., 2008). Although agricultural research originally focused on sole cropping and ignored the potential of intercropping, there has been a

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gradual recognition of the value of this kind of cropping system. However, intercropping has been shown to give higher and more stable yields in a wide range of crop combinations, while the system is characterized by minimal use of inputs such as fertilizers and pesticides, emphasizing the production of healthy, and quality food in the context of environmentally sound production.

These days the urge for organic way of farming is gaining momentum all over the world owing to burgeoning signs of unsustainability in agriculture, degradation of natural resources and heavy debit charge on ecology and environment, adversely affecting the welfare of human society. The farmers in hilly regions have the opportunity to enter organic agriculture by default because of climatic conditions, topography, rainfall etc. Therefore, an experiment was conducted to study the performance of maize-based intercropping systems and its residual effects on succeeding wheat + lentil intercropping under organic conditions.

MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) and winter (*rabi*) seasons of 2011–12 and 2012–13 at organic farm, Department of Organic Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32° 4' N and 76° 3' E, 1,224 m above mean sea-level). The experiment was conducted on silty clay loam soil, *p*H 5.01, organic carbon (0.59%), available N (173.9 kg /ha), available P (20.4 kg/ha) and available K (207.5 kg/ha). There were 9 treatments, consisting of sole maize and in additive and paired patterns of intercropping, the intercrops (soybean, cowpea, asparagus bean and ricebean) were sown. Residual effects of these treatments were studied in wheat and lentil intercropping. The experiment was laid out in a factorial randomized block design with 3 replications. Vermicompost @ 10 t/ha and enriched compost (rockphosphate, patent kali, oil seed cake and gypsum were used for enrichment) @ 2.5 t/ha were applied in the field before sowing. Maize 'Early composite', soybean 'Bragg', ricebean 'BRS 2', cowpea 'Lobia 1' and asparagus bean 'Gita' were sown on 7 and 10 June during the first and second year respectively. Maize was sown in lines at a spacing of 60 cm × 20 cm for sole crop. In additive pattern of intercropping, the intercrop (soybean, cowpea, asparagus bean and ricebean) were sown in between the 2 rows of maize spaced at 60 cm apart. In paired row system, the spacing of maize crop was reduced to 45 cm and the intercrop (soybean, cowpea, asparagus bean and ricebean) was also grown at 45 cm in pairs leaving 22.5 cm distance after 2 rows of maize crop. In the 2 intercropping patterns, number of rows remained constant in the main crop, whereas the number of rows in intercrop varied. In case of maize crop, there were 6 rows in all the treatments, in additive series, there were 5 rows of intercrop (soybean, cowpea, asparagus bean and ricebean), whereas in case of paired series, there were only 4 rows of the intercrops. Two hand-weedings were done. After harvesting, grain yield/ha and straw yield/ha were computed. The intercrops (cowpea, asparagus bean and ricebean) were harvested continuously from time to time. Soybean was harvested when it attained maturity. Wheat + lentil were intercropped after the harvest of preceding crop. 'HPW 155' and 'Bipasha' variety of wheat and lentil, respectively, were sown on 10 and 8 November during the first and second year respectively. Wheat crop was sown as main crop, whereas lentil was intercropped between 2 rows of main crop. The total N, P and K contents of plants was analysed by standard methods. The net returns/rupee invested was worked out by dividing net returns (₹/ha) with cost of cultivation (₹/ha). Since data followed the homogeneity test, pooling was done over the seasons and mean data were presented. For calculating the maize-equivalent yield, the prices of different crops were: soybean ₹30/kg, cowpea ₹30/kg, ricebean ₹18/kg, asparagus bean ₹170/kg and maize ₹10/kg, whereas for wheat-equivalent yield the price of wheat was ₹18/kg and lentil was ₹60/kg.

RESULTS AND DISCUSSION

Yield attributes and yield of maize

Cobs/plant in sole maize, maize + soybean in paired series, and maize + asparagus bean in both additive and paired series were statistically at par with each other, whereas the lowest number of cobs/plant were observed in maize + cowpea and maize + ricebean in additive series. Effect of different treatments was not significant for grains/cob. Maize + cowpea in additive series showed significantly lower 1,000-seed weight of maize, whereas all other treatments behaved statistically similar (Table1). Sole maize recorded significantly higher values of all yield contributing characters of maize than all the intercropping treatments except grains/cob in which the differences were non-significant. Although introduction of intercrops in maize reduced the yield attributes of maize. Less reduction was noted in asparagus bean in additive or paired series and soybean in additive or paired series. It may be because of the reason that the peak demand periods of the 2 crops for light, nutrients and water were different and there was optimum utilization of physical resources. In a study conducted for different intercrops with maize by Padhi (2001) reported that intercropping reduced the values of yield attributes.

