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Effect of intercropping potato (*Solanum tuberosum*) and linseed (*Linum usitatissimum*) on growth and yield attributes, yield, energetics and competition function

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season (October-April) of 1993-95 at New Delhi, to assess the production potential, energetic and competition functions of potato (*Solanum tuberosum* L.) and linseed (*Linum usitatissimum* L.) planted in sole stand, additive and replacement series. Tuber yield of potato (28.6 t/ha) and seed yield of linseed (1.76 t/ha) were the highest in sole stand, while the total productivity in terms of tuber equivalent yield (31.3 t/ha), energy output (97.8 × 10^3 MJ/ha), energy return (72.7 × 10^3 MJ/ha), LER (1.44) and net returns (Rs 12,800/ha) were the highest when every fourth row of potato interspaced 60 cm was replaced with 3 rows of linseed interspaced 20 cm (180/60 cm, 3 : 3 row ratio). Net return/rupee investment was the highest in sole linseed (Rs 1.6) followed by 3 : 3 planting pattern (Re 0.70). The aggressivity values revealed dominance of linseed over potato, while the highest value of relative crowding coefficient (2.47 and 3.76 of potato and linseed respectively) and their product (9.30) in 3 : 3 planting pattern.

Key words: Potato, Linseed, Intercropping, Yield, Energetics, Competition function

Potato (*Solanum tuberosum* L.) is an important crop of north-west part of India. Tuber yield and its returns rise and fall to the extent causing concern to the farmers. While the economic returns are commanded by market forces, the unstable tuber yield arise from the sensitiveness of the crop to the various stresses like pest and diseases, prevailing weather at a point of time, etc. Late blight of potato alone reduced tuber yield by 15-75 % (Srivastava and Shekhawat, 1989), so also the frost. On the other hand, fluctuation in the market prices between Re 0.50 and 2.00/kg is also commonly observed. To bring about stability in yield and hold along the price oscillation, means have been suggested by researchers which include *inter-alia* intercropping of mustard with potato (Singh and Rathi, 1984; Ganga Saran *et al.* 1994). But mustard being a tall stature plant with indeterminate growth causes shading and pose operational problems in harvesting, thus losing merit. To alleviate the problem of instability in sole cultivation of potato and for further diversification of potato-based intercropping system, feasibility of intercropping potato and linseed (*Linum usitatissimum* L.) was assessed through various planting patterns in the present experiment.

MATERIALS AND METHODS

The field experiment was carried out during the winter seasons (October-April) of 1993-94and 1994-95 at the Division of Agronomy, Indian Agricultural Research Institute, New Delhi. The soil of the experimental site was sandy loam of alluvial origin with adequate internal drainage. It tested low in organic carbon (0.37%) and medium in available P (12.6 kg/ha) and K (190 kg/ha), with a pH of 7.8. The experiment with 2 treatments of sole crops, 2 treatments of additive series and 5 treatments of replacement series (Table 1) was made in 3 times replicated randomized block design. The sole crop of potato 'Kufri Badshah' was raised in rows interspaced 60 cm, while linseed

Table 1. Experimental details

Treatment/ planting patterns	Population density (%)		Area occupied (%)		Net plot size
	P	L	P	L	
Sole crop					
T_1 Potato, 60 cm	100		100		2.40 × 6.00 m
T_2 Linseed, 30 cm		100		100	2.40 × 6.00 m
Additive series (P + L)					
T_3 Potato, 60 cm + 1 row of linseed (1 + 1 pattern)	100	37	67	33	2.40 × 6.00 m
T_4 Potato, 80 cm + 1 row of linseed (1+1 pattern)	100	37	67	33	2.40 × 6.00 m
Replacement series (P:L)					
T_5 Potato, 50 cm + linseed, 20 cm (50/50 cm, 1:2 pattern)	100	60	50	50	2.00 × 6.00 m
T_6 Potato, 50 cm + linseed, 20 cm (100/50 cm, 2:2 pattern)	100	40	67	33	1.50 × 6.00 m
T_7 Potato, 50 cm + linseed, 20 cm (150/50 cm, 3:2 pattern)	100	30	75	25	2.00 × 6.00 m
T_8 Potato, 60 cm + linseed 20 cm (120/60 cm, 2:3 pattern)	100	50	67	33	1.80 × 6.00 m
T_9 Potato, 60 cm + linseed, 20 cm (180/60 cm, 3:3 pattern)	100	37	75	25	2.40 × 6.00 m

