Himachal Journal of Agricultural Research 37 (2): 138-148, 2011

Promising cropping systems for mid hill agro-climatic conditions of Himachal Pradesh

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Manuscript Received: 18.05.2011; Accepted: 11.01.2012

Abstract

Nine cropping sequences, *viz.* 'maize – wheat', 'maize (baby corn) + French bean (pole type) - pea - summer squash' , 'maize (baby corn) + asparagus beans - pea - summer squash', 'brinjal – wheat' , 'brinjal – garlic', 'brinjal - brocolli – potato', 'okra – wheat', 'okra - cauliflower - French bean (bush type)' and 'okra - radish – onion' were evaluated for their production potential and economic feasibility under mid hill conditions of Himachal Pradesh. Four years' (2006-07 to 2009-10) results revealed that 'baby corn + asparagus bean - pea - summer squash' and 'baby corn + French bean - pea - summer squash' sequences resulted in higher maize grain equivalent yield (54.379 and 51.256 t/ha/annum), net returns (Rs 2,75,919 and Rs 2,57,574/ha/annum), B: C ratio (1.92 and 1.77), land utilization efficiency, productivity (162.7 and 154.0 kg/ha/day) and profitability (Rs 826.1 and 774.6/ha/day), employment (754 and 747 man days/ha/annum), water productivity (80.6 and 75.9 kg maize grain equivalent yield, MGEY/ha-mm) and sustainable yield and value index than other cropping sequences. 'Okra - radish - onion', 'okra - cauliflower - French bean' and 'brinjal - broccoli - potato' were also superior to traditional 'maize - wheat' sequence in terms of MGEY, net return, productivity, profitability, labour employed and sustainability. Economic analysis further indicated that 'baby corn + French bean - pea - summer squash' and 'baby corn + Asparagus beans - pea - summer squash' were more economically viable than the conventional 'maize - wheat' sequence. These had area equivalent ratio (AER) more that 0.50 indicating that these allow marginal farmers to put half of their land resources to some other use. Maize - wheat cropping system resulted in highest total energy out of total edible product (29.8 mega K cal/ha/annum), energy use efficiency and N, P and K uptake. Water use per kg of MGEY ranged from 12.4 under 'baby corn + asparagus bean - pea - summer squash' to 32.4 under 'brinjal - wheat'.

Key words: Economic viability, maize –wheat, maize grain equivalent, nutrient uptake, productivity, sustainability.

Introduction

Maize-wheat is the most important cropping system in mid hills of Himachal Pradesh. In spite of the significant research achievements, the productivity of this system is far below the potential yield of the crops. Although recommendations on improved crop production technologies have been made (HPKV, 2007a & b), the farmers have not succeeded in taking full advantage of these technologies (Singh *et al.*, 1998). Only 10% of the land area in the state is under cultivation, and majority of the landholdings are small and marginal. Cultivation of cereal crops on marginal land holdings is usually not profitable. Therefore, most farmers are shifting to vegetables owing to unique agro-climatic conditions and fetching reasonably good price and income. Earlier studies have also indicated superiority of alternative vegetable based cropping systems over the traditional rice-wheat

cropping system (Rana *et al.*,2010, Sharma *et al.*, 2007 & 2009). It is, therefore, imperative to evaluate sustainable and need-based cropping systems for small and marginal farmers under mid-hill conditions of Himachal Pradesh.

Materials and Methods

A field experiment was conducted for four consecutive years (2006-07 and 2009-10) in a permanent layout at Farming System Research Centre's Badhiarkhar Farm of CSK HP Krishi Vishvavidyalaya, Palampur (32.6° N latitude, 76.3° E longitude and 1250 m altitude). Nine cropping sequences (Table 1) were evaluated in a randomized block design with four replications. The soil of the experimental site was silty-clay loam with pH 5.6, organic C 0.60%, available N 514.9 kg/ha, available P 47.6 kg/ha and available K 212.0 kg/ha. The average annual precipitation of the test site was 2500 mm with mean maximum and minimum temperature ranging from 19.3 to 38.2 and 3.0 to 23.1°C, respectively. The crops in each cropping sequence were raised in accordance with the recommended package of practices (HPKV, 2007a, b & c).

