Effect of different oilseeds and pulses based cropping system on system productivity, economics, efficiency and soil health

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Abstract

Effect of different oilseeds and pulses-based cropping system on system productivity were studied. Results indicated that system productivity of different cropping system in terms of chickpea-equivalent yield was significantly higher under field pea–green gram system with 2.79 t/ha and 2.97t/ha during 2014–15 and 2015–16, respectively. Field pea–green gram system recorded significantly highest production efficiency with 12.99 and 14.20 kg/ha/day during the period of experimentation. However, land-use efficiency was higher in chickpea–soybean (79.73%) followed by gobhi sarson–soybean (76.73%) than other systems. Significantly highest available nitrogen and potassium in soil was recorded in field pea-green gram. On the other hand, numerically higher available phosphorus and sulphur was observed in mustard-green gram system. Highest water use efficiency and net returns (58598 ha/year) was recorded in field pea-green gram system.

Keywords: Cropping systems, Productivity, Production efficiency, Land-use efficiency, Energy and WUE..

1. Introduction

Oilseeds and pulses are two major pulse crops and given special emphasis to enhance their production so as to avoid heavy import bill every year (Ali *et al.* 2018). National production of pulse is 22.95 million tonnes with the productivity of 779 kg/ha from an area of 294.65 lakh hectare (Anonymous, 2020a). The UT of Jammu and Kashmir is deficient not only in cereals but in pulse and oilseed grains also and the deficit is higher for pulses and oilseeds than cereals (Anonymous, 2020a). The per capita availability of edible oils have increased from 4.0 kg per year in 1960-61 to 9.5-10.0 kg per year in India (Mandal and Chattopadahyay 2015). National production of oilseeds is 32.10 million tonnes with the productivity of 1225 kg/ha from an area of 262.06 lakh hectare (Anonymous,2020a). It is further added that among all the crops which are commonly grown by the farmers on dry lands of Jammu, oilseed and pulse crops occupy a unique position as they have comparatively the better capabilities to sustain high moisture deficits as compared to maize and wheat. Besides this thepulses are valued for their importance in nutritional security and pulse-oilseed sequences are well known for their soil amelioration and sustainable crop production impacts (Ali *et al.*, 2018). With this background, cropping systems involving pulses and oilseeds were evaluated in the Shiwalik foot hills of Jammu and Kashmir.

2. Materials & methods

A field experiment was conducted during rabi 2014-15 to kharif 2016 at Pulse Research Sub Station, Samba, SKUAST-Jammu. The experimental soil was sandy loam in texture with pH 6.74 and electrical conductivity 0.15 dS/m. The soil was low in available nitrogen (142.89 kg/ha), sulphur (7.45 ppm), available phosphorus (10.72 kg/ha), potassium (154.36 kg/ha) and organic carbon (4.2g/kg). The experiment was laid out in randomized block design with four replications. The treatments comprised of 16 cropping systems, viz. green gram preceeded by (pb) chickpea, uradbean pb chickpea, sesame pb chickpea, soybean pb chickpea, green gram pb field pea, uradbean pb field pea, sesame pb field pea, soybean pb field pea, green gram pb mustard, green gram pb gobhi sarson, uradbean pb mustard, uradbean pb gobhi sarson, sesame pb gobhi sarson and soybean pb gobhi sarson. The recommended dose of fertilizers of chickpea, field pea, mustard, gobhi sarson, green gram. uradbean, sesame and soybean were 16:40:0:0, 16:40:0:0, 60:30:15:20, 50:30:15:20, 16:40:0:0, 16:40:0:0, 20:10:0:0 and 20:40:20:0 N: P2O5: K2O: S kg/ha, respectively. The fertilizers were applied as per recommended method and time of application for each crop. Rabi oilseed/pulse crops was sown in the fourth week of October and harvested in the month of March (field pea and mustard) and April (gobhi sarson and chickpea). The kharif oilseed/pulse crops (green gram, uradbean, sesame and soybean) were sown in the fourth week of June and harvested in the month of September (green gram, uradbean and sesame) and October (soybean). Economic yields of the component crops were converted to chickpea-equivalent yield (CEY), considering the prevailing minimum support price and market prices of the crops. System productivity was calculated by adding the chickpea equivalent yield of the component crops. Production efficiency was expressed as the ratio of system productivity in kg CEY/ha to total duration of the system in days in a year during which they occupied the land. Total field duration of a cropping system expressed in percentage of 365 days was taken as the land-use efficiency of the system. For energy indices analysis, input energy divided into direct and indirect and renewable and non-renewable forms (Hatirli *et al.*2006). Total physical output referred to both grain/seed and by-product yields. The farm produce (seed yield and stover yield) was also converted into energy in terms of energy output and for that two year's average crop yield was multiplied by their energy equivalents per unit. Based on the energy equivalents of the inputs and output, energy-use efficiency and energy intensity in economic terms were calculated.

