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Productivity, profitability and energy-use efficiency of different cropping sequences in northern transition zone of Karnataka

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ABSTRACT

Field experiment was conducted at Dharwad during 2005-06 and 2006-07 to identify most productive, resource-use efficient and remunerative cropping sequence for northern transition zone of Karnataka under rainfed condition. The treatments consisted of 24 treatment combinations (cropping sequences) of six *kharif* crops (potato, groundnut, soybean, Frenchbean for grain and vegetable and mungbean) which formed the main plots and four *rabi* crops (wheat**,** sorghum**,** chickpea and sunflower), which formed the sub-plots were grown in sequence. Among the cropping sequences, potato–sunflower and potato–chickpea recorded significantly higher groundnut equivalent yield (6 691 and 6 428 kg/ha, respectively), production efficiency (30.41 and 34.75 kg/ha/day), net returns (₹ 842 620 and 80 165/ha, respectively), energy-use efficiency (278.53 and 285.96 kg/1 000 MJ) and economic efficiency (₹ 383.01 and ₹ 433.32/ha/day) over the others. Land-use efficiency was highest with groundnut–sunflower and groundnut–sorghum (65.75%) which was comparable with potato–sunflower (60.27%). Potato–chickpea sequence recorded moderate land use efficiency (50.68%). However, the fertility status of soil was improved in soybean–chickpea cropping sequence. In other cropping sequences, the fertility status was maintained.

Key words: Cropping sequence, Economic efficiency, Energy yield, Groundnut equivalent yield, Net returns, Production efficiency

India is having 2.4 % of the world land area, but it has to feed 16.7 % of the world's population. To meet the growing demand of food, the only approach left is to go for intensive cultivation of crops per unit area per unit time per unit resource. In fact we have to produce needed quantity of food on one hand and sustain care for natural resources on other hand. To achieve these twin targets, we have to think for more productive, more efficient and remunerative cropping systems, which practice sustained use of natural resources. The northern transition zone of Karnataka receives an average annual rainfall of about 760 mm. This rainfall is well distributed in two peaks (July and October) and provides an opportunity for raising two crops in a sequence. The maximum temperature (27ºC–33ºC) and minimum temperature (16ºC–21ºC) are ideal for cultivation of rainy (*kharif)* and winter (*rabi*)crops studied in this experiment. The relative humidity is in the range of 50% (*rabi*) and 80% (*kharif*) which is also ideal for these crops. Nowaday's potato is gaining area in this zone under rainfed condition due to its higher productivity and market price. However, most of the farmers have not realized the importance of this crop and have been growing traditional sequences such as groundnut–sorghum, groundnut–sunflower, mungbean–wheat and soybean–wheat due to lack of information on suitable cropping sequence in terms of productivity, profitability, land-use efficiency and production efficiency. Further understanding the energetics (carbohydrate, protein and energy yield/ha) and energy-use efficiency of crop sequence may provide an additional information for identification of a better and efficient crop sequence for this zone. Hence the present study was carried out.

MATERIALS AND METHODS

The experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad during 2005–06 and 2006–07 under rainfed condition. The geographical co-ordinates of Dharwad are 15° 26' N latitude and 75° 7' E longitude and an altitude of 678 m above mean sea level. Dharwad is located in the northern transition zone (Zone 8) of Karnataka. The maximum and minimum temperatures from June to February (period of

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Table 1 Agronomic practices, input cost and output price of different crops

Agronomic practice	Crops								
	Kharif					*Rabi*			
	Potato	Groundnut	FB(G) and FB(v)	Soybean	Mungbean	Sorghum	Chickpea	Sunflower	Wheat
Seed rate (kg/ha)	1250	125	100	75	15	7.5	50	5	50
Fertilizer (N:P:K-kg/ha)	100:32.283	25:21.5:20.7	62.5:43:62.2	40:34.4:20.7	25:21.5:0	50:10.7:0	25:10.7:0	35:21.520.7	50:10.7:0
Spacing (cm × cm)	60×30	30×10	30×10	30×10	30×10	45×15	30×10	60×30	23×5
Genotypes	Kufri Phukraj	JL 24	Contender	JS 335	Chinamung	M 35-1	A 1	KBSH 1	DWR 2006
Method of sowing	Planting of potato buds	Dibbling	Dibbling	Dibbling	Dibbling	Dibbling	Dibbling	Dibbling	Dibbling
Date of sowing of crops			30-06-05 29-06-06				22-10-05 15-10-06		
Date of harvest	30-9-05 29-9-06	20-10-05 29-10-06	24-9-05 24-9-06	30-9-05 29-9-06	10-9-05 9-9-06	2-3-06 25-2-07	27-1-06 21-1-07	4-3-06 26-2-07	15-2-06 7-2-07
	Input cost (₹/ha) and output price (₹/kg)								
Cultural operations (₹/ha)	6 657	6 427	6 279	6 277	6 277	5 097	5 207	5 417	5 407
Nutrients (₹/ha) (NPK + FYM)	8 161	5 560	5 484	4 500	3 618	966	529	1 508	966
Seed (₹/ha)	12 000	6 000	5 400	1 725	450	135	1 750	340	1 000
Output price main (₹/kg)	5.0	17.75	20	13	25	6.0	19.0	14.5	7.8
Byproduct (₹/kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

