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Research Paper

Maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system: Intensification through introduction of pulses

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ABSTRACT

A field experiment was carried out in 3 tehsils, namely Nathdwara, Rajsamand and Kumbhalgarh, of Rajsamand district (Sub-humid Southern Plain and Aravalli Hills Zone) of Rajasthan (IVa) in farmers' fields from rainy season (*kharif*) 2007 to winter season (*rabi*) 2010–11, to study the intensification of maize (*Zea mays* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping system through introduction of pulses crop. The experiment comprised 5 cropping systems, viz. maize–wheat, maize–barley (*Hordeum vulgare* L.), maize + blackgram [*Vigna mungo* (L.) Hepper] (2:2)–wheat, sorghum [*Sorghum bicolor* (L.) Moench] + greengram [*Vigna radiata* (L.) Wilczek] (2:1)–wheat and clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]–wheat. Maize + blackgram (2:2)–wheat cropping system gave the highest maize–grain-equivalent yield (8.22 t/ha), gross returns (87.4×10^3 ₹/ha), net returns (57.5×10^3 ₹/ha), land-use efficiency (64.9%), production efficiency (34.7 kg/ha/day), monetary efficiency (242.8 ₹/ha/day), sustainable yield index (0.65), sustainable value index (0.55), relative productivity efficiency (21.3%), relative economic efficiency (17.4%) and total calorific value (94.7×10^3 MJ/ha) and could intensified the existing maize–wheat cropping system. However, benefit: cost ratio was the maximum (3.18:1) in clusterbean–wheat cropping system. The maximum values of total input energy (36.97×10^3 MJ/ha), output energy (234.2×10^3 MJ/ha) and energy-output efficiency (988.3 MJ/ha/day) were recorded in maize + blackgram (2:2)–wheat, while energy intensiveness (9.37 MJ/₹) and energy-use efficiency (7.88) in maize–barley cropping system. The maximum values of specific energy (5.10 MJ/kg) and energy productivity (240.0 MJ/ha/day) were recorded in maize–wheat and clusterbean–wheat cropping systems respectively.

Key words : Energetic, Intensification, Maize–grain-equivalent yield, Maize–wheat cropping system, Profitability

In India, maize–wheat cropping system is one of the dominant and popular one among the predominant cereal–cereal cropping systems under irrigated conditions. The contribution of the cropping system to total foodgrain production of the country is considerably high. Both maize and wheat are exhaustive feeders of plant nutrients and continuous adoption of cereal–cereal cropping system on the same piece of land over the years resulted in removal of nutrients in substantial amounts leading ultimately to deterioration/imbalance in soil fertility (Usadadiya and Patel, 2013) with reduction of system productivity (Sharma *et al*., 2004). The progressive decline in total factor productivity and soil health necessitates crop diversification through inclusion of pulses in the system. An intensive cropping system is not only highly productive and profitable but also stable and sustainable over time. Inclusion or replacement of either of cereal components with suitable pulse in an exhaustive cereal–cereal production system may have advantages beyond N addition through biological nitrogen fixation which includes recycling from deeper soil layers, minimizing soil compaction, protection of soil from erosion, increasing soil organic matter through root biomass and leaf fall, breaking the weed and pest cycles and minimizing any harmful allelopathic effects (Yadav *et al*., 2003). With this objective, the present experiment was conducted to find out the feasibility of intensification and/or diversification of existing maize–wheat cropping system with pulse crop for sustainable production under irrigated areas of southern part of Rajasthan.

MATERIALS AND METHODS

The field experiment was carried out in 3 tehsils (blocks), namely Nathdwara, Rajsamand and

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Kumbhalgarh, of Rajsamand district in farmers' fields from rainy season (*kharif*) 2007 to winter season (*rabi*) 2010–11 which falls under Sub-humid Southern Plain and Aravalli Hills Zone of Rajasthan, India (23°32' to 26°20' N, 72°16' to 75°49' E, 500–1,000 m above mean sea-level). The zone enjoys a typical semi-arid and sub-tropical climate. During May–June, temperature may reach up to 43.9°C. January and February are generally the coldest months with the minimum temperature going below even to –1.5°C. The average annual rainfall of the region is 640 mm. About 90% of which is contributed by south-west monsoon from June to September. Winter showers are usually received during January-February.

