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Research Paper

Productivity, profitability and soil sustainability of small-holding farming system through suitable cropping systems

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ABSTRACT

A field experiment was conducted at the Centre for Research on Integrated Farming Systems, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, during 2016–17 to 2018–19, to study the effect of different cropping system as component of small-holding farming systems of North Gujarat. Total 8 cropping systems were evaluated based on system productivity, system profitability and possible viability. The pooled result of 3 years experiments indicated that, pearlmillet [*Pennisetum glaucum* (L.) R. Br.]–potato (*Solanum tuberosum* L.)–groundnut (*Arachis hypgaea* L.) cropping system recorded significantly higher groundnut-equivalent yield (8.65 t/ha) and same trend was observed in cropping sequences for system productivity (23.70 kg/ha/day), system profitability (₹ 613/ha/day) and net profit (₹ 223,610/ha), which was at par with groundnut– potato–pearlmillet (₹ 203,605/ha) and Bt. cotton (HDP) (*Gossypium* sp.)–wheat (*Triticum aestivum* L.)–fodder sorghum [*Sorghum bicolor* (L.) Moench] (₹ 192,540/ha) cropping sequence. The crop sequence castor (*Ricinus communis* L.)-all in greengram [*Vigna radiate* (L.) R. Wilczek] recorded the highest benefit : cost ratio (1.83), while Bt. cotton + sunhemp (*Crotalaria juncea* L.) (incorporation at flowering stage)-castor–bitter gourd (*Momordica charantia* L.) generated the maximum employment generation (303 man-days/year), followed by Bt. cotton (HDP) + wheat–fodder sorghum (259 man-days/year).

Key words: Diversification, Employment generation, High-density plantation, Land-use efficiency, System productivity, System profitability

For sustainability in an agricultural system, diversifying cropping systems is desirable in rotation with other cereals like wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), high-value crops like spices, fibre, vegetables, legumes, oilseed or fodder crops is one way for farmers to optimize their use of resources. Diversified cropping systems broaden the source of a farmer's food and income, increases their land productivity and minimizes unpredictable risks such as the build-up of pests and diseases. Crop diversification has been recognized as an effective strategy for achieving the objectives of food and nutrition security, income growth, poverty alleviation, employment generation and the judicious use of land and water resources, sustainable agriculture development and environmental improvement. Thus, both the number and type of crops included in the cropping sequence are important. Hence, it was felt necessary to work out a location-specific cropping system for North Gujarat, which can utilize resources judiciously to maximize returns, protect the environment and meet the day-to-day requirements of human and animals. Efforts are being made to promote diversification of cropping sequences in this zone with fodder, legumes, vegetables, spices, fibre and oilseed crops for sustaining the productivity and profitability.

MATERIALS AND METHODS

A field experiment was conducted at Centre for Research on Integrated Farming Systems, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India, during rainy (*kharif*)-winter (*rabi*)-summer seasons of 2016–17 to 2018–19. Therefore, an experiment was conducted to find out a suitable cropping system by introducing different crops like cereal, pulses, oilseeds, legume, fodder and cash crops. The experimental soil was loamy sand in texture, alkaline in reaction (*p*H 7.6), having 0.30% organic carbon, 224 kg/ha available nitrogen , 24.18 kg/ha P_2O_5 and 242 kg/ha K_2O. The region is predomi-

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nantly humid and diurnal and seasonal variations in temperature remain in a narrow range. Total 13 crops are cultivated in different cropping systems with different role as per theme. Among them, 8 cropping systems, viz. T_1, groundnut (*Arachis hypogaea* L.)–potato (*Solanum tuberosum* L.)–pearl millet [Pennisetum glaucum (L.) R. Br.]; T_2, castor (*Ricinus communis* L.)–greengram (*Vigna radiata* L.); T_3, groundnut–wheat (*Triticum aestivum* L.) + lucerne (*Medicago sativa* L.) (2:2)-greengram; T_4: Bt. cotton (*Gossypium* sp.) + sunhemp (*Crotalaria juncea* L.) (1:2)–castor–cotton–castor relay-bitter gourd (*Momordica charantia* L.); T_5, greengram–fennel (*Foeniculum vulgare* L.) + cauliflower (*Brassica oleracea* var. botrytis) (1:1)–fennel; T_6, forage sorghum–lucerne; T_7, pearlmillet–potato–groundnut.; T_8, Bt. cotton (HDP)–wheat–forage sorghum, were tried in a randomized block design with 3 replications. The N, P and K were supplied through urea and diammonium phosphate, respectively as per the recommended dose of respective, crops. Common application of FYM @ 10 t/ha was applied during the *kharif* season for all the treatments. Greengram and sunhemp were incorporated into the soil after picking the pods at harvesting and sunhemp was incorporated at flowering stage for soil improvement. Economic yield of the component crops was converted into groundnut-equivalent yield (GEY) taking into account the prevailing farm gate price (₹/kg) of crop produce. The productivity of different cropping systems was compared by calculating their economic groundnut-equivalent yield. System productivity was calculated as the ratio of kg GEY/ha/total crop duration of the system in days. The representative soil samples were collected and analyzed for organic carbon, available nitrogen, phosphorus and potassium after completion of crop sequence. The cost of cultivation was calculated based on existing input cost. Net returns were calculated by subtracting cost of cultivation from gross income of system. The benefit : cost ratio (BCR) was worked out dividing net returns by the cost of cultivation. The data on yield of crops and dry-matter production of crops under cropping system and economics were recorded and subjected to statistical analysis. No severe pests and diseases were observed during the crop growth; however, necessary plant-protection measures were taken on need basis. Optimum plant population was maintained for different crops.

