 IRC/TM-2/PP-28

ALTERNATE WETTING AND DRYING (AWD) A PROMISING WATER SAVING TECHNOLOGY IN RICE PRODUCTION SYSTEM FOR FARMERS OF TELANGANA, INDIA

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Millions of peoples depend on rice to maintain their livelihoods and for this reason rice is called life. Water is becoming scare for agriculture purposes at present situation.Area under rice is expected to be reduced to about 40 m.ha in the next 15-20 year and most of this reduction are attributed to water shortage and rapid urbanization. Recent estimates indicate that there would be acute water shortage in the coming decades. here is a need to develop an alternative system of rice cultivation to save the water and other inputs.Alternate Wetting and Drying (AWD) is a water-saving technology that farmers can apply to reduce their irrigation water consumption in rice fields without decreasing its yield. It is an irrigation practice of introduction of unsaturated soil conditions during the growing period that can reduce water inputs in rice without compromising yields. Tuong (2007) recorded the successful usage of field water tube in AWD management regime to monitor the water depth and capable to indicate the right time of irrigation and saved water, without any yield penalty and using of field water tube in AWD was safe to limit the water use to 25 per cent was reported by Suresh Kulkarni, 2011. The present front line demonstrations were conducted in the farmers fields at Rangareddy, Vikarabad and Medchal district of Telangana State of India with an objective to create awareness of benefits of Alternate wetting and drying (AWD) practicein rice cultivation, A climate-smart practice that presents both mitigation and adaptation benefits is critical to addressing climate change in rice production.

METHODOLOGY:

The demonstrations in farmers field were conducted in irrigated lowlands and followed alternate wetting and drying (AWD) practices by using field water tube during *kharif* 2017 and 2018. There were two treatments T1: Farmers practice(Continues ponding of water at 5 cm depth) and T2: AWD(irrigation water was applied when water level has dropped to about 5 cm below the surface of the soil).A practical way to implement AWD safely is by using a 'field water tube' ('pani pipe') to monitor the water depth on the field. After irrigation, the water depth will gradually decrease. When the water level has dropped to about 5 cm below the surface of the soil, irrigation was applied to re-flood the field to a depth of about 5 cm. From one week after transplanting to week before flowering and during flowering the field was kept flooded, topping up to a depth of 5 cm as needed. After flowering, during grain filling and ripening, the water level was allowed to drop again to 5 cm below the soil surface before re-irrigation.

A field tube in flooded field: The field water tube was made of 30 cm long plastic pipe, having a diameter of 10"15 cm so that the water table is easily visible, and it is easy to remove soil inside. Perforate the tube with many holes at 2 cm distance on all sides, so that water can flow readily in and out of the tube. The tube was hammered into the soil so that 15 cm protrudes above the soil surface. The soil from inside the tube was removed so that the bottom of the tube is visible. AWD was started a few weeks (1"2 weeks) after transplanting. When many weeds are present,

Fig. Front line demonstration of Alternate Wetting and Drying (AWD) in rice at farmers field at Rangareddy district, Telangana, India. (1. Inserting Field water Tube, 2. Measuring water level in the tube, 3. Field day celebration, 4. Crop at grain filling)

AWD was postponed for 2"3 weeks to assist suppression of the weeds by the ponded water and improve the efficacy of herbicide. fertilizer recommendations as for flooded rice was followed. N was applied on the dry soil just before irrigation.All the package of practices was followed as per PJTSAU recommendations.

RESULTS AND DISCUSSIONS:

Based on the frontline demonstrations conducted during *kharif* 2018 AND 2019 it was observed that the on an average this improved technology recorded 4.5 % higher grain yield (6031kg/ ha) as compared to farmers local practices (5772 kg/ ha). Higher Gross returns (Rs. 10,2819/-) net returns (Rs. 55552/-)and B:C ratio (2.2) was recorded with AWD practice with a saving of Rs.1900/- per ha. Over farmers practice, (GR-98,585/-, NR - 49437/- and B:C 2.0) Reasons for good performance in the AWD over farmers practice can be attributed, toAWD improves yield by increasing the proportion of productive tillers, reducing theangle of the top most leaves (thus allowing more light to penetrate the canopy), modifying shoot and root activity i.e. altered root-to-shoot signaling of phytohormones viz., Abscisic Acid and cytokinins (Yang and Zhang, 2009) and also remobilization of carbohydrates from stems to the grain could represent another important mechanism of improving grain filling under AWD treatments (Yang and Zhang, 2010). Grain and straw yield were significantly influenced by different irrigation schedules on red sandy loam soils was recorded by Avil Kumar *et al.* (2006)

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IRC/TM-2/PP-29

AGRO-TECHNIQUES TO MAXIMIZE THE YIELD OF RICE – GREENGRAM CROPPING SYSTEM

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Rice Production in India an important part of the national economy. Application of higher levels of nitrogen to lowland rice may lead to huge amount of notified losses, if adequate plant stand is not maintained in the field. Logically, higher plant density of rice would utilize higher levels of nitrogen, more efficiently than sparse plant density. The competition in a community of rice crop is greatly influenced by the population density and hence, there is a need to study the plant geometry of rice crop, which is recognized as one of the important agrotechniques for increasing yield per unit area. Maintenance of optimum plant density commensurate to the level of nitrogen supply is essential for the maximum exploitation of inherent yield potential of rice.Rice – greengram is one of the most popular cropping system of southern agroclimatic zone of Andhra Pradesh, wherein the farmers do not fertilize nor irrigate the greengram crop and they just sow and harvest to take whatever the yield that is produced, in spite of the possibility of reaping two to three times more yield what they are bagging traditionally, if they happen to glance at the nutrient recommendation to greengram, despite the belief of residual effect of preceding crop. Though the carry over effect of large quantities of major nutrients applied to lowland rice is known to exert favourable influence on the succeeding un-fertilized pulse crops, to produce reasonable yields, yet the maximum yield realization would be possible by supplying recommended level of nutrients to pulse crops by considering residual effect only as supplementary, especially under irrigated conditions. Further, use of biofertilizers like Rhizobium and phosphobacterium in addition to recommended level of N and P has been known to escalate the productivity of short duration pulse crops, by increasing the nutrient use efficiency. Though the extent of fruitfulness of bio-fertilizers is debatable, their usage in intensive farming is neither costly nor harmful. Hence the present study was taken up with an objective of to develop a variable package of agro-techniques for rice-greegram cropping system, based on productivity, economics and sustenance of soil fertility.

METHODOLOGY

Field experiments were conducted during two consecutive years on a sandy clay loam soils of wet land block of S.V. Agricultural College Farm (ANGRAU), Tirupati (Southern Agro climatic zone of Andhra Pradesh), to study the possibility of yield maximization in rice based cropping system. In these investigations, rice was grown during *rabi*season and greengram during summer. The experiment was laid out in a split plot design replicated thrice. During rabi, the treatments consisted of three plant densities of rice [10 x 5 cm (P_1), 10 x 7.5 cm (P_2) and 10 x 10 cm (P_3)] assigned to main plots and seven nitrogen management practices consisting of different combinations of nitrogen supplied through fertilizer (FN) and neem leaf (GMN) [100% FN + 25% GMN (N_1), 100% FN + 50% GMN (N_2), 100% FN + 75 GMN (N_3), 100% FN + 100 GMN (N_4), 25% FN + 100% GMN (F_5), 50% FN + 100% GMN (N_6), 75% FN + 100% GMN (N_7)] assigned to sub plots, greengram crop was raised during summer season after the harvest of rabi rice in the same undisturbed layout. Three fertilizer management practices, control (No N, No P) (F_1), 100% recommended dose of N and P

(F_2) and 100% recommended dose of N and P + biofertilizers (F_3) were imposed on summer greengram as main plots. Nitrogen management practices to *rabi* rice assigned to sub plots were considered as sub plots for greengram (R_1 to R_7), to study the residual effect.

RESULTS AND DISCUSSION

The results indicated that the plant height and total tillers per unit area were found to be the highest with the plant density of 20 lakhs ha^{-1}, whereas the leaf area index and dry matter production were the highest with the plant density of 10 lakhs ha^{-1}. Among the nitrogen management practices, N_4 resulted in taller plants, larger leaf area, more number of total tillers per unit area and higher dry matter accumulation than rest of the treatments. The next best treatments were N_3 and N_7. As regards the interaction effect, N_4 in combination with plant density of 20 lakhs ha^{-1} resulted in the tallest plants and highest number of tillers per unit area, whereas N_4 in combination with plant density of 10 lakhs ha^{-1} resulted in the largest LAI and highest dry matter accumulation.Yield attributes *viz.*, panicles m^{-2}, panicle length, number of total and filled grains $panicle^{-1}$, were highest with the plant density of 10 lakhs ha^{-1}. The highest stature of all the yield parameters was associated with N_4.While nitrogen management practices and their interaction with plant density exerted noticeable influence, during both the years of study.

Grain and straw yield of rice was the highest with the plant density of 10 lakhs ha^{-1}, whereas among the nitrogen management practices, N_4 resulted in the highest grain and straw yield of paddy.The residual effect of R_4, R_7, R_6 and R_5 with 100% recommended dose of N and P either with or without biofertilizers recorded better quality parameters of greengram seed than with non-supply of N and P in combination with R_3, R_2 and R_1, during both the years of study

CONCLUSION

The study has revealed that adoption of the package of agro-techniques consisting of, maintaining the plant density of 10 lakhs ha^{-1} of rice with the planting pattern of 10 x 10 cm along with the application of 100% each of the recommended N to rice through fertilizer (120 Kg ha^{-1}) and neem leaf (24 t ha^{-1}) and application of 100% recommended N and P (20 kg N and 50 kg $P_2O_5 ha^{-1}$) to greengram resulted in maximizing the productivity and economic returns from the rice (*rabi*) – greengram (summer) cropping system, without any impairment on the soil health and thereby addressing the sustainability concept

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 IRC/TM-2/PP-30

RESPONSE OF CROPPING SYSTEM UNDER DIFFERENT VARIETIES OF RICE AND GROUNDNUT IN ORGANIC FARMING AND SOIL FERTILITY IN KONKAN REGION

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Research carried out under AICRP-IFS project indicates that there is a scope for diversification and intensification in the existing cropping systems after *Kharif* rice with sweet corn, fodder maize, groundnut, mustard, *Dolichos* bean, brinjal and other vegetables under controlled irrigated conditions. Crop diversification shows lot of promises in alleviating these problems besides, fulfilling basic needs for cereals, pulses, oilseeds and vegetables and regulating farm income, withstanding weather aberrations, controlling price fluctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, ensuring environmental safety and creating employment opportunity (Gill and Ahlawat, 2006).Non use of organic manures and use of heavy doses of pesticides are creating ill effects on soil health, sustainability of crop productivity, increasing pesticidal residue problems on soil and crop produce and in turn health of all living beings. Moreover, there is increasing awareness amongst consumers and farmers about importance of residue free hygienic organic farm produce. Thus, demand for organically produced food grains, vegetables and fruits have been increasing both in domestic and export markets. Moreover, vicinity of metros like *Mumbai*, *New Mumbai*, *Thane*, *Panvel* and other industrial estates and urban areas spread throughout the region promises assured market. In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the suitability of a cropping system (Yadav, 2002).

METHODOLOGY

Field experiments was conducted to evaluate the response of different varieties of rice and groundnut for organic farmingduring 2017-2018 under Network Project on Organic Farming, Model Agronomic Experiment Farm, KarjatDist. Raigad.The initial soil fertility levelwere (pH 6.90, EC 0.290 dSm^{-1}, Organic Carbon1.16%, available N, P and K was 194, 6.55 and 288 kg ha^{-1}).Total 15 rice varieties were grown during *Kharif* season and 15 varieties of groundnut were grown during *Rabi*-hot weather season after harvest of *Kharif* rice varieties. The experiment was conducted in a Randomized block design with three replications.

RESULTS

Results revealed that the rice hybrid *Sahyadri*-5 produced maximum and significantly higher grain yield (67.66 q ha^{-1}), straw yield (75.35 q ha^{-1}), grain Rice Equivalent Yield (REY)(83.01 q ha^{-1}), straw REY (11.63 q ha^{-1}) and total REY (94.64 q ha^{-1}) as compared to rest of the varieties except hybrids *Sahyadri*-3 and *Sahyadri*-4. During *Rabi*-hot weather season, groundnut variety*TG 26* remained at par with *Konkan Gaurav*and recorded significantly higher dry pod yield (32.47 q ha^{-1}), haulm yield (41.90 q ha^{-1}), REY of dry pods (200.41 q ha^{-1}), haulm REY (6.47 q ha^{-1}) and total REY (206.87 q ha^{-1}) as compared to rest of the groundnut varieties except *Phule*-6021,*TAG*-24, *JL*-776 and *TG*-37*A*in respect of haulm yield and haulm REY. Rice variety *Karjat 3* grown during *Kharif* and groundnut variety *TG 26* grown after harvest of *Karjat 3* recorded maximum and significantly higher total system REY (286.66 q ha^{-1}), net returns (Rs. 3,01,655/- ha^{-1}) and B: C ratio (2.85)except '*Karjat 5 – TAG 24*' and '*Jaya-Konkan Gaurav*'. Organic carbon, available N,P and K were notably increased under all the rice-groundnut varietal sequences as compared to their initial levels.Significantly the highest organic carbon content (1.31) was observed due to *Jaya-Konkan Gaurav* varietal sequence over rest of the sequences except *Karjat 4 – phule 6021,Sahyadri*3 - *PhulePragati, Ratnagiri 2- JL 220, Ratnagiri*3 - *JL* 776 ,*Sahyadri* 5 - *TG 37A, Karjat3 - TG 26* and *Karjat*2 - *RHRG* 6083.*Jaya - Konkan Gaurav* varietal sequence recorded maximum and significantly higher available N (287.58 kg ha^{-1}), P (10.03 kg ha^{-1}) and K (349.07 kg ha^{-1}) status of soil over rest of the varietal sequences except *Ratnagiri*3 `- *JL* 776,*Sahyadri* 5 - *TG 37A,Karjat*3-*TG 26* and *Karjat*2 - *RHRG* 6083. *Karjat*3-*TG 26* varietal sequence was at par with *Jaya - Konkan Gaurav* in respect of available P and K while *Ratnagiri*3 - *JL* 776 varietal sequence was also at par with *Jaya - Konkan Gaurav* in respect of available K .

CONCLUSION

Rice variety *Karjat* 3 grown during *Kharif* and groundnut variety *TG* 26 grown after harvest of Karjat 3 recorded maximum and significantly higher total REY (286.66 q ha^{-1}) of the system, net returns (Rs. 301655 ha^{-1}) and B:C ratio (2.85) of the system as compared to other sequences except '*Jaya - Konkan Gaurav*' and 'Karjat 3–TG 26' varietal sequence with improvement in soil properties.

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IRC/TM-2/PP-31

EFFECT OF VARIOUS CROPPING SYSTEMS AND ORGANIC, INORGANIC AND INTEGRATED PRODUCTION SYSTEM ON YIELD, ECONOMICS AND NUTRIENT STATUS OF SOIL IN KONKAN REGION OF MAHARASHTRA

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There is a scope for diversification and intensification in the existing cropping systems after *kharif* rice with chickpea, field bean, brinjal,white onion and other vegetables under controlled irrigated conditions. In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the suitability of a cropping system (Yadav, 2002).Non use of organic manures and use of heavy doses of pesticides are creating ill effects on soil health, sustainability of crop productivity, increasing pesticidal residue problems on soil and crop produce and in turn health of all living beings. Moreover, there is increasing awareness amongst consumers and farmers about importance of residue free hygienic organic farm produce. Thus, demand for organically produced food grains, vegetables and fruits has been increasing both in domestic and export markets. Moreover, vicinity of metros like *Mumbai, Thane, Panvel* and other industrial estates and urban areas spread throughout the region promises assured market.

METHODOLOGY

Field experiment was conducted during 2017-2018 under Network l Project on OrganicFarming, Model Agronomic Experimental Farm, KarjatDist. Raigad .Theinitial soil fertility level were (pH 7.02, EC 0.284 dSm^{-1} Organic Carbon 1.14%, available N, P and K was 230,8.73 and 272 kg ha^{-1}).The experiment was laid out under split plot design consisting six organic Nutrient Management treatments 100 % organic package (organic manures equivalent to 100 % N requirement of the system) , 75 % organic package (organic manures equivalent to 75 % N requirement of the system) + Inovative organic practices (Cow urine 10% and vermiwash 10%),100 % inorganic package, Farmers Practice, Integrated (50 % organic package + 50 % inorganic package), Integrated (75 % organic package + 25 % inorganic package) as Main plot treatments and four cropping systems (Rice-Brinjal , Rice-Chickpea , Rice-Field beanand Rice- Onion (White)) as sub- plot treatments replicated thrice.

RESULTS

The Results revealed that the application of 100 per cent organic production system produced maximum and significantly higher total rice equivalent yield (REY) of 337.70 q ha^{-1}, higher gross returns (Rs. 5,47,076/- ha^{-1}) andnet returns (Rs. 3,44,5071/- ha^{-1}) as compared to other production systems. However, the B: C ratios were significantly higher under 100% inorganic package (2.68). The maximum and significantly higher gross returns(Rs. 8,57,389/- ha^{-1}), net returns (Rs. 5,82,698/ - ha^{-1}) and B: C ratio (3.14)were observed under Rice-Brinjal system as compared to other cropping systems studied. Rice-Brinjal system grown with 100 per cent organic package produced maximum and significantly higher REY (629.67 q ha^{-1}), net returns (Rs. 6,97,934/- ha^{-1}) and B: C ratio (3.17) of the system as compared to rest of the treatment combinations .Sharma *et al.* (2004) have also reported that intensification through inclusion of vegetables and leguminous crops increase the production and land use efficiency.The effect of different treatments on availability of soil nutrients was also studied after harvest of Rabi crops. The results showed that application of 100 % organic package recorded maximumand significantly higher organic carbon (1.52 %), available N (274.84 kg ha^{-1}), P (12.48 kg ha^{-1}) and K (319.58 kg ha^{-1}) in soil as compared to 100 % inorganic package and Farmer's Practice. Further, Rice- Field beansystem remained at par with Rice-Chickpeasystem and both the systems recorded significantly higher available N and Pand K of soil over Rice-BrinjalandWhite onionsystems.

CONCLUSION

The Results revealed that the application of 100 per cent organic production system produced maximum and significantly higher total rice equivalent yield (REY), higher gross returns and net returns as compared to other production systems. Rice-Brinjal system grown with 100 per cent organic package produced maximum and significantly higher REY, net returns and B: C ratio of the system as compared to rest of the treatment combinations. The organic carbon, available N, Pand Kcontents of soil were improved due to different production and cropping systems.

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Theme - II : Sustainable rice farming

IRC/TM-2/PP-32

ASSESSMENT THE PERFORMANCE OF SRI UNDER DIFFERENT ORGANIC, INORGANIC AND INTEGRATED NUTRIENT SUPPLY SYSTEMS

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Rice is grown in over hundred countries and is the primary food for half of the people in the world. World population is expected to 8.5 billion by 2025 and to maintain the self-sufficiency in rice an increase of 2% - 3% per year in rice production had to be maintained within limited land. Due to continuous use of chemical fertilizers in rice production, soil health related problems are emerging. Declining trend in productivity due to continuous use of chemical fertilizer alone has been observed in several long term experiments all over India.While integration of organic and inorganic sources to sustain the productivity under SRI.The efficiency of fertilizer use for nitrogen is lower than 50%, for phosphorus lower than 10% and for potassium 40%. This low efficiency of fertilizer use is also associated with other losses by immobilization, volatilization, denitrification, leaching, and clay adsorption (Ruiz *et al*., 2012). Rice cultivation is a water intensive practices. Rice alone consumed 70% of water used in agriculture, hence judicious use of water for rice production in a sustainable manner has become very important. The SRI is an alternative to existing cultivation practices to overcome the shortage of water and achieve higher yield at low cost of cultivation. Therefore, use of system of rice intensification with integrated nutrient management to maintain soil health as well as soil fertility and productivity is a need of the time.

OBJECTIVE

To assessment of SRI system under organic, inorganic and integrated nutrient management for higher production and productivity of rice.

To find out water and nutrient use efficiency in different systems of rice.

METHODLOGY

Field experiment was conducted during the Kharifseasons of 2005 to 2008 at MRRS, Nawagam. The farm is located in hot semi-arid eco-region with medium deep black soils and geographically situated at (22.480 latitude, 71.380 longitude and 32.4 m above the mean sea-level). A composite representative soil sample was collected from the experimentation and analysed for physico-chemical properties. The experimental site soil was slightly clay loam and alkalinepH value 7.4, EC 1.22 (ms). It consist 0.38 % organic carbon, 0.057 % total Nitrogen, 56.42 kgha^{-1} available P_2O_5 and 738.8 kgha^{-1} available K_2O. The experiment was laid out in large scale plot design with ten replications on GR 11 variety that is originally Nawagam province. The Three treatment combinations consisting different systems *viz*, system:S_1 Standard recommended package of practices, system:S_2 SRI under 100% organic; FYM 10 tha^{-1} + Azotobactore and PSB as per recommendation and system: S_3 SRI under INM; 50% RDF + FYM 5tha^{-1} + Azotobactore and PSB as per recommendation(root dipping 10-15 minute in 3-5 ml/liter).The field was ploughed, irrigated, puddled and made ready for sowing. Twenty five to thirty days old seedlingsare transplanted and irrigation, weeding and other agronomic practices details were done as per recommended package of practices.

RESULTS

Yield attributes& Yield:

Yield attributes of rice variety was ascribed by

Table: 1Yield attributes, yield and economics influenced by various treatments (Pooled data of 2005 to 2008)

Treat	Grain Yield kgha^{-1}	Straw Yield kgha^{-1}	Tillers hill^{-1}	Panicle m^{-2}	Panicle wt. (g)	Filled grain panicle	Water use efficiency (kg grain ha^{-1} mm)	Net return (Rs. ha^{-1})	BCR
S_1	4554	6788	10.24	229	3.19	163	5.98	30878	2.05
S_2	5240	6932	15.49	231	3.68	217	11.45	45925	3.04
S_3	5874	7793	18.12	261	3.72	241	12.84	53623	3.32
S.Em+	111	269	0.93	6.12	0.07	4.4	-	-	-
CD 0.5 %	313	NS	3.25	17	0.21	13	-	-	-

tillers per hill, paniclem^{-2}, panicle weight and filled grain per panicles was affected due to various systems of rice intensification.Four year pooled data presented in Table 1 showed that different systems of SRI found significant with effect on tillers, paniclem^{-2}, panicle weight and filled grain per panicles. Effect of system: S_3 SRI under INM gave significantly higher tillers per hill (18.12), paniclem^{-2} (261), panicle weight (3.72 g) and filled grain per panicles (241) over the rest of treatment.In case of tillers hill^{-1} and panicle weight which was statistically at par with system: S_2 SRI under 100% organic.

In four year pooled data the system: S_3 SRI under INM (50% RDF + FYM 5t/ha + Azotobactore and PSB root dipping) gave significantly highest grain yield of 5874kg ha^{-1} with 29% higher grain yield then the system S_1 and straw yield 7793 kg ha^{-1}. While lowest grain yield (4554kg ha^{-1}) and straw yield (6787 kg ha^{-1}) recorded under the system: S_1 Standard recommended package of practices. The increment of grain yield in this study at higher integrated source of organic and inorganic nutrient might be due efficient absorption of nitrogen and other elements which raise the production and translocation of dry matter from source to sink (Mortezaet *al*., 2011).

Water use efficiency & Economics:

Table 1 further indicated that the all the 4 year on average basis the higher water use efficiency of applied water was recorded under S_3 12.84 kg grain ha^{-1} mm followed by treatment S_2 (11.45 kg grain ha^{-1} mm) and S_1 (5.98 kg grain ha^{-1}mm). Economics was work out on the basis of pooled data of grain and straw yield. The result obtained that the highest net return of Rs. 53623 ha$_{-1}$ and BCR 3.32 were recorded under the system S_3 followed by system S_2 net return of Rs. 45925 ha^{-1} and 3.04 as compared to system S_1standard practices with RDF.

CONCLUSION

Based on the study conducted during four years, it may be concluded that result revealed that potential production and profit from the rice crop (GR 11) could be secured by adopting SRI under INM (50% RDF + FYM 5t ha^{-1} + Azotobactore and PSB root dipping to get higher yield in middle Gujarat Agro climatic zone III.

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IRC/TM-2/PP-33

RESPONSE OF ZINC FORTIFIED BRIQUETTES ON AVAILABILITY OF NUTRIENTS, YIELD AND NUTRIENT UPTAKE BY RICE

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Field experiment was conducted for three consecutive years in *kharif* season of 2017 to 2019 on medium black soil to study the response of Zn fortified briquettes on availability of nutrients, yield and uptake of nutrients by rice cv. KJT-3 at Regional Agricultural Research Station, Karjat, Maharashtra. The study showed that the soil pH, EC, OC, available N, P and K was not influenced significantly. However, the significantly highest DTPA-extractable Zn (0.42) and S (26.87) content in soil were recorded with UB-KAB fortified with 10 kg $ZnSO_4$ (T_8). The maximum grain (55.17 q ha^{-1}) and straw (63.56 q ha^{-1}) yield of rice was also the significantly highest N, P, K, Zn and S uptake was recorded with the same treatment.

Rice (Oryza sativa L.) is life for most of the people living in Asia. India is the world's second largest rice producer and consumer next to China. In high rainfall regions like Konkan, there are heavy losses of applied NPK fertilizers by broadcast method through various mechanisms i.e., runoff, volatilization, leaching, denitrification and fixation resulting into poor nutrient recovery. These losses can be reduced by management practices like proper timing, rate and modified forms of urea and deep placement of N fertilizers. Several strategies have been tried to enhance nitrogen use efficiency (NUE) in rice including split N application, the use of slow release N fertilizers and nitrification inhibitors (NIs). Deep placement of all essential fertilizers may be more efficient and farmers can be more benefited from this compared to broadcast method. Deep placement of briquette at 8-10 cm depth of soil can save 30% N compared to Prilled Urea (PU), increases absorption rate, improves soil health and ultimately increases rice yield (Savant *et al*., 1991). The application of briquettes obtained 25 % higher yield and decreased the expenditure cost of fertilizers by 20-30 % when fertilizer briquettes were used as the source of plant nutrients. In India, zinc (Zn) is now considered as fourth most important yield limiting nutrient in agricultural crops. Zn deficiency in Indian soils is likely to increase from 49 to 63% by 2025 which causes "khaira" disease to rice. Therefore, in the present investigation, an attempt was made to study the response of Zn fortified briquettes on soil properties, nutrient uptake and yield of rice.

METHODOLOGY

The present investigation was conducted at Regional Agricultural Research Station, Karjat, Dist. Raigad, Maharashtra, India ($18^0$91' N and $73^0$32' E at an altitude of 51.75 m above mean sea level) three consecutive years in *kharif* season of 2017 to 2019. The soil of the experimental filed was clay loam,

slightly acidic (6.7), EC 0.21 dSm^{-1}, organic carbon 9.6 g kg^{-1}, available N 127.95 kg ha^{-1}, available P 14.92 kg ha^{-1}, available K 318.53 kg ha^{-1} DTPA-extractable Zn 0.32 mg kg^{-1} and available SO_4^{-2} 19.11 kg ha^{-1} content, which classified taxonomically as *Typic Haplutepts*. The briquettes were prepared as per the ratio of fertilizers (urea, DAP, suphala, godawari and $ZnSO_4$) combination used with the help of Kranti briquetter. There were eleven treatments replicated thrice in with randomized block design. Briquettes were placed at 7-10 cm deep in soil followed by transplanting @ 1 briquette for every four hills of rice. The soil and plant samples collected at harvest were analyzed by following the standard analytical procedures.

RESULTS

Deep placement of briquettes fortified with Zn significantly enhanced the yield in comparison with conventional method of fertilization. The highest grain (55.17 q ha^{-1}) and straw (63.56 q ha^{-1}) yield was found in treatment T_8 comprising of UB-KAB fortified with 10 kg $ZnSO_4$, which was at par with treatment T_3, T_4 and T_5 in case of grain yield and with T_4 and T_5 in case of straw yield. The data revealed that total N (97.17 kg ha^{-1}), P (20.18 kg ha^{-1}) and K (74.78 kg ha^{-1}) uptake and Zn (262.44 g ha^{-1}) and S (53.92 kg ha^{-1}) uptake was recorded significantly highest in the treatment UB-KAB fortified with 10 kg $ZnSO_4$. Highest grain yield might be related to their physiological efficiency, since Zn being metallic co-factor of a number of enzyme proteins influencing such activities in plants e.g. carbonic anhydrase and a number of dehydrogenase, improved plant Zn uptake and high remobilization from leaves during grain filling in these rice systems. Further, deep placement of briquettes induces slow release of nutrient by reducing the losses and thereby higher nutrient uptake and produces higher yield.

The soil properties such as pH, EC, OC, available N, available P and available K were not influenced significantly by the different Zn fortified briquettes. However, numerically higher pH, OC, available N, available P and available K was found with UB-KAB fortified with 10 kg $ZnSO_4$. The maximum DTPA-extractable Zn (0.42 mg kg^{-1}) and SO_4-S (26.87 kg ha^{-1}) were significantly influenced by the application of Zn fortified briquettes in postharvest soil in the treatment receiving UB-KAB fortified with 10 kg $ZnSO_4$ (T_8).

CONCLUSION

From the three consecutive years study it could be concluded that application of UB-KAB fortified with 10 kg $ZnSO_4$ to rice at the time of transplanting significantly increased the grain and straw yield of rice, uptake of nutrients and DTPA-extractable Zn and found to be beneficial in order to get higher yield in Zn deficient medium black soils of Konkan.

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IRC/TM-2/PP-34

INFLUENCE OF ZINC AND SULPHURAPPLICATIONON SOIL PROPERTIES, NUTRIENT UPTAKE AND PRODUCTIVITY OF RICE

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Rice (*Oryza sativa* L.) is staple food of over half of the world's population which provide 22 percent of calories and 17 percent of protein to the world growing population. About 90 % of rice is grown and consumed in South and South East Asia. Among the nutrients, micronutrients play key role in quantitative and qualitative aspects of crop production and zinc is considered to be the most important nutrient next to N, P and K. Rice is sensitive for low Zn condition which is common in submerged paddy soils therefore Zn deficiency frequently occurs (Hazra*et al*., 1987) and therefore, considered compulsory element for rice that should be replenished in the form of chemical fertilizer for enhancing the yield and maintaining soil fertility. The availability of zinc micronutrient has importance in plant for growth, enzymatic, metabolic activities to improve the crop production, lipids, nucleic acids, gene expression and regulation, protein synthesis and reproductive development of plants. Keeping in view the present study was conducted with objective to identify suitable method of application of ZnSO4 andZnOto increase the yield and availability of zinc content.

METHODOLOGY

Field experiments were conducted four consecutive years during *kharif*2016-2019 at Regional Agricultural Research Station, Karjat, Dist. Raigad, Maharashtra, India to study the suitable method of zinc and sulphur application on soil properties, nutrient uptake and productivity of rice in *fine loamy mixed isohyperthermic* family of *TypicHaplutepts*. The geographical location of $18^0 91'$ N and $73^0 32'$ E at an altitude of 51.75 m above mean sea level (MSL). Zinc was applied in the form of zinc oxide (ZnO) and zinc sulphateheptahydrate ($ZnSO_4.7H_2O$) through soil application @ 15 kg ha^{-1} and 30 kg ha^{-1} at the time of transplanting and 30 DAT, root dipping of seedlings before transplanting @ 0.5% through ZnO and $ZnSO_4$ source and through foliar application @ 0.5 and 1.0 % through ZnO and $ZnSO_4$ after establishment of seedling and 30 DAT, respectively. The treatments were replicated thrice in randomized block design. The initial and postharvest soil samples collected and analyzed following standard analytical procedures for pH (6.67), electrical conductivity (0.19 dSm^{-1}), organic carbon (9.8 g kg^{-1}), available nitrogen (141.12 kg ha^{-1}), available phosphorus (13.78 kg ha^{-1}), available potassium (321.40 kg ha^{-1}) DTPA-extractable Zn (0.34 mg kg^{-1}) and SO_4-S (19.13 kg ha^{-1}).

RESULTS

The data revealed that maximum grain (50.65 q ha^{-1}) and straw (56.74 q ha^{-1}) yield was observed in treatment RDF + soil application of $ZnSO_4$ @ 15 kg ha^{-1}at the time of transplanting (T_7). The total N, P and K uptake were significantly influenced by the treatment T_7.The available zinc and sulphur was significantly increased the zinc 0.45 mg kg^{-1} and SO_4-S 32.40 kg ha^{-1}in postharvest soil with the treatment RDF + soil application of $ZnSO_4$ @ 30 kg ha^{-1} at the time of transplanting and 30 DAT (T_8).This may be due to the direct application of micronutrients at critical growth stages, which helped in increasing the absorption by the grain.The pooled datasoil pH, EC, OC, available N, P and K showednon significant result with application of different treatments. The favorable influence of soil application of $ZnSO_4$ on the yield of rice may be attributed to its role in various enzymatic reactions, growth processes, hormone production and protein synthesis. The data showed that every parameter was improved with the application of the minerals, this not only improving overall productivity of cropping system but also improving fertility status of soils as well (Ali *et al.,* 2012).

