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# Productivity, stability and profitability of rice (*Oryza sativa*)-based crop sequences in West Bengal and Orissa

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## ABSTRACT

A field experiment was conducted at Kalyani and Bhubaneshwar centres of All-India Co-ordinated Research Project on Cropping Systems during 1992–97, to find out efficient crop sequences. Among the crop sequences evaluated at Kalyani, rice (*Oryza sativa* L.)–potato (*Solanum tuberosum* L.)–jute (*Corchorus capsularis* L.) was found to be most productive in new alluvial zone of West Bengal, with highest mean yield in terms of rice equivalents (16,936 kg/ha/year), system productivity (67.47 kg/ha/year), energy productivity (46.93× $10^6$ K cal/ha) and net profit (Rs 51, 465/ha/year) but in other terms rice–wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–groundnut (*Arachis hypogaea* L.) was better with highest energy production (31.45 × $10^6$ K cal/ha on actual crop basis), land-use efficiency (0.86) and system stability (0.91). Among the sequences tested at Bhubaneshwar for eastern and south-eastern coastal zone of Orissa, rice–tomato (*Lycopersicon esculentum* Miller nom. cons.)–*poi* (*Basella rubra* L.) was distinctly better than others, with highest rice-yield equivalent (26,680 kg/ha/ year), productivity (90.14 kg/ha/day), rice yield equivalent-based energy (73.64 × $10^6$ K cal/ha), land-use efficiency (0.81), net profit (Rs 87,220/ha) and benefit : cost ratio (17.2). However, in terms of energy production on actual crop basis rice–potato–sesame (*Sesamum indicum* L.) sequence was distinctly better (36.16 × $10^6$ K cal/ha). The stability of the system was, however, highest (0.74) in rice–Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]–ridgegourd [*Luffa acutangula* (Roxb.) L.] sequence. On the other hand, in terms of minimum risk of financial involvement, rice–Indian mustard–rice at Kalyani and rice–Indian mustard–ridgegourd at Bhubaneshwar were advisable.

***Key words :*** Yield equivalents, Crop productivity, Land-use efficiency, Crops and system stability, Economics, Rice-based systems

To fulfil the demand of food, fibre and vegetables with increasing human population, an intensification of cropping sequences is essential depending on the need in the area. Oilseeds and pulses including vegetables are receiving more attention owing to higher prices due to increased demand. The new policies of open economy also pave the way for export of some quality food materials including vegetables. Inclusion of these crops in a sequence changes the economics of the cropping sequence (Tomar and Tiwari, 1990). In states like West Bengal and Orissa, rice–rice is the predominant cropping system. There is no scope of replacing rice during the rainy season (*kharif*) due to soil and climatic compulsions, specially water stagnation in field conditions. However, a series of crops can profitably be grown during the winter (*rabi*) and summer season to meet the need of the household with saleable surplus. Therefore, it was considered important to evaluate various rice-based crop sequences in terms of productivity, stability and profitability, so as to identify the efficient, stable, productive and profitable crop sequences for West Bengal and Orissa.

## MATERIALS AND METHODS

An experiment involving various crop sequences at Bhubaneshwar (20° 15'N and 85° 52'N) in Orissa, under All-India Co-ordinated Research Project (AICRP) on Cropping Systems, was conducted during 1992–97 in randomized block design, replicated 4 times. At Kalyani, 5 crops sequences tested were : $T_1$, rice–Indian mustard–rice; $T_2$, rice–Indian mustard–*dhaincha*; $T_3$, rice–wheat–groundnut; $T_4$, rice–potato–sesame; and $T_5$, rice–potato–jute. Similarly, at Bhubaneshwar 6 crop sequences, viz. $T_1$, rice–groundnut–cowpea; $T_2$, rice–tomato–okra; $T_3$, rice–Indian mustard–ridgegourd; $T_4$, rice–cabbage–okra, $T_5$, rice–potato–sesame; and $T_6$; rice–tomato-*poi*, were evaluated. At Kalyani, rice was sown in first week of July and harvested in second week of November. Indian mustard, potato and wheat were sown as *rabi* crops second week of November and harvested in first week of March. Groundnut and sesame were sown in first week of March, while jute was sown in fourth week of March and *dhaincha* was sown in third week of May. At Bhubaneshwar rice was sown in fourth week of June and harvested in fourth week of October. Groundnut was sown in second week of December, and it was harvested in third week of April. Indian mustard was sown in first week of December. Similarly, tomato and cabbage as *rabi* crops were sown in third week of October and harvested in fourth week of January. Sesame was sown in first week of March and was harvested in second week of June. Similarly, was sown in first week of March harvested in third week of June. Cowpea was sown in second week of April and harvested in third week of May, while ridgegourd was sown in fourth week of February and harvested in third week of May as summer crops. The details of crop varieties and quantity of fertilizer dose used in various crops sequences are given in Tables 1 and 2 with crop information. The soil of experimental site was alluvial (very deep) at Kalyani, while lateritic (very deep) at Bhubaneshwar. Average annual rainfall of 1,333 mm at Kalyani and 1,893 mm at Bhubaneshwar was received during growing period.