cropping sequence) are 27^{0}C to 33^{o}C and 16^{0}C to 21^{o}C, respectively. The soil of the experimental site was clayey which was low in available N (212 kg/ha), medium in P (13.7 kg/ha) and high in K (270.6 kg/ha). Organic carbon (%) and *p*H of the soil were respectively 0.52 % and 7.2. The treatments consisted of 24 treatment combinations (cropping sequences) of six *kharif* crops (potato, groundnut, soybean, Frenchbean for grain and vegetable and mungbean) which formed the main plots and four *rabi* crops (sorghum**,** chickpea sunflower and wheat), which formed the sub-plots. The experiment was laid out in split-plot design with three replications. All the crops were grown with recommended practices (Table 1). The data were subjected to statistical analysis as prescribed by Gomez and Gomez (1984) and significant highest order interaction effects were presented and discussed in this paper. Yield advantages and monitory benefits were calculated for the cropping sequences (*kharif-rabi*). Groundnut equivalent yield was calculated by using following formula.

$$\text{Groundnut equivalent yield (kg/ha)} = \frac{[(^{*}\text{yield of } \textit{kharif} \text{ crop (kg/ha)}) \times (\text{price of that crop}) + [(^{*}\text{yield of } \textit{rabi} \text{ crop (kg/ha)}) \times (\text{price of that crop})]}{\text{Price of groundnut (₹/kg)}}$$

*Yield= yield of both main and byproduct

Production efficiency, economic efficiency and land-use efficiency were calculated (Patil *et al.* 1995). The energetics (protein, carbohydrate and energy yield/ha) of cropping sequences were calculated (Gangwar *et al*., 2003) by using the nutrient contents as suggested by Gopalan *et al*., (1978). Energy budgeting was done according to Mittal *et al.* (1985) and energy use efficiency was calculated as suggested by Padhi (2001).Sustainable yield index of sequences was computed by using the following formula.

$$\text{SYI} = \frac{\text{Y-S}}{\text{Y}_{max}}$$

Where 'Y' is the average equivalent yield of a sequence

'S' is the standard deviation of equivalent yield over a period of years.

Y max is the maximum equivalent yield of a sequence in a certain year.

RESULTS AND DISCUSSION

Groundnut equivalent yield

Among all the cropping sequences, potato–sunflower and potato–chickpea sequences recorded significantly higher groundnut equivalent yield (6 691 and 6 428 kg/ha) than other sequences (Table 2). These sequences respectively recorded 75.01 and 68.14% higher groundnut equivalent

yield over groundnut-*rabi* sorghum sequence (popular sequence of this area). This was attributed to higher yield of potato (18 590 and 17 732 kg/ha, respectively), sunflower (1 344kg/ha) and chickpea (995 kg/ha) in these two sequences. The higher market price fetched by main product (₹ 5, 14.5 and 19/kg, respectively) and byproduct (₹ 0.5/kg) of these crops also contributed to higher groundnut equivalent yield.

Energetics

When the sequences were considered for the yield of energetics (Table 2), all the soybean-based sequences recorded significantly higher protein yield (1.043 to 1.095 × 10^6 g/ha) than other sequences (0.373 to 0.989 × 10^6 g/ha). While potato-based sequences were significantly higher in carbohydrate yield (4.44 to 4.86 × 10^6g/ ha) compared to other sequences. Energy yield was significantly higher with potato and groundnut-based sequences (21.78 to 26.36 and 22.81 to 25.24 x 10^6 k cal/ ha, respectively) than with other sequences). This was attributed to higher carbohydrate (22.6%), fat (40.1%) and protein (43.2%) content in potato, groundnut and soybean, respectively.

These results are in conformity with that of Gangwar *et al*. (2003) and Gangwar *et al*. (2006). They also reported the higher carbohydrate and energy yield with potato and groundnut-based sequences and higher protein yield with soybean-based sequences.

