



Potato (*Solanum tuberosum* L.) and pinto bean (*Phaseolus vulgaris* L. var. pinto) intercropping based on replacement method

Ali Nasrollahzadeh Asl *, Adel Dabbagh Mohammady Nassab, Said Zehtab Salmasi, Mohammad Moghaddam and Aziz Javanshir

Dept. of Agronomy and Plant Breeding, Faculty of Agriculture, Tabriz University, Tabriz, Iran.

*e-mail: ali_nasr462@yahoo.com, adeldabb@yahoo.com

Received 20 January 2009, accepted 16 April 2009.

Abstract

In order to evaluate different proportions of intercropping potato (*Solanum tuberosum* L.) and pinto bean (*Phaseolus vulgaris* L.) with their sole cropping, two experiments were carried out in Agricultural Research Station of University of Tabriz in 2005 and 2006, using randomized complete block design with three replications of eight treatments of replacement intercropping with proportions 2:1 and 3:1 of potato with pinto bean, (the densities of potato 4.7 and 5.3 plants per m² and those of pinto bean 45 and 55 plants per m²) along with two sole cropping treatments of potato (4.7 and 5.3 plants per m²) and two sole cropping treatments of pinto bean (with 45 and 55 plants per m²). In all intercropping plots, tuber yield per m² and per plant, number of leaves and branches and size of tuber per plant increased significantly as compared with their sole croppings. For pinto bean also, grain yield per m² and per plant, number of pods per plant and number of leaves and branches per plant increased significantly as compared with their sole croppings. Highest amounts of LER in two years (1.25 and 1.27) were related to intercropping proportion of 2:1 (66% potato with density of 5.3 plants per m² + 34% pinto bean with the density of 55 plants per m²). We can infer that these two crops have used more environmental resources in intercropping than sole croppings due to increase in Resources Use Efficiency (RUE).

Key words: Intercropping, pinto bean, potato, yield, LER.

Introduction

Intercropping means production of two or several crops at a growing season in a field so that two plants are adjacent to each other in most of their growing period²⁴. Today intercropping is applied extensively in many countries⁴. In this system plants use water well and Water Use Efficiency (WUE) increases as compared to sole cropping⁸. In intercropping, plant green cover takes ground surface in a short time, therefore Light Use Efficiency (LUE) increases⁷. Also, increasing of green cover amount in intercropping protects soil from erosion²².

Potato is one of the most important crops for human consumption and is regarded at the fourth crop in the world in terms of production²⁰. Bean is also one of the most important food supplements for human, and its protein content is rich³. By increasing soil nitrogen due to nitrogen fixation, bean can increase the soil fertility. It is also tolerant to shadow and can be planted in intercropping system and grows well¹⁶. Intercropping of legumes with non-legumes increases yield per unit area, because they use different nitrogen sources and have low competition for nitrogen¹³. In an intercropping of bean with corn (without using nitrogen) grain yield of corn increased 72% over its sole cropping. The increase was attributed to transfer of nitrogen from bean to corn⁹. Brophy *et al.*⁶ have also reported the transfer of nitrogen from legume to non-legume crops in the US. Dua *et al.*¹⁰ found that intercropping potato and French bean in all intercropping treatments increased yield as compared to sole cropping and the

amount of LER was more than one. Prasad *et al.*¹⁸ reported that intercropping of potato and fenugreek increased potato yield up to 2.5 tons per hectare. Ebwongu *et al.*¹¹ found that in potato and corn intercropping, LER reached to 1.58, showing the beneficial effect of intercropping. Rana *et al.*¹⁹ reported that intercropping potato and linseed increased potato yield per unit area, and in all intercropping treatments, LER was more than one with the maximum amount of 1.44. Bekele and Sommartya⁵ found that in intercropping of potato with garlic the amount of LER reached more than one and *Phytophthora infestans* decreased significantly. About 80% of the potato produced in Africa is obtained from its intercropping with sugarcane. By this method the amount of sugar has increased up to 6.12%¹⁵. Potato and pinto bean have been selected for evaluating intercropping in this experiment because of their nutritional value for human and increase of Resources Use Efficiency (RUE).

