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Potato (*Solanum tuberosum*) based intercropping systems for Southern hills

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ABSTRACT

Field trials were conducted on sandy clay loam soils of the Nilgiris during summer seasons of 2003 to 2005 to study the intercropping possibilities of French beans (*Phaseolus vulgaris* L.), maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) with potato (*Solanum tuberosum* L.) in three population proportions (75:25, 75:50 and 50:50) under rainfed conditions. The results indicated that potato + French bean at 75:50 population recorded significantly higher potato equivalent yield, (PEY) (27.1 t/ha), land equivalent ratio (LER) (1.28) and net returns (Rs 69,090) over sole potato. Intercropping of potato with wheat and maize resulted in significant decrease in PEY over sole potato. Potato is more competitive than other crops as evident from Relative Crowding Coefficient (RCC) values. However, at 50:50 ratios, French bean and maize are more competitive. Potato + maize (75:50 and 50:50) was found soil exhaustive while potato + French bean is soil restorative system.

Key words: Economics, French bean, Intercropping, Maize, Potato, Relative Crowding Coefficient, Wheat

Nilgiris, a part of Western Ghats range, is bestowed with a unique climate (moist sub-humid), which enables the farmers to grow three annual crops/year under three distinct seasons *viz.* summer, autumn and irrigated. In all the mentioned seasons, potato accounts for major crop area in the Nilgiris. Under normal monsoon conditions, potato (*Solanum tuberosum* L.) – cabbage (*Brassica oleracea* L.) is the most suitable crop rotation for the Nilgiris. However, due to climate change, the quantum of rainfall as well as number of rainy days are showing much variation in this region. Hence, the autumn crop is becoming dependent upon some life-saving irrigations. If the same trend continues, it becomes impossible to harvest the autumn crop purely under rainfed conditions.

The last ten years data showed that the cropping intensity of the region ranges from 200 to 225%, with a decreasing trend, due to vagaries in rainfall distribution. Intercropping is an alternate to improve the intensity of cropping, simultaneously helping the farmers to avoid the risk of crop failure. French beans (*Phaseolus vulgaris* L.) being a legume is known for its atmospheric nitrogen-fixation and also the produce is having good market value as a vegetable. Wheat (*Triticum aestivum* L.) being cool season crop can be a good companion for potato as a cereal - vegetable combination. Similarly, maize (*Zea mays* L.) again is another choice which has got good market value in different forms. Singh *et al.* (2008) reported that wheat and maize are suitable component crops in potato intercropping for West Central and North-Eastern plains.

There is very meager information available on intercropping studies in potato under Nilgiri conditions. Hence, aiming at improving the intensity of cropping in the region, the present investigation was carried out to find out the most suitable intercrop combination and their populations having high yield potential combined with higher monetary advantage.

MATERIALS AND METHODS

Field trials were conducted in fixed plots under rainfed conditions, at the Research Farm of Central Potato Research Station, Muthorai, The Nilgiris. The experimental site is situated at an elevation of 2,140 m above sea level at $11^0 24^{'}$ N latitude and $74^0 4^{'}$ E longitude and the soil is sandy clay loam in texture. The pH of the experimental site was 4.0, with 1.72% of organic carbon, 378-15.6-412 kg/ha of available N-P-K. The quantum of rainfall received during cropping seasons of 2003, 2004 and 2005 was 409.1 mm, 1,082.2 mm and 768.3 mm, respectively. Thirteen treatments formed by combination of potato intercropping with maize, wheat and French bean in 75:25, 75:50 and 50:50 proportions and their 4 sole crops. The recommended spacings adopted were 60 cm x 20 cm for