Yields were harvested from net plot. For comparison between crop sequences, the yields of crops were converted into maize-grain equivalent on price basis (Verma and Modgal, 1983; Tomer and Tiwari, 1990). Productivity (kg/ha/day) was obtained by dividing total production in terms of maize equivalent in a sequence by the total duration of crop, while profitability (Rs/ha/day) was obtained by dividing net monetary return by total duration of crops in a particular sequence. Economics of the crop sequences was computed based upon the prevalent market prices. Area equivalent ratio (AER), relative profit, additional profit and profit equivalent ratio (PER) were determined following the methods employed by Mohammed (2002) as follows:

AER = Cost of cultivation of conventional cropping sequence/cost of cultivation of alternative cropping sequence

Relative profit (Rs/ha) = AER x net returns (Rs/ha)

Additional profit (Rs/ha) = Relative profit of alternative cropping sequence – net returns of conventional cropping sequence

PER = Relative profit (Rs/ha)/ net returns of conventional cropping sequence

Sustainable yield index (SYI) and sustainable value index (SVI) were determined using standard procedures as below:

$$SYI = \frac{\bar{Y} - SD}{Y_{max}}$$

Where, $\bar{Y}$ is the average yield of a cropping sequence over years, SD its standard deviation and Y_{max} is the observed maximum yield in the experiment. SVI was computed in the same way as SYI by taking net returns into consideration in place of yield.

Results and Discussion

Maize grain equivalent yield

The results revealed that there is sufficient scope to replace maize-wheat cropping system with other cropping systems without any decline in economic yield. Baby corn + Asparagus bean - pea - summer squash (54.379 t/ha) and baby corn + French bean -

pea - summer squash (51.256 t/ha) cropping sequences were found superior in terms of maize grain equivalent yield throughout (Table 1). This was mainly ascribed to higher yield of pea and summer squash grown in these sequences. These cropping sequences were followed by okra - radish - onion (45.087 t/ha), brinjal - broccoli - potato (33.808 t/ha),

Table 1. Yield (t/ha) and energy output (10^6 K cal/ha/annum) of economic product under different cropping sequences (Mean of four years)