Energy use efficiency = Gross energy output (MJ/ha)/Energy input (MJ/ha)

Net energy output (MJ/ha) = Gross energy output (MJ/ha) – Energy input (MJ/ha)

Energy intensity in economic terms (MJ/kg) = Gross energy output (MJ/ha)/Cost of cultivation (/ha)

The observations recorded during the course of investigation were tabulated and analyzed statistically to draw a valid conclusion. The data were analyzed by ANOVA as described by Gomez and Gomez (1984).

3. Result and Discussion

The data indicated that the chickpea equivalent yield was significantly higher in field pea-green gram (1.03 t/ha) based cropping sequence than other sequences. Chickpea- green gram sequence proved to be next best crop sequence which also recorded higher chickpea equivalent yield (1.00

t/ha) than remaining sequences except field pea-uradbean (0.95 t/ha).The higher market price fetched by main product and byproduct of these crops contributed to higher chickpea equivalent yield. However, data pertaining to system productivity in terms of chickpea equivalent yield of different oilseed/pulse-based cropping sequences are presented in Table 3. It was observed that the cropping sequences of field pea-green gram produced significantly highest CEY of 2.88 t/ha and was found statistically at par with field pea-uradbean (2.81t/ha) and field pea- soybean systems (2.73t/ha), whereas lowest was registered in chickpea-sesame system on overall mean basis. This improvement in productivity may be attributed mainly to field pea and green gram which fetched higher price in the market besides having good productivity than rest of the cropping systems. These findings are in close conformity with Kathirvelan *et al.* (2012); Ram *et al.* (2012), Singh *et al.* (2012), Usadadiya *et al.* (2014) and Prasad *et al.* (2016). More the grain produced in shorter period results in more production efficiency. Production efficiency of different rabi oilseed/pulse-kharif oilseed/pulse systems was influenced significantly by yield of different crops in the systems. Field pea-green gram system recorded significantly highest production efficiency (13.60 kg/ha/day) followed by field pea-uradbean and field pea- soybean system (Table 3). This was due to the fact that field pea and green gram had higher potential for efficient utilization of physical resources in short time as lesser number of days taken to maturity than oilseed and other pulse crops evaluated. These results are in concurrence to the research studies of Singh *et al.* (2012). Land utilization markedly increased due to inclusion of long duration crops (chickpea, gobhi sarson and soybean) in the system, indicated a better utilization of the land which was occupied for more number of days in a year under intensive multiple cropping system. Chickpea-soybean system resulted in maximum land use efficiency (79.04%) followed by gobhi sarson-soybean (76.30%) (Table 3). This might be ascribed to occupation of land by chickpea and soybean crops for longer period. These results are in close agreement with Kathirvelan *et al.* (2012) and Ram*et al.* (2012)