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potato 'Kufri Giriraj' and maize 'Co-2', 30 cm solid rows for the wheat 'HW 3083' and 30 cm x 15 cm for French bean 'Waltex'. In inter crop combinations, the populations were adjusted by changing the intra-row spacing. In all the three years, potato crop was planted during the third week of April and the inter crops were planted after one week of potato planting as there was rainfall in the last week of April during all the years. Recommended doses of fertilizers (potato : 90:60:75, French bean : 90:40:75, wheat :80:18:33 and maize : 135:28:42 kg N:P:K/ha, respectively) as ammonium sulphate, single superphosphate, and muriate of potash were applied as basal at the planting for all the crops as per their proportions in the intercropping system. Potato was harvested in the first week of September. Harvesting of French bean started at 65 days after planting and in total there were five pickings at weekly intervals. The yield data of French bean was recorded at different pickings and pooled data is reported for analysis. Wheat (145 days) and maize (190 days) were harvested at their maturity i.e. in last week of September and first week of November, respectively and their grain and cob yields were recorded. The trial was carried out in randomized block design with three replications. To evaluate the productive efficiency of the intercropping, land equivalent ratio (LER) and relative crowding coefficient (RCC) and to study the dominance of component crop, competition ratio (CR) were estimated. Potato equivalent yield (PEY) was calculated by converting the yield of component crops into potato yield on the basis of sale price. For calculating PEY as well as economics, a mean sale price of potato tubers, French bean pods, wheat and maize grains i.e., Rs 5, 12, 12 and Rs.13.35/kg, respectively was used. Similarly, cost of cultivation was also estimated on average basis for 3 years by taking labour wages at Rs.100/unit and the cost of N, P and K at Rs. 5.25, 22.13 and 7.72/kg. The uptake of major nutrients (N-P-K) by different crops and the balance after three years of cropping was also estimated using standard methods.

RESULTS AND DISCUSSION

Yield attributes and yield

The potato tuber number in different grades is influenced by the competitive function of intercrops. Small-sized tubers were more when the intercrop (maize) competed severely for the resources. The population load also had a significant influence on the yield and other yield attributes of both main and intercrop. The total as well as different grade tuber number in potato + French bean in all the population levels remained almost similar to that of its sole crop as per its population proportion. Whereas in maize systems there was a drastic reduction in total tuber number when compared with the sole potato indicating the severe competition for resources. In wheat systems, though the total tuber number remained somewhat reasonable but, the medium-and large-sized tuber number decreased significantly with increasing proportions of wheat (Table 1).

In French bean, pod number/plant was more under intercropping when compared with sole stand but, pod weight showed non-significant reduction with respect to intercrop combinations. Under competitive environment with potato, there is an improvement in pod number of French bean. Regarding pod yield of French bean, there was a synergistic effect when the total population of component crops remained at 100% i.e., 75:25 and 50:50 ratios and the competition due to potato was not observed even in 75:50 ratio where the total population exceeded 100% (Table 1).

In wheat, number of panicles/m row length showed significant reduction especially in 75:50 ratio and no significant influence of intercropping was observed on grains/panicle and test weight. The reduction in number of panicles due to intercrop competition is clearly reflected in grain yield also (Table 1).

In maize systems, intercropping did not influence the number of cobs/plant, seeds/cob and also test weight. The difference in grain yield is mainly because of the population effect. This indicates that in potato + maize intercropping, competition existed for potato due to the intercrop maize but maize did not get influenced by potato. In Shimla hills, Dua *et al*. (2005) reported that potato is a dominant crop when it was sown in lesser proportion than that of French bean, whereas French bean dominated potato in intercropping when its proportion was equal or less than that of potato (Table 1).

Potato equivalent yield (PEY)

The PEY represents the yields of component crops in an intercrop combination converted to potato yield equivalents on the basis of sale price. In all the three years of experimentation, potato + French bean intercropping at 75: 50 population proportions produced the highest PEY and it was closely followed by potato + French bean at 75:25 proportions. This indicates the yield advantage of the intercropping system with French bean as intercrop in potato-based cropping systems. None other than these two intercrop combinations of potato could produce higher yields than the sole potato yields in all the three years. This showed that the other two intercrops i.e. wheat and maize could not prove as suitable intercrops for potato under the Nilgiri conditions. Pooled analysis also indicated the same trend and among all the combinations, potato + French bean at 75:50 ratio is the most advantageous one (Table 2).

