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**Research Paper**

# Diversification and intensification of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system for sustainable productivity and profitability

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## ABSTRACT

A field experiment was carried out on farmers' fields in 2 tehsils, namely Salumber and Sarada of Udaipur district situated in Humid Southern Plain Zone of Rajasthan (IVb) from rainy season (*kharif*) 2007 to summer 2011, to study diversification and intensification of maize (*Zea mays* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping system for sustainable productivity and profitability. The experiment, consisting of 5 cropping systems, viz. maize–wheat, maize–wheat–greengram [*Vigna radiata* (L.) R. Wilczek], maize + blackgram [*Vigna mungo* (L.) Hepper] (2:2)–wheat–okra [*Abelmoschus esculentus* (L.) Moench], clusterbean [*Cyamopsis tetragonoloba* (L.) Taubert]–wheat–greengram and clusterbean–wheat–okra, was laid out in randomized block design considering every farmer (12) as replication. Maize + blackgram (2:2)–wheat–okra cropping system recorded the highest maize–grain-equivalent yield (26.13 t/ha), gross returns (₹263.2 × $10^3$/ha), net returns (₹205.8 × $10^3$/ha), land-use efficiency (88.2%), production efficiency (81.1 kg/ha/day), sustainable yield index (0.57), sustainable value index (0.46), relative productivity efficiency (202.8%), relative economic efficiency (205.0%) and total calorific value (117.3 × $10^3$ MJ/ha). However, benefit: cost ratio (5.10:1) and monetary efficiency (₹647.2/ha/day) were the highest in clusterbean–wheat–okra. Maize + blackgram (2:2)–wheat–okra recorded the highest total input energy (52.7 × $10^3$ MJ/ha), while maize–wheat–greengram cropping system produced the highest output energy (301.8 × $10^3$ MJ/ha). On the other hand, the maximum values of energy-use efficiency (7.52), energy-output efficiency (1150.2 MJ/ha/day), energy intensiveness (9.49 MJ/₹) and specific energy (4.13 MJ/kg) were found in maize–wheat cropping system, while energy productivity in clusterbean–wheat–okra cropping system (581.9 g/MJ).

***Key words*** **:** Energy-use efficiency, Maize–grain-equivalent yield, Maize–wheat cropping system, Profitability, Sustainability

Among cereals, wheat is the second most important staple foodgrain crop after rice in India. It is grown during winter (*rabi*) season in succession of maize, rainy season (*kharif*) pulses, rice and clusterbean under irrigated conditions of Humid Southern Plain Zone of Rajasthan. Out of these crops, maize is the predominant *kharif* crop of this zone and hence maize–wheat is the predominant cropping system of the zone. Both maize and wheat are exhaustive feeders of plant nutrients and continuous adoption of the cereal–cereal system results in removal of nutrients in substantial amounts that often exceed replenishments through fertilizers and manures, leading ultimately to deterioration in soil fertility (Usadadiya and Patel, 2013) and reducing the productivity of the system (Sharma *et al*., 2004). There is a growing need to meet the foodgrain requirements of the ever-increasing human population and to sustain a reasonably higher productivity level. Hence there is an urgency to intensify and/or diversify the existing cropping system into new areas like pulses, legumes, oilseeds, fruits, vegetables, etc. In this context, crop diversification and/or intensification shows lot of opportunities in alleviating these problems besides fulfilling the basic needs, regulating farm income, withstanding weather aberrations, conserving natural resources, environmental safety and creating employment opportunities (Hegde *et al*., 2003; Gill and Ahlawat, 2006; Singh, 2010). Crop diversification essentially means shifting from growing a single crop to a number of crops depending on the availability of the resources under location-specific situation. Crop diversification may enhance profitability, reduce pests, spread out labour more uniformly, reduce risks from aberrant weather

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by different planting and harvesting times and source of high-value products from new crops (Reddy and Suresh, 2009). In the era of shrinking resource base of land, water and energy, resource-use efficiency is an important aspect for considering the suitability of a cropping system (Yadav, 2002). Hence selection of component crops needs to be suitably planned to harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Anderson, 2005). Inclusions of crops like pulses/legumes and vegetable will improve the economic condition of small and marginal farmers due to higher price and high volume of their produce particularly in case of vegetable. Gangwar and Ram (2005) reported that inclusion of legumes and other crops using intensification and interruptive approaches, depending on availability of resources led to significant improvement in productivity and profitability on one hand and soil fertility on the other hand. Singh *et al*. (2012) reported that inclusion of vegetables in rice-based cropping system not only improved the paddy-equivalent yield and profitability but also enhanced the level of employment and provide regular returns to the farmers. Keeping these facts in view, the present investigation was conducted to study the diversification and intensification of existing maize–wheat cropping system for sustainable productivity and profitability under irrigated areas of Humid Southern Zone of Rajasthan.