P = Potato, L = Linseed, cm = centimetre, m = metre

P + L, 1 row of L sandwitched between P rows; and P:L, 1 row of P after II, III or IV row of P replaced with 2 or 3 rows of L interspaced 20 cm as per treatments

'Neelam' was raised in rows interspaced 30 cm. In additive series the potato was planted with 2 inter-row spacings, 60 and 80 cm to accommodate 1 row of linseed in between the rows of potato. In replacement series, 5 planting patterns of intercropping were created by raising potato in 2 row distances at 50 and 60 cm. Three planting patterns were created in row distance of 50 cm by replacing second, third and fourth rows of potato with 2 rows of linseed interspaced at 20 cm. The other two patterns were made by replacing third and fourth rows of potato in 60 cm row distance with 3 rows of linseed interspaced 20 cm. Experimental details are given in Table 1. In potato same population was maintained in all the treatments by using 2,500 kg seed/ha and doing intra-hill seed adjustment, wherever necessary. In linseed 35 kg seed/ha was used on area basis occupied in imposed treatments. Sowing of the seed was done on 9th November and 28th October and harvesting was done on 16th March (potato) and 8th April (linseed) and 8th March (potato) and 31 st March (linseed) in respective seasons. The fertilizer and water were as recommended for potato. The experiment was raised free of weeds and insect pests. Gross plot size was 4.8 × 7.0 m while the net plot size varied, detailed in Table 1. There was 47.0 mm and 36.2 mm rainfall during crop seasons in 1993-94 and 1994-95 respectively. The mean weekly maximum temperature of the crop season ranged from 19.3 to 32.9°C and the minimum from 5.3 to 16.4°C, the lowest being in the month of January. Biometric observations were recorded on 5 randomly tagged plants. Tuber yield equivalent was computed at market price (Re 1 for potato and Rs 6 for linseed). The total energy consumed in various operations and inputs for crop raising and energy gained from products was computed by using energy equivalent coefficients as suggested by Mittal and Dhawan (1988). Land equivalent ratio (LER) was worked out as suggested by Willey (1979). Relative crowding coefficient (RCC) and aggressivity (A) were worked out as proposed by Hall (1974) and Mc Gilchrist (1965) respectively. Data were pooled over 2 years and analysed according to standard analysis of variance techniques.

RESULTS AND DISCUSSION

Growth and yield attributes

Growth and yield attributes like number of branches, number of capsules, seed yield of linseed and tuber and shoot dry weight of potato/plant were recorded (Table 2). The data (pooled analysis) showed that linseed recorded higher number of primary and secondary branches in intercropping excepting treatment number 3 compared with its sole stand. However, differences were perceptible only on secondary branches in 1:2, 2:3 and 3:3 patterns (treatments number 5, 8 and 9 respectively). Capsules/plant were significant with treatment number 5, followed by treatment number 9, which was also statistically comparable with the sole crop as well as intercropping treatment number 3, 4, 6 and 7. Significant improvement in seed yield of linseed/plant over sole stand was recorded in all intercropping system excepting treatment 6 and 9, i.e. 2:2 and 3:3 pattern. The highest seed yield/plant was recorded in linseed sandwiched between 2 rows of potato interspaced at 80 cm (treatment number 4), which was comparable with treatment

Table 2. Effect of intercropping (potato + linseed) on growth and yield attributes (Pooled over two years)

Treatment	Number/plant of linseed			Yield/plant (g)		
	Branches		Capsules	Linseed Seed	Potato	
	Primary	Secondary			Tuber	Shoot dry weight
T_1					381	3.64
T_2	2.7	11.1	37.1	2.03		
T_3	2.7	10.6	36.3	2.44	291	2.48
T_4	2.7	11.8	38.1	2.70	288	1.98
T_5	2.8	13.1	43.0	2.63	289	2.22
T_6	2.7	12.3	36.5	1.96	326	2.96
T_7	2.8	11.7	38.1	2.09	336	3.44
T_8	3.0	13.4	39.0	2.55	335	3.04
T_9	3.1	13.4	40.8	2.52	368	3.84
CD (P = 0.05)	NS	1.5	2.3	0.20	54	0.46

Details of treatments are given in Table 1

number 5 (1:2) only. The variation in growth and yield attributes could be ascribed to the change in the magnitude of competition with the change in planting patterns and border effects.