Energy budgeting

Energy used for raising different crops was computed to augment energy-use efficiency (Table3). As per computation, input energy differed due to difference in energy use under different sequences. In the present investigation, output energy was significantly higher in groundnut–sorghum (199.11×10^3 MJ/ha) groundnut–sunflower (188.33×10^3 MJ/ha) sequences (Table 2) due to the higher yield of their byproducts. Output-input ratio was significantly higher in soybean- sorghum (10.14) over other sequences due to lower input energy required by it (12.77×10^3 MJ/ha) compared to its output energy (129.47×10^3 MJ/ha). The output energy, however, is dependent on economic part of the crop as well as dry fodder and straw yields of different sequences. Hence energy use efficiency is good indicator to interpret energy relationship of different sequences, which is discussed under separate heading (system efficiency).

Table 2 Yield, equivalent yield and energetics of different cropping sequences (pooled data of two years)

Cropping sequence	Yield (kg/ha)				Groundnut equivalent yield (kg/ha)	Energetics		
	Kharif crop		*Rabi* crop			Carbohydrate yield (10^6 g/ ha))	Protein yield (10^6 g/ ha)	Energy yield (10^6 k cal)
	Main product	Byproduct	Main product	Byproduct				
Potato– sorghum	16 152	3 230	1 662	2 476	5 439	4.86	0.431	21.78
Potato – chickpea	17 732	3 546	995	1 483	6 428	4.61	0.387	22.78
Potato – sunflower	18 590	3 718	1 344	2 003	6 691	4.44	0.437	26.36
Potato – wheat	16 682	3 336	1 070	1 594	5 478	4.53	0.378	21.88
Groundnut– sorghum	3 173	4 728	1 821	2 713	3 823	2.15	0.967	24.34
Groundnut – chickpea	3 231	4 814	1 037	1 545	4 387	1.47	0.969	22.05
Groundnut – sunflower	2 862	4 264	1 455	2 168	4 068	1.01	0.989	25.24
Groundnut – wheat	3 258	4 854	1 250	1 863	3 812	1.74	0.937	22.81
Soybean – sorghum	2 012	2 998	1 873	2 791	2 135	1.78	1.064	15.22
Soybean – chickpea	1 984	2 956	1 089	1 623	2 659	1.08	1.043	12.49
Soybean – sunflower	1 845	2 749	1 506	2 244	2 592	0.65	1.095	17.30
Soybean – wheat	2 153	3 208	1 100	1 639	2 056	1.23	1.052	13.10
French bean(G) – sorghum	1 954	2 911	1 790	2 667	2 872	2.48	0.633	13.01
French bean(G) – chickpea	1 898	2 828	1 083	1 614	3 376	1.81	0.620	10.46
French bean(G) – sunflower	1 982	2 953	1 289	1 921	3 333	1.43	0.709	14.85
French bean(G) – wheat	2 040	3 040	1 331	1 983	2 921	2.18	0.615	11.66
French bean(V) –sorghum	7 537	2 261	1 762	2 625	2 890	1.62	0.311	8.11
French bean(V) – chickpea	7 872	2 362	1 162	1 731	3 655	1.06	0.330	6.23
French bean(V) – sunflower	7 497	2 249	1 522	2 268	3 510	0.61	0.429	11.38
French bean (V) – wheat	7 296	2 189	1 136	1 693	2 692	1.14	0.250	5.83
Mungbean –sorghum	1 018	1 517	1 794	2 673	2 357	1.91	0.436	9.80
Mungbean – chickpea	880	1 311	1 138	1 696	2 751	1.22	0.410	7.16
Mungbean – sunflower	1 019	1 518	1 307	1 947	2 801	0.84	0.508	11.65
Mungbean – wheat	974	1 451	1 213	1 807	2 179	1.45	0.373	7.58
SEm ±					92	0.14	0.037	1.56
CD (*P*=0.05)					272	0.43	0.110	4.59

System efficiency

Production efficiency was significantly higher in potato–sunflower and potato–chickpea sequences (30.41 and 34.75 kg/ha/day) compared to others. The major contribution for higher production efficiency (Table 3) of these sequences were by the potato rather than sunflower and chickpea, which recorded tuber yield of 16 152 and 17 732 kg/ha in a short span of 90 days. While sunflower and chickpea recorded grain yield of 1 344 and 995 kg/ha in a duration of 130 and 95 days (Table 3). Since the main constituent of economic part of potato is starch (carbohydrate), the conversion factor for 1 g glucose to carbohydrate is highest (0.83) compared to pulses (0.43) and oilseeds (0.32). Apart from this, the sink capacity was highest in the potato compared to pulses and oilseeds; hence it recorded voluminous yield over other crops. Prasad *et al.* (2011) also observed highest production efficiency in rice-potato-cowpea sequence (83.97 kg/ha/ day) over others (32.57 to 64.82 kg/ha/day)