RESULTS AND DISCUSSION

Groundnut-equivalent yield and economics

The results presented in Table 1 indicated that, pearl millet–potato–groundnut recorded significantly higher groundnut equivalent yield, which was at par with groundnut–potato–pearl millet (8,098 kg/ha) and Bt. cotton (HDP)–wheat–fodder sorghum (7.11 t/ha). Pooled results of 3 years indicated that the pearl millet–potato–groundnut system gave significantly higher gross profit (₹ 378,800/ha) and net returns (₹ 223,610/ha), which was at par with same cropping sequences, groundnut–potato–pearlmillet (₹ 356,760/ha) and Bt. Cotton (HDP)–wheat–fodder (₹ 311,050/ha). The crop sequence castor–continue–greengram showed the highest benefit : cost ratio (1.83) followed by fodder sorghum–lucerne fodder–continue (1.75) (Table 1). The results conformed the findings of Gangwar *et al.* (2012) and Patel *et al.,* (2019).

System productivity, profitability and employment generation

In case of employment generation (Table 2), crop sequence Bt. cotton + sunhemp–castor–bitter gourd generated the maximum employment (303 man-days/year), followed by Bt. cotton (HDP) + wheat–fodder sorghum (259 man-days/year). Data presented in the Table 2 revealed that, the system productivity was the highest under pearl millet–potato–groundnut (23.70 kg/ha/day), followed by

Table 1. Groundnut-equivalent yield (kg/ha) and economics (₹/ha) as influenced by different cropping sequences (pooled data of 3 years)

Treatment	Cropping system	Pooled (× 10^3 ₹/ha)			Benefit: cost
		Groundnut equivalent yield*	Gross returns	Net returns	
T_1	Groundnut–potato–pearlmillet	8.10 ^{ab}	357	204	1.33
T_2	Castor–castor greengram	4.87 ^{d}	213	138	1.83
T_3	Groundnut–wheat + lucerne (2 : 2)–greengram	5.86 ^{cd}	256	151	1.43
T_4	Bt cotton + sunhemp–castor relay bitter gourd	6.85 ^{bc}	302	175	1.38
T_5	Greengram-fennel + cauliflower (1:1)	4.94 ^{d}	217	126	1.40
T_6	Fodder sorghum–fodder lucerne	5.88 ^{cd}	255	162	1.75
T_7	Pearlmillet–potato–groundnut	8.65 ^{a}	379	224	1.44
T_8	Bt. cotton (HDP)–wheat–fodder sorghum	7.11 ^{abc}	311	193	1.62
SEm±		0.56	25.26	8.06	–
CD (P=0.05)		1.69	76.64	23.00	–
Y × T		S	–	–	–

*GEY as per Duncan's Multiple Range Test; a b c for comparing treatments groundnut–potato–pearlmillet crop sequence (22.19 kg/ha/day), while the lowest was recorded under crop sequence of castor–continue–greengram (13.34 kg/ha/day). A same trend was observed with system profitability. The highest system profitability was registered with the treatment pearl millet–potato–groundnut (₹613/ha/day), followed by groundnut–potato–pearl millet (₹558/ha/day), while the lowest under greengram–fennel + cauliflower–continue (346 ₹/ha/day).

Nutrient productivity, water productivity and land-use efficiency

The highest nutrient productivity was registered in fodder sorghum–fodder lucerne (32.64 kg/kg), followed by groundnut–wheat + lucerne–greengram. In case of water productivity, the highest water productivity was recorded with pearl millet–potato–groundnut (8.51 kg/ha-mm), followed by T_1, groundnut–potato–pearl millet crop sequence (7.97 kg/ha-mm) (Fig. 1). The land-use efficiency was the highest under Bt. cotton + sunhemp–castor relay continue–bitter gourd (102.4%) due to relay cropping of castor cropping system, which was followed by Bt. Cotton (HDP) + wheat–fodder sorghum (Table 2). These results are in agreement with the findings of Khosla *et al*. (2000), Singh and Ahlawat (2012), Rajkumara *et al.* (2014), and Singh *et al.* (2017).

