



Assessment of Pigeonpea [*Cajanus cajan* (L.) Millsp.] Based Cropping Systems in Mid-Hill Regions of Uttarakhand

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ABSTRACT

The research on productivity, energy-use efficiency and economics of pigeonpea based cropping system, viz., pigeonpea-wheat, pigeonpea - barley, pigeonpea - lentil, pigeonpea - field pea and pigeonpea - toria compared with rice-wheat cropping system was carried out at the Experimental Research Block of School of Agricultural Sciences, SGRRU, Uttarakhand. These cropping systems were evaluated under rainfed conditions. Results showed that all the pigeonpea - based cropping system were significantly superior to traditional rice - wheat cropping system in terms of productivity, net returns, benefit: cost ratio and net energy returns. Pigeonpea - lentil cropping system proved superior in terms of system net returns (Rs 63,616/ha), benefit:cost ratio (1.64) and energy ratio (1.94) to pigeonpea - wheat, pigeonpea - barley, pigeonpea - field pea and pigeonpea - toria cropping system. The plots under rice - wheat cropping system recorded the lowest pigeonpea-equivalent yield (1.32 t/ha), net returns (Rs 2,750/ha) and benefit:cost ratio (0.06). The nutrient status of the soil improved significantly due to pigeonpea - lentil cropping system over other cropping systems. Pigeonpea - lentil cropping system proved to be the best in terms of monetary returns, net energy return and soil productivity and hence, could be adopted in the mid-hill regions under rainfed conditions.

Key words: Cropping system, Economics, Energetics, Pigeon pea-equivalent yield.

INTRODUCTION

Higher productivity with sustainability remains the major concern of any crop planning. Any system which requires less input and contributes more is considered to be the efficient. In recent years, oilseeds and legumes are receiving more attention owing to limited production and higher prices. Inclusion of these crops in the sequence changes the economics of the cropping system (Chauhan *et al.*, 2011; Singh and Sharma, 2010). There is a closer relationship between cropping system productivity, economics, energy and environment. The net energy and monetary return of a cropping system can be quantified for sound planning of sustainable systems (Chaudhary *et al.*, 2016). About 80% of the cultivated land from mid-hill region is rainfed. In the rice-wheat based rainfed cropping system, hardly 10-15 days time is available between harvesting of rice and timely sowing of wheat. In this short duration, farmers find difficult to complete the timely sowing of wheat crop. Higher production cost restricts the farmers to follow the improved cropping sequences. In the mid-hill region, the yield levels are low due to erratic rainfall, lack of farmers' resources and fragmented land holdings. Most of the previous work focused on specific aspects of the rice-wheat systems with a strong emphasis on yields and nutrient management. Studies providing an integrated assessment of more diversified cropping systems have remained relatively rare in the scientific literature, but they are needed for understanding options for intensification and diversification in the mid-hill region. The advantages of legume-based cropping systems were well proven in this region (Singh *et al.*, 2008). Pigeonpea is an important legume crop of rainfed agriculture because of its ability to produce

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economic yield under limited moisture conditions. But the pigeonpea-based cropping system needs to be evaluated agronomically, economically as well as in terms of energy-use efficiency. Hence, the present study was undertaken to evaluate the productivity, profitability and energy-use efficiency of pigeonpea-based cropping systems in comparison with the traditional rice-wheat cropping system.

MATERIALS AND METHODS

A present investigation was carried out at the Experimental Research Block of School of Agricultural Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand India, situated at 29°58' N latitude and 77°34' E longitude at an elevation of 610 m above mean sea level during 2016-2018. The soil of the experiment site was slightly alkaline in reaction (pH 7.1), sandy loam in texture having bulk density 1.38 Mg/m³, plant-available water capacity 2.4 cm/15 cm, porosity 50.2%, organic C 0.63% and available N 288 kg/ha, available P