Potato–sunflower sequence recorded higher land use efficiency (60.2%) which was comparable with highest land use efficiency recorded in the study (65.75%) by groundnut–sunflower and groundnut-sorghum sequences (Table 3). Since these sequences occupied the land for longer duration (240 days) their LUE was highest. The least land-use efficiency was in Frenchbean (vegetable)–chickpea sequence (41.1%) which occupied the land for 150 days. Reddy and Kumar (1999) also obtained highest land utilization index in sunflower–groundnut–greengram (80%), followed by sunflower–maize–greengram (76%).

Economic efficiency (Table 3) was also significantly higher in potato–sunflower (383.01 ₹/ha /day) and potato-chickpea sequences (₹ 433.32/ha/day) compared to other sequences (₹ 58.55 to ₹ 318.01/ha/day), which was attributed to higher net returns (₹ 84 262 and 80 165/ha) obtained in these sequences. These results are in agreement with that of Prasad *et al*. (2011).

Among the sequences, potato–chickpea (285.96 kg/1000 MJ) and potato–sunflower sequences (278.53 kg/1 000 MJ) recorded significantly higher energy-use efficiency (Table 2) over others, since these systems have recorded higher groundnut equivalent yield (6 428 and 6 691 kg/ha, respectively) in relation to their input energy (22.12 and 23.60 $\times 10^3$ MJ/ha).

Table 3 System efficiency and energy budgeting of different cropping sequences (pooled data of two years)

Cropping sequence	Land-use efficiency (%)	Total duration of the sequence	Production efficiency (kg/ha/ day)	Economic efficiency (₹/ha/ day)	Energy-use efficiency (kg/1 000 MJ)	Energy budgeting		
						Output (1 000 MJ/ha)	Input (1 000 MJ/ha)	Output/ input ratio
Potato– sorghum	60.27	220	24.72	288.34	223.09	145.84	23.92	6.10
Potato – chickpea	50.68	185	34.75	433.32	285.96	132.46	22.12	5.99
Potato – sunflower	60.27	220	30.41	383.01	278.53	162.74	23.6	6.90
Potato – wheat	54.79	200	27.39	318.01	217.81	129.08	24.55	5.26
Groundnut–sorghum	65.75	240	15.93	190.21	176.59	199.11	21.61	9.21
Groundnut – chickpea	56.16	205	21.40	264.55	221.56	175.51	19.81	8.86
Groundnut – sunflower	65.75	240	16.95	202.75	190.68	188.33	21.29	8.85
Groundnut – wheat	60.27	220	17.33	197.66	169.69	183.79	22.23	8.27
Soybean –sorghum	60.27	220	9.70	98.35	172.14	129.47	12.77	10.14
Soybean – chickpea	50.68	185	14.37	159.46	249.03	102.41	11.31	9.05
Soybean – sunflower	60.27	220	11.78	129.22	212.78	120.31	19.49	6.17
Soybean – wheat	54.79	200	10.28	92.0	156.64	100.39	13.4	7.49
French bean(G)–sorghum	57.53	215	13.36	138.85	178.66	124.77	16.4	7.61
French bean(G)–chickpea	47.95	180	18.76	207.43	235.78	99.34	14.6	6.80
French bean(G)–sunflower	57.53	215	15.50	171.50	211.03	122.28	16.08	7.60
French bean(G)–wheat	52.05	195	14.98	147.79	173.15	112.34	17.03	6.60
French bean(V)–sorghum	50.68	185	15.62	163.98	223.93	108.46	18.69	5.80
French bean(V)–chickpea	41.10	150	24.38	225.45	193.74	90.68	16.89	5.37
French bean(V)–sunflower	50.68	185	18.97	198.83	188.28	115.88	18.37	6.31
French bean (V)–wheat	45.21	165	16.31	134.37	135.32	86.01	19.32	4.45
Mungbean–sorghum	54.79	200	11.78	74.52	148.41	93.71	11.53	8.13
Mungbean–chickpea	45.21	165	16.68	135.65	226.51	67.25	9.73	6.91
Mungbean–sunflower	54.79	200	14.00	112.20	192.23	90.98	14.54	6.26
Mungbean–wheat	49.32	180	12.11	58.55	125.91	72.88	12.15	6.00
SEm ±			1.51	7.02	9.42	4.81		0.30
CD (*P*=0.05)			4.43	19.44	27.71	13.32		0.83