Materials and Methods

The field experiments were conducted at the Research Station (Lat 38°15'N, Long 46°17' E, 1360 m altitude) of the Faculty of Agriculture, University of Tabriz, Tabriz, northwest of Iran, in 2005 and 2006 growing seasons. Soil was sandy loam with pH 7.6 and 0.8% organic matter. Each year the land was ploughed and cultivated before planting in the spring. The fertilizers, including urea, super phosphate and potassium sulphate, were applied based

on the soil test at rates of 150, 200 and 150 kg ha⁻¹, respectively. Also, about 60 tons ha⁻¹ manure was added to the soil. Prior to sowing, potato tubers and pinto bean grains were treated with benomyl at 0.2% (wt/wt) in order to protect them from soil-borne diseases. Both plants were sown in early May in spring. Potato tubers and pinto bean grains were planted at 10 and 3 cm depths, respectively, and the plots were irrigated as needed. The experiments were laid out in randomized complete block design with three replications and 12 treatments for both years. Treatments were: S1 = sole cropping of potato with the density of 5.3 plants per m², S2 = sole cropping of potato with 4.7 plants per m², S3 = sole cropping of pinto bean with 55 plants per m², S4 = sole cropping of pinto bean with 45 plants per m², S5 = intercropping with proportion of 2:1 (66% potato with 5.3 plants per m² + 34% pinto bean with 55 plants per m²), S6 = intercropping with proportion of 2:1 (66% potato with 5.3 plants per m² + 34% pinto bean with 45 plants per m²), S7 = intercropping with proportion of 2:1 (66% potato with 4.7 plants per m² + 34% pinto bean with 55 plants per m²), S8 = intercropping with proportion of 2:1 (66% potato with 4.7 plants per m² + 34% pinto bean with 45 plants per m²), S9 = intercropping with proportion of 3:1 (75% potato with 5.3 plants per m² + 25% pinto bean with 55 plants per m²), S10 = intercropping with proportion of 3:1 (75% potato with 5.3 plants per m² + 25% pinto bean with 45 plants per m²), S11 = intercropping with proportion of 3:1 (75% potato with 4.7 plants per m² + 25% pinto bean with 55 plants per m²), S12 = intercropping with proportion of 3:1 (75% potato with 4.7 plant per m² + 25% pinto bean with 45 plant per m²). The intercropping was conducted based on replacement method. In the intercropping with proportion of 3:1 and 2:1 and sole cropping, the number of rows per plot was six, five and four, respectively. In all plots, the distance between rows was 75 cm. The potato variety was Agria and pinto bean variety Native Sarabi. The potato traits under study were as follows: tuber yield per plant, number of leaves per plant, number of branches per plant, tuber size per plant and number of tubers per plant measured on 10 plants. For pinto bean the traits were: grain yield per plant, number of leaves per plant, number of branches per plant, number of pods per plant, number of grains per pod and 100-seeds weight. At final harvesting stage, tuber yield of potato from four m² and grain yield of pinto bean from two m² were also measured. Then data were analyzed by MSTATC software and means compared with Duncan's Multiple Range Test at 5% probability level. In order to evaluate the beneficial effect of intercropping, Land Equivalent Ratio (LER) was determined. LER is an index used to determine the usefulness of intercropping. If LER is more than one, then intercropping is regarded beneficial over sole cropping¹⁷. The LER was calculated as follows: $LER = RY_p + RY_b$, where RY_p and RY_b were relative yields of potato and pinto bean.

Results and Discussion

Potato: The results showed that there were significant differences among treatments for tuber yield per m², tuber yield per plant, tuber yield per hectare, tuber size and number of leaves and branches per plant, but there was no significant difference in terms of number of tubers per plant (Table 1). In all intercropping combinations, tuber yield per occupied potato unit area was significantly higher than in the sole cropping. Therefore, it is concluded that the pinto bean had facilitative effects on potato.

The maximum tuber yield per m² was obtained from S6 treatment (Table 2). This can be attributed to the decrease of intra-specific competition for potato plants and also competition for nitrogen. Dua *et al.*¹⁰ reported that in intercropping potato with French bean in the replacement method, tuber yield per m² was higher than in sole cropping in all intercropping plots due to the reduction of intra-specific competition and competition for nitrogen. Ebwongu *et al.*¹¹ found that intercropping potato and corn based on replacement method increased tuber yield and the maximum tuber yield was obtained from the intercropping proportion of 2:1 (potato + corn) due to increase in the number of leaves and branches in potato.