Out of the four different component crops of intercrop-

ping systems, the productivity of potato (22.47 t/ha) was the highest (in terms of PEY) and it was followed by French bean (19.07 t/ha), maize (8.48 t/ha) and wheat (6.48 t/ha) in order, as sole crops. Among the systems, on an average, potato with French bean recorded the highest productivity (24.65 t/ha) and it was followed by potato + wheat (18.62 t/ha) and potato + maize (13.46 t/ha) systems. This indicated that French bean is a profitable component crop in potato intercropping with almost 10% yield advantage over sole potato. Whereas, maize and wheat as intercrops led to loss in productivity by 40 and 17%, respectively over solo potato. Among the different intercrop combinations of potato + French bean, 75:50 ratio has recorded 12% increase in system productivity over sole potato. At Shimla, on the basis of land-equivalent ratio (1.50) and compensation ratio (CoR_a; 4.95; CoR_b; 1.90), the

Table 1. Mean yield and yield attributes of potato and inter-crops

Treatment	Potato				French beans				Wheat/Maize			
	Tuber No. (000/ha)			Tuber yield (t/ha)	Pods/ plant	10 pod weight (g)	Pod yield (t/ha)	Straw yield (t/ha)	No.of panicles/ m row length/ cobs/plant	No. of grains/ panicle or cob	Grain yield (t/ha)	Straw yield (t/ha)
	<25g	25-75g	>75g									
P+Fb (75:25)	71	167	45	19.51	5.2	86.5	2.38	4.51				
P+Fb (75:50)	44	160	53	17.55	4.5	85.2	3.99	7.02				
P+Fb (50:50)	23	93	39	11.42	4.4	91.8	4.24	7.25				
P+W (75:25)	92	187	25	20.73					55.1	40	0.66	1.00
P+W (75:50)	51	132	36	15.59					49.2	37	1.07	1.65
P+W (50:50)	35	119	12	12.41					52.7	39	1.24	1.95
P+M (75:25)	52	102	49	12.63					1.42	127	0.67	1.30
P+M (75:50)	32	76	51	10.58					1.51	132	1.46	2.58
P+M (50:50)	18	46	38	7.06					1.56	136	1.66	2.82
French bean (Fb)					3.9	96.7	7.98	13.33				
Wheat (W)									56.0	42	2.85	4.36
Maize (M)									1.54	134	3.18	5.91
Potato (P)	63	178	72	22.47								
SEm+	2	5	2	0.66	0.1	6.5	0.39	0.55	1.64/**0.11**	3/**9**	0.04/**0.05**	0.16/**0.28**
CD(P=0.05)	4	11	4	1.36	0.4	NS	0.96	1.35	4.01/**0.26**	NS/**NS**	0.10/**0.12**	0.38/**0.69**

Bold values are for maize

Table 2. Productivity of crops, system (Potato equivalent yields (t/ha) and LER

Treatment	2003			2004			2005				LER		
	Potato	IC	PEY	Potato	IC	PEY	Potato	IC	PEY	Mean PEY	Potato	Intercrop	System
P+Fb (75:25)	22.72	2.24	28.10	16.82	2.32	22.39	18.99	2.58	25.18	25.22	0.87	0.30	1.17
P+Fb (75:50)	21.61	3.67	30.42	14.59	4.05	24.31	16.44	4.24	26.62	27.12	0.78	0.50	1.28
P+Fb (50:50)	12.83	4.02	22.48	10.10	4.21	20.20	11.32	4.50	22.12	21.60	0.51	0.53	1.04
P+W (75:25)	23.42	0.33	24.21	18.23	0.83	20.22	20.55	0.81	22.49	22.31	0.92	0.23	1.15
P+W (75:50)	21.72	0.53	22.99	11.75	1.24	14.73	13.31	1.45	16.79	18.17	0.69	0.38	1.07
P+W (50:50)	18.37	0.64	19.91	8.91	1.42	12.32	9.95	1.66	13.93	15.39	0.55	0.44	0.99
P+M (75:25)	13.29	0.56	14.79	11.73	0.68	13.55	12.87	0.76	14.90	14.41	0.56	0.21	0.77
P+M (75:50)	11.67	1.30	15.14	10.62	1.45	14.49	9.46	1.62	13.79	14.47	0.47	0.46	0.93
P+M (50:50)	6.92	1.52	10.98	7.12	1.66	11.55	7.15	1.80	11.96	11.50	0.31	0.52	0.84
French beans (Fb)		8.24	19.78		7.50	18.00		8.10	19.44	19.07			
Wheat (W)		2.20	5.28		3.05	7.32		3.30	7.92	6.84			
Maize (M)		2.88	7.69		3.20	8.54		3.45	9.21	8.48			
Potato (P)	24.32		24.32	20.26		20.26	22.83		22.83	22.47			
SEm±	0.81		1.22	0.56		0.85	0.61		0.99	1.00			
CD (P=0.05)	1.68		3.19	1.16		2.17	1.25		4.20	3.27			

