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Research Paper

Alternate cropping system for central plateau zone of Maharashtra

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ABSTRACT

A field experiment was conducted during 2008–10 at Parbhani, to evaluate the production potential of 12 cropping systems in central plateau zone of Maharashtra. Of the 12 cropping systems, turmeric (*Curcuma longa* L.) + castor (*Ricinus communis* L.) (4:1) intercropping system gave significantly highest net profit (₹171.10 × 10^3/ha), economic efficiency of ₹616.9/day/ha on net monetary return (NMR) basis and soybean-equivalent yield (SEY) (10.5 t/ha), followed by soybean [*Glycine max* (L.) Merr.]–onion (*Allium cepa* L.), which recorded the net profit of ₹125.2 × 10^3, economic efficiency of ₹536.4/day/ha, soybean-equivalent yield of 8.2 t/ha, and Bt. cotton (*Gossypium hirsutum* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol]–coriander (*Coriandrum sativum* L.) (SEY 8.5 t/ha). Among the cropping sequences, maize (*Zea mays* L.)–chickpea (*Cicer arientinum* L.)–okra (*Abelomoschus esculentus* L) recorded the highest land-use efficiency (83.6%) followed by maize–wheat–greengram (83.4%), Bt cotton–wheat–coriander (81.7%) and turmeric + castor intercropping system (75.9%). The lowest land-use efficiency was recorded in sorghum [*Sorghum bicolor* (L.) Moench]–wheat sequence (62.1%). The highest benefit: cost ratio was recorded in turmeric + castor (4:1 ratio) intercropping system (3.8), followed by pigeonpea [*Cajanus cajan* (L.) Millsp.]–groundnut (*Arachis hypogaea* L.) (3.7). The employment generation was the highest (317 man-days/ha/year) in maize–chickpea–okra system, followed by *Bt* cotton–wheat–coriander (289 man-days/ha/year). The turmeric + castor intercropping system (4:1) recorded the lowest employment generation (136 man-days/ha/year). The highest consumptive use of water (140.2 cm) and water-use efficiency (56 kg/ha-cm) were recorded in maize–wheat–greengram cropping sequence, followed by *Bt* cotton–wheat–coriander cropping sequence. The highest soil-nutrient status was maintained in pigeonpea–groundnut cropping system, followed by cotton–summer groundnut.

Key words: Cropping system, Economics, Employment generation, Land-use efficiency, Soil fertility

In the era of shrinking base of land, water and energy, resource-use efficiency has become an importance issue for considering the suitability of cropping system (Yadav, 2002). Cropping system in a region are decided by and large, by a type of soil and climatic parameters which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crop for cultivation. Potential productivity and monetary benefit acts as a guiding principle while opting for particular crop/cropping system. Reliance on biological nitrogen fixation through inclusion of legume in a cropping system and maintenance of higher soil organic matter will help to built up soil fertility and better soil physical and microbial environment with good buffering capacity.

Diversification of cropping system is necessary to get higher yield and returns to maintain the soil health, preserve the environment and meet the daily requirement of human and animals (Samui *et al.,* 2004). Depending on just one crop can have great consequences and leave small-scale farmers open to unnecessary hazards. A slump in the market value for a particular crop could greatly reduce the income of the monoculture producers. Other factors, such as the weather or pests could destroy a large part of the crop, leaving the farmer in ruins. On the other hand, farmers with diversified production can avoid these risks, provide their families with a healthy diet and derive a whole series of other benefits. Choice of component crop in the cropping system representing the specific agro-ecological region needs to be suitably maneuvered to harvest the synergism among them toward efficient utilization of resource base and increase overall productivity and profitability. Crop diversification means growing a variety of crops in an area, not just one. The predominant field crop-based system sorghum–wheat, soybean–wheat, blackgram–*rabi* sorghum, cotton–groundnut, pearlmillet–wheat and pearlmillet–gram. These cropping systems are

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widely adopted in this region because of prevailing favourable agro-climatic condition and socio-economic situation of farmers, but the yield levels is very low. In case of sorghum–wheat system the farmer are realizing the need to replace sorghum with more remunerative crop. Diversification may prove to be of paramount importance in several farming situations to improve the productivity and profitability without deterioting the soil health for sustainable agriculture. Therefore, it is need of time to standardize and develop alternative efficient cropping sequences adoptable in existing agro-climatic condition with high yield potential and higher system productivity. The aim is to restructure alternative cropping sequence for efficient utilization of all resources which land, water, solar radiation for maintaining the stability in production and obtaining the higher return.