The maximum tuber yield per plant was obtained from the S8 treatment (Table 2). This can be attributed to the decrease in the density of both plants and the reduction of inter- and intra-specific competition. Gebremedhin¹² observed that the tuber yield per plant increased by decreasing the plant density. The maximum tuber yield per hectare (mono cropped area) was obtained from the S1 treatment (Table 2). This can be related to larger number of potato plants in the sole cropping. The highest number of leaves and branches per plant was obtained from S8 treatment (Table 2). This was mainly due to the decrease in the density of both plants by creating more space for growth. Ebwongu *et al.*¹¹ found that in intercropping potato and corn, based on replacement method, increase in the number of leaves and branches per plant can be obtained at low densities of both plants. The biggest tuber size was obtained from S8 treatment (Table 2), due to the reduction in density of both plants and also the decrease in inter- and intra-specific competition. Gebremedhin¹² reported that the yield changes in potato are attributed to tuber size, whereas, number of tubers per plant was not affected by density and the biggest tuber size was obtained from low densities. Ahmad and Sager¹ found that the number of tubers per plant is determined in advance and they are almost fixed but tuber size increases by time.

Pinto bean: The results showed that there were significant differences among treatments for grain yield per pinto bean unit area and per plant, grain yield per hectare, number of leaves and branches and number of pods per plant. However, no significant differences were obtained for the number of grains per pod and the weight of 100-seeds (Table 3). In all intercropping combinations, grain yield per m² was significantly higher than their corresponding sole cropping, and the maximum grain yield was obtained from the S7 treatment (Table 4). Dua *et al.*¹⁰ reported that intercropping of potato with French bean in the replacement method improved grain yield in all plots owing to more space for growth. In this experiment, maximum grain yield per m² was obtained from 2:2 proportion (potato + French bean). Singh²³ found that in the intercropping of corn with green bean in the replacement method, grain yield of green bean was increased and the highest grain yield was obtained from the treatment 2:1 (corn + green bean) that was attributed to the decrease in inter-specific competition as compared to intra-specific competition. The maximum grain yield per plant was obtained from S8 treatment (Table 4). This is regarded to reduction of density of both crops which decreased inter- and intra-specific competition. Herbert and Litchfield¹⁴ reported that by decreasing in the density of bean, the amount of grain yield per plant increased. They attributed this result to the decrease in competition for light and nutrients. Maximum grain

Table 1. Combined analysis of variance for different characters in potato for potato and pinto bean intercropping.

Source of variation	df	MS						
		Tuber yield per potato unit area (m ²)	Tuber yield per plant	Tuber yield per hectare	Number of leaves per plant	Number of branches per plant	Tuber size	Number of tubers per plant
Year	1	3.665 ^{ns}	9151.84 ^{ns}	12.668 ^{ns}	226.67 ^{ns}	9.656 ^{ns}	453.20 ^{ns}	0.046 ^{ns}
Replication/Year	4	2.411 ^{ns}	5914.77 ^{ns}	7.752 ^{ns}	107.806 ^{ns}	3.810 ^{ns}	147.99 ^{ns}	0.782 ^{ns}
Treatment	9	2.658*	6494.20*	7.855*	234.3**	12.754**	85.248**	0.137 ^{ns}
Year×Treatment	9	0.023 ^{ns}	52.102 ^{ns}	0.033 ^{ns}	5.389 ^{ns}	0.845 ^{ns}	3.925 ^{ns}	0.004 ^{ns}
Error	36	1.085	2737.84	3.544	60.748	1.061	62.954	0.288
CV %		14.99	14.93	15.11	10.99	9.61	11.29	10.11

*, ** = Significant at 5% and 1%, respectively. ns = not significant.

Table 2. Means of different characters of potato for potato and pinto bean intercropping.