The soils of the experimental sites were sandy loam to clay loam, having soil *p*H 7.8–8.7, low available nitrogen (150–270 kg/ha), low to medium available phosphorus (12.1–27.4 kg/ha) and medium to high potassium status (230.2–390.1 kg/ha). The experiment was carried out in a randomized block design, considering every farmer (12) as replication. The treatment includes 5 cropping systems, viz. maize–wheat, maize–barley, maize + blackgram (2:2)–wheat, sorghum + greengram (2:1)–wheat and clusterbean–wheat. A set of 5 treatments was laid out on each farmer's field. The net plot size of each treatment was 100 m^2. The details of varieties, seed rate, fertilizer doses and spacing are given in Table 1.

Recommended doses of fertilizers particularly N, P and K were supplied to sole crops through urea, single superphosphate and muriate of potash respectively. Half dose of N and full doses of P and K were applied at the time of sowing, while remaining N was applied 1 month after sowing in case of maize and sorghum. In case of clusterbean, full doses of N, P and K were applied at the time of sowing as per Table 1. In intercropping systems, 100% of recommended dose of N, P and K was applied to maize and sorghum, whereas fertilizers in intercrops (blackgram and greengram) were applied based on their populations in the system at the time of sowing. At maturity, all the crops were harvested manually just above the ground. After drying in the sun, the total biomass was weighed. Then grains/seeds were separated out and weighed to record economic yield. Stover/straw yield was obtained as the difference between total biomass and economic yield. After harvesting of rainy (*kharif*) season crops, wheat and barley were sown in the same plots as per treatments without disturbing the layout as per recommended package of practices mentioned in Table 1. Half dose of N and full doses of P and K were applied at the time of sowing, while remaining N was top-dressed at first and second irrigation. Wheat and barley were harvested at physiological maturity stage and after sun drying and threshing, weighed to record grain and straw yields.

The yields obtained from *kharif* and *rabi* crops were converted into maize–grain-equivalent yield (MGEY), based on prevailing market price for comparison among the cropping systems as per following formula:

$$\text{MGEY (t/ha)} = \frac{\text{Yield of each crop (t/ha)} \times \text{Economic value (₹/t)}}{\text{Price of maize (₹/t)}}$$

System productivity was worked out by adding maize–grain equivalent yield of *rabi* crops and intercrops to maize grain yield, while in case of clusterbran–wheat and sorghum + greengram (2:1)–wheat cropping systems, yields of component crops were converted into maize–grain-equivalent yield and then added for calculating system productivity expressed in terms of maize-grain-equivalent yield.

The economic returns and cost of cultivation for individual crops in sequences were calculated on the basis of prevailing market prices of inputs and outputs. The inten-

Table 1. Cropping systems and production technology adopted

Cropping system	Variety		Seed rate (kg/ha)		Spacing (cm × cm)		Fertilizer (kg/ha) (N: P_2O_5: K_2O)		Duration (days)
	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	
Maize–wheat	'Pratap Makka 5'	'Raj 4037'	25	100	60 × 25	23	90:35:30	120:40:30	235
Maize–barley	'Pratap Makka 5'	'RD 2035'	25	90	60 × 25	23	90:35:30	60:20:30	233
Maize+blackgram (2:2)–wheat	'Pratap Makka 5' ('RBU 38'/'T 9')	'Raj 4037'	25 (10)	100	30 × 25 (30 × 10)	23	90:35:30 (10 :20:15)	120:40:30	237
Sorghum+greengram (2:1)–wheat	'SPV 1616' ('SML 668'/ 'RMG 344')	'Raj 4037'	20 (6.5)	100	30 × 25 (30 × 10)	23	80:40:30 (7:13:10)	120:40:30	230
Clusterbean–wheat	'RGC 936'/'RGC 1003'	'Raj 4037'	20	100	30 × 10	23	20:40:30	120:40:30	228

