

Crop intensification in red soils

predominated rainfed upland rice monocrop areas

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In a systematic study on upland rice-based cropping systems, different cropping systems were agro-economically assessed for their performance. It was inferred that upland rice intercropped with pigeonpea was the best system for rainfed red sandy loam soils. From the gross returns view, rice cv. intercropped with groundnut appeared to be the next best system, though higher cost of cultivation involved with groundnut cultivation placed it on 3rd rank. On the other hand, rice intercropped with finger millet stood on second place as cost of cultivation was less in former than later. It was noted that in the given soils, intercropping out yielded other cropping systems. Relay or sequence cropping of rabi crops proved economically unviable when compared with rice + pigeonpea intercropping under red sandy loam soils even if relay or sequence crop established in the presence of optimum moisture at sowing. As the response of rice varieties varied with rainfall pattern during the cropping season, varietal mixtures of rice cultivars intercropped with pigeonpea in 2:2:1 row ratio proved better than single rice cultivar intercropped with pigeonpea. Farmers usually broadcast upland rice and show their reluctance for sowing rice behind the plough in furrows. To overcome this problem studies were conducted involving different methods of sowings and it was observed that broadcast of rice seed @100 kg/ha in the interspace of 75 cm between two rows of pigeonpea was as good as row seeding of both crop in 4:1 row ratio.

Key words: Crop intensification, Groundnut, Pigeonpea, Red soils

OF the total rice area, upland rice roughly accounts for 14% covering level to rolling topography. Eastern region is dominated by upland rice and nearly 70% of total rainfed upland rice area of India (6.1 m ha) is located in this region comprising Odisha, West Bengal, Asom, Jharkhand, Chhattisgarh and eastern Uttar Pradesh. Upland rice yields are quite low (<1.0 tonne/ha) due to subsistence nature of cultivation practised with limited available resources by the less privileged rice farmers. Crop productivity is affected by several constraints including weeds, diseases, moisture stress caused by erratic distribution of rainfall. In the years of scanty or adverse distribution of rainfall, the crop fails owing to drought whereas years with heavy rainfall, particularly during

blossoming or harvest, witness poor grain setting or the matured grains germinating on the panicles. Besides rainfall, solar radiation and temperature also strongly influence productivity of upland rice. Most of the upland rice is grown on soils ranging between pH 4.5 and 6.5. Aluminum (Al) and Manganese (Mn) toxicity is observed when chemical profile of the soil showed a less pH than 4.0. Alfisols, Ultisols, Oxisols and Inceptisols are the most common soils for upland rice cultivation. Ustalfs (earlier known as Lateritics), the sub-order of Alfisols, are dominant upland soils of India and commonly present in tropical and subtropical areas with a seasonal rainfall. Alfisols characteristically have less Clay in A than B horizon. Ultisols are common in the areas receiving high rainfall with a low

subsoil pH. Udults, a sub-order of Ultisols, is most common under uplands prone to erosion with a undulating topography where shifting cultivation is practised. Alfisols have a higher pH than Oxisols. These soils are deep, well drained, low erodibility and a good water retention capacity. Andepts, a sub-order of Inceptisols, are porous, dark-coloured soils with a top soil having high organic content, high phosphate sorption capacity and highly pH dependent carbon exchange capacity.

Both cropping systems and cropping intensity in rainfed upland areas are governed mainly by the amount and distribution of rainfall besides other climatic factors. Soil moisture retention capacity of coarse or medium-to-coarse is low compared to fine soils and hence



Fig. 1. Rice + pigeonpea intercropping system in rainfed upland rice. Fig. 2. Rice + finger millet intercropping in rainfed uplands.

selection of suitable upland rice variety is of paramount importance for obtaining high grain yields from a rainfed crop. Upland rice soils are mostly acidic in nature and low in nitrogen (N), phosphorus (P) and sulphur (S). Phosphorus (P) fixation is a problem in acidic soils and reduces phosphorous availability to crop. Rainfall is the most variable and least predictable component of the physical environment in upland rice ecosystem. Uplands in India are broadly classified into moderate (700-1,100 mm/annum) and high (1,100-2,000 mm/annum) rainfall areas. Most of the eastern Indian states receive more than 1,100 mm rainfall. The distribution, however, is more critical than total seasonal rainfall. Eastern India experiences a mono-modal rainfall distribution with its peak in July-August, and dry spells of 5 to 15 days may occur any time during the wet season. Diurnal temperature regimes and radiation levels during wet season are not restrictive to rice crop growth. Climate during the wet season may be characterized as hot and humid with a mean temperature of 30 °C. Normal date for arrival of the monsoon is third week of June (16 – 18 June) based on a cumulative rainfall of ≥ 30 mm and relative humidity of $\geq 75\%$ criteria and normal date for withdrawal of monsoon is between 7 and 11 October. Analysis of long term rainfall data (31 years) of typical upland site, Hazaribag, Jharkhand showed that moderate to severe drought is expected once in nine years whereas mild-drought is likely to occur once in four years. Surplus rainfall is expected once in 6-7 years. A single crop of upland rice is grown

