CLIMATE RESILIENT RICE PRODUCTION, RICE INTERCROP, ALTERNATE CROP AND INSITU WATER HARVESIG AND GROUND WATER RECHARGE TECHNOLOGIES TO ADDRESS DEFICIT RAINFALL

Abstract

Rainfall and its distribution have become uncertain and erratic during the rice growing season under changing climatic scenario. Under deficit rainfall (50% & 19% in 210 and 2012) from dry sowing or dry transplanting of rice to its harvest (48-52 cm rainfall from August to October), 42.8 q/ha coarse rice (cv, Annada) and 29-45 q/ha medium rice (cv. Satabdi and Himsagar) were harvested with one irrigation of 7.5 cm at panicle initiation stage. Water productivity ranged from 1250 to 1810 lit/kg of raw rice in different years. Dry seeded/dry transplanted rice was established receiving 55 to 74 mm rainfall within seven days. However, one supplemental irrigation following dry sowing/transplanting will ensure better seedlings establishment. Soil mulching by CRIJAF nail weeder at field capacity at 6-21 days after rice dry transplanting/dry sowing will maintain better hydro thermal regime and aeration of soil under deficit rainfall and ascertain composite weed control. Field capacity moisture during rice growth was enough to produce 45q/ha grain yield. This practice of rice production will mimimise methane gas emission over waterlogged rice paddies. *In situ* rain water harvesting in micro pond (12 m x 10 m x 1.5 m) sacrificing 9 per cent of total area (1333 m^2) at lowest corner of the field provides life saving irrigation and produced 3-3.5 tonnes medium rice/ha. Through these micro ponds (7 in one hectare), in porous alluvial or sandy loam soils, annually around 3.58 to 7.47 crore litres of water can be recharged/ha to the unconfined aquifer in rainy season (July to September). Inter/relay cropping in rice field will produce 3.5 to 4.5 tonnes of rice along with 15- 200 q of different vegetables/ha, increase nutritional security of resource poor farmers, net return and make effective utilization of rainwater. Under deficit rainfall, as alternate crops of rice, yield of rain fed green gram (cv. Pant mung-5, RMG 62), arhar (UPAS -120) and sweet corn green cobs on ridges, were 21-23 q, 30 q/ha and 1,20,000 numbers/ha respectively. Adopting these rice production/intercrop/alternate crop/water harvesting technologies, sustainability can be ensured under a deficit rainfall, in current changing climatic scenario.

Key words: Direct seeded rice, dry transplanting of rice, rain water harvesting, inter/relay cropping, alternate cropping.

Introduction:

Deficit rainfall during rice sowing/transplanting in kharif season has become a bottleneck for rice cultivation in some rice growing states of India. According to Indian Meteorological Department, deficit rainfall till 17th August 2022 in some rice growing states of India were: West Bengal, 35%; Bihar 40%, Eastern & Western UP, 47% & 40% and Jharkhand 36% [1]. This year the rainfall deficit in June and July is hovering around 45-80 per cent in different rice growing districts of West Bengal **(**2022). In the year 2010 and 2012, we faced deficit rainfall in WB (50 & 19%, respectively) during rice growth and thus puddling was not possible for establishment of kharif rice. This type of deficit and erratic rainfall will lead to uncertainty to rice cultivation and affect the food security of the rice growers. Saving of irrigation water in direct seeded rice (DSR) has been reported by many workers e.g., [2,3,4]. This method eliminated the irrigation requirement for puddling (20 cm approximately) and saves soil structure which is usually lost due to puddling. Direct-seeding methods have several advantages over trans-planting [5]. In addition to higher economic returns, DSR crops are faster and easier to plant, less labour intensive and consume less water [4], are conducive to mechanisation [6] generally flower earlier leading to shorter crop duration [7] and mature 7–10 days earlier and have less methane emissions [8,9] than transplanted rice (TPR). In kharif season highest plausible rice grain yield was possible at saturation or at no standing water from dwarf HYV (cv, IR-36) at Bhubaneswar Odisha, [10]. To overcome this problems of deficit rainfall during crop establishment stage attempts were made to grow rice by direct seeding method (DRS)/dry transplant rice (25-30 days old seedlings) following jute harvest at field capacity on unpuddled pulverized soil and on saturated soil under minimal tillage condition at ICAR-CRIJAF, West Bengal, India. Rice-vegetable intercropping was also tested to increase nutritional security, net return and make efficient use of rain water. *Insitu* water conservation methods were developed and tested in farmer's field for life saving water under deficit rainfall. To bring sustainability alternate crops of rice were also tested under such situation. This system will minimize the risk of rice crop failure and produce rice at low rainfall years with higher water productivity and sustainability can be ascertained growing inter/alternate crops.