Crop sequence		Yield main product				MGEY*	Energy output
		Kharif	Intercrop	Rabi (I)	Rabi (II)		
			2006-07				
C_1	Maize-wheat	1.944	-	4.054	-	7.012	20.93
C_2	Baby corn + French bean - pea-Summer squash	5.003	0.363	15.306	18.205	64.793	20.19
C_3	Baby corn + Asparagus beans- pea-Summer squash	6.134	0.772	15.537	23.728	76.952	22.21
C_4	Brinjal – Wheat	0.130	-	4.750	-	6.110	16.47
C_5	Brinjal – Garlic	0.139	-	3.333	-	14.074	1.03
C_6	Brinjal – Brocolli – potato	0.120	-	8.796	3.861	18.039	5.97
C_7	Okra – wheat	5.480	-	4.248	-	12.617	16.62
C_8	Okra – Cauliflower – French bean	5.396	-	9.301	7.279	34.827	6.86
C_9	Okra – Radish – Onion	6.035	-	29.365	9.877	42.395	12.04
	LSD (P=0.05)					11.325	3.22
			2007-08				
C_1	Maize-wheat	7.139	-	4.020	-	12.019	39.25
C_2	Baby corn + French bean - pea-Summer squash	4.909	0.069	13.935	7.146	35.187	16.04
C_3	Baby corn + Asparagus beans- pea-Summer squash	5.870	2.045	14.676	3.852	36.675	16.75
C_4	Brinjal – Wheat	2.583	-	5.310	-	9.032	18.99
C_5	Brinjal – Garlic	2.639	-	7.435	-	23.881	2.86
C_6	Brinjal – Brocolli – potato	2.704	-	4.704	23.704	27.698	24.82
C_7	Okra – wheat	7.963	-	4.771	-	14.894	19.30
C_8	Okra – Cauliflower – French bean	4.928	-	9.434	12.492	36.953	8.30
C_9	Okra – Radish – Onion	3.779	-	29.563	12.731	36.349	12.71
	LSD (P=0.05)					11.670	5.41
			2008-09				
C_1	Maize-wheat	1.296	-	5.515	-	9.174	23.68
C_2	Baby corn + French bean - pea-Summer squash	1.574	0.000	18.954	15.031	60.043	21.79
C_3	Baby corn + Asparagus beans- pea-Summer squash	1.593	0.000	17.528	17.466	59.796	21.08
C_4	Brinjal – Wheat	0.000	-	5.784	-	8.263	20.01
C_5	Brinjal – Garlic	0.000	-	7.843	-	22.409	2.35
C_6	Brinjal – Brocolli – potato	0.000	-	4.899	37.407	49.750	37.51
C_7	Okra – wheat	0.219	-	5.711	-	8.377	19.84
C_8	Okra – Cauliflower – French bean	0.101	-	12.601	7.071	26.623	5.94
C_9	Okra – Radish – Onion	0.572	-	15.675	22.068	39.228	13.90
	LSD (P=0.05)					6.592	3.74
			2009-10				
C_1	Maize-wheat	4.074	-	6.070	-	12.746	35.47
C_2	Baby corn + French bean - pea-Summer squash	3.537	0.540	8.333	18.653	44.999	13.49
C_3	Baby corn + Asparagus beans- pea-Summer squash	2.778	0.000	8.519	19.138	44.094	13.43
C_4	Brinjal – Wheat	8.083	-	6.495	-	18.517	24.41
C_5	Brinjal – Garlic	8.148	-	9.804	-	51.329	4.90
C_6	Brinjal – Brocolli – potato	8.907	-	4.377	20.185	39.745	22.81
C_7	Okra – wheat	1.717	-	6.471	-	11.206	22.99
C_8	Okra – Cauliflower – French bean	1.818	-	14.983	6.902	29.062	7.20
C_9	Okra – Radish – Onion	1.726	-	35.185	30.864	62.378	22.02
	LSD (P=0.05)					1.144	2.01
			Mean				
C_1	Maize-wheat	3.613	-	4.915	-	10.238	29.83
C_2	Baby corn + French bean - pea-Summer squash	3.756	0.243	14.132	14.759	51.256	17.88
C_3	Baby corn + Asparagus beans- pea-Summer squash	4.094	0.704	14.065	16.046	54.379	18.37
C_4	Brinjal – Wheat	2.699	-	5.585	-	10.480	19.97
C_5	Brinjal – Garlic	2.732	-	7.104	-	27.923	2.79
C_6	Brinjal – Brocolli – potato	2.933	-	5.694	21.289	33.808	22.78
C_7	Okra – wheat	3.845	-	5.300	-	11.774	19.68
C_8	Okra – Cauliflower – French bean	3.061	-	11.580	8.436	31.866	7.08
C_9	Okra – Radish – Onion	3.028	-	27.447	18.885	45.087	15.17
	LSD (P=0.05)					4.300	2.46

*MGEY: maize grain equivalent yield

okra - cauliflower - French bean (bush type) (31.866 t/ha) and brinjal - garlic (27.923 t/ha). The remaining cropping sequences, *viz*. brinjal - wheat and okra - wheat did not significantly increase maize grain equivalent yield over the prevalent maize - wheat cropping sequence. The low maize grain equivalent was mainly owing to poor performance of brinjal and okra in 2 and 1 year, respectively out of the total 4 years.