Treatment	Tuber yield per unit area (kg)	Tuber yield per plant (g)	Tuber yield per hectare (ton)	Number of leaves per plant	Number of branches per plant	Tuber size (mm)
S1	1.595 ^{bc}	301.3 ^c	16.01 ^a	57.88 ^d	8.17 ^e	59.5 ^c
S2	1.577 ^c	335.6 ^{bc}	15.77 ^a	67.68 ^{bc}	9.94 ^d	65.9 ^{bc}
S3	-	-	-	-	-	-
S4	-	-	-	-	-	-
S5	2.032 ^a	383.5 ^{ab}	13.54 ^{ab}	72.15 ^{abc}	10.14 ^d	70.6 ^{ab}
S6	2.067 ^a	390.1 ^{ab}	13.77 ^{ab}	73.9 ^{abc}	11.67 ^{bc}	72.5 ^{ab}
S7	1.884 ^{abc}	400.9 ^{ab}	12.55 ^b	77.03 ^{ab}	12.15 ^{ab}	75.3 ^{ab}
S8	1.935 ^{ab}	411.8 ^a	12.90 ^b	79.46 ^a	13.13 ^a	79.2 ^a
S9	1.915 ^{abc}	361.4 ^{abc}	14.36 ^{ab}	65.55 ^{cd}	9.62 ^d	66.1 ^{bc}
S10	1.977 ^a	373.1 ^{ab}	14.83 ^{ab}	68.80 ^{bc}	9.81 ^d	68.2 ^{bc}
S11	1.80 ^{abc}	382.8 ^{ab}	13.49 ^{ab}	72.05 ^{abc}	10.83 ^{cd}	71.9 ^{ab}
S12	1.832 ^{abc}	390.2 ^{ab}	13.76 ^{ab}	74.86 ^{abc}	11.69 ^{bc}	73.1 ^{ab}

Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test (P = 0.05).

Table 3. Combined analysis of variance for different characters of pinto bean in intercropping of potato with pinto bean.

Source of variation	df	MS							
		Grain yield per pinto bean unit area (m ²)	Grain yield per plant	Grain yield per hectare	Number of leaves per plant	Number of branches per plant	Number of pods per plant	Number of grains per pod	100-seed weight
Year	1	64429.75 ^{ns}	2.966 ^{ns}	0.161 ^{ns}	245.39 ^{ns}	0.468 ^{ns}	0.526 ^{ns}	0.022 ^{ns}	0.01 ^{ns}
Replication /Year	4	58419.92 ^{ns}	2.478 ^{ns}	0.061 ^{ns}	101.123 ^{ns}	1.151 ^{ns}	1.130 ^{ns}	0.273 ^{ns}	21.036 ^{ns}
Treatment	9	58552.41**	2.071**	4.135**	179.314**	3.368**	2.968**	0.054 ^{ns}	1.537 ^{ns}
Treatment × Year	9	1076.79 ^{ns}	0.054 ^{ns}	0.016 ^{ns}	1.306 ^{ns}	0.006 ^{ns}	0.002 ^{ns}	0.001 ^{ns}	0.188 ^{ns}
Error	36	17622.73	0.762	0.025	23.256	0.435	0.528	0.059	13.489 ^{ns}
CV %		13.01	12.78	13.11	10.86	10.42	10.69	7.15	8.76

*, ** = Significant at 5%, 1% probability level respectively. ns = not significant

Table 4. Means of different characters of pinto bean in intercropping of potato with pinto bean.

Treatment	Grain yield per unit area (g)	Grain yield per plant (g)	Grain yield per hectare (ton)	Number of leaves per plant	Number of branches per plant	Number of pods per plant
S1	-	-	-	-	-	-
S2	-	-	-	-	-	-
S3	303.7 ^{cd}	5.52 ^b	3.037 ^a	33.17 ^e	4.247 ^d	4.29 ^d
S4	288.06 ^d	6.402 ^{ab}	2.787 ^a	40.15 ^d	5.398 ^c	5.27 ^c
S5	372.66 ^{ab}	6.775 ^a	1.268 ^{bc}	43.15 ^{cd}	5.55 ^{bc}	5.46 ^c
S6	326.73 ^{bcd}	7.262 ^a	1.108 ^{cd}	48.20 ^{abc}	6.358 ^{ab}	6.21 ^{abc}
S7	389.01 ^a	7.072 ^a	1.322 ^b	47.80 ^{abc}	6.05 ^{abc}	5.82 ^{abc}
S8	341.33 ^{abcd}	7.588 ^a	1.160 ^{bc}	51.79 ^a	6.817 ^a	6.68 ^a
S9	357 ^{abc}	6.488 ^{ab}	0.8917 ^e	40.64 ^d	5.195 ^c	5.24 ^c
S10	317.63 ^{bcd}	7.058 ^a	0.7930 ^e	45.76 ^{abcd}	5.99 ^{abc}	6.07 ^{abc}
S11	374.66 ^{ab}	6.845 ^a	0.9392 ^{de}	43.98 ^{bcd}	5.648 ^{bc}	5.71 ^{bc}
S12	329.66 ^{bcd}	7.298 ^a	0.8195 ^e	49.53 ^{ab}	6.567 ^a	6.51 ^{ab}

