

## Rice (*Oryza sativa*)-based system intensification in north-eastern India: Effect on yield, economics and soil properties

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### ABSTRACT

Attempt was made to adjust three rice crops in a cropping sequence in irrigated lowland, and also to compare productivity and efficiency of rice (*Oryza sativa* L.)–rice–rice cropping system with rice–rice and rice–fallow. Results of the 8 years study (2001–09) revealed that rice variety ‘Chandrama’ as winter crop, followed by the same variety as summer crop and ‘Vandana’ as autumn crop could be grown in sequence. The grain yield from the 3 rice cropping sequence was 15.3 t/ha. The productivity of the summer crop (6.8 t/ha) was the highest, followed by the winter crop (5.6 t/ha). The lowest productivity was obtained from autumn crop (2.9 t/ha). Rice–rice cropping system produced the lower grain yield of 12.4 t/ha. However, considering production efficiency (48.8 kg grain/ha/day), sustainable yield index (0.98), net return (₹23,187/ha) and benefit: cost ratio (1.43), it was better than rice–rice–rice cropping system. Results on soil chemical properties after eight cropping cycles under rice–rice–rice cropping system revealed that soil pH and available N content were similar to the initial value. However, a buildup of organic carbon (12%), and available phosphorus (39.5%) and potassium (6.4%) in soil was noted.

**Key words :** Cropping sequence, Economics, Irrigated lowlands, Production efficiency, Rice–fallow, Rice–rice, Rice–rice–rice

In India, more than 80% of the farming community belongs to marginal and small farmers having only 32.5% of the total operational area. The income from single season field crop is hardly sufficient to sustain the small farmers’ family. In lowland areas, it is difficult to diversify the cropping system because of high clay content in soil and longer duration of field occupation by lowland rice varieties. Northeast India receives high annual rainfall (2,450 mm) distributed over prolonged period. Major amount of rainfall (66 to 85%) is received during June to September due to south west monsoon followed by 20 to 30% from pre-monsoon rains during April–May and 13% in dry season during December to March. Rice–rice cropping sequence is practiced in irrigated lowlands to take advantage of high and well distributed rainfall received in north-eastern India. Also, the clayey soils in lowlands are suitable for rice crop due to low seepage and percolation loss of water (Tsubo *et al.*, 2007). Modern rice varieties with shorter duration have helped in increasing the cropping intensity. Rice–rice–rice cropping sequence with 300%

intensity along with high productivity (11.0 to 15.9 t/ha) and land use efficiency (86–94%) is reported under mild agro-climatic conditions of South India. Recently, Gangwar and Singh (2011) reported a low yield of 8.76 t/ha under rice–rice–rice cropping sequence. In case of north-east India, low temperature stress during November to February slows down the vegetative growth of summer rice and thereby increases the crop duration up to 60 days. Results on productivity and efficiency of rice–rice–rice system and its comparison with rice–rice and sole rice cropping are meagre. Hence, an experiment was conducted for comparing yield, economics and soil properties under different rice-based system intensifications in an irrigated lowland field in north-east India.

### MATERIALS AND METHODS

An experiment was conducted in an irrigated lowland field at Regional Rainfed Lowland Rice Research Station, Gerua, Asom for consecutive 8 years (2001–09). The test soil was silty clay loam, moderately acidic (pH 6.0) and high in organic carbon content (10 g/kg). It was medium in available N (280 kg/ha), P (19 kg/ha) and K (298 kg/ha). The bulk density (Core sampler method) varied from 1.2 to 1.3 Mg/m<sup>3</sup> and saturated water content (Gravimet-

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ric method) from 0.50 to 0.52 m<sup>3</sup>/m<sup>3</sup>. Three rice crops were grown successively in winter (*sali/kharif*), summer (*boro/rabi*) and autumn (*ahu*) seasons under rice–rice–rice cropping sequence. The system of classification of rice and growing season is based on the maturity time of the crop. For rice–rice cropping sequence, winter and summer seasons were selected while rice–fallow cropping was considered taking rice in winter season and then fallow for the remaining period (as per the traditional practice). For finding suitable rice varieties, ‘Chandrama’ and ‘Tapaswini’ were tested in winter season, ‘PHB 71’ and ‘Jaya’ in summer season while ‘Vandana’ and ‘Lachit’ in autumn season in the first cropping cycle (C<sub>1</sub>) during the year 2001–02. Similarly, the last cropping cycle (C<sub>8</sub>) refers to the year 2008–09. For subsequent years (cropping cycles C<sub>2</sub> to C<sub>8</sub>), the promising variety ‘Chandrama’ in winter as well as summer season and ‘Vandana’ in autumn season was used. The sowing time in nursery, transplanting and harvesting dates in main field, and fertilizer doses are presented in (Table 1).

