

Productivity, economics, energetics and soil properties of vegetables-based relay intercropping systems

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ABSTRACT

A field experiment was conducted during 2002-03 and 2003-04 at Almora to find out the most productive and remunerative relay intercropping of tomato (*Lycopersicon esculentum* Mill. nom. cons.) or french bean (*Phaseolus vulgaris* L.) in maize (*Zea mays* L.), garden pea (*Pisum sativum* L. var. *arvense* Poir.) in tomato or french bean, and french bean in garden pea. Results showed that relay intercropping of maize (green cobs) + tomato + garden pea + french bean, and maize (green cobs) + french bean + garden pea + french bean proved significantly superior in terms of maize grain-equivalent yield (71.3 and 51.5 t/ha), and net returns (Rs 2,39,558 and Rs 1,52,624/ha) than maize (green cobs) – garden pea (18.8 t/ha and Rs 48,020/ha) and french bean – garden pea (30.7 t/ha, and Rs 94,021/ha) sequential cropping. Also, maize (green cobs) + tomato + garden pea + french bean recorded significantly highest production efficiency (195.4 kg/day/ha) and economic efficiency (Rs 656/ha/day), system energy output (10,83,760 MJ/ha), system net energy return (10,40,856 MJ/ha) and system energy-use efficiency (2,852 MJ/ha/day). The lowest maize grain equivalent yield (18.8 t/ha), net returns (Rs 48,020/ha), production efficiency (51.5 kg/day/ha) and economic efficiency (Rs 132/ha/day) were recorded under maize (green cobs) - garden pea sequential cropping. Physico-chemical properties of the soil improved significantly due to relay intercropping systems over maize (green cobs) – garden pea sequence. Relay intercropping of maize (green cobs) + tomato + garden pea + french bean proved the best in terms of total production and monetary returns.

Key words: Cultivated land-utilization index, Land-use efficiency, NW Himalayas, Production efficiency, Relay intercropping, Vegetables

North-western Himalayan region has only 10% of the cultivated land under irrigation, but has niche advantage of growing off-season vegetables in comparison to north Indian plains. Maize is cultivated during rainy (*khari*) season, covers a substantial area under rainfed as well as irrigated conditions, mainly for use of its cobs as a cash crop. In winter, wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is commonly grown after maize (*Zea mays*) under rainfed situation but under irrigated conditions, the cultivation of off-season vegetables like tomato (*Lycopersicon esculentum*), garden pea (*Pisum sativum*) and french bean (*Phaseolus vulgaris*) are common. Taking the vegetables like tomato and french bean during rainy season is risky because of higher incidence of diseases and insects-pests. Therefore shifting of transplanting or sowing date of tomato and french bean towards winter or post-rainy season may give good harvest. However, keeping the land fallow during rainy season for post-rainy season tomato and french bean may be a net loss of good rainy period. Therefore, taking short-duration crops like maize

(green cobs) during rainy season will be the preferred choice of the farmers. Taking off-season vegetables in standing maize would be a good option for small and marginal farmers in hilly region to further intensify the cropping system by taking two crops in a season. Similarly, for winter crops, with the advancement in sowing or transplanting through relay intercropping, one good off-season crop can be taken during spring season. In this manner, four crops can be grown in a year successfully. The advantages of relay intercropping of vegetables in maize are well proven in this region (Kesta *et al.*, 2000; Prakash *et al.*, 2004). But the vegetables-based triple relay intercropping system needs to be evaluated economically as well as agronomically. Hence the present investigation was undertaken to evaluate the productivity and profitability of vegetable-based triple relay intercropping systems.

MATERIALS AND METHODS

A field experiment was conducted during 2002-03 and 2003-04 at Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora. The area has a typical subtropical climate, with severe cold winter, and hot and dry summer

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and rainy season. Long-term average rainfall is 1,030 mm. Soil at the experimental site was sandy clay loam, with bulk density 1.35 Mg/m³, plant-available water capacity 2.55 cm/15 cm, porosity 49.1%, organic C 0.66% and available N 310 kg/ha, available P 14.2 kg/ha and available K 184 kg/ha respectively. The annual rainfall at the research station was 739 mm in 2002, 1,061 mm in 2003 and 738 mm in 2004. Nearly 70% rainfall was confined to June-September.

