Evaluation of rice (*Oryza sativa* L.)-based cropping systems for productivity and profitability in the vertisols of Telangana, India


Professor Jayashankar Telangana State Agricultural University, Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad District 500 030, India

Field experiment with different rice based cropping systems, viz. rice–rice, rice–mustard, rice–chickpea, rice–green gram, rice–sorghum, rice–maize, rice–black gram, rice–cowpea (fodder), rice–sorghum (fodder) were evaluated with rice–rice at RS & RRS, Rudrur, Nizamabad, PJTSAU, Telangana. Green manure–rice–maize and green manure–rice–fodder sorghum produced 15,848 kg REY/ha and 15,292 kg REY/ha respectively, which was significantly more than other cropping systems. Production efficiency of green manure–rice–maize was significantly more (58.26 kg/ha/day) closely followed by green manure–rice–sorghum (54.32 kg/ha/day) and green manure–rice–black gram (54.04 kg/ha/day), while it was lower for green manure–rice–fodder cowpea (39.16 kg/ha/day) and green manure–rice–fodder sorghum (42.09 kg/ha/day). Green manure–rice–maize, green manure–rice–black gram and green manure–rice–fodder sorghum were at par with each other for system net returns with 202,341 Rs/ha, 199,916 Rs/ha, 189,623 Rs/ha respectively, and was least with green manure–rice–fodder cowpea (124,981 Rs/ha) and green manure–rice–rice (148,937 Rs/ha). Energy productivity was higher with green manure–rice–black gram (1.13 kg/MJ) and green manure–rice–green gram (0.91 kg/MJ) cropping system. Green manure–rice–maize, green manure–rice–blackgram are most suitable cropping systems over existing green manure–rice–rice cropping system for vertisols of Telangana state.

**Keywords:** Cropping systems, energy input and output, productivity and profitability, rice.

FOOD security in South Asia is mainly contributed from three major cereal crops, viz. rice, wheat and maize. Rice is cultivated as the first food crop and hence rice-based cropping systems make significant contribution towards food production with rice–rice as the major cropping system in irrigated agriculture, whereas rice–pulse–fallow is the predominant system in rainfed agriculture. In rice-growing tracts different crop combinations are followed depending on the agro-ecological situations, prevailing market price, and domestic demands and resources available at the farms. In South India rice–rice is the predominant cropping system in both tropical weather characterized by dry and wet seasons and subtropical weather with cool winter. Most of the rice–wheat area is confined to the Indo-Gangetic Plains, whereas rice–maize system is followed in tropical, subtropical and warm temperate climates. Sustainability in productivity is the major objective in any crop planning. Cropping systems with greater productivity and low input demand are considered as efficient towards sustainability. In the recent past, oilseeds and legumes have gained more attention due to low production and high costs. These crops if incorporated in the cropping sequence will influence the economics of the cropping system. There is a close relationship between cropping system, productivity, economics, energy and environment. Green manuring during summer mitigates the ill-effects of leaving barren lands and is the best practice for sustainable rice production.

Tuti et al. reported that crop yield is inversely related to energy use efficiency, energy productivity and energy intensiveness. Atmospheric pollution can be reduced by adopting energy-efficient cropping systems which require less external inputs, thus providing an economically viable production choice for the future.

With the decline in availability of natural resources like land, water and energy, resource use efficiency plays a vital role in the suitability of any cropping system to a particular area. Hence selection of component crops should be planned for a synergistic effect in efficient utilization of resources with enhanced productivity. There is a need to evaluate suitable rice-based cropping systems in order to establish stability in the system. Inclusion of pulses and vegetables in any cropping system results in beneficial output.

Evaluating the possibilities of replacing post-rainy-season rice with suitable upland crops, including summer season crops with improved resource use efficiency and increased productivity and sustainability is needed in the prevailing agricultural scenario.
Rice–cowpea (fodder)
Rice–black gram
Rice–sorghum
Rice–chickpea
Rice–mustard

medium available K₂O (298 kg/ha).

inputs used.

practices. Table 1 provides details of crop duration and

All the crops in the cropping sequence were grown in a

shankar Telangana State Agricultural University, Telan-

Sugarcane and Rice Research Station at Professor Jaya-
gana at 18°–30°N lat. and 77–51°E long. and an elevation of 404 m amsl.

