Oryza Vol. 43. No.4, 2006 (282-286)

Rainwater management for three-crop system in high rainfall areas of rainfed ecosystem

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ABSTRACT

Study of rainfall and evaporation in coastal districts of Orissa showed that field crops like sesame, green gram and black gram could be grown in summer using summer showers; whereas winter crops like mustard, groundnut and vegetables required supplementary irrigation. The cropping sequences identified to be suitable were: rice-mustard-pulses, rice-mustard-sesame, rice-mustard-vegetables, rice-groundnut/chilli/vegetables/ sesame and rice-black gram (paira) -sesame. Of these, the rice-mustard-sesame sequence was widely adopted by farmers. The 3-crop system increased farm earnings from Rs. 1.25 to Rs. 6.15 rupee^{-1} invested with total net-profit of Rs. 32,600 ha^{-1}. It provided round the year employment to the farm families.

Key words: *Rainfed ecosystem, rainwater management, evapotranspiration, three-crop systems, water use efficiency, economics*

In rainfed areas, land remains fallow after harvest of wet season rice due to scarcity of irrigation water. Farmers get employment only during wet season and remain idle during rest of the year. The mono-crop system has forced the farm community to live in abject poverty. Introduction of multiple cropping systems by adoption of suitable rainwater management techniques is an effective option to improve their economic condition. Identification of cultivars for higher yield, water use efficiency and profitability is of paramount importance for this purpose (Mohapatra and Panda, 2003).Yields increased two to three times as compared with conventional dry and semi-dry land farming in several countries by rainwater harvesting (FAO website, 2004). Premanand and Venkatesan (2003) reported that restoration of tanks to their old capacities is being taken up in large scale with active participation of village communities in Tamilnadu and Pondicherry (India). Thirunavukkarasu (2003) reported that 95% of surface water, 60% of groundwater and 21.3% of tank-water potentials are currently utilised for irrigation. Hatibu (2004) reviewed options available for improved utilization and management of rainwater resources available in semi-arid and arid areas. According to him, the most critical management challenge is how to deal with the poor distribution of rainwater leading to flash floods and long periods of dry spell. Zaman and Choudhury (2001) reported that all maize based sequences gave highest production efficiency (17.34 kg ha^{-1}day^{-1}) followed by rice based sequences (16.41 kg ha^{-1}day^{-1}). Bangwar and Katyal (2001) evaluated various crop sequences at Bhubaneswar, Orissa and reported that performance of rice-tomato-poi was distinctly better than others with highest rice yield-equivalent of 26.68 t ha^{-1} yr^{-1} and productivity of 90.14 kg ha^{-1}day^{-1} while profit and stability of rice-mustard-ridge gourd sequence was the highest. Kar et al. (2003) reported that wet season intercropping of rice+pigeonpea and rice+blackgram increased rainwater use efficiency (in terms of rice equivalent yield) from 2.2 kg ha^{-1} mm^{-1} in sole rice to 4.35 kg ha^{-1} mm^{-1} in the deficit rainfall year of 2000. But in the excess rainfall year of 2001, rainwater use efficiency of 2.53, 3.43, 4.4 and 3.93 kg ha^{-1}mm^{-1} was obtained from sole rice, rice+pigeonpea, rice+blackgram and rice+groundnut respectively. Therefore experiments involving rice based multi-crop systems were taken in farmers' fields in an area of 485 ha with 415 farmers under National Agricultural Technology Project (NATP) during the years 2001-2004.

MATERIALS AND METHODS

Trials were conducted in farmers' fields in wet, winter and summer seasons in 3 coastal districts of Orissa during the years, 2001-04. For estimation of climatic parameters, daily rainfall, evaporation, relative humidity and maximum and minimum temperature were recorded. To provide supplemental irrigation, unused village tanks were renovated to work as storage structure of water harvesting. Water use efficiency of different cultivars of rice and rice based crops were calculated basing on rainwater parameters like rainfall, runoff, seepage and percolation and evaporation. Runoff from individual showers was recorded by installing a 5-slot device. Evapotranspiration (ET) of crops, determined from field observation, was compared with empirical methods like pan evaporation method and Blaney-Criddle method (1950). Profitability of a crop/ cultivar was calculated as the net profit from the cultivation per rupee investment.