There were five treatments comparing three common crop rotations and two relay intercropping systems, in randomized block design with four replications. The treatments were maize (green cobs) - garden pea, tomato - garden pea and french bean - garden pea in sequential cropping; and maize (green cobs) + tomato + garden pea + french bean and maize (green cobs) + french bean + garden pea + french bean in relay intercropping. In maize (green cobs) - garden pea in sequential cropping, maize (green cobs) + tomato + garden pea + french bean and maize (green cobs) + french bean + garden pea + french bean in relay cropping the maize crop was sown on 18 June, but tomato in tomato-garden pea was transplanted, and french bean in french bean - garden pea was sown on 20 August. Tomato in maize (green cobs) + tomato + garden pea + french bean was transplanted, and french bean in maize (green cobs) + french bean + garden pea + french bean as relay intercrop was sown on 23 August in the standing maize crops. Garden pea in all the treatments was sown on 20 November. The fourth crop of french bean in relay intercropping system was sown at the end of March. Maize 'Him 129', tomato 'Manisha', garden pea 'VL Ageti Matar 7' and french bean 'Contender' were used for the experimentation. In both the years of study, similar sowing and transplanting dates were maintained with variation of 2-3 days.

In the treatment maize (green cobs) - garden pea, tomato - garden pea and french bean - garden pea, 10 t/ha farmyard manure (FYM) along with recommended dose of NPK for maize (90 kg N, 26.4 kg P and 33.2 kg K/ha), tomato (100 kg N, 22 kg P and 41.5 kg K/ha) and french bean (40 kg N, 35.2 kg P and 33.2 kg K/ha) were applied. Full amount of FYM, P and K, and half the amount of N were applied basal, whereas the remaining amount of N were applied at knee-high stage in maize, and at flowering stage in tomato and french bean. In garden pea, 20 kg N, 26.4 kg P and 33.2 kg K/ha were applied as basal. In the treatments maize (green cobs) + tomato + garden pea + french bean and maize (green cobs) + french bean + garden pea + french bean, similar dose of fertilizer was applied in maize as in maize (green cobs) - garden pea. Tomato and french bean were transplanted or sown between maize rows in the standing crop. Before planting, 10 t/ha

FYM along with 50 kg N, 22 kg P and 41.5 kg K/ha for tomato, and 20 kg N, 35.2 kg P and 33.2 kg K/ha for french bean were added between maize with *kutla* (a local intercultural tool). After harvesting maize cobs, top 50% portion of maize stalks was removed along with all leaves manually and was used in tomato plots for staking purpose, whereas in french bean plots, maize plants were uprooted. At the time of flowering 50 kg N in tomato and 20 kg N/ha in french bean were top-dressed. The third crop, garden pea, was sown between the rows of standing tomato and french bean. A fertilizer dose of 20 kg N, 26.4 kg P and 33.2 kg K/ha was applied during sowing as side placement. Similarly, french bean was sown between rows of standing garden pea along with side placement of basal fertilizers, as mentioned above. One intercultural operation was carried out at 30-35 days after sowing or transplanting of crops to remove the weeds and debris of previous crop.

Production indices like maize-equivalent yield (MEY), production efficiency (PE) and land-use efficiency (LUE) of the cropping system were worked out to evaluate the system efficiency. Sustainability yield index (Singh *et al.*, 1990), water requirement (Allen *et al.*, 1998), water-use efficiency and energy budgeting were calculated for the different systems on the basis of maize grain-equivalent yield.

In 2004, after the harvest of *rabi* (winter) crops, triplicate soil samples were collected with the help of a hammer auger from 0-15 cm depth. Samples were analysed for physical and chemical properties of the soil. For economic evaluation of the system, prevailing market price was used for different outputs and inputs. The total cost of cultivation of each crop was calculated on the basis of different operations performed and materials used for raising the crops including the cost of fertilizers and manure. The cost of labour for staking in tomato and other intercultural operations was also included. The price of produce used for calculation was: Rs 0.50/cob for maize cobs, Rs 5.0/kg for tomato, Rs 7.0/kg for french bean and garden pea, and Rs 5.0/kg for maize grains. The inputs costs used for calculation of net returns were: Rs 100/ manday, Rs 11/kg of N, Rs 23/kg of P, Rs 8/kg of K and Rs 5000/ ha for land preparation, whereas, plant-protection chemicals and seed price were based on actual market price.

RESULTS AND DISCUSSION

System productivity

There was not much variation in yields of sole crop and relay intercrop of maize, tomato, garden pea and french bean (Table 1). However, tomato yield was higher in 2002-03 than in 2003-04 as the crop was adversely affected by late blight. Garden pea and french bean yields

were lower during the first year than during the second year mainly because of disease infestation (white rot in garden pea and angular leaf spot in french bean). Higher rainfall during January to April 2002-03 and August to mid-September 2003-04 was the main reason for higher disease infestation and poor yields of the respective crops. Total system productivity in terms of maize equivalent yield MEY was affected significantly due to different sequential or relay intercropping systems. Pooled data on yield showed that maize + tomato + garden pea + french bean relay intercropping recorded the highest MEY (71.3 t/ha), which was significantly higher than of all the rest treatments (Table 1). This was mainly due to fairly good yield of tomato and its good market price. Maize – garden pea sequence recorded the lowest MEY because of the lower yield of these crops. Among the maize (green cobs) – garden pea, tomato – garden pea and french bean – garden pea sequential croppings, tomato – garden pea sequence was found significantly superior in terms of MEY. It was mainly due to higher fruit yield of tomato compared

