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Effects of additive intercropping on field performance of potato and green bean at different densities

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ABSTRACT: One of the best methods for moving towards sustainable agriculture and environmental protection is mixed culture. Accordingly, the experiment was conducted in 2008 and 2009 at the Experimental Research Station of College of Agriculture Tabriz University. The pattern of intercropping was an additive series. The experiment was laid out in a factorial set of treatments was arranged within a randomized complete block design with three replications. The treatments were green bean densities 15, 20 and 25 plant/m^2 and potato densities 5, 7.5 and 10 plant/m^2 and sole cropping of two species with these densities. In two years, results showed that the highest and lowest yield of green bean was belong to 25 and 15 plant/m^2 densities, respectively. The maximum and minimum yield of tuber potato was observed in 10 and 5 plant per m^2 in first year. In second year, the highest and lowest potato tuber yield was 3.86 and 2.79 kg/m^2 by 10 and 5 plant/m^2 densities.

Keywords: intercropping, pod length, plant height, tuber yield

INTRODUCTION

Overpopulation, environmental degradation and lower production efficiency per unit area are the greatest and most disturbing problems of human society (Timothy *et al*., 2000). One of the farming practices is concurrent cultivation of two or more crops in the same field which is experienced in many regions of the world. Potatoes are amongst the world's main food crops and their demand is increasing at a greater rate than many other food crops. The snap bean or green bean (*Phaseolus vulgaris* L.) is a warm season crop harvested for its immature seed pods. This plant can be a suitable choice for intercropping because of the ability to fix N and reduce the use of nitrogen in soil. Potato intercropping with legumes such as beans is a common practice in most tropical and subtropical South America and Asia.

Water use efficiently in intercropping system is more than sole cropping. In intercropping, absorption of nitrogen, phosphorus and potassium in a certain area of land is more than pure cultures (Kuo & Jellum, 2002). Watikai *et al.* (1993) and Willy (1990) confirmed that increasing the yield of biomass in intercropping is due to the more absorption of light. The highest performance is achieved when intercropping canopy is composed of two layers: 1. Tall plants with narrow leaves and high photosynthetic capacity, 2. Dwarf plants with lying leaves and low photosynthetic capacity (Wiley, 1990). Maize and soybean intercropping increased economic output and net income (Hayder *et al*., 2003). The intercropping of tea and rubber in comparison with sole crop of tea increased economic efficiency and farmers' income (Iqbal *et al*., 2005). Other advantages of intercropping include reducing the use of fertilizer and chemical pesticides, environmental protection, less energy requirement, suitable distribution of labor during the growing season and more income in a shorter time. Accordingly, this research was conducted to evaluate the effects of additive intercropping on field performance of potato and green bean at different plant population densities.

MATERIALS AND METHODS

Two experiments were conducted in 2008 and 2009 at the Research Station of Tabriz University (46°17' N, 38°05' and elevation of 1350 m) with a sandy loam soil, located in the East of Tabriz. In both years, a factorial set of treatments was arranged within a randomized complete block design in three replications. Treatments were green bean (local variety) densities of 15, 20 and 25 plant/m^2 and potato (cv. Agria) densities of 5, 7.5 and 10 plant/m^2. The pattern of intercropping was an additive series. Each plot consisted of four rows, 6 m long and 80 cm row spacing. After sterilization by 0.1% Benomyl for 15 min, potato tubers with 40-50g weight were planted in the middle of the stack in 10 cm soil depth. Bean seeds were sown at a depth of 5 cm on both sides of the stacks. Irrigation and weed control were carried out as required.

Statistical analysis

Analysis of variance was performed using MSTAT-C software. Means of treatments were compared using the least significant difference (LSD) test at the 5% probability level.

RESULTS AND DISCUSSION

A. First year (green bean)

(i) First harvest

Pod length. The analysis of variance showed significant effect of potato density and interaction of potato and bean densities on pod length ($P \leq 0.05$) (Table 1). The highest pod length was achieved in sole culture of bean with15 plant/m^2.

In contrast, the lowest pod length was obtained in bean-potato intercropping with 25:7.5 densities (Fig. 1). There was no significant difference in pod length among intercropping treatments.

Yield. The result revealed that the effect of potato density was significant on yield of green bean in first harvest ($P \leq 0.01$) (Table 1). The maximum yield of green bean was obtained under mono-cropping, while the minimum yield was produced under intercropping with 10 plants/m^2 potato (Table 3). Ofari and Stern (1987) stated that the reduction of bean yield in intercropping with maize may be due to reduce the number of pods/m^2 because of competition.