Since information on productive alternative cropping system is lacking, the present investigation was carried out to identify the alternate cropping sequences and tried for their suitability for higher productivity, energy utilization and comparing their economic feasibility among the alternative cropping sequences for central plateau zone of Maharashtra.

MATERIALS AND METHODS

The field experiment was conducted for 3 consecutive cropping seasons on fixed site during 2008 to 2010 at main station farm of All India Coordinated Research Project on Integrated Farming Systems, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra (19ˆ 16' N and 76ˆ 48' E and 409 m above the mean sea-level). The climate of the region is characterized by dry and hot summer and cool and dry winter. Total rainfall received was 603.1, 650.5 and 1071.9 mm during 2008, 2009 and 2010 respectively. The soil was Vertisols having *p*H 8.2, EC 0.22 dS/m, organic carbon 0.47%, available nitrogen 358.3 kg/ha, available phosphorus 11.1 kg/ha and available potassium 412.6 kg/ha at the start of experiment. The field capacity of soil was 41.2% and permanent wilting point 18.2%. The crop was managed as per the recommended package of practices. The plot-wise grain and straw yields of both the crops for 3 years were recorded. Before harvesting 5 plants were harvested and used for chemical analysis after oven drying. Nitrogen was determined by Micro-kjeldhal method, phosphorus by vanadophosphomolybdate yellow colour method, potassium by triacid extract on flame-photometer method. The nutrient uptake was worked out by multiplying the nutrient concentration in plant/grain with representative yield. The soil sample were collected after harvesting of rabi/summer crop in cropping sequence for 3 years of study for analysis of available nitrogen determined by alkaline per magnate method (Subbiah and Asija, 1956), available phosphorus by Olsen method (Jackson, 1973), available potassium by flame photometer (Jackson, 1973).

The irrigation was given as per need of crops and 60 mm depth water was applied at each irrigation. The total irrigation water applied in each irrigation for respective crop sequence was summed up. The experiment was conducted under irrigated condition as per recommended practices for different crops. Final crop yields were recorded and their net monetary returns were calculated on the basis of average market price of the produce. The inter-culture operation, seed rate, spacing, plant-protection measures were carried out as per the recommendation of respective crop in sequence. The experiment was laid out in randomized block design with 3 replications and 12 crop sequences, *viz.* sorghum ‘CSH 16’–wheat ‘NIAW 301’, *Bt* cotton ‘NCS 207’–summer groundnut ‘TAG 24’, soybean ‘MAUS 71’–onion ‘AFLR’, soybean ‘MAUS 71’–wheat ‘NIAW 301’–cowpea ‘Pusa Barsati’, pigeonpea ‘BSMR 853’–groundnut ‘TAG 24’, maize ‘Maharaja’, wheat ‘NIAW 301’–greengram ‘BPMR 145’, *Bt* cotton ‘NCS 207’–wheat ‘NIAW 301’–coriander ‘Multi cut’, maize ‘Maharaja’–chickpea ‘Digvijay’–okra ‘Anamika’, soybean ‘MAUS 71’–chickpea ‘Digvijay’–coriander ‘Multi cut’, turmeric ‘Selum’ + castor ‘DCH 9’ (4:1 ratio), *Bt* cotton ‘NCS 207’–chickpea ‘Digvijay’, soybean ‘MAUS 71’–safflower ‘PBNS 12’–maize (Fodder) ‘African Tall’. The recommended dose of NPK kg/ha for sorghum 80 : 40 : 40, wheat 100 : 50 : 50, *Bt* cotton 120 : 60 : 60, groundnut 25 : 50 : 0, soybean 30 : 60 : 30, onion 100 : 50 : 50, coriander 50 : 50 : 50, pigeonpea 25 : 50 : 0, maize 100 : 50 : 50, greengram 25 : 50 : 00, chickpea 25 : 50 : 0, cowpea 25 : 50 : 0, okra 100 : 50 : 50, safflower 60 : 40 : 0, maize fodder 80 : 40 : 40 and turmeric 100 : 50 : 50 were applied through urea, single superphosphate and muriate of potash. Final crop yields were recorded and their monetary returns were calculated on the basis of average market prices of the produce. Different crop sequences were compared by converting the yield of all the crop in a sequence into soybean-equivalent yield (SEY) on prevailing market prices basis (Verma and Modgal, 1983). Net return was calculated by deducting the variable cost from gross return. Economic efficiency in term of /ha/day was worked by dividing the net return of the sequence by the total duration of crops in a system in an agriculture year. Benefit: cost ratio was calculated by dividing the net returns with cost of cultivation. Land-use efficiency was calculated the total duration of crop in cropping system divided by 365 days. The water-use efficiency was calculated by total yield obtained in cropping sequence to the total water use in cropping sequence. The energies of different cropping sequences were calculated as described by

