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Diversification of cropping systems under assured irrigated conditions in central plateau zone of Maharashtra

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ABSTRACT

A field experiment was conducted for three consecutive years (2005-2007) at Parbhani to find out most productive and profitable cropping system. Among the different cropping systems, highest wheat [(*Triticum aestivum* (L.) emend. Fiori & Paol] equivalent yield (19.9 t/ha) and net monetary returns (₹107.8x10^3/ha) were obtained from soybean [*Glycine max* (L. Merr.)]–onion (*Allium capa* L.) cropping system, followed by turmeric (*Curcuma domestica* L.)+ castor (*Ricinus communis* L.) (WEY-14.0 t/ha, and NMR ₹89.8x10^3/ha). The soybean–onion system also recorded maximum net monetary advantage per unit time (₹573/ha/day), employment (374 mandays) and water use efficiency (221 kg/ha-cm), followed by turmeric+castor intercropping system. The highest nutrient uptake was recorded in sorghum [*Sorghum bicolor* (L.) Moench]–wheat followed by maize (*Zea mays* L.) + cowpea (*Vigna sinensis* L.)–wheat and maize–wheat cropping systems. The highest soil nutrient status was observed in cotton (*Gossypium* sp.)–summer groundnut (*Arachis hypogaea* L.) followed by soybean–onion cropping systems.

Key words : Cropping systems, Crop productivity, Economics, Nutrient uptakes, Soil fertility, Water use efficiency.

Cropping system needs to be inherently flexible to take advantage of economic opportunities and or adapt to environmental realities. A dynamic cropping systems concept characterized by a management approach, whereby crop sequencing decisions are made on an annual basis which has been proposed to improve the adaptability of cropping practices to externalities. A dynamic cropping system represents a long-term strategy of annual crop sequencing that optimizes crop and soil use options to attain production, economic and resource conservation goals by using sound ecological management principles. Dynamic cropping systems are region-specific, differing in their crop portfolios (i.e., adapted crop species) from one region to another. Critical to the successful implementation of dynamic cropping systems within a region is a thorough understanding of short-term crop sequencing effects on relevant agronomic and environmental parameters. Such short-term research efforts can help to identify crop sequence synergisms and antagonisms, thereby providing the necessary foundation for developing strategies to sequence crops over a longer period of time. Sorghum-wheat is a most dominating crop sequence of Marathwada region. Continuous cropping of cereal-cereal crop sequence over long period of time reduces productivity and soil fertility. In view of this, an investigation was carried out for three consecutive years to find out the relatively profitable and remunerative crop sequences, which maintains the soil health too.

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MATERIALS AND METHODS

The field experiment was conducted for three consecutive cropping seasons on fix site during 2005 to 2007 at main station farm of All India Coordinated Research Project on Integrated Farming Systems, Marathwada Krishi Vidyapeeth, Parbhani (19^0.16' N Latitude and 76^0.48' E Longitude and 409 m above mean sea level). The average maximum and minimum atmospheric temperatures were 30.1 ÚC and 25.5 ÚC respectively. The average relative humidity was 70.5 % in morning and 36.3 % in the evening. Rainfall received during 2005-2006, 2006-2007 and 2007-2008 was 994.6, 861.2 and 767.1 mm, respectively. The soil type was vertisol having pH 7.8, EC 0.22 dS/m, organic carbon 0.45%, available N 240 kg/ha, P 17.14 kg/ha and K 484 kg/ha. Soil (0-15 cm) and plant samples were collected after every crop sequence and analysed following standard procedures, for their nutrient status. The experiment was laid out in randomized block design with three replications and twelve crop sequences viz., sorghum 'CSH-9' – wheat 'Lok-1', cotton