Among the different kharif oilseed/pulse crops in rabi oilseed/pulse-kharif oilseed/pulse systems, available nitrogen in soil was significantly improved due to growing of field pea-green gram crops in the systems or having one legume crop in the system as compared to only oilseed crops in the rotation. This might be due to the fact that pulses leave behind substantial amount of N in soil after harvest due to atmospheric nitrogen fixation by root nodules (Singh *et al.* 2012). Numerically available phosphorus and potassium were improved due to legume-legume system but highest phosphorus recorded in oilseed-oilseed system. This might be due to the reason that phosphorus was utilized as a source of energy by root nodules for nitrogen fixation in legume crops. These results corroborate to the field investigations of Sree and Sridhar (2015), Hemalatha *et al.* (2013) and Usadadiya, *et al.* (2014). Inclusion of legumes in crop sequences increases the N, P and K of the soil (Mandal and Chattopadhyay, 2015). This could be due to the fact that ample supply of phosphorus in soil provides a congenial environment in rhizosphere for microbial population and mineralization through its energy currency functions (Balai *et al.*2017). The available sulphur was highest in oilseed plots as compare to pulse crops this might be due to the reason that recommended dose of sulphur applied only in plots where mustard and gobhi sarson were grown. Besides higher uptake of sulphur from the soils of experimental plots in which mustard and gobhi sarson were taken up in the system, still quantity of available sulphur recorded in these plots was higher. This has resulted due to the addition of recommended doses of sulphur wherein mustard and gobhi sarson were taken up which ultimately enriched the soils of these plots with sulphur. These results are in close agreement with the findings of Kumar (2015). Whereas in pulses plot slight increase in available sulphur was noticed, this was due to the fact that adequate application of phosphorus to the pulse crop might have induced increased root growth and nodulation resulting in increased absorption and availability of sulphur in upper soil layer (Patel *et al.* 2014).

Energy used for raising different crops was computed to augment energy use efficiency (Table 4). As per the computation, input energy different due to difference in energy use under different crops in sequences. In the present investigation, output energy was significantly higher in soybean in field pea-soybean (28323.89MJ/MJ) sequence which was statistically at par with soybean in chickpea-soybean and mustard-soybean sequence due to the higher yield of their byproducts. Energy use efficiency was statistically higher in green gram in field pea-green gram (6.20) over other sequences due to lower input energy required by it (4176.78MJ/ha) compared to its output energy (25896.61MJ/ha). The output energy, however, is dependent on economic part of the crop as well as dry fodder and straw yields of different sequences. Energy productivity of 0.25 kg/MJ and energy intensiveness of 1.50 MJ/Rs (Table 3). Moreover, it also recorded the highest net energy 21719.83MJ/ha though it was marginally less compared to the sequence of soybean in field pea-soybean system that recorded net energy of 23225.38 MJ/ha. Since, energy productivity is the ratio of chickpea equivalent yield (kg/ha) to total energy input (MJ/ha), the corresponding values relating to the system will determine the energy productivity. In this experiment the sequence of field pea-green gram recorded the highest chickpea equivalent yield that might have also contributed towards higher energy indices. Bastia (2015) too has reported higher energy indices utilization when green gram was included in the system. However,the specific energywas found lower with field pea-green gram (4.09MJ/kg).

Data pertaining to water use/expense efficiency of kharif oilseed/pulse crops in rabi oilseed/pulse-kharif oilseed/pulse systems given in Table 4revealed that there was improvement in water use/expense efficiency in plots where field pea in system was taken. Green gram in field pea-green gram system recorded highest water use/expense efficiency followed by green gram with chickpea, mustard and gobhi sarson systems. Similar trend was recorded in rest of the kharif crops in systems with field pea, chickpea, mustard and gobhi sarson. It might also be due to the fact that increase in yield of fieldpea-green gram system was more than the corresponding increase in consumptive use of water, which finally resulted in considerable increase in water-use efficiency (Wanga *et al.* 2010). The residue of legume fallen on the surface of soil at maturity worked as residue mulch that probably resulted in better utilization of rainfall. Such crop residues would likely to have improved the soil organic fertility status that resulted in better moisture utilization and crop nutrient availability (Prasad *et al.*2016). The size of legume canopy increased under fertile soil and large crop canopy reduces soil evaporation loses by shading the surface soil and increase the available water for transpiration, resulting in an increase in water use efficiency (Richards *et al.*, 2012 and Sadras 2013). Pulse crops in the sequences results in higher water use efficiency these observations are concurrence to the results of research investigations of Prasad *et al.* 2016.