Table 1. Analyses of variance of bean parameters in two years.

Source of variation	df	First year					Second year				
		Harvest 1		Harvest 2		Total yield	Harvest 1		Harvest 2		Total yield
		Pod length	Yield	Pod length	Yield		Pod length	Yield	Pod length	Yield	
Rep	2	0.141ns	0.007ns	0.285ns	0.001ns	0.009ns	0.331ns	0.025ns	0.318ns	0.004ns	0.013ns
Density of bean (db)	2	0.908ns	0.022ns	1.548**	0.011**	0.062*	1.96**	0.17**	1.093ns	0.004ns	0.221**
Density of potato (dp)	3	1.525*	0.635**	1.292**	0.064**	1.092**	2.035**	0.436**	9.505**	0.085**	0.886**
db×dp	6	1.23*	0.024ns	3.477**	0.002ns	0.032ns	0.887*	0.016ns	1.492ns	0.01ns	0.012ns
Error	22	0.388	0.011	0.258	0.001	0.015	0.34	0.015	1.247	0.01	0.02
CV (%)		5.9	17.63	5.53	21.21	16.91	5.74	24.09	9.56	26.84	16.11

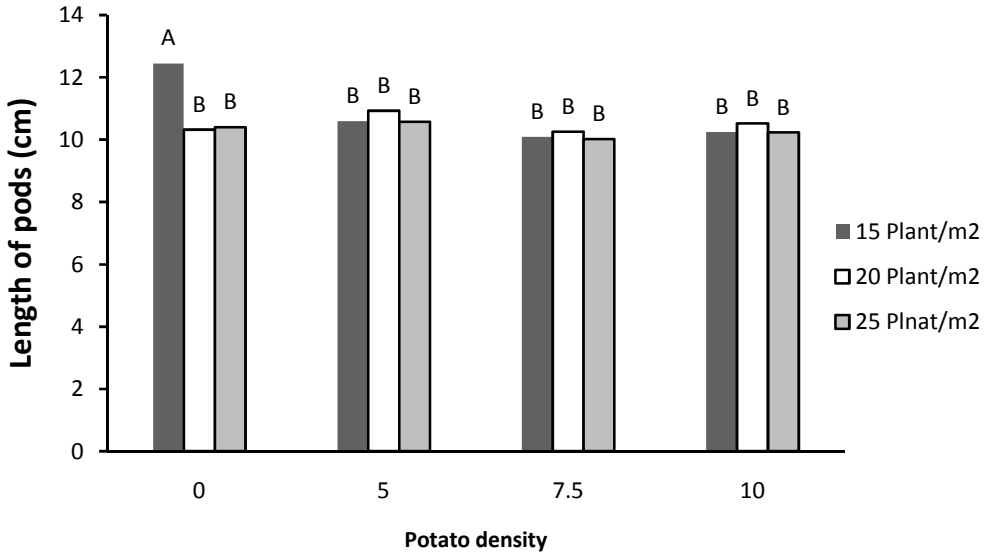

Fig. 1. Effects of potato and green bean intercropping on pod length of bean in the first harvest of the first year.

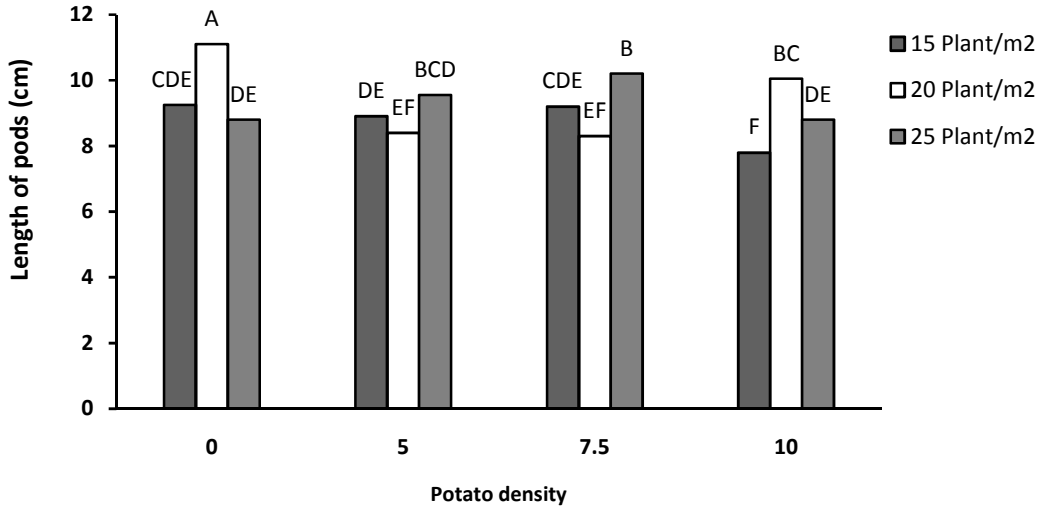

Fig. 2. Effects of potato and green bean intercropping on pod length of bean in the second harvest of the first year.