in majority of the rainfed area due to dependence of rice cultivation on rainwater. Drought years proved disastrous in upland rice growing monocropped areas for small-and marginal-farmers who are dependent on rainfed agriculture for their livelihood. Crop diversification in such areas has added insurance against failure of rice crops under acute drought conditions.

Crop rotation: Crop rotation may be defined as growing of different crops in succession on same piece of land that may help controlling various insect, pests and diseases besides sustaining the soil fertility. The nitrogen (N) supply of the soil is maintained when leguminous crops are alternated with other crops, including upland rice. Inclusion of crops with different root systems in a crop rotation may help balanced removal of plant nutrients from the soil. Farmers engaged in upland rice cultivation with surplus uplands prefer to follow block rotation with a predefined 3-4 years cycle involving a leguminous crop, a cereal crop and minor millet.

Crop cycle is shown below.

- *First year:* A pulse crop –improves soil fertility.
- *Second year:* Upland rice – rice yields are increased due to N-added by the preceding pulse crop.
- *Third year:* Minor millets – produces good yield using remaining nutrients from soil.
- *Fourth year:* Fallow field - used for grazing animals –reduces weeds seed bank.

Farmers' wisdom is reflected in adoption of above mentioned crop rotation considering many benefits associated with selection of different crops and inclusion of fallow period

in between the crop cycle. Albeit a sustainable system of crop production, it may not be adjudged as an economically viable production system considering the fragmented land-holdings, subsistence nature of farming and lack of safeguard against vagaries of monsoon. Hence, various opportunities available to farmers in terms of inter-/mixed-cropping, sequential/relay-cropping and contingent cropping were explored.

Intercropping/Mixed-cropping

Production /unit area /unit time may be increased, without adversely affecting the production of main crop, to a great extent. Intercropping in cereal crops such as rice with leguminous crops, help improve nitrogen (N) availability to rice and associated crops, reduce effect of late drought stress on rice and increase cash availability to farmers besides fulfilling protein demands to some extent. Intercropping of other rainy season crops viz., pigeonpea, greengram, blackgram, groundnut, soybean and finger millet in slightly acidic red sandy loam soils with rice and associated crops (pigeonpea, greengram, blackgram, groundnut, soybean and finger millet) showed that intercropped rice produced between 71.1 and 90.4% yield compared to sole rice crop (Table 1).

In comparison to many other crops used as companion crops, upland rice produced maximum grain yield when intercropped with pigeonpea (4:1 row ratio). Conversion of grain yields into rice equivalent yield showed that intercropping, in general, proved profitable barring situations where greengram and blackgram were grown in association with rice. This showed the efficient

Table 1. Intercropping of rice with other season crops.

Treatment	Grain yield (kg/ha)*		REY (kg/ha)	LER	Gross return (₹/ha)	Net return (₹/ha)	Return investment in ₹
Sole rice	2,280 (100)	-	2,280	1.00	4,218	2,069	1.96
Rice + Pigeonpea (4:1)	2,060 (90.4)	600 (75.0)	3,438	1.65	6,361	4,020	2.72
Rice + Groundnut (2:1)	1,700 (76.4)	370 (56.4)	2,700	1.63	4,995	2,462	1.97
Rice + Finger millet (2:1)	1,720 (76.4)	1010 (88.6)	2,621	1.32	4,848	2,754	2.32
Rice + Soybean (2:1)	1,800 (78.9)	340 (79.1)	2,397	1.58	4,435	1,972	1.80
Rice + Blackgram (2:1)	1,750 (76.8)	210 (47.7)	2,232	1.24	4,130	1,896	1.85
Rice + Greengram (2:1)	1,620 (71.1)	220 (56.7)	2,125	1.27	3,951	1,717	1.76

*Figures in parenthesis are values in per cent of sole yield

Source: *Indian J. agric. Sci.*, **63** (10):621-4, 1993.