Economic analysis of cropping systems as a whole under different oilseed and pulse crop sequences revealed that (Table 5) highest net returns (58598/ha) and benefit cost ratio (1.60) were obtained in field pea-green gram system followed by field pea-uradbean system. This is due to higher production of field pea and green gram crops in this system along with the higher market price of their produce. These results are in close agreement with the findings of Kathirvelan *et al.* (2012). Another possible reason for highest value might be due to short duration of crops reducing their infestation to insect pest and early harvest reducing the cost of maintenance in the field. These findings are in close agreement with from the results, it was concluded that field pea–green gram system enhanced chickpea-equivalent yield and was found to be most remunerative.

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Tables:

Table 1. Energy equivalents conversion factors for various inputs and outputs used in the study

Items	Units	Energy equivalent (MJ/unit)
Inputs		
Labour(Adult man)	Man-hour	1.96
Diesel	L	56.31
N	kg	60.60
P	kg	11.10
K	kg	6.70
Superior chemicals	kg	120.00
Inferior chemicals	kg	10.00 (chemical require dilution at the time of application)
Output	Main product	
Stover	(dry mass)	12.50
Chickpea (seed)	kg (dry weight)	14.7
Field pea	kg (dry weight)	14.7
Mustard	kg (dry weight)	25.0
Gobhi sarson	kg (dry weight)	25.0
Green gram	kg (dry weight)	14.7
Black gram	kg (dry weight)	14.7
Sesame	kg (dry weight)	25.0
Soybean	kg (dry weight)	14.7
By product		
Straw	kg (dry weight)	12.50
Stalks	kg (dry weight)	18.0
Leaves and straw from leaves	kg (dry weight)	10.0

Table 2. Aronomic practices, input cost and output price of different Oilseed/pulse crops

Agronomic practices	Crops							
	Kharif		*Rabi*					
	Chick pea	Field pea	Mustard	Gobhi sarson	Green gram	Black gram	Sesame	Soybean
Seed rate(kg/ha)	65	65	5	5	20	20	2.5	65
Fertilizer (Urea: DAP: Phosphorus: Gypsum-kg/ha)	0:88:0:0	0:88:0:0	105:65:25:100	85:65:25:100	0:90:0:0	0:90:0:0	35:22:0:0	10:88:33:0
Weedicide (kg/ha)	3.33	3.33	2.50	2.50	3.33	3.33	3.33	3.33
Insecticides (lt/ha)	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0
Fungicide(g/ha)	162.50	187.50	12.5	12.5	50.0	50.0	6.25	162.50
Spacing (cm x cm)	30x10	30x10	30x10	45x10	30x10	30x10	30x15	45x10
Genotypes	GNG-469	Rachna	RSPR-03	DGS-1	SML-668	Uttara	Punjab Til-1	SL-958
Method of sowing	Line sowing	Line sowing	Line sowing	Line sowing	Line sowing	Line sowing	Line sowing	Line sowing
Date of sowing of crops	29-10-2014 & 27-10-2015				25-06-2015 & 30-06-2016			
Date of Harvesting	15-04-2015 & 07-04-2016	12-03-2015 & 07-03-2016	20-03-2015 & 16-03-2016	05-04-2015 & 30-03-2016	14-09-2015 & 16-09-2016	21-09-2015 & 25-09-2016	29-09-2015 & 03-10-2016	26-10-2015 & 29-10-2016
	Input cost (₹/ha) and out put cost (₹/t)							
Cultural operations which includes land preparation and labours used for other field	10711.04	10152.19	11643.63	11643.63	10711.48	10711.48	11084.34	10711.48