Fertilizer dose of 60 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O/ha was applied in the winter rice. For the summer rice, the dose was 80 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O/ha in the initial 3 years and a higher dose of 100 kg N, 50 kg P<sub>2</sub>O<sub>5</sub> and 50 kg K<sub>2</sub>O/ha was used for the remaining 5 years based on leaf colour chart. For the autumn rice, 60 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O/ha was applied in the initial 2 years and a lower dose of 40 kg N, 20 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O/ha in the remaining years. The reason for lowering the fertilizer dose for autumn rice in the remaining years was due to lowest yield and monetary return. A closer spacing of 15 × 15 cm was adopted for short duration varieties in autumn season while it was higher (20 × 15 cm) in summer and winter seasons. Duration of varieties, yield and yield attributes, disease and pest problems and other constraints encountered in each season were noted.

Rice hispa (*Dicladispa armigera*) was most problematic in winter rice and it was controlled with Endosulfan (@ 2 mL/L). Gundhibug (*Leptocorisa oratorious*) was problematic during grain filling stage of autumn and summer rice crop and it was managed using 5 traps of rotten crabs in 1600 m<sup>2</sup> area in the beginning of flowering. Bacterial leaf blight (*Xanthomonas campestris* pv *oryzae*) disease was problematic at the reproductive phase of autumn rice crop and it was managed by skipping application of N at this stage and also by reducing the fertilizer dose in the last 6 cropping cycles. Aquatic weeds *Monochoria vaginalis* (76% of the weed population), *Ludwigia* sp. (10%), *Echinochloa* sp. (14%) were observed. These weeds were managed by running of cono weeder just after first top dressing of N followed by one hand weeding after one month. Crabs were controlled by placing 1

thimet granule per crab hole.

Cost of cultivation, gross and net returns in each season were calculated for knowing the economics of different rice cropping systems. Local market price of inputs and outputs for the respective years were considered for calculating economics and mean values are presented. Land utilization index (%) was estimated as a percentage of number of days during which the crops in a sequence occupy the main field during a year to the total number of days in a year, i.e. 365 (Tomar and Tiwari, 1990). Production efficiency (PE) was expressed as the ratio of system productivity in kg/ha rice yield to total duration of the system in days (Patil *et al.*, 1995). The sustainability expressed as sustainable yield index (SYI) was calculated as per Guggari and Kalaghatagi (2004). For computing SYI; average yield, maximum yield and standard deviation (SD) over 8 cropping cycles was taken into account.

$$\text{Sustainable yield Index} = \frac{\text{Average yield} - \text{SD}}{\text{Maximum yield}}$$

The treatments consisted of three cropping systems, viz. rice–fallow, rice–rice, and rice–rice–rice. The experiment was continued for eight cropping cycles (C<sub>1</sub> to C<sub>8</sub>) and these were considered as eight replications. In order to compare the treatments, the yield data were pooled and the analysis of variance (ANOVA) technique was carried out following randomized block design (Gomez and Gomez, 1984). The significance of the treatment effect was determined using F-test at 5% level. The mean differences between treatments were compared using the least significant difference (LSD).

## RESULTS AND DISCUSSION

### *Varietal suitability*

In winter season, two medium duration rice varieties ‘Tapaswini’ and ‘Chandrama’ were grown. Grain yield was marginally higher with variety ‘Chandrama’ as compared to ‘Tapaswini’ (Table 2). It was also observed that the variety ‘Tapaswini’ suffered from sheath rot (17.5% infected tillers) and false smut (7.4 number of false smut balls per panicle) whereas the variety ‘Chandrama’ was free from these 2 diseases. Susceptibility of ‘Tapaswini’ rice to sheath rot and false smut is reported (Rautaray, 2007 a) and ill drained soil conditions of rice–rice–rice cropping sequence might have favoured the disease incidence. For summer rice, low temperature stress at seedling and early vegetative stages resulted in prolonged duration of the varieties up to 45 days in this season as compared with the winter rice. Thus, long duration varieties are not suitable for summer rice, especially under the 3 rice cropping sequence. In summer season, medium duration rice hybrid ‘PHB 71’ and variety ‘Jaya’ having cold tolerance

at vegetative stage were grown. Hybrid 'PHB 71' was superior to 'Jaya' regarding cold tolerance, early seedling vigour, and grain yield. In the subsequent years, variety 'Chandrama' possessing favourable attributes like cold tolerance, moderate dormancy (two weeks), less grain shattering nature and early seedling vigour (Rautaray, 2008) was grown in summer season. Less grain shattering and moderate dormancy are especially desired in summer rice to avoid grain loss and sprouting problem in East and Northeast India receiving enough pre-monsoon rainfall.