The average annual rainfall recorded during the period
of study (May 2018 to May 2019) was 473.5 mm, 30.66% lower than the decennial average rainfall (682.96 mm). The soil of experimental sites was clay loam with me-
dium organic carbon content (0.67%), medium available N (387 kg/ha), medium available P₂O₅ (48 kg/ha) and medium available K₂O (298 kg/ha).

All the crops in the cropping sequence were grown in a
gross area of 1080 sq. m, with recommended package and
practices. Table 1 provides details of crop duration and
inputs used.

Field preparation during kharif was done by running a
rotavator once and green manure seeds were evenly
broadcasted @ 50 kg ha⁻¹. Crops were grown up to 50% flowering stage (40 DAS) and incorporated in the soil by running cultivator followed by rotavator. Following sub-
mergence irrigation, single super phosphate was applied, and allowed to decompose for 48 h. The water was
drained out from the field and freshwater was provided, and puddling was done with the rotavator. The 25-day-
old rice seedlings were transplanted in the first week of
July. After the harvest of rice in the second fortnight of
September, rabi crops were sown in the second fortnight of
October. Recommended doses of fertilizers to each
crop in various cropping systems were applied. Irrigation
was done according to the crop needs. At maturity all
crops were harvested manually from a net plot area of
750 sq. m out of 1230 sq. m gross plot area. After har-
esting, data pertaining to biproduce and economic yield

Materials and methods

Field experiments with eight different rice-based crop-
gram, rice–cowpea (fodder) and rice–sorghum (fodder) were performed with rice–rice during kharif (June to Sep-
tember) and rabi (October to January) at the Regional Sugarcane and Rice Research Station at Professor Jaya-
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of 404 m amsl.

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of each crop were converted into per hectare. Economic produce of all the crops was obtained manually.

To compare the performance of different cropping
sequences, economic yield of all the crops was converted
into rice equivalent yield (REY) based on the prevailing
market price using following formula

\[ \text{REY (of a crop)} = Y_x \left( \frac{P_x}{P_r} \right), \]

where \( Y_x \) is the yield of crop \( x \) (tonne/ha of economic harvest), \( P_x \) the price of crop \( x \) and \( P_r \) is the price of rice.

To study resource use efficiency of the system, land-
use efficiency (LUE) was calculated from total duration
of the crop in cropping system divided by 365 and produc-
tion efficiency (PE; kg/ha/day) was calculated by divid-
ing total economic yield (REY) by total duration of crops
in the cropping system. The relative production efficiency
(RPE) of the system was calculated and expressed as per-
centage.

\[ \text{RPE} = \left( 1 - \frac{A}{B} \right) \times 100, \]

where \( A \) is the productivity (REY) of rice–rice system
and \( B \) is the productivity (REY) of the diversified crop-
ing system.

Energetics

Energy input and energy output for the individual crops
in the cropping system were calculated and the energy
value was determined. Energy input from humans, animals,
machineries, fuel sources, seeds, fertilizers, farmyard
manure and pesticides was recorded during different stages
of application. Energy input and output were converted
from physical to energy unit measures through published
conversion coefficients. The biomass of the crop was
separated into economic product (grain/fodder) and by-pro-
duct (straw). Energy output from the economic product
(grain/fodder) and by-product (straw) was calculated by
multiplying the amount of production and its correspond-
ing energy equivalent. The total energy was calculated
from total material input energy with the required oper-
ational energy.