13.0 kg/ha and available K 175 kg/ha, respectively. The treatments comprised of five pigeonpea-based cropping systems along with the rice - wheat cropping system were taken in randomized block design with four replications. The treatments were pigeonpea - wheat, pigeonpea - barley, pigeonpea - lentil, pigeonpea - field pea, pigeonpea - toria and rice - wheat in sequential cropping. The pigeonpea crop was sown on 18th and 15th June in 2016 and 2017, respectively and all other *rabi* season crops were sown on 01st November in 2016 and 16th October in 2017. Pigeonpea 'Mukta', wheat 'UP-262', barley 'Ratna', lentil 'Pant-L-639', field pea 'Type-163' and rice 'Pusa-2-21' were used for the experimentation. In all the treatments, 10 t/ha farmyard manure (FYM) along with recommended dose of NPK of respective crops was applied. Recommended dose of fertilizers applied to different crops were, 20 kg N + 26.4 kg P + 33.3 kg K/ha to pigeonpea, 60 kg N + 13.2 kg P + 16.7 kg K/ha to rice, wheat and barley, 20 kg N + 17.6 kg P + 16.7 kg K/ha to lentil, 20 kg N + 26.4 kg P + 33.3 kg K/ha to field pea and 50 kg N + 13.2 kg P + 16.7 kg K/ha to toria. Full amount of N, P and K in pigeonpea, lentil and field pea and half the amount of N and full amount of P and K in rice, wheat, barley and toria was applied at the time of sowing. The remaining half of N was top-dressed in rice, wheat and barley after the rains in August and February, respectively for *kharif* (rainy) and *rabi* (winter season) crops. Seeds of pigeonpea and rice during *kharif* and wheat, barley, lentil, field pea and toria during *rabi* were sown after tilling the fields once in minimum tillage. Before sowing of *kharif* crops, weeds were controlled with the application of Glyphosate at 1.0 kg/ha followed by one hand weeding at 45 days after sowing. Similarly, during the *rabi* season, weeds were controlled in all the cropping systems by spraying Isoproturon at 1.0 kg/ha at 35 days after sowing wheat and barley; and Pendimethalin at 1.0 kg/ha (as pre-emergence) in plots of lentil, field pea and toria, followed by hand weeding as and when required. Production indices like pigeonpea-equivalent yield (PEY), system productivity of the cropping system were worked out to evaluate the system efficiency. To calculate the input energy, all inputs in the form of labour, seed, chemical fertilizer, herbicides and pesticides used in all crop sequences were taken into consideration with use of energy conversion factors. The energy requirement of the different field operations were calculated by using the energy conversion factors as given in Table 1. The farm produce (grain yield + straw/stalk yield) was also converted into energy in terms of energy output (MJ) by using two year's average yield under different crops of selected sequences. Input energy was worked out in terms of different external sources utilized, *i.e.* seed, fertilizer, herbicide and plant protection chemicals. The parameters measured or calculated were input energy, output energy, net energy returns and energy ratio (energy efficiency). Input energy (E_i) can be classified in two main groups: direct-use energy and indirect-use energy. Direct and indirect energy inputs were calculated as seen in Eq. (1) for biological energy (BE):

human labour, seed), chemical energy (ChE : fertilizer, toxin), and field operational energy (FOE). Energy equivalents (EE) for all inputs were summed to provide an estimate for total energy input (Table 1).

$$E_i = BE + ChE + FOE$$

Output energy (E_o) from the product (grain) was calculated by multiplying the amount of production and its corresponding energy equivalent. Energy output from the by-product (stalk and straw) was estimated by multiplying the amount of by-product and its corresponding equivalent. Net energy returns or net energy production, is the difference between the gross energy output produced and the total energy required to obtain it (energy input). In agricultural processes, this energy is normally related to the unit of production. Energy ratio (ER) was determined as energy output divided by input, $ER = E_o/E_i$.

Different economic indicators were calculated based on the existing market price of the inputs and outputs. Variable cost of cultivation was worked out and the fixed cost was not taken into account. Gross income was calculated out by taking into account the main product and the by-product. The prices of different produce per tonne used for calculation were: Rs. 35,500 for pigeonpea grains, Rs. 8,500 for rice grains, Rs. 10,800 for wheat grains, Rs. 6,500 for barley grains, Rs. 23,000 for lentil grains, Rs. 18,000 for field pea grains, Rs. 17,350 for toria grains, Rs. 1,600 for rice/wheat/barley straw and Rs. 2,750 for field pea/lentil/toria straw. The inputs costs used for calculation of

Table 1: Energy conversion factors used in the study.