In autumn rice season 2002, yield of 'Vandana' (3.4 t/ha) was more than in 'Lachit' (3.2 t/ha). Besides, higher yield, semi-tall height of 'Vandana' was beneficial at the event of flash flood as compared to the dwarf architecture of 'Lachit'. However, the tendency of sparrows to sit on the plant and attack grains was more in 'Vandana' than in 'Lachit'. This might be due to taller and sturdier stem of 'Vandana' as compared with 'Lachit'.

#### Comparison of cropping systems

**Grain yield:** Mean grain yield of the 8 cropping cycles (Table 3) revealed that highest grain yield of 15.3 t/ha was recorded under rice–rice–rice cropping system. This was followed by rice–rice (12.4 t/ha) and lowest with the rice–fallow system (5.6 t/ha). Yield variation of a cropping system in different years was low. This might be due to irrigated situation with controlled water depth and crop management. The yield difference between the winter rice, and winter rice–summer rice system was 6.8 t/ha. This could be ascribed to longer field duration in summer rice, bright sunshine hours, controlled water depth under irrigated

situation, and response to higher fertilizer dose (Singh *et al.*, 2003; Rautaray, 2007b). Inclusion of autumn rice under rice–rice–rice cropping system improved yield marginally by 2.9 t/ha. Short duration rice varieties with low yield potential and fertilizer response were responsible for this.

**Economics:** Cost of cultivation for winter rice was (₹24,917/ha), while for summer rice it was ₹28,992/ha (Table 4). This was due to higher fertilizer and irrigation need for the summer rice. Lowest expenditure was recorded with autumn rice (₹19,084/ha). Short duration autumn rice required less fertilizer and weeding. Irrigation requirement was also low due to enough pre-monsoon showers received in Northeast India. Net returns were similar under rice–rice–rice and rice–rice cropping system. This indicates under normal situations, rice–rice is better than the rice–rice–rice cropping system. However, in years of low yield from winter and summer rice due to poor weather and/or pest outbreak, rice–rice–rice system may be followed. This may be especially required for marginal and small holder farms. Rice–rice was distinctly superior to the remaining 2 cropping systems considering benefit: cost ratio. Considering the individual seasons, net returns under summer rice was ₹14,509/ha, followed by winter rice ₹8,678/ha and lowest with the autumn rice (₹537/ha). Higher cost of cultivation for summer rice is more than compensated by higher yield and gross returns leading to higher net returns.

**SYI and system efficiency:** Lower values of standard deviation and greater value of SYI indicates greater yield sustainability of the system. Rice–rice cropping system with highest SYI (0.98) and low standard deviation indi-

**Table 1.** Varieties used, time of critical cultural operations, and fertilizer doses used in different seasons under rice–rice–rice cropping system during 2001 to 2009

Rice season	Variety	Sowing date in nursery	Transplanting dates	Harvest date	Fertilizer dose N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O (kg/ha)	Field duration (Days)
Winter	'Chandrama'	29 June to 3 July	*29 July to 13 August	18 to 29 November	60-40-40	110
Summer	'Chandrama'	9 to 15 November	15 to 24 December	3 to 12 May	**80-40-40	145
Autumn	'Vandana'	12 to 15 April	6 to 15 May	2 to 10 August	***40-20-20	87

\*Date of transplanting for the first season winter rice was on 29 July, 2001 and for the subsequent

Seasons, it ranged between 8 to 13 August; \*\*Summer rice was provided with 80–40–40 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for initial 3 years and then with 100–50–50 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for remaining 5 years; \*\*\* Autumn rice was provided with 60–40–40 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for initial 2 years and then with 40–20–20 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for remaining 6 years

**Table 2.** Varietal performance of rice in different seasons under rice–rice–rice cropping sequence

Season	Variety	Transplanting date	Duration (days)	Panicles/m <sup>2</sup>	Grains/panicle	Yield (t/ha)	Sheath rot (% tillers)	False smut (Balls/panicle)
Winter 2001	'Chandrama' 'Tapaswini'	29 Jul	116112	286314	125127	5.85.3	017.5	07.4
Summer 2001-02	'PHB 71' 'Jaya'	24 Dec	131132	319305	10197	6.25.4	1.30.8	2.11.5
Autumn 2002	'Vandana' 'Lachit'	6 May	8891	241265	8681	3.43.2	1.63.4	00