(ii) Second harvest

Length of pods. Statistical analysis showed that the effects of green bean and potato densities and the interactions of potato and green bean densities on pod length of bean were significant (P ≤0.01)(Table 1). The highest pod length of bean was recorded in mono-cropping with 20 plants/m^2 density, however, the lowest was observed in intercropping with densities of 15-10 plant/m^2 bean-potato (Fig. 2).

Yield. The effect of potato and green bean densities was significant on yield of bean in second harvest (P≤0.01 (Table 1). Maximum and minimum yield of bean were recorded in densities of 20 and 15 bean/m^2 (Table 3). Generally, with increasing plant density, grain yield increased and then decrease rapidly with increasing plant population pressure (Brothers & Kelly 1993). The highest and lowest yield of green bean was obtained in densities of 0 and 10 potato/m2, respectively. In study of Abera *et al*. (2005) on the absorption of nutrients in intercropping of maize with bean concluded that the yield of bean decreased with increasing of maize density.

Total yield of green bean. The effects of bean densities (P ≤0.05) and potato densities (P ≤0.01) on total yield of bean were significant (Table 1). The maximum and minimum total yield was recorded in densities of 25 and 15 bean/m^2, respectively (Table 3).

According to Isik *et al*. (1997) with increasing plant density, number and weight of seeds decrease, but grain yield per unit area increases. The highest total yield was obtained in density of 0 potato (sole cropping of bean), while the lowest was recorded in 10 potato/m^2. Grain yield per unit area of intercropped beans decreased as maize population increased (Mutungamiri *et al*., 2001). Morgado and Willey (2008) reported that the reduction of bean yield in intercropping with maize was due to the decrease in number of pods in bean plants.

B. Potato

Plant height. The result indicated that plant height of potato was affected by potato and green bean densities ($P \leq 0.05$) (Table 2). The highest (52.47 cm) and lowest (45.72 cm) height of potato were attained by densities of 5 and 10 potato/m^2, respectively (Table 3). As well as, in green bean densities, maximum and minimum of potato height were observed in 20 and 15 bean/m^2, respectively. Height of potato increased in intercropping with bean compared with sole cropping by alternative method (Dua *et al*., 2005).

Number of stem. The result showed that the effects of densities of potato and green bean were not significant on number of potato stem.

Potato tuber yield. Presented results in Table 3 clearly show that potato tuber yield was significantly influenced by potato ($P \leq 0.01$) and bean densities ($P \leq 0.05$) (Table 2). The highest (3.957 kg/m^2) and lowest (2.335 kg/m^2) of potato tuber yield were recorded in densities of 10 and 5 potato/m^2, respectively (Table 3). Moreover, maximum (3.73 kg/m^2) and minimum (2.66 kg/m^2) of potato tuber yield were belong to densities of 0 (sole cropping of potato) and 25 bean/m^2, respectively. Ebwongu *et al*. (2001) reported that reduction of maize density in intercropping with potato lead to the increasing in potato tuber yield which was due to reduction of inter competition. Pilbeam *et al*. (1994) has noted that grain yield of maize in sole culture was greater than intercropping with bean. Competition for nutrient uptake and deficiency of nitrogen transport are responsible for the reduction of maize yield in intercropping with legumes (Tomar *et al*., 1988). Always grain yield of plants did not reduce in intercropping. As an illustration, Lang *et al*. (2001) showed that the grain yield of wheat increased 28 to 30% in intercropping with soybean compared to monoculture. *B. Second year (green bean)*

First harvest

Length of pods. The result in table 3 showed that the effects of potato and green bean densities ($P \leq 0.01$) and interactions ($P \leq 0.05$) were significant on pod length of green bean in second year (Table 1). The highest length of pod (11.73 cm) was obtained in sole cropping of bean with 20 plant/m^2, while the lowest (8.7 cm) was observed at intercropping of 10 potato plant/m^2 with 15 bean plant/m^2 (Fig. 3).