'PH-348' - summer groundnut 'TAG-26', soybean 'MAUS-71' – onion 'AFLR', greengram 'kopergaon'-*rabi* sorghum 'CSH-9', soybean 'MAUS-71'-wheat, soybean–chilli 'Jwala', pigeonpea 'BSMR-736'-pearlmillet 'AIMP-92901', maize 'PMH-19'-wheat, maize+cowpea 'Pusa barsati'-wheat, sole turmeric Salem', turmeric + castor 'DCH-9' (4:1 ratio) and sole castor 'DCH-9'. The recommended dose of NPK (kg/ha) for sorghum 80:40:40, wheat 100:50:50, cotton 80:40:40, groundnut 25:50:0, soybean 30:60:0, onion 100:50:50, greengram 25:50:0 and *Rabi* sorghum 80:40:40, chilli 100:50:50, pigeon pea 25:50:0, pearlmillet 60:30:30, maize 100:50:50, turmeric 100:50:50 and castor 60:40:30 was applied. Rainfall received during 2005-2006, 2006-2007 and 2007-2008 were 994.6, 861.2 and 767.1 mm, respectively. The irrigations were given as per need of the crop and at each irrigation 60 mm water applied. Final crop yields were recorded and their net monetary returns were calculated on the basis of average market prices of the produce. The intercultural operations, seed rate, spacing and plant protection measures were carried out as per the recommendations of respective crops in the command area.

RESULTS AND DISCUSSION

Yield of component Crops

The year wise data regarding grain yield and fodder yield of different crop sequences is presented in Table 1. Based on mean, onion recorded the highest productivity (26.14 t/ha) over three years experimentation followed by turmeric and wheat. The mean cotton and groundnut productivity was 1.61 t/ha and 2.35 t/ha respectively, while the mean crop productivity of sorghum and wheat was recorded 2.34 and 3.82 t/ha respectively. Similarly in case of sorghum-wheat system, the productivity of sorghum and wheat was 3.81 and 4.16 t/ha respectively. The productivity of sole turmeric rhizome was 12.31 t/ha. The least productivity was recorded in greengram-sorghum crop sequence (0.70 and 2.17 t/ha respectively). The results indicate that onion and turmeric were more contributor to the system productivity than the other crops. This might be owing to the higher production potential of these crops than grain crop. The above results are in conformity with the findings reported by Reddy and Suresh (2008) and Sarkar and Gangwar (1998).

Wheat equivalent yield

Based on three years mean, maximum wheat equivalent yield (WEY) (19.9 t/ha) was obtained from soybean-onion cropping system, which was significantly superior over turmeric + castor (14.0 t/ha) and sole turmeric (11.6 t/ha). Cotton-groundnut cropping system occupied fourth position in term of WEY (9.0 t/ha) (Table 1). The high selling

Table 1. Grain, fodder and wheat equivalent yield (t/ha) of different crops and cropping systems

Crop sequences	Grain yield 2005-06			Grain yield 2006-07			Grain yield 2007-08			Wheat equivalent yield (WEY)				**Monetary Advantage on NMR basis (₹/ha/day) Mean	**Land use Efficiency (%) Mean
	K	R	S	K	R	S	K	R	S	2005-06	2006-07	2007-08	Pooled Mean		
Sorghum-wheat	3.2 *(7.8)	4.8		4.3(5.7)	4.7		3.9(7.4)	2.9		7.1	7.5	5.7	6.8	161.7	61.0
Cotton-summer groundnut	1.5		2.8(4.9)	1.6		2.4(5.2)	1.6		1.8(3.9)	10.0	9.3	7.8	9.0	182.2	84.9
Soybean-onion	1.8	32.0		3.5	22.1		2.4	24.2		22.1	19.4	18.4	19.9	513.6	67.4
Greengram-*rabi* sorghum	0.6	1.6(3.6)		0.5	2.2(3.3)		1.0	2.7(5.7)		3.1	3.5	5.2	3.9	96.6	53.8
Soybean-wheat	1.7	4.2		3.3	4.1		1.9	3.1		7.0	9.5	6.3	7.6	149.1	58.3
Soybean-chilli	2.1	2.0		3.3	2.1		2.1	2.5		5.3	7.2	5.7	6.0	128.0	68.5
Pigeonpea-pearlmillet	2.6		2.6 (4.2)	1.9		2.6(5.7)	1.9		2.2(4.0)	7.7	6.1	5.8	6.5	144.4	80.6
Maize-wheat	3.4 (7.5)	4.6		4.9(12.6)	4.3		5.6(8.0)	3.1		7.3	8.2	7.2	7.5	242.2	55.0
Maize+cowpea-wheat	(26.5)	4.8		(36.7)	5.2		(22.9)	3.2		8.8	10.7	6.6	8.7	246.1	51.4
Sole turmeric	9.2			13.7			13.8			8.8	13.0	13.1	11.6	242.7	78.6
Turmeric+castor	12.2+1.5			13.0+2.3			13.0+1.0			13.4	15.1	13.6	14.0	308.0	78.6
Sole castor	2.5			2.6			2.9			3.0	3.1	3.5	3.2	127.7	47.6
SEm±										0.38	0.25	0.27	0.28		
CD (P=0.05)										1.08	0.71	0.78	0.79		