Significantly highest grain and stover yields were obtained in sole crop of maize. Intercropping of maize with different intercrops resulted in statistically at par results with all treatments except maize + cowpea and maize + ricebean in additive series with lowest grain and stover yields. The highest harvest index was recorded in sole maize owing to the highest grain yield compared to the other treatments which was statistically at par with maize + asparagus bean, maize + cowpea and maize + soybean in paired series. However, the lowest harvest index was found in maize + cowpea and maize + ricebean in additive series (Table 1). Intercropping system caused reduction in maize yield compared with sole stand in maize and soybean intercropping because of the reason that in sole stand there was less competition for light, nutrients, and water and the resources were also utilized in a proper manner for better growth and yield (Singh and Singh, 2001).

Yield of intercrops

The yield of all the intercrops with maize was the lowest compared to the sole crops (Table 1). However, degree of reduction was the maximum in asparagus bean additive as well as paired series followed by cowpea in additive and paired series, whereas the highest yield was observed in soybean in additive and paired series followed by ricebean. Maximum yield loss with asparagus bean and cowpea might be due to spatial and temporal competition for growth factors for a prolonged period and their susceptibility to shading effect of maize crop, whereas minimum loss with soybean and ricebean might be due to tolerance to shading effect, staggering of peak demands for growth factors. The results confirm the findings of Padhi and Panigrahi (2006).

Maize-equivalent yield

Intercropping of soybean with maize in either paired or additive series gave significantly higher maize-equivalent yield (Table 1). Sowing of maize + soybean in the paired series resulted in significantly higher maize-equivalent yield, being statistically at par with maize + soybean in additive series. The lowest maize-equivalent yield was recorded in maize + asparagus bean in additive series which was comparable with maize + cowpea in additive series. Despite of the higher market price of asparagus bean, maize + asparagus bean recorded the lowest maize-equivalent yield among the intercropping systems due to significant reduction in seed yield of asparagus bean as compared to the other intercrops. Mandal *et al*. (2014) also reported similar results.

Residual effect of maize treatments on wheat and lentil

Residual effect was observed in the yield attributes and yield of succeeding wheat crop. Significantly higher number of spikes were recorded under residual effect of maize intercropped treatment than sole maize. Spikelets/spike were the maximum in maize + soybean paired series which was statistically at par with maize + ricebean additive series, sole maize and maize + ricebean paired series. Different treatments resulted in statistically similar results for spike length except maize + asparagus bean in both additive and paired series and maize + cowpea in paired series. The highest biological yield (t/ha) was recorded in maize + soybean paired series which was statistically at par with maize + soybean additive series and maize + ricebean additive series. The lowest biological yield was recorded in maize + asparagus bean in both additive and paired series. Harvest index was statistically similar in all treatments except maize + soybean additive series which varied (Table 2). In pooled results of wheat, grain yield under sole maize treatment gave the lowest yield compared to the treatment where maize was intercropped with different crops. The residual effect of maize intercropped

Table 1. Effect of maize-based intercropping treatments on yield attributes, yield of grain maize seed yields of intercrops and maize-equivalent yield (pooled data of 2 years)

Treatment	Cobs/plant	Grains/cob	1,000-seeds weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index	Intercrops seed yield (t/ha)	Maize-equivalent yield (t/ha)
Maize sole	1.14	202.8	224.4	2.6	5.8	0.31	-	2.60
Maize + soybean (additive)	1.02	173.3	219.8	1.9	5.2	0.27	1.27	5.73
Maize + cowpea (additive)	0.97	119.5	216.9	1.6	4.1	0.25	0.40	2.80
Maize + asparagus bean (additive)	1.04	175.6	223.3	1.8	4.9	0.27	0.06	2.86
Maize + ricebean (additive)	0.96	155.1	220.1	1.5	4.2	0.24	1.05	3.43
Maize + soybean (paired)	1.10	196.2	223.6	2.0	5.2	0.28	1.27	5.83
Maize + cowpea (paired)	1.00	189.5	222.3	1.9	5.1	0.29	0.42	3.26
Maize + asparagus bean (paired)	1.06	199.3	221.1	1.8	5.3	0.30	0.07	3.05
Maize + ricebean (paired)	1.02	165.3	218.7	1.8	4.9	0.27	1.12	3.77
SEm±	0.03	27.6	1.16	0.10	0.15	0.01	-	0.16
CD (P=0.05)	0.10	NS	3.47	0.31	0.45	0.03	-	0.47