Materials and Methods:

Field experiments were conducted in West Bengal ,CRIJAF in 2009,2010 and 2012 on upland in sandy clay loam and sandy loam soils and its N, P & K content were 347 kg/ha, 32.25 kg/ha and 189 kg/ha, respectively. The experimental soil had 44 per cent sand, 28 per cent silt and 28 per cent. For direct seeded rice (DSR), shallow furrows were drawn by cultivator (Photo 1.) and seeds were shown on shallow furrows and covered by wooden planks behind tractor. For dry transplanting of rice, after jute harvest, soil was pulverized by rotavator and shallow furrows were drawn by cultivator (Photo1). Basal NPK were applied before rice transplanting. In 2009 rice Cv. Ananda was transplanted on shallow furrows developed by cultivators at field capacity on pulverized soil (30 days old seedling) on 21-7-09 which established with a rainfall of 73.6 mm from 21-7-09- to 30-7-2009. Six to seven seedlings were placed on furrows and the basal region was covered with soil for firm anchorage. In 2010, the soil was pulverized rotavator and 25-35 days old rice seedlings (Cv. Satabdi, Annda, kshitish) were transplanted randomly or in rows developed by cultivator, manually. In this year, the rice crop received 63 mm rain within 7 days (11 to 18-8-2010) following transplanting and got established. In 2012, 40 days old rice seedling was transplanted in field capacity soil with N:P:K::40::40:40 as basal and 60 Kg N as top dressing in two splits. This year (2012) the rice crop received 55.5 mm rain within 7 days following its transplanting in field capacity (FC) soil and got established. The rice crop was grown under rain fed condition at field capacity throughout the crop growing period.

In another system (2012), rice cv. Satabdi received only 77 cm rain within 7 days of its transplanting in sticky soil on shallow furrows developed in between harvested jute rows developed by wheel hoes (minimal tillage, Photo 2a). Dry transplanting of rice were also done after jute harvest by dibbling/transplanting rice seedlings (5-6 seedling/hole) on shallow holes (5-6 cm) made by strong jute pegs (Photo 2b). For comparison, direct seeded rice (DSR) were also grown following jute harvest (2009 & 2010) and good yield (4.2 t/ha) was obtained from Coarse rice (Cv. Annada). DSR were also tested in pilot scale in larger plots at ICAR-CRIJAF on 2017, 2019 and 2021 successfully under rain fed condition and rice yield varied from 3.5 to 4.5 t/ha. Here in also same agronomic management practices were made. In these years, rice crops were primarily grown under rain fed condition and one irrigation was given to it during panicle initiation (PI) stage using ground water. Following rice transplanting, butachlor 50 EC was applied @ 1 kg ai/ha at 3-4 DAT for grass weed control and the rest of the weeds were removed either manually or by applying 2,4 D @ 0.8 kg/ha at 25 DAT (days after transplanting). Pretilachlor 50 EC @ 0.9 lit. a.i/ha was applied 2-3 days after transplanting (DAT) for composite weed control. Immediately after rice seedling establishment (6-21 DAS/DAT), the soil in between rows were loosened by CRIJAF nail weeder at FC for weed control, improved hydrothermal regime and better soil aeration. Required plant protection measures were taken up to save rice crop from pest and disease attack. The monthly rainfall distribution from sowing to harvest of rice is shown in Table 2.

Rice-vegetable intercropping was also tested using gunny bag based soil columns, to increase nutritional security, net return and make efficient use of rain water and tested with success in farmer's field West Bengal (in different districts), Assam and Odisha. For this purpose, used old gunny bags of standard size (90 cm height and 45 cm diameter) were cut into two equal pieces (45 cm height). These cut gunny bags were soaked in carbendazim (Bavistin 2g/l) and copper-oxychloride (Blitox 4.5g/l) solution for an hour, to avoid fungal or bacterial growth. The columns are made using field soil and organic matter in alternate layers with a straw cushion at the base within the soil. It can be made using an iron die or fixing gunny bags using bamboo pegs. Fertilser dose and pesticide managements are as per standard norms. Soil columns have to be made in the skipped rows of rice field (one row skipped after each 8^{th} row) recommended for control of brown plant hopper, Within rows, the inter column distances have to be kept from 50 cm to 200 cm for different crops. *Insitu* water conservation methods in micro ponds (12m x10m x1.5m) were developed sacrificing 9 per cent area of 1333 m^2 land and tested in farmer's field for life saving irrigation of rice to mitigate deficit rainfall. To bring sustainability alternate crops of rice e.g. green gram (cv. Pant Mung 5, RMG 62), arhar (UPAS 120) and sweet corn were tested on ridges under such deficit rainfall condition. This system will minimize the risk of rice crop failure and produce rice at low rainfall years with higher water productivity and sustainability can be ascertained growing inter/alternate crops.