### Table 1. Agronomic management adopted for crops grown during the experiment

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Variety</th>
<th>Kharif Seed rate (kg/ha)</th>
<th>Rabi Seed rate (kg/ha)</th>
<th>Spacing (cm × cm)</th>
<th>Fertilizer (kg/ha; N : P₂O₅ : K₂O)</th>
<th>No. of irrigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice–rice</td>
<td>KMN 118</td>
<td>50</td>
<td>50</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–mustard</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–chickpea</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–green gram</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–sorghum</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–maize</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–black gram</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–cowpea (fodder)</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td>Rice–sorghum (fodder)</td>
<td>KMN 118</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>SSG 293</td>
<td>50</td>
<td>5</td>
<td>20 × 15</td>
<td>100 : 60 : 40</td>
<td>10</td>
</tr>
</tbody>
</table>
Energy input was calculated as follows

$$EI = \left[ \frac{1}{A} \left( \sum (E_i \cdot \varepsilon_i) + \sum (M_m \cdot t_m) \right) \right] / A,$$

where $EI$ is the total energy input to a particular type of crop production (MJ ha$^{-1}$), $E_i$ the total energy input and output components utilized for agricultural production of a specific crop, $\varepsilon_i$ the energy equivalent coefficient for various input energy forms, $M_m$ the machinery energy equivalent (MJ h$^{-1}$), $t_m$ the actual working time of the machinery or equipment (h), and $A$ is the total cropped area under a particular cropping system (ha).

The energy output was calculated as follows

$$EO = \left[ \sum (P_{mc} \cdot \varepsilon_{om}) \right] / A,$$

where $EO$ is the net energy content of the output product (MJ ha$^{-1}$), $P_{mc}$ the total production quantity of the main crop (kg), $\varepsilon_{om}$ the net calorific value (NCV) of the main crop and by-products (MJ kg$^{-1}$) respectively and $A$ is the total cropped area under a particular cropping system (ha).

The energy input–output relationship was determined by calculating energy use efficiency, energy productivity and specific energy as follows

$$\text{Energy productivity} = \frac{\text{Grain + by-product (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})},$$

$$\text{Specific energy} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Grain yield (kg ha}^{-1})},$$

$$\text{Energy efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}.$$

Economics

Total expenditure incurred was calculated by taking into account the prevailing market price of the inputs. Minimum support price was used for grain and local market price was used for green fodder and by-products (straw) of crops for calculating gross returns. Profitability of the system was calculated by dividing the net return (Rs ha$^{-1}$) in a sequence by 365 days. The relative economic efficiency (REE) of the system was calculated and expressed as percentage.

$$\text{REE} = \frac{(B - A)}{A} \times 100,$$

where $A$ is the net return (Rs ha$^{-1}$) of the existing system and $B$ is the net return (Rs ha$^{-1}$) of the diversified cropping system.

The data were subjected to statistical analysis using the analysis of variance and the significance of different sources of variations was tested by error mean square of Fisher Snedecor’s ‘$F$’ test at probability level 0.05, as suggested by Cochran and Cox$^2$.

Results

Productivity analysis

During kharif, rice grain yield was non-significant between treatments (Table 2). Performance of crops in terms of REY-yield was significant between treatments during rabi. Maize crop was significantly superior with 7677 kg REY/ha followed by grain sorghum (6385 kg REY/ha) and black gram (6336 kg REY/ha), indicating the possibility of replacing rabi rice with maize. Lowest REY was observed in fodder cowpea (1987 kg REY/ha), mustard (4505 kg REY/ha) and rice (4630 kg REY/ha). Cropping sequence green manure–rice–maize and green manure–rice–fodder sorghum produced 15,848 and 15,292 kg REY/ha respectively, which was significantly greater than other cropping systems with production of more than 2537 and 1981 kg than the prevailing rice–rice cropping system. Variations in the yield of crops may be due to the biological and environmental complexities and interactions in the cropping systems$^{10}$. Rice after rice cropping sequence is an exhaustive system$^{11}$. PE of different cropping systems (Table 3) indicated that green manure–rice–maize was significantly more efficient (58.26 kg/ha/day) closely followed by green manure–rice–sorghum (54.32 kg/ha/day) and green manure–rice–black gram (54.04 kg/ha/day). Lowest PE was with fodder-based cropping systems green manure–rice–fodder cowpea (39.16 kg/ha/day) and green manure–rice–fodder sorghum (42.09 kg/ha/day). Analysis of all the cropping systems for RPE revealed that except for green manure–rice–fodder cowpea, all other cropping systems with positive values were better compared to the existing rice–rice system and that the green manure–rice–maize cropping system with RPE of 20.06% could replace the existing rice–rice system. Highest LUE was recorded with cropping system green manure–rice–fodder sorghum (95.89%) followed by green manure–rice–maize (84.93%), proving their efficiency for occupying the land for maximum duration.