## MATERIALS AND METHODS

A field experiment was conducted from the rainy season (*kharif*) 2007 to summer 2011 on farmers' fields in 2 tehsils, namely Salumber and Sarada of Udaipur district, situated in Humid Southern Plain Zone of Rajasthan (India). The average annual rainfall of the zone is 918.7 mm. The soils of the experimental sites were sandy loam to clay loam, having pH 7.3–8.6, low to medium available nitrogen (220–350 kg/ha) and available phosphorus (16–21 kg/ha) and medium to high potassium status (215–395 kg/ha). The experiment was carried out in randomized block design considering every farmer (12) as replication. The treatments include 5 cropping systems, viz. maize–wheat, maize–wheat–greengram, maize + blackgram (2:2)–wheat–okra, clusterbean–wheat–greengram and clusterbean–wheat–okra. 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 used, seed rate, fertilizer doses and spacing are given in Table 1. Nitrogen, phosphorus and potassium were applied through urea, single superphosphate and muriate of potash, respectively. In maize, half dose of nitrogen and full doses of phosphorus and potassium were applied at the time of sowing, while remaining N was applied 1 month after sowing. Full doses of N, P and K were applied at sowing time in clusterbean. In intercropped blackgram, N, P and K were applied based on number of rows at the time of sowing. At physiological stage of 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 *kharif* crops, wheat was sown in the same plots without disturbing the lay out as per recommended package of practices mentioned in Table 1. Half dose of nitrogen and full doses of P and K were applied at the time of sowing, while remaining nitrogen was top-dressed at the first irrigation. Wheat was harvested at physiological maturity stage and after sun drying and threshing, weighed to record grain and straw yields. After harvesting of wheat, summer crops, viz. greengram and okra, were raised as per treatments without disturbing the original layout following standard package of practices (Table 1). Greengram was harvested at physiological stage of maturity while 3–4 pickings of okra were taken to harvest it in green and immature stage.

The productivity of different cropping systems was computed by converting yield of all crops into maize–grain-equivalent yield (MGEY) based on the prevailing market/minimum support price during each year. The economic returns and cost of cultivation for individual crop in sequences were calculated on the basis of prevailing market prices of inputs used in raising a crop and selling prices of produce during individual year. The intensification 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 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) as suggested by Singh *et al*. (1990) were also calculated for measuring sustainability from yield or income point of view of a cropping system under a set of management practices. In sustainable value index, monetary values of the economic produce were used instead of yield values.

Energy inputs and outputs were calculated using energy equivalents, as suggested by Singh and Mittal (1992) and the energy equivalents used are given in Table 2. Energy-use efficiency, energy-output efficiency, energy productivity, energy intensiveness and specific energy were calculated by using standard formulae. For treatment comparisons in the field experiments the F-test was used following the procedure for randomized block design (Cochran and Cox, 1957).

## RESULTS AND DISCUSSION

### *Season-wise productivity of component crops*

During the rainy (*kharif*) season, sole crop of maize gave higher grain and stover yields than intercropped maize and sole crop of clusterbean (Table 3). Further, the preceding crops also influenced grain and straw yields of succeeding wheat (Table 3). Wheat raised after intercropped maize with blackgram (2:2) gave higher grain yield than the preceding sole maize and clusterbean crops. However, straw yield of wheat was higher when preceded by clusterbean, closely followed by preceded intercropped maize. The lower grain and straw yields of wheat were recorded, when preceded by maize due to exhaustive nature of the maize crop, as it mined more nutrients from the soil than its replenishment through fertilizers. On the other hand, higher yield of wheat after pulse/legume might be owing to the fact that inclusion of legume in crop rotation improves soil microbial biomass and their activity that could be vital for soil health and productivity. Singh *et al*. (2002) were of the opinion that maize–cob equivalents of succeeding crops improved when grown after maize + cowpea than sole maize and maize + okra. Bisht (2009) was also of the opinion that all the winter crops (wheat, barley and mustard) gave higher grain yields after a legume than that after a cereal. Among the summer crops, yield of okra was higher than greengram. Maximum okra yield was obtained in clusterbean–wheat–okra than maize + blackgram (2:2)–wheat–okra cropping system. Seed and straw yields of greengram were higher in clusterbean–wheat–greengram than maize–wheat–greengram system.