Means within each column followed by the same letter were not significantly different according to Duncan's multiple range test (P = 0.05).

Table 5. Land equivalent ratio (LER) of potato and pinto bean in 2005 and 2006 growing season.

Intercropping treatment	2005			2006		
	RY _p	RY _b	LER	RY _p	RY _b	LER
S5	0.83	0.42	1.25	0.86	0.41	1.27
S6	0.85	0.39	1.24	0.87	0.37	1.24
S7	0.79	0.44	1.23	0.80	0.42	1.22
S8	0.80	0.41	1.21	0.82	0.39	1.21
S9	0.88	0.29	1.17	0.91	0.29	1.20
S10	0.91	0.28	1.19	0.94	0.27	1.21
S11	0.85	0.31	1.16	0.85	0.32	1.17
S12	0.86	0.30	1.16	0.88	0.27	1.15

yield per hectare was obtained from S3 treatment (Table 4), which can be due to the increase in the number of plants in the mono cropping. The largest number of leaves and branches per plant was found in S8 treatment (Table 4). This can be due to the decrease in densities of both crops by creating more space for growth. Herbert and Litchfield¹⁴ reported that at the low density of bean, number of leaves and branches increased due to the decrease in competition for light and nutrients. Dua *et al.*¹⁰ indicated that in intercropping of potato and French bean, the number of leaves and branches per plant in French bean increased due to providing more space in the intercropping condition. Largest number of pods per plant was obtained from S8 treatment (Table 4), which is regarded to the decrease in the density of both crops causing the decrease in inter- and intra-specific competition. According to Herbert and Litchfield¹⁴, number of pods per plant increased at low densities. Shafshak *et al.*²¹ reported that in intercropping soybean with sunflower, among yield components of soybean, only number of pods per plant increased significantly in the intercropping condition. Allen and Obura² reported that in intercropping of corn, cowpea and soybean, only the number of pods per plant increased significantly in the intercropping condition.

The benefits of intercropping: In all intercropping plots, amount of LER was more than one, and the maximum amount in two years (1.25 and 1.27, respectively) was obtained for S5 treatment (Table 5), because Land Use Efficiency in intercropping was higher than in mono cropping. This can be attributed to the increase in the density of both plants and their use of more environmental resources. Based on Dua *et al.*¹⁰ in intercropping of potato with French bean in the replacement method, amounts of LER were more than one in all cases of intercropping and its maximum amount was 1.49. Ebwongu *et al.*¹¹ found that in intercropping potato with corn based on replacement method, amounts of LER in all intercropping conditions were more than one and maximum amount was 1.58 when the potato:corn proportion was 2:1.

Conclusions

Crop yield of potato and pinto bean was more than their sole cropping in all intercropping combinations. Both crops used environmental resources better than their corresponding sole cropping, and the maximum benefit was obtained from the S5 intercropping treatment. Therefore, optimum effect of intercropping was observed in the highest density of both species.