Information in parentheses indicate production technologies for intercrops sification of time was measured by calculating values of land-use efficiency taking crop duration in individual cropping system dividing by 365; production efficiency by taking maize-grain equivalent yield of cropping system dividing by total duration of that cropping system and monetary efficiency by taking net monetary returns of the cropping system dividing by total duration of that cropping system (Yadav *et al*., 2005). The relative productivity efficiency (RPE) and relative economic efficiency (REE) were calculated as per Urkurkar *et al*. (2006).

Sustainable yield index (SYI) and sustainable value index (SVI) were also calculated for measuring sustainability from yield or income point of view of a cropping system under a set of management practices as per Singh *et al*. (1990).

Energy inputs and outputs were calculated using energy equivalents, as suggested by Mittal *et al*. (1985) and the energy equivalents used are given in Table 2.The data collected were subjected to statistical analysis by applying the techniques of Analysis of Variance.

RESULTS AND DISCUSSION

Productivity of component crops

Based on mean (Table 3), sole maize gave the highest grain and stover yields in maize–barley cropping system during *kharif* season. In the intercropping systems, sorghum recorded higher grain and stover yields than that of maize. Intercropped maize provided slightly lower grain yield than sole cropping on mean basis. This decline in the grain yield despite similar plant population in sole and intercropped stand may be attributed to change in the planting pattern, which induced more inter-species and intra-species competition in the intercropped stand, both underground and above-ground. Furthermore, seed and straw yields of intercrop blackgram were higher than that of greengram.

Data further indicated that the preceding crops influenced the grain and straw yields of succeeding crops (Table 3). Wheat raised after clusterbean gave higher grain and straw yields than the preceding maize, intercropped maize + blackgram and sorghum + greengram and was closely followed by wheat grown after maize + blackgram (2:2) intercropping. Barley grown after maize also exhibited higher grain and straw yields than that of wheat grown after sorghum + greengram (2:1) intercropping. Singh *et al*. (2002) were of the opinion that maize-cob equivalents of succeeding crops improved when grown after maize + cowpea intercropping than sole maize and maize + okra intercropping owing to nitrogen-fixing ability of cowpea. Bana and Shivay (2012) also obtained significantly higher grain yield of basmati rice when grown after preceding forage cowpea which was statistically at par with pearlmillet + cowpea intercropping. The lowest grain and straw yields of wheat was recorded when preceded by intercropping of sorghum with greengram, followed by barley and/or wheat grown after maize. This was due to exhaustive nature of the sorghum and maize crops, as they mined more nutrients from the soil than its replenishment through fertilizers and led to poor yields of the succeeding crops. On the other hand, higher yield of wheat after legumes (clusterbean and blackgram) might be owing to the fact that inclusion of legume in crop rotation improved the soil microbial biomass and their activity that could be vital for the soil health and productivity.

Maize-grain-equivalent yield

Maximum maize–grain-equivalent yield was obtained from maize + blackgram (2:2)–wheat cropping system which was significantly higher over all the cropping systems tried and was followed by sorghum + greengram (2:1)–wheat cropping system (Table 3). It gave 21.2, 42.2, 16.9 and 18.3% more maize–grain-equivalent yield than