*Figures in the parenthesis indicate the fodder yield; **Mean of three year K : *Kharif*, R : *Rabi*, S : Summer

price of onion bulbs and soybean grain was responsible for higher production of wheat equivalent yield under these crop sequences. The higher WEY recorded in soybean-onion system was due to higher yield of onion which was in confirmation with Sharma *et al.* (2008). Sole castor recorded the lowest WEY (3.2 t/ha) followed by groundnut-*rabi* sorghum (3.9 t/ha)

Labour requirement

The soybean-onion-system was found more labour intensive and engaged 374.3 mandays followed by cotton–groundnut (352 mandays). The highest labour required in soybean–onion system is due to more labour requirement for cultural operation viz., planting, weeding and harvesting in onion crop. The turmeric–castor system (304 mandays) required more labour due to longer crop duration.

Land use efficiency

The highest land use efficiency was recorded in cotton-groundnut (84.9 %) followed by pigeonpea-pearlmillet cropping sequence (80.6 %) as these crops occupied the field for longer period. The cotton-groundnut cropping sequences have more crop duration of both crops i.e. cotton 185 days and groundnut 125 days. Sole turmeric land use efficiency was 78.6%. The lowest land use efficiency was recorded in sole castor (47.6%) closely followed by maize + cowpea intercropping – wheat sequence (51.4). These results confirm the findings of Tomar and Tiwari (1990).

Monetary advantage

Net monetary advantage on per unit times basis was recorded maximum in soybean-onion crop sequence (₹513.6/ha/day) followed by turmeric + castor intercropping system (₹308/ha/day). The maize+cowpea–wheat cropping sequence recorded monetary advantage of (₹246.1/ha/day). The lowest monetary advantage was recorded in greengram–*rabi* sorghum sequence (₹96.6/ha/day) (Table 1).

Soybean-onion crop sequence also recorded significantly higher net monetary returns of ₹107.8 x10^3/ha followed by turmeric + castor (₹89.8x10^3/ha) and cotton-summer groundnut (₹69.6x10^3/ha) (Table 2). The lowest net monetary return recorded in greengram–*rabi* sorghum cropping sequence with ₹20.7x10^3/ha. The sole castor recorded the highest B:C ratio of 3.1 followed by soybean-onion cropping system (2.7), and turmeric + castor (2.3). The lowest B:C ratio was recorded in greengram - *rabi* sorghum cropping system (1.0), which might be due to low productivity of greengram. Cotton-groundnut (2.6) and pearlmillet–pigeonpea (1.8) also gave higher benefit

Table 2. Economics (×10^3 ₹/ha) and labour requirement of various cropping systems.