### *System productivity*

The total productivity of various cropping systems was worked out after converting the economic yield of all the crops grown in sequence into maize–grain-equivalent yield (Table 3). System productivity was considerably higher where okra (vegetable) was introduced during the summer season than greengram (pulse). Among the various cropping systems, maize + blackgram (2:2)–wheat–okra cropping system gave significantly higher maize–grain-equivalent yield, being 202.8, 113.8, 101.5 and 3.3% more than maize–wheat, maize–wheat–greengram, clusterbean–wheat–greengram and clusterbean–wheat–okra cropping systems respectively, and was at par with clusterbean–wheat–okra cropping system.Intensification of maize during the rainy (*kharif*) season with blackgram

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rainy season (*kharif*) | Winter season (*rabi*) | Summer | *Kharif* | Rabi | Summer | *Kharif* | *Rabi* | Summer | *Kharif* | *Rabi* | Summer | (days) |
| Maize–wheat | 'Pratap Makka 5' | 'Raj 4037' | | 25 | 100 | | 60 × 25 | 23 | | 90:40:30 | 120:40:30 | | 233 |
| Maize–wheat–greengram | 'Pratap Makka 5' | 'Raj 4037' | 'K 851'/ 'SML 668' | 25 | 100 | 20 | 60 × 25 | 23 | 30 × 10 | 90:40:30 | 120:40:30 | 20:40:30 | 307 |
| Maize + blackgram (2:2)–wheat–okra | 'Pratap Makka 5' (T9) | 'Raj 4037' | 'Arka Anamika' | 25(10) | 100 | 20 | 30 × 25 (30 × 10) | 23 | | 90:40:30 (10:20:15) | 120:40:30 | 60:30:30 | 322 |
| Clusterbean–wheat greengram | 'RGC 936'/'RGC 1003' | 'Raj 4037' | 'K 851'/ 'SML 668' | 20 | 100 | 20 | 30 × 10 | 23 | 30 × 10 | 20:40:30 | 120:40:30 | 20:40:30 | 301 |
| Clusterbean–wheat–okra | 'RGC 936'/'RGC 1003' | 'Raj 4037' | 'Arka Anamika' | 20 | 100 | 20 | 30 × 10 | 23 | | 20:40:30 | 120:40:30 | 60:30:30 | 315 |

Figures in parentheses indicate production technologies for intercrops and inclusion of okra (vegetable) during summer season may be attributed to higher system productivity. In fact, the crop sequence involving pulse/legume played an important role in restoring the soil fertility in terms of N and other biological parameters due to atmospheric N fixation through symbiotic process, which in turn improved the yield of the succeeding crop compared with that of the cereal–cereal crop sequence (Ramesh and Reddy, 2004). Further, higher tonnage of vegetable (okra) and additional intercrop yield as bonus (blackgram) and better price of both okra and blackgram also played a vital role in improving the maize–grain-equivalent yield. The results revealed the importance of legumes and vegetable in the cropping systems for diversification and intensification of the system. Mishra *et al*. (2007) also obtained higher productivity with the inclusion of vegetables and pulses in rice-based cropping systems. On the other hand, the lowest maize–grain-equivalent yield was achieved in maize–wheat cropping system mainly due to lower price of maize grain, raising of only 2 crops in a year and could also be attributed to the exhaustive nature of maize crop which leads to poor yield of succeeding wheat crop. It clearly shows the importance of summer crops to raise the system productivity and sustainability under irrigated conditions.

### *Economics*

Maximum cost of cultivation was incurred in maize + blackgram (2:2)–wheat–okra cropping system, followed by clusterbean–wheat–okra cropping system. Inclusion of vegetable (okra) in both the systems and intercropping with blackgram in maize + blackgram (2:2)–wheat–okra increased the cultivation cost. On the other hand, the lowest cost of cultivation incurred in maize–wheat cropping system owing to raising of only 2 crops in a year. The highest gross returns were realized from maize + blackgram (2:2)–wheat–okra cropping system, followed by clusterbean–wheat–okra cropping system. It was owing to higher system productivity among all 5 cropping systems tried. Significantly higher net returns were realized from maize + blackgram (2:2)–wheat–okra cropping system over all the other cropping system and was on a par with clusterbean–wheat–okra. This system fetched an additional income of 138.3, 107.3, 100.5 and 1.9 × $10^3$₹/ha over maize–wheat, maize–wheat–greengram, clusterbean–wheat–greengram and clusterbean–wheat–okra cropping systems respectively. Inclusion of vegetable crop (okra) in these systems, besides improving the system productivity, fetched higher market price thereby, increasing net returns. Further, intensification of maize with blackgram intercropping gave additional yield which also fetched higher market price and increased net returns of the system. Mishra *et al*. (2007) also reported higher profitability with the inclusion of vegetables and pulses in rice-based cropping systems. Kumar *et al*. (2008) also reported that inclusion of vegetable crop in rice-based cropping system improved net returns. Under assured irrigated areas, raising of vegetable crop during summer season is economically remunerative as supply of vegetables from rainfed area is drastically reduced and vegetable prices are much higher. Therefore, surplus vegetables produced can be transported in areas of high demand. However, significantly higher benefit: cost ratio was recorded under clusterbean–wheat–okra cropping system probably owing to higher returns in comparison to cost of cultivation.