Gopalan *et al.* (1978). All data obtained in the cropping sequence experiment for 3 consecutive year of study were statistically analysed using the *F*- test, the procedure given by Gomez and Gomez (1984), critical difference (CD) values at *P*=0.05 were used to determine the significance of differences between means.

RESULTS AND DISCUSSION

Cropping system productivity (Soybean-equivalent yield)

Productivity of cropping sequence is a function of cumulative economic biomass obtained from different crops grown on the same piece of land during the year. Sequence productivity evaluates the efficiency of various crops to harvest solar energy while using the available resource optimally. System productivity in term of soybean-equivalent yield and profitability played a vital role in determining the most productive and profitable cropping sequence (Table 1). Turmeric + castor (4:1) intercropping system, soybean–onion and *Bt* cotton–wheat–coriander sequence gave 10.5, 8.5 and 8.2 t/ha soybean-equivalent yield, respectively, as against 4.8 t/ha/annum sorghum–wheat sequence. Turmeric + castor (4:1) intercropping system gave significantly higher soybean-equivalent yield (SEY) of 10.5 t/ha (Table 2), which was significantly superior to cotton–wheat–coriander cropping sequence. Among the crop sequences, sorghum–wheat cropping sequence which recorded the lower soybean-equivalent yield. Turmeric + castor (4:1) intercropping system gave additional yield of 45.7% over the established sorghum–wheat cropping sequence and 28.4% over soybean–onion cropping sequence. The turmeric + castor (4:1) intercropping system show higher productivity as well as higher selling price resulted into higher soybean-equivalent yield than sorghum–wheat system. Narkhede *et al.* (2011) reported that, highest total productivity was noticed under soybean–onion cropping sequence. The variation in yield of crop sequences could be attributed to synergism of some crop to the following crop. Yield variation was observed in different crop sequences. This type of variation in the yield of crop might be attributed to the biological and environmental complexities and interaction in cropping system (Francis, 1989).

Consumptive use and water-use efficiency

The consumptive use and water-use efficiency of different cropping sequences consumes varied quantities of irrigation water (Table 1). The highest consumptive use of water was observed in maize–wheat–greengram cropping sequence (140.2 cm; total number of applied irrigations 13), followed by *Bt* cotton–wheat–coriander cropping sequence. The highest consumptive use of water by these cropping sequences might be due to long duration of crop with high requirement of water. The highest water-use efficiency was recorded in turmeric + castor (4:1) intercropping system followed by soybean–onion cropping sequence. This cropping sequence gave higher yields with minimum quantity of water. This results are in agreement with the findings of Rajkumara *et al.* (2014). The lowest water-use efficiency was recorded in soybean–safflower–maize (fodder) cropping sequence.

Land-use efficiency

Maize–chickpea–okra expressed the maximum land-use efficiency, followed by maize–wheat–greengram cropping sequence. The specific reason behind maximization of land-use efficiency attributed to long duration of the crop in system. Three crop sequences showed higher land-use efficiency (76.3–81.7%) than 2 cropped sequences (Table 1). Marginal land-use efficiency was noted in sorghum-wheat cropping sequence due to shorter crop duration of the crop sequence. The maximum or minimum land-use efficiency depends upon the 2 or 3 crops and their duration for completion of life-cycle. Gangwar *et al.* (2003) reported highest land-use efficiency in rice–groundnut–cowpea cropping sequence at Bhubaneswar and Kumar *et al.* (2005) for rice–groundnut crop sequence (73%) in Andhra Pradesh.