with that of other crops, Maize + tomato + garden pea + french bean and maize + french bean + garden pea + french bean relay intercropping improved the system productivity in terms of MEY by 279.3 and 173.0%, respectively compared with the traditional maize – garden pea sequence (18.8 t/ha). Padhi (2001) and Prakash *et al.* (2004), also reported that relay intercropping of vegetables in maize is advantageous. Higher grain maize-equivalent yield under relay intercropping system than under maize – garden pea sequential cropping indicated higher biomass production resulting in more efficient utilization of land and available resources under the former system (Jha *et al.*, 2000; Prakash *et al.*, 2004).

The highest sustainability index (0.91) was observed in tomato – garden pea, followed by maize – garden pea (0.81) sequence and maize + tomato + garden pea + french bean (0.69) relay intercropping system. However, french bean – garden pea sequential cropping recorded the lowest sustainability index (0.50).

Table 1. Productivity, economics and land-use efficiency of different relay or sequence cropping systems

Treatment	2002-03 (2003-04)*				MEY (t/ha)	Cost of cultivation (x 10 ³ Rs/ha)	Net returns (x 10 ³ Rs/ha)	Economic efficiency (Rs/ha/ day)	Production efficiency (kg/day/ha)	B : C ratio	Land-use efficiency (%)
	Maize (cobs/ha)	Tomato/ french bean (t/ha)	Garden pea (t/ha)	French bean (t/ha)							
Maize - garden pea	67,666 (72,667)		7.5 (9.4)		18.8	46.0	48.02	132	51.5	2.04	64
Tomato - garden pea		44.6 (35.6)	8.1 (16.7)		53.9	73.1	196.50	538	147.7	3.69	66
French bean - garden pea			9.2 (10.7)	12.1 (15.9)	30.7	59.5	94.02	258	84.1	2.58	66
Maize + tomato + garden pea + french bean	67,333 (72,000)	41.2 (33.8)	7.6 (10.7)	6.8 (16.7)	71.3	117.0	239.56	656	195.4	3.05	96
Maize + french bean + garden pea + french bean	67,333 (72,667)	11.9 (15.6)	8.6 (10.7)	6.9 (17.4)	51.5	105.0	152.62	418	141.2	2.45	96
SEm ±					1.7		8.37	26	0.5		
CD (P=0.05)					5.2		25.80	81	1.5		

*Figures in parentheses refer to 2003-04

Table 2. Sustainability index, water requirement, water-use efficiency and energy-use efficiency of different relay or sequence cropping systems (mean of 2 years)

Treatment	Sustainability index	System water requirement (mm)	System water- use efficiency (kg/ha/mm)	System energy input (x 10 ³ MJ/ha)	System energy output (x 10 ³ MJ/ha)	System net energy return (x 10 ³ MJ/ha)	System energy-use efficiency (MJ/ha/day)
Maize - garden pea	0.81	689	20.9	24.61	285.76	261.15	715
Tomato - garden pea	0.91	732	64.7	27.79	820.04	792.25	2,171
French bean - garden pea	0.50	746	37.0	23.62	466.64	443.02	1,214
Maize + tomato + garden pea + french bean	0.69	1,149	51.4	42.90	1083.76	1040.86	2,852
Maize + french bean + garden pea + french bean	0.56	1,159	37.2	43.90	783.56	739.66	2,026

Energy budgeting

The energy budget revealed that the maximum energy input of the system was recorded under maize + french bean + garden pea + french bean followed by maize + tomato + garden pea + french bean relay intercropping system (Table 2). The lowest energy input was noted with garden pea + french bean cropping sequence. The energy input increased with the increase in inputs (seed, fertilizer, pesticide and human labours etc.) due to inclusion of more number of vegetable crops in the relay intercropping system. The maximum system energy output, system net energy return, and system energy-use efficiency were obtained with maize + tomato + garden pea + french bean relay intercropping system because of higher system productivity. The lowest values were noted with maize-garden pea sequence, mainly because of too low system productivity.

Water requirement and use efficiency

The highest water requirement of the system was noted in maize + french bean + garden pea + french bean (1,159 mm) followed by maize + tomato + garden pea + french bean (1,149 mm) relay intercropping system (Table 2). Maize - garden pea sequence recorded the lowest water requirement (689 mm). The water requirement of the system increased with the increase in number of vegetable under vegetables based relay intercropping system. Among the double cropping systems the highest water-use efficiency was noted in tomato-gardenpea sequence (64.7 kg/ha-mm), mainly due to higher yield of tomato. However, the vegetable based relay intercropping system (maize + tomato + garden pea + french bean) recorded the maximum water-use efficiency (51.4 kg/ha-mm), followed by maize + french bean + garden pea + french bean (37.2 kg/ha-mm).