use of growth resources by component crops having temporal complementarities with upland rice in intercropping system. The highest rice equivalent yield was obtained in rice + pigeonpea (4:1), followed by rice + groundnut (2:1). Yield advantages due to intercropping ranged between 25 and 65% as judged by land equivalent ratio (LER). Rice + pigeonpea (4:1) recorded maximum LER value of 1.65 and proved the best intercropping system followed by rice + groundnut (2:1) that gave a LER value of 1.63. Economic analysis of different intercropping systems showed that rice + pigeon pea (4:1), rice + groundnut (2:1) and rice + finger millet (2:1) gave higher gross returns than monocropped rice and other systems. Results indicated profitability of intercropping systems, especially intercropping of pigeonpea, groundnut and finger millet with rice in red sandy soils of plateau region. Further attempts to fine tune these findings resulted in better productivity of profitable intercropping systems with modified row ratios. It was noted that productivity of rice + groundnut intercropping may further have improved, if rice and groundnut were planted in 4:2 row ratio at uniform row spacings of 20 cm.

Higher LER values were found when intercropping was done in 4:2 row ratios of rice and groundnut than 2:1 row ratio. Majority of groundnut varieties had less incidence of Tikka disease in 4:2 row ratio of intercrop system with rice. Similarly, improvement in productivity was achieved planting rice and finger millet cultivars of differing maturity

in 2:2 row ratio maintaining uniform row spacings as used for rainfed upland rice.

In other studies, conducted to explore the suitability of varietal combinations of rice mixtures with pigeonpea, row ratio of 2:2:1 proved more efficient than the rice or pigeonpea sole cropping. Growing of varietal mixtures of two rice varieties of variable growth habits as alternate row intercropping appeared to provide more stable rice yields across the years. In rice and groundnut intercropping system, deferred planting at 30 DARE of groundnut in the timely sown rice crop produced more gross returns and LER compared to simultaneous sown crops. Further delay in planting of groundnut caused reduction in its yield.

Farmers often face difficulty in planting intercrops in rows since they lack machines (seed drills) for planting more than one crop simultaneously. Based on the farmers' feedback, several alternatives were considered. Mixed-cropping refers to growing two or more crops simultaneously in the same field with no distinct row arrangement. Farmers in rainfed uplands of India sow by broadcasting a mixture of rice seeds and pigeonpea or maize and pigeonpea in red sandy soils. Farmers prefer to practice farming in conventional ways in rainfed uplands. Line-sowing is not common for mixed-cropping in uplands. Scope for improvement in productivity of mixed cropping exists through selection of compatible crops, optimization of seed rates, fertilizer application and methods of crop establishment. Productivity of mixed-cropping may be improved

using judiciously selected crop combinations. Growing of maize with rice or pigeonpea in mixed-cropping does not appear to be a proper choice since fertilizer requirements of these crops are different. Nitrogen (N) requirement and shading effect of maize is comparatively more than direct seeded rice and pigeonpea and these characteristics prevent it from being a good choice for mixed-cropping in upland areas. Studies on the mixed cropping, involving rice and pigeonpea, were carried out at Central Rainfed Upland Rice Research Station, Hazaribag to evaluate mixed cropping in comparison to intercropping using same crops. Results of study are presented in the Table 2.

Farmers reluctant to adopt intercropping due to unavailability of suitable machinery may find it convenient to follow a middle path by broadcasting rice in upland fields and sow pigeonpea in furrows opened 75 cm apart. Broadcast of rice seed @100 kg/ha in the inter-space of 75 cm between two rows of pigeonpea proved as good as row seeding of both crop in 4:1 row ratio. Rice may be broadcast first and pigeonpea later in the furrows at 75 to 80 cm furrow spacing. This method proved as good as rice + pigeonpea intercropping in 4:1 row ratio or even better from land utilization or yield advantages point of view. Although incidence of brown spot disease was marginally higher in broadcast rice but differences in grain yield of intercropped/mixed rice crop were made up by increased yield of pigeonpea.

Intercropping of okra in association with upland rice proved profitable both in land utilization and monetary terms and even proved more economical than pigeonpea when averaged over three years but data of the individual years showed that it proved inferior to rice + pigeonpea intercropping in two out of three years of experimentation. Profitability of vegetable-based intercropping depended on the price variations in the market. Prices of okra varied greatly from year to year whereas prices of pigeonpea

Table 2. Productivity and economics of mixed/intercropping system of rice and pigeon pea cultivation at CRURRS, Hazaribag (2 years mean).

