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Productivity, profitability and resource use efficiency of potato (*Solanum tuberosum*) based cropping systems in eastern Himalayan region

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ABSTRACT

A field experiment was conducted during three consecutive years of 2011 to 2013 at Central Potato Research Station, Shillong to evaluate the economic feasibility of potato (*Solanum tuberosum* L.) based cropping system under rainfed condition of eastern Himalayan region. There were seven cropping systems replicated thrice under randomized block design. The potato was the main crop during summer season while succeeding seven crops (potato, maize, cabbage, cauliflower, carrot, rajmash and radish) were taken during autumn season. Results revealed that potato based various cropping sequence differ significantly for most of the desirable parameters which decided the economic viability to adopt the system approach for efficient utilization of natural resources. Among the cropping systems, potato-cabbage recorded significantly the highest potato tuber equivalent yield (51.6 tonnes/ha), production efficiency (210.5 kg/ha/day), economic efficiency (₹ 1414.6 /ha/day), maximum net monetary return (₹ 366.8 × 10^3/ha), benefit cost ratio (3.5) and energy productivity (1.35 kg/MJ). Hence, potato-cabbage was concluded as the most stable and profitable cropping system for the ecosystem of eastern Himalayan region.

Key words: Cropping system, Energy use efficiency, High value crops, Potato

Agricultural economy of north eastern Himalayan region is affected by excessive climatic anomalies, like deficient and/or heavy rainfall. The region experiences heavy rainfall which varies from 800-5000 mm, a major part (70-90%) of which is received during pre-monsoon and monsoon period (April-October). Besides the plenty of rainfall, temperature of the region is much favorable for cultivation of high value crops. However, the average cropping intensity in this landlocked region is stagnating at 125%, which is below all India average (138%). In Indian agriculture, it has been reported that consumption of energy has been increasing at a steady rate for improving the productivity, but the energy use efficiency is declining consistently (Chaudhary *et al*. 2009). With the rising cost of production and depleting energy reserves, one of the paramount concerns is the increase in crop productivity with minimum input of energy and cost (Garg and Singh 2002). The non-renewable energy is expensive and liable to exhaust in near future. In the changing climatic scenario, sustainability of any cropping system lie on energy use pattern/consumption in the system. Further, energy productivity is decreasing as a consequence of escalating inputs cost without proportionate improvement in output of particular crops. Hence, a feasible strategy is needed to improve the profitability and energy productivity of prevailing cropping system through utilizing natural climatic condition of region. Therefore, the present investigation was carried out at CPRS, Shillong to evaluate the system productivity and the resource use efficiency of potato (*Solanum tuberosum* L.) based cropping systems.

MATERIALS AND METHODS

A field experiment was conducted for three consecutive years from 2011 to 2013 at Central Potato Research Station, Shillong. The geographical co-ordinates of experimental field are 25^{0}55" N latitude and 91^{0}85' E longitude and an altitude of 1 740 meters above mean sea level. The soil was sandy loam with pH 4.8, moderately fertile, being high in organic carbon (2.45%), medium in available nitrogen (345.0 kg/ha) and potassium (326.4 kg/ha) and low in available phosphorus (7.5 kg/ha). The experiment on potato based cropping systems was laid out in randomized block design with three replications. Seven potatoes based cropping systems, viz. potato-potato, potato-maize, potato-carrot, potato-radish, potato-cauliflower, potato-french bean and potato-cabbage were assigned. With a view to avoid the mixing of soil in different treatments, individual plots were thoroughly prepared by power tiller and manual labourers

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in each season. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash, respectively. Half of N, whole of phosphate and potash were applied at planting of the crop. Rest half of nitrogen was applied at the time of earthing up. The farmyard manure contained 0.50% N; 0.30% P_2O_5 and 0.50 % K_2O. Cultivation practices of the region were followed as per standard recommendation for each crop. The major agronomic practices followed are given in Table 1. Potato tuber equivalent yield and economics were calculated at the prevailing market price of produces, viz. potato ₹ 10/kg, radish ₹ 8/kg, and other crops ₹ 15/kg). To compare the performance of different cropping sequences, economic yield of all the crops were converted into potato equivalent yield (PEY) based on prevailing market price using the formula:

