

1 CLIMATE RESILIENT RICE PRODUCTION, RICE INTERCROP, ALTERNATE CROP  
2 AND INSITU WATER HARVESIG AND GROUND WATER RECHARGE  
3 TECHNOLOGIES TO ADDRESS DEFICIT RAINFALL  
4

5 **Abstract**

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

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

32  
33 **Introduction:**

34 Deficit rainfall during rice sowing/transplanting in kharif season has become a bottleneck for rice  
35 cultivation in some rice growing states of India. According to Indian Meteorological Department,  
36 deficit rainfall till 17<sup>th</sup> August 2022 in some rice growing states of India were: West Bengal,

Comment [u1]: enter the research objective

Comment [S2]: check again what year

Comment [u3]: Include research objectives should be written clearly in the introduction

37 35%; Bihar 40%, Eastern & Western UP, 47% & 40% and Jharkhand 36% [1]. This year the  
38 rainfall deficit in June and July is hovering around 45-80 per cent in different rice growing  
39 districts of West Bengal (2022). In the year 2010 and 2012, we faced deficit rainfall in WB (50  
40 & 19%, respectively) during rice growth and thus puddling was not possible for establishment of  
41 kharif rice. This type of deficit and erratic rainfall will lead to uncertainty to rice cultivation and  
42 affect the food security of the rice growers. Saving of irrigation water in direct seeded rice (DSR)  
43 has been reported by many workers e.g., [2,3,4]. This method eliminated the irrigation  
44 requirement for puddling (20 cm approximately) and saves soil structure which is usually lost  
45 due to puddling. Direct-seeding methods have several advantages over trans-planting [5]. In  
46 addition to higher economic returns, DSR crops are faster and easier to plant, less labour  
47 intensive and consume less water [4], are conducive to mechanisation [6] generally flower earlier  
48 leading to shorter crop duration [7] and mature 7–10 days earlier and have less methane  
49 emissions [8,9] than transplanted rice (TPR). In kharif season highest plausible rice grain yield  
50 was possible at saturation or at no standing water from dwarf HYV (cv, IR-36) at Bhubaneswar  
51 Odisha, [10]. To overcome this problems of deficit rainfall during crop establishment stage  
52 attempts were made to grow rice by direct seeding method (DRS)/dry transplant rice (25-30 days  
53 old seedlings) following jute harvest at field capacity on unpuddled pulverized soil and on  
54 saturated soil under minimal tillage condition at ICAR-CRIJAF, West Bengal, India. Rice-  
55 vegetable intercropping was also tested to increase nutritional security, net return and make  
56 efficient use of rain water. *In situ* water conservation methods were developed and tested in  
57 farmer's field for life saving water under deficit rainfall. To bring sustainability alternate crops  
58 of rice were also tested under such situation. This system will minimize the risk of rice crop  
59 failure and produce rice at low rainfall years with higher water productivity and sustainability  
60 can be ascertained growing inter/alternate crops.

## 61 **Materials and Methods:**

62 Field experiments were conducted in West Bengal ,CRIJAF in 2009,2010 and 2012 on upland in  
63 sandy clay loam and sandy loam soils and its N, P & K content were 347 kg/ha, 32.25 kg/ha and  
64 189 kg/ha, respectively. The experimental soil had 44 per cent sand, 28 per cent silt and 28 per  
65 cent. For direct seeded rice (DSR), shallow furrows were drawn by cultivator (Photo 1.) and  
66 seeds were shown on shallow furrows and covered by wooden planks behind tractor. For dry  
67 transplanting of rice, after jute harvest, soil was pulverized by rotavator and shallow furrows  
68 were drawn by cultivator (Photo1). Basal NPK were applied before rice transplanting. In 2009  
69 rice Cv. Ananda was transplanted on shallow furrows developed by cultivators at field capacity  
70 on pulverized soil (30 days old seedling) on 21-7-09 which established with a rainfall of 73.6  
71 mm from 21-7-09- to 30-7-2009. Six to seven seedlings were placed on furrows and the basal  
72 region was covered with soil for firm anchorage. In 2010, the soil was pulverized rotavator and  
73 25-35 days old rice seedlings (Cv. Satabdi, Annda, kshitish) were transplanted randomly or in  
74 rows developed by cultivator, manually. In this year, the rice crop received 63 mm rain within 7  
75 days (11 to 18-8-2010) following transplanting and got established. In 2012, 40 days old rice

Comment [u4]: preferably a map image of the research location is included

Comment [u5]: it's best to use new data five years from now

76 seedling was transplanted in field capacity soil with N:P:K::40::40:40 as basal and 60 Kg N as  
77 top dressing in two splits. This year (2012) the rice crop received 55.5 mm rain within 7 days  
78 following its transplanting in field capacity (FC) soil and got established. The rice crop was  
79 grown under rain fed condition at field capacity throughout the crop growing period.