CONCLUSION

It is concluded that application of RDF + soil application of $ZnSO_4$ @ 15 kg ha^{-1} at the time of transplanting has improved grain and straw yield of rice and maintaining fertility status of soil.

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Theme - II : Sustainable rice farming
IRC/TM-2/PP-35

ENHANCING WATER PRODUCTIVITY OF RICE USING INTERNET OF THINGS IN RICE-WHEAT CROPPING SYSTEM IN PUNJAB

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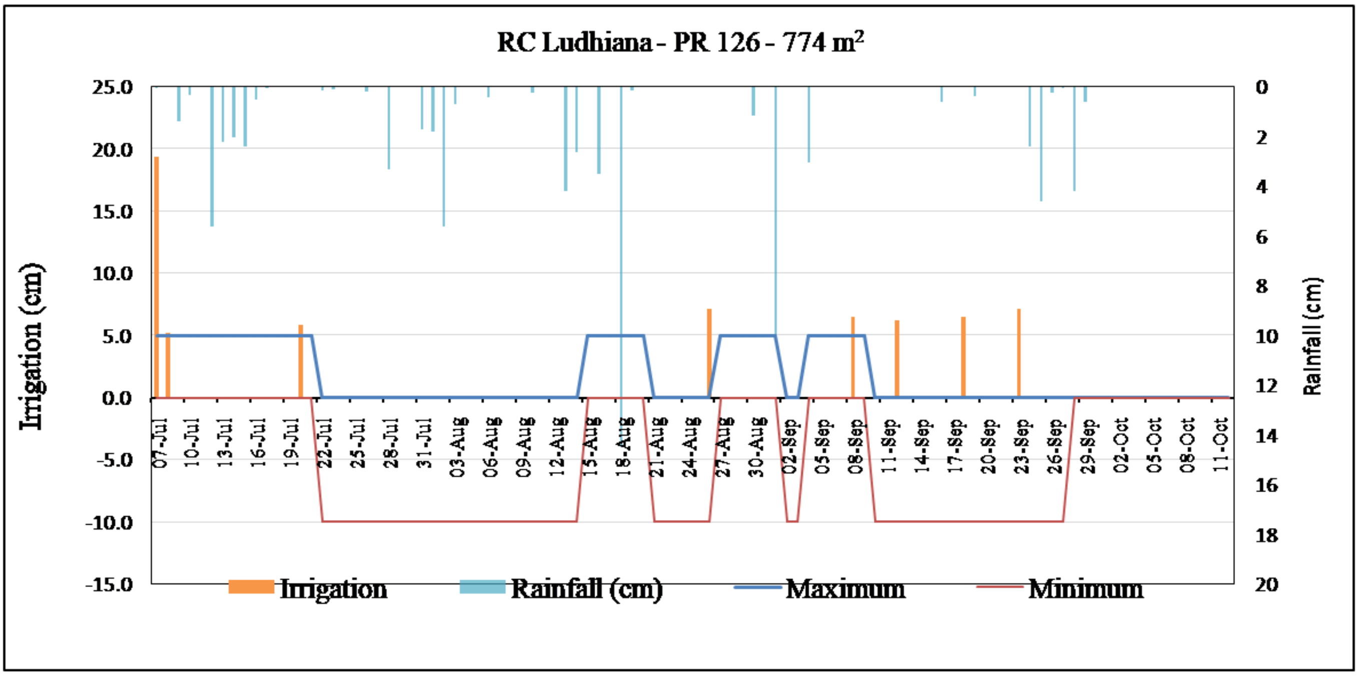
At present with total availability of 3.43 M ha-m water and population of 28 million, the amount of available water per capita in the Punjab state is 1225 m^3/person. The level of ground water in Punjab is decreasing very rapidly and it is considered critical in many blocks. The major reason of depletion of water level is the cultivation of rice crop which requires huge amount of water and is grown in peak summer season when the rate of water evaporation is high. In rice, management of water is of utmost important not only for higher yield but also for water saving. Because of over irrigation in rice, higher moisture content in grains leads to reduced quality traits including lower head rice recovery. Hence, proper irrigation scheduling (time as well as depth of irrigation water input) is of utmost importance for sustainability and better water-use efficiency. In this direction PAU has developed tensiometer for scheduling irrigation in rice to check over-irrigation and recommended alternate wetting and drying system of irrigation. But these practices could not become a choice of the farmers because of daily monitoring and non-automation.Keeping in view the availability of smart ultrasonic water sensors and other digital tools,experiments were planned with the objectivesnamely(i) standardization of water sensors for scheduling irrigation in rice for higher water productivityin different textured soils (ii) evaluation of IoT model for crop growth and water productivity (iii) estimation of possible reduction in water use, labour use, energy, overall cost of cultivation and yield impact and (iv) estimation of other co-benefits *viz.* social benefits, associated environmental benefits, reduction of energy use in irrigation etc.

METHODOLOGY

Field experiments were conducted during *Kharif* 2019 at farmers' field in three districts of Punjab namely Ludhiana, TaranTaran and Bathinda. Ten progressive farmers were selected in each district in clusters mode for efficient monitoring and data collection apart from three Research Farms/Centres of the Punjab Agricultural University in these districts. The treatment comprised of one control plot (irrigation schedule recommended by PAU) and another irrigation based on ultrasonic sensor with fully automated irrigation water delivery system and water level measurement in rice. Rice was transplanted after puddling and water was kept standing for initial two weeks and thereafter irrigations were delivered as per treatments mentioned above. In PAU recommended schedule, irrigations were applied 2-3 days after infiltration of ponded water at all the locations. In order to put the alternate wetting and drying (AWD) instruments in line with the IOT system, a system oriented dynamic website and mobile application was developed which can be used to view the data being collected and to operate water pumps remotely. Thirty pulse water meters were installed at farmer fields to measure irrigation water. The water level data received from the AWD system was compared and matched to ensure the crop water requirement during wetting and drying periods. IoT system monitored and recorded water level at an interval of 15 minutes and shared this information on the website which was also publicly available for farmers for consideration and decision making. IoT system generated SMS notifications based on the desired water level required in the field according



water applied in paddy at Research Cente, Ludhiana

to the AWD schedule. IoT system kept AWD water level or field water level in the range of predefined limits in the time of wet period. IoT system started pump operation if the field level is below minimum level of the water requirement as per the predetermined wet or dry period. When field water level went above maximum water level of the water requirement, then pump was automatically stopped. In dry period, the threshold limit for fall of soil moisture (water level) was e" -10 cm to d" -15 cm and for rise of the water level, it was d" 3cm. During wet period, standing water level for paddy was maintained at e" 5cm to d" 10cm.

RESULTS

There was high initial capital investment of IOT installation at these locations. During 2019, average of 107.6 cm and 129.9 cm irrigation water was applied in IOT plots and control plots, respectively in fields sown with parmal(non-basmati) rice varieties.

Analysis of yield data showed 4-6% and 2-5% improvement in grain yield along with 17% and 10% water saving for parmal rice and basmati rice varieties, respectively using IOT based AWD irrigation systems over the control plots.

CONCLUSION

IoT based irrigation to PR varieties of rice resulted in 4-6% increase in grain yield and saved about 17% irrigation water as compared to conventional irrigation practice. In case of basmati rice, there was 2-5% improvement in grain yield with 10% saving of irrigation water. "START the irrigation"triggerswere successfully developed and implemented,however challenges were faced to develop the "STOPthe irrigation trigger" which depended on the position of the sensors with respect to the distance from the entry point of water in the field, frequent power supply interruption to pumps and limitations in the numbers of sensors per field.

IRC/TM-2/PP-36

RICE BASED INTEGRATED FARMING SYSTEM MODEL FOR LIVELIHOOD SECURITY AND PROFITABILITY TO FARMERSUNDER KONKAN AGRO-CLIMATIC CONDITION

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India is the single largest employer in the world, providing livelihoods for 40% of global population. Food security, employment, income generation, resource conservation and environment protection have emerged as major world concerns.The integrated farming systems (IFS) are vulnerable to climate change and must adapt to maintain and improve productivity and its stability.IFS are a powerful tool; it holds the key for ensuring income, employment, livelihood and nutritional security in a sustainable mode for small and marginal farmers.IFS approach is a judicious mix of two or more components while minimizing competition and maximizing complementarities with advance agronomic management tools aimed at sustainable and environment friendly improvement of farm income and family nutrition (Singh and Ravisankar, 2015).

OBJECTIVES:

i. To develop an ideal and profitable model of IFS.

ii. To demonstrate efficient use of available farm resources.

iii. To assess the impact of Integrated Farming System model in respect of employment generation, recycling of farm produce and increasing profit per unit area per unit time.

METHODOLOGY

Konkan region of Maharashtra comes under high rainfall zone receiving on an average 3000 to 3500 mm rainfall in 95 to 110 rainy days during *kharif* season. The IFS model comprised of different enterprises *viz.*, crops and cropping systems on an area of 0.50 ha, horticulture component (fruit crops + nursery) 0.40 ha, livestock components namely, dairy, goatary and poultry on area of 35.75 m^2 each (107.25 m^2), vermicompost unit on 18.00 m^2 and rest of the land (874.75 m^2) is used for operational and other purposes.

RESULTS

Considering the Agro-climatic conditions, natural resources, land holding of farmers and farmer's needs of Konkan region, an ideal integrated farming system model for small and marginal farmers has been developed on an area of 1.00 ha for family having 3 males and 3 females (6 persons)at Regional Agricultural Research Station, Karjat, Dist. Raigad under All India Co-ordinated Research Project on Integrated Farming Systems. This region is dominated by rice based cropping systems due to high rainfall. Therefore, the total production of the model is converted in terms of Rice Equivalent Yield (REY). The average of six years data showed that (Table 1) the total production of 47-09 t REY was obtained from 1.00 ha area. In terms of economic returns, the gross and net returns were Rs. 7,15,957/- and Rs. 2,10,553/-, respectively. IFS have created more number of working days in the system due to involvement of more enterprises than cropping systems alone. Six years average employment generation through present IFS model was found to be 1085 man days and its value was Rs. 2,04,819/- which contributed 40.53 % in the total cost of production. This has provided employment opportunity almost throughout the year.

Table 1: Rice equivalent yield, economic parameters and employment generation of IFS Model

Particular	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	Mean of 6 yrs
REY (t)	**36.15**	**34.91**	**44.08**	**49.78**	**60.17**	**57.47**	**47.09**
Gross Returns (Rs.)	488057	474925	621502	731765	936377	1043118	**715957**
Cost of Cultivation (Rs.)	365152	372288	476605	539598	623948	654834	**505404**
Purchased cost (Rs.)	131847	135134	170925	202236	260947	258408	**193250**
Recycled cost (Rs.)	97873	71284	101470	111162	116601	145626	**107336**
Labour cost (Rs.)	135432	165870	204210	226200	246400	250800	**204819**
Employment generation	836	922	1135	1131	1232	1254	**1085**
Net Returns (Rs.)	122905	102637	144897	192168	312429	388284	**210553**
B:C ratio	1.34	1.28	1.30	1.36	1.50	1.59	**1.42**

The average total cost of production of the IFS model was Rs. 5,05,404/- ha^{-1}, which included outside purchase for Rs. 1,93,250/- ha^{-1} (38.24 %), value of recycled material within the system of Rs. 1,07,336/- ha^{-1} (21.24%) and for farm labours costing Rs. 2,04,819/- ha^{-1} (40.53 %). On an average of six year study, the benefit : cost ratio was 1.42 by inclusion of different modules in the model. These results are in conformity with the Channabasavanna et al., (2009) and Patel et al., (2018), who found integration of different enterprises as beneficial in their research at different states.

CONCLUSION

Farmers can increase their net returns by saving the expenditure on farm labours through employment of family labours. The six years compiled data of IFS model showed that as far as the demand of essential foods for a family of 6 members per annum is considered, the annual production in this model was surplus for cereals, oilseeds, milk, fruits and vegetables commodities.

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IRC/TM-2/PP-37

NUTRIENT EXPERT- A TOOL TO OPTIMIZE NUTRIENTS AND ENHANCE RICEPRODUCTIVITY

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The stagnation of rice yields both at national and state level vis a vis the indiscriminate use of fertilizers particularly nitrogen has created dual problems of food insecurity and environment degradation. Keeping in view these facts, a simple computer based decision support tool 'Nutrient Expert for Rice -NE^R', a fertilizer guiding tool, was evaluated and compared with different nutrient management practices. NE is an easy to use simple decision support tool which require certain basic input data of the site where experiment is to be conducted to generate the site specific fertilizer recommendation.

METHODOLOGY

The experiment was conducted at Mountain Research Centre for Field Crops, Khudwani Anantnag, Kashmirduring kharif 2016 and 2017 seasons, preferably because certain data required to be entered in Nutrient Expert software were already available from this site. However, for better precision nutrient omission plots of N, P and Kwere also included in the experiment to get a clear insight about the response of crop to a particular nutrient.A yield target of 8.5 tonnes of grain ha^{-1}was fixed for NE^R as yield of 7 to 7.5 tonnes ha^{-1}has been obtained from the site previously via the state recommended fertilizer dose. A computer generated fertilizer recommendation through NE^R was created which was implicated at field level to check the precision of the software. The main objective was to compare this computer based fertilizer recommendation with the widely practiced state or blanket recommended practice. Further, two more treatments were augmented in NE^R based recommendation to fine tune nitrogen fertilizer via LCC scores of 4 and 5, which helped to apply nitrogen based on crop demand. In LCC guided scores P and K was applied as per NE^R recommendation while nitrogen was applied 30 kg as basal and rest in splits of 20 kg N ha^{-1} as per leaf color score reading.

Table 1: Effect of Nutrient Management Practices on grain yield, biological yield and Agronomic Efficiency of rice

Nutrient Management Practices	Grain yield (t ha^{-1})		Biological yield (t ha^{-1})		Agronomic efficiency (kg grain/kg N applied)	
Recommended Practice (RP)- $N_{120}P_{60}K_{30}$	7.13	6.82	9.72	9.63	19.58	19.17
Nutrient Expert Recommendation (NE^R)-$N_{141}P_{51}K_{75}$	8.93	8.61	10.95	10.91	29.66	28.55
NE^R + LCC**d"** 4 @ 20 kg ha^{-1} –$N_{110}P_{51}K_{75}$	7.63	7.32	10.01	9.86	26.47	25.68
NE^R + LCC**d"** 5 @ 20 kg ha^{-1} - $N_{130}P_{51}K_{75}$	8.41	8.17	10.37	10.25	28.08	26.85
Absolute control ($N_0P_0K_0$)	3.75	3.45	5.27	5.12	-	-
Nitrogen omission plot – $N_0P_{51}K_{75}$	4.74	4.45	6.52	6.46	-	-
Phosphorous omission plot - $N_{110}P_0K_{75}$	6.61	6.31	8.45	8.38	13.26	13.12
Potassium omission plot - $N_{110}P_{51}K_0$	7.09	6.79	8.94	8.87	16.95	16.68
SEm±	0.19	0.16	0.21	0.26	1.38	1.31
CD (pd" 0.05)	0.57	0.47	0.61	0.74	4.05	3.88

RESULTS

The results of the study revealed significantly higher grain (8.93 and 8.61 t ha^{-1}) and biological yield(19.71 and 19.49 t ha^{-1}) in NE^R guided treatments compared to blanket recommendation during both the years of study period and the increase in yield in NE^{R}was to the tune of around 20 %. Also, the nitrogen of the NE^R recommendation which was guided through LCC 4 & 5 revealed that LCC 5 was better able to optimize the higher productivity of rice in temperate environments with the saving of around 10 kg N ha^{-1} than NE^R and produced yield comparable to that of NE^R. Also, LCC 4 proved better over the recommended practice in saving nitrogen and producing yield significantly better than recommended practice with the additional saving of around 10 kg N ha^{-1} over state recommended practice and 31 kg N ha^{-1}over NE^R. The results were in tandem with the findings of Dobermann and Singh (2007) and Bhat (2014). Similarly, the nitrogen use efficiency was found significantly higher for NE^R(29.66 and 28.55kg grain/ kg N) over blanket recommendation (19.58 and 19.17 kg grain/kg N) but was at par with both LCC 4 andLCC 5 which might be due to better splitting and availability of nitrogen as and when required by the crop. The findings were in agreement with the findings of Khuong*et al.*(2007).

CONCLUSION

The Nutrient Expert based decision support tool enhanced not only the crop productivity but also increased the agronomic use efficiency of nitrogen which means twin benefits – ensuring food security through higher yields and minimal environmental footprint through better utilization of every unit of applied nitrogen in grain production.

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IRC/TM-2/PP-38

YIELD AND SOIL FERTILITY OF RICE AS INFLUENCEDBY ORGANIC MANURES AND INORGANIC FERTILIZERS

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Rice (*Oryza sativa* L.) is the prime source of food for nearly half of the world's population and it is one of the most important food crop, that plays a key role for food security. Among the various factors known to augment the crop production, fertilizer aided with suitable management practices play a pivotal role to boost up the crop yield. But heavy use of chemical fertilizers in agriculture has weakened the ecological base in addition to degradation the soil, water resources and quality of the food. Exclusive use of chemical fertilizers leads to depletion of soil health and create imbalance in the composition as well as availability of micro nutrients. At this junction, a keen awareness has sprung on the adoption of organic farming as a remedy to overcome the ill effects of modern chemical agriculture. Addition of organic manures to soil creates a favorable environment and the crop shows a good response to all management practices. Hence an attempt was made to study the effect of organic manures on soil fertility statues and yield of rice.

MRTHODOLOGY

A field experiment was conducted on a sandy loam soils at Agricultural Research Station, Perumallapalle, Andhra Pradesh with the variety NLR 34449 during *Kharif* 2015 to study the effect of organic manures and inorganic fertilizers on soil fertility status, nutrient content and yield of rice. The experiment consisted of two treatments *viz.*, organic and inorganic plots. FYM and vermi compost were applied to organic treated plot based on N equivalent and recommended dose of fertilizers (80:60:40 kg NPK ha^{-1}) were applied to inorganic treated plot. Well decomposed FYM was applied 10 days before planting. Bio fertilizers *viz.*, Azatobactor @ 5 kg ha^{-1} and Phospharussolubilising bacteria @ 10 kg ha^{-1} were mixed with FYM and applied as basal. Plant and soil samples were collected at harvest stage. Chemical analysis of soil and plant samples was done as per the procedure described by Tandon (1973).

RESULTS

The results revealed that grain yield (4.102 t ha^{-1}), plant height (82.06 cm), panicle length (17.01 cm), N content in grain (1.03%) were higher with application of inorganic fertilizers when compared with organic manures (3.665 t ha^{-1} of grain yield, 78.10 cm of plant height, 15.24 cm of panicle length and 0.92% of N content in grain). Significantly higher grain yield with application of chemical fertilizers might be due to greater solubility and accelerated release of nutrients and also by providing an opportunity to rice to utilize higher quantities of nutrients. Apart from that the nutrients present in chemical fertilizers might have involved in various physiological activities like increased photosynthetic activity and better light interception which in turn resulted in more number of productive tillers and grain yield (Sisodia and Kewat, 2009).

The available nitrogen, potassium and DTPA extractable zinc were significantly influence by application of chemical fertilizer and organic manures. Highest available nitrogen in soil was recorded with application of chemical fertilizer (264 kg ha^{-1}) over organic manures application (251 kg ha^{-1}). The buildup of available N was noticed both in organic and inorganic treatments (21.84% and 28.15%, respectively) when compared with initial value of 206 kg ha^{-1}. Available potassium was higher with organic treatment (281 kg ha^{-1}) than inorganic treatment (260 kg ha^{-1}). Regarding to available potassium 1.05% and 8.45% of deletion was observed in organic and inorganic treatment respectively over initial value of 284 kg ha^{-1}. The organic carbon per cent was increased 0.08 % in organic plot and 0.04% in inorganic plot over initial value (0.40%) i.e. at start of the experiment (2009). The buildup of organic carbon could be attributed to the manures and subsequently addition of leaf residue and debris of plants (Bhandari *et al*., 2002).

CONCLUSION

The study revealed that higher grain yield, number of effective bearing tillers, panicle length was recorded with application of inorganic fertilizers. The inorganic treated plot showed higher build up of available N in soil than organic treated plot.

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IRC/TM-2/PP-39

GERMINABILITY OF INDIGENOUS AROMATIC RICE SEEDS AT POST-HARVEST STORAGE PERIODS

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Quality seed has been recognized as an important input in present-day agriculture system. Germinabilty and seedling vigour of rice seed determine theplant growth and yield to some extent. Seasonal dormancy is a common selection for environment tolerance particularly in indigenous cultivars. Most cultivated rice seeds have no or shallow degree of dormancy. Besides, the mature seed of some cultivars can germinate in panicles of standing crop known as pre-harvest sprouting or vivipary, which reduces both seed yield and quality.In the context, there is a little information on germinability and storability of seeds of aromatic rice landraces of West Bengal.

METHODOLOGY

Panicles of 17 indigenous aromatic rice cultivars at maturity were collected from the organic field of University Farm during end of November, 2019; which were hand-threshed, cleaned and seeds were sun-dried before storage. Seeds were kept in small seed bins at room temperature (28±4°C) for six months and that was designated as 'naturally aged seed'. The experiment was done at 1-month interval upto 6 months of post-harvest storage during 2020at Aromatic Rice Laboratory, Department of Agronomy,Bidhan Chandra KrishiViswavidyalaya, Mohanpur, Nadia, West Bengal, India. Germination tests were conducted using the standard method (ISTA, 1985) with three replicates of 100 seeds in petri-dishes containing two filter papers moistened with 7.5 ml of distilled water. The observation was recorded on each day and the final count was taken on 14 days of germination test. Seeds were scored germinated, when the radicle had emerged by at least 2 mm. The germination rate (%) of seeds was calculated by the following formula:

Germination (%) =

The speed of germination was calculated by the formula given by Czabator (1962):

Speed of germination= $n_1/d_1+n_2/d_2+n_3/d_3+....$

where n = number of germinated seeds, d= number of days

RESULTS

The germination rate (%) of indigenous aromatic rice seeds was steadily increased from 1 monthto4 months of post-harvest storage in the experiment, which continued at a plateau upto 6 months (Table 1). All the rice cultivars had certain dormancy at initial period, while a few (Gandheswari, Kalonunia, Kaminibhog and Radhunipagal) remained dormant (0.0% germination) immediately after harvest of paddy particularly during winter months (December-January). The variation in germination (%) among 17 scented rice landraces was noted as: 0.0 (Gandheswari, Kalonunia, Kaminibhog and Radhunipagal) and 18.7% (Mohanbhog) after one month storage (January), 9.3% (Kalonunia) and 73.3% (Gandhamalati) after 2 months (February), 46.7% (Kalonunia) and 96.0% (Gopalbhog) after 3 months (March), 84.0% (Kataribhog) and 100.0% (Gobindabhog) after 4 months (April),88.0% (Mohanbhog) and 100.0% (Harinakhuri, Radhatilak and Tulaipanji) after 5 months (May) and 86.7% (Tulsibhog) and 100.0% (Gobindabhog) after 6-monthsof storage (June). The findings clearly indicated that all seventeen cultivars reached minimum germination standard (>80%) at 4

Table 1.Germination rate (%) and speed of germination of aromatic rice landraces at different periodsof post-harvest storage

Aromatic rice landrace	Post-harvest storage (month)											
	1		2		3		4		5		6	
	G (%)	SG	G (%)	SG	G (%)	SG	G (%)	SG	G (%)	SG	G (%)	SG
Badshabhog	10.7	0.3	61.3	3.8	77.3	6.0	97.3	9.0	94.7	11.8	94.7	11.8
Gandhamalati	10.7	0.3	73.3	4.4	93.3	8.7	92.0	10.0	93.3	11.7	90.7	11.3
Gandheswari	0.0	0.0	16.0	0.7	74.7	6.2	93.3	8.8	97.3	12.2	98.7	12.1
Gobindabhog	8.0	0.2	48.0	3.0	86.7	8.0	100.0	10.4	97.3	12.1	100.0	12.4
Gopalbhog	10.7	0.3	68.0	4.2	96.0	8.9	89.3	9.3	98.7	12.2	94.7	11.7
Harinakhuri	5.3	0.2	34.7	1.8	84.0	6.9	94.7	8.8	100.0	12.5	98.7	12.0
Jamainaru	5.3	0.2	56.0	3.7	76.0	7.0	88.0	8.4	92.0	11.3	90.7	11.2
Kalojira	4.0	0.1	37.3	1.8	84.0	6.4	96.0	9.8	94.7	11.8	97.3	12.2
Kalonunia	0.0	0.0	9.3	0.4	46.7	3.0	85.3	7.6	94.7	11.6	93.3	11.1
Kaminibhog	0.0	0.0	13.3	0.5	62.7	4.2	97.3	8.5	97.3	12.1	98.7	12.2
Kataribhog	10.7	0.4	56.0	3.2	88.0	7.9	84.0	8.4	89.3	11.2	97.3	12.2
Lal Badshabhog	6.7	0.2	46.7	2.7	80.0	7.2	93.3	8.4	94.7	11.8	92.0	11.2
Mohanbhog	18.7	0.8	66.7	4.5	89.3	9.5	93.3	10.1	88.0	10.9	94.7	11.8
Radhatilak	5.3	0.2	32.0	1.6	82.7	6.6	98.7	9.2	100.0	12.5	97.3	11.9
Radhunipagal	0.0	0.0	13.3	0.6	50.7	3.9	96.0	7.9	96.0	11.9	97.3	12.1
Tulaipanji	4.0	0.1	25.3	1.2	80.0	6.4	92.0	8.9	100.0	12.5	97.3	12.1
Tulsibhog	6.7	0.2	57.3	3.4	85.3	6.9	96.0	9.2	92.0	11.5	86.7	10.4
CD ($P<0.05$)	7.8	0.27	14.91	0.95	12.48	0.98	8.08	1.12	6.14	0.85	7.23	1.01

G= Germination, SG= Speed of germination

months after harvest (April). Among cultivars, Mohanbhog, Gandhamalati, Gopalbhog and Badshabhog usually had better germinability throughout normal post-harvest storage condition.

Speed of germination was very low at initial 1-2 months of storage; which was slightly improved after 3 months of harvest(March), but it reached to the maximum after 5 months (May) of normal storage condition(Table 1). The variability in speed of germination among 17 scented rice cultivars was recorded as: 0.0 and 0.8after 1 month of storage (January), 0.4 and 4.5 after 2 months (February), 3.0 and 9.5 after 3 months (March), 7.6 and 10.4 after 4 months, 10.9 and 12.5 after 5 months (May), and 10.4 and 12.4 after 6 months (June).

CONCLUSION

Germination rate (%) of 17 indigenous aromatic rice cultivars was steadily increased from 1 month (January) to 4 months of post-harvest storage (April), andthey reached minimum germination standard (>80%) after 4 months*i.e.* just before next growing season. Four varieties (Gandheswari, Kalonunia, Kaminibhog and Radhunipagal) had significant dormancy upto 2 months; while Mohanbhog, Gandhamalati, Gopalbhog and Badshabhog usually had better germinability throughout normal storage condition. Speed of germination was very low at initial 1-2 months after harvest; which was gradually improved during normal storage condition.

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ISOLATION AND SCREENING OF BENEFICAL ENDOPHYTIC BACTERIA FROM RICE GROWN UNDER COASTAL SALINE SOILS

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Coastal region covers a long strip along the east coast (Tamil Nadu, Puducherry, Andhra Pradesh, Odisha and West Bengal) and west coast (Gujarat, Maharashtra, Karnataka and Kerala). In India, nearly 9.38 million ha area is occupied by salt -affected soils out of which 5.5 million ha are saline (including coastal regions). Better management practices are needed to improve the productivity and quality of such low productive salty soils. Endophytes are the group of microorganisms that colonize the internal tissues of plants either by symbiotically or in a mutualistic relationship (Dudeja*et al.,* 2012). They are consistently present in the root, stem, leaf, fruit and tuber tissues of a wide range of agricultural, horticultural and forest species. Endophytes promote plant growth through nitrogen fixation, phytohormone production and nutrient acquisition. Endophytic bacteria carrying plants grow more vigorously and also more tolerantto drought than other plants. Various researchers reported that bacteria isolated from saline environment are more likely to withstand salt stress. The present investigation was carried out to exploit the diverse endophytic bacteria from rice (*Oryza sativa*) which are cultivated in coastal saline soil regions of TamilNadu.

METHODOLOGY

For that, the endophytic bacterial isolates were isolated from leaf and stem tissues of rice grown at Cuddalore, Puducherry, Nagapattinam, Karaikal and Ramanathapuram districts of Tamil Nadu through the method adopted by Araújo*et al*., (2002). Biochemical tests and salt tolerant tests were conducted for the endophytic bacterial isolates.

RESULT

After careful morphological and growth examinations, 20 bacterial endophytes were screened and they were designated serially as Ri 1 to Ri 20. The results of biochemical tests revealed that 80, 65,55, and 31 per cent of isolates were positive for catalase test, oxidase test, starch test, methyl red and vogesproskauer test respectively. Salt tolerance of endophytic isolates wasalso tested with different concentrations of NaCl*viz.*,0,2.5, 5.0, 7.5 and 10 %. All 20 endophytic isolates showed good growth at 0 to 5%NaCl concentration. Except Ri 5 and Ri 11, all other isolates grow up to 7.5% NaCl concentration. The isolates Ri 1, Ri 5, Ri 7, Ri 11, Ri 13 and Ri14 did not show any growth at 10 per cent Na Cl concentration which indicated that fourteen isolates were found to be tolerated higher salinity.

CONCLUSION

Saline tolerant and highly promising plant growth promoting endophytic bacterial cultures will be used for further research in rice grown under coastal saline condition to mitigate alt stress.

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MUTUAL EFFECTS OF ASCORBIC ACID AND *Azotobacter chroococcum* Avi2 ON PHOTOSYNTHETIC EFFICACY, ANTIOXIDANTS AND GROWTH PROMOTION INRICE UNDER MOISTURE DEFICIT STRESS

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Moisture deficit stress (MDS) is one of the serious factors, diminishing plant growth, development, metabolism, and yield in several agricultural crops including rice (Kumar et al., 2019). An array of physiological and biochemical changes can occur in plant under influence of MDS that causes severe metabolic disorders and ultimately affect its yield and quality. Ascorbic acid (AA) is a known antioxidant and it is able to scavenge the stressor molecules, released particularly in the form of ROS in agricultural crops imposed with several oxidative stresses. Besides, AA is the most essential reducing substrate in plants and also having the synergistic effect to enhance the other antioxidant molecules to sustain the plant photo-systems. Our previous study showed that higher H_2O_2 concentrations decreased the growth of *Azotobacter chroococcum* (Avi2) (an endophyticdiazotrophs) and even affected its PGP traits, whereas, Avi2 in combination with AA enhanced its survivability and functional traits including its nitrogen fixing efficacy (Banik et al., 2019; Kumar et al., 2019).

Information related to effect of either AA alone or endophytic bacteria on PGP in rice under drought are plenty, however the combined effect of AA and endophytic diazotrophs (*A. chroococcum*Avi2*)* is scare, especially in rice under MDS (Karthikeyan et al., 2007; Kelman et al., 2009). Therefore, the present study aimed to assess the role of combined application of AA and *A. chroococcum*Avi2 to alleviate MDS (-60 kPa) by analyzing ChlF characteristics, antioxidants and growth-promotion in drought-susceptible (Naveen and IR64) and tolerant (Ankit and Satybhama) rice cultivars.

METHODOLOGY

During dry season (*Rabi*) of 2018, a pot experiment was conducted at ICAR-National Rice Research Institute (NRRI), Cuttack, Odisha, India. Two each drought susceptible (IR64 and Naveen) and tolerant (Ankit and Satybhama) rice cultivars were used for this experiment. *A.chroococcum*Avi2(MCC no. 3432; NCBI no. KP099933) and ascorbic acid as biological agent and antioxidant, respectivelywere used for the present study.

For each rice cultivar, the following five treatments were imposed *viz.*, (i) flooded control (FC), (ii) moisture deficit stress (MDS), (iii) MDS + *A. chroococcum*(Avi2) inoculation, (iv) MDS + ascorbic acid (AA), and (v) MS + Avi2 + AA. The roots of 25 days old rice seedlings of each cultivar were treated with Avi2 suspension (10^{-7} CFU ml^{-1}). Seedlings were also treated with 1 mg l^{-1} AA alone and in combination with Avi2 at 25 °C for 1 h. Treated seedlings were then transplanted in each pot. Pots were fertilized as per recommended dose of phosphorous, potassium and 75% of recommended dose of nitrogen applied in the form of urea into two splits. After 45 days, plants were treated with second dose of AA by the soil-drenching method, in which 100 ml AA solution was poured per pot at rice roots of each cultivar.