Photo 1. Field preparation and dry transplanting of rice seedling in furrows under field capacity condition

Photo. 2a. Shallow furrows development on pulvesrised soil or in between jute rows (5-10 cm) by wheel hoe for dry transplating of rice.

Photo. 2b. Shallow holes developed by jute pegs in between harvested jute rows (5-10 cm) for dibbling rice seedlings in minimal tillage in FC soil under deficit rainfall.

Photo 3. CRIJAF Nail Weeder operation for composite weed control, better aeration and improved hydrothermal regime of soil leading to better rice harvest

Results and Discussions:

The direct seeded rice or dry tans planted rice seedlings could be established with a rainfall of 55 to 74 mm within seven days of its sowing/transplanting. The rice crop grown and matured well with available rainfall (Table 1, Photo 3) supplemented with one irrigation at panicle initiation (PI) stage. A rainfall 45-52 cm and 7.5 cm irrigation at PI could produce 29 q- 45 q/ha medium rice (cv. Satabdi, Table 1) and 42.5 q/ha coarse rice (cv, Annada). The water productivity of rice ranged from 1250 to 1810 lit/kg of raw rice in different years. Dry seeding of rice (cv. Annada) @ 100 kg/ha on 8-8-2010, sown on shallow furrows developed by cultivator (DSR; direct seeded rice) and covered by planks behind it with a fertiliser dose of N:P:K::100:40:40 produced 42.8 q coarse rice in 100 days. It received 45 cm rain after sowing and one irrigation (75 mm) was provided at panicle initiation (PI) stage (Table 1). However,one light irrigation (50 mm) following dry sowing or dry transplanting will minimize the risk of crop establishment during prolonged drought. For this irrigation water has to be supplied either from surface or ground water. Soil mulching by CRIJAF nail weeder at 6-21 days after rice transplanting/sowing is necessary to retain more moisture in rice field under deficit rainfall, improve aeration, maintain better hydro thermal regime of soil [11,12], apart from its composite weed management.

This method has reduced the water requirement of rice to 52.5-70.0 cm only with respect to 120-150 cm under irrigated/waterlogged rice culture [2]. This method has merit over aerobic rice culture on puddle soil in the sense that, it eliminates the time required for seedling development (30-35 days) which increases the cropping intensity, reduces the risk of seedling death due to waterlogging in the direct seeded rice on puddled soil. We got 3-4.0 tonnes of scented rice (cv. Tulaipanji) and non scented rice cv. Kshitish,) from direct seeded rice (DSR) on puddled soil at ICAR-CRIJAF, Barrackpore in 2010. Success of DSR has been reported by many scientists which minimizes cost of production saves labour and minimizes methane emission [9, 13]. If grown under minimum tillage situation, it will eliminate costly massive fossil fuel requirement necessary for puddling by power tillers and tractors. Dry transplanting of rice avoided puddling, saved 85-90 percent irrigation water requirement over conventional rice cultivation under irrigated situation (20 nos. up to maturity) in sandy loam alluvial soil in Kharif season. Similar results have been reported by [14]. Thus even if we get 448-525 mm rainfall and 7.5 cm irrigation at PI stage from August to October we will be able to produce 42-45 q rice/ha under FC condition. Dry-seeding on flat land or raised beds with successive saturated soil conditions reduces the amount of water needed for land preparation and thus overall water demand [15].

In Kharif season, highest plausible rice grain yield was plausible at saturation or at no standing water from dwarf HYV (cv, IR-36) at Bhubaneswar Odisha.

$$Z \text{ (Pooled)} = 0.995 - 0.775 X, R^2 = 0.96^{**} \quad \text{--} \quad (1)$$

Where Z is the dimensionless relative grain yield, Y/Y_{max}; Y is the yield of paddy in kg/ha corresponding to depth of ponding height in cm, Y_{max} is the maximum yield of paddy in kg/ha, X is the dimensionless ponding ratio d/h_{mat}, d is corresponding height of ponding (cm) and h_{mat} is the average plant height at maturity. The average water requirement was 4.5 mm/day [16]. The net income from rice cultivation will be increased as the irrigation requirement is limited. Added advantage of rice cultivation by DSR/dry transplanting under field capacity is that the methane emission from these types of rice fields (not waterlogged), is expected to be very low [[8,9,13]. Direct seeding has the potential to decrease CH_4 emissions [17]. From PAU, Ludhiana, [18], reported that irrigating the field at 0.15 bar matric potential reduced seasonal methane flux by 60% (0.99 and 0.41 mg m^{-2} hr^{-1}, respectively in 2005 and 2006) as compared to completely flooded conditions, without any decline in grain yield (60 q ha^{-1}). [19] proposed that CH4 emissions may be suppressed by up to 50% if DSR fields are drained mid-season.