80 In another system (2012), rice cv. Satabdi received only 77 cm rain within 7 days of its  
81 transplanting in sticky soil on shallow furrows developed in between harvested jute rows  
82 developed by wheel hoes (minimal tillage, Photo 2a). Dry transplanting of rice were also done  
83 after jute harvest by dibbling/transplanting rice seedlings (5-6 seedling/hole) on shallow holes (5-  
84 6 cm) made by strong jute pegs (Photo 2b). For comparison, direct seeded rice (DSR) were also  
85 grown following jute harvest (2009 & 2010) and good yield (4.2 t/ha) was obtained from Coarse  
86 rice (Cv. Annada). DSR were also tested in pilot scale in larger plots at ICAR-CRIJAF on 2017,  
87 2019 and 2021 successfully under rain fed condition and rice yield varied from 3.5 to 4.5 t/ha.  
88 Here in also same agronomic management practices were made. In these years, rice crops were  
89 primarily grown under rain fed condition and one irrigation was given to it during panicle  
90 initiation (PI) stage using ground water. Following rice transplanting, butachlor 50 EC was  
91 applied @ 1 kg ai/ha at 3-4 DAT for grass weed control and the rest of the weeds were removed  
92 either manually or by applying 2,4 D @ 0.8 kg/ha at 25 DAT (days after transplanting).  
93 Pretilachlor 50 EC @ 0.9 lit. a.i/ha was applied 2-3 days after transplanting (DAT) for composite  
94 weed control. Immediately after rice seedling establishment (6-21 DAS/DAT), the soil in  
95 between rows were loosened by CRIJAF nail weeder at FC for weed control, improved  
96 hydrothermal regime and better soil aeration. Required plant protection measures were taken up  
97 to save rice crop from pest and disease attack. The monthly rainfall distribution from sowing to  
98 harvest of rice is shown in Table 2

99 Rice-vegetable intercropping was also tested using gunny bag based soil columns, to increase  
100 nutritional security, net return and make efficient use of rain water and tested with success in  
101 farmer's field West Bengal (in different districts), Assam and Odisha. For this purpose, used old  
102 gunny bags of standard size (90 cm height and 45 cm diameter) were cut into two equal pieces  
103 (45 cm height). These cut gunny bags were soaked in carbendazim (Bavistin 2g/l) and copper-  
104 oxychloride (Blitox 4.5g/l) solution for an hour, to avoid fungal or bacterial growth. The  
105 columns are made using field soil and organic matter in alternate layers with a straw cushion at  
106 the base within the soil. It can be made using an iron die or fixing gunny bags using bamboo  
107 pegs. Fertiliser dose and pesticide managements are as per standard norms. Soil columns have to  
108 be made in the skipped rows of rice field ( one row skipped after each 8<sup>th</sup> row) recommended for  
109 control of brown plant hopper, Within rows, the inter column distances have to be kept from 50  
110 cm to 200 cm for different crops. *In situ* water conservation methods in micro ponds (12m x10m  
111 x1.5m) were developed sacrificing 9 per cent area of 1333 m<sup>2</sup> land and tested in farmer's field  
112 for life saving irrigation of rice to mitigate deficit rainfall. To bring sustainability alternate crops  
113 of rice e.g. green gram (cv. Pant Mung 5, RMG 62), arhar (UPAS 120) and sweet corn were  
114 tested on ridges under such deficit rainfall condition. This system will minimize the risk of rice

Comment [S6]: complete the data according to the year written

115 crop failure and produce rice at low rainfall years with higher water productivity and  
116 sustainability can be ascertained growing inter/alternate crops.