Thus to diversify maize-wheat system, several options are available which give more productivity and ensure rational use of resources. However, Palampur is a high rainfall area, and intense and frequent rains especially during *kharif* create hindrance in carrying out field operations timely. Many a time crops are more prone to weeds, insect-pests and diseases leading to wide fluctuations in economic yield. In *kharif*, brinjal was highly unstable (-0.423 to -0.395) in all cropping systems (C_4, C_5 and C_6). Similarly, French bean (-0.041) and asparagus bean (-0.370) as intercrop with baby corn in C_2 and C_3, respectively were not stable in yield and performance due to high moisture and severe attack of blister beetle at flowering stage. Okra was also not stable in all crop sequences (0.083, 0.173 and 0.206, respectively in C_7, C_8 and C_9) due to damping off at the seedling stage in the third and fourth year. There is also an indication that vegetable crops like okra and many others must be rotated after every third year. Babycorn in C_2 (0.57) and C_3 (0.45) was more stable than maize in C_1 (0.27). Amongst rabi crops, the wheat was more stable with the highest stability index of 0.87, 0.81 and 0.79 when grown after brinjal (C_4), okra (C_7) and maize (C_1), respectively. There was a marked effect on the proceeding crops on the performance of wheat. The wheat after brinjal showed improvement in grain yield by over 0.6 t/ha as compared to that after maize. This was probably owing to lesser uptake of nutrients (Table 4) and more residual fertility (Table 5). Wheat after okra had grain yield 0.4 t/ha more than that after maize. Cauliflower after okra in C_8 had stability index of 0.76. This was followed by pea after babycorn + asparagus bean in C_3 (0.72), radish in C_9 (0.70), peas in C_2 (0.69), broccoli in C_6 (0.635) and garlic in C_5 (0.617). In summer, French in C_8 was more stable (0.68) followed by summer squash in C_2 (0.64), onion in C_9 (0.50), summer squash in C_3 (0.47) and potato (0.35). The low stability in yield with regard to summer squash and potato was mainly owed to fruit fly/pumpkin beetle and wild boars attack, respectively. However, the alternative cropping sequences evaluated might be more effective than the prevalent maize – wheat system in other parts of the state especially low and mid hills where rainfall is comparatively low.

Energetics

Total energy output of the main product was highest under maize-wheat cropping system (29.83 mega kcal/ha/annum) (Table 1). Total energy output due to the new cropping systems was significantly lower than maize – wheat. Baby corn + asparagus beans - pea - summer squash and Baby corn + French bean - pea - summer squash, the better cropping sequences in terms of maize grain

equivalent and net return had only 61.6 and 59.9% of the total energy output under the conventional maize-wheat cropping system. However, these cropping systems as well as brinjal - wheat, brinjal - broccoli - potato, okra - wheat and okra - radish - onion were superior to brinjal-garlic and okra - cauliflower - French bean cropping systems. Brinjal - garlic and okra - cauliflower - French bean produced only 9.4 and 23.7% of the total energy output of the maize - wheat cropping system. This indicated that complete diversification of maize – wheat cropping system is neither possible nor advisable. Only 15-20% of the net sown irrigated area may be diversified by small and marginal farmers taking into account the comparative advantage to meet out their cash requirement.

The comparison of energy use pattern (Table 2) in cropping patterns revealed that the highest input energy were consumed in brinjal – broccoli – potato (64,147 MJ/ha) followed by baby corn + asparagus/French bean – pea – summer squash, okra – cauliflower – French bean and okra – radish – onion. The remaining cropping sequences consumed lower energy than maize – wheat cropping system. The output energy (4,40,063 MJ/ha) and energy use efficiency (12.16) was highest under maize – wheat which further indicated that this cropping system cannot be replaced completely.

Productivity, profitability and sustainability

Owing to better utilization of resources and higher yield and price of produce, baby corn + asparagus bean - pea - summer squash followed by baby corn + French bean - pea - summer squash recorded greater productivity (162.7 and 154.0 kg/ha/day, respectively) and profitability (Rs 826.1 and Rs 774.6/ha/day) (Table 2). Thus, there was sufficient per day availability of food and cash for the better livelihood of the marginal and small farmers who would follow these cropping sequences.

Table 2. Energetics, duration, LUE, productivity, profitability, sustainable yield and value index and labour employed under different crop sequences (Mean of four years)

Cropping sequence	Energy input (MJ/ha)	Energy output (MJ/ha)	Energy use efficiency	Duration (days)	LUE (%)	Productivity (kg/ha/day)*	Profitability (Rs/ha/day)$	SYI#	SVI@	Labour employed (mandays/ha/ annum)
C_1	36276	440063	12.16	272	74.6	37.5	136.0	0.099	0.007	396
C_2	57433	288864	5.03	332	90.9	154.0	774.6	0.481	0.427	747
C_3	57535	305723	5.31	332	90.9	162.7	826.1	0.474	0.443	754
C_4	34382	191141	5.55	265	72.6	40.0	49.7	0.065	- 0.076	386
C_5	33812	73036	2.15	329	90.0	85.1	277.2	0.152	- 0.043	381
C_6	64147	182803	2.85	317	86.8	107.5	184.7	0.259	- 0.076	708
C_7	32456	194324	5.99	263	71.9	44.7	69.4	0.118	- 0.010	346
C_8	44433	110406	2.49	280	76.6	113.8	321.8	0.351	0.120	521
C_9	48250	105990	2.20	316	86.5	143.9	544.1	0.433	0.219	591
LSD (P=0.05)		16986	0.40	-	-	-	-	-	-	-

* Based on maize grain equivalent yield; $ Based on net return, # SYI, sustainable yield index; @ sustainable value index.