Power source	Units	Equivalent energy (MJ)
Human labour		
Adult man	Man-hour	1.96
Woman	Woman-hour	1.57
Farm machinery	kg	62.7
Chemical fertilizers		
N	kg	60.60
P ₂ O ₅	kg	11.10
K ₂ O	kg	6.70
Farm yard manure	kg (dry mass)	0.30
Plant protection chemicals	kg	120
Crop produce		
Pigeonpea	kg	14.7
Rice	kg	14.7
Wheat	kg	14.7
Barley	kg	14.7
Lentil	kg	14.7
Field pea	kg	14.7
Toria	kg	25.0
By-product		
Straw, vines etc.	kg	12.5
Stalks	kg	18.0

(Singh *et al.*, 2010).

net returns were: Rs. 115/manday, Rs. 11/kg N, Rs. 23/kg P, Rs. 8/kg K and Rs. 6,000/ha for land preparation. The data collected were subjected to statistical analysis of variance (ANOVA). The least significant difference (LSD) test was carried out for analyzed mean square errors. The procedure provides for a single LSD value at 5% level of significance, which serves as a boundary between significant and non-significant differences between any pair of treatment means.

RESULTS AND DISCUSSION

System productivity

There was not much variation in yields of pigeonpea in different cropping sequence (Table 2). Significantly higher number of pods/plant in pigeonpea was observed under pigeonpea - lentil cropping system. However, seeds/pod and 1000-seed weight was found to be non-significant among the treatments. Total system productivity in terms of pigeonpea equivalent yield (PEY) was affected significantly due to different sequential cropping systems. Pooled data on yield showed that pigeonpea-wheat cropping system recorded the highest PEY (2.80 t/ha), which was significantly higher than the rest of the treatments. This was mainly due to fairly good yield of wheat and its good market price. Mukherjee (2010) also reported the productivity and profitability were higher under legume-wheat cropping sequence than the traditional rice-wheat sequence. Similar things also observed in pigeonpea - lentil cropping system. This also corroborates the earlier findings of Rao and Rogers

(2006). Rice - wheat sequence recorded the lowest PEY because of the lower yield of these crops. Similarly, pigeonpea - barley, pigeonpea - field pea and pigeonpea - toria were found significantly superior to rice - wheat in terms of PEY. It was mainly due to higher price of pigeonpea, field pea as well as toria compared with that of rice and wheat. Pigeonpea - wheat and pigeonpea-lentil cropping system improved the system productivity in terms of PEY by 112 and 108%, respectively, compared to the traditional rice - wheat sequence (1.32 t/ha). Ghosh *et al.* (2006) also reported that cropping sequence with a high yielding or legume crop in pigeonpea is advantageous. Higher PEY under different cropping systems than rice - wheat sequential cropping indicated higher biomass production resulting in more efficient utilization of land and available resources in pigeonpea based cropping systems. Prakash *et al.* (2004) reported similar findings in soybean-lentil cropping system.

Energetics

The energy budget revealed that the maximum input energy of the system was recorded under rice - wheat followed by pigeonpea - wheat cropping system (Table 3). The lowest input energy was noted with pigeonpea - lentil cropping sequence. The input energy increased with the increase in inputs (seed, fertilizer, pesticide and human labours *etc.*). The maximum system output energy, net energy return and energy ratio were obtained with pigeonpea - lentil cropping system followed by pigeonpea - toria cropping system because of higher system productivity. The lowest values

Table 2: Productivity and economics of pigeonpea-based cropping systems (pooled analysis of 2 years data).