Life saving water from rain water harvesting in *insitu* micro ponds under deficit rainfall.

For life saving irrigations using surface water, an *insitu* micro pond (120 m^2 only with a depth of 1.5 m) has to be dug out in 1/3rd of an acre (1333 m^2) sacrificing 9 percent of its area at the lowest corner of the field to harvest rain water. It can collect runoff water up to 1,80,000 litres of water or even more if the dugout soil is used for making embankment over it (Photo 4, [20,21]. At ICAR-CRIJAF, Kolkata, in last week of June (2010), it was observed that runoff collection from one 30 mm rain from 1/3rd an acre was 60000 litres of water in such dug out *insitu* ponds. Thus collection of 1,80,000 litres of runoff water in such *insitu* micro ponds are very easy. In porous soil, lining can be done with tarpaulin/silpaulin sheets (250 GSM, Photo 4) to prevent seepage and deep percolation losses. *Insitu* micro ponds were dug at ICAR-CRIJAF (2010), Barrackpore, 24 PGS (N) and at Bikpur, Bankura, West Bengal in 14 farmers' fields for pilot scale studies from 2019-2022 (Photo 4). Farmers' of Bankura, Bikpur could harvest 3-3.5 tonnes rice/ha using this water. They could save their rice seedlings and rice crop from erratic and deficit rainfall using the harvested rain water in their own micro ponds [20]. The harvested rain water was used by the farmers for duck rearing, pisciculture and was even used for growing mustard after rice in 2022. Vegetables were grown on embankment for household purposes.

Some people used the pond water for bathing and other house hold purposes. These micro tanks require 4-6 hours to dig out by JCB machine, costing around Rs.4800 - Rs.6000 only (Rs.1200/hr).

Photo 4. *In situ* rain water harvesting for life saving irrigation of rice in Kharif season at Bikpur, Bankura, WB in coarse soil and at ICAR-CRIJAF in sandy loam soil.

As the Gangetic soils does not have any hard pan or impervious layer underneath the surface soil, it is expected that majority of water is recharged to its unconfined aquifer with little loss through lateral rice seepage and evaporation, provided the rice fields are bunded all round to check run off. Thus if a network of micro ponds in rice paddies are developed gradually, an enormous amount of water could be recharged to the aquifer enriching groundwater level over time apart from meeting fresh water requirement for assured rice harvest and quality jute retting in jute growing belts of the country. Taking 40% as run off of total rainfall in a year (1200-2500 mm at South and North Bengal, WB), annually around 48 to 100 lakh litres water/ha from these micro ponds (which acts as percolation tanks) can be recharged to the unconfined aquifer through these dugout ponds alone apart from its additional recharges from rest of the area (1213 m^2) where rice is grown in sequence till the retreat of monsoon season [20]. So as high as 3.58 to 7.47 crore litres of water can be recharged/ha annually (in 90 days: July to September) to the unconfined aquifer in pours alluvial or sandy loam soil, if one micro pond is constructed in each bigha (**0.1334 ha**) rice field. If a huge net work of micro pond system is developed across permeable soils, it will strengthen ground water position, supply fresh water requirement for assured rice harvest, quality jute retting and save mankind against drought under changing climatic scenario.

Inter/relay cropping in rice for better nutritional security: In Kharif season on upland (DSR) and medium lands, inter/relay cropping can be done in rice field using jute reinforced soil columns [22,23] to grow variety of early high value vegetables (cauliflower, cabbage, radish, summer palak, coriander, brinjal, chilli, tomato, maize/sweet corn, arhar and other cucurbits, Photo 5) under deficit rainfall. It will produce 3.5 to 4.5 tonnes of rice along with 15- 200 q of different vegetables/ha, increase nutritional security of resource poor farmers, net return and effective utilization of rainwater. Yield of arhar in this system was 18.8 q/ha [23]. This system acts as insurance against crop failure under unprecedented drought during panicle initiation to grain filling of rice. This system has been tested with success by Department of Agriculture Govt. of WB from 2013-2022 in different districts. AINP Jaf (ICAR-CRIJAF) has also tested this technology with success in different districts of WB, Assam and Odisha.

Photo 5: Intercropping in rice on upland using gunny bag based soil columns for nutritional security and higher profit.