These sequences were followed by okra - radish - onion, okra – cauliflower - French bean, brinjal – garlic and brinjal - broccoli - potato. The brinjal - wheat and okra - wheat resulted in a bit higher productivity but were poor as far as profitability is concerned which was 0.37 and 0.51 times that under the maize - wheat cropping system. Baby corn + asparagus bean - pea - summer squash and baby corn + French bean - pea - summer squash were superior to other crop sequences both in terms of sustainable yield index (0.489 and 0.474, respectively) and sustainable value index (0.427 and 0.443, respectively). Okra - radish - onion and okra - cauliflower - French bean were next superior treatments with regard to SYI and SVI. The remaining sequences were very poor in terms of SVI.

Employment generation

Baby corn + asparagus bean - pea - summer squash and baby corn + French bean – pea - summer squash cropping sequences generated 358 and 351 additional man days/ha/annum, respectively over the maize - wheat copping sequence. Fertilizer consumption worth Rs 12293/ha/annum was highest (809 kg/ha/annum) under these cropping sequences (Table 3). For employment generation and nutrient consumption these cropping systems were followed by brinjal - broccoli - potato (708 man days/ha/annum and 676 kg N+P+K/ha/annum), okra - radish - onion (591 man days/ha/annum and 604 kg N+P+K/ha) and okra - cauliflower - French bean (521 man days/ha/annum and 566 kg N+P+K/ha). The rest of the cropping sequences, *viz.* brinjal - wheat, brinjal - garlic and okra - wheat neither generated additional employment nor consumed more nutrients over the traditional maize - wheat cropping sequence owing to fewer crops in the sequences and lower yields of brinjal and okra.

Table 3. Value of fertilizers and nutrient use productivity under different crop sequences (Pooled data from 2006-07 to 2009-10)

Crop sequence		Nutrients used in sequence (kg/ha/annum)					Value of fertilizers (Rs/ha/ annum)	Fertilizer nutrient use productivity (kg MGEY/kg nutrient applied)
		N	P	K	NPK	FYM (t/ha)		
C_1	Maize-wheat	240	120	70	430	20	6263	23.8
C_2	Baby corn + French bean – pea - Summer squash	334	270	205	809	30	12293	63.4
C_3	Baby corn + Asparagus beans – pea - Summer squash	334	270	205	809	30	12293	67.2
C_4	Brinjal – Wheat	213	106	75	394	20	5641	26.6
C_5	Brinjal – Garlic	208	122	105	435	20	6241	64.2
C_6	Brinjal – Brocolli – potato	308	222	146	676	40	10282	50.0
C_7	Okra – wheat	189	110	84	383	20	5574	30.7
C_8	Okra – Cauliflower – French bean	224	186	156	566	30	8517	56.3
C_9	Okra – Radish – Onion	276	178	150	604	30	8804	74.6
	LSD (P=0.05)							

Nutrient use productivity, nutrient uptake and residual soil fertility

The okra – radish - onion cropping system showed highest nutrient use productivity of 74.6 kg MGEY/kg nutrient applied followed by baby corn + asparagus bean - pea – summer squash (67.2 kg MGEY/kg nutrient applied), brinjal – garlic (64.2), baby corn + French bean – pea – summer squash (63.4), okra - cauliflower – French bean (56.3) and brinjal – broccoli – potato which may be due to higher yield potential and price especially of *rabi* and summer crops. The nutrient use productivity of okra - wheat, brinjal – wheat and maize – wheat cropping systems was 30.7, 26.6 and 23.6 kg MGEY/kg nutrient applied, respectively.