Comment [S7]: complete and include the source of the theory

117



118

119

120

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



121

122

123

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



124

125

126

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

127

128

129

130

### 131 **Results and Discussions:**

132 The direct seeded rice or dry tans planted rice seedlings could be established with a rainfall of 55  
133 to 74 mm within seven days of its sowing/transplanting. The rice crop grown and matured well  
134 with available rainfall (Table 1, Photo 3) supplemented with one irrigation at panicle initiation  
135 (PI) stage. A rainfall 45-52 cm and 7.5 cm irrigation at PI could produce 29 q- 45 q/ha medium  
136 rice (cv. Satabdi, Table 1) and 42.5 q/ha coarse rice (cv, Annada). The water productivity of rice  
137 ranged from 1250 to 1810 lit/kg of raw rice in different years. Dry seeding of rice (cv. Annada)  
138 @ 100 kg/ha on 8-8-2010, sown on shallow furrows developed by cultivator (DSR; direct seeded  
139 rice) and covered by planks behind it with a fertiliser dose of N:P:K::100:40:40 produced 42.8 q  
140 coarse rice in 100 days. It received 45 cm rain after sowing and one irrigation (75 mm) was  
141 provided at panicle initiation (PI) stage (Table 1). However, one light irrigation (50 mm)  
142 following dry sowing or dry transplanting will minimize the risk of crop establishment during  
143 prolonged drought. For this irrigation water has to be supplied either from surface or ground  
144 water. Soil mulching by CRIJAF nail weeder at 6-21 days after rice transplanting/sowing is  
145 necessary to retain more moisture in rice field under deficit rainfall, improve aeration, maintain  
146 better hydro thermal regime of soil [11,12], apart from its composite weed management.

147 This method has reduced the water requirement of rice to 52.5-70.0 cm only with respect to 120-  
148 150 cm under irrigated/waterlogged rice culture [2]. This method has merit over aerobic rice  
149 culture on puddle soil in the sense that, it eliminates the time required for seedling development  
150 (30-35 days) which increases the cropping intensity, reduces the risk of seedling death due to  
151 waterlogging in the direct seeded rice on puddled soil. We got 3-4.0 tonnes of scented rice (cv.  
152 Tulaipanji) and non scented rice cv. Kshitish,) from direct seeded rice (DSR) on puddled soil at  
153 ICAR-CRIJAF, Barrackpore in 2010. Success of DSR has been reported by many scientists  
154 which minimizes cost of production saves labour and minimizes methane emission [9, 13]. If  
155 grown under minimum tillage situation, it will eliminate costly massive fossil fuel requirement  
156 necessary for puddling by power tillers and tractors. Dry transplanting of rice avoided puddling,  
157 saved 85-90 percent irrigation water requirement over conventional rice cultivation under

158 irrigated situation (20 nos. up to maturity) in sandy loam alluvial soil in Kharif season. Similar  
159 results have been reported by [14]. Thus even if we get 448-525 mm rainfall and 7.5 cm  
160 irrigation at PI stage from August to October we will be able to produce 42-45 q rice/ha under  
161 FC condition. Dry-seeding on flat land or raised beds with successive saturated soil conditions  
162 reduces the amount of water needed for land preparation and thus overall water demand [15].

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

165 
$$Z \text{ (Pooled)} = 0.995 - 0.775 X, R^2 = 0.96^{**} \text{ ----- (1)}$$

166 Where Z is the dimensionless relative grain yield,  $Y/Y_{\max}$ ; Y is the yield of paddy in kg/ha  
167 corresponding to depth of ponding height in cm,  $Y_{\max}$  is the maximum yield of paddy in kg/ha, X  
168 is the dimensionless ponding ratio  $d/h_{\text{mat}}$ , d is corresponding height of ponding (cm) and  $h_{\text{mat}}$  is  
169 the average plant height at maturity. The average water requirement was 4.5 mm/day [16]. The  
170 net income from rice cultivation will be increased as the irrigation requirement is limited. Added  
171 advantage of rice cultivation by DSR/dry transplanting under field capacity is that the methane  
172 emission from these types of rice fields (not waterlogged), is expected to be very low [ [8,9,13].  
173 Direct seeding has the potential to decrease  $\text{CH}_4$  emissions [17]. From PAU, Ludhiana, [18],  
174 reported that irrigating the field at 0.15 bar matric potential reduced seasonal methane flux by  
175 60% (0.99 and 0.41  $\text{mg m}^{-2} \text{ hr}^{-1}$ , respectively in 2005 and 2006) as compared to completely  
176 flooded conditions, without any decline in grain yield (60 q  $\text{ha}^{-1}$ ). [19] proposed that  $\text{CH}_4$   
177 emissions may be suppressed by up to 50% if DSR fields are drained mid-season.

