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Adaptation of Direct Seeded Rice under Water Stress Conditions in Andhra Pradesh, Krishna Basin

CLIMARICE II: **"Sustaining rice production in a changing climate"**

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Rice is a major cereal crop grown in India. The share of rice in total cereal crops accounts for 24 % and wheat for 14%. The two crops constitute 175 million tonnes of the total food grain production (rice 96.5 and wheat 78.5 m.tonnes) (Directorate of Economics and statistics, 2011). In India, 48 % of the rice area is irrigated while the rest is grown under rain-fed conditions. Rain-fed rice cultivation in West Bengal amounts to 15 % of the Indian rice production, While in Andhra Pradesh contributes 13 % of the country's rice output with 9 % of the total rice area. As rice and wheat are India's major staple foods, the area under cultivation as well as production are increasing along with the increasing demands of the population (FAOSTAT, 2007). Nonetheless, rice production is facing three major challenges: (i) High water demand: Around 95 % of the rice area under modern varieties is irrigated, and requires about 1200 mm to 2500 mm of water depending on soil texture, structure and profile conditions (Reddy, 1995). Unfavourable weather conditions and drought can cause water related stress in rice production.

(ii) High labour demand: About 10 to 15 labourers (mandays) per acre are required for transplanting, weeding (20 per acre) and harvesting (10 per acre) (Technical program, 2011). The availability of labour is becoming scarce; as rural people are migrating to nearby cities and towns for various reasons or being hired in the government rural employment guarantee program and non-agricultural activities with higher wage rates (personal communication with farmers). Hence, the cost of labour in rice production increased during recent years. For example, in the Krishna zone (Krishna, Guntur and Prakasam districts) of Andhra Pradesh costs for labour in rice cultivation accounted for 29 % of the total cultivation costs during 2006-07, and increased to 49 % in 2010-11 (Technical program, 2011).

(iii) Methane emissions from rice ecosystems: It is a known fact that, rice fields release methane into the environment that contributes to global warming. Emissions from flooded fields are higher than those from drained fields (Komiya, et al. 2010). Methane is generated when organic matter decays in anaerobic conditions. Hou et al. 2000 reported that the factors affecting methane and nitrous oxide emissions are soil temperature and soil redox potential, net irradiance and organic matter content. The IPCC 4th assessment report states that agriculture accounts for 50% of the methane emissions, 11% of these emissions come from rice production. Overall, South and East Asia are responsible for 82 % of methane emissions from rice production. Annually, 4.5 million tonnes of methane are emitted from paddy in India (Pepsico International, 2011). Rice cultivation is the second largest contributor of global agricultural methane after enteric fermentation. Estimation of methane emission from Indian paddy fields, therefore acquires a special significance (Lakshmanan et al., 2009).

Hence, to sustain rice production and ensure food security with the above mentioned challenges new adaptation strategies have to be developed. Field experiments that were tested in Climarice I (direct seed rice, alternate wetting and drying, SRI etc www.tnau.ac.in/climarice.) were validated on the farmers fields in 2010 and 2011. Results from direct seeded rice trials are presented and explained here.

Direct seeding of paddy:

The direct seeding of rice refers to the spreading of seeds in fields before or immediately after pre-monsoon showers. The method does not require raising and transplanting of seedlings. The seeds are directly sown in the main field by spreading manually or with the help of a tractor and attached implements at a depth of 2-3 cm. Depending upon the availability of water fields need to be irrigated 45-60 days after sowing and turned into a wet system. Hence, the direct seeding method requires less water and labour, and has lower cultivation costs with comparatively equal grain yields than traditional systems and the crop matures in less duration. Nonetheless, weed growth is high in the directseeded rice and famers are using pre- and post-emergence herbicides to overcome the problem. Moreover, the crop comes to an early harvest. Timely sowing gives farmers the possibility to take up a second pulse crop in time. This method can be a good measure when the monsoons are delayed and farmers do not have time and water to raise nurseries.The direct seeding method was validated in two villages (Jonnalagadda and Modukur located in Guntur district) located in the Nagarjuna Sagar and Krishna delta command areas of Krishna river basin. In Jonnalagadda village, direct seeding of rice is practiced for more than 20 years, in addition to the transplantation method depending upon water availability. Direct seeding method is localized in the village and has not been adequately validated from research perspective. Hence, CLIMARICE II project has started to document the experience of farmers, create awareness about the practice and develop guidelines for scaling up together with local agricultural research station and government agencies

Picture 1: Direct seeding vs. manual transplantation at Modukur and Jonnalagadda village

Data collection and analysis -2010 and 2011

Jonnalagadda village is about 5 Km from the RARS, Lam. Hence, rainfall data from the research station was taken for the years 2010 and 2011 (Table 1). The amount of rainfall and the number of rainy days in the area was significantly higher in 2010 than normal years. Rainfall was 26% less in 2011 than the normal years, but there is no difference concerning the number of rainy days.