The data related to physiological characteristics were recorded after 25 days of stress imposition. Then determine its nitrogen fixation (*nifH* gene quantification) efficiency, antioxidants (SOD, CAT, H_2O_2), stress indicator proline, photosynthetic efficacy (chlorophyll content and chlorophyll florescence imaging),and plant-growth promotion traits underMS (-60kPa)condition.Absolute quantification of *nifH* gene was calculated by using five points standard curve, following the protocol of Kumar et al. 2017. Measurement of antioxidants *viz.*catalase, superoxide dismutase, hydrogen peroxide activities and proline were measured by Aebi (1984), Dhindsa et al. (1981), Sergiev et al. (1997) and Bates (1973), respectively.After 70 days of experiment, treated second rice leaves were collected and ChlF was taken after placing 30 min dark incubation of each leaf by imaging ûuorometer (Imaging PAM – MAXI version, Heinz Walz GmbH), adopting the methodology proposed by van Kooten and Snel (1990). This imaging-PAM maxi-series was used to measure, minimum (F_o) and maximum fluorescence (Fm), quantum yield of PSII (Y (II)), photochemical quenching (qP), non-photochemical quenching (qN), electron transport rate (ETR) in each treated leaf.

RESULT

The results indicated that combined application of AA and Avi2 significantly (p<0.05) increased the total chlorophyll, relative water content, electrolytic leakage, super oxide dismutase, and catalase activities in all rice cultivars as compared to other MDS treatments, whereas stress indicators like proline and H_2O_2 contents were proportionally increased under MS and their concentration were subsidized under combined application of AA and Avi2. Photochemical quenching, non-photochemical quenching, photosynthetic electron transport rate, and the effective quantum efficiency were found to be increased significantly (p<0.05) in Avi2+AA as compared to other MDS treatments. Moreover, rice roots harbored significantly (p<0.05) higher copy number of *nifH* gene in Avi2+AA treatment under MDS. Combined application of AA and Avi2 also increased the grain yield significantly (p<0.05) by 7.09%, 3.92%, 34.19% and 31.70% in Satyabhama, Ankit, IR64, and Naveen, respectively under MDS compared to MDS alone (Fig. 1). Overall, the present study indicated that AA along with Avi2 could be an effective formulation to alleviate MDS *vis a vis* enhances PGP traits in rice.

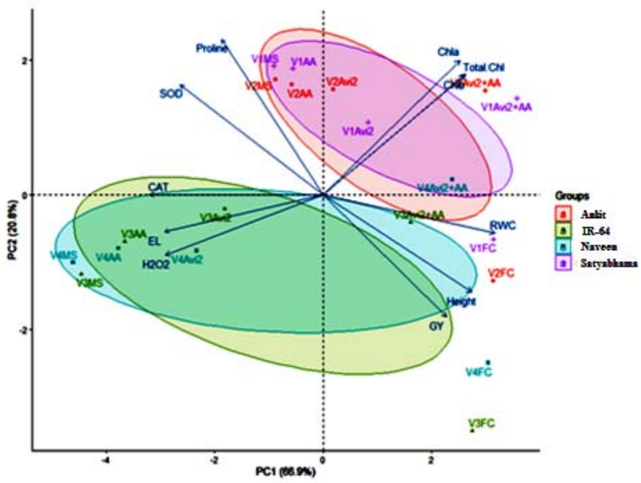

Fig. 1. Principle component analysis (PCA) among the treatments of FC- flooded control; MS- moisture stress; Avi2- *Azotobacterchroococcum*; AA- ascorbic acid; Avi2+AA- *A. chroococcum* + ascorbic acid and measured variables *viz.* RWC: relative water content; EL: electrolytic leakage; SOD: super oxide dismutase; CAT: catalase; H_2O_2: hydrogen peroxide; Proline: proline content; chla: chlorophyll a; chlb: chlorophyll b; total chlorophyll; height and GY: grain yieldindrought tolerant (Satyabhama-V1, Ankit-V2) and drought susceptible (IR64-V3, Naveen-V4) rice cultivars.

CONCLUSION

The present study concludes that the combined application of *A. chroococcum* Avi2 and AA could improve plant growth by alleviating the MDS through increasing RWC, chlorophyll pigments, antioxidant enzyme activities, *nifH* gene copy number and ChlF-based photosynthetic coefficients and reducing EL content and proline activity in drought-tolerant (Satyabhama and Ankit) and susceptible (IR64 and Naveen) cultivars. Moreover, evaluation of ChlF-based photosynthetic coefficients and*nifH* gene quantification were used for the first time to assess the correlation between photosynthesis and plant N under MS in drought-susceptible and tolerant rice cultivars which depicted that both were found higher in all cultivars after combined application of Avi2 and AA, thereby resulted in higher grain yield under MS. Overall, the present study summarizes that AA + Avi2 could serve as an effective formulation to alleviate MS *vis a vis* enhance PGP traits in rice, however, further studies are needed to assess its effects under drought-prone field condition.

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IRC/TM-2/PP-42

MORPHOLOGICAL ANDPHYSIOLOGICAL IDENTIFICATION OFSPOROCARP PRODUCING *Azolla* STRAINS

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Azolla is one of the genera under pteridophytes and a small water floating fern, which is known as'green gold mine'because of its potentialuse in several commercial purposes such as biofertilizer, livestock feed, human food, wastewater treatment, medicine, biofuel, etc.However, studies regarding its taxonomy are still under confusion. In the late 20th century, seven distinct species were grouped under two subgenera namely *Azolla* and *Tetrasporocarpia* based on their morphological and reproductive structures. Again, subgenus *Azolla* is divided further into two section namely Euazolla (*A. caroliniana*, *A. filiculoides*, *A. mexicana*, *A. microphylla* and *A. rubra*) and Rhizosperma (*A. pinnata*). For identification of *Azolla* species, other than using microscopic techniques, many different cytological and physiological techniques were also used. But still confusion persists in its species level mainly under section Euazolla, due to showing similar appearance and transforms under differing environmental conditions. Thus, in orderto identify 102 strains of *Azolla* germplasm including six known species (*A. caroliniana*, *A. filiculoides*, *A. mexicana*, *A. microphylla*, *A. pinnata* and *A. rubra*) which are maintained at ICAR- National Rice Research Institute, Cuttack, Odisha (Kumar et al., 2019; Kumar and Nayak, 2019). The identification mainly based on the morphological and physiological characters using stereo and compound light microscopy as well as different advance technologies like root imaging and chlorophyll florescence imaging.

METHODOLOGY

Identification of *Azolla* strains based on their emergence of sporocarp during December, 2017 to February, 2018 and these strains were maintained in IRRI-2 media for further analysis at ICAR- NRRI, microbiology net house condition. For microscopy analysis, 15 days old matured fronds of sporocarp-producing *Azolla* strains were used and observed different morphological characters such as type of shape and imbrications of fronds, dorsal leaf lobe (DLL) shape, ventral leaf lobe (VLL) colour, angle between DLL and VLL and root hairs under stereo-zoom microscope. To observe associated cyanobacteria, single leaf of each frond was smashed on the slide and image was taken under compound microscope with 40x magnification.For physiological analysis, moisture content (MC%), relative growth rate (RGR), relative frond number (RFN), and doubling time (DT) were calculated using formulae derived by Hechler and Dawson, 1995, Vafaei, 2012 and Pistori, 2004respectively.Photosynthetic piments such as chlorophyll a (chl*a*), chlorophyll b (chl*b*) and carotenoids using100% acetone with the help of spectrophotometer then calculated using equations derived by Lichtenthaler and Wellburn, 1983 for chlorophyll estimation and Sumantaet al., 2014 for carotenoids estimation.For chlorophyll florescence imaging,F_v/F_m was measured by using an imaging pulse amplitude modulated (PAM) fluorimeter where ImageWIN software processed data along with virtual colour images which shows the maximum quantum efficiency of PS II.For root imaging, WinRHIZO software is used for collecting data of root morphology like length, volume, surface area, average diameter and projectile area of each strains of *Azolla* and analysed.

RESULTS

The results showed that of 96, 21 strains (CRRI-1, CRRI-2, CRRI-3, CRRI-4, CRRI-5, CRRI-6, CRRI-7, CRRI-8, CRRI-9, CRRI-10,

CRR-11, CRRI-12, CRRI-14, CRRI-15, CRRI-16, IEPI-1, IEPI-4, R-86, R-94, and Pinnata Assam)were sporulated at NRRI during December to February, 2018 along with 2 known species i.e. *A. microphylla* and *A. Pinnata*(Fig. 1). Interestingly, all sporulating strains except GSMI-1 showed morphologically resemblance with *Azolla pinnata*. Morphological characters such as sporocarp production, star shaped frond and medium imbricated leaves of GSMI-1 made it resembled with *A. microphylla*. Moreover,heat-map and biplot analysis derived from physiological data also revealed that GSMI1 was resembled with *A. microphylla*. Interestingly,presence of rounded leaf lobe in *Azollacaroliniana*made it a unique species in Euzolla section and hence, differentiated from other four species (*A. filiculoides*, *A. mexicana*, *A. microphylla* and *A. rubra*) from this section. WinRHIZO-based root imaging technique showed the presence of thick root hairs in *A. pinnata* compared to other *Azolla* strains, whereas chlorophyll fluorescence imaging-derived F_v/F_m and relative growth rate was found higher in CRRI-4 strain.

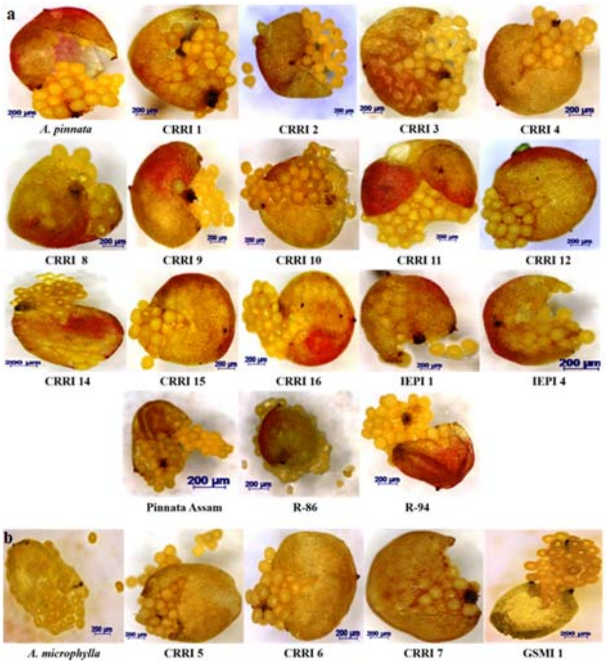

Fig. 1. Coat colourofmicrosporocarpsin different *Azolla*strains.(a) Red tinted, (b) Translucent yellow colour of microsporocarp layers.

CONCLUSION

The present study concludes that only one-fourth of *Azolla* strains showed sporulation at NRRI, Cuttack, which indicates that climatic condition, is the most important to induce sporocarp formation. Results also showed that all sporulating strains except GSMI-1 were morphologically resembles with *A. pinnata*, belonged to Rhizosperma sub-section. Sporulation, star shaped frond, medium imbricated leaves and thin root hairs of GSMI-1 resembled to *A. microphylla* but differ in presence of VLL colour.Interestingly,rounded DLL was only present in *A. caroliniana*amongEuazolla sub-section (*A. microphylla*, *A. mexicana*, *A. filiculoides* and *A. rubra*) which could serve as a unique morphological marker to differentiate it from other four species of Euazolla. Moreover, our study strainsusedrootimaging of sporocarpproducing*Azolla* strains for the first time which also revealed the close association of GSMI-1 with *A. microphylla*. Chlorophyll florescence imaging technique was revealed for the first time to differentiate *A. rubra* from other strains as F_v/F_m value was found to be lowest in it, hence, this technique could also be used as a remarkable physiological marker. Overall, the morphological and physiological markers identified in the present study to differentiate *Azolla* strains will be further utilized to identify unique molecular markers to revalidate and differentiate wide strains of *Azolla* sp.

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EFFECT OF SOWING TIME, SOIL MIX AND PHOSPHORUS NUTRITION ON GERMINATION AND SEEDLING VIGOUR OF SUMMER RICE IN MAT NURSERY UNDER *TERAI*ZONE OF WEST BENGAL, INDIA

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Mechanized rice cultivation is a step with the target of production enhancement keeping in mind labour scarcity, timeliness in operation and cost reduction. Paddytransplanter is getting popular now-a-days in *terai* region of West Bengal for both monsoon and summer rice. For establishing a good crop throughpaddytransplanter, raising healthy seedlings in mat nursery is a pre-requisite. Though a modified rice mat nursery may produce robust seedlings in much shorter time, but it is really challenging for summer rice as cold injury has been identified as one of the major abiotic constraint hampering the growth of seedlings and thus limiting the yield of summer rice. Low temperature severely restricts seedling growth and sometimes death of the seedlings. Seeding in appropriate window in mat nursery favoursmuch quicker growth of the seedlings with good vigour. We are targeting to transplant healthy seedlings under unpuddledconditionthroughpaddytransplanter which has been proved as a productive, profitable and energy-efficient establishment technique in this region (Mitraet al. 2018). For last couple of years this unpuddled transplanting has got momentum in *terai*regionof West Bengal with the rapid adoption of paddy transplanter. With a view to produce robust seedlings, an attempt has been made to identify appropriate sowing window for summer rice in mat nursery and to evaluate the media for preparing mat. It has also been reported that it is necessary to apply higher doses of P fertilizers during cooler months and this experiment has also been focused to standardize the P application rate for mat nursery.

METHODOLOGY

The experiment was conducted at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India during *boro* season, 2018-19 with a target to raise healthy seedlings in mat nursery for its transplanting through paddy transplanter. The design of the experiment was 3 factor-CRD. Dates of seeding, growing media and phosphorus application rates were served as three factors. There were three seeding dates*viz.* December 25, January 09 and January 24; two different growing media *viz.* 80% soil with 20% vermicompost and 80% soil with 20% FYM; four levels of P application in *viz.* control (No SSP),10 g SSP/tray,20 g SSP/tray and30 g SSP/tray. The tray dimension was 58 cm × 28 cm × 2.5 cm to fit into thepaddytransplanter

The seeds were primed with 0.5% Zn-EDTA before putting them to mat nursery. In mat-type nursery rice seedlings were raised on a thin layer of soil and farm yard manure (FYM) or vermi-compost mixture (based on treatments) @ 4:1 placed on a tray. The thickness of soil + compost layer was kept at exactly 1 inch to facilitate the picking of seedlings by the paddy transplanter from the tray. The variety used in the experiment was MTU 1010.All the observations were takenconsidering end-December to end-January is the appropriate sowing window of the crop for this region.

RESULTS

Results showed that date of seeding in tray nursery had a significant effect on germination percentage, root and shoot length *vis-à-vis*vigour index

Table 1.Germination percentage, vigour index, shoot and root dry weight as influenced by different sowing dates, soil media and P-nutrition

Treatments	Germination (%)	Shoot Length (cm)	Root Length (cm)	Vigour index	Shoot dry weight (mg 10 seedlings^{-1})	Root dry weight (mg 10 seedlings^{-1})
Seeding dates						
25 December	80.4	7.11	4.42	927	67.5	83.2
9 January	87.5	8.36	6.09	1265	80.1	91.6
24 January	95.2	10.18	7.13	1648	118.6	135.8
SEm(±)	0.45	0.12	0.16	0.14	1.18	0.73
CD(P=0.05)	1.40	0.36	0.48	0.43	3.55	2.19
Soil Media						
80% soil with 20% Vermicompost	87.8	9.36	5.82	1334	93.3	107.0
80% soil with 20% FYM	87.6	8.55	5.43	1225	85.4	99.5
SEm(±)	0.67	0.10	0.13	0.12	0.95	0.57
CD(P=0.05)	NS	0.31	0.40	0.35	2.86	1.73
P Nutrition						
No SSP	87.7	7.38	5.02	1087	60.5	72.2
10 g SSP/Tray	87.8	8.23	5.73	1225	69.0	76.5
20 g SSP/Tray	87.4	9.20	6.14	1341	72.9	85.1
30 g SSP/tray	88.0	9.98	6.68	1466	77.3	89.3
SEm(±)	0.90	0.15	0.19	0.16	1.34	0.81
CD(P=0.05)	NS	0.44	0.57	0.49	4.04	2.44

(VI)as well as seedling shoot and root dry weight. It was evident that amongst the various dates, the germination percentage was lower with 25December seeding (Table 1). During that period, the temperature particularly the night temperature dropped down to 6.3°C for which germination was hampered (meteorological parameters not given). Similarly due to fair cool temperature, the growth of the seedlings were poor which reflected through the lower shoot and root length as well as root and shoot dry weight. Ultimately the VI showed lower value (927) under December 25 seeding.

It was noted that the seedling germination percentage, root and shoot length, VI and seedling dry weight (both root and shoot) were progressively increased with successive sowing dates. When the seeds were sown in 24 January, it recorded the maximum germination percentage (95.2) with higher VI (1648) and seedling shoots(118.6mg/ 10 seedlings) and root dry weight (135.8 mg/ 10 seedlings). With later sowing dates, there was increase in mean temperature, particularly the night temperature for which the cold injury to the seedling was lesser. It attributed to vigorous growth of the seedlings for which there was higher VI and higher seedling shoot and root dry weight. Though soil media had no significant effect on germination percentage, use of vermicompost in the seedbed recorded significantly higher shoot and root length *vis-à-vis*VI and seedling shoot and root dry weight. Incremental P doses had no significant effect on germination percentage; however, VI and seedling dry weights differed significantly under varying P nutrition levels. The maximum VI (1466), seedling shoot dry weight (77.3 mg 10 seedlings^{-1}) and root dry weight (89.3 mg 10 seedlings^{-1}) were achieved with trays where 30 g SSP as a source of P were added/tray.

CONCLUSION

Date of sowing had a significant effect on germination percentage, root and shoot length *vis-à-vis*vigour index (VI)as well as seedling shoot and root dry weight for summer rice. Using vermicompost(20%) in soil media and addition of 30 g SSP/tray had a significant effect towards increasing the seedling vigour. Seeding during fourth week of January with 30 g SSP/ tray could be recommended for better growth and management of rice seedlings for mat nursery.

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EVALUATION OF DRR LEAF COLOUR CHART FOR RICE VARIETIES SOWN WITH DRUM SEEDER

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It is well known that the fertilizer requirements of rice vary with the type of soil and agroclimatic sitation and method of crop establishment. As direct sowing with drum seeder is being actively adopted by farmers of North Coastal Zone of Andhra Pradesh, trial on the timing of nitrogen application on real time management would further the productivity of rice. Research conducted at Agricultural College, Naira during *kharif* 2011 indicated that for semi dry rice Nitrogen management with LCC (value 4) based nitrogen application produced higher grain yield 4484 kg/ha and was comparable with N applied in four splits ¼ each at basal, conversion to wet, panicle initiation and flowering (4649 kg/ha). Hence the present trial was taken up with an objective to optimize the nitrogen requirement of direct seeded drum seeded rice based on real time N management for rice.

METHODOLOGY:

A trial was conducted at Agricultural Research Station, Ragolu during *kharif* 2013 to optimize the nitrogen requirement of direct seeded drum seeded rice based on real time N management for rice in the North coastal zone of Andhra Pradesh.For this purpose the leaf colour chart developed by Directorate of Rice Research, Hyderabad was tested. It consisted of seven LCC bands from 1 to 7. The treatments consisted of four varieties V1-Swarna, V2-Sambamahsuri, V3-Vijetha and V4- Srikurma in main plots and four LCC values of DRR leaf colour chart L1-LCC 4, L2-LCC 5 , L3- LCC 6 and L4- LCC 7 in subplots in three replications in split plot design tested in Red Sandy lands with clay base. A rainfall of 890.8 mm in 30 rainy days was recorded against the normal rainfall of 776.4 mm in 34 rainy days during the crop growth period and was congenial for crop growth. respectively. Pregerminated seeds of rice were sown on puddled soil through drum seeder at the rate of 30 kg ha^{-1}. All the plots received a uniform dose of N, P and K @ 120-60-50 kg/ha. Nitrogen was applied in three equal split does at 15 DAS, maximum tillering and at panicle initiation stage. Ten plants were marked in the net plot and the intensity of colour of top fully expanded leaf was measured by holding the leaf colour chart against the leaf. The readings were taken at 8-10 days interval starting from 21 days after seeding and continued up to flowering. When the mean leaf colour fell below the set threshold LCC value, N was applied @ 20 kg/ha. Observation on growth and yield parameters were recorded and analysed statistically.

RESULTS:

The results of the trial as shown in table indicated that grain yield and straw yield of rice was the highest with Swarna and significantly superior to all the varieties except Vijetha with which it was comparable. The highest grain yield and straw yield was obtained with LCC 7 but was on par with LCC 6. The interaction was significant for grain yield between varieties and LCC values and the interaction effect revealed that Vijetha with LCC 7 recorded higher grain yield, whereas swarna gave higher grain yield with LCC 5.Number of filled grains per panicle were non significant with varieties while they were the highest with LCC 7 in subplots. Panicles/m^2 were the highest with Srikurma variety but did not differ among subplots.

Table 1: Effect of leaf colur chart on performance of different varieties of rice

Varieties/LCC Value	Grain yield (kg/ha)	Straw Yield (kg/ha)	Panicles/Sq.m	filled spikelets/ panicle	1000 grain wt (g)
Varieties					
V1-Swarna	4561	5701	413	104	20.08
V2-Sambamahsuri	4059	5074	417	103	18.75
V3- Vijetha	4439	5549	540	111	24.25
V4- Srikurma	4116	5145	410	112	21.5
SEm+/-	123.8	182	12.75	3.48	0.61
CD	427	543	44	NS	2.11
LCC Value					
L1-LCC 4	3210	4013	446	101	19.33
L2-LCC 5	4233	5291	441	105	19.67
L3- LCC 6	4814	6018	447	110	20.17
L4- LCC 7	4918	6148	457	117	20.42
SEm+/-	135.6	172	14.04	3.77	0.67
CD	396	502	NS	11	NS

Thousand grain weight was the least with sambamahsuri which was comparable with Swarna but did not differ among LCC values tested.

The above results corroborate with experiment by Sathiya and Ramesh (2009) at Tamilnadu Agricultural University, Coimbatore during *kharif*, 2006 showed that nitrogen management at LCC value of 4 (150 kg N ha^{-1}) produced significantly higher tillers (369.3 m^{-2}) at maximum tillering stage, plant height (81.7 cm) at maturity, dry matter at flowering (5.71 t ha^{-1}) and grain yield (2915 kg ha^{-1}) than LCC value of 3 that produced grain yield of 2211 kg ha^{-1}. Study by Masthana Reddy et al (2005) clearly indicated that scheduling of N to drum seeded rice based on LCC value 6 appeared to be promising and assured the farmer with higher yield and monetary benefits

CONCLUSION:

It was concluded that variety Swarna has shown superior performance in terms of yield attributes and grain yield, which was closely followed by Vijetha. Among the LCC values LCC 7 recorded higher grain yield followed by LCC 6.Interaction effect revealed that Vijetha with LCC 7 recorded higher grain yield, whereas swarna gave higher grain yield with LCC 5.

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 IRC/TM-2/PP-45

RESPONSE OF DIRECT SEEDED RICE TO INTEGRATED WEED AND NUTRIENT MANAGEMENT UNDER RAINFED CONDITION OF MANIPUR VALLEY

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Direct seeding of rice in low lying areas before the onset or after the onset of monsoon is becoming common among the farmers of Manipur as it is less laborious and time saving. Moreover direct seeded rice matures 7-10 days earlier than transplanted rice due to the absence of transplanting shock. However, a major hindrance in the successful cultivation of direct seeded rice is heavy infestation of weeds which cause drastic reduction in yield. Uncontrolled growth of weeds caused 33-45% reduction in rice grain yield (Manhas*et al.,* 2012). The integration of chemical followed by mechanical weedingis cheaper and more effective than hand weeding alone as well as more sustainable than the application of herbicides alone. In rice, weed control by a single method is not remunerative because of higher infestation of weeds. Integrated nutrient management aims at efficient and judicious use of all the sources of plant nutrients in an integrated manner, to attain sustainable crop production with minimum deleterious effect of chemical fertilizers on soil health and least disturbance to the plant-soil-environment. Moreover, chemical fertilizers release plant nutrients more rapidly into the soil as compared to organic manures as a result there is proliferation in weed growth.Keeping the above points in mind, the present investigation was carried out in order to find out the response of direct seeded rice with respect to yield attributes and yield under different integrated weed and nutrient management practices.

METHODOLOGY

The field experiment was conducted at the Research farm of College of Agriculture, Central Agricultural University, Imphal during the kharif season of 2016 and 2017. The soil of the experimental field was clayey in texture. The soil was medium in fertility with good drainage facility with 5.34 pH, high in organic carbon with 1.89%, 280.88 kg ha^{-1} available nitrogen, 32.20 kg ha^{-1} available P_2O_5 and 270 kg ha^{-1} available K_2O, respectively. The experiment was laid out in a factorial randomized block design (FRBD) in 3 replications. The treatments comprised of 5 levels of weed management practices viz., Pyrazosulfuron ethyl (PSE)@50g a.i at 7 DAS, Pyrazosulfuron ethyl (PSE)@30g a.i at 7 DAS + 1 HW at 40 DAS, Pyrazosulfuron ethyl (PSE)@30 g a.i at 7 DAS + 1 MW at 40 DAS, Pyrazosulfuron ethyl (PSE)@30g a.i at 7 DAS + 2, 4-D @ 0.75kg a.i at 40 DAS and weedy check and three levels of nutrient management practices i.e. 50% N from RDF + 6 t FYM, 50% N from RDF + Azolla (dual crop)@10 t/ha + 3t FYM and 100% RDF. The variety used in the experiment was CAU-R1. The plots receiving FYM were applied at final puddling operation. The recommended dose of fertilizer was 60:40:30 kg N, P_2O_5 and K_2O ha^{-1} respectively. Sowing was done in first week of June @80 kg ha^{-1} in lines with 20 cm x 10 cm spacing. Azolla was applied in rice as per treatment as a dual crop at 25 DAS @ 10 t/ha and was incorporated at 40 DAS. Weed management practices were given as per the treatments. Yield attributes and yield were recorded at the time of harvest. The data so obtained were subjected to statistical analysis by the analysis of variance method described by Panse and Sukhatme (1995) and the significant of different sources of variations were tested by error mean square by Fisher and Snedecor's F test at probability level 0.05.

RESULTS

As evident from the pooled data in Table 1, the plots receiving PSE@30 g a.i at 7 DAS followed by eitherhand weeding or mechanical weeding at 40 DAS recorded the highest number of effective tillers hill^{-1} (9.95 and 9.36), longest panicle (25.66 cm and 26.15 cm), highest panicle weight (4.07 g and 4.15 g), grain yield (48.34 q ha^{-1} and 46.70 q ha^{-1}) and straw yield (68.15 q ha^{-1} and 63.06 q ha^{-1}) with no significant difference between them except for straw yield. However, significantly highest number of spikelets and filled grains panicle^{-1} were observed in the plot receiving PSE@30 g a.i at 7 DAS + 1 MW at 40 DAS (226.88 and 174.63) which was closely followed by the application of PSE@30 g a.i at 7 DAS + 1 HW at 40 DAS (215.28 and 167.83). The lowest grain and straw yield was obtained from the weedy check plot.

Application of 50% N from RDF + 6 t FYM gave the longest panicle length (25.61 cm) but remained at par with 100% RDF (25.55 cm) followed by the application of 50% N from RDF + Azolla (dual crop)@10 t/ha + 3t FYM (24.86 cm). Similarly, significantly highest number of spikelets (209.59) and filled grains panicle^{-1} (160.71) were recorded from the application of 50% N from RDF + 6t FYM. It was observed that number of spikelets and filled grains panicle^{-1} did not differ significantly in the pooled data with the application of 50% N from RDF + Azolla (dual crop)@10 t/ha + 3t FYM and 100% RDF. No

Table 1: Effect of integrated weed and nutrient management on the yield attributes and yield of kharif rice at harvest (pooled data of two years)

Treatment	Number of effective tillers hill^{-1}	Panicle length (cm)	Panicle weight (g)	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
PSE @50g a.i at 7 DAS	8.46	24.94	3.65	190.99	156.61	41.75	56.47
PSE@30g a.i at 7 DAS + 1 HW at 40 DAS	9.95	25.65	4.07	215.28	167.83	48.34	68.15
PSE@30 g a.i at 7 DAS+1 MW at 40 DAS	9.36	26.15	4.15	226.88	174.63	46.70	63.06
PSE@30g a.i at 7 DAS + 2, 4-D @ 0.75kg a.i at 40 DAS	8.86	25.66	3.85	212.27	162.45	44.43	60.15
Weedy check	4.74	24.30	3.58	161.29	123.58	27.47	37.73
SEm(±)	0.24	0.18	0.10	2.45	2.11	0.89	1.50
CD(p=0.05)	0.69	0.51	0.28	7.10	6.10	2.59	4.35
50% N from RDF + 6 t FYM	8.56	25.61	3.91	209.59	160.71	43.17	58.32
50% N from RDF + Azolla (dual crop) @10 t/ha + 3t FYM	7.95	24.86	3.75	198.61	153.63	41.92	56.70
100% RDF	8.31	25.55	3.91	195.82	156.71	40.12	56.31
SEm(±)	0.19	0.14	0.08	1.90	1.63	0.69	1.16
CD(p=0.05)	NS	0.40	NS	5.50	4.73	2.01	NS

significant effect was found in the number of effective tillers hill^{-1} and panicle weight. The highest grain yield (43.17 q ha^{-1}) was recorded with the application of 50% N from RDF + 6t FYM which was at par with the application of 50% N from RDF + Azolla(dual crop)@10 t/ha + 3t FYM (41.92 q ha^{-1}).

CONCLUSION

From the above results, it can be concluded that application of Pyrazosulfuron ethyl@30 g a.i at 7 DAS followed by eitherhand weeding or mechanical weeding at 40 DAS and integrated nutrient management with 50% N from RDF + 6t FYM and 50% N from RDF + Azolla(dual crop)@10 t/ha + 3t FYM resulted in better productivity. Thus, it can be recommended to the farmers as a feasible practice to control weeds and improve the productivity of direct seeded kharif rice under rainfed condition in the north east region of India.

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Theme - II : Sustainable rice farming IRC/TM-2/PP-46

ENHANCING RICE PRODUCTIVITY UNDER DIFFERENT IRRIGATION REGIMES AND SYSTEMS OF CULTIVATION

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Indian farmers cultivating transplanted rice in rained and irrigated/flooded areas are progressively confronted with water deficiencies because of shortage precipitation, declining groundwater table because of insufficient recharge, late and limited release of irrigation water from canals/trenches, and poor inflows into tanks(Swain *et al.*, 2013). Rice Production in 2018-19 was 493.79 million tons. 2019-20 year 501.96 estimated millions tons could represent an increase of 8.17 million tons or 1.65% in rice production around the globe (GAIN, 2020).Rice might face a threat due to water shortage and hence it's needed to follow water-saving strategies in rice cultivation so that production and productivity levels are elevated despite the looming water crisis. Among the strategies for rice cultivation, the system of rice intensification method envisages on alternate wetting and drying could facilitate to chop back water losses and improve productivity.To generate more information on the performance of rice cultivars under different irrigation regimes andsystems of cultivation thepresent study was conducted with the objectives of (1) the performance of rice under different systems of cultivation, (2) to evaluate rice cultivars for growth and yield under different irrigation regimes and systems of cultivation.

METHODOLOGY

Field experiments were carried out during *Kharif*, 2017, and 2018 at Indian Institute of Rice Research (IIRR), Rajendranagar Hyderabad. The treatments consisted of two irrigation regimes alternate wetting and drying (AWD) and saturation as main plot treatments, three systems of cultivation *viz.*,a system of rice intensification (SRI) with a spacing of 25 cm x 25 cm, drum seeding (DS) with the spacing of 20 cm x 10 cm and normal transplanting (NTP) with the spacing of 20 cm x 15 cm as subplot treatments and four cultivars namely DRR Dhan 42, DRR Dhan 43, MTU-1010 and NLR-34449 as sub-sub plot treatments laid out in split-split plot design with three replications.The area of each gross plot was 7 x 3 m^2. Seedlings were transplanted with an average of one seedling per hill in the SRI method of planting. FYM at @ 10 t ha^{-1} was uniformly applied to all the plots before final puddling and leveling. The recommended dose of phosphorus @ 60 kg P_2O_5 kg ha^{-1} as single super phosphate (SSP) was applied to all the treatments uniformly as basal and potassium @ 40 kg K_2O ha^{-1} as muriate of potash (MOP) was applied in two splits, 75 percent as basal and the remaining 25 percent at 75 DAS/DAT. The recommended dose of nitrogen (120 kg ha^{-1}) was applied through urea in three splits, 50 percent as basal, 25 percent at 50 DAS/DAT, and the remaining 25 percent at 75 DAS/DAT.