178

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

180 For life saving irrigations using surface water, an *insitu* micro pond (120  $\text{m}^2$  only with a  
181 depth of 1.5 m) has to be dug out in  $1/3^{\text{rd}}$  of an acre (1333  $\text{m}^2$ ) sacrificing 9 percent of its area at  
182 the lowest corner of the field to harvest rain water. It can collect runoff water up to 1,80,000  
183 litres of water or even more if the dugout soil is used for making embankment over it (Photo 4,  
184 [20,21]. At ICAR-CRIJAF, Kolkata, in last week of June (2010), it was observed that runoff  
185 collection from one 30 mm rain from  $1/3^{\text{rd}}$  an acre was 60000 litres of water in such dug out  
186 *insitu* ponds. Thus collection of 1,80,000 litres of runoff water in such *insitu* micro ponds are  
187 very easy. In porous soil, lining can be done with tarpaulin/silpaulin sheets (250 GSM, Photo 4)  
188 to prevent seepage and deep percolation losses. *Insitu* micro ponds were dug at ICAR-CRIJAF  
189 (2010), Barrackpore, 24 PGS (N) and at Bikpur, Bankura, West Bengal in 14 farmers' fields for  
190 pilot scale studies from 2019-2022 (Photo 4). Farmers' of Bankura, Bikpur could harvest 3-3.5  
191 tonnes rice/ha using this water. They could save their rice seedlings and rice crop from erratic  
192 and deficit rainfall using the harvested rain water in their own micro ponds [20]. The harvested  
193 rain water was used by the farmers for duck rearing, pisciculture and was even used for growing  
194 mustard after rice in 2022. Vegetables were grown on embankment for household purposes.

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



198  
199 Photo 4. *In situ* rain water harvesting for life saving irrigation of rice in Kharif season at  
200 Bikpur, Bankura, WB in coarse soil and at ICAR-CRIJAF in sandy loam soil.

201 As the Gangetic soils does not have any hard pan or impervious layer underneath the surface  
202 soil, it is expected that majority of water is recharged to its unconfined aquifer with little loss  
203 through lateral rice seepage and evaporation, provided the rice fields are bunded all round to  
204 check run off. Thus if a network of micro ponds in rice paddies are developed gradually, an  
205 enormous amount of water could be recharged to the aquifer enriching groundwater level over  
206 time apart from meeting fresh water requirement for assured rice harvest and quality jute retting  
207 in jute growing belts of the country. Taking 40% as run off of total rainfall in a year (1200-2500  
208 mm at South and North Bengal, WB), annually around 48 to 100 lakh litres water/ha from these  
209 micro ponds (which acts as percolation tanks) can be recharged to the unconfined aquifer  
210 through these dugout ponds alone apart from its additional recharges from rest of the area (1213  
211 m<sup>2</sup>) where rice is grown in sequence till the retreat of monsoon season [20]. So as high as 3.58 to  
212 7.47 crore litres of water can be recharged/ha annually (in 90 days: July to September) to the  
213 unconfined aquifer in pours alluvial or sandy loam soil, if one micro pond is constructed in each  
214 bigha (0.1334 ha) rice field. If a huge net work of micro pond system is developed across  
215 permeable soils, it will strengthen ground water position, supply fresh water requirement for  
216 assured rice harvest, quality jute retting and save mankind against drought under changing  
217 climatic scenario.

Comment [S8]: complete and include the source of the theory

218  
219 **Inter/relay cropping in rice for better nutritional security:** In Kharif season on upland (DSR)  
220 and medium lands, inter/relay cropping can be done in rice field using jute reinforced soil  
221 columns [22,23] to grow variety of early high value vegetables (cauliflower, cabbage, radish,  
222 summer palak, coriander, brinjal, chilli, tomato, maize/sweet corn, arhar and other cucurbits,  
223 Photo 5) under deficit rainfall. It will produce 3.5 to 4.5 tonnes of rice along with 15- 200 q of  
224 different vegetables/ha, increase nutritional security of resource poor farmers, net return and

225 effective utilization of rainwater. Yield of arhar in this system was 18.8 q/ha [23]. This system  
226 acts as insurance against crop failure under unprecedented drought during panicle initiation to  
227 grain filling of rice. This system has been tested with success by Department of Agriculture  
228 Govt. of WB from 2013-2022 in different districts. AINP Jaf (ICAR-CRIJAF) has also tested  
229 this technology with success in different districts of WB, Assam and Odisha.