Table 1: **Meteorological data: RARS, Lam for 2010 and 2011 Kharif season**

Month	2011		2010		Normal	
	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days
June	52.4	6	78.1	7	110.3	6.8
July	265.2	14	196.3	11	186.8	10.5
August	244.6	14	240.5	14	183.9	10.9
September	64.0	08	462.8	14	171.8	8.1
October	62.8	05	977.7	09	166.4	7.9
November	0	0	75.2	07	28.2	1.6
December	0	0	115.3	03	24.0	0.9
Total	**689.0**	**47**	**1351.7**	**65**	**871.4**	**46.7**

Table 2: **Meteorological data Tsundur Mandal for 2010 and 2011 Kharif season**

Month	2010		2011	
	Rainfall (mm)	No. of Rainy days	Rainfall (mm)	No. of Rainy days
June	138.4	5	22.4	4
July	265.2	15	161.2	11
August	145.6	14	156	7
September	225.6	13	59	5
October	187	8	62.8	5
November	174.2	11	0	0
December	151.7	5	0	0
Total	**1287.7**	**71**	**461.4**	**32**

The rainfall data from Tsundur mandal (Modukur village) also showed that there is a 50% decrease concerning the number of days with rainfall (table 2). The amount of rainfall is also less than 64% compared to 2010.

Biometrics cost of cultivation and water measurements were carried out in the farmers' fields at Jonnalgadda and Modukur villages. The data presented in table 3 was recorded during Kharif seasons of 2010-11 and 2011-12. Data was also collected from the traditional transplantation method for the control plots during these years. The seed rate in the direct seeded field is about 50 % lower than with the traditional transplantation method (Table 3). The days required for transplantation (about 30 days) are avoided with the direct seeding practice.

Table 3: Field observation for Kharif 2010-11 and 2011-12

S No	Item	2010-11		2011-12	
		Traditional	Direct seeding	Traditional	Direct Seeding
1.	Seed rate (Kg/ha)	60-75	30-40	60-75	30-40
2.	Days to transplant	30-35	0	30-35	0
3.	Cost of nursery including seed, Transplanting (Rs)	10170	1540	10400	1540
4.	Labour required for transplanting/ seeding operations	25	2	25	2
5.	Spacing (cm)	30 X15 (ziggag)	30 X10-12	30 X15 (ziiggag)	30 X10-12
6.	No of hills/sq-meter	21	23.60	22	27
7.	No of effective tillers/hill	12.10	11.40	15.90	13.90
8.	No of grains/ panicle	118	117	125	123
9.	Days to maturity	152	146	143	138
10.	Water utilized (mm)	1291	995	1127	868
11.	Yield recovered (kg/ha)	4565	4753	6563	6738
12.	Water use efficieny (kg/ha/mm)	3.53	4.77	5.82	7.99
13.	Total variable cost of cultivation (Rs/ha)	40511	36211	45473	39742
14.	Gross returns (Rs) @993/- (2010-11) & 1000/- (2011-12)	45331	47198	65630	67380
15.	Gross margin (Rs/ha)	4820	10987	20157	27638
16.	Benefit cost ratio	1.11	1.30	1.44	1.69

The number of hills/sq.m are slightly more in case of the direct seeding method compared to the traditional transplanting method, and less tillers and grain formation but not at a significant rate. The yield difference between the direct seeding and the transplantation method was around 175-188 kg/ha. The variable costs of the farmers was also less by about Rs.4300 to 5700 per hectare. This was the reduced costs normally required for nursery raising and transplantation. Only two labourers are required for direct seeding, while 25 are needed for the transplantation method (Average manday/ labour cost is about 150 Rs/day).

Water measurements:

RBC flumes were installed in farmers' fields for both the direct seeding and the traditional transplanting method. Five flumes were installed in the direct seeded fields and two flumes in the control (traditional transplantation). The RBC flume has the capacity to discharge 50 lps at its maximum point. The farmers were asked to observe the flume point and the amount of water applied each time they irrigated their fields. The applied water was computed with the flumes discharge capacity chart. The effective rainfall amount was also considered in the water utilisation, which is about 70% in the semidry areas (equation 2). The direct seeding practice has reduced water consumption by 250-300 mm (table 3).

Water use efficiency was found to be higher in direct seeded fields; this was also true for the season with little rainfall and more sunshine (2011-12).