### *Resource-use efficiency*

Maize + blackgram (2:2)–wheat–okra system registered the highest land-use efficiency, as it used land for maxi-

**Table 2**. Energy equivalents for various inputs and outputs

| Input | Unit | Equivalent energy (MJ) | Output | Unit | Equivalent energy (MJ) |
|---|---|---|---|---|---|
| Adult man | Man-hour | 1.96 | *Main Product* | | |
| Woman | Woman-hour | 1.57 | Maize | kg | 14.7 |
| Diesel (including lubricants) | l | 56.3 | Wheat | kg | 14.7 |
| Electricity | KWh | 11.93 | Blackgram | kg | 14.7 |
| Farm Machinery | kg | 62.70 | Greengram | kg | 14.7 |
| Tractor | kg | 64.80 | Clusterbean | kg | 1.9 |
| N | kg | 60.60 | Okra | kg | 1.9 |
| $P_2O_5$ | kg | 11.10 | *By-product* | | |
| $K_2O$ | kg | 6.7 | Straw (wheat, greengram and blackgram) | kg | 12.5 |
| Chemicals requiring dilution at the time of application | kg | 120 | Straw (clusterbean) | kg | 10.0 |
| Chemicals not requiring dilution | kg | 10 | Stover (maize) | kg | 18.0 |

Source: Singh and Mittal (1992)

mum period in a year (322 days), followed by clusterbean–wheat–okra. On the other hand, land-use efficiency was the lowest in maize–wheat cropping system (63.8%) because the system utilized the field for less duration (233 days) due to raising of 2 crops in a year. Maize + blackgram (2:2)–wheat–okra cropping system registered the highest production efficiency, while monetary efficiency was the highest in clusterbean–wheat–okra cropping system. Minimum production and monetary efficiencies were recorded under maize–wheat cropping system. This was obviously owing to lower maize–grain-equivalent yield as well as gross and net returns in comparison with the other cropping systems tried (Table 3). Sharma *et al*. (2004) have also reported that intensification through inclusion of vegetables and leguminous crops increase the production and land use efficiency.

### *Relative efficiency of the systems*

Maximum values of relative productivity efficiency and relative economic efficiency were recorded in maize + blackgram (2:2)–wheat–okra cropping system over and above the exiting maize–wheat cropping system (Table 3). It showed that maize-wheat cropping system could be suitably intensified with intercropping of blackgram during *kharif* and raising of okra during summer season.

### *Sustainability*

The sustainability of different cropping systems (Table 3) examined over a period of 4 years indicated that maize + blackgram (2:2)–wheat–okra cropping system recorded the highest sustainable yield index, followed by clusterbean–wheat–okra cropping system irrespective of variation in weather and price. It indicates that the minimum guaranteed yields obtained from these sequences are 57 and 50% respectively. The lowest value of sustainable yield index was recorded in maize–wheat cropping system. Sustainable value index was also higher in maize + blackgram (2:2)–wheat–okra cropping system, while the lowest value was recorded in maize–wheat cropping system.

### *Energetics*

The highest calorific value was registered in maize + blackgram (2:2)–wheat–okra cropping system closely followed by maize–wheat–greengram among the 5 cropping systems tried. On the other hand, the lowest calorific value was recorded in clusterbean–wheat–okra cropping system owing to lower energy values of both clusterbean and okra and lower yield of clusterbean compared to other crops.