Yield. The results of this study indicated that the yield of green bean in first harvest affected by potato and bean densities ($P \leq 0.01$) (Table 1). Maximum (0.97 kg/m^2) and minimum (0.72 kg/m^2) yield of bean were recorded in densities of 25 and 15 bean/m^2. Additionally, the highest (1.24 kg/m^2) and lowest (0.51 kg/m^2) yield of green bean were obtained in densities of 0 and 10 potato/m^2, respectively (Table 3).

Second harvest

Length of pods. Significant effect of potato density on pod length of green bean was found ($P \leq 0.01$) (Table 2). The highest (13.15 cm) length of pod was achieved in density of 0 potato/m^2, whereas, the lowest (10.97 cm) was obtained in 10 potato plant/m^2 (Table 3).

Yield. The result showed that the effect of potato density ($P \leq 0.01$) was significant on yield of green bean in second harvest of second year (Table 1). The highest and lowest yield of green bean was obtained in densities of 0 and 10 potato/m^2, respectively (Table 3). Morgado and Willey (2008) reported that the reduction of bean grain yield in intercropping with maize was the result of a reduction in the number of pods per bean plant. **Total yield of green bean.** Analysis of variance indicated that the effects of bean and potato densities ($P \leq 0.01$) on total yield of bean were significant (Table 1). The maximum and minimum total yield was recorded in densities of 25 and 15 bean/m^2, respectively (Table 3).

Table 2: Analyses of variance of potato parameters in two years.

Source of variation	df	First year			Second year		
		Plant height	Stem number	Tuber yield	Plant height	Stem number	Tuber yield
Rep	2	106.023**	1.87**	0.141ns	271.825**	1.031ns	4.711**
Density of potato (dp)	2	137.055*	0.053ns	7.96**	62.44ns	7.23**	3.448**
Density of bean (db)	3	167.419*	0.069ns	1.833*	38.442ns	0.178ns	0.622ns
dp×db	6	8.799**	0.187ns	0.117ns	23.816ns	1.819ns	0.71ns
Error	22	35.654	0.208	0.582	34.162	0.802	0.547
CV (%)		12.18	11.99	24.54	14.4	19.37	22.39

Table 3: Effects of additive intercropping at different densities on field performance of potato and green bean in two years.

Year	First year					Second year					
Harvest	First harvest	Second harvest				First harvest	Second harvest				
Parameters	Bean yield	Bean yield	Bean total yield	Potato plant height	Potato tuber yield	Bean yield	Bean Pod length	Bean yield	Bean total yield	Potato stem number	Potato tuber yield
Potato density											
0	0.93a	0.25a	1.19a	46.15bc	3.72a	0.76a	13.15a	0.48a	0.48a		
5	0.60b	0.14b	0.74b	44.68c	3.02ab	0.55b	10.98b	0.44a	0.44a		
7.5	0.54b	0.09c	0.64b	53.81a	2.94ab	0.44b	11.61b	0.32b	0.32b		
10	0.29c	0.06d	0.35c	51.42ab	2.65b	0.23c	10.97b	0.27b	0.27b		
Bean density											
10		0.10b	0.65b	52.47a	2.33c	0.36b			0.72b	3.72b	2.78b
20		0.15a	0.75ab	48.85ab	3.01b	0.56a			0.94a	5.04a	3.26ab
25		0.15a	0.79a	45.72b	3.95a	0.57a			0.97a	5.10a	3.85a

Moreover, the highest (1.24 kg/m^2) and lowest (0.51 kg/m^2) total yield of bean were obtained in density of 0 and 10 potato/m^2, respectively. Obuo *et al*. (1998) reported that grain yield and total biomass of cowpea reduced 50% in intercropping.

Potato

Plant height. There is no significant effect on plant height of potato. In contrast, height of potato decreased in intercropping with green bean which was due to inter competition (Bindera & Thakur, 2005; Dua *et al*., 2005).

Number of stem. Presented results in Table 2 showed that the stem number of potato affected by potato density ($P \leq 0.01$).

The maximum and minimum number of stem was recorded in densities of 10 and 5 potato/m^2, respectively (Table 3). Dua *et al*. (2005) reported that bean could limit growth and development of potato in intercropping, as a result the number of branches and leaves of potato decreased. The study of Dava *et al*. (2005) revealed that inter competition decreased compared to intra competition in intercropping of potato with green bean, consequently number of branch and leaf of potato was more than a pure culture. It seems that in pure culture due to the effect of light on auxin and lack of inter competition for light, plant increased its high instead of the branch development.