Treatments	Rice yield (tonne/ha)	Pigeonpea yield (tonne/ha)	Rice equivalent Yield	Land Equivalent Ratio	Brown Spot Incidence (%)
Rice Sole	1.95		1.68	1.00	15.7
Pigeon pea (PP)		0.79	1.69	1.00	-
Rice sows 15 cm apart + PP rows 100 cm apart	1.29	0.50	2.36	1.29	15.0
Rice rows 15 cm apart + PP rows 75 cm apart	1.45	0.51	2.58	1.41	12.0
Rice broadcast + PP rows 75 cm apart	1.25	0.61	2.62	1.42	18.7
Rice rows 20 cm apart + PP broadcast	1.05	0.60	2.16	1.19	14.1
CD 5%			0.29	0.14	

Source: CRURRS Technology Bulletin 2014/1

remained stable over the years. Response of rice-based intercropping systems to lime application was studied and it was observed that upland rice requires less lime application as sole crop since response was limited to application of 0.5 tonne/ha once in 3 to 5 years. However, pigeonpea showed a good response to lime application in red acidic soils. Blanket application of lime to both rice and pigeonpea in intercropping was made and economics of lime application was worked out. Application of lime either once in 3 years @1.5 tonne/ha or alternate years @1.0 tonne/ha or every year @0.5 tonne/ha proved beneficial to pigeonpea intercropped with upland rice. However, rice responded to 0.5 tonne/ha only once in 3 year. Further research on reducing cost on lime application suggested that lime may be applied in furrows of pigeonpea alone at the planting and dose in this manner may be reduced to 0.20 to 0.30 tonne/ha.

Sequential cropping

Sequential cropping is defined as growing crops in sequence within a crop year. After harvest of one crop, other crop is sown on the same piece of land. The system is referred to be double cropping or multiple cropping when two or more crops are grown in a year on the same land. Soil moisture being a crucial factor for successful sequential cropping in rainfed areas, success of sequential cropping is largely dependent on suitable duration of the crops, timely planting and winter rains. Since cultivation of crops after rice depends

on the winter rains, growth of crops grown after rice is usually poor and yield levels are uneconomical. It becomes more apparent in red soils due to low water retention capacity. Residual soil moisture, if present in sufficient quantity, may help succeeding crop to emerge properly but can't support proper crop growth, if winter rains fail to take place. It was observed from the research results of various studies that probability of growing a second crop profitably in red soils is extremely low (<20%). Sequence cropping and relay cropping options were evaluated for their economic viability in relation to intercropping system with an aim to explore the possibility of crop intensification in red sandy soils. Rice + pigeonpea intercropping system was evaluated against sequence and relay cropping (niger, *toria* and horsegram). Intercropping system proved superior and indicated that intercropping of rice and pigeonpea was the most remunerative cropping system for red sandy loam soils. Although rice grain yield got reduced due to simultaneous cropping of pigeonpea as an intercrop, this reduction was made up by the higher grain yield of pigeonpea that fetched a relatively higher price for its produce than the former. On the other hand, rice grain yields were higher in the relay or sequence cropping but grain yields of either of associated crop could not add up to surpass the returns extended by pigeonpea as an intercrop. Total grain yields were higher in both relay and sequence cropping than intercropping but were

less remunerative in monetary terms as judged by the rice equivalent yield and gross returns. Selection of varieties for intercropping and mixed cropping is of paramount importance. Plant type and varietal duration have great influence on productivity of the intercrop system. Profitability of the system is largely impacted by relative yield losses of the crop having greater economic importance. In intercropping studies of rice with pigeonpea, reduction in the grain yield of both rice and pigeonpea under different varietal combinations varied depending on varietal characteristics. Average per cent reduction in rice and pigeonpea grain yield under intercropping ranged from 23.8 to 47.8, and 0 to 51.7%, respectively. Growing pigeonpea with rice in rainfed uplands provides insurance against crop failure in drought since pigeonpea has a deep root system and has ability to utilize water and nutrients from deeper depths than the rice. Intercropping of two or more rice varieties differing in maturity with pigeonpea may provide additional insurance against risks of yield losses.

Contingency crop planning

Total dependence of rice cultivation on rainfall in uplands of eastern states makes the cultivation vulnerable to risks of crop failure, substantial decline in the crop productivity and migration of farmers to other areas in search of employment. To make cultivation resilient, contingency crop planning is the ultimate strategy to negate impact of erratic distribution of rainfall and late onset of monsoon. Few strategies to combat vagaries of monsoon are listed below.

- Weather forecast and fortnightly agro-advisories.
- Planting of contingent crops like finger millet, niger and horsegram.
- Alterations in cultivation practices to match the changed weather parameters.

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