Table 2. Energy values of various inputs and outputs used

Input	Unit	Equivalent energy (MJ)	Output	Unit	Equivalent energy (MJ)
Adult man	Man-hour	1.96	*Main product*		
Woman	Woman-hour	1.57	Maize, wheat, sorghum, barley, blackgram and greengram	kg	14.7
Diesel (including lubricants)	l	56.31	Clusterbean	kg	1.9
Electricity	KWh	11.93	*By-product*		
Farm machinery	kg	62.7	Straw (wheat, barley, blackgram and greengram)	kg	12.5
Tractor	kg	64.8	Stover (maize and sorghum)	kg	18.0
N	kg	60.6	Straw (clusterbean)	kg	10.0
P_2O_5	kg	11.1			
K_2O	kg	6.7			
Chemicals requiring dilution at the time of application	kg	120			
Chemicals not requiring dilution	kg	10			

maize–wheat, maize–barley, sorghum + greengram (2:1) and clusterbean–wheat cropping systems respectively.

Economics

Maximum total cost was involved in maize + blackgram (2:2)–wheat cropping system followed by sorghum + greengram (2:1)–wheat cropping system (Table 3). Inclusion of blackgram and greengram as intercrop(s) in the system increased the cost of cultivation. On the other hand, the lowest cost was incurred on clusterbean–wheat cropping system mainly owing to lower fertilizer requirement. Maize + blackgram (2:2)–wheat cropping system fetched the highest gross returns owing to higher system productivity among all the 5 cropping systems. The net returns also followed the similar trend that of gross returns. Significantly higher net returns were realized from maize + blackgram (2:2)–wheat cropping system and gave an additional income of ₹ 8.5, 16.2, 7.9 and 5.8 × 10^3/ha over maize–wheat, maize–barley, sorghum + greengram (2:1)–wheat and clusterbean–wheat cropping systems respectively. It may be owing to additional yield and higher selling price of intercrop and higher wheat grain yield. However, significantly higher benefit: cost ratio was recorded in clusterbean–wheat cropping system mainly owing to lower cost of cultivation.

Land-use efficiency

Maize + blackgram (2:2)–wheat cropping system used the land for more period in a year having land-use efficiency of 64.9% and was followed by maize–wheat and maize–barley cropping systems (Table 3).

Production and monetary efficiencies

Maize + blackgram (2:2)–wheat cropping system recorded higher production and monetary efficiencies over all the cropping systems tried mainly owing to higher maize–grain-equivalent yield.

Sustainability

The sustainability of the different cropping systems (Table 3) analysed over a period of 4 years indicated that maize + blackgram (2:2)–wheat cropping system exhibited the maximum sustainable yield index irrespective of variation in weather and price. The lowest value of sustainable yield index was recorded in maize–barley cropping system. Further, stability with respect to net returns also followed the similar trend. Sustainable value index was also found maximum in maize + blackgram (2:2)–wheat cropping system, while the lowest in maize–barley cropping system.

Relative efficiency of the systems

Maize + blackgram (2:2)–wheat cropping system exhibited the highest positive values in respects of relative productivity efficiency and relative economic efficiency over and above the

Table 3. Yield, maize-grain-equivalent yield, economics, land-use efficiency (LUE), production efficiency (PE), monetary efficiency (ME), sustainable yield index (SYI), sustainable value index (SVI), total calories, relative productivity and relative economic efficiencies as affected by cropping systems (mean data of 4 years)