The crop-wise yield data of various sequences were pooled over period of 5 years. The system-wise rice-yield equivalents were calculated. Since these equivalents may change based on price of commodities the energy equivalents were also calculated based on the procedure as suggested by Bhatnagar *et al.* (1989) and using basic figures as per ICMR standards (Gopalan *et al.*, 1978). The land-use efficiency, and crop-wise and sequence-wise stabilities were calculated as per the procedure described by Singh *et al.* (1990). The profitability in terms of net return with benefit : cost ratio and extent of risk involved was calculated for various crop sequences using prevailing market rates for various commodities.

## RESULTS AND DISCUSSION

### *Crop yield*

The yield of rice was the highest when *dhaincha* as green-manure crop at Kalyani and cowpea at Bhubaneshwar in summer were raised for 5 years. During winter season, the vegetable crops like tomato, potato and cabbage outyielded other crops which offers good scope for their introduction. In West Bengal, raising of crops like summer groundnut, rice, jute and *dhaincha* was feasible with varying yield. However, in Orissa vegetable crops specially okra and *poi* were found highly productive (Table 1).

### *System productivity*

In term of the rice-yield equivalent rice–potato–jute sequence yielded the highest during all the years, with mean yield of 16,936 kg/ha/year with system productivity of 67.47 kg/day/ha at Kalyani. Similarly, sequence involving rice–tomato–*poi* was distinctly better than others over years with mean yield equivalents of 26,680 kg/ha/year at Bhubaneshwar with highest system productivity of 90.14 kg/day/ha. The lowest productivity was obtained in rice–Indian mustard–rice sequence at Kalyani and in rice–Indian mustard–ridgegourd sequence at Bhubaneshwar.

### *Energy equivalents*

The energy-yield equivalents was calculated both on individual crop basis and also on further conversion of rice equivalents as the energy because figures for crops like *dhaincha* and jute were not readily available. On actual crop basis, the sequence involving rice–wheat–groundnut was highest producer of energy at Kalyani (Table 1), while at Bhubaneshwar the sequence involving rice–potato–sesame was distinctly better than other sequences. The converted figures of energy based on rice–grain equivalent shows that rice–potato–jute at Kalyani and at Bhubaneshwar rice–tomato–poi were the highest contributors.

### *Land-use efficiency*

At Kalyani, the highest land-use efficiency (LUE) was recorded in rice–wheat–groundnut sequence (0.86) which occupied the field for maximum number of days (315) in this sequence, while it was lowest (0.66) in rice–Indian mustard–*dhaincha* sequence, wherein field remained occupied for 232 days only. In other sequences, the LUE varied from 0.69 to 0.78 (Table 2). At Bhubaneshwar, the highest land-use efficiency (0.81) was recorded in rice–tomato–*poi* sequence

**Table 1.** Crop productivity, yield equivalents and energetics of various crop sequences at 2 locations in West Bengal and Orissa