Table 2. Residual effect of maize-based intercropping on yield attributes and yield of wheat, lentil and wheat-equivalent yield of wheat + lentil intercropping system (pooled data of 2 years)

Treatment in previous season	Wheat						Lentil					Wheat equivalent yield (t/ha)
	Spikes/m^2	Spikelets/ spike	Spike length (cm)	Biological yield (t/ha)	Grain yield (t/ha)	Harvest index	Pods/ plant	Seeds/ pod	Pod length (cm)	Biological yield (t/ha)	Seed yield (t/ha)	
Maize sole	210.0	19.4	9.9	5.43	1.94	0.36	38.0	1.34	1.99	3.34	0.87	4.84
Maize + soybean (additive)	227.5	17.5	10.5	5.98	2.55	0.43	40.5	1.52	2.12	3.16	1.05	6.05
Maize + cowpea (additive)	217.5	17.1	10.2	5.45	2.39	0.44	37.7	1.36	2.08	3.02	0.95	5.56
Maize + asparagus bean (additive)	212.5	17.6	9.5	5.09	2.10	0.41	41.4	1.60	2.13	3.44	1.25	6.27
Maize + ricebean (additive)	225.0	19.7	10.8	5.81	2.58	0.44	36.1	1.58	2.11	3.37	0.99	5.87
Maize + soybean (paired)	237.5	20.1	10.8	6.23	2.62	0.42	36.2	1.37	2.07	3.19	0.89	5.58
Maize + cowpea (paired)	222.5	18.2	9.5	5.24	2.19	0.42	40.4	1.74	2.12	3.15	1.13	5.97
Maize + asparagus bean (paired)	222.0	17.3	9.6	4.75	2.05	0.43	38.3	1.50	1.99	3.52	0.99	5.36
Maize + ricebean (paired)	225.5	18.6	10.0	5.64	2.47	0.44	35.5	1.42	2.14	2.78	0.94	5.58
SEm±	5.6	0.43	0.36	0.16	0.08	0.01	1.4	0.05	0.06	0.12	0.06	0.20
CD (P=0.05)	16.8	1.3	1.08	0.49	0.235	0.04	4.2	0.17	0.18	0.36	0.18	0.59

with soybean in paired series resulted in higher wheat grain yield which was statistically at par with the residual effect of maize + ricebean in both additive and paired series and maize + soybean in additive series treatment. The grain yield of succeeding wheat crop increased probably owing to the nitrogen fixation by the legume in the preceding maize crop. The findings are in close conformity with those of Das and Mathur, (1980) and Singh and Singh (1984).

The grain yield of lentil grown under residual effect of maize treatments is presented in (Table 2). The residual effect of maize + asparagus bean additive series resulted in significantly higher grain yield of lentil which was statistically at par with maize + cowpea paired series. All treatments were statistically similar for pods/plant except maize + ricebean in both additive and paired series and maize + soybean paired series. Seeds/pod were more in maize + cowpea paired series treatment in the preceding season, being statistically at par with maize + asparagus bean and maize + ricebean both in additive series. Pod length showed statistically similar results. Biological yield (t/ha) also showed statistically similar results except for maize + cowpea both in additive and paired series and maize + ricebean paired series treatments in the *kharif* season.

Wheat-equivalent yield

Wheat-equivalent yield reflected the total productivity of the intercropping system which showed significant improvement owing to intercropping over sole cropping (Table 2). Residual effect of maize + asparagus additive series gave higher wheat-equivalent yield which was statistically at par with maize + soybean additive series, maize + cowpea paired series and maize + ricebean additive series.