RESULTS

Among the irrigation regimes, AWD irrigation practice recorded higher grain yield (5755, 5952 and 5854 kg ha^{-1} in 2017, 2018 and pooled means, respectively) than saturation (5346, 5491 and 5439 kg ha^{-1} in 2017, 2018, and in pooled means, respectively).Among the different systems of cultivation,theSRI recorded significantly higher grain yield (5953, 6129, and 6041 kg ha^{-1} during 2017, 2018, and in pooled means, respectively) over the normal transplanting method. (5144, 5259 and 5202 kg ha^{-1} during 2017, 2018 and in pooled means, respectively). This was however on par with the drum seeding method (5784, 5826, and 5805 kg ha^{-1} during 2017, 2018, and in pooled means, respectively).Among the different rice cultivars, DRR Dhan 43 registered higher grain yieldthan other cultivars during 2017 and 2018.Higher grain yieldwas noticed in DRR Dhan 43 (6055, 6122 and 6089 kg ha^{-1} during 2017, 2018 and in pooled means, respectively) followed by MTU-1010 (5631, 5733 and 5682 kg ha^{-1} during 2017, 2018 and in pooled means, respectively) and NLR-34449 (5476, 5590 and 5533 kg ha^{-1} during 2017, 2018 and in pooled means, respectively). However, significantly lower grain yield was recorded in DRR Dhan 42.

Within irrigation regimes, AWD recorded significantly higher straw yield (6287, 6558, and 6423 kg ha^{-1} during 2017, 2018, and in pooled means, respectively) than saturation (5878, 6011 and 5995 kg ha^{-1} in 2017, 2018, and pooled means, respectively).Among the different systems of cultivation,the SRI method recorded higher straw yield (6246, 6546, and 6396 kg ha^{-1} during 2017, 2018, and in pooled means, respectively) over other systems of cultivation. Among the different rice cultivars, DRR Dhan 43 recorded significantly higher straw yield than other cultivars (6459, 6981, and 6620 kg ha^{-1} during 2017, 2018, and in pooled means, respectively). The lower straw yield was observed in DRR Dhan 42 (5710, 5899, and 5805 kg ha^{-1} during 2017, 2018, and in pooled means, respectively). However, cultivars MTU - 1010, NLR -34449, and DRR Dhan 42 were on par with each other during 2017 and 2018.

Irrigation with AWDmethod recorded a significantly higher B:C ratio (2.81, 2.92 and 2.87 during 2017, 2018 and in pooled means, respectively) than saturation. The higher mean values of the B: C ratio were observed in drum seeding (2.98, 3.06 and 3.02 during 2017, 2018 and in pooled means, respectively) than normal transplanting.DRRDhan 43 noticed significantly higher B:C ratio (2.87, 2.96 and 2.91 during 2017, 2018 and in pooled means, respectively) over other cultivars.

CONCLUSION

Either DRR Dhan 43 (long and bold grain type) or NLR-34449 (fine grain type) cultivars of rice can be grown under SRI or drum seeding method of sowing with alternate wetting and drying irrigation system for higher yield and economic returns.

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IRC/TM-2/PP-47

SIMULATION OF METHANE AND NITROUS OXIDE EMISSIONS BY DNDC MODEL IN LOWLAND RICE AMENDED BY BIO- AND INDUSTRIAL WASTE

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The DNDC (De Nitrification and De Composition) model is a process based simulation model and a powerful assessment tool which could predict carbon and nitrogen dynamics in soil as well as in plant. In DNDC, the details of management (e.g., tillage, crop rotation, manure modification, fertilization, irrigation, and weeding) have been defined and identified with the different biogeochemical processes (e.g., crop growth, soil water infiltration, decomposition, nitrification, denitrification etc.).Calibration and validation against observed records is a necessary first step of model establishment. If observed value agree well with the simulated value, we can assume that the model simulates precisely considering the biogeochemical activities. The emissions of GHGs (methane, nitrous oxide) could be simulated in rice and the effects of amendments including fertilizers, manures, wastes etc., also could be modelled. In this study we try to simulate and validate the methane and nitrous oxide emissions from lowland rice as affected by different bio- and industrial wastes.

METHODOLOGY

The DNDC model has been calibrated and validated for GHGs emissions in lowland rice in eastern India. The DNDC model was calibrated against the treatments in rice included, (i) T_1- urea (60 kg N ha^{-1}); (ii) T_2 - rice straw + urea (1:1 N basis) (30 kg ha^{-1} each from two different sources). The *kharif* season data for calibration were taken from the published literature (Bhattacharyya *et al.*, 2012). The model was validate against the field data set of CH_4 and N_2O emission from the lowland rice amended by bio- and industrial wastes during 2018 and 2019 *kharif* from experimental field of NRRI, Cuttack with two different treatments i.e. (i) RDF; 80:40:40:: N:P_2O_5:K_2O kg ha^{-1} (ii) RDF + rice straw-incorporation (5t ha^{-1}). The simulations were also done with another three different treatments i.e. (i) RDF; nitrogen through ammonium sulphate (as a substitute of neem coated urea), (ii) RDF + phosphogypsum (2t ha^{-1}) (iii) RDF + rice straw-compost (5t ha^{-1}).

RESULTS

In calibration, the observed emission of CH_4 during the growing season in T_1 and T_2 were 92.6 and 115.4 kg ha^{-1}, while the simulated emissions were 91.9 and 117.4 kg ha^{-1}, respectively. Emissions of N_2O were 1.00 and 0.84 kg ha^{-1} under both the treatments (NPK and NPK + straw), while the simulated values were 0.73 and 0.61 kg N_2O ha^{-1}. In all the cases the deviation of the simulated values from the observed values were less than 5% in methane. However, in case of N_2O the deviations were 17 and 15%, in NPK and NPK + straw treatment, respectively,

During validation and simulation, the methane emission was followed similar patterns in RDF as well as in other amended plots although the magnitude of emissions varied. Our observed data suggested a significant reduction in seasonal methane emission in both the *kharif* seasons of 2018 and 2019 in lowland rice ecology by application of phosphogypsum and ammonium sulphate. The DNDC model also well simulated the methane emission in both the treatments. The higher sulphate content of phosphogypsum might be the reason for lower emission as it prevents the CH_4 formation due to a stronger competition for substrates (hydrogen or acetate) between sulphur reducing

Table 1: Observed and simulated values of yield, N uptake and GHG emission in lowland rice (*kharif* 2011).

Parameters	NPK			NPK + Rice straw		
	Observed(O)	Simulated(M)	Deviation (%)	Observed	Simulated	Deviation (%)
Grain yield (t ha^{-1})	5.13	5.14	0.19	5.57	5.58	0.17
Crop N uptake (kg ha^{-1})	142	141	0.7	154	153	0.6
Seasonal CH_4 emission (kg ha^{-1})	92.6	91.9	0.7	115.4	117.4	1.7
Seasonal N_2O emission (kg ha^{-1})	1.00	0.83	17	0.84	0.71	15

bacteria (SRB) and methanogens in rice soils. The simulated methane emission by the DNDC model in rice straw-incorporation and rice straw-compost treatment was also well fitted with the observed values in both the *kharif* seasons of 2018 and 2019.

CONCLUSION

There are uncertainties in estimation of GHG emissions from different rice ecologies because of its diverse soil and climate conditions. Moreover, various crop management practices, water and fertilizer management for example, play a major role in the emission. What is Indian agriculture's real contribution to GHG emissions could be answered precisely by using simulation models. Validating and evaluating the performance of DNDC in simulating the CH_4 and N_2O emissions in side-by-side field trials of various management treatments is the necessary first step in determining the applicability of the model for quantifying GHGs mitigation potentials of alternative practices and for upscaling to a larger spatial scales. The output from these works would be helpful to formulate the management strategies for mitigating the greenhouse gases emission from rice-based cropping systems.

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MITIGATION CUM ADAPTATION OPTIONS FOR REDUCING GHG EMISSION IN RICE GREEN GRAM CROPPING SYSTEM

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Rice production currently accounts for approximately 10% of total global agricultural greenhouse gas (GHG) emissions, most of which (approximately 90%) are emitted from rice paddies in Asia (FAO, 2018). Many approaches for reducing GHG emission and enhancing water use efficiency have been identified in rice based cropping systems. The management of rice residue is also a major problem due to its poor digestibility, low protein, high lignin and silica contents and it is not also preferable as cattle feed. Many farmers, therefore, burn the rice straw on field to save time before sowing of the next crop. Open field straw burning leads to nutrient loss, emission of GHG and air pollutants thereby posing threat to human health (Gupta et al., 2016). Retention of straw on soil surface is an effective mitigation technology to reduce soil emissions and increase soil organic carbon (SOC) stock and also curtail the burning practice. There are some mitigation cum adaptation options to climate change in rice based cropping system which not only reduces the GHGs emission but also sustain the crop yield. Keeping those in view, a field experiment was conducted to assess the mitigation potential of eight different options (bio and industrial waste amendments) in rice green gram cropping system. Therefore, the objective of this study was (i) to quantify the emission of methane and nitrous oxide in rice green gram system as affected by bio and industrial amendments, and (ii) to estimate the GWP and yield scaled GWP in the system as affected by various amendments.

METHODOLOGY

The experiment was conducted at the research plots of ICAR-National Rice Research Institute, Cuttack, in tropical India. The site is characterized by monsoon climate with an average annual rain fall of 1500 mm and the soil texture was sandy loam. Different biological and industrial amendments were chosen for the study those were, rhizobium (Rh), mushroom waste (MW), biochar (BC), rice straw compost (RSC), phosphogypsum (PG) along with methanotroph (MT) and zero tillage treatments. Rice (*Oryza sativa L.*) variety, *CR 202* was planted in *Kharif* season in the month of July, @ row to plant spacing of 20×15 cm. Recommended dose of fertilizer (RDF) as per of this region, were applied *i.e.* @ 80:40:40 kg ha^{-1} ($N:P_2O_5:K_2O$) for wet season rice. Nitrogen (N) was applied as neem coated urea in three splits (50% basal +25% each as two top dressings) in rice. Phosphorus and potassium were applied in a single dose as basal through single super phosphate (SSP) and muriate of potash (KCl), respectively. In dry season, green gram (*Vigna radiata L.*) variety, *Virat* was sown in dry (*rabi*) season at the first week of January, at the seed rate of 25 kg ha^{-1} and row to plant spacing of 30 × 10 cm. A recommended dose of 20: 40: 20 kg ha^{-1} ($N:P_2O_5:K_2O$) was applied in green gram. Full doses of N, P and K were applied at sowing.

The gas samples were collected from different treatments at seven days interval by using manual close chamber method. The gas was collected by using 50 ml syringe and measured the GHGs in gas chromatograph (GC) (Model no. Trace 1110, Thermo Scientific). Integrated values of GHG emissions expressed as global warming potential (GWP) was computed using the IPCC factors for calculating the combined GWPs for 100 years' time scale. The system yield (SY) was calculated from the addition of kharif and rice equivalent yield (REY) of green gram crop.

Table 1: Annual CH_4, N_2O emission, GWP, GHGI and REY from soil in rice green gram system.

Treatments	CH_4 (kg ha^{-1})	N_2O (kg ha^{-1})	GWP (kg ha^{-1})	SY (Mg ha^{-1})	GHGI (kg ha^{-1})
RDF + Rhizobium	63.1±1.80	1.84±0.05	2314.1±6.6	7.71±0.22	0.300±0.01
RDF + Zero tillage	62.7±1.79	1.29±0.04	2142.0±6.1	7.26±0.21	0.295±0.01
RDF + Mushroom waste	65.2±1.86	1.54±0.04	2285.6±6.5	7.57±0.22	0.302±0.01
RDF + Biochar	64.6±1.85	1.54±0.04	2269.3±6.4	7.49±0.21	0.303±0.01
RDF + Rice straw compost	68.4±1.95	1.59±0.05	2392.8±6.8	7.69±0.22	0.311±0.01
RDF + Methanotroph	59.5±1.70	1.54±0.04	2125.3±6.0	7.40±0.21	0.287±0.01
RDF + Phosphogypsum	61.5±1.76	1.66±0.05	2215.4±6.3	7.35±0.21	0.301±0.01
RDF	63.5±1.81	1.78±0.05	2311.5±6.6	7.52±0.21	0.307±0.01

REY was calculated by multiplying the minimum support price of green gram in the respective year with rice crop. Greenhouse gas intensity (GHGI) was calculated using GWP and SY.

RESULTS

Annual CH_4 emissions were more under RDF + rice straw compost treatment in the rice green gram system. Methane emission was less under RDF+MT followed by RDF+PG than other treatments. Mitigation potential of RDF with methanotroph bacterial culture towards methane emission 3-15% compared to other treatments. However, N_2O emissions were higher under RDF+Rh and less in RDF+ZT. Zero tillage treatment with RDF could reduce 42.0% the N_2O emission than RDF+Rh. The GWP were in the range of 2125.3 to 2392.8 kg CO_2 equivalent ha^{-1}. Les GWP was estimated in RDF+MT and could mitigate up to 12.6% compared to RDF+RSC treatment. Maximum system yield was observed under RSC+RDF (5.3 Mg ha^{-1}) and least in RDF+ZT (4.8 Mg ha^{-1}) among the treatments. However, yield scaled greenhouse gas was less under RDF+MT and it is 2.8-7.0% less compared to other treatments.

CONCLUSION

Incorporation of rice straw in combination with RDF was resulted higher yield but at the same time caused higher GHG emissions. On the other hand, RDF + methanotroph treatment showed a lower trend of GWP. Methanotroph treatment along with phosphogypsum are shown potential to mitigate CH_4 emission, which could be adopted in rice green gram system. Therefore, environmental and sustainability point of view RDF with methanotroph and Phosphogypsum offer a potential option of mitigation cum adaptation of GHGs emission in rice green gram cropping system.

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ELUCIDATION OF THE FACTORS AFFECTING ADOPTION OF CLIMATE SMART AGRICULTURAL TECHNOLOGIES FOR VULNERABLE RICE ECOSYSTEM

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In the present context of climate change agricultural production is going to decrease due to various vagaries of adverse climate. To overcome this problem, climate smart agricultural (CSA) technologies are capable of reducing vulnerabilities, increasing productivity and sustainability in production as it is based on three pillars of mitigation, adaption and productivity (Faurès et al., 2013, Khatri-Chhetri et al., 2017). Adoption of CSA technologies dependon the farmers' socioeconomic status, landholding, educational level and many other factors. However,literature comparing adoption of technologies for drought, flood and cyclone affectedrice-growing areas are not much available.This lead use to conduct the present research with the objectives: (i) prioritization of technologies based on experts' opinion for drought, flood and cyclone prone areas. (ii) Identifying the drivers controlling the adoption of CSA technologies in climate vulnerable areas.

METHODOLOGY

Opinion of 10 independent experts were collected and ranked the CSA technologies based on their opinion by the formula (1).

$$\text{Cumulative score} = \frac{(W1\times w1\times a) + (W1\times w2\times b) + (W2\times w3\times c) + (W2\times w4\times d) + (W2\times w5\times e) + (W3\times w6\times f) + (W3\times w7\times g)}{(W1\times 2+W2\times 3+W3\times 2)\times(w1+w2+w3+w4+w5+w6+w7)}$$

Whereas, W1, W2, W3 are the weightage of CSA pillars, *w1, w2, w3, w4, w5, w6, w7*are the weightage of CSA indicators, and a, b, c, d, e, f, g are the score of a specific technology against each CSA indicator. Based on the cumulative score the technology were ranked.

The study area was selected based on climate change and agricultural vulnerability assessment report. About 20 farm household from each villages Harekrishnapur (Dhenkanal sadar block, Dhenkanal district, Odisha state, drought prone), Kujang (Kujang block, Jagatsinghpur district, Odisha state, flood prone), Malipara (Polba-Dadpur block, Hooghly district, West Bengal state, cyclone prone) and Jougram-Dharmatala (Jamalpur block, Purba Burdwan district, West Bengal state, cyclone prone) were interviewed. The villages were selected in such a way so that they can represent the zones with respect toagricultural practices of the entire study area. The team had also collected the basic information like family, education, social, land holding, income, assets, *etc.* so that the ground factors behind the adoption of technologies can be elucidated. The list of CSA technologies which was already ranked by using expert opinion were again scored by them in three categories: highly essential (score 3), essential (score 2) and not essential (score 1). The set of independent variables were run for multinomial probit model using 'nnet' package of R (R version 3.4.1).

RESULTS

The results showed number of members and earning members in the family ranged from 5.15-5.85 and 1.70-2.13, respectively. Land holding ranged 1.58-1.75 ha and found highest in drought prone area. The highest mean response from farmers was recorded in rainwater harvesting (2.50) for drought; drainage management (2.50) for flood; drainage management (2.28) and contingent crop planning (2.28) for cyclone among the different CSA technologies (Table 1). This result comply the ranking obtained for drought by the experts, while drainage management was ranked second

Table 1: Specific adoption rates of the climate-smart agricultural practices

Climate smart	Technologies	Mean		
		Drought prone	Flood prone	Cyclone prone
1. Water-smart	Rainwater Harvesting (RH)	**2.50**	-	-
	Ridge and Furrow Method (RF)	-	-	2.10
	Laser Land Levelling (LL)	2.15	-	-
	Furrow Irrigated Bed Planting (FIBP)	2.30	-	-
	Community Nursery (CUN)	-	1.85	-
	Drainage Management (DM)	-	**2.50**	**2.28**
	Cover Crops Method (CCM)	2.20	-	
2. Energy-smart	Zero Tillage/Minimum Tillage (ZT/MT)	2.05	2.20	1.63
3. Nutrient-smart	Site Specific Integrated Nutrient Management (SSNM)	2.05	1.90	1.98
	Neem coated urea (NCU)	-	2.00	2.35
	Leaf Color Chart (LCC)	2.20	2.25	-
	Crop Rotation (CR)	2.35	-	1.30
	Green Manuring (GM)	-	1.80	-
4. Carbon-smart	Rice-Fish Integrated Farming (RFI)	-	2.10	-
	Fodder Management (FM)	2.25	2.00	1.73
	Boundary Plantaion (BP)	-	-	1.78
5. Weather-smart	Weather-based Crop Agro-advisory (CA)	2.20	2.25	2.13
6. Knowledge-smart	Contingent Crop Planning (CC)	2.20	2.00	**2.28**
	Improved Crop Varieties (ICV)	2.15	2.10	1.75
	Seed and Fodder Banks (SFB)	-	-	1.90

by the experts for flood-prone area. In cyclone prone area, drainage management and contingent crop planning were ranked second and fifth by the experts. The coefficients of the factors were generated using multinomial probit model after removal of multicollinearity and redundancy in independent variables dataset. It was observed that in drought prone area education status of the adult family members (EAFM), no of adults in the family (AF), farming experience (FE), leased in (LI), land in share cropping (SC) and gross cropped area (GCA), positively influence the response ("high essential") to the adoption of rainwater harvesting. In flood-prone area, drainage management (DM) is one of the major technology. Education (E), numbers of earning members in family (EM) and land holding (LH) are the three important criteria controlling the favourable response (both 'essential' and 'highly essential') to this technology. Use of lodging resistant varieties (LRV) has good potential for adoption in cyclone prone region and it was ranked first by the experts. It was recorded EAFM, SC and cropping intensity (CI) positively influenced the adoption of LRV.

CONCLUSION

In order to make befitting policy to get sustainable yields in climate vulnerable region, the CSA technology based on expert opinion only may not be suitable for all the time until and unless it is vetted by the farmers, especially when CSA technologies are going to be implemented in a climate vulnerable region. This study offers a better knowledge of the drivers of CSA technologies in climate vulnerable areas, and should allow policymakers to plan more competent development aimed policies.

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EFFICACY OF VARIOUS HERBICIDES TO CONTROL THE COMPLEX WEED FLORA IN DRY DIRECT SEEDED UPLAND RICE

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Rice is the staple food with a significant contribution to the economy of Odisha. Weed infestation is one of the major constraints for poor productivity in direct seeded rice especially in dry seeding (Singh *et al*.2006). In direct seeded rice, initial 30 to 40 days of crop growth is critical for crop weed competition. The yield reduction in direct seeded rice increases with increase in competition during this period. Uncontrolled weeds reduce the grain yield by 96% in dry direct seeded rice and 61% in wet direct seeded rice (Maity and Mukherjee 2008). The traditional methods like manual and mechanical weeding are not effective in controlling weeds in direct seeded rice because of scarcity of labour and high labour cost during critical period of weed competition and take more time for weeding operation. Hence, usage of herbicides is becoming popular as viable alternative to other weeding methods. The continuous use of herbicides with similar mode of action has to be restricted to avoid herbicide resistance in weeds. Farmers in general use only pre emergence herbicides in direct seeded rice which is not sufficient to control the weed flora through out the crop period. The sole application of pre or post emergence herbicides did not provide effective control of weeds as compared to combination of pre and post emergence herbicides in rice(Walia *et al*.2012) In this situation , the suitable combinations of pre and post-emergence herbicides are needed to control the weeds. Therefore, the present study was undertaken to evaluate of efficacy of herbicides and their combinations for control of complex weed flora in dry direct seeded upland rice in west central table land zone of odisha.

METHODOLOGY

A field experiment was conducted in order to find out the efficacy of various herbicides to control the complex weed flora in dry direct seeded upland rice in west central table land zone of odisha at All India Coordinated Rice Improvement Project, Regional Research and Technology Transfer Station, Odisha University of Agriculture and Technology,Chiplima during the *rabi* season of 2017 and 2018. The experiment was laid out in randomized block design with seven treatments such as oxadiargyl 80WP(70g a.i/ha), oxadiargyl(70ga.i/ha)fb bis pyribac sodium 10%SC(20g a.i/ha),oxadiargyl(70g a.i/ha) fb ethoxysulphuron 15%WDG (18g a.i/ha), oxadiargyl(70g a.i/ha) fb chlorimuron ethyl 10% + met-sulfuron methyl 10% WP(4g a.i/ha), oxadiargyl (70g a.i/ha) fb one HW at 40DAS, HW at 20,40 and 60 DAS and un weeded check in three replications. Dry seeds of early medium duration rice variety 'MTU-1010' was manually sown @ 45kg/ ha at 20×10cm spacing during the first week of January in both the years. The recommended package of practices was adopted to raise the experimental crop. Herbicides were applied as per treatment at spray volume of 500 l /ha using flat nozzle. Data on weed density and dry weight of weeds were recorded at 30 as well as 60 DAS .Weed samples were air dried before oven drying. Then, they were kept in an oven at 65^{0}C until constant weight was obtained. The data on weed density and dry weight were subjected to square root transformation. The absolute effect of particular herbicide in reducing the weed competitions and increasing crop productivity were measured effectively by weed control efficiency. The higher value of WCE means better is the efficiency of treatment and vice versa. Yield and yield attributes of rice were recorded at harvest stage.

RESULTS

Effect on weed flora

The major weed flora infesting in the experimental field were *Cynodondactylon*, *Echinochloacolonum*, *Echinochloacrusgalli*, *Leptochloachinesis* among grasses, *Fimbristylismiliaceae*, *Cyperusdifformis*, *Cyperus iria*and *Cyperus rotundus*among sedges and *Monochoria vaginalis*, *Ludwigiaspp*, *Sphenocleazeylanica*and *Commelinabenghalensis* among broadleaves weeds.The composition of grasses,sedges and broadleaf weeds in weedy check plot was 38 %, 49% and 13% of total weed population ,respectively.The result showed that different weed management practices exerted significant effect on dry weight and density of weed at 30 and 60DAS as well as harvest (Table.1). HW at 20,40 and 60 DAS recorded significantly the lowest weed density as well as weed dry weight. Among the herbicides treatments, oxadiargyl fb chlorimuron ethyl + metasulfuron methyl recorded lower density of weeds, which was at par oxadiargyl fb bis pyribacand significantly lower to rest of the herbicidal treatments 30 and 60DAS as well as harvest. But in case of dry weight of weeds,oxadiargyl fb chlorimuron ethyl + metasulfuron methyl recorded lower density of weeds in 30 and 60DAS as well as harvest. It was at par with oxadiargyl fb bis pyribac and oxadiargyl fb ethoxysulfuronand significantly lower to rest of the herbicidal treatments 30 DAS . Whereas , in 60DAS as well as harvest, it was at par with oxadiargyl fb bis pyribacand significantly lower to rest of the herbicidal treatmentsIn respect to weed control efficiency, oxadiargyl fb chlorimuron ethyl + metasulfuron methyl recorded higher value of weed control efficiency(65%) among the different herbicide treatments.

Effect on yield and its attributes

Weed free treatment (Table.2). recorded higher yield and its attributing characters. Among the herbicides treatments, oxadiargyl fb chlorimuron ethyl + metasulfuron methyl recorded higher yield attributing

Table 1. Effect of different herbicides combinations on density and dry weight of weed in dry direct seeded rice under upland condition

Treatments	Weed density(No./ m^2)			Weed dry weight(g/m^2)			WCE(%) at
	30DAS	60DAS	At harvest	30DAS	60DAS	At harvest	harvest
Oxadiargyl (70g a.i/ha)	4.6(20.8)	5.2(27.5)	5.9(34.4)	3.0(9.4)	4.6(21.5)	5.6(31.4)	48
Oxadiargyl fb bis pyribac Na (20g a.i/ha)	3.1(9.6)	4.1(16.9)	4.8(22.8)	2.0(3.9)	3.2(10.7)	4.3(18.5)	60
Oxadiargyl fb ethoxysulphuron (18g a.i/ha)	3.5(12.5)	4.6(21.6)	5.4(29.3)	2.2(4.9)	3.7(13.8)	4.9(23.8)	55
Oxadiargyl fb chlorimuron ethyl + metasulfuron methyl(4g a.i/ha)	2.9(8.3)	3.6(13.2)	4.2(17.5)	1.9(3.7)	2.7(7.2)	3.8(14.6)	65
Oxadiargyl fb one HW at 40DAS	4.1(16.9)	5.0(25.2)	5.6(31.7)	2.5(6.3)	4.0(15.7)	5.2(27.3)	52
Weed free(HW at 20,40 and 60 DAS)	2.3(5.3)	3.0(9.4)	2.8(7.9)	1.7(2.8)	2.5(6.3)	3.2(10.6)	70
Unweeded	7.7(59.4)	9.997.5)	11.4(129.6)	5.0(25.8)	8.0(65.4)	10.8(116.7)	—
CD (P=0.05)	0.53	0.70	0.83	0.43	0.65	0.81	-

Figure in the parentheses are the original values
DAS-Days after sowing

Table 2 Effect of different herbicides combinations on yield and economics as well in dry direct seeded rice under upland condition

Treatments	Effective panicles /m^2	No. of grains/ panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Net return (₹/ha)	B:C ratio
T Oxadiargyl (70g a.i/ha)	232.00	86.25	23.61	2.88	4.01	13413	1.38
Oxadiargyl fb bis pyribac Na (20g a.i/ha)	259.00	90.15	24.37	3.30	4.55	19454	1.57
Oxadiargyl fb ethoxysulphuron (18g a.i/ha)	244.00	94.60	24.55	3.14	4.35	16660	1.48
Oxadiargyl fb chlorimuron ethyl + metasulfuron methyl(4g a.i/ha)	262.33	95.72	24.61	3.62	4.89	24713	1.68
Oxadiargyl fb one HW at 40DAS	260.00	93.07	24.59	3.56	4.67	16266	1.25
Weed free(HW at 20,40 and 60 DAS)	273.33	103.00	25.00	3.95	5.27	11450	1.21
Unweeded	111.67	69.23	22.13	1.54	2.55	13256	0.72
CD (P=0.05)	23.95	6.8	1.54	0.47	0.39	-	-

characters such as panicle /m^2, filled grains panicle^{-1} and test weight, which was significantly higher to oxadiargyl and at par with rest of the herbicidal treatments. There was 61% reduction grain yield of rice unweeded as compared with HW at 20,40 and 60 DAS treatment .Among the herbicide treatements, the higher grain yield was obtained in oxadiargyl fb chlorimuron ethyl + metasulfuron methyl (3.62 t /ha) which significantly superior to oxadiargyl and at par with rest of the herbicidal treatments. This might be due to low crop weed competition and longer weed free period under these treatments which leads to high growth and yield of rice..The higher net return(₹ 24713) and benefit: cost ratio (1.68)was obtained from oxadiargyl fb chlorimuron ethyl + metasulfuron methyl among the herbicide treatments.

CONCLUSION

Weed management is a fundamental practice in rice cultivation.Unsuccessful weed control can result in almost total loss of rice yield under upland direct seeded conditions .It may be suggested from this study that oxadiargyl(70g a.i/ha or 90 g product/ha) followed by post emergence herbicide like chlorimuron ethyl + metasulfuron methyl (4g a.i/ha or 20 g product/ ha)used for economically (B:C ratio 1.68) effective management of complex weed flora with increase in grain yield (3.62 t /ha) in upland direct seeded rice conditions in west central table land zone of Odisha

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DIRECT SEEDED RICE- A WAY TO CURTAIL METHANE EMISSION

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Rice (*Oryza sativa* L.) is one of the most important food crops in the world, and staple food for more than 50% of the global population. Transplanting after repeated puddling is the conventional method of growing rice which is not only intensive water user but also cumbersome and laborious. Different problems like lowering water table, scarcity of labour during peak periods and deterioration of soil health, demands for some alternative establishment method to sustain the productivity of rice as well as natural resources. The major problem includes emission of CH_4, N_2O and CO_2which are the potential sources of global warming. In conventional method of paddy cultivation, prolonged flooding leads to anaerobic conditions in soil and creates favourable environment for methanogenic bacteria and stimulates CH_4 emission. Direct seeded rice (DSR), probably one of the oldest methods of crop establishment, is gaining popularity because of its low-input demand. It offers certain advantages *viz*., saves labour, requires less water, less drudgery, early crop maturity, low production cost, better soil physical conditions at harvest and less methane emission, which provides better option to be the best fit in different cropping systems. The crop may experience with less water or even drought at early growth stages. DSR offers benefits like saving irrigation water, reducing production cost and mitigating CH_4 production (Kaur and Singh. 2017).Direct seeded rice has an immense potential to reduce CH_4 emission by various management practices such as reducing the number of irrigations, multiple drainage system during the crop cycle and alternate wetting and drying.Direct seeding is the oldest method of rice establishment and was shifted with time by transplanting. The objectives are to reduce the emission of methane from rice fields by shifting from flooded rice to direct seeded rice, to minimize the role of paddy fields in global warming and to reduce the emission of green house gases.

METHODOLOGY

Rice can be established by three principal methods: transplanting, dry-DSR and wet- DSR. These methods differ from others either in land preparation (tillage) or crop establishment method or in both. Transplanting is the dominant crop establishment practice in Asia particularly in tropical part in which the land is puddled and seedlings raised in nursery are transplanted. Dry and wet-seeding, in which seeds are sown directly in the main field instead of transplanting rice seedlings, are commonly referred to as direct seeding. In Dry-DSR, rice is established using several different methods, including (i) broadcasting of dry seeds on unpuddled soil (ii) dibbled method in a well-prepared field and (iii) drilling of seeds in rows or raised beds. Wet-DSR involves sowing of pregerminated seeds (radicle 1- 3 mm) on or into puddled soil. When pregerminated seeds are sown on the surface of puddled soil, the seed environment is mostly aerobic and this is known as aerobic Wet-DSR. Wet-DSR under aerobic and anaerobic, seeds can either be broadcasted or sown in-line using a drum seeder or an anaerobic seeder with a furrow opener and closer.