The higher recommended application of nutrients was not reflected to accumulate more nutrients in the crop plants as evidenced from Table 4. In spite of low economic yield maize - wheat cropping system resulted in highest uptake of N, P and K. This was followed by baby corn + asparagus bean - pea - summer squash and baby corn + French bean - pea - summer squash for the mean uptake of all the three nutrients. However, brinjal - broccoli - potato was also at par with both of these cropping sequences for mean N uptake.

Table 4. Nutrient uptake by different crop sequences

	Crop sequence	2006-07	2007-08	2008-09	2009-10	Mean
				N		
C_1	Maize-wheat	276.9	474.6	263.7	370.3	346.4
C_2	Baby corn + French bean - pea - Summer squash	282.1	302.1	234.9	205.1	256.1
C_3	Baby corn + Asparagus beans - pea-Summer squash	287.3	347.9	248.6	208.3	273.0
C_4	Brinjal – Wheat	131.3	187.6	192.4	213.3	181.2
C_5	Brinjal – Garlic	35.3	124.1	139.0	246.4	136.2
C_6	Brinjal - Brocolli – potato	204.9	292.9	287.8	235.7	255.3
C_7	Okra – wheat	226.6	266.6	204.9	173.6	217.9
C_8	Okra - Cauliflower - French bean	383.4	303.2	58.1	86.0	207.7
C_9	Okra - Radish – Onion	148.9	138.3	84.0	107.9	119.8
	LSD (P=0.05)	*48.8*	42.8	29.0	22.3	35.7
				P		
C_1	Maize-wheat	21.0	47.3	32.6	73.4	43.6
C_2	Baby corn + French bean - pea-Summer squash	20.0	21.1	62.2	50.7	38.5
C_3	Baby corn + Asparagus beans- pea-Summer squash	19.2	22.5	63.0	52.2	39.2
C_4	Brinjal – Wheat	6.3	10.6	18.2	33.2	17.1
C_5	Brinjal – Garlic	2.9	9.9	28.9	48.6	22.6
C_6	Brinjal – Brocolli – potato	13.6	21.2	34.5	33.1	25.6
C_7	Okra – wheat	14.7	18.0	19.8	25.0	19.4
C_8	Okra – Cauliflower – French bean	37.3	28.6	7.9	10.5	21.1
C_9	Okra – Radish – Onion	11.8	9.3	18.0	34.7	18.5
	LSD (P=0.05)	*3.7*	4.4	5.3	5.0	4.6
				K		
C_1	Maize-wheat	111.8	279.9	148.3	217.3	189.3
C_2	Baby corn + French bean - pea-Summer squash	65.9	69.5	347.3	129.2	153.0
C_3	Baby corn + Asparagus beans- pea-Summer squash	68.0	78.8	389.0	120.9	164.2
C_4	Brinjal – Wheat	26.2	53.5	86.1	145.6	77.9
C_5	Brinjal – Garlic	17.5	64.6	138.9	212.1	108.3
C_6	Brinjal – Brocolli – potato	60.1	110.5	170.3	177.4	129.6
C_7	Okra – wheat	45.0	56.5	76.4	112.6	72.6
C_8	Okra – Cauliflower – French bean	146.1	114.7	41.1	63.3	91.3
C_9	Okra – Radish – Onion	79.6	75.0	78.6	124.3	89.4
	LSD (P=0.05)	16.9	20.6	31.7	23.9	23.3

VIR SOFTECH

Since FYM was added to each crop every year, there was tremendous build-up of organic carbon over the initial content under each cropping sequence at the termination of the study (Table 5). There was slight decrease in soil pH over the initial status under all the sequences except okra - radish - onion. Despite doubling of the organic C content, there was mining of N. Palampur being a temperate area build up of organic C was quite obvious as the rate of decomposition was low. Being a high rainfall area, leaching losses might have caused reduction in available N status over the initial. There was reduction in the available K status also, but build up of P except under maize – wheat. The maize - wheat cropping system appears to be exhaustive with respect to all the nutrients. The added nutrients were more efficiently utilized by this cropping system and there was mining of potassium as the nutrient was removed by the crops larger than that is applied during a period of four years. Losses of N were highest in C_9 followed by C_6, C_2, C_3 and C_5. Losses were probably owing to weeds, leaching and runoff and denitrification. Highest losses of P were in C_2 and C_3 followed by C_6, C_8 and C_9 which might be due to runoff along with soil eroded in rainy season, fixation and immobilization and weeds. Losses of K were highest in C_8 followed by C_2, C_9, C_6 and C_3. Losses of K were mostly due to leaching and runoff and weeds.