Crop Sequence	Cost of cultivation			Net monetary returns				B:C ratio				Labour requirement (mandays)			
	2005-06	2006-07	2007-08	2005-06	2006-07	2007-08	Pooled Mean	2005-06	2006-07	2007-08	Mean	2005-06	2006-07	2007-08	Mean
Sorghum-wheat	30.4	30.6	31.6	34.4	44.7	30.2	36.4	1.1	1.5	1.0	1.2	282	289	289	286
Cotton-summer groundnut	26.6	26.8	27.0	101.2	54.3	53.4	69.6	3.8	2.0	2.0	2.6	353	357	347	352
Soybean-onion	39.9	40.3	39.3	43.5	135.0	144.9	107.8	1.1	3.4	3.7	2.7	371	384	368	374
Greengram-*rabi*-sorghum	18.6	19.0	19.3	11.1	14.1	32.3	20.7	0.6	0.7	1.7	1.0	200	210	208	206
Soybean-wheat	18.6	26.6	27.2	24.4	54.7	36.0	40.9	1.3	2.1	1.3	1.6	235	240	241	238
Soybean-chilli	18.8	19.6	20.2	20.3	40.0	36.7	32.3	1.1	2.0	1.8	1.6	281	284	278	281
Pigeonpea-pearlmillet	18.2	18.2	18.2	38.9	29.4	32.2	35.8	2.1	1.6	1.8	1.8	195	200	200	198
Maize-wheat	32.3	33.0	30.6	42.0	75.6	37.6	51.7	1.3	2.3	1.2	1.6	265	279	257	267
Maize+cowpea-wheat	29.5	30.0	27.3	34.3	45.3	37.0	37.8	1.2	1.5	1.4	1.4	210	209	215	211
Sole turmeric	38.7	38.8	38.8	34.6	75.5	93.2	67.8	0.9	2.0	2.4	1.8	265	291	260	272
Turmeric+castor	37.0	37.8	37.8	60.2	101.8	98.6	89.8	1.6	2.7	2.6	2.3	300	317	295	304
Sole castor	7.0	6.7	7.5	18.4	19.9	28.0	22.1	2.6	3.0	3.7	3.1	65	68	70	67
SEm±				2.6	2.2	1.6	1.6								
CD (P=0.05)				7.6	6.6	4.8	6.7								

Prices ₹/tonne: Sorghum–6,000, Sorghum fodder–500, Wheat–10,040, Cotton–20,700, Groundnut–22,560, Groundnut Haulm–900, Soybean–16110, Onion–6000, Green gram–21,050, Chilli–9,000, *Rabi* Sorghum–9,890, *Rabi* Sorghum fodder–700, Pigeonpea–21330, Pearlmillet–6,620 (fodder–500), Maize–6,500 (fodder–500), Cowpea fodder-1,500, Maize green fodder–1,500, Turmeric–9,500, Castor–12,000.

cost ratio than greengram – *rabi* sorghum. Similar results were also reported by Deshpande *et al.* (1996) and AICRPCS (2008).

Consumptive water use and water use efficiency

Different cropping systems consumed varied quantities of irrigation water. The highest consumptive use was observed in cotton–groundnut cropping system (104.8 cm). The highest consumptive use cropping systems might be due to longer duration of crop sequence. The above results confirmed the findings of Sharma *et al.* (2008). Next to cotton-groundnut, maximum irrigation water was utilized by maize + cowpea-wheat sequence (102.7cm), because of longer growth period and more foliage which resulted in higher evapo-transpiration. The highest water use efficiency was obtained with soybean-onion cropping system (221.6 kg/ha-cm) followed by turmeric + castor (181.8), sole turmeric (155.9) and cotton–groundnut crop sequence (86.4) (Table 3). The highest water use efficiency recorded in soybean-onion system may be due to higher production of onion with minimum water use while lowest recorded in greengram–*rabi* sorghum (49.5) due to low productivity.

Nutrient uptake and soil fertility

In respect of nutrient uptake, the highest system uptake was noticed in sorghum - wheat cropping system followed by sole maize+cowpea–wheat and maize–wheat cropping systems. Higher nutrient uptake in these systems may be attributed due to higher biomass production of these systems. The higher nutrient doses applied in this system were favourable on the growth and yield attributes, particularly root and shoots growths which might have facilitate the absorption of nutrients from the rhizosphere in the soil. Similar results were also reported by Singh and Singh (1998).

The available N, P and K content of cropping systems at the end of experiment was worked out and (Table 4). In

Table 3. No of irrigations, consumptive use, water use efficiency (wheat equivalent yield kg/ha-cm) under various crop sequence.