$$\text{PEY (of a crop)} = \text{Yx (Px)/Pp}$$

where, Yx is the yield of crop x (tonnes/ha of economic harvest), Px is the price of crop x, and Pp is the price of potato. To assess the resource use efficiency of the system, land use efficiency (LUE) was calculated from total duration of crop in cropping system divided by 365 and production efficiency in terms of kg/ha/day was calculated by dividing total economic yield (PEY) by total duration of crops in the cropping system. The energy value of each cropping system was determined based on energy inputs and energy production for the individual crops in the system. The total input parameters, viz. human labour, diesel, herbicides, farmyard manure (FYM) and fertilizers, seed, fungicides, insecticides used for cultivation of potato based cropping system was considered for calculation of energy inputs. Inputs and outputs were converted from physical to energy unit measures through published conversion coefficients (Mittal *et al*. 1985, Sriram *et al.* 1999, Devsenapathy *et al.* 2009, Gulati and Singh 2011).The biomass of the crop is separated into economic yield and by-product (straw/stalk/vine). Energy output from the economic product (grain/pod/tuber) and by-product (straw/stalk/vine) was calculated by multiplying the amount of production and its corresponding value energy equivalent. The energy input-output relationship was determined by calculating energy use efficiency and energy productivity by following formula

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ)}}{\text{Energy intput (MJ)}}$$

$$\text{Energy use efficiency} = \frac{\text{Potato equivalent yield (kg/ha)}}{\text{Energy intput (MJ/ha)}}$$

Economic efficiency was calculated in terms of (₹/ha/day) from net return of the cropping system divided by total duration of crop in a cropping system. All observations for each character were subjected to statistical analysis according to the standard method (Panse and Sukhatme 1978). The calculated values of the treatments and error variance ratio were compared with Fisher and Yates F table at 5% level of significance. The significance of differences between treatments means was tested at 5% probability.

RESULTS AND DISCUSSION

Crops and system productivity

Productivity of potato did not differ significant among different cropping systems. However, higher yield was observed in the system where French bean was included in succeeding year (Table 2). The range of potato productivity varied from 19.5 to 30.5 and higher values were found during third year of potato due to timely rainfall during initial growth period. However, very less variation was recorded in the productivity of the potato during first year and second year. The autumn season productivity of potato in potato-potato cropping system was very low due to incidence of wilting during peak growth stage of the crop. However, the mean data of three years of experimentation revealed that the productivity of radish was the highest followed by the cabbage in autumn season. This results is also in conformity with the finding of Singh *et al.* (2004). The lowest productivity was recorded in maize crop due to frost injury at the milking stage of the crop during the month of November in the all the years. French bean productivity was also affected by frost in first year at peak growth stage due to early incidence of frost while it was affected at later stages of picking of pod but majority of pods had been picked before the incidence of frost. Carrot productivity was also poor due to slow growth during the initial stage especially at the time of emergence. Further, heavy rains during August and September restricted the growth of carrot due to poor establishment. The cabbage and cauliflower plants established well, whereas the radish crop was harvested the early September and thus not affected by the heavy rainfall in this month. The maximum potato equivalent yield (27.8 tonnes/ha) during

Table 1 Inputs used in different crops in sequence

Season	Crops	Variety	Seed rate (kg/ha)	Spacing (cm)	Nutrients applied as N. P_2O_5. K_2O
Summer	Potato	K. Jyoti	2 500	60 × 20	140.120.60 + 5t FYM
Autumn	Potato	K. Himalini	2 500	60 × 20	140.120.60 + 5t FYM
Autumn	Maize	Vivek 21	20	60 × 20	140.120.60 + 5t FYM
Autumn	Carrot	Nantes	8	60 × 20	140.120.60 + 5t FYM
Autumn	Radish	Kitchen garden	15	30 × 10	140.120.60 + 5t FYM
Autumn	Cauliflower	Pusa Synthetic	1	45 × 45	140.120.60 + 5t FYM
Autumn	Rajmash	Contender	50	45 × 20	140.120.60 + 5t FYM
Autumn	Cabbage	Wonder Ball	1	45 × 45	140.120.60 + 5t FYM

Table 2 Effect of potato based cropping systems on productivity of individual crops and equivalent yield of system.