Sole crop of linseed produced the greatest biological yield. Amongst mixed stands, treatment number 5 (1:2) produced the greatest biological yield followed by treatments 8 and 4. The harvest index of linseed was the lowest in sole crop and the highest in 3:3 pattern, followed by 1:2 pattern.

Contrarily, the intercropping adversely affected dry weight of shoot and yield of tuber/plant. But dry weight of shoot/plant of planting pattern 3:2 and 3:3 were statistically comparable with sole crop. Similarly, tuber yield/plant of treatment number 7,8 and 9 were also on a par with sole crop.

Yield

The seed yield of linseed/ha was the greatest in sole crop. Amongst intercropping treatments, statistically higher seed yield was noted in treatment 5 (Table 3). The tuber yield like seed yield of linseed was also the greatest in sole stand than intercrop. Within intercropping treatments, tuber yield was the greatest in 3:3 planting pattern. The variation in tuber and seed yield under different planting patterns was observed to be closely related to yield attributes.

Yield recovery

Compared with sole crop, per cent tuber yield recovery was low in all intercropping systems (Table 3). However, in replacement series, the recovery in proportion to area occupied was perceivable. It was 88 % from 75 % area occupied by potato in 3:3 pattern. The advantage seems to have come from the higher plant population per unit area owing to uniform seed rate maintained and border effects. The recovery of seed yield of linseed

Table 3. Effect of intercropping (potato + linseed) on yield and net return (pooled over 2 years)

Treatment	Yield (t/ha)			HI (%) (linseed)	Tuber equivalent yield (t/ha)	Net return/Re investment	Net return/ ha (Rs)
	Linseed		Potato (tuber)				
	Biol.	Seed					
T_1			28.6 (100)		28.6	0.56	10,600
T_2	8.0	1.76 (100)		22	10.5	1.60	6,600
T_3	3.4	0.90 (51.1)	20.9 (73.1)	26	26.3	0.42	7,800
T_4	4.0	1.03 (58.5)	16.8 (58.7)	26	23.0	0.26	4,500
T_5	4.4	1.25 (71.0)	15.6 (54.5)	28	23.0	0.26	4,500
T_6	3.5	0.86 (48.8)	21.3 (74.5)	25	25.7	0.40	7,200
T_7	3.3	0.77 (43.7)	22.5 (78.7)	24	27.1	0.47	8,600
T_8	4.1	1.07 (60.8)	22.2 (77.6)	26	28.6	0.55	10,100
T_9	3.4	0.98 (55.7)	25.2 (88.1)	29	31.3	0.70	12,800
CD (P = 0.05)	0.5	0.10	1.4		1.8		679

Figures in parentheses refer to % yield recovery in intercropping systems with reference to sole stand

in proportion to area occupied was also much higher in this treatment, i.e. 58 % from 25 % area occupied. In contrast to this, while working on intercropping of potato and mustard, Ganga Saran *et al.* (1994) reported yield advantage only to mustard.

Tuber equivalent

The maximum total productivity in terms of tuber equivalent was recorded in treatment number 9 (3:3 pattern) which was significantly superior to all other treatments (Table 3). This could be reckoned with higher recovery of the component crops in this treatment. The tuber equivalent yield was the lowest in sole stand of linseed.