cates greater yield sustainability followed by rice–rice–rice (0.95) and rice–fallow system (0.90). Cropping index and land use–efficiency were the highest under rice–rice–rice cropping system and distinctly lowest with rice–fallow system. Farmers with small land holding may enhance food production by adopting higher land use–efficiency and cropping index with the rice–rice–rice system. Yield production kg/ha/day was highest under rice–fallow system (50.5) followed by rice–rice system (48.8) and rice–rice–rice system (44.6). Lower yield kg/ha/day under rice–rice system as compared to rice–fallow was due to longer duration in main field by 35 days for summer rice as compared to winter rice (Table 1). Low temperature stress at early vegetative stage increased the field duration of summer rice. Monetary production ₹/ha/day was highest under rice–rice system (90.9) and lowest with the rice–rice–rice system (69.4). Thus, production efficiency, both in terms of yield and net returns was higher under rice–rice system as compared to the rice–rice–rice system.

#### Effect on soil chemical properties

Results on soil chemical properties (Table 5) revealed

that there was hardly any change in soil pH and available N content after the eighth cropping cycle with rice based intensive cropping sequences. However, there was maximum buildup of organic carbon in soil from initial value of 10.0 to 11.2 g/kg under rice–rice–rice system followed by rice–rice (10.9 g/kg) and rice–fallow (10.5 g/kg). Rice crop was harvested 20 cm above the soil surface. Thus, rice stubble and root might have contributed to the organic carbon pool in each season. Waterlogging and ill drained condition might have contributed to organic carbon build up by moderating the adverse effects of high temperature under tropical and sub-tropical climate. Also, the experimental site was a lowland field with 30 cm bund all around. This might have helped in accumulating silt, nutrients and organic molecules from flood water in rainy season (Rautaray, 2011). The buildup of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O might be mainly due to the residual amount from applied fertilizer in each crop season. Higher buildup of P<sub>2</sub>O<sub>5</sub> (39.5%) might be due to fixation of this nutrient as compared to potassium.

Thus, a grain yield of 15.3 t/ha could be obtained from an irrigated lowland field under rice–rice–rice cropping

**Table 3.** Grain yield (t/ha) of rice under different rice based system intensification

Treatment	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	Mean
Rice (winter rice)–fallow	5.8	5.9	5.5	5.6	5.4	5.3	5.4	5.8	5.6
Rice–rice (winter rice–summer rice sequence)	12.2	12.5	12.4	12.5	12.6	12.6	12.3	12.4	12.4
Rice–rice–rice (winter rice–summer rice–autumn rice sequence)	15.4	15.7	15.2	15.6	15.1	15.1	14.8	15.3	15.3
SEm±	0.11	0.10	0.12	0.06	0.05	0.05	0.05	0.09	0.07
CD (P=0.05)	0.34	0.31	0.38	0.19	0.16	0.16	0.15	0.27	0.21

**Table 4.** Economics of production, sustainable yield index, land use efficiency and production efficiency under different rice based system intensification (Pooled data of 8 cropping cycles)

Treatment	Cost of cultivation (×10 <sup>3</sup> ₹/ha)	Gross returns (×10 <sup>3</sup> ₹/ha)	Net returns (10 <sup>3</sup> ₹/ha)	Benefit: cost ratio	SYI	Cropping index	Land use–efficiency (%)	Production efficiency kg/ha/day	₹/ha/day
Rice–fallow	24.9	33.6	8.7	1.35	0.90	1	30.1	50.5	78.9
Rice–rice	53.9	77.1	23.2	1.43	0.98	2	69.9	48.8	90.9
Rice–rice–rice	73.0	96.7	23.7	1.33	0.95	3	93.7	44.6	69.4
SEm±	0.56	0.67	0.40	0.017					
CD (P=0.05)	1.74	2.02	1.18	0.05					

**Table 5.** Soil chemical properties after the eighth cropping cycle under different rice based system intensification

Soil properties	pH	Organic carbon (g/kg)	Available N (kg/ha)	Available P <sub>2</sub> O <sub>5</sub> (kg/ha)	Available K <sub>2</sub> O (kg/ha)
Initial	6.0	10.0	280	19.0	298
Rice–fallow	6.0	10.5 (5)*	285	21.2 (11.6)	303 (1.7)
Rice–rice	5.9	10.9 (9)	279	24.7 (30.0)	312 (4.7)
Rice–rice–rice	5.9	11.2 (12)	278	26.5 (39.5)	317 (6.4)

\*Figures in bracket indicate % increase over the initial value

system without adverse effect on soil properties. Also, this system is suitable for marginal and small holder farms under adverse climatic conditions of north-eastern India. However, considering production efficiency, sustainable yield index, net returns and benefit: cost ratio, rice–rice cropping system was better than rice–rice–rice cropping system.

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