Treatment	Economic yield (tonnes/ha)								Potato equivalent yield (tonnes/ha)	
	Summer season				Autumn season				Pooled	
	2011	2012	2013	Pooled	2011	2012	2013	Pooled	Autumn	system
Potato-potato	19.8	20.6	28.8	23.1	8.9	14.3	13.8	12.3	12.3	35.4
Potato- maize	20.3	21.5	30.5	24.1	1.6	1.6	1.4	1.5	2.3	26.4
Potato-carrot	20.0	19.5	28.3	22.6	4.8	6.8	6.7	6.1	9.2	31.8
Potato-radish	19.7	20.3	27.9	22.6	24.1	25.6	24.0	24.6	19.2	41.8
Potato-cauliflower	20.0	23.4	29.3	24.2	8.5	8.7	10.2	9.1	13.7	37.9
Potato-French bean	20.3	25.8	30.2	25.4	1.7	5.5	6.1	4.4	6.6	32.1
Potato-cabbage	19.9	23.2	28.1	23.7	16.7	19.2	19.8	18.6	27.8	51.6
SE±	0.9	1.8	0.9	1.2	0.5	0.6	0.6	0.5	0.7	1.1
CD (P=0.05)	NS	NS	NS	NS	1.4	1.9	1.7	1.7	2.0	3.3

autumn season was recorded under potato-cabbage system, which was significantly higher than other cropping systems. Critical analysis of data revealed that the improvement in potato equivalent yield of cabbage was 44.8% higher than potato-radish cropping system which was significantly superior over rest of the treatments. It may be emphasized here that potato equivalent yield of crops is the function of market price along with yield of particular crop in the system. Although, radish produced higher economic yield than cabbage, cabbage had better market price than radish. As a result potato equivalent yield was the highest in potato-cabbage cropping system. Similarly the system productivity in potato-cabbage cropping system was noticed to be the highest under potato cabbage cropping system followed by the potato radish cropping system during the investigation. The lowest system productivity was obtained under potato-maize cropping system.

System efficiency indicators and net return

Pooled data on system efficiency indicators, viz. production efficiency, land use efficiency, economic efficiency and net return of system as affected by various cropping systems during three years of experimentation are presented in Table 3. The data revealed that potato-cabbage cropping system recorded significantly the highest production efficiency (210.5 kg/ha/days), economic efficiency/profitability (₹ 1 415/ha/days) and net return (₹ 366 800/ha) than rest of the treatments. The second highest production efficiency (209.1 kg/ha/days), economic efficiency (₹ 1 160/ha/day) and net return (₹ 270 400/ha) were observed under potato-radish cropping system. The maximum production, economic efficiency and net return were associated with higher production potential of cabbage and radish due to the highest moisture content of their fresh produce. However, the land use efficiency was found to be the highest under potato-cabbage cropping system followed by potato-carrot cropping system. The lowest land utilization efficiency was found under potato-radish cropping system because the average duration of radish for harvesting was just about 75 days (from sowing to harvesting)

Energy budgeting of system

In general, systems involving potato crops resulted in higher energy input. Accordingly, the maximum energy input (51.1×10^3 MJ/ha) was recorded in potato-potato cropping systems. The other systems that recorded higher energy input were potato-French bean cropping systems. It is clear from the Table 4 that systems having either potato or French bean recorded higher energy because of intensive

Table 3 Effect of cropping system on production efficiency and profitability and land-use efficiency (Pooled)

Cropping system	Production efficiency (kg/ha/days)	Cost of cultivation (₹ × 10^3 /ha)	Gross return (₹ × 10^3 /ha)	Net return (×10^3 /ha)	B:C ratio	Profita-bility (₹/ha/day)	Total duration (days)	Land utilization efficiency (%)
Potato-potato	138.8	190.1	355.0	164.9	1.9	972.6	125+130=255	69.9
Potato- maize	101.5	143.0	265.5	122.5	1.9	727.4	125+145=260	71.2
Potato-carrot	120.0	155.0	318.0	163.0	2.1	871.2	125+150=265	72.6
Potato-radish	209.1	153.2	423.5	270.4	2.8	1160.3	125+75=200	54.8
Potato-cauliflower	137.9	149.5	380.1	230.6	2.5	1041.5	125+150=275	75.3
Potato-French bean	128.3	150.9	321.3	170.4	2.1	880.4	125+125=250	68.5
Potato-cabbage	210.5	149.5	516.3	366.8	3.5	1414.6	125+120=245	67.1
SE±	4.3							
CD (P=0.05)	13.2							