Energy budget

Planting patterns induced significant variation in all the energy parameters (Table 4). Energy requirement (24.1×10^3 MJ) of sole cultivation of potato was 2.5 times that of linseed (10.5×10^3 MJ). Intercropping system consumed slightly more energy than sole potato due to input variations mainly in the form of operational cost. Energy output of the sole crop of potato and linseed was higher than their energy output in intercropping. Amongst intercropping systems, energy output of potato was the highest in 3:3 planting pattern closely followed by 2:3 and 3:2 planting patterns. Energy output of linseed was the highest in 1:2 planting pattern, however, it was on a par with 1+1 (treatment 4), 2:3 and 3:3 planting patterns, the lowest was in 3:2 pattern. This variation in energy output can be derived from the variation in yield in different systems. The total energy output 97.8×10^3 MJ and return 72.7×10^3 MJ was maximum in 3:3 planting pattern. These values were significantly different from the values of other systems excepting 2:3 planting pattern. Better performance of 3:3 pattern over sole potato could be attributed to the yield advantages accrued to linseed in the intercropping system over sole crop by way of reduced competition. The higher tuber yield in proportion to area occupied in this planting pattern also contributed to it. Mallik *et al.* (1993) and Rana and Ganga Saran (1995) also found intercropping better than sole stand in terms of energy output and return. Contrary to energy output and return, the energy use efficiency was the highest in sole linseed followed by 3 : 3 planting pattern. The sole linseed could have this advantage due to its high energy equivalent per unit weight (25 MJ/kg seed).

Table 4. Energetics (per ha) of potato and linseed in various planting patterns (pooled over 2 years)

Treatment	Energy output ($MJ \times 10^3$)			Energy return ($MJ \times 10^3$)	Energy use efficiency
	P	L	Total		
T_1	83.2		83.2	59.1	3.45
T_2		44.0	44.0	33.5	4.19
T_3	60.8	22.5	83.3	58.2	3.31
T_4	48.8	25.7	74.6	49.5	2.97
T_5	45.3	31.2	76.6	51.5	3.05
T_6	61.9	21.5	83.4	58.4	3.52
T_7	65.4	19.2	84.7	59.6	3.37
T_8	64.6	26.7	91.3	66.2	3.63
T_9	73.3	24.5	97.8	72.7	3.89
CD ($P = 0.05$)	10.3	6.9	8.8		

MJ = Mega Joule

Table 5. LER and competition function of potato and linseed in various planting patterns (pooled over 2 years)

Tremt-ment	LER			Aggressivity		RCC		Product of RCCs
	P	L	Total	P	L	P	L	
T_1	1.00		1.00					
T_2		1.00	1.00					
T_3	0.73	0.51	1.24	-0.15	0.15	1.35	2.09	2.82
T_4	0.59	0.58	1.17	-0.28	0.28	0.71	2.80	1.98
T_5	0.54	0.71	1.25	-0.17	0.17	1.20	2.45	2.94
T_6	0.74	0.49	1.23	-0.11	0.11	1.45	1.90	2.75
T_7	0.79	0.44	1.23	-0.15	0.15	1.22	2.33	2.84
T_8	0.78	0.61	1.39	-0.22	0.22	1.73	3.10	5.36
T_9	0.88	0.56	1.44	-0.24	0.24	2.47	3.76	9.30

P = Potato, L = Linseed, RCC = Rrelative crowding coefficient

Competition function

The partial land equivalent ratio of potato was the highest (0.88) with linseed in 3:3 pattern (Table 5) and of linseed (0.71) in 1:2 pattern. Based on total land equivalent ratio, (75 % potato + 25% linseed) 3:3 pattern in replacement series was found 44 % more productive than sole cropping. The aggressivity values of the potato and linseed under various planting patterns clearly indicated that linseed with positive values and potato with negative values was a dominated component in the system. Linseed maintained RCC (relative crowding coefficient) values more than 1 in all the intercropping systems which indicated that it produced more yield than expected. Similarly, potato gave RCC values greater than 1 except 1+1 (treatment 4) row ratio, however, the RCC values of potato were comparatively smaller than the corresponding values of linseed. The maximum values of the RCCs were recorded in 3:3 planting pattern for both the crops which indicated comparative advantage of this system over other planting patterns which was further established from the highest value of the product of the RCCs in the same system.

Monetary returns

The economic feasibility of the systems was tested as net returns obtained. The net return/ha was the highest with 3:3 pattern followed by sole potato. This could be attributed to the yield recovery, LER, and RCC achieved with the treatment. In contrast to net returns/ha, returns/rupee investment was the greatest in sole crop of linseed followed by 3:3 pattern. The net returns were the lowest with treatments 4 and 5.

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