Adaptive research trial of wet season rice. Experiments were conducted in wet seasons to evaluate the performance of different cultural practices on yield and water use efficiency of rice in rainfed ecosystems of intermediate lowland, shallow lowland and flood-prone lowland situations in a randomised complete block design. From initial survey, predominant varieties and prevalent cultural practices of the study areas were identified. These were considered as farmers' practice. Cultural practices including fertliser and pest management and varieties giving consistently higher yield in similar land-water situations at research stations were included as improved practices. The experiment consisted of 4 treatments, namely: Farmer's variety with traditional practices (T_1), Farmer's variety with improved practices (T_2), Improved variety with traditional practices (T_3) and Improved variety with improved practices (T_4).

Varietal trial of dry season crops. Water use efficiency and profitability of varieties of dry season crops (winter and summer crops) were studied through varietal trials. Each variety was taken as a treatment and the crop, grown by a farmer was treated as a replication. Data was collected from 10 farmers for analysis. Factors known to have influence on grain yield, such as dates of sowing, transplanting and application of fertilizer, dose of fertilizer etc. were maintained same for all the treatment plots.

Field evaluation of water use by a crop. In rainfed ecosystem the field water used (FW) by a crop, is obtained from rainwater balance, $FW = R - R_o - SP \pm S_r + W_s$; where R= rainfall, R_o= runoff, SP= seepage and percolation, S_r = soil profile contribution or retention, and W_s= water applied from other sources.

Conservation of residual soil moisture. In addition to introduction of cultivars with high water use efficiency (WUE), several steps were taken to conserve rainwater for production of winter and summer crops. These include: rice varieties of lesser duration and early sowing of second crop of mustard in shallow lowlands, paira cropping with base crop of rice in flood-prone area, and laying of field channels, field-bunding of un bunded uplands and furrow-ploughing.

RESULTS AND DISCUSSION

From the daily rainfall and evaporation data, it was found that on an average 8.48 mm rainfall was received daily during July-November whereas only 4.9 mm of water was required for crop evapotranspiration. Rest of the rainfall (about 42%) was lost from fields in the form of runoff and aquifer recharge.

The summer (April-June) daily average rainfall was found to be 4.17 mm. It was sufficient to grow crops like sesame (evapotranspiration (ET) = 2.4 mm day^{-1}), lathyrus, green gram and black gram (ET=1.9 mm day^{-1}) without irrigation. But during winter (December-March), average evaporation was found to be higher than rainfall (1.42 mm day^{-1}). To grow crops like mustard, groundnut and vegetables, this shortfall and other unavoidable losses are to be met by supplementary irrigation.

Mean daily seepage-percolation rates were recorded from rice fields during wet season. Mean value was found to be 1.04 mm day^{-1} from 3 years data of alluvial soils under shallow lowland situation. Runoff (Y) from individual showers, collected from a rice plot of 100 m^2 area, could be computed as: $Y = 0.556 x - 2.556$, where x = rainfall in mm.(minimum value of Y = 0)

Total loss from paddy fields in the form of runoff and seepage-percolation was found to be 42%.

Barring minor variations, evapotranspiration of rice cultivars of same duration was found to be almost same. About 100 mm of water was found to be saved due to transplanting over beushaning in shallow lowland. This indicated that the transplanted rice was more efficient on water use than direct sown rice of same duration. (Fig.1). In flood-prone areas, yield of varieties was dependant on timing of submergence. Accordingly, none of the varieties provided consistency in yield and WUE. Their performance varied from season to season. With submergence at booting stage during the wet season of 2003, performance of *Kishori* (yield: 3.45 t ha^{-1}, WUE: 3.34 kg ha^{-1} mm^{-1}) was better than others while in previous years performance of *Gayatri*, *Ranjeet* and *Sarala* was better.

Effect of improved cultural practices on yield, water use efficiency and profitability. Improved cultural practices gave a boost to production, water use

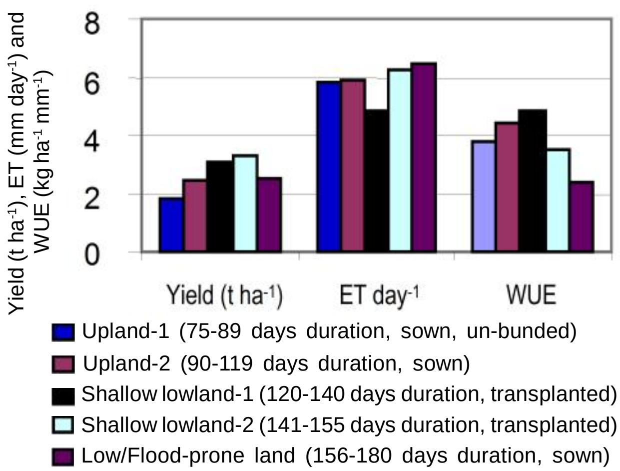

Fig. 1. Yield, evapotranspiration and water use efficiency of cultivars under different rainfed ecosystems