The total input energy requirement in various cropping systems ranged from $35.6 \times 10^3$ to $52.7 \times 10^3$ MJ/ha (Table 4). Among the different cropping systems, maize +

**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), relative efficiencies and total calories as affected by various cropping systems (Mean data of 4 years)

| Cropping system | Seed/grain/green pod (t/ha) | | | Stover/straw yield (t/ha) | | | Maize-grain equivalent yield (t/ha) | Gross returns ($\times 10^3$ ₹/ha) | Cost of cultivation ($\times 10^3$ ₹/ha) | Net returns ($\times 10^3$ ₹/ha) | Benefit cost ratio | LUE (%) | PE(kg/ha/day)* | ME (₹/ha/day)** | SYI | SVI | RPE (%) | REE (%) | Total calories ($\times 10^3$ MJ/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Kharif* | *Rabi* | Summer | *Kharif* | *Rabi* | Summer | | | | | | | | | | | | | |
| Maize–wheat | 2.71 | 4.31 | | 4.25 | 7.08 | | 8.63 | 95.7 | 28.2 | 67.5 | 3.39 | 63.8 | 37.0 | 289.6 | 0.23 | 0.19 | | | 101.1 |
| Maize–wheat–greengram | 2.81 | 4.26 | 1.04 | 4.37 | 6.73 | 1.59 | 12.22 | 134.5 | 36.0 | 98.5 | 3.74 | 84.1 | 39.8 | 321.0 | 0.33 | 0.24 | 41.7 | 46.0 | 116.5 |
| Maize + blackgram(2:2)–wheat–okra | 2.30 (0.46) | 4.71 | 6.44 | 3.76 (0.81) | 7.33 | | 26.13 | 263.2 | 57.3 | 205.8 | 4.59 | 88.2 | 81.1 | 639.3 | 0.57 | 0.46 | 202.8 | 205.0 | 117.3 |
| Clusterbean–wheat–greengram | 1.05 | 4.69 | 1.07 | 1.74 | 7.45 | 1.66 | 12.97 | 137.6 | 32.3 | 105.3 | 4.26 | 82.5 | 43.1 | 349.8 | 0.33 | 0.25 | 50.3 | 56.0 | 83.5 |
| Clusterbean–wheat–okra | 1.11 | 4.70 | 6.55 | 1.86 | 7.48 | | 25.30 | 253.6 | 49.7 | 203.9 | 5.10 | 86.3 | 80.3 | 647.2 | 0.50 | 0.39 | 193.2 | 202.1 | 78.4 |
| SEm± | | | | | | | 0.39 | | | 3.42 | 0.06 | | | | | | | | |
| CD (P=0.05) | | | | | | | 1.09 | | | 9.56 | 0.18 | | | | | | | | |

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

**Table 4**. Energetics of different wheat-based cropping systems (mean data of 4 years)

| Cropping system | Input energy (× $10^3$MJ/ha) | Output energy (× $10^3$MJ/ha) | Energy-use efficiency | Energy-output efficiency (MJ/ha/day) | Energy productivity (g/MJ) | Energy intensiveness (MJ/₹) | Specific energy (MJ/kg) |
|---|---|---|---|---|---|---|---|
| Maize–wheat | 35.6 | 268.0 | 7.52 | 1150.2 | 242.2 | 9.49 | 4.13 |
| Maize–wheat–greengram | 46.0 | 301.8 | 6.56 | 983.2 | 265.5 | 8.39 | 3.77 |
| Maize + blackgram (2:2)–wheat–okra | 52.7 | 291.5 | 5.53 | 897.0 | 495.4 | 5.08 | 2.02 |
| Clusterbean–wheat–greengram | 40.4 | 217.8 | 5.39 | 731.0 | 320.8 | 6.75 | 3.12 |
| Clusterbean–wheat–okra | 43.5 | 195.7 | 4.50 | 621.4 | 581.9 | 3.94 | 1.72 |

blackgram (2:2)–wheat–okra required maximum input energy, while minimum input energy was used in maize–wheat cropping system. On the other hand, maize–wheat–greengram cropping system produced maximum total output energy followed by maize + blackgram (2:2)–wheat–okra due to inclusion of pulse either as a sole or intercrop while minimum in clusterbean–wheat–okra cropping system. The maximum values of energy-use efficiency, energy output efficiency, energy intensiveness and specific energy were found in maize–wheat cropping system. On the other hand, energy productivity was higher in clusterbean–wheat–okra cropping system owing to more maize–grain-equivalent yield in comparison to input energy used, while minimum energy productivity was under maize–wheat cropping system. Jain *et al*. (2011) also reported the lowest energy productivity in cereal–cereal cropping system.

On the basis of 4 year experimentation, it can be concluded that maize + blackgram (2:2)–wheat–okra cropping system was found to be more productive, profitable and sustainable and can suitably intensified the existing maize–wheat cropping system under irrigated areas of Humid Southern Plain Zone of Rajasthan (India), which not only enhances the level of employment but also provide the farmers a regular return through out the year.

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