Efficiency of different cropping systems

Maize (green cobs) – garden pea sequence had significantly lowest production efficiency of 47.1 - 55.9 kg/day/

ha (Table 1). Inclusion of high-yielding and high-value crops like tomato and french bean in relay intercropping system under maize-based cropping with their high market prices recorded significantly highest production efficiency in terms of MEY (182.5 - 208.1 kg/day/ha). Triple relay intercropping of maize (green cobs) + french bean + garden pea + french bean was on a par with tomato – garden pea sequence and significantly superior in terms of MEY than maize (green cobs) – garden pea and french bean – garden pea sequence in both the years.

Maize + tomato + garden pea + french bean and maize + french bean + garden pea + french bean relay intercropping systems recorded the highest land-use efficiency (96 percent), which occupied the fields for maximum number of days (350). The lowest land use efficiency (66%) was recorded under french bean – garden pea sequence, where the field remained occupied for 232 days.

Economics

The triple relay intercropping of maize + tomato + garden pea + french bean proved significantly superior based on net returns. The mean net returns were 399 and 155% more in maize + tomato + garden pea + french bean, and 218 and 62% in maize + french bean + garden pea + french bean relay intercropping systems than maize – garden pea (Rs 48,020/ha) and french bean – garden pea (Rs 94,021/ha) sequential cropping respectively. Relay cropping of different crops in short-cycle maize proved more beneficial than sole maize (Prakash *et al.*, 2004). The lowest mean net return (Rs 48,020/ha) was obtained under maize – garden pea, followed by french bean – garden pea (Rs 94,021/ha). These results corroborate the finding of Sharma *et al.* (1993) in potato + wheat relay intercropping system. Maize + french bean + garden pea + french bean relay intercropping also recorded significantly higher net return (Rs 1,52,624/ha) than maize – garden pea (Rs 48,020/ha) and french bean – garden pea sequence (Rs 94,021/ha). The lower cost of cultivation under sequential cropping in comparison with relay intercropping systems

Table 3. Effect of different cropping systems on physico-chemical properties of surface soil

Treatment	Bulk density (Mg/m ³)	Plant-available water capacity (cm/15 cm)	Mean weight diameter (mm)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic C (%)
Maize - garden pea	1.36	2.40	0.55	290.6	13.7	177.8	0.64
Tomato - garden pea	1.36	2.40	0.54	292.3	13.7	176.0	0.65
French bean - garden pea	1.34	2.70	0.58	312.8	13.4	184.8	0.68
Maize + tomato + garden pea + french bean	1.33	2.76	0.61	304.0	14.3	192.8	0.68
Maize + french bean + garden pea + french bean	1.33	2.85	0.62	314.9	14.7	196.8	0.70
SEm±	0.006	0.09	0.01	1.4	0.1	3.4	0.006
CD (P=0.05)	0.02	0.28	0.03	4.3	0.3	10.4	0.02

resulted in higher benefit : cost (B : C) ratio under tomato-garden pea sequence, followed by maize + tomato + garden pea + french bean relay intercropping system. The lowest B : C ratio under maize – garden pea sequence was mainly due to lowest gross return owing to low yield of maize. The highest economic efficiency was obtained under maize + tomato + garden pea + french bean (Rs 656/ha/day), which was significantly higher than rest of the treatments owing to higher returns from tomato (Table 1). The lowest economic efficiency was recorded under maize – garden pea sequence due to poor returns from both the crops.

Soil properties

There was significant decrease in bulk density of the soil in the plots under maize + tomato + garden pea + french bean and maize + french bean + garden pea + french bean relay intercropping. On the contrary, plant-available water capacity and mean weight diameter increased in the plots under maize - garden pea and tomato - garden pea sequences (Table 3). The improvement in these physical properties of the soil under relay intercropping systems was mainly attributed to the increase in organic C content of the soil after 2 years of cropping. There was also significant improvement in the available N, P and K under maize + tomato + garden pea + french bean and maize + french bean + garden pea + french bean relay intercropping compared with that under maize – garden pea sequence, despite higher removal of nutrients under the former systems. It shows that relay intercrop components not only utilized the growth resources more efficiently but also improved the physical and chemical properties of the soil.

Thus, it can be inferred that relay intercropping systems of maize (green cobs) + tomato + garden pea + french bean and maize (green cobs) + french bean + garden pea + french bean are more viable options to improve the system productivity and profitability per unit area and time in north-west Himalayan region.

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