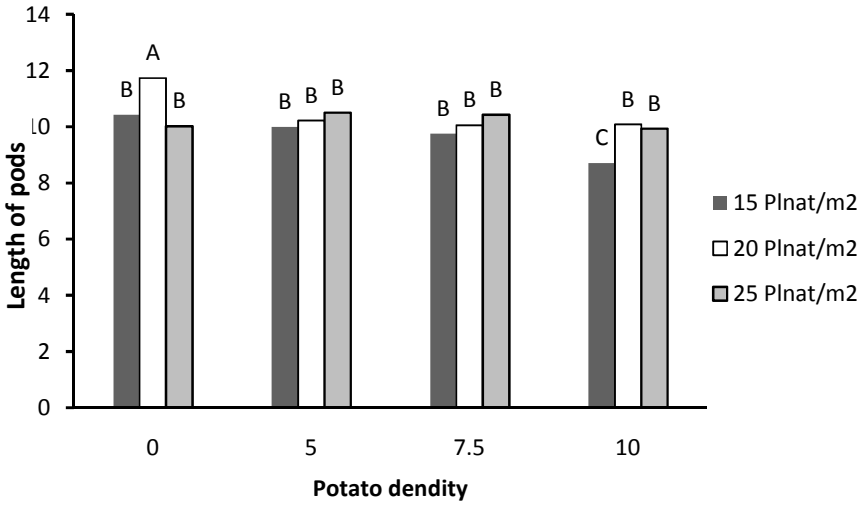

Fig. 3. Effects of potato and green bean intercropping on pod length of bean in the second harvest of the second year.

Potato tuber yield. Statistical analysis showed that the effect of potato density was significant on potato tube yield in second year (P≤0.01) (Table 2). The maximum (3.86 kg/m^2) and minimum (2.79 kg/m^2) potato tube yield were recorded in densities of 10 and 5 potato/m2, respectively (Table 3).

Evaluation of intercropping

Land equivalent ratio (LER). Except 5:25 in first year, the LER of the all intercropping treatments was more than 1 which indicated an advantage of intercropping in comparison with monoculture of potato and green bean (Table 4). In both years, the highest and lowest of LER were recorded for the ratio of 15:10 and 25:5 bean- potato, respectively. These values were 1.699 and 0.876 in first year and 2.075 and 1.017 in second year (Table 4). The LER of maize-soybean intercrops ranged from 0.98 to 1.55 in Zambia (Mwipaya, 1990), and 1.2 to 1.8 in Ethiopia (Kidane, 1990). Hayder *et al*. (2003) reported that the range of LER was 1.39 to 1.52 in intercropping of corn with soybean. In the intercropping system root interaction could increase the root activity and microbial quantity in the rhizosphere (Zhang, 2013). Interspecific interaction between species in the rhizosphere can also affect nutrient availability and uptake in intercropping (Hauggard-Nielsen, 2001; Li *et al*. 2010).

Table 4: Evaluation of intercropping efficiency of treatments.

Intercropping	LER		RVT	
	2008	2009	2008	2009
5/15	1.163	1.51	1.107	1.331
5/20	1.186	1.257	1.128	1.234
5/25	0.876	1.017	0.84	1.004
7.5/15	1.453	1.849	1.433	1.759
7.5/20	1.365	1.877	1.366	1.77
7.5/25	1.039	1.519	1.028	1.413
10/15	1.699	2.075	1.491	1.942
10/20	1.412	1.564	1.269	1.464
10/25	1.081	1.271	1.013	1.199

Total relative value (RVT). Today the pattern of crops cultivation is based on the economic performance. Thus, for economic justification of intercropping, it should be compared with the most favorable conditions of crop monoculture that is possible by use of RVT (Table 4). RVT of intercropping treatments (except the ratio of 25:5 in the first year) was higher than 1 which showed the economic advantage of intercropping compared to monoculture. The highest and the lowest RVT in first year were observed in the ratio of 15:10 and 25:5 bean-potato by 1.491 and 0.84, respectively. In second year, the highest RVT was recorded for the ratio of 15:10 bean- potato by 1.942, in contrast, the lowest RVT was belong to 25:5 bean- potato by 1.004.

In fact, in two years the highest and lowest RVT were obtained in the ratio of 15:10 and 25:5 bean- potato, respectively. Therefore it can be concluded that intercropping diversify ecosystems and produce sustainable production and increase economic income, in addition, can be effective the use of agricultural land considerably.

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