| Cropping sequence (Variety) | | | Pooled yield (kg/ha) | | | Duration of field remained occupied (Number of days) | Rice-yield equivalent over years (kg/ha/year) | | | | | | System productivity (kg/day/ha) | Energy equivalents ($\times 10^6$ K.Cal/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainy season | Winter | Summer | Rainy season | Winter | Summer | | 1992–93 | 1993–94 | 1994–95 | 1995–96 | 1996–97 | Mean | | Actual crop basis | Rice equivalent basis |
| *Kalyani* | | | | | | | | | | | | | | | |
| Rice ('IET 1094') | Indian mustard ('B 85') | Rice ('IET 1094') | 3,347 | 591 | 3,072 | 270 | 9,787 | 9,294 | 8,300 | 7,697 | 7,094 | 8,434 | 30.44 | 17.92 | 22.69 |
| Rice ('IET 1094') | Indian mustard ('B 85') | *Dhaincha* ('Local') | 3,905 | 592 | 43,202 | 232 | 15,014 | 7,431 | 6,541 | 11,489 | 9,810 | 10,057 | 43.35 | 10.98* | 33.20 |
| Rice ('IET 1094') | Wheat ('UP 62') | Groundnut ('ICGS 44') | 3,765 | 3,223 | 1,748 | 315 | 14,304 | 14,128 | 11,271 | 12,282 | 11,138 | 12,625 | 40.08 | 31.45 | 33.81 |
| Rice ('IET 1094') | Potato ('K. Jyoti') | Sesame ('B 67') | 3,700 | 12,367 | 808 | 286 | 13,232 | 18,990 | 12,662 | 8,856 | 5,355 | 11,819 | 41.33 | 26.49 | 27.67 |
| Rice ('IET 1094') | Potato ('K. Jyoti') | Jute ('JRO 7835') | 3,823 | 15,522 | 2,127 | 251 | 16,055 | 22,841 | 16,077 | 14,870 | 14,839 | 16,936 | 67.47 | 25.61* | 46.93 |
| Rice ('Konark') | Groundnut ('AK 1224') | Cowpea ('SEB 2') | 4,383 | 2,286 | 2,101 | 267 | 18,090 | 14,777 | 16,871 | 17,423 | 6,896 | 14.811 | 55.47 | 31.85 | 40.80 |
| Rice ('Konark') | Tomato ('BT 10') | Okra ('Supriya') | 4,146 | 24,341 | 10,286 | 274 | 29,121 | 24,302 | 5,873 | 21,900 | 14,913 | 19,222 | 70.15 | 20.64 | 53.06 |

**Table 1.** *Continued*

| Cropping sequence (Variety) | | | Pooled yield (kg/ha) | | | Duration of field remained occupied (Number of days) | Rice-yield equivalent over years (kg/ha/year) | | | | | | System productivity (kg/day/ha) | Energy equivalents (×10$^6$ K.Cal/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainy season | Winter | Summer | Rainy season | Winter | Summer | | 1992–93 | 1993–94 | 1994–95 | 1995–96 | 1996–97 | Mean | | Actual crop basis | Rice equivalent basis |
| *Bhubaneshwar* | | | | | | | | | | | | | | | |
| Rice ('Konark') | Indian mustard ('PT 303') | Ridge-guard ('Local') | 4,083 | 1,496 | 8,834 | 238 | 13,898 | 11,771 | 13,721 | 12,735 | 6,584 | 11,742 | 49.34 | 13.28 | 32.41 |
| Rice ('Konark') | Cabbage ('Golden Acre') | Okra ('Supriya') | 4,341 | 2,5059 | 12,498 | 250 | 28,880 | 23,785 | 12,759 | 21,404 | 16,335 | 20,633 | 82.52 | 23.12 | 56.94 |
| Rice ('Konark') | Potato ('K. Chandramukhi') | Seasme ('Uma') | 4,181 | 18,304 | 1,210 | 283 | 20,139 | 16,802 | 8,686 | 18,378 | 10,624 | 14,926 | 52.72 | 36.16 | 41.18 |
| Rice ('Konark') | Tomato ('BT 10') | *Poi* ('Local') | 4,084 | 25,776 | 26,082 | 296 | 36,490 | 29,924 | 20,916 | 28,423 | 17,648 | 26,680 | 90.14 | 30.75 | 73.64 |

Prevailing market rates were used for computing yield equivalents

*Summer crop yield could not be included in terms of energy (exclusive figures of *dhaincha* and jute)

**Table 2.** Land-use efficiency, stability, profitability of various crop sequences at 2 locations in West Bengal and Orissa