IC, Intercrop; PEY, Potato equivalent yield; LER, Land equivalent ratio

maximum advantage from the intercropping of potato + French bean was obtained when planted in 2:2 row ratio with 100% population density of each crop.

Competitive functions

The land equivalent ratio (LER) of different years indicated the biological advantage of the intercropping systems with all the three combinations of potato and French bean (75:25, 75:50 and 50:50) in all the three years and all the three combinations of potato + wheat in 2003, only 75:25 combination in 2004 and 75:25 and 75:50 combinations in 2005 (Table 2). In potato + maize intercropping, no biological advantage of intercropping could be recorded in any of the combinations in none of the years tried. This clearly showed the trend that the most suitable intercrop among the three crops tried in this trial is French bean followed by wheat. Maize proved to be an incompetent intercrop for potato-based cropping systems under the Nilgiri conditions. However, intercropping of potato with maize increased the net benefit by 12 to 15 % in Kangma region with an LER ranging between 1.11 and 1.49 when comparison with the LER of potato + faba bean intercropping (1.03 to 1.06) (Walter Roder *et al*., 1992).

In potato, very high value for RCC was recorded when it was grown with wheat in 75:25 proportions. But RCC value of wheat was very low (Table 3). The combined RCC of the intercropping system (k_{potato} x $k_{intercrop}$) was higher in potato + French bean (75:50) and also for potato + wheat (75: 25). Very low values were recorded for potato + maize intercropping.

Higher values of CR for potato were recorded in potato + wheat system. This indicated that wheat crop is more dominated by potato when compared with other crops. However, the value of CR for the best treatment in terms of yield advantage was just above one (1.04) indicating almost equal dominance of both the component crops.

Economics

Among the intercrop combinations, the net profit of the treatments with higher LER were seen in potato + French bean at 75 : 50 and 75 : 25 proportions when compared with all other combinations. However, the net benefit:cost ratio of the treatment potato + French bean intercropping at 50 : 50 proportions was the highest (1.34).

Nutrient removal and soil fertility balance

Among the sole crops, maize removed more nutrients (N-P-K) when compared with other crops i.e. wheat, French bean as well as potato. The nutrient removal in wheat is low because of lower biomass and grain yields. In maize, the higher plant biomass contributed to the higher level of nutrient removal. In intercrop combinations also, potato + maize removed more N-P-K, than potato + French bean and potato + wheat systems, although the PEY of this system was very low (Table 4).

The organic carbon and available N content of the soil improved when French bean was cultivated (as sole or intercrops). Negative balance was observed for soil avail-