Table 5. Available status and balance sheet of nutrients

Crop sequence	OC (%)	pH	Available (kg/ha) after completion of experiment			Total nutrients available (kg/ha) for crop growth (soil + fertilizers and manures) during four years			Crop uptake (kg/ha) during a period of four years			Losses of nutrients (kg/ha) during a period of four years {2-1-3}		
			(1)			(2)			(3)			(4)		
			N	P	K	N	P	K	N	P	K	N	P	K
C_1	1.13	5.55	304.5	43.1	89.1	1715	301	644	1386	174	757	25	84	-203
C_2	1.09	5.43	307.6	73.9	93.9	2211	586	1191	1024	154	612	879	358	486
C_3	1.12	5.35	319.6	72.8	92.6	2211	586	1191	1092	157	657	799	357	442
C_4	1.07	5.45	316.6	67.8	88.7	1607	276	660	725	68	312	566	140	260
C_5	1.10	5.53	316.6	68.3	83.2	1587	305	760	545	90	433	726	146	243
C_6	1.10	5.55	313.6	71.1	130.1	2227	523	1095	1021	102	518	892	349	447
C_7	1.07	5.53	304.6	65.5	91.4	1511	283	690	872	78	290	335	140	308
C_8	1.04	5.45	298.3	74.5	146.5	1771	438	1029	831	84	365	642	279	517
C_9	1.07	5.65	304.6	73.9	170.2	1979	424	1009	479	74	358	1195	276	481
Initial	0.60	5.60	514.9	47.6	212									

Water productivity

Water productivity in terms of maize grain equivalent per unit amount of water applied was highest under baby corn + asparagus bean - pea - summer squash, followed by baby corn + French bean - pea - summer squash and brinjal - garlic (Table 6). The other cropping systems having higher water productivity over the traditional 'maize-wheat cropping system were: okra - cauliflower - French bean and okra – radish – onion. Brinjal - wheat and okra - wheat had lower water productivity mainly due to lower yield than maize-wheat system. Similarly, brinjal - brocolli - potato had also lower water productivity than maize - wheat cropping system mainly due to higher water use under the system. Conversely to produce a kg of

Table 6. Water productivity under different cropping sequences

	Water productivity (kg mgey/ha-mm)					Water use (l/kg mgey)				
	2006-7	2007-8	2008-9	2009-10	Mean	2006-7	2007-8	2008-9	2009-10	Mean
C_1	28.0	48.1	61.2	63.7	41.0	35.7	20.8	16.4	15.7	24.4
C_2	117.8	78.2	66.7	69.2	75.9	8.5	12.8	15.0	14.4	13.2
C_3	139.9	81.5	66.4	67.8	80.6	7.1	12.3	15.1	14.7	12.4
C_4	17.5	20.1	33.1	61.7	31.1	57.3	49.8	30.3	16.2	32.2
C_5	46.9	59.7	56.0	128.3	74.5	21.3	16.7	17.8	7.8	13.4
C_6	30.1	39.6	41.5	46.8	40.4	33.3	25.3	24.1	21.4	24.8
C_7	42.1	59.6	55.8	56.0	39.2	23.8	16.8	17.9	17.8	25.5
C_8	69.7	82.1	38.0	44.7	49.0	14.4	12.2	26.3	22.4	20.4
C_9	65.2	72.7	43.6	73.4	56.4	15.3	13.8	22.9	13.6	17.7

maize grain equivalent, irrigation water used under different cropping systems ranged from 12.4 to 32.2 litre. This was besides rain and profile water which was assumed constant under all cropping sequences.