operations (₹/ha)								
Nutrients(₹/ha)	1997.60	1997.60	2921,5	2811.5	2043.0	2043.0	691.9	2583.9
Fungicide(₹ha)	105.62	121.87	8.12	8.12	32.5	32.5	4.06	105.60
Seed(₹/ha)	4875.00	4690.00	325	325	1800	1700	462.5	5525.0
Weedicide (₹ha)	1170	1170	880.0	880.0	1165.5	1165.5	1165.5	1165.5
Insecticide (₹/ha)	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0
Output price main (₹/t)	31750-1^{st} year 34250-2^{nd} year	40000-1^{st} year 41000-2^{nd} year	31000-1^{st} year 33500-2^{nd} year	31000-1^{st} year 33500-2^{nd} year	46000-1^{st} year 48500-2^{nd} year	43500-1^{st} year 46250-2^{nd} year	46000-1^{st} year 47000-2^{nd} year	25600-1^{st} year 26000-2^{nd} year

Table 3: Chickpea equivalent yield, system productivity, production efficiency and land use efficiency of different *rabi* oilseed /pulse- *Kharif* oilseed / pulse systems taken (Pooled mean of two years)

Treatment	CEY (q/ha)	System productivity (t/ha)	Production efficiency (kg/ha/day)	Land use efficiency (%)	Total duration of the sequence (Days)	Available nutrient status of the soil (kg/ha)			
	mean	mean	mean	mean	mean	N	P	K	S
Chickpea - moongbean	10.03	2.06	8.39	67.40	246	163.44	11.74	156.57	8.15
Field pea-moongbean	10.26	2.88	13.60	58.08	212	166.82	12.02	156.83	8.34
Mustard-moongbean	8.83	2.27	10.32	60.41	221	149.54	13.34	155.66	9.37
Gobhi sarson-moongbean	8.49	2.49	10.55	64.66	236	147.99	13.18	155.61	9.23
Chickpea-uradbean	8.73	1.93	7.61	69.59	254	161.92	11.75	156.47	7.76
Field pea-uradbean	9.51	2.81	12.76	60.27	220	166.16	11.89	156.72	8.11

Mustard-uradbean	8.53	2.25	9.83	62.60	229	148.45	13.22	155.42	9.25
Gobhi sarson-uradbean	8.32	2.47	10.13	66.85	244	147.38	13.08	155.30	9.06
Chickpea - til	5.19	1.58	6.03	71.78	262	155.36	11.36	153.80	7.28
Field pea-til	5.44	2.40	10.52	62.47	228	156.08	11.54	154.36	7.37
Mustard-til	4.84	1.88	7.94	64.79	237	143.84	11.94	149.33	7.63
Gobhi sarson- til	4.57	2.10	8.32	69.04	252	143.52	11.84	147.84	7.45
Chickpea-soybean	8.19	1.88	6.52	79.04	289	160.97	12.49	156.67	8.34
Field pea-soybean	8.77	2.73	10.74	69.73	255	163.15	12.70	156.71	8.68
Mustard-soybean	7.56	2.15	8.17	72.05	263	147.17	13.11	156.56	9.55
Gobhi sarson-soybean	7.39	2.38	8.54	76.30	279	146.15	12.90	156.38	9.49
SEm (±)	0.58	0.05	0.18	-	-	1.90	0.66	2.13	1.04
LSD (*p=0.05*)	1.78	0.13	0.52	-	-	5.41	NS	NS	NS

Initial status: N-142.89, P-10.72, K-154.36 and S-7.45

Table 4: Energy use pattern and WUE of different *rabi* oilseed /pulse- *Kharif* oilseed / pulse cropping system (Pooled data of two year)