RESULTS

Methane emission in DSR was lower compared to transplanted rice. It happens because there was no flooding condition of the DSR field and it results aerobic condition. While in transplanted rice, the field was flooded throughout the rice growing season and it creates anaerobic condition. CH_4 is produced under anaerobic condition by metabolic activities of

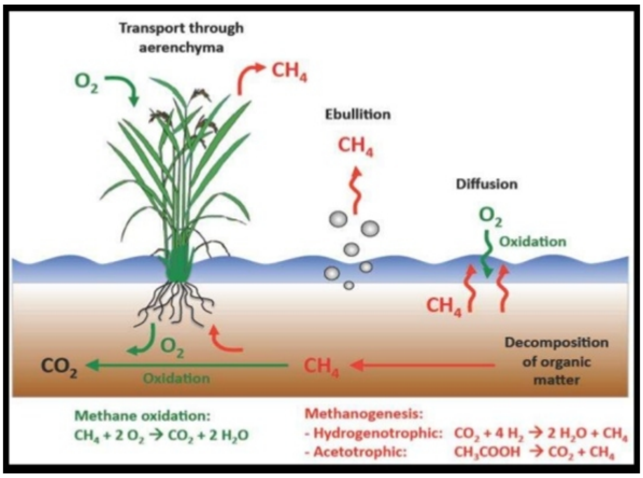

Fig. 1. Emission of methane from flooded rice.

methanogens (Conrod. 2007). The standing water on rice soil surface inhibits oxygen transport from atmosphere to rhizosphere. The absence of oxygen, the activity of anaerobic bacterial and the presence of decomposable organic matter is the favourable condition to produce CH_4. Agriculture contributes in the emission of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) – these three GHGs contribute to global warming. Agriculture's share in the total emissions of N_2O, CH_4, and CO_2 are 60, 39, and 1, respectively,and rice-based cropping systems playing a major role. Rice production systems impact global warming potential (GWP) primarily through effects on methane but N_2O and CO_2 effects can also be important in some systems. The GWP of CH_4 and N_2O is 25 and 298 times higher than that of CO_2. GHG emissions, especially CO_2 and CH_4 from rice fields, are large and very sensitive to management practices. Therefore, rice is an important target for mitigating GHG emissions. Flooded rice culture with puddling and transplanting is considered one of the major sources of CH_4 emissions because of prolonged flooding resulting in lack of oxygen (anaerobic) soil conditions. It accounts for 10-20% (50–100 Tg year^{-1}) of total global annual CH_4 emissions.When DSR was combined with mid-season drainage, the reduction in CH_4 emissions increased further compared with flooded transplanted rice.

CONCLUSION

Methane emission from rice fields cannot be fully controlled. However, it can be reduced. The direct seeded could be a feasible option for mitigating and adapting to climate change. Comparable grain yields may be obtained from DSR if properly managed. Thus, in the present scenario of global scarcity of water, increasing labourwages and adverse effect of changing climate, DSR is the most viable option for getting sustainable yields without any overexploitation of the available natural resources and to minimize the methane emission from paddy fields.

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SOIL LABILE CARBON POOLS AND INTERRELATED SOIL PHYSICO-CHEMICAL PROPERTIES IN DEGRADED MANGROVE AND ADJACENT AGRICULTURAL SYSTEMS

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Mangroves are unique wetland ecosystems that covers approximately 60–70% of World's tropical and subtropical coastlines which contributes towards huge ecological services and carbon (C) sequestration. The organic C decomposition kinetics plays a crucial role in the energy flow as well as nutrient cycling of the coastal ecosystems (Ghizelini et al., 2012). The Indian Sundarban is one of the largest contiguous mangroves in the world which is about 40% of the total Sundarban (rest 60% in Bangladesh). Tidal behaviour in mangrove ecosystem causes water stagnation, lower rate of SOC decomposition which leads to a reduction in CO_2 production and enhances the long-term C storage. The labile soil carbon pools are sensitive indicators to determine the C dynamics in degraded mangrove ecologies. Studies have indicated that the labile C fractions are significantly associated with the GHGs emission and nutrient availability of soils and small change of which could be detected precisely. Similarly, in the rice rhizosphere, the soil labile C pools play an important role for enhancing the microbial activities. We focused on two important labile C pools i.e. microbial biomass C (MBC), and potassium permanganate oxidizable C ($KMnO_4$-C) whichare used as indicators for soil quality assessment in wetlands like mangrove, lowland rice and aquaculture ecologies. These carbon pools are significantly influenced by the physical soil/sediment properties like pH, electrical conductivity (EC), and salinity (Padhy et al., 2020). Therefore, we fixed the objectives of our study was to estimate the soil labile C pools and their interaction with physico-chemical properties of soil in mangrove-rice-aquaculture ecologies in three different locations of Sundarban, India.

METHODOLOGY

Study area and sample collection: The mangrove areas in Sundarban, mainly converted to rice and aquaculture. We selected three degraded mangrove sites (Mathurakhand, Satarkona and Bijoyanagar) in Balley Island, Gosaba block, Sundarban for our study based on the remote sensing data/maps developed by NRSA, Hyderabad, India in respect of mangrove-degradation status between 1930 to 2013-year period. The soil sampling was done at four seasons (winter, summer, pre-monsoon and monsoon) from the mangrove and adjacent rice-aquaculture ecologies at 0-15cm depth by using soil auger. The pooled data of these four seasons of respective three sites were analysed.

*Soil labile carbon pools and physico-chemical properties:*The MBC was estimated by chloroform fumigation-extraction method. The $KMnO_4$-C was determined from air-dried soil followed by $KMnO_4$ extraction method.Soil pH, EC and salinity were measured by using 'Multi-Parameter Tester 35 Series' (Eutech PCSTEST35-01X441506/ Oakton 35425-10).

Corelation study: The pearsoncorrelation matrix among the labile C pools (MBC and $KMnO_4$-C) with pH, EC and salinity was estimated by using the online software OPSTAT.

RESULTS

The MBC and $KMnO_4$-C are sensitive indicators of soil quality in the mangrove sediments as well as in agriculture. The average MBC and $KMnO_4$-

Table 1: Soil labile carbon pools and physical soil/sediment properties in mangrove-rice-aquaculture ecologies in three different location (Mathurakhand, Satarkona and Bijoyanagar) of Sundarban, India.

Locations	Vegetation	MBC(µg C g^{-1})	$KMnO_4$-C (µg C g^{-1})	pH	EC(ms Cm^{-1})	Salinity (ppt)
Mathurakhand	Mangrove	702.8±20.8	814.7±24.2	7.9±0.12	8.95±0.36	1.54±0.04
	Rice	294.6±19.5	647.7±22.9	6.8±0.12	0.78±0.05	0.40±0.02
	Aquaculture	262.6±24.2	386.4±19.9	7.8±0.08	1.88±0.06	0.72±0.04
Satarkona	Mangrove	680.1±23.1	890.3±27.4	7.9±0.13	9.09±0.23	1.54±0.05
	Rice	287.1±19.9	645.0±25.4	6.7±0.19	0.81±0.07	0.39±0.02
	Aquaculture	255.9±24.9	419.0±17.1	7.8±0.10	1.76±0.06	0.76±0.03
Bijoyanagar	Mangrove	685.6±20.2	877.3±22.3	8.1±0.10	10.31±0.24	1.68±0.04
	Rice	294.3±24.1	642.7±23.4	6.6±0.10	0.79±0.04	0.37±0.02
	Aquaculture	233.0±19.1	403.3±20.9	7.6±0.05	1.76±0.05	0.73±0.03
Pearson Correlation Matrix		MBC	$KMnO_4$-C	pH	EC	Salinity
	MBC	1.000				
	$KMnO_4$-C	0.881**	1.000			
	pH	0.569^{NS}	0.141^{NS}	1.000		
	EC	0.978**	0.781*	0.719*	1.000	
	Salinity	0.925**	0.666^{NS}	0.826**	0.982**	1.000

[Note: MBC: microbial biomass carbon; $KMnO_4$-C: Potassium permanganate oxidizable carbon; EC: electrical conductivity]

C contents were more in degraded mangrove (689.5 and 860.8 µg C g-^{1}, respectively) as compared to rice (292.0 and 645.1 µg C g-^{1}, respectively) and aquaculture (250.5 and 402.9 µg C g-^{1}, respectively) (Table 1). The pH, EC and salinty were higher under degraded mangrove followed by adjacent aquaculture and rice ecologies. Direct flow of the tide water in the magrove and adjacent aquaculture resulting higher EC and salinity than that of rice ecology. These two labile C pools were not significantly correlated with pH. However, EC (which was in moderate range) was significantly corelated with MBC (0.978**) and $KMnO_4$-C (0.781**).

CONCLUSION

In our study at three different locations of Sundarban, the soil labile C pools (MBC and $KMnO_4$-C) were higher in degraded mangrove sediments than that of adjacent rice and aquaculture systems. The regular deposition of litre and decaying of mangrove plants may be the reason for more labile C pools in mangrove sediments. The pH, EC and salinity were higher (in middle range in respect to crop production) in degraded mangrove due to continuous flow of tidal water into the respective mangrove and adjacent aquaculture. The electrical conductivity was significantly corelated with the MBC and $KMnO_4$-C contents of soil/sediment.

ACKNOWLEDGEMENT

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IRC/TM-2/PP-53

MODELING PUFFING OF RICE IN MICROWAVE HEATING

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Rice ranks first in terms of global production (603 million tonnes) and used as a staple food for approximately 400 million people in the developing countries. Though rice is mainly consumed as whole cooked grains, a variety of products are also prepared as breakfast foods, snacks and fermented products. Puffing of pre-conditioned rice using domestic microwave oven have been reported to give as high as 95 - 100% puffing and hygienic product. Puffing takes few milliseconds to puff once the grain attains temperature sufficient for puffing.

Heat transfer characteristics and mode of heating are very important in puffing of grains. Modeling for microwave heating of rice kernel and prediction of its time-temperature profile would be very useful to understand puffing characteristics of the kernel. Several studies have been reported for microwave heating of food materials, (Geedipalli et al. 2007, Oliveira and Franca, 2002, Pandit and Prasad, 2003) but information on microwave puffing of cereals, particularly for rice is very limited.

The temperature distribution during microwave heating in various food materials is a major concern. Rice with salmonella when heated inside a microwave oven an uneven temperature distribution occurred (Ramaswamy and Pillet Will, 1992,). The difference in the temperature between the coldest and the hottest spot was as high as 65ºC. Temperatures at the corner, edge, near center and center of the rice are 96.8ºC, 65.4ºC, 44.2ºC and 33.6ºC respectively. The temperature attained at the corner of the sample was comparatively higher than the center.

METHODOLOGY

The energy equation in microwave heating of solid foodstuff is comprised of conduction heat transfer with a heat generation term; the latter part, that arises due to electromagnetic field distribution. Therefore, transient heat transfer equation containing heat generation term was solved through mathematical modeling, and time-temperature profiles inside the rice kernel with the specific wavelength of the microwave was arrived.

The domestic microwave oven is basically a 3D cavity connected to a 1 kW, 2.45 GHz microwave source. The energy propagates via a rectangular waveguide operating in transverse electric (TE_{10}) mode; a wave that has magnetic field in the direction of propagation. Rice grain is considered at the center of the turntable of the oven, and volumetric heat generation within the rice grain is calculated with Maxwell's equation of electromagnetic radiation.

RESULTS AND DISCUSSION

Temperature Profile of Rice Kernel in Microwave Heating

Figure 1 shows the predicted temperature profile of the pre-conditioned rice kernel along the major axis when heated inside a microwave oven at power inputs 850 and 1000W. The analysis using COMSOL Multiphysics 3.3a software showed that the kernel temperature profile was symmetrical along the mid-axis; maximum at the ends and minima at slightly away from the center point. The colour scale clearly showed the higher temperature at the both ends of the kernels.

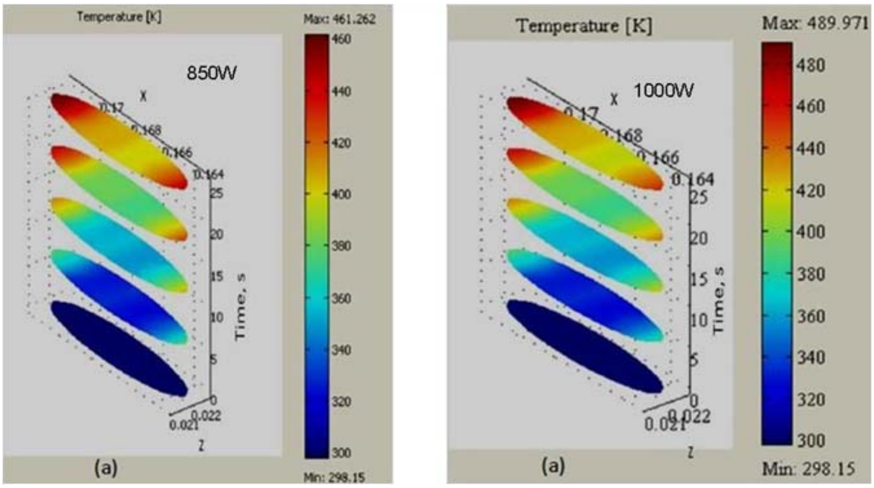

Fig.1: Temperature contours of rice kernel in XZ plain at varying microwave power input heating

CONCLUSIONS

Transient heat transfer equation containing heat generation term solved through Maxwell's equation of electromagnetic field distribution in COMSOL Multiphysics 3.3a software in a 3D microwave oven cavity modeled time-temperature profiles inside the rice kernel showed that during microwave puffing of rice kernel, the expansion initiates at the ends; but faster at one end than the other - in agreement with the heat transfer analysis.

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IRC/TM-2/PP-54

ZINC USE EFFICIENCY OF INDIGENOUS RICE VARIETIES INFLUENCED BY ZINC APPLICATIONMETHODS

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Rice occupies about 23% of the gross cropped area in India and is considered as the backbone of food security of the country. In the time of widespread micronutrient deficiency especially in Indian agriculture; agriculturists, scientists and policy makers are concerned about nutritional security along with the food security.Rice is generally very sensitive to Zn deficiency particularly in the wet puddle cultivation system (Wissuwa et al., 2008).Zinc deficiency is very prominent in extremely leached acidic light soils of *Terai* region of West Bengal. Soil analysis revealed that a major part of West Bengal including Darjeeling, Jalpaiguri, Coochbehar have deficiency in zinc (Das, 2008). In conventional rice production system Zn availability is reduced due to lowered redox potential as after application of Zn fertilizers to Zn-deficient soils Zn is rapidly fixed by soil.On the other hand, utilizing the vast genetic pool of rice existing in rice cultivars for enhancing the zinc use efficiency is of immense importance to withstand Zn deficiencies in developing countries. In West Bengal several indigenous rice cultivars are grown by farmers even without application of Zn fertilizers in the Zn deficient soil.Obtaining a substantial amount of grain yield may be attributed to the zinc content and uptake in rice cultivars differs due to their genetic make-up.Indigenous rice genotypes may have different capacity of zinc mobilizing and zinc use efficiency.Therefore, evaluating indigenous rice genotypes traditionally grown in West Bengal is highly necessary to understand their zinc use efficiency.Keeping in view the limited information on effect of zinc application on zinc use efficiency of indigenous rice varietiesin the highly leached acid soils of *Terai* region of West Bengal, the present study was undertaken.

METHODOLOGY

A field experiment was conducted during rainy seasons of 2018 and 2019 at the Research farm of Uttar BangaKrishiViswavidyalaya, Pundibari, West Bengal to study the effect of zinc fertilization on zinc use efficiency in four indigenous rice varieties (Kalonunia, Fulpakri, Dudhkalam and Gobindobhog) along with a high zinc rice variety (DRR Dhan 45) under split-plot design containing three main plots *viz.* no zinc application (Z_0), soil application of 5 kg Zn ha^{-1} as basal through $ZnSO_4.7H_2O$ (Z_S) and foliarsprays of zincat maximum tillering and at booting stage through 0.25% Zn-EDTA solution (Z_F).Macro nutrients (N, P and K) were applied through urea, SSP and MOP as per recommended practice of that area.Zinc content of straw and grains was estimated using atomic absorption spectrophotometer, after di-acid digestion of samples.The zinc harvest index (ZnHI), zinc mobilization efficiency index (ZnMEI),Zn-efficiency and Zn-response werecalculated using following expressions given below.

$$\text{ZnHI} = \frac{(\text{Zn uptake by grain at harvest})}{(\text{Zn uptake by grain + straw at harvest})} \times 100$$

$$\text{ZnMEI} = \frac{(\text{Zn concentration in grain})}{(\text{Zn concentration in straw})}$$

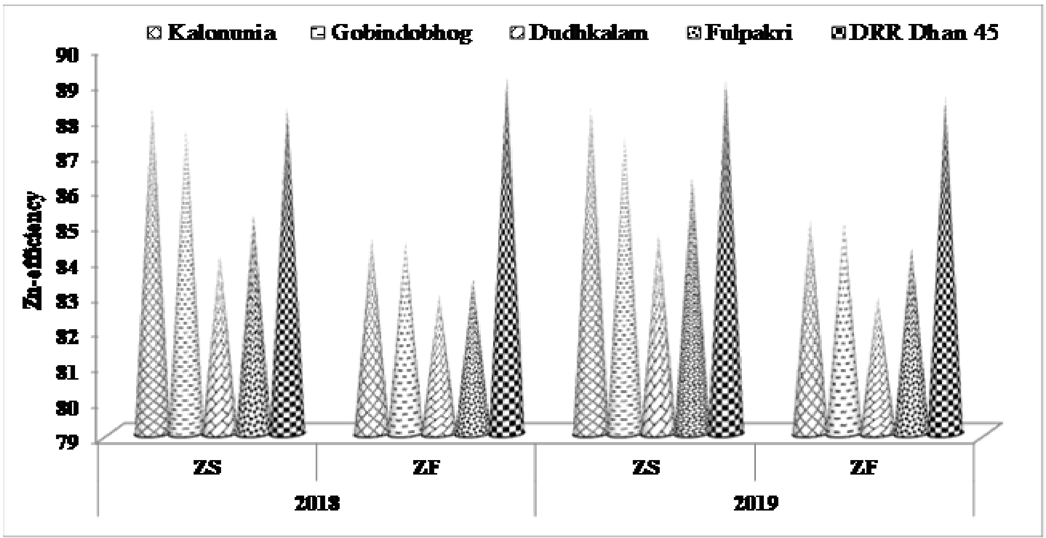

Fig. Zn-efficiency of rice varieties as affected by zinc fertilization

$$\text{Zn efficiency} = \frac{(\text{Grain yield of control plot})}{(\text{Grain yield of treated plot})} \times 100$$

$$\text{Zn response} = \frac{(\text{Grain yield of treated plot})}{(\text{Grain yield of control plot})}$$

RESULTS

Zinc application in soil at basal was recorded with higher values of Zn-harvest index and ZnMEIacross the varieties. Highest zinc harvest index was found with 'DRR Dhan 45' followed by 'Dudhkalam'. Zinc mobilization efficiency index is the ratio of zinc content in grain to the zinc content of straw. Among rice varieties, higher value of ZnMEI was found with 'DRR Dhan 45'. The order of ZnMEI among indigenous varieties was Dudhkalam> Gobindobhog> Kalonunia> Fulpakri.The 'Zn-efficiency' of a variety is relative ability of the variety to grow and yield under marginal Zn supply.In all the indigenous varieties, higher values of Zn-efficiency were found with soil application of Zn compared to the foliar spray. In soil application method, Zn-efficiency value of 'Kalonunia' (88.3 and 88.2%) was found very close with that of 'DRR Dhan 45' (88.2 and 89%).Higher value of Zn-response was found with foliar application of Zn through Zn-EDTA at maximum tillering and booting stage. Among five rice varieties, highest value Zn-response was found with 'Dudhkalam' (1.21 during both years) followed by 'Fulpakri' (1.2 and 1.19) in foliar application method.

CONCLUSION

Among the indigenous varieties 'Kalonunia', 'Gobindobhog' were recorded with higher values of Zn-efficiency, whereas 'Dudhkalam' was found most Zn responsive among five varieties.Zinc response being reciprocal of Zn-efficiency was found higher with 'Dudhkalam',which was least Zn efficient among the tested varieties.Information obtained from the investigation may be used in the future crop improvement research in connection with zinc bio-fortification.

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NITROGEN RESPONSE AND USE EFFICIENCY OF DIFFERENT RICE CULTIVARS

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Globally rice cultivation consumes approximately 9 to 10 million tons of fertilizer N which accounts for about 10% of the total fertilizer N consumption in the year 2010-11(Heffer, 2013). However only 30-40 % applied N is recovered by the crop due to poor N use efficiency of flooded low land rice leading to several economic and environmental repercussions.Improving N use efficiency of rice is therefore is crucial to ensure profitability and environmental sustainability of rice production.Complex interactions of crop, environmentand management factors regulate N flow in soil-plant system, crop N uptake and yield. Cultivars differ among themselves in N use efficiency depending on their ability to uptake N from both indigenous and external sources and to convert it into final economic product. The study was conducted to evaluate different rice cultivars in relation to their N use efficiency and response to applied N.

METHODOLOGY

The seven rice cultivars (Naveen , Indira , Ratna, Surendra , Birupa and Daya) were grown with six nitrogenlevels i.e. 0, 40, 60, 80, 100, 150 kg N ha-1 in a factorial randomized block design replicatedthree times.Rice grain and straw yields were determined at physiological maturity (PM) stage. Oven dried grain and straw samples were analyzed for N content using the micro- Kjeldahl distillation method (Yoshida et al., 1976) for calculating N uptake and N use efficiencies.Nitrogen recovery efficiency (RE_N) was estimated using following formula

$$RE_N = \frac{(NUP_N - NUP_{N0})}{F_N}$$

WhereNUP_N: Nitrogen uptake with N application; NUP_{N0}: Nitrogen uptake without N application; F_N: Amount of fertilizer N applied.The yield response to applied N was fitted to quadratic equation $y=-ax^2+bx+c$, where y is yield (t ha^{-1}) and x is N applied in kg ha^{-1}. Intercept (c) is the yield at 0 N and slopes of curve were calculated for different N level.

RESULTS

Significant ($P< 0.05$) interaction effects of cultivars and N level on RE_N could be observed. Most of the cultivars showed a declining trend of RE_N with increasing N level beyond 80 kg ha^{-1} Average RE_N among the cultivars varied from 36.25 to 44.23% and the highest value was observed in Birupa and the lowest in Surendra. However effect of cultivars also varied with N level. Naveen showed higher RE_N at lower N level but its N use efficiency decreased with increasing N level, Whereas Birupa showed higher N use efficiency at both lower and higher N level. The intercept (c) and slopes of yield-N response curve at different N level have been presented in table 1.

Table 1; Intercept and slopes of yield-N response curve ($y = -ax^2 + bx + c$) for different varieties

varieties	Y Intercept (c)	Slope 1 (0- 60)	Slope 2 (60-90)	Slope 3 (90- 120)
Naveen	3	11.5	1.9	-7.7
Indira	2.3	18.2	9.4	0.6
Ratna	2.5	15.5	7.3	-0.9
Surendra	2.9	16.9	10.4	3.8
Birupa	3	17.2	7.3	-2.6
Daya	2.4	15	6.1	-2.9

Y intercepts i.e. yield at 0 N is an indicator of N efficiency due to varietal character and the slope of the curve (dy/dx = 2ax+b) indicates response of cultivar to applied N. The cultivars that produce higher yield at zero or low level of N can be termed as efficient variety and the cultivars that produce higher yield at high level of N can be termed as responders. Accordingly Naveen that showed a higher Y-intercept can be termed as N efficient cultivar and cultivars like Indira and Surendra that showed higher yield at high N levels, can be called as responders. Whereas Birupa that showed higher yield at both low and high levels of N can be termed as both Nefficient and responder cultivar.

CONCLUSIONS

Cultivars varied significantly in relation to N recovery efficiency and response to applied N. Some varieties showed higher N uptake and yield at lower N level and some at higher N level. Accordingly cultivars can be grouped as efficient and responders. Cultivars like Naveen showed higher N use efficiency at lower N level hence can be termed as efficient, whereas Indira and Surendra are responders and Birupa is identified as both efficient and responders.

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EVALUATION OF ARSENIC TRANSFERABILITY IN FIVE DIFFERENT INDIAN RICE (*ORYZA SATIVA* L.) CULTIVARS FROM SOIL TO HUMAN

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Rice cultivation requires a lot of water and groundwater serve as the main source of irrigation, particularly in *boro* cultivation (December to April). In Asia, typical amount of water needed for irrigated (*boro*) and *kharif* rice ranges 1300-1500 and 1500-2000 mm, respectively. It is not economically feasible to filter a huge amount of water before applying into the field. Therefore, two options are left; either to stop *boro*cultivation or to adopt low accumulating rice genotypes for cultivation. Considering great variation in the total As content in rice grains among different cultivars, acquiring information on total As content in rice cultivars could be an important factor for the reduction of the As health risk from rice grown in As affected areas.

Considering these issues, an attempt was made to evaluate the magnitude of As loading in selected five high rice varieties yielding varieties (HYVs). Further, translocation factor (TF), daily intake of As (ADI), hazard quotient (HQ) and Incremental Lifetime Cancer Risk (ILCR) were calculated to assess the human exposure and risk through consumption of rice grown in the As contaminated area of Nadia district, West Bengal.

METHODOLOGY

The experiment was set at the farmers' field at DakhinPanchpota village of Chakdah block, Nadia district inbetween N 23°01.899' and E 88°34.715' which is one of worst As affected zone in West Bengal. The experiment using five selected rice varieties was laid out in a randomized block design with three replications. Plants from three different growth stages, viz. tillering, booting and maturing stages were collected and analyzed for root and shoot As following standard protocol. Grain samples were separated in husk, bran and polished rice with hulling milling equipment. Total arsenic content was analyzed in all the pltparts following the protocol given by Rahman et al., 2009. Indices for arsenic transfer (BAF and TF) and arsenic risk assessment (ADI, HQ and ILCR) were calculated following standard equation (US, EPA, 2011).

RESULTS AND DISCUSSIONS

Root As concentration in the tillering, booting and maturity stages of HYVs was in the range of 1.35-4.16 mg kg^{-1}, 6.57-9.89 mg kg^{-1} and 7.3-10.28 mg kg^{-1}, respectively. Arsenic accumulation in shoot at tillering, booting and maturity varied in between 1.15-3.89 mg kg^{-1}, 1.22-4.26 mg kg^{-1} and 2.9-4.48 mg kg^{-1}, respectively. However, it was much lower than the root As concentration. CR dhan 1010 continued to harness more As both in roots and shoots at maturity i.e., 10.28 and 4.48 mg kg^{-1}, respectively. The root As concentration followed the sequence of CR dhan 1010 (10.28 mg kg^{-1}) > Swarna masuri (9.25 mg kg^{-1}) > Swarna-sub 1(9.21) >Pratikhya (9.13 mg kg^{-1}) >Satabdi (8.3 mg kg^{-1}). It is noticeable that at maturity stage, among the all varieties Satabdi recorded the lowest As in both root and shoot.

Grain As loading among selected varieties of HYV group varied significantly. Maximum grain As was observed in CR dhan 1010 (1.62 mg kg^{-1}) followed by Swarna masuri (1.18 mg kg^{-1}). Further, regardless of varieties, grain As demonstrated a significantly ($p< 0.01$) positive correlation with root As (r= 0.81**) and shoot As (r=0.89**).

The absorption capacity of As from soil to root was found highest in CR dhan 1010 (3.89) and lowest BAF value was observed in Satabdi (2.77). However, the highest translocation factor of As from root to shoot was recorded in Pratikhya (TF = 0.53), but the lowest was found with Satabdi (0.42). Such value of TF from shoot to grain was lowest with Swarna-sub-1 (0.21), but highest with CR Dhan 1010 (0.36). CR Dhan 1010 thus had both higher BAF as well as TF shoot to grains.

Arsenic contents in husk of HYVs varied from 0.38-0.71mg kg^{-1}. Among the HYVs, the maximum accumulation of As in the husk was found in Swarna masuri (0.71mg kg^{-1}), whereas, the lowest accumulation was found in Satabdi (0.38 mg kg^{-1}). Arsenic concentration in bran polish of different cultivars under HYVs varied significantly from 0.29-0.51 mg kg^{-1}. Highest As content in bran layer was found in CR Dhan 1010 (0.51mg kg^{-1}), followed by Pratikya (0.50 mg kg^{-1}). These values for Swarna masuri, Swarna-sub-1 and Satabdi were 0.38 mg kg^{-1}, 0.31 mg kg^{-1} and 0.29 mg kg^{-1}, respectively. Among HYVs, the highest As content in polished rice was observed in Pratikhya (0.27 mg kg^{-1}); while the lowest was in Satabdi (0.14 mg kg^{-1}) and the trend was Pratikya (0.27 mg kg^{-1}) > CR dhan 1010 (0.24 mg kg^{-1}) >Swarnamasuri (0.19 mg kg^{-1}) > Swarna-sub1 (0.17 mg kg^{-1}) > Shatabdi (0.14 mg kg^{-1}). It can thus be interpreted that regardless of rice cultivars, As distribution in rice grain fractions followed the trend: husk > bran-polish > brown rice > polished rice.

To demonstrate the health risk assessment of As, estimated daily intake of As, estimated weekly intake of As, HQ and calculated ILCR values are computed. The calculated HQ and ILCR from rice consumption of HYVs ranged from 3.3 to 4.0; .51× 10^{-3} - 2.89×10^{-3}, respectively.

Table 1. Average estimated daily intake for inorganic As from rice in different varieties and excess internal cancer risk.

Rice variety	As in polished rice (µg/kg)	Daily intake of As (µg/kg BW)	Incremental Lifetime Cancer Risk (ILCR)	Hazard Quotient (HQ)
Swarna sub-1	173	1.22	1.83×10^{-3}	4.07
Swarnamasuri	190	1.34	2.02×10^{-3}	4.48
CR dhan 1010	241	1.70	2.55×10^{-3}	5.66
Pratikhya	273	1.93	2.89×10^{-3}	6.42
Satabdi	143	1.01	1.51×10^{-3}	3.36
Mean	204	1.44	2.16×10^{-3}	4.798

CONCLUSION

From the present investigation it is noticed that consumption of Shatabdi can result in the lowest daily intake of As compared to other selected HYVs and leading to less thread for carcinogenic and non-carcinogenic health risk. Regardless of varieties, As concentration was followed the order; root>shoot> grain> husk>brown rice >polished rice > cooked rice with excess water. Upon detailed investigation the Shatabdi and Swarna-sub-1 can be considered the safest of the five selected cultivars for human consumption owing to their low TF values and highest drop in As during processing and cooking. Furthermore, due to low the TF, growing Shatabdi in soils with elevated As level could help improve the food safety level in food chain.

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IRC/TM-2/PP-57

EFFECT OF NUTRIENT MANAGEMENT ON YIELD AND ECONOMICS OF RICE VARIETIES IN COASTAL ODISHA

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Rice (*Oryza sativa* L.) dominates overall crop production and food consumption in Asia. Rice is cultivated in an area of 44 million hectares in India contributing 21.5% of global rice production and plays an important role in the economic development of the country. Rice production systems need to be more equitable, efficient, environment-friendly, and more resilient to climate change, while contributing less to greenhouse gas emissions. Efficient integration of nutrient responsive high yielding varieties and feasible nutrient supply system is essential to achieve higher and sustained yield of the crop. Selection of varieties of different duration will pave way for crop intensification for inclusion of crops like pulses (green gram, black gram, lentil etc.) and oilseeds (linseed, sesame etc.) for efficient utilisation of resources in rice-based cropping system for achieving nutritional security and greater profitability.

METHODOLOGY

A field trial was conducted during kharif season of 2019 in Odisha University of Agriculture and Technology, Bhubaneswar, Odisha to study the varietal performance in relation to different nutrient management practices. The experiment comprising of six treatments *i.e.*, combination of two rice varieties namely Maudamani (135days) and Hasanta (145 days) and three nutrient management practices *i.e.*, inorganic (100% STBFR of NPK through inorganic sources), organic (Green manuring + Vermicompost and Neem oil cake to supply 1/3rd STBNR each+ BF) andintegrated nutrient management (50% STBNR through green manuring using *dhaincha* +50% STBNR through inorganic fertilisers + 100% P & K) was conducted in randomized complete block design with three replications. The soil of the experimental site was sandy loam in texture with slightly acidic reaction (pH-6.1), low in available nitrogen (218.0 kg/ha), phosphorous (8.4 kg/ha) and medium in potassium (140 kg/ha).

RESULTS

The test varieties did not differ significantly in their grain yield, though cv. 'Hasanta' produced

Illustration 1: Effect of rice varieties and nutrient managementon yieldand economics of rice

Particular	Plant height at harvest (cm)	Ear-bearing tillers/m^2	Grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)	Net returns (Rs./ha)	B:C
Variety								
Maudamani	116.8	331	171.2	5.50	7.86	41.19	37389	1.59
Hasanta	118.9	346	192.3	5.80	7.62	43.39	42660	1.68
SE(m)+	1.18	13.0	4.16	0.14	0.25	0.77	-	-
CD (0.05)	NS	NS	13.1	NS	NS	NS	-	-
Nutrient management practice								
Inorganic	117.9	334	185.3	5.41	7.29	42.57	45102	1.71
Organic	114.8	286	167.4	5.31	7.05	42.98	9844	1.10
INM	120.8	395	192.4	6.23	8.88	41.28	65128	2.08
SE(m)+	1.44	15.9	5.09	0.17	0.30	0.94	-	-
CD (0.05)	4.6	50	16.1	0.53	0.946	NS	-	-

numerically higher yield (5.80 t/ha) owing to greater plant height at harvest (118.9 cm), ear-bearing tillers/ m^2(346), grains/panicle (192.3) and greater B:C (1.68) than cv. 'Maudamani'. Among the nutrient management practices, application of 50% STBNR through green manuring + 50% STBNRthrough inorganic fertilizers and 100% P & K recorded maximum yield attributes (plant height at harvest of 120.8cm, ear-bearing tillers/ m^2(395), grains/panicle (192.4), grain yield (6.23 t/ha) and straw yield (8.88 t/ha), which was superior to both inorganic and organic mode of nutrient supply. Greater net return (Rs. 65128/ha) and B:C (2.08) was also obtained from INM practice. However, the harvest index was superior with organic treatment (42.98%). There was better response for the combined application of organic and inorganic fertilizers rather than the *per se* application (Babu *et al*., 2001), owing to improvement in physical, chemical and biological environment of soil favouring increased availability of macro and micro-nutrients (Sengar*et al*., 2000). The marked increase in grain yield with incorporation of *S. aculeata* could be attributed to the enrichment of soil fertility resulting from N fixation by rhizobial nodules of the preceding green manure as well as green biomass addition into the soil.