efficiency and profitability. In uplands, drought tolerant variety, *Vandana*, due to better root development basal application of phosphate and efficient control of weeds by pretilachlor increased yield and WUE by 108% and profitability by 544%. In flood-prone lowlands, submergence tolerant varieties, basal application of fertilizer and control of lowland weeds by post-emergent almix; increased yield and WUE by 175% and profitability by 1120% (maximum). The reason for the spectacular success in problem areas may be attributed to the age old cultural practices being followed by resource poor tribal farmers in unfavourable situations. Results from the study are shown in Fig.2 and 3. Effect of individual components on stability of yield and profitability was analysed and observed that control of weeds in upland and submergence-tolerant cultivars in flood-prone lowland were most important. The problem

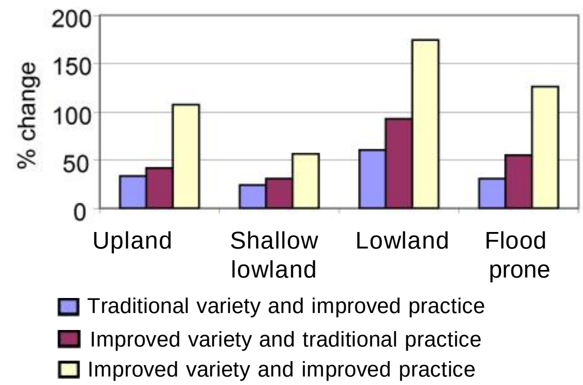

Fig.2. Effect of management practices on yield & WUE over traditional practices

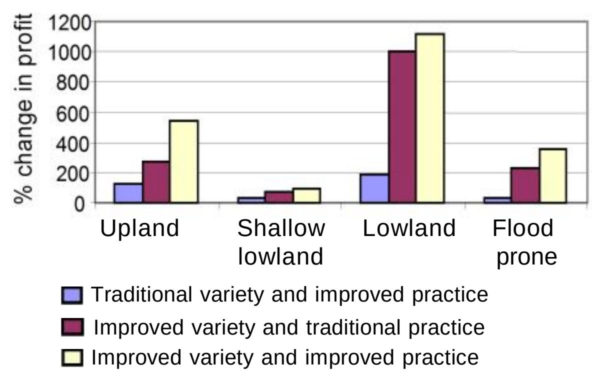

Fig. 3. Effect of management practices on Profit of wet season rice over traditional

of unpredictable duration of submergence at any stage of growth, makes rice cultivation most challenging in flood-prone areas among all the rainfed ecosystems.

Cultivars of winter crops were evaluated for their grain yield, water use efficiency and profitability. Rainfall, soil profile contribution and irrigation were taken in to consideration for estimation of field water use. In case of transplanted crops, duration of first stage of growth was reduced by 20 days to accommodate nursery time. Results obtained from these studies are presented in Table 1.

Availability of residual soil moisture after second crop and summer rainfall were utilized to grow pulses, vegetables and oilseeds. While sesame, green gram and black gram could be raised without irrigation, vegetables and groundnut required supplementary irrigation. Cultivation of vegetables and groundnut was started in winter but were harvested during summer. Performance of summer crops is shown in Table 2.

Table 1. Performance of winter crops (2001-04)

Crop	No of varieties	Duration Range (days)	Mean yield ($t\ ha^{-1}$)	ET ($mm\ d^{-1}$)			Field WUE ($kg\ ha\text{-}\ mm^{-1}$)	Profitability	
				Field	Pan evaporation	Bl-Cr**		Expenditure ha^{-1}	NPI
Mustard	5	75-95	0.85	153	129	280	5.56	5,000	2.4
Tomato	13	90-140	47.82	260	231	510	183.92	19,165	6.49
Cabbage	10	90-150	43.03	363	166	375	118.54	16,100	4.35
Cauliflower	8	75-122	26.37	329	137	328	80.2	16,700	6.11
Radish	7	50-65	36.56	340	90	179	108	6,900	9.6
Cucumber*	3	65	7.08	165	103	249	42.9	8,870	2.99
Pumpkin*	9	80-110	10.13	156	184	389	64.74	7,810	0.94
Ridge gourd*	1	65	10.91	141	83	209	77.4	7,350	7.16

* Ring irrigation, NPI: Net profit per rupee invested ** : Blaney – Criddle method

Table 2. Water use efficiency of summer crops (2003-04)