Crop diversification under deficit rainfall in traditional upland/midland rice field:

Under deficit rainfall of 19-50% situation, alternate crops like green gram cv, Pant mung 5 and RMG 62 produced 21 and 23 q pulse grains/ha and arhar (cv UPAS -120) produced 30 q grains/ha, when sown on ridges (15-25 cm high and base 25-35 cm) developed by cultivator or spades to avoid waterlogging stress (Photo 6) in late kharif months [24]. Sweet corn, and sorghum should be grown on ridges made by ridge makers or BBF makers. The yield potential of sweet corn was 120000 cobs/ha at ICAR-CRIJAF, Barrackpore, WB.

Photo 6. Green gram (cv. Pant mung 5) and arhar (cv. UPAS-120) grown on ridges after jute harvest on medium land, under deficit rainfall to escape sudden water logging stress.

Conclusions:

Adopting different tested rice production/intercrop/alternate crop/water harvesting technologies, sustainability can be ensured under changing climatic scenario. Under deficit rainfall (19-50 %) from dry sowing or dry transplanting of rice to its harvest (48-52 cm rainfall only), 42.8 q/ha coarse rice (cv, Annada) and 29-45 q/ha medium rice (cv. Satabdi and Himsagar) were harvested with one irrigation of 7.5 cm at PI stage. Water productivity ranged from 1250 to 1810 lit/kg of raw rice in different years. The dry seeded/dry transplanted rice were established receiving a rainfall of 55 to 74 mm within seven days. However, one supplemental irrigation following dry sowing/transplanting will ensure rice seedlings establishment. Field capacity moisture during rice growth was enough to produce rice up to 45 q/ha. This practice of rice production will mimimise methane gas emission over waterlogged rice paddies, *In situ* rain water harvesting in micro pond (12 m x 10 m x 1.5 m) sacrificing 9 per cent of total area (1333 m^2) at lowest corner of the field provides life saving irrigation and produced 3-3.5 tonnes medium rice/ha. Inter/relay cropping in rice field will produce 3.5 to 4.5 tonnes of rice along with 15- 200 q of different vegetables/ha, increase nutritional security of resource poor farmers, net return and make effective utilization of rainwater. Under deficit rainfall, as alternate crops of rice, yield of rain fed green gram (cv. Pant mung-5, RMG 62), arhar (UPAS -120) and sweet corn green cobs on ridges, were 21-23 q, 30 q/ha and 1,20,000 numbers/ha respectively..

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Table 1: Comparative performances of rice establishment methods under deficit rainfall

Method of sowing	Rice Cultivars	Feriliser Dose (N:P:K)	Total rainfall from sowing /transplanting to maturity mm)	Total irrigation (mm)	Jute fibre yield (q/ha)	Rice yield (q/ha)	Days to matured (seed to seed)	Water productivity (Lit/kg of raw rice)	Rain fed pulse yield on ridges in kharif (q/ha)

A. Dry seeding on lines with seed rate 100kg/ha									
Sowing date 8-8-2010	Annada after Jute (JRO-524)	100:40:40	448 mm	75 mm	28.00 (JRO-204)	42.8 q/ha	100 days	1250	----
B. Dry rice transplanting in field capacity soil with 30 days old seedlings									
Transplanting dates 21-7-2009	Annada (Coarse rice)	80:40:40			--	42.00	110 days		21-23q (cv.Pant mung - 5& RMG 62)
11-8-2010	Satabdi (Medium grain)	100:40:40	448 mm	75 mm	30 q/ha	29 q/ha	120 days	1810	30q/ha Arhar (UPAS 120)-
23-6-2012	Himsagar (Minikit, Medium grain	100:40:40	1044 mm	75 mm	--	33q/ha	121 days	1742	--
13-8-2012	Satabdi Medium grain	100:40:40	519 mm	75 mm	--	45 q/ha	121 days	1320	--
SD ±	---	---	--	--	--	6.170	--	286.2	--

Table 2: Rainfall distribution of 2010 and 2012 (August to October) in rice growing period and its deficit over expected rainfall.

Months	**Rainfall received (mm)**		**Expected rainfall (mm), June to October**	**Deficit rainfall during rice growing period over expected rainfall (August to October)**		**Monthly rainy days**	
	2010	**2012**		**2010**	**2012**	**2010**	**2012**
June	193.2	150.7	300			11	**13**
July	204.6	414.4	300			13	**23**
August	**240.3**	**259.2**	**300**	**50%**	**19%**	15	**19**
September	**148.5**	**148.8**	**300**			12	**17**
October	**059.2**	**152**	**100**			3	**09**