Soil-fertility status at the end of the crop sequence (2018–19)

The data presented in Table 3 indicated that, the highest available nitrogen (242.75 kg/ha), available phosphorus (31.92 kg/ha) and available potassium (257.6 kg/ha) were noted with groundnut–wheat + lucerne–greengram and pearl millet–potato–groundnut (30.92 kg/ha). The organic carbon was the highest (Fig. 2) under Bt. cotton (HDP)–wheat– fodder sorghum (3.83 g/kg). Minimum bulk density value (1.493 g/cc) was recorded in Bt cotton + sunhemp–castor relay continue–bitter gourd and maximum water-holding capacity recorded in groundnut–wheat + lucerne–greengram (31.54 %). Status of available N, P, K, organic carbon content and water-holding capacity (%) were improved over its initial status owing to different cropping sequences.

It can be concluded that the pearl millet–potato–groundnut or groundnut–potato–pearl millet or Bt cotton (HDP) wheat–fodder sorghum crop sequence recorded higher

Table 2. System productivity, profitability, employment generation and land use efficiency as influence by different cropping systems

Treatment	Cropping system	System productivity (kg/ha/day)	System profitability (₹/ha/day)	Employment generation (man-days/ ha/year)	Land-use efficiency (%)
T_1	Groundnut–potato–pearlmillet	22.19	558	245	76.26
T_2	Castor–castor greengram	13.34	378	142	61.64
T_3	Groundnut–wheat + lucerne (2 : 2)–greengram	16.05	412	244	74.79
T_4	Bt cotton + sunhemp–castor relay bitter gourd	18.77	479	303	103.20
T_5	Greengram-fennel + cauliflower (1:1)	13.53	346	197	59.73
T_6	Fodder sorghum–fodder lucerne	16.10	445	205	66.30
T_7	Pearlmillet–potato–groundnut	23.70	613	252	76.35
T_8	Bt. cotton (HDP)–wheat–fodder sorghum	19.47	528	259	98.81

Table 3. Soil fertility status at the end of cropping sequence of initial year 2018–19

Treatment	Available nutrients (kg/ha)			*p*H	EC (dS/m)	Bulk density (g/cc)	Water-holding capacity (%)
	N	P	K				
T_1	242.78	31.72	257.60	7.41	0.163	1.497	30.66
T_2	238.07	27.53	248.27	7.36	0.168	1.497	30.10
T_3	236.51	30.92	245.84	7.36	0.206	1.505	31.54
T_4	242.52	30.32	252.37	7.31	0.180	1.493	29.90
T_5	234.68	29.32	247.52	7.39	0.159	1.503	29.95
T_6	238.60	28.52	250.69	7.38	0.196	1.495	30.95
T_7	241.99	30.92	255.36	7.42	0.166	1.478	29.73
T_8	236.77	28.53	245.28	7.40	0.231	1.499	29.75
Initial	224.00	24.18	242.00	7.33	0.142	1.472	30.8

EC, electrical conductivity
Details of treatments are given under Materials and Methods

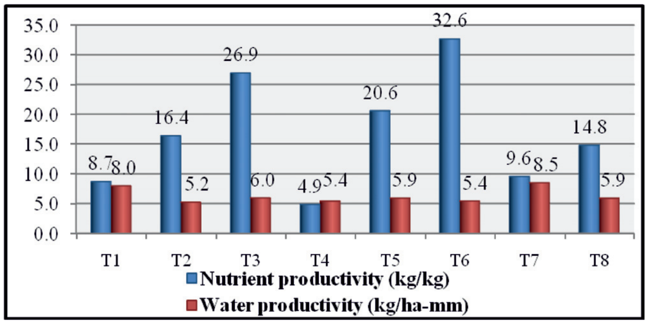

Fig. 1. Nutrient productivity and water productivity of different treatments (Details of treatments are given under Materials and Methods)

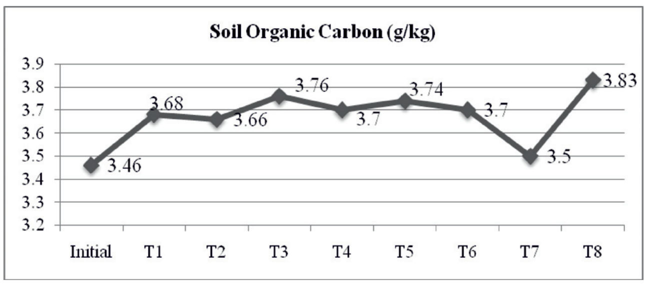

Fig. 2. Effect of soil organic carbon (g/kg) of different treatments (Details of treatments are given under Materials and Methods)

production and net income.

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