Energy

In general, the highest gross energy was produced under turmeric + castor (4:1) intercropping system which gave the highest productivity of 10.5 t/ha/annum followed by maize–wheat–greengram cropping sequence. The higher energy output under turmeric + castor (4:1) intercropping system was mainly owing to higher rhizome yield and lower energy requirement (Shahan *et al.,* 2008). The lowest gross energy was observed in soybean–onion cropping sequence. Intensification through inclusion of oilseed and pulse crop resulted in increasing the energy output.

Economics

Among the different crop sequences, the net returns were the highest under turmeric + castor (4:1) intercropping system with a benefit: cost ratio of 3.8. This was owing to the highest gross return and moderate cost of cultivation in turmeric + castor (4:1) intercropping system and higher productivity and high value of the produce in this crop sequence (Table 2). Whereas sorghum–wheat cropping sequence registered the lowest net returns and benefit: cost ratio. Soybean–onion, *Bt* cotton–wheat–coriander and maize–wheat–greengram cropping sequences were found at par. The turmeric + castor (4:1) intercropping system was found significantly superior to all other

Table 1. Soybean-equivalent yield, energy, net monetary return, benefit: cost ratio, monetary advantage on net monetary returns basis, land-use efficiency, employment generation, mean number of irrigations, consumptive use, water-use efficiency as influenced by different crop sequences (pooled data of 2 years)

Crop sequences	Soybean equivalent yield (t/ha)	Energy output ($\times 10^3$ MJ/ha)	Cost of cultivation ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)	Land-use efficiency (%)	Employment generation (Man-days/ ha/year)	Irrigations (Nos.)	Consumptive use (cm)	Water-use efficiency (kg/ha-cm)
Sorghum–wheat	4.8	298.9	32.9	65.1	2.0	284.9	62.1	182	7.0	93.3	51.2
Bt Cotton–groundnut (s)	6.8	214.6	38.2	101.8	2.7	396.3	70.4	209	12.7	128.2	53.2
Soybean–onion	8.2	197.9	43.9	125.2	2.9	536.4	63.9	286	8.7	103.9	79.3
Soybean–wheat–cowpea	5.8	260.5	40.1	78.8	2.0	282.8	76.3	241	13.3	133.5	43.4
Pigeonpea–groundnut	7.0	203.7	30.3	112.9	3.7	379.0	81.6	188	12.7	135.3	51.6
Maize–wheat–greengram	7.8	435.3	44.0	117.1	2.7	368.1	83.4	270	13.0	140.2	56.0
Bt cotton–wheat–coriander	8.5	376.9	50.6	123.4	2.4	413.6	81.7	289	13.7	136.6	62.1
Maize–chickpea–okra	6.1	301.2	46.2	78.4	1.7	256.8	83.6	317	9.7	132.8	45.7
Soybean–chickpea–coriander	5.7	280.4	40.6	76.5	1.9	293.6	71.4	278	8.7	116.7	49.0
Turmeric + castor	10.5	615.3	44.8	171.1	3.8	616.9	75.9	136	7.7	75.5	139.4
Bt cotton–chickpea	5.9	298.9	35.3	86.0	2.4	332.1	70.9	198	4.0	89.6	66.0
Soybean–safflower–maize fodder	4.9	214.6	36.4	65.0	1.8	218.3	81.5	192	10.7	129.2	38.3
SEm±	0.27			3.93							
CD (P=0.05)	0.77			10.90							

Prices ₹/tonne**:** sorghum 7,963, sorghum fodder 1,667, wheat 11,533, wheat straw 500, cotton 31,000, cotton stalk 1,000, groundnut 25,277, groundnut haulm 3,000, soybean 20,517, onion 6,000, greengram 36,467, pigeonpea 31,003, pigeonpea stalk 1,000, maize 8,167 (fodder 1,000), cowpea fodder 1,250, okra 6,333, turmeric 14,000, castor 12,000, safflower 20,087, coriander 8,000, green maize fodder 1,250