CONCLUSION

Rice cv. 'Hasanta' with integrated nutrient management practice comprising of 50% soil test based nitrogen requirement through *dhaincha* green manuring and rest nitrogen through inorganic sources alongwith 100% P and K suggested for higher productivity and profitability in coastal Odisha.

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EFFECT OF POTASSIUM FERTILIZATION ON WATER PRODUCTIVITY AND IRRIGATION WATER USE EFFICIENCY OF DRY DIRECT SEEDED RICE

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Among the cereals, rice consume highest amount of irrigation water and many technologies like direct seeded rice (DSR), alternate wetting and drying, system of rice intensification etc. were developed to minimize the irrigation water use in rice cultivation (Vijayakumar et al., 2019). However, in DSR, optimization of nutrient management especially potassium (K) fertilization to suits upland system is very important to ensure higher yield and efficient water use. Tailoring appropriate nutrient management practice to suits particular ecosystem, climate and crop management practice is very important to maximize nutrient use efficiency and crop productivity (Kumar et al 2014). Thus, the present study was undertaken to find out the effect of K fertilization on water productivity and water use efficiency of dry DSR.

METHODOLOGY

A two-year field investigation was conducted during Kharif 2015 and 2016 at Research farm, ICAR-IARI, New Delhi, to find out effect of potassium (K) fertilization on water productivity and irrigation water use efficiency of dry direct seeded rice. The field trials were conducted in a completely randomized block design with 7 treatmentsand 3 replications. The treatments details were presented in Table 1. Potassium was applied according to the treatments. The recommended dose of potassium (RDK) for rice 60 kg K_2O ha^{-1}.In case of foliar spray (FS) treatment, the first spray was given at active tillering (40 DAS) and the second spray at panicle initiation (PI) stage (70-75 DAS).The total depth of irrigation water applied during 2015 and 2016 was 64.1 and 53.9 cm respectively.

Water productivity (kg ha^{-1} mm^{-1}) =

$$\frac{\text{Grain yield (kg ha}^{-1})}{\text{Total water consumed (mm)}}$$

Irrigation water use efficiency (kg ha^{-1} mm^{-1}) =

$$\frac{\text{Grain yield (kg ha}^{-1})}{\text{Irrigation water supplied (mm)}}$$

All the data were subjected to one-way analysis of variance (ANOVA) using the Statistical Analysis System (SAS Institute, Cary, NC). The F-test was used to determine significant effects of the K fertilization on water productivity, and irrigation water use efficiency and least significant difference (LSD) was used to compare means.

RESULTS

The effect of K fertilization on water productivity and irrigation water use efficiency of DSR was found significant both the year. Among the treatments, the highest water productivity and irrigation water use efficiency was recorded in T3, T5 and T6 whilecontrol (T1) plot recorded the lowest of it. The split application of 100% RDK (T3) increased the water productivity by 11.5 and 10.1% and irrigation water use efficiencyby 11.3% and 10.0% during 2015 and 2016 respectively over basal application of 100% RDK. The basal application of 75% RDK followed by 2 foliar sprays of 2.5% KNO_3 recorded similar rate of increase in water productivity and irrigation water use efficiency that of split application of RDK (T3).

Table 1: Effect of K fertilization on water productivity and irrigation water use efficiency of DSR

Treatments	Treatment details	Kg K_2O ha^{-1}	Water productivity ($kg\ ha^{-1}\ mm^{-1}$)		Irrigation WUE ($kg\ ha^{-1}\ mm^{-1}$)	
			2015	2016	2015	2016
T1	No K application	0	2.75^{C}	2.33^{C}	6.25^{C}	7.32^{C}
T2	Entire recommended dose of K (RDK) applied through muriate of potash (MOP) at sowing	60	3.40^{B}	2.86^{B}	7.74^{B}	8.98^{B}
T3	50% of the RDK was applied at sowing, remaining 50% applied at panicle initiation (PI) stage through MOP	60	3.79^{A}	3.15^{A}	8.62^{A}	9.88^{A}
T4	Two foliar spray (FS) of 2.5% KNO_3 [1st FS at active tillering (AT), 2nd FS at PI]	8.8	2.96^{C}	2.54^{C}	6.74^{C}	7.97^{C}
T5	Basal application of 100% RDK at sowing + 2 FS of 2.5 % KNO_3	68.8	3.78^{A}	3.15^{A}	8.61^{A}	9.88^{A}
T6	Basal application of 75% RDK at sowing + 2 FS of 2.5 % KNO_3	53.8	3.79^{A}	3.14^{A}	8.62^{A}	9.87^{A}
T7	150% RDK was applied at sowing in both the crops	90	3.40^{B}	3.08^{AB}	7.75^{B}	9.67^{AB}
SE(d)			0.122	0.118	0.277	0.371
LSD at 5%			0.265	0.257	0.604	0.808

However, the basal application of 150% RDK (T7) recorded significantly lower water productivity and irrigation water use efficiency over split application of RDK (T3). It shows, time of K application in DSR is more important than the rate of K application. Supplementation of K in later stage either through foliar sprays or top dressing increased the water productivity and irrigation water use efficiency through enhancing the growth and productivity of DSR. This may be due to supply of K at right time to meet the crop demand. Rice crop uptake K entire growth period but the maximum uptake was seen during maximum tillering stage (Singh et al 2004). In our study, the top dressing of K during tillering and flowering stage increased the K uptake which in-turn improved the water productivity and irrigation water use efficiency by improving the yield. The significantly lower water productivity and irrigation water use efficiency in T7 (150% RDK) might be due to lower supply of K because of higher fixation and leaching loss of applied K.

CONCLUSION

Our field study clearly demonstrated that split application of RDK and foliar sprays of K besides basal dressing is superior over basal dressing of entire RDK in dry DSR with respect to water productivity and irrigation water use efficiency. Thus, time of K application is very important than rate of K application in DSR. Adequate supply of K during tillering and panicle initiation stage enhance water productivity and irrigation water use efficiency in DSR.

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CUSTOMISED LEAF COLOUR CHART (CLCC) BASED REAL TIME N MANAGEMENT INFLUENCE THE AGRONOMIC ATTRIBUTES AND PROTEIN CONTENT OF RICE

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Rice is the principal cereal crop of Asia, which ensuresfood and nutritional security to the major population. Itaccounts for about 43% of total food grain productionand 46% of total cereal production in the country. Urea is the major N providing fertilizer today; itcontributes about 80% to the total fertilizer consumption in India. Fertilizer N is relativelyinexpensive, but deficiencies can result in substantialyield reduction.ExcessiveN application causes nutrient imbalances and producesplants which are susceptible to diseases and pests.Since farmers generally prefer to keep leavesof the crop dark green, it leads to over application offertilizer N resulting in low recovery efficiency. The spectral properties of leaves should be used in amore rational manner to guide need-based fertilizer N applications. To support decision-making on the timingof N application in rice, National Rice Research Institute(ICAR-NRRI) introduced the use of relativelyinexpensive customised leaf colour chart (CLCC), asimple and portable tool. Alam et al., 2005 observeda linear relationship between a CLCC reading and leafN content. The CLCC management approach may bea valuable tool for on-farm decision making.

METHODOLOGY

*Experimental site:*The field experiment was conducted during rainy(kharif) season of 2015 at Crop Research Farm,SHIATS, Allahabad (U.P.) which is located at 250 24'42" N latitude, 810 50' 56" E longitude at 98 m altitudeabove the mean sea level and lies in Indo-Gangeticplains. The soil (0 to 15 cm depth) of the experimentalsite was of sandy loam textural class having pH 7.79,EC 0.18 dSm^{-1}, organic carbon 0.52 %, availableN;126.3, P; 28.3and K;185.0 kg ha^{-1}.

*Experimental design:*The experiment was conducted in randomised blockdesign consisting of sixteen treatment combinations withthree replications. Out of the 16 treatments the resultsof the 8 treatments are presented in this manuscript.Therice crop variety used was SHIATS Dhan 1. Nutrient management was done through thestraight fertilizers, viz., neem coated urea (NCU), SSPand MOP to supply the required NPK respectively.Recommended dose of P_2O_5 and K_2O @ 60 kg $ha^{-1}$was applied to all the treatments as basal dressing. Thenitrogen application varied between treatments.Micronutrient zinc as $ZnSO_4$ at 25 kg ha^{-1} was alsoapplied to all the treatments as basal dressing. Thedetails of N fertiliser dose and time of applicationadopted in the experiment was as follows: - T_1= 70%RDN based on CLCC, T_2= 80% RDN based on CLCC,T_3= 90% RDN based on CLCC, T_4= 100% RDNbased on CLCC, T_5= 70% RDN based onconventional,T_6= 80% RDN based on conventional, T_7= 90% RDNbased on conventional, T_8= 100% RDN based onconventional.

RESULTS

Yield, yield attributes and economic analysisApplication of NCU at100% RDN resulted in highestnumber of effective tillers m^{-2} and panicle length (Table 1). However, the application of NCU as per

Table 1. Effect of nitrogen management on yield, yield attributes, harvest index and grain protein content of rice.

Treatment	No, of Grains Panicle^{-1}	Grain Fertility(%)	Test weight (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Harvest index (%)	Grain Protein (%)
T_1	148.60	83.22	15.63	4.72	5.17	47.73	6.24
T_2	153.52	87.75	16.16	4.80	6.13	43.93	6.90
T_3	155.59	89.42	17.08	5.33	6.47	45.19	7.63
T_4	159.54	92.50	17.47	5.93	6.76	48.63	8.23
T_5	147.15	81.79	15.44	4.60	5.06	47.62	6.09
T_6	152.08	86.29	16.06	4.91	5.29	48.15	6.50
T_7	154.01	88.83	16.14	5.11	5.82	46.76	7.35
T_8	155.62	89.05	16.31	5.35	6.07	46.85	7.84

CLCC(T_4) schedule resulted in significantly higher number ofeffective tillers m-2. Total number of grains per panicle and % fertility (Table 1) increased as the dose of NCUfertilizer increased and highest value was obtained at100% RDN in both conventional and CLCC basedmethods. For total number of grains per panicle, CLCCand conventional methods did not differ significantly,whereas grain fertility under CLCC was significantlyhigher as compared to conventional at 100% RDN.There was no significant effect of fertilizer dose andapplication schedule on test weight.There was a significant increase in grain yieldas the dose of NCU increased from 70 to 100% RDN.The increase in grain and straw yield was 26 and 16%under CLCC based application, whereas underconventional method the increase was 31 and 20%respectively under 100% RDN as NCU as comparedto 70% RDN as NCU. Use of

CLCC increased bothgrain and straw yield by 11% as compared toconventional method under 100% RDN as NCU.Real time application of NCU on the basis ofCLCC increased the PFPN by 11% under conventionalapplication method for 100% RDN. The use ofCLCC increased the grain protein content by 2.5, 6, 4and 5% respectively, under 70, 80, 90 and 100% RDNas compared to conventional method.

CONCLUSION

We conclude that the recommended dose of nitrogen,application of 120 kg N ha^{-1} through NCU with the helpof CLCC resulted in highest grain yield (5.93 t ha^{-1}),grain protein content (8.23%).Sincethe findings are based on the research done in oneseason, hence further studies are needed forconfirmation.

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IRC/TM-2/PP-60

HERBICIDE MIXTURES ON BROAD SPECTRUM WEED CONTROL AND YIELD PERFORMANCE OF DIRECT-SOWN SUMMER RICE (*ORYZA SATIVA* L.)

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Wet seeding of pre germinated seeds in puddle soil is competitive where water is not a scarce resource and gives yield comparable with the transplanted rice. But the production system is more vulnerable to weed infestation and uncontrolled weeds reduce the grain yield up to 61% (Maity and Mukherjee, 2009). Manual weeding is time consuming, tedious, and no more cost effective whereas herbicidal weed control is easy and economically viable. Though several pre- and post-emergence herbicides are available for weed control in rice but continuous use of herbicides with same mode of action year after year in the same field may lead to shifting of weed flora and development of herbicide resistance in weed. (Kumawat*et al.* 2018). Herbicides in mixture of products having different modes of action might contribute to sustainable weed management. By considering the facts, the new formulations of penoxsulam 1.02 % + cyhalofop butyl 5.1% developed by Dow Agro Science India Private Limited has been evaluated to find out the efficacy for weed control and increase in grain yield in wet direct seeded rice.

MATERIALS AND METHODS

The field experiments were carried out at research farm of ICAR-National Rice Research Institute, Cuttack during dry season, 2018 and 2019. The experiment was arranged in randomized complete block design with three replications. The treatments consist of penoxsulam 1.02 % + cyhalofop butyl 5.1% (new formulation) @120 g/ ha at 15 DAS, penoxsulam 1.02 % + cyhalofop butyl 5.1% (new formulation) @135 g/ ha at 15 DAS, bispyribac sodium 10% SC @ 25 g/ ha at 15 DAS, penoxsulam 1.02 % + cyhalofop butyl 5.1% (Vivaya)@120 g/ ha at 15 DAS, penoxsulam 1.02 % + cyhalofop butyl 5.1% (Vivaya)@135g/ ha at 15 DAS, hand weeding twice, and weedy check.

Pre-germinated seeds of rice variety 'Naveen' were sown in wet puddle soil. Weed control treatments were imposed as per the schedule of treatments. The data on weed density and biomass were recorded at 45 and 60 days after sowing. Grain yield of rice along with other yield components were recorded at harvest. The data were analyzed statistically in Ms-Excel for RBDas per the standard procedures, following the "Analysis of Variance" (ANOVA). The differences in the treatment means were tested by using least significant difference (LSD) at 5% level of probability. Weed data were subjected to square root transformation [Ö(x + 0.5)] before statistical analysis to normalize their distribution.

RESULTS AND DISCUSSION

At 45 DAS in weedy check grasses were dominant (45.0%) followed by broadleaved weeds (27.8%) and density of sedges was 27.2%. Grassy weed*Echinochloa crus-galli*was most dominant (23.2%) followed by sedge *Cyperus difformis* (14.3%) and *Echinochloaglabrescens* (12.8%). Among the broad leaved weeds average population of *Ludwigiaadscendens*was 8.7 % of total weed population followed by*Eclipta alba (7.9%).* All the herbicidal weed control treatments registered significant reduction in weed density and biomass of all three categories of weeds as compared to weedy check. Post emergence application ready mix penoxsulam

Table: Weed biomass, rice grain yield and yield attributes as influenced by the weed control practices

Treatments	Weed biomass (g m^2)	Plant height (cm)	Panicles/m^2	Grains/panicle	Test weight (g)	Grain yield (t/ha)	Weed index
T_1	7.16(50.8)	105.5	324.5	127	22.7	4.99	11.9
T_2	6.59(43.05)	105.5	328.5	128	22.8	5.20	8.3
T_3	6.50(41.8)	106.5	323.5	129.5	22.8	5.12	9.7
T_4	6.87(46.8)	105.5	324.0	128.0	22.9	5.13	9.7
T_5	6.01(35.6)	105.5	341.5	130.0	23.1	5.39	5.0
T_6	4.48(19.6)	106.5	361.0	132.0	23.3	5.67	0
T_7	12.92(166.5)	91.5	252.0	104.0	20.9	3.7	37.5
CD (p=0.05)	0.82	2.1	21.4	3.6	0.55	0.34	-

T_1:Penoxsulam 1.02 % (w/w) + Cyhalofop butyl 5.1% (w/w) OD (New Source) @120 g/ ha at 15 DAS, T_2:Penoxsulam 1.02 % (w/w) + Cyhalofop butyl 5.1% (w/w) OD (New Source) @135 g/ ha at 15 DAS, T_3:Bispyribac sodium 10% SC @ 25 g/ ha at 15 DAS, T_4:Penoxsulam 1.02 % (w/w) + Cyhalofop butyl 5.1% (w/w) OD (Vivaya 60 OD) @120 g/ ha at 15 DAS, T_5:Penoxsulam 1.02 % (w/w) + Cyhalofop butyl 5.1% (w/w) OD (Vivaya 60 OD) @135 g/ ha at 15 DAS, T_6: Hand weeding twice, T_7: Weedy check

1.02 % + cyhalofop butyl 5.1% in both the formulation and doses registered significant reduction in weed density and biomass as compared to weedy check. Both the technical formulation (Vivaya and new formulation) of penoxsulam 1.02 % + cyhalofop butyl 5.1% recorded at par in terms of reduction in total weed density and biomass.

Crop weed competition in weedy check has significant effect on plant height, yield attributes and grain yield of rice and resulted loss in grain yield to the extent of 37.5%. Post emergence application of ready mix penoxsulam 1.02 % + Cyhalofop butyl 5.1% (Vivaya 60 OD) registered lowest weed index (5.0%) due to broad spectrum weed control. Among the herbicidal treatments penoxsulam 1.02 % + Cyhalofop butyl 5.1% (Vivaya 60 OD) @ 135g/haregistered grain yield of 5.39 t/ha and yield attributes which was comparable with the manual weeding. New formulation ready mix penoxsulam 1.02 % + cyhalofop butyl 5.1% @ 135 g/ha recorded grain yield comparable with the bispyribac-sodium and existing formulation' Vivaya' in terms of increase in grain yield and decrees in weed biomass.

The present investigation suggests that penoxsulam + cyhalofop (ready-mix) @ 120 or 135 g ha^{-1} applied at 15DAS could be an alternative option for effective and economic control of broad spectrum weeds and enhancement of direct wet seeded rice. Post emergence application of ready mix penoxsulam + cyhalofop @ 135 g/ hawas quite safe to direct wet seeded summer rice and it could be recommended as an alternate to costly manual weeding for weed management in wet seeded rice under lowland rice ecosystem.

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POTENTIAL OF VALUE ADDED PRODUCTS OF SILICA FOR IMPROVING CROP YIELD

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Silicon (Si) has been described as a non-essential plant nutrient which performs useful functions for the plants. Trials on a variety of crops have shown the beneficial effects of using silicon fertilizers which include increase in root development, more effective tillers and an increase in plant mass. Leaves, stems and culms of plants, grown in the presence of adequate silicon levels, also show enhanced strength and rigidity and an erect growth (Epstein, 1999). Many experiments under different soil and climatic conditions on many different crops have shown a significant increase in both crop productivity and quality as a result of silicon amendments. Improvement in plant growth and yield is thought to be due to its indirect effects on photosynthetic and biochemical processes. Beneficial effects also arise from a higher resistance to biotic stresses and abiotic stresses due to biofortification of the plant with silicon.

There is an abundance of Si in almost any soil type, mainly as silicates, silicon dioxide, (mono- and poly-) silicic acid and biogenic silica. But these large quantities do not reflect the amount of soluble and plant available monosilicic acid (MSA). Due to many variables in the soil, conversion of these silica products in to MSA is very low. Moreover, with increasing concentration it polymerizes and is no longer bio-available. Furthermore, the solubility of monosilicic acid can be decreased by interactions with heavy metals, iron, aluminium and manganese. Due to these factors, there is a silicic acid deficiency in many types of soil (Laane, 2017). Although several silica based products are available, most of them have protected under IPR.

With this background, the objectives of this work were to develop silica based products adopting different route using rice husk as source of amorphous silica, and test their potential on different crops for improving their productivity. The developed products were potassium silicate of high modulas, silicic acid and slow release urea. The chosen crops were rice and maize.

METHODOLOGY

The starting material amorphous silica was derived from abundantly available rice husk which is a rich source of amorphous silica (20-25%).Both silicic acid and potassium silicate solution was prepared from the silica extracted from rice husk. Amorphous silica was first extracted from rice husk using conventional method of extraction. K-silicate of high modulus (M=3.5) was prepared by treating extracted silica with calculated amount of potassium hydroxide. Silicic acid (Si =1.60 %) was prepared by acidification of the K-silicate. Silica base slow release urea products were prepared by gellation method.

The experiments on rice and maize were conducted in Kharif-2019 and Rabi 2019-20. The experiment comprised of 6 treatments (T_1: Si, 20 ppm, T_2: Si, 40 ppm, T_3: Si, 80 ppm, T_4: Potassium silicate, SiO_2 4g/L, T_5: Potassium silicate, SiO_2 8g/L and T_6: Control) and laid out in randomized block design with four replications. Silicic acid and potassium silicate solution of different concentration as per the treatments were applied in both the crops by foliar spray at 15, 30 and 45 days after sowing/plantation of both the crops. In control (T_6) nutrients were applied as per the normal recommended practice. The fertilizer nutrients were supplied through urea, single super phosphate (SSP) and muriate of potash (MOP) at recommended dose of 120:60:40 N: P_2O_5: K_2O kg/ha. Plot size for each treatment was 1m^2 area. Apart from plot experiments, pot experiment was also conducted in for treatment with silica based slow releasing urea

RESULTS

Maize

All silicon treated plots resulted higher plant height, dry matter accumulation at harvest, crop growth rate and seed yield than those under control plots. Among the different silicon treatments, silicic acid 80 ppm resulted significantly the highest plant height (199 cm) at harvest stage, however, at par with silicic acid at 40 ppm (190 cm). Control plots where silicon was not applied in any form resulted the lowest plant height of 181 cm. The highest dry matter accumulation at harvest was under silicic acid 80 ppm treated plots (149.2 g/plant), however, at par with silicic acid 40 ppm (142.4 g/plant). The crop growth rate was the highest under silicic acid 80 ppm (14.5 g/m^2/day).

Rice

The grain yield in all the three silicic acid treatment was higher than the control (control-NPK- 5.10 t/ha; silicid acid+ NPK: 5.25-5.41 t/ha). Straw yield was also higher in all the silicic acid treated crop than the control (control-NPK- 6.62 t/ha; silicid acid+ NPK: 6.59—6.97 t/ha). Similarly, silicate treatment also produced higher yield of grain (control-NPK- 5.10 t/ha; silicate+ NPK: 5.36-5.89 t/ha) and straw (control-NPK- 6.62 t/ha; silicate+ NPK: 6.7 -7.7. t/ha) than the control.

In both the seasons, performance of SRU was better than control (without nitrogen) and NCU (50 kg N/ha and 100 kg N/ha). In Rabi 2019-20, number of grains/pot ranging from 302 to 537 in SRU treated experiment(applied with 50 kg N/ha) was higher than the number of grains in NCU(247, 100 kg N/ha; 211, 50 kg N/ha). Total grain wt in SRU treated pots (50 kg N/ha, 4.8-7.51 g/pot; 100 kg N/ha, 6.71-8.74 g/pot) was higher than that of NCU treated pots (50 kg N/ha, 3.42 g/pot; 100 kg N/ha, 3.83 g/pot) and control (no urea, 1.24 g/pot).

CONCLUSION

It shows that silicic acid, K-silicate had a positive effect on vegetative growth of the crop as the concentration increases. Foliar application of silicic acid three times at 15 days interval might have played a major role to increase the biomass of the crop. Silica based slow release urea has improved the productivity.

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IRC/TM-2/PP-62

EFFECT OF ORGANIC AND INORGANIC AMENDMENT ON NUTRIENT UPTAKE, PHENOTYPIC VARIABILITY AND YIELD OF VARIOUS RICE GENOTYPES UNDER *SODIC* SOILS

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Worldwide, approximately 1.2 billion hectare of area is estimated to be salt affected with different levels of salinity and sodicity of soils (Massoud 1974; Ponnamperuma 1984; Tanji 1990 and FAO 2007). However, India has the largest area under salt affected soils i.e. 6.74 million hectare. In India alone, 1.25 million hectare areas are characterized by coastal salinity, 3.79 million hectare as sodic and 1.71 million hectare area under saline soils. However, in Bihar, the total salt affected soils are spread over 0.15 million hectare area among which 0.11 million hectare area is under alkaline (sodic) soils and 0.047 million hectare area is under saline soils (NRSA and Associates 1996). Over 6.74 million hectare of the area is estimated to be lost each year to salinity, sodicity and drainage problems (Gupta and Abrol 1990). Moreover, economic loss is about 9% of the global value resulting from salt related land degradation (Ghassemi*et al.* 1995).In this experiment an attempt was made to assess the effect of nutrient uptake, phenotypic variabilityand rice productivity in various rice genotypes.

MATERIALS AND METHODS

Afield experiment was carried out during *Kharif* 2018 and 2019 at Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), Bihar. Experiment was laidout in split plot design with four treatments i.e. T_1 - Control, T_2 - Gypsum @ 100 % G.R., T_3 - Gypsum @ 50% G.R. + Biocompost @ 2.5 t ha^{-1} and T_4 - Biocompost @ 5.0 t ha^{-1} in main plots and ten rice genotypes G_1 - Suwasini, G_2 - Rajendra Bhagwati, G_3 - Boro-3, G_4 - Rajendra Neelam, G_5 - CSR-30, G_6 - CSR-36, G_7 - CR-3884-244-8-5-6-1-1, G_8 - CR-2851-SB-1-2-B-1, G_9 - CSR-27 and G_{10} - Pusa-44 in sub plots and replicated thrice. Application of N: P_2O_5: K_2O @ 120: 60: 40 kg ha^{-1} of urea, diammonium phosphate and murate of potash. Application of inorganic and organic amendment separately in treatment T_2 (Gypsum @100% G.R. in 2.5 kg $plots^{-1}$) and T_4 (Biocompost @ 5.0 t ha^{-1} in 5 kg $plots^{-1}$) and both inorganic and organic combined application in treatment T_3 (Gypsum @50% G.R. in 1.25 kg $plots^{-1}$ + Biocompost @ 2.5 t ha^{-1} in 2.5 kg $plots^{-1}$). The same treatment is applied on the same plots. The treatment was applied during 2018-19.

RESULTS AND DISCUSSION

The mean of among the different genotypes, nitrogen, phosphorous and potassium uptake in grain varied from 28.69 kg ha^{-1} to 44.09 kg ha^{-1}, 30.85 kg ha^{-1} to 44.43 kg ha^{-1} and 29.77 kg ha^{-1} to 43.70 kg ha^{-1}, 10.01 kg ha^{-1} to 15.35 kg ha^{-1}, 10.56 kg ha^{-1} to 15.15 kg ha^{-1} and 10.28 kg ha^{-1} to 14.98 kg ha^{-1} and 7.28 kg ha^{-1} to 12.21 kg ha^{-1}, 7.16 kg ha^{-1} to 10.88 kg ha^{-1} and 7.22 kg ha^{-1} to 11.50 kg ha^{-1} during 2018, 2019 and pooled mean of both the years, respectively. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and biocompost had higher nitrogen, phosphorous and potassium uptake in grain (42.65 kg ha^{-1}, 43.51 kg ha^{-1} and 43.08 kg ha^{-1}, 14.43 kg ha^{-1}, 15.21 kg ha^{-1} and 14.82 kg ha^{-1} and 10.89 kg ha^{-1}, 11.19 kg ha^{-1} and 11.04 kg ha^{-1} during 2018, 2019 and pooled mean of 2018 and 2019, respectively). The interaction between genotypes and soil amendments was non-significant. Nitrogen, phosphorous and potassium uptake in grain varied between 22.73 kg ha^{-1} to 50.69 kg ha^{-1}, 26.29 kg ha^{-1} to 49.45 kg ha^{-1} and 24.51 kg ha^{-1} to 49.96 kg ha^{-1}, 7.54 kg ha^{-1} to 17.65 kg ha^{-1}, 8.53 kg ha^{-1} to 17.64 kg ha^{-1} and 8.03 kg ha^{-1} to 17.51 kg ha^{-1} and 5.19 kg ha^{-1} to 13.79 kg ha^{-1}, 6.02 kg ha^{-1} to 12.82 kg ha^{-1} and 5.60 kg ha^{-1} to 13.30 kg ha^{-1} during 2018, 2019 and pooled mean of 2018 and 2019, respectively.

The mean of among the different genotypes, spikelet fertility, weight of 1000 grain and grain yield varied from 77.72 % to 89.82 %, 77.05 % to 86.46 % and 77.38 % to 88.14 %, 21.38 gm to 26.92 gm, 21.18 gm to 26.73 gm and 21.28 gm to 26.82 gm and 2.53 t ha^{-1} to 3.38 t ha^{-1}, 2.55 t ha^{-1} to 3.40 t ha^{-1} and 2.54 t ha^{-1} to 3.39 t ha^{-1} during 2018, 2019 and pooled mean of both the years, respectively. The minimum and maximum value was obtained in Pusa-44 and CSR-36, respectively. Similar values were observed among CSR-36, CR-3884-244-8-5-6-1-1 and CSR-27. All the soil amendments had significantly higher values as compared to the control plot. The combination of gypsum and biocompost application had higher spikelet fertility, weight of 1000 grain and grain yield (89.66 %, 86.59 % and 88.13 %, 25.63 gm, 25.59 gm and 25.61 gm and 3.35 t ha^{-1}, 3.32 t ha^{-1} and 3.34 t ha^{-1} during 2018, 2019 and pooled mean of both the years, respectively). Soil amendments and genotypes interaction was non-significant. Spikelet fertility,weight of 1000 grain and grain yield varied from 74.05 % to 91.83 %, 70.67 % to 89.74 % and 72.36 % to 90.30 %, 21.17 gm to 27.82 gm, 20.77 gm to 27.70 gm and 21.03 gm to 27.76 gm and 2.15 t ha^{-1}to 3.78 t ha^{-1}, 2.37 t ha^{-1} to 3.67 t ha^{-1} and 2.26 t ha^{-1} to 3.70 t ha^{-1} during 2018, 2019 and pooled mean of 2018 and 2019, respectively.

CONCLUSION

N, P and K uptake in grain had significantly higher in the genotypes CSR-27 followed by CSR-36 and CR-3884-244-8-5-6-1-1 and combination of gypsum @ 50% G.R. and biocompost @ 2.5 t ha^{-1} application had significantly higher followed by gypsum @ 100% G.R. application.

Spikelet fertility, weight of 1000 grain and grain yield had significantly higher in the genotypes CSR-36 followed by CSR-27 and CR-3884-244-8-5-6-1-1 and combination of gypsum @ 50% G.R. and biocompost @ 2.5 t ha^{-1} application had significantly higher followed by gypsum @ 100% G.R. application.

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IRC/TM-2/PP-63

GENOTYPIC VARIABILITY ASSESSMENT FOR NITROGEN USE EFFICIENCY AND ITS IMPROVEMENT IN IRRIGATED RICE

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Nitrogen (N) is the key nutrient element required in large quantities and the most limiting nutrient in irrigated rice is N and it's recovery efficiency is only about 25-40% of applied N in most farmers' fields. Hence improving nitrogen use efficiency in irrigated rice is a major concern at present. Varieties differ in their ability to absorb and utilize nutrients and genetic variation in nitrogen use efficiency in rice was reported by many workers (Ladha et al. 1995 and Hiroshi 2003). The existing N use efficiency pattern and the factors responsible for N use efficiency in existing popular rice varieties need to be well understood for further improvement in N use efficiency. Hiroshi (2003) reported that at reduced N rate, many of the high-yielding cultivars performed best not only in grain yield, but also in above ground drymatter, harvest index, N utilisation efficiency and sink capacity. Hence, to evaluate the N use efficiency of existing popular rice varieties to identify efficient rice genotypes across locations and to improve the N use efficiency of irrigated rice using various sources, field experiments were conducted during 2017-18.

METHODOLOGY:

Field experiments were conducted at the ICAR-Indian Institute of Rice Research, Hyderabad on a black clayey vertisol during *kharif* 2017 and *rabi* 2017-18 under N-0 (without external application of N) and N-100 (with 100 kg N/ha application) as main treatments and fifteen popularly grown high yielding varieties and hybrids as sub treatments in a split plot design with 3 replications. The experimental soil characteristics were: slightly alkaline (pH 8.2); non-saline (EC 0.65 dS/m); calcareous (free $CaCO_3$ 5.01%); with CEC 44.1 C mol (p+)/kg soil and medium soil organic carbon (0.64%) content. Soil available N was low (221 kg/ha); available phosphorus was high (102 kg P_2O_5/ha); available potassium was high (535 kg K_2O /ha). In another experiment, the variety, Varadhan was evaluated at graded levels of N (0-N, seed treatment with *T. harzianum*, 50, 75 and 100 kg N/ha) with five different nutrient combinations viz; Control with neem coated urea(NCU); rice straw compost (RSC); vermicompost (VC); NCU+nitrification inhibitor (NI), karanjin and NCU+VC+NI for improving NUE during *kharif* 2017 under transplanted rice. Also, a multilocation trial was conducted at four locations with 15 nitrogen use efficient cultures identified by six AICRP centres were tested at four locations [Bapatla (BPT), Chinsurah (CHN), Dharwad (DHR) and Gangavathi (GNG)] at two N levels (50%/ RDN and 100% RDN).