Economic viability

The economic analysis of the data revealed superiority of baby corn + asparagus bean - pea - summer squash (Rs 2,75,919/ha/annum) and baby corn + French bean - pea – summer squash (Rs2,57,574/ha/annum) in fetching higher net returns than remaining crop sequences (Table 7). The higher net returns were associated owing to higher yields. However, market for baby corn has yet to be explored. However, if market for baby corn is not available, farmers can easily shift to green cobs or even to maize grain without any trouble or economic loss. Rather the latter products would be more economically viable as visible from the present level of baby corn yield (Table 1). These were followed by okra-radish-onion (Rs 169942/ha/annum), okra - cauliflower - French bean (Rs 92763/ha/annum), brinjal - garlic (Rs 90708/ha/annum) and brinjal - broccoli – potato (Rs 57099/ha/annum). These findings are in conformity with those of Thakur *et al.* (1994) and Chaudhary *et al.* (2001) who also reported higher net returns due to multiple cropping systems. Earlier studies also indicated that multiple cropping systems offer special advantages and reduce the probability of low income for small and marginal farmers (Rana *et al.*, 2010: Sharma *et al.*, 2007 & 2009). The net gain owing to baby corn + asparagus bean - pea - summer squash, baby corn + French bean - pea - summer squash, okra-radish-onion, okra - cauliflower - French bean, brinjal - garlic and brinjal - broccoli - potato was about 636.2, 587.2, 354.4, 147.5, 142.0 and 52.3%, respectively higher over the prevalent maize - wheat cropping system. Brinjal - wheat and okra - wheat cropping sequences recorded lower net return than maize - wheat cropping sequence. Highest B: C ratio was recorded under baby corn + asparagus bean - pea - summer squash followed by baby corn + French bean - pea - summer squash. The other crop sequences found remunerative in terms of B: C ratio over the existing maize - wheat cropping sequence

Table 7. Economics of different cropping sequences

Crop sequence	Returns (Rs/ha)		B: C ratio	Cultivation cost (Rs/ha)	AER	Relative profit (Rs/ha)	Additional profit (Rs/ha)	PER
	Gross	Net						
C_1	113278	37480	0.52	75798	-	-	-	-
C_2	403545	257574	1.77	145971	0.519	133750	96270	3.57
C_3	422232	275919	1.92	146313	0.518	142941	105461	3.81
C_4	89190	12435	0.16	76755	0.988	12280	-25200	0.33
C_5	186976	90708	0.86	96268	0.787	71420	33940	1.91
C_6	229234	57099	0.29	172135	0.440	25143	-12337	0.67
C_7	94297	18336	0.29	75961	0.998	18297	-19183	0.49
C_8	218528	92763	0.84	125765	0.603	55908	18428	1.49
C_9	297487	169942	1.39	127545	0.594	100994	63514	2.69

AER, area equivalent ratio; PER, profit equivalent ratio

were: okra - radish - onion, brinjal - garlic and okra - cauliflower - French bean. As indicated by AER (0.518-0.519), a farmer cultivating maize - wheat in one ha with cultivation cost of Rs 75,798, when switches to alternative maize + bean - pea - summer squash cropping sequences (C_3 and C_2) can cultivate half of the area with the same amount. Consequently relative profit from these alternative cropping sequences is also reduced to half of that obtained from one ha. However, additional profit was still higher by 1,05,461 and Rs 96,270/ha/annum, respectively under baby corn + Asparagus bean - pea - summer squash and baby corn + French bean - pea - summer squash. Their cultivation in half the area under 'maize - wheat' gave 3.81 and 3.57 times, respectively higher profit than cultivation of 'maize - wheat' in the entire area. Thus by switching to cultivation of these alternative cropping systems, a farmer with resources just sufficient for cultivation of maize - wheat can spare half of his land resource for some other economic activity. Okra - radish - onion, 'brinjal - garlic and okra - cauliflower - French bean were next to baby corn + asparagus bean - pea - summer squash' and baby corn + French bean - pea - summer squash with regard to economic viability. However, brinjal - wheat, brinjal - broccoli – potato and okra - wheat were not viable.

Thus it is concluded that for higher net income besides employment to the local people and family itself, farmers of irrigated mid hills ecosystems of Himachal Pradesh can successfully adopt baby corn + Asparagus beans - pea - summer squash and baby corn + French bean (pole type) - pea - summer squash with adequate inputs. Even a poor marginal farmer can improve his financial condition by cultivating these alternative sequences on half of his entire land with the same amount he is spending to cultivate 'maize - wheat' on entire area, thus sparing half of the area to some other economic activity.

Acknowledgement

The study was undertaken under 'All India Coordinated Research Project on Integrated Farming Systems'.

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