Maize-equivalent yield of the whole cropping system

Growing of soybean with maize in either paired or additive series resulted in significantly higher maize-equivalent yield of the whole cropping system. Maize + soybean in additive series resulted in significantly higher maize-equivalent yield of the whole system, which was statistically at par with maize + soybean in paired series (Table 3). The lowest maize-equivalent yield of the whole system was recorded in maize + cowpea in additive series which was statistically similar to maize + asparagus bean in paired series. Shivay *et al*. (2001) also recorded similar findings.

Economics

Maize + soybean in additive series gave the highest net returns and net returns/rupee invested followed by maize

+ soybean in paired series with net returns and net returns per rupee invested (Table 3). Net returns from the intercropping treatments were more than sole crops. The results are in close conformity with the findings of Shivay *et al*. (2001) and Padhi and Panigrahi (2006).

Soil-nutrient status after harvest

Soil *p*H slightly increased with the application of enriched compost and vermicompost. Soil *p*H, in general, increased with application of organic manures. This might be because of quick release of K^+ from compost and also the buffering property of compost when added to acidic soils. Statistically similar result was observed for organic carbon. It may be due to the fact that because of application of enriched compost and vermicompost microbial population might have increased and as a result soil aggregation and decomposition have resulted in increased organic C in soil. Available NPK were influenced by different treatments. The highest available N was recorded in maize + soybean in paired series and additive series, whereas, the lowest available N was recorded in sole maize. The available N in soil might have increased due to intercropping of different legumes because of N fixed by associated legume crops compared to sole maize. Among the intercrops, soybean fixed more N followed by ricebean, cowpea and asparagus bean. Higher available phosphorus and potassium were found in sole maize which was significantly superior to the other treatments. On the contrary, soil available P and K showed a downward trend due to legume incorporation compared to sole crop.

Maize + soybean proved to be the best intercropping combination in both additive and paired series with higher production potential in terms of maize-equivalent yield under organic farming conditions with a net returns of ₹68,807, ₹65,078 and net returns/rupee invested of 1.13 and ₹1.08 respectively. However, wheat and lentil on residual basis showed more yield on intercropping treatment than sole maize.

Table 3. Effect of maize-based intercropping on maize-equivalent yield of the whole system and economics of different intercropping systems (pooled data of 2 years)

Treatment	Maize equivalent yield of system (t/ha)	Total cost of cultivation ($\times10^3$₹/ha)	Net returns ($\times10^3$₹/ha)	Net returns/ rupee invested
Maize sole	8.4	54.5	29.6	0.54
Maize + soybean (additive)	13.0	61.2	68.8	1.13
Maize + cowpea (additive)	9.5	60.1	34.6	0.57
Maize + asparagusbean (additive)	10.4	64.5	39.4	0.60
Maize + ricebean (additive)	10.5	59.8	44.9	0.75
Maize + soybean (paired)	12.5	60.2	65.1	1.08
Maize + cowpea (paired)	10.4	59.6	44.5	0.74
Maize + asparagus bean (paired)	9.5	63.2	31.7	0.50
Maize + ricebean (paired)	10.5	59.4	45.3	0.76
SEm±	0.20	-	-	-
CD (P=0.05)	0.59	-	-	-

Table 4. Effect of maize-based intercropping systems on *p*H, organic carbon, available N, P and K in soil after harvest of maize (pooled data of 2 years)

Treatment	pH	Organic carbon (%)	N(kg/ha)	P(kg/ha)	K(kg/ha)
Maize sole	5.16	1.72	156	10.5	228.1
Maize + soybean (additive)	5.03	1.60	250	9.4	197.8
Maize + cowpea (additive)	4.94	1.56	235	8.8	183.7
Maize + asparagus bean (additive)	5.04	1.56	235	9.2	154.9
Maize + ricebean (additive)	4.94	1.39	219	8.4	199.7
Maize + soybean (paired)	5.05	1.53	250	8.3	173.6
Maize + cowpea (paired)	5.05	1.54	232	9.6	186.5
Maize + asparagus bean (paired)	5.15	1.65	235	8.7	172.3
Maize + ricebean (paired)	4.94	1.62	235	8.3	184.8
SEm±	0.08	0.06	3.84	0.69	8.57
CD (P=0.05)	NS	0.13	11.54	0.23	2.86
Initial values	5.01	1.35	235	8.91	231.0

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