Treatment	Energy input (MJ/ha)	Energy output (MJ/ha)	Energy use efficiency (MJ/MJ)	Net energy (MJ/ha)	Energy productivity (kg/MJ)	Specific energy (MJ/kg)	Energy intensity (MJ/Rs.)	WUE kg/ha/mm)	WEE (kg/ha/mm)
								Mean	Mean
Moongbean in Chickpea moongbean system	4176.78	25765.12	6.17	21588.34	0.24	4.20	1.49	1.75	0.74
Moongbean in Field pea-moongbean system	4176.78	25896.61	6.20	21719.83	0.25	4.09	1.50	1.80	0.76
Moongbean in Mustard-moongbean system	4176.78	23016.45	5.51	18839.67	0.21	4.75	1.33	1.55	0.66

Moongbean in Gobhi sarson-moongbean system	4176.78	22498.17	5.39	18321.39	0.20	4.96	1.30	1.49	0.63
Uradbean in Chickpea-uradbean system	4176.8	25074.06	6.00	20897.26	0.21	4.80	1.45	1.44	0.67
Uradbean in Field pea-uradbean system	4176.8	25095.17	6.01	20918.37	0.23	4.41	1.46	1.56	0.73
Uradbean in Mustard-uradbean system	4176.8	23473.66	5.62	19296.86	0.20	4.93	1.36	1.40	0.65
Uradbean in Gobhi sarson-uradbean system	4176.8	23064.73	5.52	18887.93	0.20	5.06	1.34	1.36	0.64
Til in Chickpea - til system	3828.71	21991.55	5.74	18162.84	0.12	8.65	1.48	0.81	0.35
Til in Field pea- til system	3828.71	22409.35	5.85	18580.64	0.14	7.10	1.51	0.84	0.37
Til in Mustard- til system	3828.71	20559.73	5.37	16731.02	0.13	7.95	1.38	0.74	0.33
Til in Gobhi sarson-til system	3828.71	19937.09	5.21	16108.38	0.12	8.44	1.34	0.69	0.31
Soybean in Chickpea-soybean system	5098.51	26627.00	5.22	21528.49	0.16	6.24	1.24	2.13	0.96
Soybean in Field pea-soybean system	5098.51	28323.89	5.56	23225.38	0.17	5.84	1.32	2.28	1.03
Soybean in Mustard-soybean system	5098.51	26275.92	5.15	21177.41	0.15	6.75	1.22	1.97	0.89
Soybean in Gobhi sarson-soybean system	5098.51	25800.41	5.06	20701.90	0.14	6.92	1.20	1.93	0.87
SEm (±)	-	821.36	0.20	821.36	0.01	0.25	0.05	-	-
LSD *(p=0.05)*	-	2339.55	0.56	2339.55	0.02	0.72	0.14	-	-

Table 5: Cost of cultivation, gross returns, net returns, benefit cost ratio of different *rabi* oilseed

/pulse- *Kharif* oilseed / pulse systems taken from *rabi* 2014-15 to *kharif* 2016

Treatment	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C Ratio
	Mean	Mean	Mean	Mean
Chickpea -moongbean	37611	68220	30609	0.81
Field pea-moongbean	36568	95167	58598	1.60
Mustard-moongbean	34521	75235	40714	1.18
Gobhi sarson-moongbean	34436	82251	47815	1.39
Chickpea-uradbean	37536	64021	26485	0.71
Field pea-uradbean	36493	92680	56186	1.54
Mustard-uradbean	34446	74268	39821	1.16
Gobhi sarson-uradbean	34361	81687	47325	1.38
Chickpea - til	35147	52314	17166	0.49
Field pea- til	34104	79272	45167	1.32
Mustard- til	32057	62084	30026	0.94
Gobhi sarson- til	31972	69293	37320	1.17
Chickpea-soybean	41828	62147	20319	0.49
Field pea-soybean	40785	90191	49405	1.21
Mustard-soybean	38738	71000	32261	0.83
Gobhi sarson-soybean	38653	78580	39927	1.03