230



231

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

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

235 Under deficit rainfall of 19-50% situation, alternate crops like green gram cv, Pant mung  
236 5 and RMG 62 produced 21 and 23 q pulse grains/ha and arhar (cv UPAS -120) produced 30 q  
237 grains/ha, when sown on ridges (15-25 cm high and base 25-35 cm) developed by cultivator or  
238 spades to avoid waterlogging stress (Photo 6) in late kharif months [24]. Sweet corn, and  
239 sorghum should be grown on ridges made by ridge makers or BBF makers. The yield potential of  
240 sweet corn was 120000 cobs/ha at ICAR-CRIJAF, Barrackpore, WB.

**Comment [S9]:** check again the results are not in the table



241

242

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.

243

244

245 **Conclusions:**

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

Comment [S10]: better include the year

Comment [S11]: better include the year

263

264 **References:**

- 265 [1] . Shambhabi Anand (2022). Kharif output may take big hits: Experts. The Economic Times.  
266 [https://m.economictimes.com/news/economy/agriculture/kharif-output-may-take-big-hit-](https://m.economictimes.com/news/economy/agriculture/kharif-output-may-take-big-hit-experts/articleshow/93623915.cms)  
267 [experts/articleshow/93623915.cms](https://m.economictimes.com/news/economy/agriculture/kharif-output-may-take-big-hit-experts/articleshow/93623915.cms)  
268
- 269 [2]. Ghorai A.K., Hembram, P., Chowdhury M.Kumar H., and D.K. Kundu (2012). Dry  
270 transplanting of rice in kharif season in jute-rice-pulse sequence under deficit rainfall. Jafnews.  
271 10(1)14-15  
272
- 273 [3]. Farooq, M., Kadambot H.M. Siddique, H. Rehman , T. Aziz , Dong-Jin Lee , A. Wahid  
274 (2011). Rice direct seeding: Experiences, challenges and opportunities. *Soil & Tillage Research*  
275 111: 87–98  
276
- 277 [4]. Bhushan, L., Ladha, J.K., Gupta, R.K., Singh, S., Tirol-Padre, A., Saharawat, Y.S., Gathala,  
278 M., Pathak, H., (2007). Saving of water and labor in a rice–wheat system with no-tillage and  
279 direct seeding technologies. *Agron. J.* 99, 1288–1296.  
280

- 281 [5]. Singh, Y., Singh, G., Johnson, D., Mortimer, M. (2005a). Changing from transplanted rice to  
282 direct seeding in the rice–wheat cropping system in India. In: Rice is Life: Scientific  
283 Perspectives for the 21st Century, Tsukuba, Japan: Proceedings of the World Rice Research  
284 Conference, 4–7 November 2004, pp. 198–201.  
285
- 286 [6]. Khade, V.N., Patil, B.D., Khanvilkar, S.A., Chavan, L.S. (1993). Effect of seeding rates  
287 and level of N on yield of direct-seeded (Rahu) summer rice in Konkan. J.Maharash. Agric.  
288 Univ. **18**: 32–35.  
289
- 290 [7]. Santhi, P., Ponnuswamy, K., Cheety, N.K., 1998. Effect of seeding methods and  
291 efficient nitrogen management practices on the growth of lowland rice. J.Ecobiol. **10**: 123–132.
- 292 [8]. Balasubramanian, V., Hill, J.E. (2002). Direct seeding of rice in Asia: emerging issues and  
293 strategic research needs for the 21st century. In: Pandey, S., Mortimer, M., Wade, L., Tuong,  
294 T.P., Lopez, K., Hardy, B. (Eds.), Direct Seeding: Research Strategies and Opportunities. Inter.  
295 Rice Res. Inst., Los Banos, Philippines, pp. 15–42.
- 296 [9]. Pandey, S., Velasco, L.E.(1999). Economics of alternative rice establishment methods  
297 in Asia: a strategic analysis. In: Social Sciences Division Discussion Paper, International Rice  
298 Research Institute, Los Bano's, Philippines.  
299
- 300 [10]. Ghorai, A.K and S.R. Singh (1999). Permissible continuous ponding depths in dwarf HWY  
301 rice fields. *J. Argil. Water Management*.**7**(1&2) :1-7.
- 302 [11]. Ghorai, A.K., Kundu, D.K and D. Barman (2016-17). Irrigation methods and soil water  
303 conservation practices for improving water productivity in jute. ICAR-CRIJAF Ann. Rep, (TMJ  
304 MM 56.0), 2016-17.pp 27-28  
305
- 306 [12]. Chakraborty, A.K, Dutta, D, Ghorai, A.K, Majumdar, S.P.,N.M. Alam and R.K. De  
307 (2021). CRIJAF Nail Weeder and straw mulch improves soil hydrothermal regimes and aeration  
308 under drought condition in jute fields for the Indo-Gangetic alluvial soil of West Bengal.  
309 Proceed. XV AGRICULTURAL SCIENCE CONGRESS & ASC EXPO. Abstract ID.  
310 XVASCBHU/Abst/144
- 311 [13]. IRRI (2018).What is DSR? Direct Seeded rice consortium ([https://dsrc.irri.org/our-](https://dsrc.irri.org/our-work/what-is-dsr)  
312 [work/what-is-dsr](https://dsrc.irri.org/our-work/what-is-dsr))
- 313 [14]. Jehangir, W.A., Masih, I., Ahmed, S., Gill, M.A., Ahmad, M., Mann, R.A., Chaudhary,  
314 M.R., Turrall, H. (2005). Sustaining crop water productivity in rice–wheat systems of South Asia:  
315 a case study from Punjab Pakistan. In: Draft Working Paper, Inter.Water Managmt. Institute,  
316 Lahore, Pakistan.  
317
- 318 [15]. Bouman, B.A.M., Tuong, T.P. (2001). Field water management to save water and increase  
319 its productivity in irrigated lowland rice. Agric. Water Manage. **49**: 11–30.  
320