Cropping system	Seed/grain yield (t/ha)		Stover/straw yield (t/ha)		Maize-grain equivalent yield (t/ha)	Gross returns (×10^3 ₹/ha)	Cost of cultivation (× 10^3) (₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	LUE (%)	PE (kg/ha/ day)*	ME (₹/ha/ day)**	SYI	SVI	RPE (%)	REE (%)	Total calories (× 10^3 MJ/ha)
	Kharif	*Rabi*	*Kharif*	*Rabi*													
Maize–wheat	2.55	3.57	3.97	5.20	6.78	74.4	25.4	49.0	2.93	64.4	28.9	208.7	0.58	0.49			88.3
Maize–barley	2.71	3.51	4.11	5.14	5.78	65.8	24.5	41.3	2.69	63.8	24.8	177.4	0.45	0.37	–14.8	–15.7	88.0
Maize+blackgram (2:2)–wheat	2.31 (0.43)	3.82	3.51 (0.69)	5.28	8.22	87.4	29.8	57.5	2.93	64.9	34.7	242.8	0.65	0.55	21.3	17.4	94.7
Sorghum+greengram (2:1)–wheat	2.49 (0.29)	3.22	4.10 (0.49)	4.64	7.03	77.7	28.1	49.6	2.77	63.0	30.6	215.7	0.57	0.48	3.7	1.2	87.1
Clusterbean–wheat	0.87	3.98	1.32	5.87	6.95	75.5	23.8	51.7	3.18	62.5	30.5	226.9	0.58	0.48	2.6	5.5	58.3
SEm±					0.10			1.0	0.04								
CD (P=0.05)					0.28			2.9	0.11								

Figures in parentheses indicate intercrop yield; *calculated on maize-grain-equivalent yield basis; **calculated on net returns basis

Table 4. Energy-use efficiency of 5 cropping systems (mean data of 4 years)

Cropping system	Total input energy (× 10^3 MJ/ha)	Total output energy (× 10^3 MJ/ha)	Energy output efficiency (MJ/ha/day)	Energy productivity (g/MJ)	Energy intensiveness (MJ/₹)	Energy-use efficiency	Specific energy (MJ/kg)
Maize–wheat	34.55	226.5	963.9	196.2	8.92	6.56	5.10
Maize–barley	29.12	229.5	984.9	198.4	9.37	7.88	5.04
Maize+blackgram (2:2)–wheat	36.97	234.2	988.3	222.4	7.86	6.34	4.50
Sorghum+greengram (2:1)–wheat	35.58	226.1	982.8	197.5	8.05	6.35	5.06
Clusterbean–wheat	28.97	146.8	643.9	240.0	6.18	5.07	4.17

existing maize–wheat cropping system (Table 3). It showed that maize–wheat cropping system could be suitably intensified with blackgram intercropping in maize. On the other hand, maize–barley cropping system exhibited the negative values of both relative productivity efficiency and relative economic efficiency over and above the existing maize–wheat cropping system.

Energetic

Among the 5 cropping systems, maize + blackgram (2:2)–wheat cropping system had the highest calorific value, followed by maize–wheat system. On the other hand, the lowest calorific value was with clusterbean–wheat cropping system probably due to lower energy value and low yield of clusterbean compared to the other crops. Maximum total input energy requirement was recorded in maize + blackgram (2:2)–wheat cropping system and was minimum in clusterbean–wheat cropping system (Table 4). The highest total output energy was also produced by maize + blackgram (2:2)–wheat cropping system owing to inclusion of pulse crop and higher yield of wheat, while the lowest value was recorded in clusterbean–wheat cropping system due to low yields of the component crops and lower energy value of clusterbean. Energy-output efficiency was also maximum in maize + blackgram (2:2)–wheat owing to higher total output energy because of more production, while the minimum in clusterbean–wheat cropping system due to lower output energy due to less production. However, energy productivity was the highest in clusterbean–wheat cropping system. The highest energy intensiveness and energy-use efficiency were recorded in maize–barley cropping system, while the lowest in clusterbean–wheat. The existing maize–wheat cropping system recorded the highest specific energy closely followed by sorghum + greengram (2:1)–wheat cropping system. This indicated that these systems require higher inputs to produce a unit of produce. Clusterbean–wheat consumed very low input to produce a unit of produce than the existing maize–wheat cropping system, followed by maize + blackgram (2:2)–wheat cropping system.

It may be concluded that existing less-productive and profitable maize–wheat cropping system can be suitably intensified with blackgram intercropped in maize which was found to be more sustainable, produced the highest maize–grain-equivalent yield, realized higher net returns, production efficiency, total output energy and energy output efficiency than the other cropping systems under irrigated areas.

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