Economics of cropping sequences

The superiority of potato–sunflower/chickpea in terms of productivity among the sequences was further strengthened by higher net returns (₹ 842 622/ha and ₹ 80 165/ha, respectively) and B:C ratio (3.45 and 3.31 respectively). These sequences recorded 84.58 and 75.60% higher net returns over groundnut-*rabi* sorghum, which was a popular cropping system of this area (Table 4). This was attributed to higher yield (main and byproduct) of potato, sunflower and chickpea and the market prices fetched by them. Gangwar *et al.* (2006) also reported that potato-based sequence recorded higher net returns than the cereal, pulse and oilseed-based sequences. Prasad *et al*. (2011) also observed higher net returns with rice–potato–cowpea sequence (₹ 116 929/ha) over others (₹ 15 249–77 661/ha).

Sustainable yield index

Sustainable yield index (SYI) was also highest in potato–sunflower (0.78), followed by potato–chickpea (0.75) sequences compared to other sequences. This clearly indicates the sustainability of these sequences over the years.

Fertility status of the soil

On perusal of initial and final status of soil fertility, it was revealed that the fertility status was maintained with the use of recommended doses of nutrients in different crop sequences (Table 4). Available N and P were significantly higher in pulse-based sequence (growing of pulses in both the seasons), viz soybean–chickpea (290.8 and 16.0 kg/ha) compared to other sequences. Available K was also high with soybean–chickpea (324.8 kg/ha) which was at par with potato–chickpea (323.1 kg/ha), potato–sunflower (322.6 kg/ha) and soybean–sunflower (322.4 kg/ha).

Thus it can be concluded that among different cropping sequences, potato–sunflower and potato–chickpea sequence was more productive, profitable, sustainable and efficient in using energy compared to other cropping sequences studied. Land-use efficiency was high for potato–sunflower (60.2%) and medium for potato–chickpea (50%).

Table 4 Economics and available nutrient status of the soil after harvest of *rabi* crops in different cropping sequences (pooled data of two years)

Cropping sequence	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	Available nutrient status of the soil (kg/ha)			SYI
				N	P	K	
Potato–sorghum	95 750	63 435	2.90	236.15	14.3	302.0	0.60
Potato–chickpea	114 882	80 165	3.31	246.77	14.8	322.6	0.75
Potato–sunflower	118 671	84 262	3.45	256.91	15.4	323.1	0.78
Potato–wheat	98 132	63 602	2.84	242.09	14.0	307.6	0.60
Groundnut–sorghum	70 120	45 650	2.87	255.84	14.4	295.6	0.37
Groundnut–chickpea	80 105	54 234	3.10	287.72	15.2	306.0	0.45
Groundnut–sunflower	74 225	48 660	2.90	253.11	15.4	315.0	0.41
Groundnut–wheat	69 171	43 486	2.69	261.79	14.2	298.0	0.36
Soybean–sorghum	40 778	21 636	2.13	255.65	14.8	296.4	0.13
Soybean–chickpea	50 043	29 499	2.44	290.84	16.1	324.8	0.21
Soybean–sunflower	48 666	28 429	2.41	257.89	15.7	322.4	0.19
Soybean–wheat	38 756	18 399	1.90	264.42	14.5	297.2	0.11
French bean(G)–sorghum	53 812	29 853	2.25	253.99	14.6	297.4	0.24
French bean(G)–chickpea	62 698	37 338	2.47	281.09	15.0	307.7	0.31
French bean(G)–sunflower	61 926	36 873	2.42	246.77	15.5	316.6	0.31
French bean(G)–wheat	53 992	28 819	2.15	254.67	14.1	297.9	0.24
French bean(V)–sorghum	54 672	30 336	2.25	256.72	14.3	297.2	0.24
French bean(V)–chickpea	59 555	33 817	2.31	282.17	14.8	307.6	0.29
French bean(V)–sunflower	62 215	36 783	2.45	249.21	15.3	315.7	0.32
French bean (V)–wheat	47 723	22 172	1.87	256.91	13.9	298.0	0.19
Mungbean–sorghum	31 762	14 903	1.88	253.31	14.6	296.5	0.05
Mungbean–chickpea	40 643	22 383	2.23	279.05	14.9	304.5	0.13
Mungbean–sunflower	40 393	22 439	2.25	244.04	15.4	312.5	0.12
Mungbean–wheat	28 393	10 539	1.58	253.11	14.1	293.1	0.03
SEm ±	1 579	1 580	0.14	0.81	0.15	0.92	
CD (*P*=0.05)	4 231	4 234	0.42	2.17	0.40	2.46	

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