RESULTS:

During *kharif* and *rabi* seasons, mean yield was significantly higher at N100 compared to N0 which was higher by 30-40% and difference was high in *rabi*. Based on the grain yield, out of 15 genotypes, Rasi, Varadhan, PUP 221 MTP 5, MTP 3, and , B/V 243-1698 were found most promising for both soil and applied N utilization and responsiveness. At graded levels of N (N0, N50, N75 and N100 kg/ha) with different sources of N, grain yield of variety Varadhan was maximum with 100 kg N/ha while the yield at 50 and 75 kg N/ha was at par (Table 1). Whereas, seed treatment with *Trichoderma harzianum* resulted in

Table 1: Influence of N levels and sources on grain yield and Nitrogen use efficiency (Variety: Varadhan)

N levels (kg/ha)	Grain yield (t/ha)	N sources	Grain yield (t/ha)	AE (kg grain yield increase/kg N)	Recovery efficiency (%)
N-0	3.12 [d]	NCU	5.67 [a]	29	53
N-0 (seed treated with *Trichoderma harzianum*)	3.57 [c]	Rice Str. compost	3.93 [c]	11	24
N-50	4.16 [b]	Vermi compost (VC)	3.74 [c]	10	21
N-75	4.53 [b]	NCU+NI	5.53 [a]	25	50
N-100	5.41 [a]	NCU+VC+NI	4.76 [b]	18	40

AE- Agronomic efficiency; Figures with same letters are not significantly different.

significant yield increase by 14% over absolute control. Among the N sources, neem coated urea (NCU) either alone or along with nitrification inhibitor (NI) was superior to combined application of NCU+Vermi compost (VC)+NI and sole organic sources viz., rice straw compost (RSC) and VC at all N levels with maximum AE (25-29 kg grain yield increase/kg N) N recovery (50-53%) due to their slow N release and high recovery efficiency under transplanted conditions.

In the multi location trial, no significant difference between N levels was observed at two centres (BPT and GNG). This could be attributed to the higher recommended N (150-160 kg N/ha) at these centres so that the reduced N dose could not reflect in significant decrease in grain yield. Whereas, at CHN and DHR, 100% RD-N (75-80 kg N/h) recorded significantly higher grain yield by 20 and 34%, respectively, over reduced N level. With regard to genotypes, there was significant variation in grain yield among the genotypes and grain yield ranged from 3.45-6.84; 2.57-4.59; 1.93-7.27 and 2.71-8.74t/ha at BPT, CHN, DHR and GNG, respectively. Based on the grain yield performance, top 5 genotypes at each centre were identified. The variety, MGD -1605 can be ranked number 1 as it occupied top 5 list of all locations followed by MO 22- Shreyas and RNUE-10 at 3 locations, followed by GV- NUE-1 at 2 locations

CONCLUSIONS:

Significant genotypic variation was observed with regard to grain yield without N application and recommended N levels and some genotypes performed well even without N addition/at lower level of N addition showing their high NUE. Some genotypes were efficient without N addition and also responded well to N addition. Among the N sources, NCU either alone or with nitrification inhibitor (NI) was superior to other sources with their slow N release nature and high N recovery efficiency.

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IRC/TM-2/PP-64

CRADLE TO FARM GATE LIFE CYCLE CARBON FOOTPRINT ASSESSMENT FOR RICE-GREEN GRAM CROPPING SYSTEM UNDER DIFFERENT RESOURCE CONSERVATION TECHNOLOGIES

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Rice is a the third most consumed grain in the world and is a staple food for many people. About 90% of market supply and demand of the producer and consumer, comes from Asia. With the ever increasing population, the rice production requires to be annually increased by 1% to fulfill the demand. Although the economic contribution of rice is crucial, the sustainability in rice production is also necessary. In recent years, for realizing food security the emphasis has been shifted to resource conservation from exploitative agriculture. Rice cultivation is considered to be a significant contributor to the emission of green house gases (GHG). Measuring the carbon footprint of a product across the supply chain is a recent trend that has several benefits. It will help to make informed decision and identify the carbon effective products. To identify, proportionate and evaluate all sources contributing to GHG emissions from rice cultivation and assess the carbon footprint of the system this study is undertaken. Life Cycle Assessment (LCA) is an emergingand appropriate mechanism to achieve this objective.

METHODOLOGY:

The present investigation was taken up in the research farm of ICAR-National Rice Research Institute, Cuttack (Odisha). The experiment was laid out in randomized block design (RBD) withseven treatments namely conventional direct seeded rice (DSR) without N (Control); conventional DSR+ recommended dose of N fertilizer; brown manuring; green manuring; green manuring + CLCC; drum seeding; zero tillage DSR with three replications. Cradle to farm gate life cycle carbon footprint assessment was done by the method of ISO 14040–44 (https://www.iso.org/standard/37456.html). A mass balance approach was followedfor the estimation of the inputs and outputs per tonne production of rice equivalent yield (REY) up to farmgate(Alam et al. 2019).The greenhouse gasesemission which are related to the pre-farm activities wasmeasured by multiplying the amount of inputs with their respective emission factors (EF), whereasemissions by on-farm activities are related to the outputs by operating farm machinery, applying chemicals, and emission from soil.The total emission of GHG emission from the production of one tonne of rice equivalent yield was estimated by totaling emissions from pre-farm and on-farm activities of both rice and green gram crop.Net life cycle GHGs emission (carbon foot print; CF) wasevaluated by the difference of the total CO_2equivalentemission and SOC sequestered during the rice crop.

RESULTS:

Among the treatments, higher yield for rice was recorded in the green manuring + CLCC treatment which was significantly higher than other treatments. Under the zero tillage treatment, significantly higher value was recorded as compared to the control but at par with the DSR+RDF-N. With regard to the green gram, higher yield was found under zero tillage treatment which is significantly higher than other treatments. Overall systems yield expressed in terms of rice equivalent yield (REY), higher value was recorded for green manure + CLCC. It was found that the carbon sequestration varies significantly among the treatments and the higher value of it was recorded in the zero tillage DSR treatment which was at par with

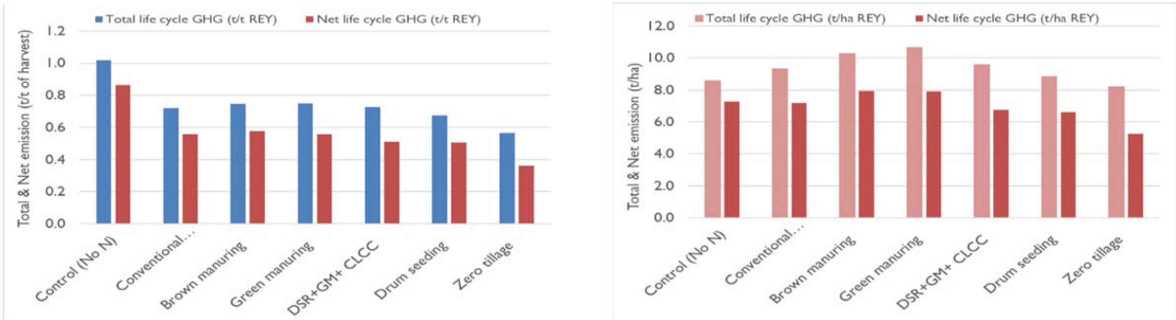

Fig. 1 Cradle to farm gate life cycle carbon footprint of rice-green gram cropping system under different resource conservation technologies

green manuring and significantly higher than other treatments. Aprofiling study was carried out to analyze the output (impact ofGHG) from the LCA inventory. Based on the inventory and actual measurements of the methane and nitrous oxide emission from the field under different treatments, cradle to farm gate carbon footprint (CF) was calculated and expressed as total emission based on t/t of harvest and t/ha for rice, green gram and whole system. Higher total emission of GHG for rice based on per unit area (t/ha) was observed in green manuring treatment and lower value was found in zero tillage, however, based on per unit production (t/t) higher emission was for the control treatment having no application of nitrogen, whereas the lower emission was observed in zero tillage. Similar trend was also observed for the green gram. The carbon footprint (net emission) for whole system (rice-green gram) was higher in green manuring treatment based on per unit area, however on per unit production basis, higher CF was observed in control followed by green manuring.

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LIMITATION AND POTENTIAL FOR UTILIZATION OF RICE STRAWFOR PULP AND BIOETHANOL PRODUCTION

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Rice (*Oryza sativa*) is the main staple food of the Asian countries. In most of the Asian countries, open field burning of rice straw is in common practice for its disposal that leads to air pollution. In India, 60% of rice straw is either left or burnt in the field and the open burning of straw is a threat to atmosphere and climate as it contributes 0.05% to GHG emissions. Efficient utilization of rice straw resource could provide bioenergy and reducing the risk of environmental pollution. Cellulose, hemicellulose, and lignin are the major cell wall components in lignocellulosic materials, like rice straw. Rice straw can be used in bio-ethanol production and bring additional income to farmers. It could also provide clean energy solution to ever increasing energy demand in India. On an average straw contains 50–80% carbohydrates are also viewed as a potential substrate for pulp making industries. However, the major limitation of using rice straw in paper pulp is its high ash content 10–17%. Therefore, to remove the silica the chemicals used for pulp making causes scaling of equipment and inhibits the recovery of black liquor released during pulping process. Viewing the above-mentioned points, in the present study we reviewed the limitation and potential of rice straw for pulp making and bioethanol production.

METHODOLOGY

The paper has been synthesized after thorough study of research articles on rice straw characterisation and its application in pulp and bioethanol production. In this regard, many search platforms were approached online like Research Gate, Wiley Online Library and Elsevier Science Direct. To collect the literature, many journals like Journal of Cleaner Production, Industrial Crops and Products, Bioresources, Bioresource Technology, IPPTA and Carbohydrate Polymer etc were reviewed. Specifically, in India, the research papers from IIT Roorkee, Saharanpur campus and annual reports of governmental agencies like CPPRI, Saharanpur, were extensively analysed. The technological, economic, and environmental aspects of limitation and opportunity of production of bioethanol and paper-pulp from rice straw were analysed from the collected data of around 80 published articles.

RESULT

Limitation and potential for utilisation of rice straw for pulp and bioethanol production were analysed on the light of second-generation ethanol production and improvement of pre-treatment technique. High silica content in rice straw poses problems for both industry and environment; however, high cellulose contain favours enzymatic saccharification, due to cellulosic-based biofuel compared to food derived bioethanol originating mainly from corn starch and sugarcane.

Bioethanol from Straw

Limitation

High silica in rice straw poses a problem in bio-ethanol production. In rice straw, cellulose is embedded in the lignin matrix, some pretreatment to be carried out to make cellulose accessible for enzymatic saccharification (Wi et al., 2013). Pretreatment of rice straw with alkali results in an increase in interfacial adhesion between rice straw flour and polypropylene thereby improving the mechanical properties. High cost of pre-treatment is the key limitation of production of bioethanol from rice straw (Table 1).

Table-1: Limitation and Potential of bioethanol production and pulp making from Rice Straw

Limitation	Potential
A. Bioethanol Production 1- High silica contains (60-80%) 2- Costly Pre-treatment to make cellulose accessible for enzymatic saccharification. 3- High capital and transportation costs which affect the ethanol cost of production 4- Economically not widely acceptable.	1. High Cellulose contains (40-45% 2. Cellulosic-based biofuel potential. 3. Production of second-generation biofuel 4. Rapid progress of improved pre-treatment technology.
B. Pulp making	
1- High silica contains (60-80%). 2- Diversion of agro based mills to waste paper mill. 3- Indian mills are continuously using chlorine as a bleaching agent due to techno-economic reasons and threatening the environmental quality. 4- High ash contains (10-17%)	1. Efficient Chlorine free technology 2. Develop reliable and cost-effective method for pulp bleaching. 3. Development of eco-friendly, economic, and reliable pulping and bleaching method for rice straw 4. High Cellulosic contains (32-40%)

(Source: S. Soam et al., 2016;D. Kaur et.al., 2016)

Potential

Rice straw can effectively be used to produce second-generation biofuels. Several reports were there on utilization of rice straw for the production of second-generation biofuels. Anaerobic digestion of rice straw is a green technology since it produces better option for waste utilization as well as reducing greenhouse gas emissions. Several pretreatment are currently available which includes physical, chemical, biological and hybrid processes for effective hemicelluloses and lignin removal from straw (Table 1).

Pulp from Rice Straw

Limitation

High silica content in rice straw poses problems for both industry and environment for pulp making. Use of chlorine compounds as bleaching agents were known to generate various toxic materials. About 500 chlorinated compounds were found to exist in the bleaching spent liquors, causing health hazards like liver and kidney damages, reduce gonads development and hormonal diseases in many aquatic species (Hostachy, 2010). India has a large number of agro based pulp and paper mills with lower production capacity (< 60 tonnes/day).

Potential

The agro based paper industry in India concentrated mainly in Western U.P., Punjab, Andhra Pradesh, and Maharashtra, but spreading rapidly in recent past in all over India. Pollution abatement can be done by effluent treatments through pulp washing, by xylanase pre-treatment, oxidative alkaline extraction, and elemental chlorine free technology. Such practices may be adopted by industry with aim of finding suitable, eco-friendly, economical and reliable pulping and bleaching sequence in case of rice straw raw material.

CONCLUSION

The high silica content and costly pre-treatment of straw are the major limitation of bioethanol production from rice straw. However, economic and environment friendly enzymatic pre-treatment methods gets momentum in last decades which needs further investment and commercialization. In pulp making from straw efficient bleaching (with minimum use of chlorine) to minimize the silica content in black liquor is the key for environmental point of view. However, industries are still using conventional methods for pulp bleaching using chlorine and chlorine derivatives with significant pressure on environmental resources. But more emphasis must be given to improve the bleaching techniques to make the process environment friendly.

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ORGANIC NUTRIENT MANAGEMENT IN RICE-BASED SYSTEM FOR SUSTENANCE OF SOIL HEALTH, GRAIN QUALITY AND PRODUCTIVITY

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Green Revolution, though achieved a quantum jumpin cereal production, greatly relied on chemical fertilizers to enhance the yield potentiality but it took a heavy toll on soil health in the subsequent decades caused a yield stagnation (Sheehy et al. 2007). Organic manures, often preferred as a low-cost and easily accessible nutrient source for improving thesoil's physical-chemical-biological parameters, and better access to soil nutrients for long-run (Kassam et al. 2011). So far more emphasis was given on the INM approach, however the present study highlights the significance of sole ONM for achieving a sustainable soil health and crop yield as well as grain quality of rice.

METHODOLOGY

The experiment is being maintained in rice (*kharif*)- groundnut (*rabi*-summer) system since *kharif*, 2016 at institute farm, while the particular plot has been cultivated avoiding chemical fertilizers from more than a decade. The eight distinct organic nutrient treatments were as follows: T1-Control; T2-FYM; T3-Azolla; T4-Green manure; T5-Vermicompost; T6-FYM+Azolla, T7- FYM+green manure; T8-FYM+Vermicompost. Groundnut was grown under irrigated condition with two treatments: R- Rhizobium-treated; NR- Non-rhizobium, with only residual N supplemented by organic manures applied in previous rice crop. Two rice varieties, Padmini and Ketakijohawere grown whereas split-plot design was followed for establishment of the experiment.

To assess the impact of ONM on soil health, several soil parameters like physico-chemical (pH, EC), fertility (SOC, TOC, available N, P, K and micronutrients),soil microbial activity (dehydrogenase, phosphatase, urease, β-glucosidase, aryl sulfatase, fluorescein diacetate hydrolysis enzymes and glomalin content) was analysed using standard protocols. Besides, biochemical analyses of grain quality parameters (amylose, protein and water uptake) were also performed. Yield data (both grain and straw) was recorded at the harvesting of every season.

RESULTS

At the end of three years of field experimentation with the different organic nutrient sources (single and in combination) under rice-groundnut rotation, results showed that both the cultivars had responsiveness towards organic sources of nutrients, as the grain yield of Ketakijoha was enhanced by 25% over control at T5; while Padmini performed better by 33% over control at T8, hence the effect of vermicompost was seen prominent in both cases. Groundnut,the next crop in rotation also showed responsiveness towards residual organic sources of nutrients applied in the past rice season, and seed treatment with rhizobium culture improved pod yield at T6 and T7 treatments. Nodule count improved via rhizobium inoculation at FYM+Green manure which indicates better biological N fixation in the treatments. Consequently, the soil parameters like SOC, TOC contents and availability of major and micronutrientswere higher in T6, T7 T8 (i.e. FYM+ Azolla/Green manure/Vermicompost). Further, the same treatments(T6, T7, T8) could also improve soil microbial activities like dehydrogenase, urease, acid and alkaline phosphatases, â-glucosidase, aryl sulfatase and fluorescein diacetate hydrolysis enzymes. The glomalin contents varied between 0.75-0.92 mg g^{-1} soil (easily-extractable glomalin-related soil protein i.e. EEGRSP) and 1.07-1.37 mg g^{-1} soil (total-extractable glomalin-related soil protein i.e. TEGRSP). This is an indirect expression of arbuscular mycorrhizal fungi, and favoring the formation of stable aggregates.Azolla supplemented treatment improved the grain protein content with non-significant changes in amylose and water uptake. These findings direct towards soil fertility enrichment through FYM combined with other organic manures that further impacted on nutrient uptake by rice grain.

CONCLUSION

This particular study emphasizes that organic manures could enrich the rice-cultivated soil that reflects in soil nutrient availability, soil inhabiting microbial activity and grain quality so that it can be proposed as a long-term strategy for agricultural sustainability. Besides the INM, the practice of ONM can also be alternatively adopted among the rice farmers considering its importance in soil fertility management and yield sustenance.

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RINSKOR™ ACTIVE: ANALTERNATIVE SOLUTION FOR BROAD-SPECTRUM WEED MANAGEMENTOF RICE IN INDIA

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Rice, the staple diet for over half of the world's populationis grown over 113 countries. More than 90% of total rice produced globally, comes from Asia with China and India as the major contributors. Depending on geography, soil type, rainfall distribution, irrigation facility, labor availability, Indian farmers grow rice crop by direct sowingor transplanting. Irrespective of rice cultures, weeds are major threat to farmers and its management is very complex and challenging. Weeds can cause significant yield loss, if not manage properly.

Rinskor™ active is a new arylpicolinate herbicide and has global utility in direct seededand transplanted rice along with utility in several other cropping systems. It has broad spectrum activity on important grasses, sedges, and broadleaf weed species in rice.Novlect™ 120 EC and Novixid™ 32.5 OD are two post emergence pre-mix rice herbicides with Rinskor™ active, aredesigned for broad spectrum rice weeds management.

OBJECTIVES:

Novlect 120 EC and Novixid32.5 OD herbicides were evaluated under direct seeded rice and transplanted rice cultures respectively throughdifferent field trials during Kharif 2018 and 2019 in Chattishgarh and Karnataka provinces of India. Objectives of these studies were to evaluate the bio-efficacy of Novlectand Novixidfor grass, sedge and broadleaf weeds control under diverse geographical conditions.

METHODOLOGY:

Field study treatments for Novlectincluded Novlect 120 EC at 150 g ai ha^{-1},a comparison reference standard, bispyribac-sodium 100 SC at 25 g ai ha^{-1} and non-treated control. Similarly, field study treatments for Novixidincluded Novixid 32.5 OD at 40.6 g ai ha^{-1},bispyribac-sodium 100 SC at 25 g ai ha^{-1} and a non-treated control. Foliar applications targeting 3 to 5leaf stage of grass weeds wereperformed using a knapsack sprayer fitted with flood jet nozzle. Experiments were conducted in multiple locations and the number of locations (8) weretreated as replications for the analysis. Treatments were assessed based on percent visual weed control at 15 and 30 days after application (DAA) and weed count at 30 DAA. Crop response was also evaluated at 7, 15 and 30 DAA based on a visual assessment scale of 0-4.

RESULTS:

Novlect 120 EC at 150 g ai ha^{-1} provided effective control (>90% visual weed control) of *Echinochloa colona*, *Echinochloa crusgalli*, *Leptochloa chinensis*,*Cyperus difformis*, *Ludwigia* sp. and *Bergia capensis* at 30 DAA. Efficacy of Novlect 120 EC at 150 g ai ha^{-1} was either similar to or better than reference standard against evaluated weeds. Novlect 120 EC was found to be safe to the rice crop.

Novixid 32.5 OD at 40.6 g ai ha^{-1} provided effective control (>90% visual weed control) of *Echinochloa colona*, *Echinochloa crusgalli*,*Cyperus difformis*, *Ludwigia* sp., *Eclipta alba*and *Bergia capensis*at 30 DAA and the efficacy of Novixid32.5 OD at 40.6 g ai ha^{-1} was either similar to or better than reference standard against evaluated weeds. Novixid 32.5 OD was found to be safe to the rice crop.

CONCLUSION:

Novlect 120 EC and Novixid 32.5 OD herbicides demonstrated excellent control of key grasses, sedges and broadleaf weeds with adequate crop safety and it can provide a novel and effective solution to farmers for weed managementunder different rice cultures of India.

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Keywords: Rinskor™ Active, Novlect 120 EC, Novixid 32.5 OD, Rice, Weed control

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MECHANIZATION IN DIRECT SEEDING WETLAND PADDY CULTIVATION SYSTEM USING ANIMAL POWER ON SMALL FARMS

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Rice covers about 69% of the cultivated area and is the major crop, covering about 63% of the total area under food grains in Odisha (Das,2012). Growth of mechanisation in rice production has been phenomenal in the state during last two decades and it has started to take place even on small farms in response to rural labour shortage and increased labour cost. Under wet land rice cultivation system, it has been shown that wet seeding or direct seeding of sprouted seeds on puddled soil gives as much yield as a transplanted crop, and the cultural practices of wet seeding are similar to those of a transplanted crop (Das,2012). The wet seeding method is adopted as a contingent measure when there is a shortage of seedlings, especially in post flood situations (Pani and Patra 2004).The animal energy for agriculture is often regarded as renewable energy/ green energy or clean energy has got a key role since the small and marginal farmers who dominate the Indian as well as state agrarian sector survive with bullock farming system. At present, more than 91.84 % farmers of the state of Odisha come under small and marginal farmers' category who cultivates around 70.34 % of the total cultivable land. An attempt was made to assess the direct seeding wetland paddy cultivation system using animal power on small farms in Gajapati district of Odisha. The performance of improved bullock drawn implements, developed through All India Coordinated Research Project on Utilization of Animal Energy, OUAT, Bhubaneswar for wet land paddy cultivation were evaluated in farmers' field and compared with conventional method of rice cultivation.

METHODOLOGY

The field experiment was conducted during Rabi and Kharif seasons, 2019 with 5 farmers in village-Govindpur, Mohana, Gajapati district where rice-green gram cropping system is the prevailing practice. Under mechanized wet land rice cultivation method, performance evaluation of OUAT bullock drawn mb plough, OUAT puddler and OUAT 8 row bullock drawn drum seeder was conducted for line sowing of pre-germinated paddy seeds during *kharif* season which was compared with conventional random transplanting method for wet land paddy cultivation. For paddy, high yielding variety *Swarna* were selected. Recommended package of practices with references to fertilizer and plant protection measure were followed for the experiment. The functional parameters, plant growth parameters and yield parameters were recorded to compare the performance of improved bullock drawn implements for mechanization of wet land rice cultivation system.

RESULTS

The results on functional parameters, plant growth parameters and yield parameters of mechanized wet land rice cultivation system using improved OUAT bullock drawn 8 row pre-germinated paddy seeder for line sowing of pre-germinated paddy seeds and conventional method of rice cultivation using manual random transplanting method, conducted during Kharif-2018 season have been presented in Table 1. The results indicated that the average actual field capacity of the bullock drawn drum seeder was 0.16 ha/h with 62.5% field efficiency and average seed requirement

Table 1. Results on functional parameters, plant growth and yield parameters of mechanized wet land rice cultivation system and conventional method of random transplanting method (Kharif, 2018)

Parameters	Mechanized wet land rice cultivation method	Conventional random transplanting method
Actual field capacity, ha/hh/ha	0.166.25	-
Speed of operation, kmph	1.6	-
Draft, N	453.2	-
Power, hp	0.27	-
Cost of operation, Rs/ha	1275	10900
Seed rate, kg/ha	30.25	41.52
Labour requirement, man days/ha	3.71	52.0
Field efficiency, percent	62.5	-
No of plants/sqm at maximum tillering	387	333
Plant height, cm	121.1	109.5
No of panicles/square m	349	311
No of grains/ panicle	119	112
1000 grain weight, g	24.6	22.1
Grain yield, q/ha	54.5	46.6
Straw yield, q/ha	66.9	60.1
B:C ratio	2.44	1.66

- Cost of conventional transplanting: Rs 10900/- per ha [(30 workers/ha for transplanting + 20 workers for nursery uprooting + bullock with plough man 1 day with 2 workers for nursery bed preparation)
- Cost of planting by 8-row bullock drawn drum seeder: Rs 1275/- per ha [(operating cost of drum seeder is Rs 108/h) x 6.25 hrs/ha) + 1 worker for watching 3 days]

of 30.25 kg/h. The average power requirement was found to be 0.27 hp with average speed of operation of 1.6 kmph and average draft of 453.2 N. The results on plant growth parameters (no of plants/sqm at maximum tillering, plant height, no of panicles/sq m) and yield parameters (no of grains/ panicle, 1000 grain weight, grain yield and straw yield) revealed that the mechanized method of wet land rice cultivation using improved bullock drawn implements were superior to those in conventional method of manual random transplanting method.The average cost of operation and B:C ratio were found out to be Rs1275.00 per ha and 2.44 as compared to Rs10,900.00 per ha and 1.66 respectively for conventional method of manual random transplanting. The labour requirement for conventional method was 52man days per ha as compared to 3.71man days per ha. Although there are a number of limitations in the bullock drawn drum seeder method like controlled condition of field, protection of pre-germinated paddy seeds from birds up to 3 days after sowing and unwarranted weather conditions; but this method is superior to the conventional method considering the higher labour requirement, shortage of labour during peak hours, higher drudgery and most importantly higher cost involvement. Considering the plant growth parameters and yield parameters, the mechanized method of wet land rice cultivation using the OUAT bullock drawn 8 row pre-germinated paddy seeder for line sowing of pregerminated paddy seeds is found superior to conventional random transplanting method for small farm mechanization.

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RESPONSE OF PRE-RELEASED RICE VARIETIES TO DIFFERENT LEVELS OF NITROGEN IN COASTAL ANDHRA PRADESH

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"Rice is Life" reflects the importance of rice as primary food source and drawn from an understanding that rice-based systems are essential to everyone directly or indirectly for food security, livelihood improvement, cultural heritage and sustainable development for global peace. Rice is grown in more than 90 percent of rice produced and consumed Asian countries as staple food crop. In India, it is cultivated over 43.79 m.ha. area with a production of 112.91 m.t. of milled rice and an average productivity of 2578 kg ha^{-1} (DES, 2018). In Andhra Pradesh, rice is grown in 2.1 m ha of area with annual production of 12.0 m.t. and 5.70 t ha^{-1} productivity (Anonymous, 2018). The production and productivity of rice growing areas are fluctuating every year due to different biotic and abiotic constraints. Fertilizer is one of the most efficient means of increasing rice yield (Reddy *et.al.* 2014). Among essential plant nutrients, nitrogen plays a very important role for growth and development of rice crop and considered as quantity and quality limiting factor (Manukonda, 2017 and Singh *et.al.* 2015). The use of high yielding varieties with modern production technologies has increased the rice production substantially. Application of inadequate and unbalanced fertilization to crops not only results in low crop yields but also deteriorate the soil health. The medium duration rice varieties have a potentiality of 8-10 t/ha is not attaining due to biotic and abiotic stresses. Keeping this in view, present investigation was formulated for standardization of nitrogen doses for medium duration pre-released rice varieties to attain maximum economic yield.

METHODOLOGY

An experiment was conducted during *Kharif*, 2018 at Regional Agricultural Research Station, Maruteru, Andhra Pradesh under deltaic alluvial soils to work out the optimum level of nitrogen and also to find out the interaction effect between nitrogen levels and performance of pre-released rice varieties. Experimental site was located at 16.38^0 N latitude, 18.44^0 E longitude with an average elevation of 5 m above MSL altitude. The experiment was laid out in split plot design and replicated thrice with three levels of nitrogen (75% RDN – 67.5 kg/ha, 100% RDN – 90 kg/ha and 125% RDN- 112.5 kg/ha) and seven pre-released medium duration rice varieties (MTU 1229, MTU 1224, MTU 1226, MTU 1184, MTU 1194, MTU 1239, MTU 1262 and one check variety MTU 1075. The recommended dose of 60 kg/ha P_2O_5 and 60 kg/ha K_2O was applied commonly to all the treatments as basal. The soil of experimental plot was clay loam in texture, which was neutral in reaction (6.95) and medium in organic carbon (0.85%), low in available nitrogen (294 kg/ha), medium in available phosphorus (28 kg/ha) and high in available potassium (325 kg/ha).

RESULTS

The response of pre-released rice varieties to different levels of nitrogen was significant and highest average grain yield of 7222 kg/ha was recorded with MTU 1194 which is superior over rest of the varieties including check MTU 1075 (6597 kg/ha) and remaining varieties are at par with local check. The response of varieties to lower level of nitrogen (75% RDN) was well established with MTU 1194 (7375

Table. Grain yield (kg/ha) of rice varieties as influenced by nitrogen levels (*Kharif*, 2018)

Pre-Released Rice Varieties	N1 (75% RDN)	N2 (100% RDN)	N3 (125% RDN)	Mean of Variety
V1: MTU 1229	5575	6875	6142	6197
V2: MTU 1224	4575	5875	6075	5508
V3: MTU 1226	5475	5175	5508	5386
V4: MTU 1184	4775	6108	5608	5497
V5: MTU 1194	7375	7250	7042	7222
V6: MTU 1239	5675	5608	5792	5692
V7: MTU 1262	6842	5942	6275	6353
Check: MTU 1075	6442	6808	6542	6597
Mean	5842	6205	6123	
Factors	C.D. (5%)	SE (d)	SE (m)	
N Levels	N.S.	144.1	101.9	
Varieties	464	229.9	162.6	
V at same level of N	842	398.2	288.2	
N at same level of V	845	399.4	282.4	

kg/ha) and MTU 1262 (6842 kg/ha) and superior over 100% and 125 % RDN. But majority of the varieties are responded well to 100% RDN. The lowest grain yield was recorded with pre-released variety MTU 1226 (5386 kg/ha) even at normal recommended dose of fertilizers. This may be due to poor source to sink ratio in productive tillers and filled grains per panicle resulted less yields in MTU 1224 and MTU 1126 rice varieties. Some pre-released varieties like MTU 1224, MTU 1239 and MTU 1184 responded well with increased levels of nitrogen up to 125% RDN. It shows that medium duration rice varieties under favorable conditions will respond more with more fertilization but it leads to extension of crop duration by 5-7 days. Supply of nitrogen enables rice plant to assimilate sufficient photosynthates resulting in increased by dry matter production and these together produced more panicles leading to higher grain yield was reported by Sivaleela*et.al* (2018). It indicates that, varieties released from Maruteru rice research station are well suited under recommended dose of fertilizers under normal soils and some varieties like MTU 1174 and MTU 1262 are well fitted even under low nitrogen fertility soils of Andhra Pradesh.

CONCLUSION

It clearly shows that increase in nitrogen level there was a positive response with medium duration rice varieties. Application of 100% RDN is found optimum for realizing higher grain yield in medium duration pre-released rice varieties however MTU 1194 and MTU 1262 were well established even under lower dose of nitrogen (75% RDN) and registered highest grain yield among all pre-released cultures and local high yielding check MTU 1075.

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INTEGRATED AGRICULTURE-AQUACULTURE (IAA) BASED FARMING SYSTEMS IN DOUBLING OF FARMER'S INCOME IN EASTERN INDIA

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Acceleration of agricultural growth has been paramount essential for achieving sustainable development goals (SDG) in respect to food and related livelihood security for every Nations. In the past, our agricultural developmental strategies and policies have been successful in meeting the countries food demands, however, it lacks proper emphasis on enhancing farmer's incomes (increase in quality and higher income generation etc.) or measures to promote farmer welfares. Additionally, after 50 or more years of adoption of Green Revolutions, India has been experiencing the second generation challenges like decline in factor of productivity growth, degradation in soil health, loss of soil organic carbon, water related stress (ground and surface water pollution, declining ground water), increased incidence of pests and diseases, increased cost of inputs, decline in farm profits and the adverse impact of climate change. The net results caused large scale agrarian distress (low farmer's income, remain poor and disparity in income levels farmer and non-agricultural workers) which eventually leads to varied social and economic problems among the farmer's communities.