Table 4 Effect of potato based cropping systems on energy budgeting of system (Pooled)

Cropping system	Input energy (₹ × 10^3 MJ/ha)			Output energy (₹ × 10^3 MJ/ha)			NER[a]	EUE[b]	EP[c]
	Summer	Autumn	System	Summer	Autumn	System	(₹ × 10^3 MJ/ha)		(kg/MJ)
Potato-potato	26.6	24.5	51.1	84.5	64.4	148.9	97.8	2.91	0.69
Potato- maize	26.6	12.0	38.6	88.3	45.6	133.8	95.2	3.47	0.68
Potato-carrot	26.6	11.9	38.4	82.9	19.8	102.6	64.2	2.67	0.83
Potato-radish	26.6	11.9	38.5	83.0	52.3	135.3	96.8	3.52	1.09
Potato-Cauliflower	26.6	11.8	38.4	88.7	41.3	130.0	91.7	3.39	0.99
Potato-French bean	26.6	12.5	39.1	93.1	18.4	111.5	72.4	2.85	0.82
Potato-Cabbage	26.6	11.8	38.4	86.9	24.9	111.8	73.4	2.91	1.35

[a]Net energy return, [b]Energy use efficiency, [c]Energy productivity

input of seed in potato attributed more energy compared to other vegetable in the autumn season, respectively. Similar results of energy use efficiency of different cropping system were reported by Yadav *et al*. (2013). Pooled data pertaining to energy output and net energy return under different cropping systems presented in Table 3 revealed marked variation in energy output and net energy return of different cropping systems. The maximum energy output (148.9 × 10^3MJ/ha) and net energy return (97.8 × 10^3MJ/ha) were recorded in potato-potato system, which proved to be higher than all the other systems. The energy output and net energy return, however, are dependent on the energy coefficient of the crop under different cropping systems. Higher coefficient per unit weight resulted from greater output and net energy return. Nevertheless, the lowest energy (102.6 × 10^3MJ/ha) output and net energy return (64.2 × 10^3MJ/ha) was found in potato-carrot system during the investigation.

In general, higher energy input resulted in lower energy use efficiency while higher energy output is directly proportional to energy use efficiency (Walia *et al.* 2014). A critical analysis (Table 4) of the data revealed that among the various cropping systems, potato-maize cropping system recorded the highest (3.47) energy use efficiency than others. This was due to higher stalk yield of maize compared to other crops by-products (straw/vine/haulm) responsible for highest energy use efficiency. However, the lowest energy-use efficiency was recorded under potato-French bean followed by potato-potato/cabbage cropping systems. In the case of potato-potato cropping system potato has the lowest energy use efficiency, although, potato produced the highest output. But due to higher seed requirement in potato cultivation accompanied by higher energy input, this system resulted in poor energy use efficiency. Similar results were also reported by Singh *et al*. (2008).

The most important indicator to evaluate the resource-use efficiency of a particular cropping system is directly related to the energy productivity per unit energy consumption (Biswas *et al.* 2006). Potato-cabbage cropping system recorded the highest energy productivity followed by the potato-radish in all the years. Lowest energy productivity was in potato-maize cropping system followed by potato-potato cropping system. This was due to the lower productivity of autumn potato and maize. The energy productivity of both the systems, i.e. potato-cabbage and potato-radish noticed more positive balance because they produced more output energy per unit consumption of energy while other systems produced negative balance. This was due to the poor productivity of the crop in the system which resulted the poor energy productivity per unit of energy use.

The potato-cabbage cropping system resulted in the highest system productivity, production efficiency, profitability, net return, B C ratio and energy productivity per unit energy consumption. Hence it may be concluded that the potato-cabbage cropping systems was more productive, profitable and energy productive compared to other cropping systems.

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