Crop sequence	Number of Irrigations			Consumptive use (cm)				Water use efficiency (kg/ha-cm)			
	2005–06	2006–07	2007–08	2005–06	2006–07	2007–08	Mean	2005–06	2006–07	2007–08	Mean
Sorghum-wheat	1 (5)	2 (6)	2 (6)	92.0	94.3	93.0	93.1	72.2	79.5	61.3	72.7
Cotton-summer groundnut	3 (7)	2 (8)	3 (8)	107.2	103.2	103.0	104.8	93.3	90.1	75.7	86.4
Soybean-onion	0 (6)	2 (5)	2 (5)	93.0	89.5	87.5	90.0	237.6	216.8	210.3	221.6
Greengram-*rabi*-sorghum	0(4)	2 (3)	2 (3)	83.0	77.0	79.1	79.7	37.3	45.4	65.7	49.5
Soybean-wheat	0 (5)	2 (6)	2 (6)	87.5	91.3	86.6	88.5	80.0	104.1	72.5	85.6
Soybean-chilli	0 (6)	2 (5)	2 (6)	99.0	98.7	94.9	97.5	53.5	72.9	60.1	62.2
Pigeonpea-pearlmillet	2 (2)	2 (5)	2 (5)	94.0	92.3	93.2	93.2	81.9	66.1	62.3	70.1
Maize-wheat	0 (5)	2 (6)	2 (6)	95.2	95.3	99.0	96.5	76.7	86.1	72.7	78.5
Maize+cowpea-wheat	0 (5)	2 (6)	1 (5)	101.5	101.6	105.0	102.7	86.7	105.3	62.8	85.0
Sole turmeric	7	8	8	76.2	72.8	75.5	74.8	115.5	178.6	173.5	155.9
Turmeric+castor	7	8	8	78.5	76.2	77.0	77.2	170.7	198.2	176.6	181.8
Sole castor	2	2	2	42.0	40.0	39.5	40.5	71.4	77.5	88.1	79.2

Figures in parenthesis indicate the value of second crop in the sequence

Table 4. Nutrient uptake and soil nutrient status (kg/ha) after three years of experimentation.

Sequence	Nutrient uptake (kg/ha) (Mean of 3 years)			Available nutrients (kg/ha)		
	N	P	K	N	P	K
Sorghum-wheat	176.6	42.7	162.4	157	10.57	425
Cotton-summer groundnut	145.1	38.1	106.7	178	13.62	465
Soybean-onion	96.0	12.61	68.8	185	13.17	436
Greengram-*rabi*-sorghum	137.1	42.2	119.4	168	12.88	442
Soybean-wheat	153.3	27.19	105.1	170	12.54	445
Soybean-chilli	94.0	14.57	63.6	171	12.75	411
Pigeonpea-pearlmillet	111.5	33.4	75.4	160	11.48	418
Maize-wheat	180.0	40.2	156.5	145	10.16	406
Maize+cowpea-wheat	180.5	41.5	158.8	152	12.17	425
Sole turmeric	95.6	22.7	98.8	165	12.65	437
Turmeric+castor	123.9	25.38	106.8	163	12.73	426
Sole castor	40.7	6.9	17.4	160	12.65	436
Initial status				240	17.1	484

all the cropping systems, decline in available N, P and K was recorded. Decline in N, P and K was not similar among the cropping systems. In legume based systems, N available status was found higher than non-legume based system. Cotton-summer groundnut and soybean-onion cropping sequences was in marginal range in available nutrient status as compared to other crop sequences. Highest nutrient depletion in respect of available N, P and K status of soil was noticed in maize-wheat and sorghum-wheat cropping systems. Similar types of results were also reported by Jain *et al* (2005).

Based on three years experiment, soybean-onion crop sequence was found more productive, profitable and efficient water user compared to other cropping sequences. The next best treatment was turmeric + castor (4:1) intercropping system. The fertility status of soil was also maintained in soybean–onion cropping systems.

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