References

- ¹Ahmed, C. H. M. S. and Sagar, G. R. 1981. Volume increase of individual tubers of potato grown under field condition. *Potato Research* **24**:279–288.
- ²Allen, J. R. and Obura, R. K. 1983. Yield of corn, cowpea and soybean under different intercropping systems. *Agronomy Journal* **75**:1005–1014.
- ³Arija, I., Centeno, C., Viveros, A., Brenes, A., Marzo, F., Illera, J. C. and Silvan, G. 2007. Nutritional evaluation of raw and extruded kidney bean (*Phaseolus vulgaris* L. var. *pinto*) in chicken diets. *Poultry Science* **85**:635–644.
- ⁴Baker, E. F. I. 1988. Mixed cropping in Northern Nigeria. *Exp. Agr.* **14**:293–298.
- ⁵Bekele, K. and Sommartya, T. 2006. Effect of intercropping on potato late blight, *Phytophthora infestans*, de Bary development and potato tuber yield in Ethiopia. *Kasetsart Journal Natural Science* **40**:914–924.
- ⁶Brophy, L. S., Heichel, G. H. and Russelle, M. P. 1987. Nitrogen transfer from forage legumes grass in a systematic planting design. *Crop Science* **27**:553–558.
- ⁷Clarck, E. A. and Francis, C. A. 1985. Transgressive yielding in time and space. *Field Crop Research* **11**:37–53.
- ⁸Davis, J. H. C., Woolley, J. N. and Moreno, R. A. 1986. Multiple cropping with legumes and starchy roots. *Multiple Cropping Systems*. Macmillan Publishing Company New York, pp. 82–110.
- ⁹Dil, K. and Mulder, E. E. 1982. Effect of associated growth on yield and nitrogen control of legume and grass. *Plant and Soil* **16**:229–237.
- ¹⁰Dua, V. K., Lal, S. S. and Covindakrishnan, P. M. 2005. Potential and competition indices in potato + French bean intercropping system in Shimla Hills. *Indian Journal Agricultural Science* **75**:321–327.
- ¹¹Ebwongu, M., Adipala, E., Ssekabembe, C. K., Kyamanywa, S. and Bhagsari, A. 2001. Effects of intercropping maize and potato on yield of the component crops in Central Uganda. *African Crop Science Journal* **9**:83–96.
- ¹²Gebremedhin, W. 2001. Effects of spatial arrangement on tuber yields of some potato. *African Crop Science Journal* **9**:67–76.
- ¹³Haugard-Nielsen, H., Ambus, P. and Jensen, E. S. 2001. Inter-specific competition and with weed in pea-barley intercropping. *Field Crop Research* **70**:101–109.
- ¹⁴Herbert, S. J. and Litchfield, G.V. 1992. Effect of location and plant density on yield and architectural trait in beans. *Crop Science* **25**:579–581.
- ¹⁵Khurana, S. M. and Pandey, S. K. 2001. Intercropping of potato and other vegetables with autumn-planted sugarcane. *Journal of the Indian Potato Association* **28**:48–49.
- ¹⁶Kowal, J. M. and Kassam, H. 1978. *Agricultural Ecology of Savanna*. Clarendon Press, Oxford, 403 pp.
- ¹⁷Mead, R. and Willy, R.W. 1980. The concept of a land equivalent ratio and advantages in yields from intercropping. *Exp. Agr.* **16**:217–218.
- ¹⁸Prasad, R., Sing, S. and Pal, M. 2001. Studies on intercropping potato with fenugreek. *Acta Agronomica Hungarica* **49**:189–192.
- ¹⁹Rana, D. S., Ganga, S. and Rana, K. S. 1999. Effect of intercropping potato and linseed on growth and yield attributes, yield, energetics and competition function. *Indian Journal of Agronomy* **44**:518–524.
- ²⁰Sayed, J. A., Ghulab, R., Syed, R. U. S. and Arshad, I. 2008. Analysis of genetic diversity in Pakistani potato cultivars by using randomly amplified polymorphic DNA primers. *American-Eurasian Journal of Sustainable Agricultural* **2**:50–53.
- ²¹Shafshak, S. E., Shokr, E. S. and Ahmar, B. A. 1989. Studies on soybean and sunflower intercropping, plant characteristics, yield and yield components of soybean and sunflower. *Field Crop Research* **10**:41–56.
- ²²Siddoway, F. H. and Barntt, A. P. 1976. Water and wind erosion control aspects of multiple cropping. *ASA Special Publication* **27**:317–335.
- ²³Singh, N. B. 1986. Intercropping of legumes in maize under varying nitrogen levels and maizes population. *Annals of Agricultural Research* **7**:37–43.
- ²⁴Sullivan, P. 2003. Intercropping principles and practices. Available on: [http://www. Attar. Ncat. Org.](http://www.Attar.Ncat.Org)