cropping sequences. The highest benefit: cost ratio was also recorded in turmeric + castor intercropping system followed by pigeonpea–groundnut cropping sequence. The next best cropping sequence was soybean–onion as far as the benefit: cost ratio is concern. The highest economic efficiency was recorded with turmeric + castor (4:1) intercropping system with 616.9/ha/day followed by soybean–onion cropping sequence of 536.4/ha/day. Bastia *et al.,* (2008) reported similar results. The cotton-based cropping system showed net profit in range of 101.8×10^3/ha to 123.4×10^3/ha, maize-based cropping system 78.4×10^3/ha to 117.1×10^3/ha and soybean-based cropping system 78.4×10^3/ha to 125.2×10^3/ha. The benefit: cost ratio of cotton-based cropping system ranged from 2.4 to 2.7, soybean-based cropping system from 1.9 to 2.7 and in sorghum–wheat cropping system the benefit: cost ratio was 2.0.

NPK uptake, residual soil fertility and balance sheet

Among various cropping sequences, the N, P and K uptake was significantly varied due to adoption of various crops tested in specific season (Table 3). Maximum N uptake was recorded in maize–wheat–okra cropping sequence, followed by *Bt* cotton–wheat–coriander and soybean–wheat–cowpea (fodder) cropping sequences. The higher pattern of P uptake was noticed in maize–chickpea–okra cropping sequence followed by maize–wheat–greengram and soybean–chickpea–coriander cropping sequences. Maximum removal of these nutrients may be attributed to greater biomass production under these cropping sequences. The results are in conformity with the findings of Narkhede *et al*. (2011). The higher amount of nitrogen and potassium contents were maintained in pigeonpea–groundnut cropping sequence followed by Bt. cotton–groundnut, soybean–onion and *Bt* cotton–chickpea cropping sequences respectively. The maximum build up of nitrogen and potassium was observed due to inclusion of legumes crop in cropping sequence. All sequences included leguminous crops were improved the availability of N, P and K of soil besides intensifying the system for higher productivity and profitability. Similar results were reported by Kumar *et al.* (2012). The maximum phosphorus status was noted in *Bt* cotton–chickpea, turmeric + castor intercropping system (4:1) followed by maize–wheat–greengram cropping system respectively. The different cropping systems with high intensity under modern and heavy inputs coupled with improved technologies simultaneously removes the

Table 2. Nutrient added (kg/ha), removed (kg) and balance sheet in different cropping sequences

Crop sequences	N status				P status				K status			
	N added	N removed	N status at the end	Net gain (+) loss (–)	P added	P removed	P status at the end	Net gain (+) end	K added loss (–)	K removed	K status at the end	Net gain (+) loss (–)
Sorghum–wheat	180	321	142.3	–15.6	90	119	10.8	–1.2	90	158	346.0	–12.0
Bt cotton–groundnut (s)	145	302	180.5	+22.5	100	139	11.9	–0.1	50	162	378.9	+20.9
Soybean–onion	130	222	168.7	+20.7	110	77	12.1	+0.1	80	111	369.8	+11.8
Soybean–wheat–cowpea	130	399	165.3	+7.3	160	93	11.7	+–0.4	130	132	365.1	+7.1
Pigeonpea–groundnut	50	258	188.1	+30.1	100	109	12.0	–0.0	00	128	385.5	+27.5
Maize–wheat–greengram	245	423	145.2	–13.8	150	187	12.6	+0.5	100	252	345.3	–12.8
Bt cotton–wheat–coriander	270	512	162.6	+4.6	150	134	11.6	–0.4	150	179	352.9	–5.1
Maize–chickpea–okra	195	527	159.0	+1.0	150	234	12.4	+0.4	100	318	335.9	–22.1
Soybean–chickpea–coriander	105	284	165.2	+7.2	160	146	12.6	+0.8	80	142	375.7	+17.7
Turmeric + castor	160	148	170.0	+12.2	90	55	12.9	+0.8	80	68	375.4	+22.4
Bt cotton–chickpea	145	295	179.9	+21.9	100	113	13.0	+1.0	50	158	382.6	+24.6
Soybean–safflower–maize fodder	190	221	142.0	–16.0	150	86	10.9	–1.2	80	120	360.9	+2.9
Initial value		158.0				12.0				358.0		

large quantities of nutrients reflecting to their depletion or imbalance in soil.

In general, turmeric + castor (4:1) intercropping system followed by soybean–onion cropping sequence proved most biologically productive, resource-efficient and remunerative cropping system under irrigated condition than conventional sorghum–wheat cropping system.

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