Crop	No of varieties	Duration Range (days)	Mean yield ($t\ ha^{-1}$)	ET ($mm\ d^{-1}$)			Field WUE ($kg\ ha\ \text{-}\ mm^{-1}$)	Profitability	
				Field	Pan evaporation	Bl-Cr*		Expenditure ha^{-1}	NPI[1]
Sesame	4	90	0.47	138	253	422	3.41	3,350	2.51
Groundnut	4	120	1.66	287	349	625	5.78	10,860	2.21
Greengram	5	90	0.61	130	186	349	4.69	2,280	4.89
Blackgram	3	90	0.51	115	160	320	4.43	2,180	3.21
Okra	13	97-148	10.38	395	459	797	26.3	16,650	2.74
Chilli	9	150-240	12.06	591	502	948	15.4	20,500	3.71
Brinjal	12	120-185	31.05	452	405	873	68.76	18,100	9.29
Tomato	4	90-120	27.52	350	312	610	78.6	12,550	9.96

[1]NPI: Net profit per rupee invested *: Blaney – Criddle method

Among different combinations tried, the field crop sequence of rice-mustard-sesame was most widely adopted (400 farmers: 95 ha) due to low investment, ready marketability and risk free production. Among rice-vegetables combination, rice-tomato-sesame and rice-brinjal sequences were most profitable. But the price range of vegetables was volatile depending on time of production. Profitability of different rice based sequences is presented in (Table 3). Expenditure and profit accrued from shallow lowland rice *(Surendra)* has been taken as the reference.

Advantage of frequent silting in flood-prone areas was taken to grow black gram as paira crop with rice as base crop. The crop could sustain its growth due to long moisture retention capacity of silts. Whenever precipitation after harvest of rice was there, yield of the black gram crop almost doubled. An average yield of 3.2 q ha^{-1} (range: 1.2-9.4 q ha^{-1}) was obtained from the variety, *Nayagarh-local*. This gave a net profit of Rs.2.11 per rupee invested. Fertiliser was not applied for the paira crop.

Enormous scope exists in eastern India for creation of water resources to store and utilise monsoon runoff by renovating existing unused ponds. A large portion of post-kharif fallows can be converted to round the year greenery with rainwater management. Taking advantage of fairly good summer rainfall, it is possible to grow crops like sesame, green gram and black gram without irrigation.But winter crops require supplementary irrigation. With one supplementary irrigation of 30 mm, mustard gave a yield of 11.5q ha^{-1} in alluvial soils of Bhadrak district. For rice based 3-crop system, shallow low lands were more suitable than flood-prone lowlands or hilly uplands. Rice varieties of 130-140 days duration were ideal for the purpose. This duration ensures cooler environment to mustard and

Table 3. Profitability of multi-crop systems

Sequence	First crop		Second crop		Third crop		Total net
	Expenditure ha^{-1}	Net profit Re^{-1}	Expenditure ha^{-1}	Net profit Re^{-1}	Expendture ha^{-1}	Net profit Re^{-1}	profit Re^{-1} invested
Rice-Mustard-Sesame	9,945	1.23	5,000	2.4	3,350	2.51	6.14
Rice-Mustard-Okra	9,945	1.23	5,000	2.4	16,650	2.74	6.37
Rice-Mustard-Gr.gram	9,945	1.23	5,000	2.4	2,280	4.89	8.52
Rice-Mustard-Bl.gram	9,945	1.23	5,000	2.4	2,180	3.21	6.84
Rice-Cabbage-Sesame	9,945	1.23	16,100	4.35	3,350	2.51	8.09
Rice-C.flower-Sesame	9,945	1.23	16,700	6.11	3,350	2.51	9.85
Rice-Pumpkin-Sesame	9,945	1.23	7,810	0.94	3,350	2.51	4.68
Rice-Cucumber-Sesame	9,945	1.23	8,870	2.99	3,350	2.51	6.73
Rice-Tomato-Sesame	9,945	1.23	19,165	6.59	3,350	2.51	10.23
Rice- Brinjal	9,945	1.23	18,100	9.29	Contd.	10.5	
Rice-Groundnut	9,945	1.23	10,860	2.21	Contd.	3.44	
Rice-Chilli	9,945	1.23	20,500	5.90	Contd.	7.13	

(All figures are in rupees)

sufficient time for sesame to be harvested before onset of monsoon. The field-crop sequence of rice-mustard-sesame has been widely adopted by farmers. Net profit per rupee investment has gone up from Rs. 1.25 of sole rice to Rs. 6.15 with total net profit of Rs. 32,600 ha^{-1}. It has also provided round the year employment to the farming community. Mass adoption of this 3-crop system has brought a metamorphic change in agricultural scenario and life style of farming community of Narasinghpur gram panchayat in Bhadrak district of Orissa.

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