| Crop sequences (fertilizer dose of $N:P_2O_5:K_2O$ kg/ha) | | | Land-use efficiency | Season-wise crop stability index | | | System-stability Index | Net profit (Rs/ha) | Benefit : cost ratio | Risk (Rs/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rainy season | Winter | Summer | | Rainy season | Winter | Summer | | | | |
| | | | | *Kalyani* | | | | | | |
| Rice (80:50:50) | Indian mustard (60:60:60) | Rice (80:50:50) | 0.74 | 0.74 | 0.78 | 0.74 | 0.78 | 21,226 | 3.60 | 979 |
| Rice (80:50:50) | Indian mustard (60:60:60) | *Dhaincha* (0:0:0) | 0.66 | 0.77 | 0.74 | 0.92 | 0.72 | 36,604 | 9.18 | 9,339 |
| Rice (80:50:50) | Wheat (100:60:40) | Groundnut (20:80:20) | 0.86 | 0.77 | 0.88 | 0.66 | 0.91 | 34,947 | 6.25 | 2,202 |
| Rice (80:50:50) | Potato (180:90:90) | Sesame (50:50:40) | 0.78 | 0.79 | 0.65 | 0.76 | 0.70 | 25,257 | 3.51 | 6,656 |
| Rice (80:50:50) | Potato (180:90:90) | Jute (50:50:40) | 0.69 | 0.81 | 0.80 | 0.71 | 0.67 | 51,465 | 8.45 | 9,779 |
| | | | | *Bhubaneshwar* | | | | | | |
| Rice (80:40:40) | Groundnut (20:40:40) | Cowpea (60:30:30) | 0.73 | 0.94 | 0.58 | 0.24 | 0.56 | 47,033 | 11.6 | 11,364 |
| Rice (80:40:40) | Tomato (100:50:50) | Okra (80:40:40) | 0.75 | 0.94 | 0.33 | 0.12 | 0.35 | 61,272 | 11.2 | 23,006 |
| Rice (80:40:40) | Indian mustard (60:30:30) | Ridge guard (80:40:40) | 0.65 | 0.97 | 0.61 | 0.28 | 0.74 | 36,192 | 8.0 | 7,370 |
| Rice (80:40:40) | Cabbage (120:60:60) | Okra (80:40:40) | 0.68 | 0.91 | 0.30 | 0.28 | 0.50 | 66,108 | 11.5 | 13,186 |
| Rice (80:40:40) | Potato (160:80:120) | Sesame (10:0:0) | 0.78 | 0.94 | 0.30 | 0.34 | 0.49 | 46,786 | 8.8 | 13,183 |
| Rice (80:40:40) | Tomato (100:50:50) | *Poi* (80:40:0) | 0.81 | 0.74 | 0.25 | 0.33 | 0.53 | 87,220 | 17.2 | 16,846 |

wherein the field remained occupied for maximum number of 296 days, while it was lowest in rice–Indian mustard–ridgegourd (0.65) with lowest number of days (238) the field remained occupied. In other sequences, the LUE varied from 0.68 to 0.78 (Table 2).

### Stability

The rice crop showed highest stability (0.81) during rainy season when raised in rice–potato–jute sequence, while lowest when it was grown in rice–Indian mustard–rice sequence (0.74) at Kalyani. It was probably because of higher nutrient use in crop leading to accumulation with favourable effects on rice yield in the system. But at Bhubaneshwar, the rice stability during rainy season was highest (0.97) in rice–Indian mustard–ridgegourd sequence, which was closely followed by rice–groundnut–cowpea, rice–tomato–okra and rice–potato–sesame sequences, with equal stability of 0.94 (Table 2). In winter season among the various crops raised in rice-based sequences, wheat showed highest stability followed by potato (0.80) at Kalyani, while at Bhubaneshwar Indian mustard crop was more stable, followed by groundnut and the stabilityof other crops was low (0.25 to 0.33) due to higher year-to-year fluctuation in their yield. In summer, the green-manure crop of *dhaincha* was highly stable with stability index of 0.92, while stability of other crops varied from 0.66 to 0.76 at Kalyani. But at Bhubaneshwar, sesame and *poi* crops showed higher stability while the lowest by okra.

The crops raised during winter and summer at Kalyani were more stable than the crops grown at Bhubaneshwar because of climatic variations and other limitations leading to fluctuation on crop yield in year-to-year basis.

The highest sequence stability was recorded in rice–wheat–groundnut sequence at Kalyani, followed by rice–Indian mustard–rice sequence, while lowest being 0.67 recorded in rice–potato–jute. At Bhubaneshwar, highest system stability was recorded in rice–Indian mustard–ridgegourd sequence and lowest in sequence involving rice–tomato–okra (Table 2).

### Profitability

The highest net profit could be obtained in an agricultural year using rice–potato–jute sequence and the lowest profit in rice–Indian mustard–rice sequence at Kalyani (Table 2). At Bhubaneshwar, highest net profit was obtained from the sequence involving rice–tomato–*poi* and the lowest in rice–Indian–Indian mustard–ridgegourd sequence. Benefit : cost ratio in rice–Indian mustard–*dhaincha* and rice–potato–jute sequence were better than others at Kalyani. But at Bhubaneshwar rice–tomato–*poi* was distinctly better than others. On comparison of risk factor at Kalyani, the involvement of money was lowest in the sequence rice–Indian mustard–rice which may be considered most suited for resource poor farmers while highest in rice–potato-jute most suited for comparatively rich farmers having money to spend. At Bhubaneshwar, the lowest risk was involved in rice–Indian mustard–ridgegourd sequence, while it was highest in rice–tomato–okra revealing that higher cost was involved being the vegetable crops both in winter and summer.

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