Table 3. Efficiency and economic analysis of different intercrop combinations

Treatment	Mean cost of cultivation ($x10^3$ Rs/ha)	2003		2004		2005		RCC of potato (k_{potato})	RCC of intercrop ($k_{intercrop}$)	RCC (k) (k_{potato} x $k_{intercrop}$)	CR (potato)
		Net profit ($x10^3$ Rs/ha)	Net B:C ratio	Net profit ($x10^3$ Rs/ha)	Net B:C ratio	Net profit ($x10^3$Rs/ha)	Net B:C ratio				
P+Fb (75:25)	63.66	76.82	1.21	48.28	0.76	62.25	0.98	6.59	0.43	2.80	0.97
P+Fb (75:50)	66.48	85.61	1.29	55.07	0.83	66.60	1.00	3.56	1.00	3.56	1.04
P+Fb (50:50)	46.20	66.19	1.43	54.82	1.19	64.40	1.39	1.03	1.14	1.17	0.96
P+W (75:25)	84.43	36.64	0.43	16.69	0.20	28.05	0.33	11.94	0.30	3.57	1.33
P+W (75:50)	67.45	47.51	0.70	6.18	0.09	16.50	0.24	2.27	0.60	1.37	1.23
P+W (50:50)	47.17	52.36	1.11	14.42	0.31	22.50	0.48	1.23	0.77	0.95	1.27
P+M (75:25)	63.49	10.44	0.16	4.24	0.07	11.01	0.17	1.28	0.27	0.34	0.89
P+M (75:50)	66.14	9.57	0.14	6.32	0.10	2.79	0.04	0.89	0.85	0.75	0.69
P+M (50:50)	45.86	9.03	0.20	11.90	0.26	13.92	0.30	0.46	1.09	0.50	0.60
French beans (Fb)	35.23	63.65	1.81	54.77	1.55	61.97	1.76				
Wheat (W)	13.22	13.18	1.00	23.38	1.77	26.38	2.00				
Maize (M)	10.60	27.85	2.63	32.12	3.03	35.46	3.35				
Potato (P)	81.12	40.48	0.50	20.18	0.25	33.03	0.41				
SEm±		4.49		3.70		3.98					
CD (P=0.05)		6.50		5.30		6.24					

RCC, Relative Crowding Coefficient; CR, Competition ratio

Table 4. Nutrient uptake of potato based intercropping systems

Treatment	Nutrient removal (kg/ha/season)									Available nutrient status (kg/ha) of soil after three years of cropping				
	Potato			Intercrop (Fb/ wheat/maize)			Total							
	N	P	K	N	P	K	N	P	K	OC (%)	pH	N	P	K
P+Fb (75:25)	65.9	13.9	61.5	25.2	4.5	12.5	91.1	18.4	74.0	1.74	4.2	386	14	415
P+Fb (75:50)	62.4	12.8	60.2	40.6	6.5	21.3	103.0	19.3	81.5	1.74	4.2	394	13	410
P+Fb (50:50)	46.7	10.6	43.0	42.3	6.9	22.5	89.0	17.5	65.5	1.74	4.2	402	15	412
P+W (75:25)	60.8	12.6	57.3	13.8	5.2	3.2	74.6	17.8	60.5	1.72	4.2	380	15	414
P+W (75:50)	55.3	11.2	53.0	22.5	6.6	4.1	77.8	17.8	57.1	1.70	4.2	366	15	412
P+W (50:50)	41.8	8.9	41.8	26.2	7.8	4.9	68.0	16.7	46.7	1.72	4.2	370	15	410
P+M (75:25)	43.6	9.1	40.5	42.6	11.3	51.1	86.2	20.4	91.6	1.70	4.2	356	12	408
P+M (75:50)	38.2	8.2	35.3	68.3	13.4	60.8	106.5	21.6	96.1	1.68	4.2	345	11	402
P+M (50:50)	33.7	7.5	31.0	72.2	15.9	71.2	105.9	23.4	102.2	1.71	4.2	342	11	400
French beans (Fb)							80.4	13.2	41.8	1.80	4.2	410	15	410
Wheat (W)							60.2	10.3	8.6	1.71	4.2	372	15	406
Maize (M)							97.3	23.6	100.6	1.65	4.2	327	10	396
Potato (P)	85.2	18.2	80.6				85.2	18.2	80.6	1.72	4.2	380	15	409
SEm±	2.1	0.5	2.0	4.5	1.0	4.5	6.7	1.5	3.8					
CD (P = 0.05)	4.4	0.9	4.2	9.4	2.0	9.2	13.8	3.1	7.8					
Initial level										1.72	4.0	378	15.6	412

able P and K content in almost all the treatments. Nutrient balance showed negative values mainly for potassium that too when maize is grown either alone or as an intercrop in potato.

Hence, potato and French bean intercropping in 75:50 population proportions is the most suitable and sustainable system for the Nilgiris region of Tamil Nadu.

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