Economic analysis

Among cropping systems, green manure–rice–maize, green manure–rice–black gram and green manure–rice–fodder sorghum were at par with each other for system net returns of Rs 202,341/ha, Rs 199,916/ha and Rs 189,623/ha respectively (Table 4). Higher system productivity recorded with these cropping systems has contributed to higher returns. Lowest net returns were recorded with green manure–rice–fodder cowpea (Rs 124,981/ha) and green manure–rice–rice (Rs 148,937/ha) due lower productivity recorded with these systems. In terms of returns per rupee...
Table 2. Grain and straw yield of different rice-based cropping systems during 2018–19

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg/ha)</th>
<th>REY (kg/ha)</th>
<th>Total grain REY (kg/ha)</th>
<th>Straw yield (kg/ha)</th>
<th>Straw REY (kg/ha)</th>
<th>Total straw REY (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kharif Rabi</td>
<td>Rabi</td>
<td>Kharif Rabi</td>
<td>Kharif Rabi</td>
<td>Kharif Rabi</td>
<td>Kharif Rabi</td>
</tr>
<tr>
<td>T1-GM–rice–rice</td>
<td>8681 8692</td>
<td>4630</td>
<td>13,311</td>
<td>9722 9561</td>
<td>1111 1093</td>
<td>2204</td>
</tr>
<tr>
<td>T2-GM–rice–mustard</td>
<td>8758 1971</td>
<td>4505</td>
<td>13,263</td>
<td>9809 4336</td>
<td>1121 496</td>
<td>1617</td>
</tr>
<tr>
<td>T3-GM–rice–chickpea</td>
<td>8381 2149</td>
<td>5219</td>
<td>13,600</td>
<td>9387 2472</td>
<td>1073 282</td>
<td>1355</td>
</tr>
<tr>
<td>T4-GM–rice–green gram</td>
<td>8585 1186</td>
<td>4726</td>
<td>15,927</td>
<td>9615 1304</td>
<td>1099 149</td>
<td>1248</td>
</tr>
<tr>
<td>T5-GM–rice–sorghum</td>
<td>8552 4598</td>
<td>6385</td>
<td>14,937</td>
<td>9749 6438</td>
<td>1114 736</td>
<td>1850</td>
</tr>
<tr>
<td>T6-GM–rice–maize</td>
<td>8784 7903</td>
<td>6777</td>
<td>15,848</td>
<td>9315 10431</td>
<td>1065 1192</td>
<td>2257</td>
</tr>
<tr>
<td>T7-GM–rice–black gram</td>
<td>8956 1980</td>
<td>6336</td>
<td>15,292</td>
<td>10210 2218</td>
<td>1167 253</td>
<td>1420</td>
</tr>
<tr>
<td>T8-GM–rice–cowpea (fodder)</td>
<td>8371 17,383</td>
<td>1987</td>
<td>10,770</td>
<td>10013 0</td>
<td>1144 0</td>
<td>1144</td>
</tr>
<tr>
<td>T9-GM–rice–sorghum (fodder)</td>
<td>8674 43,750</td>
<td>6059</td>
<td>14,733</td>
<td>9888 0</td>
<td>1130 0</td>
<td>1130</td>
</tr>
</tbody>
</table>

SEm = ±133.61 788.62 198.57 259.61 157.06 142.46 18 49 24.86
CD (P = 0.05) NS 2384.64 600.45 785.01 474.92 430.80 54 16 75.17

GM, Green manure; REY, Rice equivalent yield.