Measuring irrigation water through RBC flume:

Water applied in ltr/ha (Li) = (Water height in flume per irrigation x Discharge in ltrs from annexure chart) x (No of hours x 3600) *equation (1)*

Effective rainfall ltr/ha L2= Rainfall in mm X 10000 X 70/100 *equation (2)*

Total water utilised mm/ha = (Li + L2)/ 10000 *equation (3)*

Where i is 1 to n

RBC flume in the farmers field

Farmers' perception on the Adaptation of direct seeded rice

The farmers were questioned on their perceptions of the direct seeding method as an adaptation measure. Positive responses were given concerning the reduced costs by avoiding transplantation, free tillering with more number of tillers, a deeper root system that absorbed nutrients effectively from deeper layers, resistance to lodging, higher panicle length, lower occurrence of pests and disease due to less rainfall and lower water demand in the initial crop growth stages.

Constraints in practicing the direct seeding method

Farmers also responded on the constraints; major problems pointed out were weed control issues, field levelling and rainfall after seed sowing. Weed growth was high during the intial stages. However, weeds are controlled by pre-emergence and post-emergence herbicides. Generally, pendimethaline (1 lt/acre), pretilachlor+safener (600 ml/acre) is used as a pre-emergence herbicide, and Machetti-Butachlor (1-1.5 lt/acre), Oxydiargyl (30-40 gm/acre), Bispyribacsodium (100 ml/acre) and 2,4-D sodium salt (500 gms/acre) are used as post-emergence herbicides based on the type of weed. Bispyribacsodium controls weeds effectively at the 2-4 leaf stage. After using the herbicide, 3-4 labourers are sufficient for controlling weeds manually.

Management practices for reducing Methane in Paddy fields:

Methane emitted from paddy can be controlled by various management practices such as reducing the number of irrigations, multiple drainage system during the crop cycle, alternate wetting and drying, azolla application, semi-dry cultivation, Mycorrhiza and methanotrophs application (Khosa et al. 2011, Zheng et al. 2000, Lakshmanan et al., 2009 a & b). For example, the mid-season drainage has been reported to reduce methane emissions by 50% compared to continuous flooding (Gupta et al., 2002). Tyagi et al.(2010) observed that methane flux was reduced by 9% when drainage was done at the tillering stage. While mid-season drainage and multiple drainage reduced methane fluxes by 36.7 and 41%, respectively. Alternate wetting and drying of rice fields eliminated the second flux of methane because strong anaerobic conditions could not develop in the scheduled irrigation (Cai et al., 1997). This favors an increased oxygen supply to the soil inhibiting methane production by methanogens (Wang et al., 1999). The direct seeding method combined with a reduced number of irrigations at the intial stages of crop gowth, followed by alternate wetting and drying of rice fields, can reduce methane emissions. The water regime of soil is an important factor for the gas exchange between soil and atmosphere and has a direct impact on the processes involved in methane emission. For methanogenesis to take place, it is of primary importance that the soils should have enough moisture to create an anoxic condition. Drainage is a major modifier of seasonal methane emission pattern. A single mid-season drainage may reduce seasonal methane emission. This emission could be reduced further by intermittent irrigation yielding a 30 per cent reduction as compared to mid-season drainage (Lu *et al*., 2000).

Conclusion and Recommendations

The direct seeding method in paddy reduced water utilisation and cost of labour. The method is efficient in terms of water use and economics reducing the resource scarcity. The yields are slightly higher in the direct seeding but not at a significant rate (3-4 % increase). The number of hills are also more in the method but less effective tillers compared to the traditional transplanting method. Given the advantages of efficient resource utilisation the direct seeding paddy need to be upscaled in a large scale. The upscaling procedure requires more awareness on the practice by organizing field visit, publications with scientific results, block level recommendations through the agricultural department etc. The method can be more focused in the canal commands at a larger scale for equal distribution of water to all the head, middle and tail end regions. Nonetheless, more scientific studies are required with seed variety testing, methane gas emissions, socio-economic and adaptation studies.

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ClimaRice II Project (2009-2012)

ClimaRice II is an integrated project that aims to test and validate climate change adaptation techniques related to rice production, in close co-operation with farmers and local agencies in two study areas in the Cauvery River Basin, Tamil Nadu, and Krishna River Basin, Andhra Pradesh, in India.
The overall goal is to contribute to the regional and national adaptation strategies to sustain rice production and ensure food security amidst changing climate.

The partners are:

- Bioforsk - Norwegian Institute for Agricultural and Environmental Research (Project Co-ordinator)
- Tamil Nadu Agricultural University, Coimbatore, India
- International Pacific Research Institute, Hawaii, USA
- International Water Management Institute, Hyderabad, India

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