Cropping system		Yield (t/ha)	Pods /plant	Seeds /pod seeds)	Test weight (g/1000	PEY* (t/ha) (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns	B:C ratio**	
Pigeonpea- Wheat		1.58	2.20	118.7	3.2	77.3	2.80	49173	55889	1.14
Pigeonpea- Barley		1.53	1.54	107.3	3.2	75.5	2.36	42900	45500	1.06
Pigeonpea- Lentil		1.61	0.65	129.3	3.1	77.5	2.74	38845	63616	1.64
Pigeonpea- Field pea		1.52	0.65	104.7	3.1	76.7	2.53	39921	54713	1.37
Pigeonpea- Toria		1.49	0.75	110.3	3.2	76.1	2.51	37550	56484	1.50
Rice- Wheat		1.80	2.14	-	-	-	1.32	46793	2750	0.06
SEm ±		0.31	0.24	3.2	0.15	1.0	0.06			
LSD (<i>P</i> = 0.05)		0.66	0.87	9.3	NS	NS	0.18			

*PEY: Pigeonpea equivalent yield;

**B:C ratio: benefit:cost ratio

Table 3: Energy-use efficiency as influenced by different cropping systems (mean of 2 years).

Cropping system	System input energy (x 10 ³ MJ/ha)	System output energy (x 10 ³ MJ/ha)	System net energy returns (x 10 ³ MJ/ha)	Energy ratio
Pigeonpea- Wheat	155.54	213.66	58.12	1.37
Pigeonpea- Barley	145.57	186.65	41.08	1.28
Pigeonpea- Lentil	100.27	194.04	93.77	1.94
Pigeonpea- Field pea	131.07	185.39	54.32	1.41
Pigeonpea- Toria	120.27	206.00	85.73	1.71
Rice- Wheat	157.37	141.53	-15.84	0.90

Table 4: Effect of pigeonpea-based cropping systems on chemical properties of surface soil (pooled analysis of 2 years).

Cropping system		Soil pH	Soil organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Pigeonpea-	Wheat	7.10	0.64	284.5	13.8	176.8
Pigeonpea-	Barley	7.11	0.64	293.4	13.2	174.8
Pigeonpea-	Lentil	7.08	0.68	310.8	13.7	196.5
Pigeonpea-	Field pea	7.09	0.67	305.6	13.4	188.3
Pigeonpea-	Toria	7.11	0.66	290.5	13.0	179.4
Rice-	Wheat	7.12	0.63	260.4	12.9	166.6
SEm \pm		0.23	0.02	7.2	0.2	5.9
LSD ($P=0.05$)		NS	NS	21.3	0.6	17.4

were noted with rice - wheat, mainly because of high input energy and too low system productivity. Singh *et al.* (2008) also reported more net energy returns and energy ratio due to less input energy and more output energy in different cropping systems studied in the north-western Himalaya. Therefore, pigeonpea - lentil was recommended for rainfed farming in this region.

Soil properties

No significant changes in pH and soil organic carbon were observed among the different cropping systems (Table 4). There was significant improvement in the available N, P and K under all pigeonpea - based cropping systems compared to that in the plots under the rice - wheat sequence. The highest available N, P and K were observed under the pigeonpea - lentil cropping system. It shows that lentil crop not only utilized the growth resources more efficiently but also improved the nutrient status of the soil. Thus, it can be inferred that pigeonpea - lentil is a more viable option to improve the concentration of major plant nutrients (N, P and K) in soils in this region.

Economics

The pigeonpea - lentil proved significantly superior based on net returns (Table 2). The mean net returns were more in pigeonpea - lentil (Rs. 63,616) and pigeonpea - toria (Rs. 56,484) than in rice - wheat (Rs. 2,750/ha) cropping system. These results corroborate the findings of Gangwar *et al.* (2006). The lower cost of cultivation and higher net returns under sequential cropping resulted in higher benefit: cost ratio under pigeonpea - lentil (1.64) cropping system, followed by pigeonpea - toria (1.50) cropping system. Similarly, lentil-based cropping system was found to be a remunerative cropping system in mid-hills of North-west Himalaya (Tripathi and Sah, 2001). The lowest benefit: cost ratio under rice - wheat cropping system was mainly due to higher cost of cultivation and lowest gross return owing to low yield of rice and wheat. Thus, it can be inferred that pigeonpea - lentil cropping system is a more viable option to improve the system productivity, profitability per unit area and time and energy productivity in mid hill regions and can be adopted in future for remunerative agriculture.

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