Table 3. Production efficiency (PE) and land-use efficiency (LUE) of different rice-based cropping systems during 2018–19

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Duration of crops (days)</th>
<th>PE (kg/ha/day)</th>
<th>Relative PE (%)</th>
<th>LUE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1-GM–rice–rice</td>
<td>285</td>
<td>46.70</td>
<td>–</td>
<td>78.08</td>
</tr>
<tr>
<td>T2-GM–rice–mustard</td>
<td>272</td>
<td>50.16</td>
<td>2.50</td>
<td>74.52</td>
</tr>
<tr>
<td>T3-GM–rice–chickpea</td>
<td>310</td>
<td>43.87</td>
<td>2.18</td>
<td>84.93</td>
</tr>
<tr>
<td>T4-GM–rice–green gram</td>
<td>270</td>
<td>49.79</td>
<td>1.00</td>
<td>73.97</td>
</tr>
<tr>
<td>T5-GM–rice–sorghum</td>
<td>275</td>
<td>54.32</td>
<td>12.22</td>
<td>75.34</td>
</tr>
<tr>
<td>T6-GM–rice–maize</td>
<td>310</td>
<td>58.26</td>
<td>20.06</td>
<td>84.93</td>
</tr>
<tr>
<td>T7-GM–rice–black gram</td>
<td>283</td>
<td>54.04</td>
<td>14.89</td>
<td>77.53</td>
</tr>
<tr>
<td>T8-GM–rice–cowpea (fodder)</td>
<td>275</td>
<td>39.16</td>
<td>–19.08</td>
<td>75.34</td>
</tr>
<tr>
<td>T9-GM–rice–sorghum (fodder)</td>
<td>350</td>
<td>42.09</td>
<td>10.68</td>
<td>95.89</td>
</tr>
</tbody>
</table>

SEm = ±0.886 0.064 12.376
CD (P = 0.05) – 2.678 –

Table 4. Economics of different rice-based cropping systems during 2018–19

<table>
<thead>
<tr>
<th>Treatment</th>
<th>System cost of cultivation (Rs)</th>
<th>Total net returns (Rs/ha)</th>
<th>B : C ratio</th>
<th>System profitability (Rs/ha/day)</th>
<th>Relative economic efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1-GM–rice–rice</td>
<td>84,000</td>
<td>148,937</td>
<td>1.77</td>
<td>408.00</td>
<td>–</td>
</tr>
<tr>
<td>T2-GM–rice–mustard</td>
<td>72,500</td>
<td>159,604</td>
<td>2.20</td>
<td>437.67</td>
<td>7.16</td>
</tr>
<tr>
<td>T3-GM–rice–chickpea</td>
<td>68,200</td>
<td>169,807</td>
<td>2.49</td>
<td>465.35</td>
<td>14.01</td>
</tr>
<tr>
<td>T4-GM–rice–green gram</td>
<td>66,500</td>
<td>166,444</td>
<td>2.50</td>
<td>450.00</td>
<td>11.75</td>
</tr>
<tr>
<td>T5-GM–rice–sorghum</td>
<td>74,200</td>
<td>187,194</td>
<td>2.52</td>
<td>512.86</td>
<td>25.69</td>
</tr>
<tr>
<td>T6-GM–rice–maize</td>
<td>75,000</td>
<td>202,341</td>
<td>2.78</td>
<td>554.54</td>
<td>35.86</td>
</tr>
<tr>
<td>T7-GM–rice–black gram</td>
<td>67,700</td>
<td>199,916</td>
<td>2.95</td>
<td>547.68</td>
<td>34.23</td>
</tr>
<tr>
<td>T8-GM–rice–cowpea (fodder)</td>
<td>63,500</td>
<td>124,981</td>
<td>1.97</td>
<td>342.45</td>
<td>–16.08</td>
</tr>
<tr>
<td>T9-GM–rice–sorghum (fodder)</td>
<td>68,200</td>
<td>189,623</td>
<td>2.70</td>
<td>519.28</td>
<td>27.32</td>
</tr>
</tbody>
</table>