- 321 [16]. Ghorai, A.K and Sita Ram Singh (1994). Surface drainage requirement of dwarf HYV rice  
322 (cv. IR-36) during wet season. WTCER, BBSR, Tech. Bulltin No.3. P-34
- 323 [17]. Ko, J.Y., Kang, H.W. (2000). The effects of cultural practices on methane emission from  
324 rice fields. Nut. Cycl. Agroecosys. **58**: 311–314.
- 325 [18]. Khosa M.K, B S Sidhu, D K Benbi (2011). Methane emission from rice fields in  
326 relation to management of irrigation water . J Environ Biol. **32**(2):169-72.
- 327 [19]. Wassmann, R., Neue, H.U., Ladha, J.K., Aulakh, M.S. (2004). Mitigating greenhouse gas  
328 emissions from rice–wheat cropping systems in Asia. Environ. Sustain. Dev. **6**, 65–90.
- 329  
330 [20]. Ghorai, A .K (2019). Ground water recharge and life saving irrigation potential of dugout  
331 ponds for *insitu* jute retting in rice paddies.  
332 <https://www.researchgate.net/publication/335757494> DOI: 10.13140/RG.2.2.16733.15848
- 333 [21] Ghorai, A.K and Asim Kumar Chakraborty.(2020). Sustainable In-situ Jute Retting  
334 Technology in Low Volume Water using Native Microbial Culture to Improve Fibre Quality and  
335 Retting Waste Management. Int.J.Curr.Microbiol.App.Sci. **9** (11): 1080-1099. doi:  
336 <https://doi.org/10.20546/ijcmas.2020.911.126>
- 337 [22]. Ghorai A. K., D. K. Kundu, Shailesh Kumar, A. Shamna and Debarati Datta (2020). Gunny  
338 bag based soil columns for crop diversification in rice field to enhance livelihood security of land  
339 scarce farmers. Current Science, **119** (7):1190-1195.
- 340  
341 [23] Ghorai, Ankit Kumar and Aresh kumar Ghorai (2022). Inter/relay cropping vegetables with  
342 anaerobic rice: A technology to boost small and marginal farmers’ income and improve their nutritional  
343 security. SATSA Mukhapatra Ann. Tech. Issue. **26**: 228-233
- 344  
345 [24]. Ghorai, A.K.; Saha, S.; Saren, B.K; P.K. Hembram; B.K. Mandal; J.G. Thokle; S.R. More,  
346 T.Srilata, G.Jagannadham, M.K. Tripathi Shailesh Kumar, D.K. Kundu and B.S.  
347 Mahapatra (2013). Drought Management of jute and mesta crop under deficit rainfall.  
348 Technical bulletin No.5/2013. PP 67
- 349  
350

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

Method of sowing	Rice Cultivars	Fertiliser 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)

<b>A. Dry seeding on lines with seed rate 100kg/ha</b>									
<b>Sowing date</b> 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>B. Dry rice transplanting in field capacity soil with 30 days old seedlings</b>									
<b>Transplanting dates</b> 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	--
<b>SD ±</b>	---	---	--	--	--	6.170	--	286.2	--

352

353

354

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

357

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	50%	19%	11	13
July	204.6	414.4	300			13	23
August	240.3	259.2	300			15	19
September	148.5	148.8	300			12	17
October	059.2	152	100			3	09

358

UNDER PEER REVIEW