SEm = ±4,541.84 0.064 12.376
CD (P = 0.05) – 13,733.67 0.195 37.423

Invested, green manure–rice–black gram (2.95) and green manure–rice–maize (2.78), were more economical and on par with each other, closely followed by green manure–rice–fodder sorghum (2.70) due to more market price coupled with higher productivity and lower cost of cultivation for black gram and higher productivity for maize and fodder sorghum. Cropping systems green manure–rice–fodder cowpea (1.97) and green manure–rice–rice (1.77) were observed to be less economical. Economic analysis of cropping systems clearly indicated that green manure–rice–maize, green manure–rice–black gram and green manure–rice–fodder sorghum were significantly superior over other cropping systems with system profitability of Rs 554.54/ha/day, Rs 547.68/ha/day and Rs 519.68/ha/day and higher relative economic efficiency of 35.86%, 34.23% and 27.32% respectively.

Energy analysis

Energy input and output relationships for growing crops in the studied cropping systems have been analysed and
are presented here (Tables 5 and 6). The highest input energy (31,105.67 MJ ha⁻¹) was required for growing rice crop in sequence and the lowest energy was required for growing fodder cowpea (6,982.51 MJ ha⁻¹) and green gram (7,645.52 MJ ha⁻¹) and black gram (7,848.84 MJ ha⁻¹) in sequence. This was mainly due to variable amount of inputs required for growing the crops. Hence the highest input energy was required for cereal-based cropping systems green manure–rice–rice (66,108.42 MJ ha⁻¹), green manure–rice–sorghum (60,191.67 MJ ha⁻¹), green manure–rice–maize (59,846.43 MJ ha⁻¹), while the lowest was for pulse-based cropping systems green manure–rice–fodder cowpea (41,985.26 MJ ha⁻¹), green manure–rice–green gram (42,648.27 MJ ha⁻¹), green manure–rice–black gram (42,859.89 MJ ha⁻¹) and green manure–rice–chickpea (46,805.94 MJ ha⁻¹).

Maximum output energy was realized with fodder-based cropping systems green manure–rice–fodder sorghum (1,038,603 MJ ha⁻¹) and green manure–rice–fodder cowpea (558,186 MJ ha⁻¹) and hence higher energy efficiency of 18.84% and 13.29% respectively, because of higher energy equivalents of the produce. This indicates that more energy would be incurred for the yield (both grain and straw).

Energy productivity was higher with green manure–rice–black gram (1.13 kg/MJ) and green manure–rice–green gram (0.91 kg/MJ) cropping systems, which may be attributed to inclusion of legumes which require less inputs. During rabi, lower specific energy values were recorded with fodder cowpea (0.40 MJ/kg) and fodder sorghum (0.46 MJ/kg), followed by maize (3.14) rice (3.58) and black gram (3.96). Hence the total specific energy of the cropping system which includes these crops was low compared to other crops. This indicates that the amount of energy utilized to produce unit output was lower with these cropping systems. Walia et al. reported, that groundnut–toria+ gobi+ sarson and maize–potato–onion cropping were more energy efficient than rice–wheat cropping system.

Conclusion

From the present study it can be concluded that maize, black gram and fodder sorghum are the most suitable crops in rabi after harvest of kharif rice. The performance of these crops was superior with higher productivity, profitability and efficient energy utilization. Growing manure crops during summer sustained soil fertility of the system. The quick decomposing nature of green manure crop might have contributed towards enhancing soil
nutrient availability during both *kharif* and *rabi* crops. Therefore green manure–rice–maize and green manure–rice–black gram are more suitable cropping systems than the existing green manure–rice–rice systems for vertisols of Telangana. Farmers practising dairy with crops can follow green manure–rice–sorgum (fodder) cropping sequence for assured green fodder production for the cattle during post-rainy season.


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