Agrarian distresses are very crucial and needs to be addressed suitably with enhancing the farmer's income and promoting the farmers welfare measures. For achieving profitability from farming, farmers do requires newer technological innovations (low cost agricultural inputs with higher productivity), policy supports for easy credit (with lower interest) and proper facilitation for marketing their products to get maximum benefits. Keeping view of the above, a target set by the Hon'ble Prime Minister of India "doubling of farmer's income" by 2022-23. The economic think-tank at *Niti Aayog* has put forth four-point action plans for doubling the farmer's income in India i.e. provisioning of remunerative prices, increasing productivity, reforming agriculture policy and with provisioning of adequate relief measures. The strategies of doubling real income of farmers (by 2022-23 over the base year of 2015-16, requires 10.4 % growth rate) required massive investments in agricultural research and development, creation of agricultural infrastructures, adaption of good agricultural practices (GAP), conservation agriculture technology, implementation of farmers friendly policies, judicious use of available resources and inputs, along with improved market and transportation facility and adequate facilitation of policies reform on minimum support price (MSP) reform and easier and timely availability of bank credits etc. Diversification of agriculture with involving high value crops may prove as a game changer and experts engaged in searching the options, identified integrated farming system (IFS) approach is one of the potential systems for doubling the farmer's income within a reasonable time frame. Moreover, IFS becoming more relevant in the contexts of climate change, declining natural resources, increasing water scarcity etc. as IFS provisioned for diversification, higher productivity, recycling of farm wastes, safeguarding the environments with embedding of adaptation and mitigation options along with provide multiple sources of income etc. (Nayak et al., 2018; Nayak et al. 2020). Therefore, integrated aquaculture-agriculture (IAA) involving rice -fish-livestock-horticultural and agroforestry system and allied enterprises can contribute towards sustainability, enhancing productivity and possibly, doubled the farmer's incomes within the reasonable time frame.

METHODOLOGY

ICAR-NRRI has developed integrated aquaculture-agricultural (IAA) systems involving various combination of enterprises of crop-livestock-horticulture and agroforestry IFS for enhancing productivity with provisioning of adaptation and mitigation options. The system designed (65% rice cultivation area, 15% water refuge and 20% bund area) with suitable land shaping using ecological engineering concepts of soil, water conservation, nutrient and farm waste recycling (composting, mushroom and vermicomposting) with multi-enterprising components of crops, seasonal vegetables, horticultural plants (banana, papaya, mango, guava, coconut), livestock (fish, duckery, poultry, goatry), fodder grass and agroforestry etc. The four key agro-ecological strategies (bio-diversification, soil conservation, water harvesting and farm waste recycling) were used in the design and managements in rice-fish based integrated agro-ecosystems for enhancing the farm productivity and economic benefits.

RESULTS

Adoption of crop-livestock-agroforestry systems or its related combination of enterprises resulted significant enhancements of productivity (Nayak et al., 2020). Pilot studies conducted in low land rice ecologies using various combinations of enterprises indicated accrual of the higher productivity andincreased levels of benefit cost ratio and can be potentially adopted for doubling of farmer's income (Table 1).

The benefit-cost ratio indicated in each type of integrated systems invariably depends on the type of enterprise combinations and extent of their managements. The impact analysis of IFS indicated higher productivity, increases energy and water use efficiency with bio-control prospecting of weeds and pests. In addition to this, the IFS having efficient nutrient and farm waste recycling (composting, mushroom cultivation and vermicomposting), provisioning of enhanced benefits of ecosystem services, improvements in biodiversity along with climate adaptation and mitigation options (Nayak et al., 2020). IFS enhanced soil and water quality index (SQI,WQI) is an indicative of improvements in soil health and fertility. The study indicated IFS are more productive and ecologically efficient agricultural system, accommodate multiple subsystems and multiple enterprises which diversifying the source of farmers income and generating additional employments, and have the potentialities for doubling the farmers' incomes.

Table 1. Comparison of profitability (benefit cost ratio) in different type combination of enterprises in IFS

Integrated farming systems and their components	Combination and nos. of animals	Benefit cost ratio (B:C)
Rice	R	1.55
Rice + duck	R+150	1.86
Rice + duck + fish	R+ 150+ F	2.13
Rice + duck + fish + goat	R+150+F+10	2.33
Rice + duck + fish + goat + Poultry	R+150+F+10+100	2.45
Rice + duck + fish + goat + Poultry + Horti	R+150+F+10+100+Hort	2.96
Rice- ornamental fish culture	R + Ornamental fish	2.5
Crop-livestock-agroforestry based IFS	Crop + livestock + agroforestry + fodder etc.	2.9-3.4
Rice –fish –*Azolla* –duck IFS	R + F + duck + Azolla	2.7-3.0
Multitier rice-fish horticulture-based IFS	R + F + Hort. + agroforestry	2.0-2.5

R- Improved varieties of rice; F- fish; Hort. – horticultural crops

CONCLUSION

The synergistic diversification of the farming systems with crop intensification, addition of higher value crops and compatible livestock components along with inclusions of agroforestry, horticultural plants, kitchen garden and seasonal vegetables etc. will enhances the income of small and marginal farmer'sin India. The systems (IFS) considered as an eco-efficient land management practices, and up-scaling with new varieties of cash crops and their ensuing management technologies invariably enhances the productivity. Additionally, making direct link or creation of new market opportunities for marketing their products could potentially doubling the income of farmers. The system provides production sustainability with nutritional, economic, employment and environmental security for Indian small and marginal farmers.

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IRC/TM-2/PP-71

ENHANCEMENT OF PLANT GROWTH AND NITROGEN UPTAKE BY PLANT GROWTH PROMOTING RHIZOBACTERIA FROM LONG-TERM ORGANIC FARMING SOIL OF SIKKIM, INDIA

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Sikkim an agricultural state located at the Himalayan mountain range in the North Eastern India cultivates rice as the major cereal crop under organic farming practice. As hill farming becomes the predominant farming practice in mountainous regions, crops cultivated are vulnerable towards edaphic stresses among which soil nutrients been given importance due to their role in plant growth and development. As organic farming has been the only form of agriculture judiciously practiced in Sikkim, application of nitrogenous biofertilizers shall provide viable solution to combat soil N depletion and improve plant health. Moreover, as soil management in this region has been maintained by organic methods, the soil microbial diversity could have been well preserved as compared to regions where rice cultivation is carried by conventional farming practices (Panneerselvam et al., 2019). Among the different macronutrients present in soil, nitrogen (N) has been regarded as one of the primary growth limiting nutrient required excessively by plant for biosynthesis of chlorophyll and enzymes, as compared to other macro nutrients and has been calculated to be 1 kg N for production of 15-20 kg grains in rice plant (Ladha and Reddy 2000). Hence, rice cultivation greatly depends upon the soil N content and has been estimated in terms of chemical N fertilizers to require atleast 100 kg N ha-1 for paddy soil to maintain productivity. Therefore, in order to provide sustainable measures for counteracting N loss from soil, the diazotrophic bacterial diversity was studied and indigenous diazotrophic isolates were assayed for their competency as plant growth regulators in rice plants cultivated under organic farming practices at Sikkim, India.

METHODOLOGY

Soil samples were collected at depth of 0-15 cm from surface of soil in five organic rice (*Oryza sativa* L.) growing areas located at East Sikkim (27.3084ºN and 88.6724ºE). From the soil samples, roots and stones were removed and samples were stored at 4ºC.Nitrogen fixed by free living bacteria was evaluated from the amount of nitrogen present in N free Jensen’s broth medium after fifteen days of incubation and expressed as mg of N fixed per g of sucrose consumed and N assimilated in broth from atmosphere by the diazotrophs was estimated using Kjeldahl method.Genomic DNA isolation from bacteria isolates were carried using Bacterial DNA isolation kit manufactured by Zymo™, USA and gene sequencing of the purified PCR product was conducted through Sanger sequencing by Eurofins, Bengaluru, India. This study addresses the plant beneficial nature of enterobacteria present in rice rhizosphere and evaluates their efficiency through seed inoculation process for enhancing nitrogen uptake in rice plant.

RESULTS

Using culturable approaches, the population of total diazotrophs present in rhizosphere samples collected from different organic rice fields of Sikkim were studied and found to range between 4.62 to 4.97 log_{10} CFU/g soil. These isolates were screened based upon their ability to fix nitrogen in milligram fixed per gram of sugar consumed. The efficiency of these isolates for assimilation of atmospheric nitrogen was compared with reference diazotrophic strains of *Azotobacter tropicalis*and*Bacillus subtilis*Bio-CWB. In addition to nitrogen fixation, plant growth promoting traits such as production of indole-3-acetic acid and gibberellic acid were estimated using spectrophotometric approaches and compared against *B. subtilis* Bio-CWB asreference multi-potent plant growth promoting strain.*In-vivo* evaluation of these diazotrophic species in rice found improvement in both above ground and below ground responses in rice plant evaluated by estimating changes in chlorophyll concentration, plant biomass, root architecture, nitrogen uptake, microbial biomass and associated biochemical activity of soil (Fig. 1). Further, the selected isolates were identified through DNA targeted analysis of 16S rRNA gene present in diazotrophs and confirmed using *in-silico* DNA-DNA homogeneity analysis with standard nucleotide database, which identified the isolates belonged to *Enterobacter* genus. This study concludes with the fact that *Enterobacter* spp. are the functionally dominant diazotrophic bacteria present in paddy soils of Sikkim whose selective enrichment in rhizosphere improved nitrogen dynamics between soil and plant.

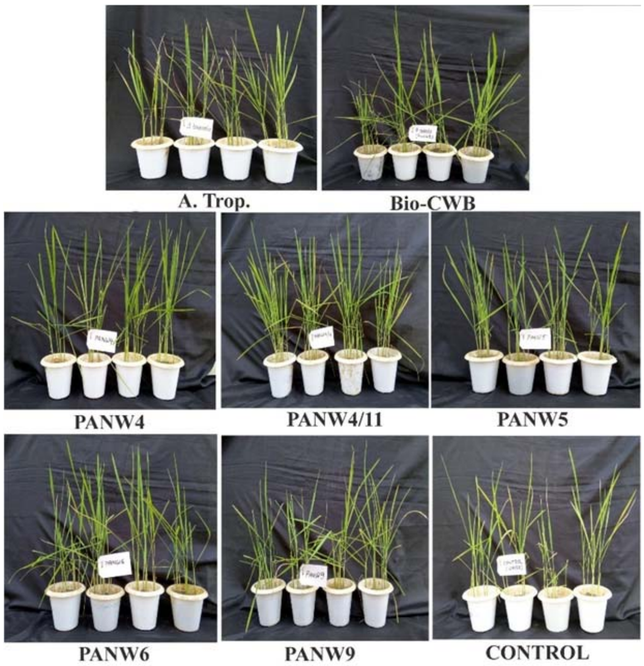

Fig. 1. Effects of diazotrophic bacteria in rice growth

CONCLUSION

Through this preliminary investigation potent culturable diazotrophs were identified which could to be used as potent nitrogenous biofertilizer for improving rice growth under organic farming practices. In long terms, these diazotrophs have maintained soil N content by improving their function diversity. Based on presumptive models generated by combining soil and plant parameters, this study provided conclusive evidence for the associative nature of *Enterobacter* in rice plants and participation in crop improvement through soil nitrogen assimilation from atmosphere. Contribution of *Enterobacter* species towards BNF in soil was compared with other free living heterotrophic diazotrophs. This study clearly demonstrated the ability of *Enterobacter* species to alleviate nitrogen stress in rice plant under organic farming practices by improving plant nitrogen uptake through cumulative contribution of nitrogen fixing and phytohormone production traits of heterotrophic bacterial diazotrophs. This study also emphasizes on enriching autochthonous beneficial microflora in paddy soil particularly the beneficial *Enterobacter* spp. for sustaining rice productivity under organic farming practices in Sikkim.

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PERFORMANCE OF RICE AND RICE FALLOW CROPS AS INFLUENCED BY METHODS OF ESTABLISHMENT OF RICE AND NUTRIENT MANAGEMENT PRACTICES

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In Andhra Pradesh, rice being one of the most important crops of coastal districts contribute 60 per cent of the state's rice production following different establishment techniques. Among all thediversified factors, the crop establishment pattern with proper nutrient management practices assumes a pragmatic role to achieve targeted results. However, vibrant instinctiveness of cropping system results in judicious use of production resources and nutrient management in cropping systems being more complex than individual crops. INM concept off late comprising use of dissimilar resources in the most efficient manner is gaining attention. The summary is drawn with the objective of careful discretion in blending both organic and inorganic sources has been known to reciprocate strengthening the efficacy of both these sources resulting in higher productivity coupled with increased fertilizer use efficiency.

METHODOLOGY

A field experiment was conducted during both *kharif* and *rabi* seasons and during *kharif* at Agricultural College farm, Naira. The experiment was laid out in split plot design with three replications. The treatments consisted of two main plots (Wet seeded rice (Drum seeding) and transplanting method) and four sub plots *Viz*., S_1: 100% RDF (Chemical fertilizers); S_2: 75% RDF+ 25% RDF through FYM; S_3: 75% RDF + 25% RDF through green manure crop (Sunhemp); S_4: 50% RDF + 25% RDF through FYM + 25% RDF through green manure crop (Sunhemp).During *rabi* rice fallow crops *viz.*, blackgram, ragi and sunhemp were sown each where in *kharif* sub plot treatment which was sub divided into three sub-sub treatments and thus, double split plot design was adopted for *rabi* and the total number of plots during *kharif* was 24 (8×3=24) and during *rabi* was 72 (24×3=72) respectively. The experiment on rice-rice fallow crops sequence was repeated in another site during the 2nd year.

RESULTS

The fertilizer treatments did not show any significant difference in REY for kharif and rabi crops. Among the three rice fallow crops, sunhemp crop recorded significantly higher REY for kharif, and rabi crops. The rice fallow sunhemp grown in the plots of transplanting method and in the fertilizer treatment 75%RDF + 25% RDFthroughgreen manure crop, 50% RDF + 25% RDF through FYM+ 25% RDFthroughgreen manure crop and 75%RDF + 25% RDF through FYM has recorded significantly higher REY and on par to each other. The lowest REY was recorded with wet seeding method with 100% RDF through chemical sources in rice fallow blackgram.

Different rice fallow crops and rice crop grown during *kharif* season have significant variations in internal utilization of nitrogen which had direct influence on yield parameters and yield. The interaction between fertilizer treatments and sunhemp crop grown as rice fallow during *rabi* was significantly higher when compared with other rice fallow crops. Significant variations in residual nitrogen are due to fertilizer treatments in the preceding *kharif* rice. Yields were

Table 1. Rice Equivalent Yield for *rabi,* crops, Rice Equivalent Yield for *kharif* and *rabi* crops as influenced by methods of establishment of rice and nutrient management practices

Treatment	2017-18		2018-19		Pooled data	
	REY (rabi)	REY (kharif,&rabi)	REY (rabi)	REY (kharif &rabi)	REY (rabi)	REY (kharif &rabi)
Different rice establishment methods (M)						
M1- Wet seeded method	3062	8690	2749	8279	5898	8484
M2- Transplanting method	2924	8896	2683	8489	2793	8692
SEm±	28.21	147	25.43	223	25.32	184
CD (p = 0.05)	NS	NS	NS	NS	NS	NS
CV (%)	5.65	10.0	5.62	16.0	5.34	12.91
Fertilizer treatments (F)						
F1 - 100 % RDF	2609	8535	2414	8136	2497	8335
F2 - 75% RDF + 25% RDF (FYM)	3122	8805	2816	8481	2962	8643
F3 - 75% RDF + 25% RDF (GM)	2967	9233	2667	8553	2811	8843
F4- 50% RDF + 25% RDF(FYM) + 25% RDF (GM)	3275	8696	2966	8366	3113	8531
SEm±	65.29	189	55.8	156	49.6	153
CD (p = 0.05)	201.0	NS	172.0	NS	144.0	NS
CV (%)	9.25	9.13	8.72	7.91	6.95	7.57
Different rice fallow crops grown during rabi,(C)						
C1 –Blackgram	2110	7909	1870	7500	1983	7705
C2 – Ragi	2518	8318	2619	7909	2578	8113
C3 –Sunhemp	4351	10151	3659	9742	3976	9946
SEm±	53.8	58.3	53.65	58.3	48.84	58.3
CD (p = 0.05)	168.0	168	155.0	168	141.0	168
CV (%)	9.54	5.25	9.68	5.41	8.41	5.33
Interaction	S	S	S	S	S	S

significantly higher in 75% RDF + 25% RDF through green manure crop and 100% RDF through chemical fertilizers. More nutrients were drawn from the soil to produce more rice yield and leaving less residual nutrients for the rice fallow crops. In fertilizer treatments 50% RDF + 25% RDF through FYM + 25% RDFthroughgreen manure crop and 75%RDF + 25% RDF through FYM the nutrient release was slow and hence nutrient availability was less for preceding rice crop and more nutrient availability for the succeeding rice fallow cropsJat*et al*. (2013).

CONCLUSION

Thus, it may be concluded that, The cost of fertilizer treatment under 75% RDF + 25% RDF through green manure crop was less compared to other fertilizer treatments and the result in supplying the nutrients was also found to be high during *kharif* season. Hence, the yield of rice recorded significantly higher values than other treatments. The overall performance of the treatment 75% RDF along with 25% RDF through green manure crop had significantly increased residual fertility and soil moisture availability to rice

Table 2. Internal utilization of N in *rabi,* crops, Internal utilization of N in *kharif,* and *rabi,* crops and N available after harvesting *rabi,* crops (Kg ha^{-1})as influenced by methods of establishment of rice and nutrient management practices

Treatment	Pooled data of 2017-18 and 2018-19		
	Internal utilization of N by *rabi,* crops	Internal utilization of N by *kharif,&rabi,* crops	N available after harvesting *rabi,* crops
Different rice establishment methods (M)			
M1- Wet seeded method	77.50	64.32	211
M2- Transplanting method	75.97	61.81	214
SEm±	1.02	0.39	1.05
CD (p = 0.05)	NS	2.35	NS
CV (%)	7.96	3.67	4.97
Fertilizer treatments (F)			
F1 - 100 % RDF	84.11	61.90	206
F2 - 75% RDF + 25% RDF (FYM)	73.85	63.36	216
F3 - 75% RDF + 25% RDF (GM)	78.12	63.41	210
F4- 50% RDF + 25% RDF(FYM) + 25% RDF (GM)	70.85	63.51	218
SEm±	1.50	0.91	2.79
CD (p = 0.05)	4.63	NS	8.61
CV (%)	8.31	6.14	5.58
Different rice fallow crops grown during *rabi,*(C)			
C1 –Blackgram	63.33	53.67	213
C2 – Ragi	59.03	57.50	213
C3 –Sunhemp	107.84	73.01	211
SEm±	1.16	0.45	2.70
CD (p = 0.05)	3.35	1.30	NS
CV (%)	7.42	5.52	6.23
Interaction	S	S	NS

Initial N – 229 Kg/ha

fallow crop sunhemp, but was at par with the treatment applied with 75% RDF + 25% RDF through FYM.

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Theme - II : Sustainable rice farming

IRC/TM-2/PP-73

SOIL QUALITY IMPROVED WITH APPLICATION OF RICE HUSK DERIVED BIOCHAR

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Agronomic yield is strongly dependent on soil quality. However, the assumption that higher crop yields is a sign of good soil quality may not be always true. Soil quality index (SQI) could give a better prospect for monitoring the soil condition to plan management strategies much before the visible indications of soil deterioration or improvement occur. Application of biochar is reported to have both positive and negative impacts on crop yields and soils. However, long term impact under field condition is yet to be established. We hypothesized that biochar application in lowland rice would promote sustainability and, there also exists a possibility that some of the soil factors are more positively influenced by biochar than others, contributing to the soil quality. The objective of the study was to develop SQI in rice husk derived biochar (RHB) amended soil by integrating soil indicators and compare its trend with agronomic yield and sustainable yield index.

METHODOLOGY

For determination of SQI, the methodical steps were followed (Andrews et al., 2002) with some modifications. Minimum data set (MDS) of soil properties was created using the principal component analysis (PCA) to arrive at the most potential indicators (soil properties) that represent soil functions. Then, the MDS indicators were scored based on their importance and scientific relevance, and multiple regression analysis. The scores were weighed using PCA outcomes and transformed using the method described by Shahid et al. (2013). The weighted variable scores of MDS were added for each observation to calculate the SQI using the following equation:

$$SQI = \sum_{i=1}^{n} Wi \times Si$$

where W_i is the weighing factor derived from the PCA (absolute value) and S_i is the score for the subscripted variable. It was assumed that higher scores represented better soil quality. The resultant SQI values were tested for their significance at *P*d"0.05.

Sustainable yield index (SYI) was calculated with yield data of eight crop cycles in four years using the following formula (Singh et al., 1990):

$$SYI = (Y - \sigma_{n-1}) / Y_m$$

where Y is average yield, σ_{n-1} the standard deviation and Y_m the maximum yield obtained during the experiment.

RESULTS

There was positive response of RHB application. Grain yield of rice increased with increase in RHB application rates. This was consistent across the seasons and years of experimentation. The dry season yield ranged from 525.4 to 640.4 g m^{-2} and wet season rice yield ranged from 531.0 to 637.4 g m^{-2}. Grain yield, on sequential application of 0.5 t/ha of RHB (4 t/ha, cumulative in 4 years) did not differ significantly over recommended dose of fertilizers (RDF). SYI recorded a similar trend.

SQI improved by 4.85% and 16.02% with application of 0.5 tha^{-1} and 10 tha^{-1} RHB, respectively, over RDF alone. The value of the dimensionless SQI ranged from 2.06 in the RDF to 2.39 in RDF + 10 t ha^{-1} RHB treatment. In RDF + 10 tha^{-1} RHB treatment, maximum contribution was made by C_{tot}(32.57%) and

Table 1: Sustainable yield index, Non-linear scoring results and effect of biochar application on soil quality index (SQI). The difference between the means of treatment is separated by least significant difference (LSD) at 5% level of significance

Treatments	pH	Bulk density	C_{tot}	MBC	Available K	DTPA-Zn	SYI	SQI
T1	0.83^{D}	0.47^{B}	0.99	0.05^{CD}	0.01^{C}	0.95	0.71^{C}	2.06^{D}
T2	0.83^{CD}	0.48^{B}	1.00	0.23^{BCD}	0.01^{C}	0.96	0.76^{BC}	2.16^{C}
T3	0.84^{C}	0.52^{A}	1.00	0.27^{BC}	0.02^{C}	0.96	0.80^{AB}	2.21^{BC}
T4	0.86^{B}	0.54^{A}	1.00	0.03^{D}	0.02^{C}	0.97	0.80^{AB}	2.16^{C}
T5	0.86^{AB}	0.54^{A}	1.00	0.20^{CD}	0.03^{B}	0.97	0.83^{A}	2.24^{B}
T6	0.87^{AB}	0.55^{A}	1.00	0.46^{AB}	0.04^{AB}	0.94	0.86^{A}	2.35^{A}
T7	0.87^{A}	0.55^{A}	1.00	0.53^{A}	0.05^{A}	0.94	0.86^{A}	2.39^{A}
SE(d)	0.005	0.014	0.002	0.110	0.006	0.013	0.020	0.038
LSD	0.0105	0.0298	NS	0.2399	0.0125	NS	0.0715	0.082

T1, Recommended dose of fertilizers (RDF); T2, RDF + 0.5 t ha^{-1} RHB; T3, RDF + 1.0 t ha^{-1} RHB; T4, RDF + 2.0 t ha^{-1} RHB; T5, RDF + 4.0 t ha^{-1} RHB; T6, RDF + 8.0 t ha^{-1} RHB; T7, RDF + 10.0 t ha^{-1} RHB

minimum contribution was made by available K (1.62%). Overall, the indicators pH, bulk density, C_{tot}, microbial biomass carbon (MBC), available K and DTPA-Zn contributed 23.67, 14.47, 27.79, 6.76, 0.70 and 26.61%, respectively, towards the developed SQI (Table 1). The results indicate that even the lowest application rate of RHB (0.5 t ha^{-1}) increased the SQI substantially over RDF, however, the difference was found to be non-significant in terms of grain yield and sustainable yield index. This result also coveys the message that grain yield will be misleading if taken alone as measure of soil quality or sustainability.

CONCLUSION

The following conclusions may be drawn from the present study: (i) substantial improvement in soil quality, even in fertile, well managed, lowland rice soil is possible with application of rice husk derived biochar, (ii) after four years of sequential biochar application, soil quality index (SQI) improved with increase in application rates of RHB. Soil quality indicators like C_{tot}, DTPA-Zn, pH and BD are the main contributors to SQI, (iii) significant improvement in SQI was recorded even with lowest dose (0.5 t ha^{-1}) of RHB.However, SYI was higher at higher application rates but did not record such improvement at lower doses. Finally, it can be concluded that rice grain yields increases sustainably with sequential application of high RHB doses but soil quality improves even with low RHB doses.

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 IRC/TM-2/PP-74

EFFECT OF TRANSPLANTING DATES ON THE GROWTH, YIELD AND QUALITY PARAMETERS OF AROMATIC RICE VARIETIES

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India is the world's largest rice exporting country. Among the rice varieties, aromatic rice occupies a prime position due to its excellent quality and has great export potentiality. West Bengal is a home of many unique traditional non-basmati aromatic rice varieties which are tall with weak stem, prone to lodging, photosensitive, having moderate to very strong aroma, more susceptible towards diseases and pests and are restricted to certain areas. However, each variety is highly priced in the growing pockets. In North Bengal and other part of NE states, aromatic rice played a vital role in a global rice trading system. The issue of lower productivity of local aromatic rice is mainly due to improper sowing time and lack of location specific selection suitable verities for maximizing quality production. The information for transplanting non-basmati aromatic varieties in optimum time is still lacking in the state. Therefore, present was conducted to determine the optimum transplanting time for potential satisfactory yield of non-basmati aromatic rice variety in the Eastern Himalayan Region-2.

MATERIALS AND METHODS

An experiment was conducted to study the effects of transplanting dates at Instructional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar. Plots were laid out in split plot design with 3 transplanting dates viz. D_1: 10th July, D_2: 25th July and D_3: 10th August in main plots and 4 varieties (Tulaipanji, Khasa, Gobindobhog and Kalonunia) in sub plots. For both the respective years 2015-16 and 2016-17, pooled mean was calculated for every parameter recorded like yield attributing characters (number of effective tillers m^{-1}, numbers of panicle m^{-2}, panicle length (cm), numbers of filled grain $panicle^{-1}$, test weight), yield (straw and grain yield) and quality parameter (hulling%, milling %, Head rice recovery %, Carbohydrate and protein content) was calculated.Protein and Carbohydrate content of rice was determined by standard method.

RESULTS AND DISCUSSION

Effects of date of transplanting and varieties on the Yield attributes, yield and quality parameters:

Crop transplanted on 10th July i.e. D_1 indicate highest number of effective tillers m^{-2} (323), number of panicles m^{-2} (275), panicle length (25.50 cm), number of filled grain $panicle^{-1}$ (151.99), test weight (21.3), grain yield (2.44 t ha^{-1}), straw yield (5.41 t ha^{-1}) and harvest index (31.05 %) of aromatic rice followed by 25th July (D_2) and was significantly affected the panicle length and reduced yield was observed in delayed planting i.e. 10th August. Dhiman et al., 1995 also observed similar finding. Among the varieties, there was a significant variation and Khasa variety recorded highest yield attributes and yield which was closely followed by Gobindobog and minimum was reported in Tulaipanji variety.

In case of grain quality parameters, maximum milling (64.40 %), Hulling (73.60 %), head rice recovery (53.00 %), protein (11.39 %) and carbohydrate (63.13 %) content were recorded in

Table 1: Effect of different date of transplanting and variety on yield attributes, yield and quality parameters of aromatic rice:

Date of transplanting (A)	No. of tillers m^{-2}	No. of Panicles m^{-2}	Panicle length (cm)	No. of filled grains $panicle^{-1}$	Test weight (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Harvest Index (%)	Milling %	Hulling %	Head Rice Reco very	Carbo-hydrate (%)	Protein (%)
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
D_1-10th July	*323	275	25.50	151.99	21.30	2.44	5.41	31.05	64.40	73.60	53.00	63.13	11.39
D_2-25th July	267	216	25.20	125.83	21.20	2.21	5.01	30.62	63.10	73.10	52.30	52.42	10.51
D_3-10th August	193	132	24.70	104.27	21.20	1.85	4.51	29.62	61.90	72.10	51.00	40.81	9.70
SEm(±)	14.71	10.61	0.40	3.56	0.03	0.013	0.025	0.196	0.459	0.388	0.387	0.516	0.154
CD (p=0.05)	57.74	41.67	N.S.	13.99	0.09	0.053	0.097	0.771	1.804	1.523	1.520	2.026	0.607
Variety (B)													
V_1- Tulaipanji	221	178	24.20	117.61	20.61	1.91	4.66	29.18	60.70	71.20	50.50	50.74	9.55
V_2-Khasa	306	240	25.00	138.68	21.87	2.38	5.17	31.51	64.70	74.70	53.20	52.68	11.44
V_3-Gobindabhog	278	219	24.50	131.79	21.72	2.31	5.18	30.84	65.00	74.20	53.30	53.42	10.93
V_4-Kalonunia	246	195	26.80	121.36	20.81	2.07	4.89	29.82	62.20	71.80	51.30	51.64	10.20
SEm(±)	12.86	9.47	0.50	2.49	0.13	0.027	0.046	0.34	0.623	0.521	0.631	0.729	0.206
CD(p=0.05)	38.20	31.13	1.40	7.39	0.39	0.080	0.137	1.01	1.850	1.548	1.875	2.166	0.611
Interaction effect (AxB)													
SEm(±)	22.27	16.40	0.80	4.31	0.23	0.047	0.08	0.59	1.078	0.903	1.093	1.263	0.356
CD(p=0.05)	NS	48.73	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Data are mean of two season, NS- Nonsignificant.

plots where transplanting was done on 10th July followed by 25th July and 10th August. Ali *et al.*, 1991 also obtained similar results. Pooled mean (Table 1) pertaining to quality parameters indicatesignificant effect on the aromatic rice varieties. The variety Khasa observed maximum hulling (74.70 %) and Protein content (11.44 %) followed by Gobindobog whereas highest milling (65.00 %), head rice recovery (53.30 %) and carbohydrate content (53.42 %) was reported in Gobindobog variety which was at par with Khasa. But, all the quality parameters were found lowest in Tulaipanji. Analysis of variance showed that there was no significant interaction effect in dates of transplanting and varieties on the yield attributes, yield and quality parameter except number of panicles m^{-2}.

CONCLUSION

The result of the present study show that date of transplanting has significant effect on plant growth parameter, yield attributing character and quality parameter of aromatic rice. Further, the present study also showed that the date of transplanting of Eastern Himalayan Region-2 should be first part of 10th July or for quality trait of aromatic rice.

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THE MORPHOLOGICAL, BIOCHEMICAL AND MOLECULAR CHARACTERIZATION OF CYANOBACTERIA FROM PADDY SOILS

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Cyanobacteria are oxygen evolving photo-autotrophic, prokaryotic nitrogen fixing organisms and are highly populated in paddy fields.Cyanobacteria isolates were collected from paddy field soils of ICAR-National Rice Research Institute, Cuttack, having different management practices. The main objective of this study was to isolate and identify the paddy field cyanobacteria having different physiological characteristics. This investigation was done to find out morphological and biochemical variations of cyanobacteria present in paddy soil. The diverse cyanobacteria will be further used as biofertilizer and biodegradation of pesticides.

METHODOLOGY

The pH and electric conductance (EC) of the soil were measured using a pH and EC meter. The purification of cyanobacterial strains was carried out by spreading technique. Purified strains were maintained in BG11 liquid medium at 7.2 pH, 28±2°C and light intensity of 50-55 µE/m^{2}s with a 14/10 h light/dark cycle. The morphological examinations of cyanobacteria were made by using a Zeiss compound microscope equipped with a digital camera. Taxonomic identification was based on the morphological keys of Desikachary (1959). The growth (through cell dry weight), pigments and biochemical properties of cyanobacteria were determined as per the standard procedures. The biochemical parameters such as chlorophyll a, carotenoid, phycobiliprotein, protein, total carbohydrate, and nitrate reductase activity (NR) were estimated. Glutamine synthatase (GS) activity was calculated by using standard curve of glutamyl hydroxamate. The 16S r RNA technique have been widely used to study the cyanobacterial species. Here, cyanobacteria-specific primers such as CYA106F, CYA359F, CYA781R (a), CYA781R (b) and CYA1281R have been used to amplify the cyanobacteria specific site and evident the presence of cyanobacteria community. Statistical analysis was performed by using the Statistical Analysis Software (SAS).

RESULTS

Total 20 strains of cyanobacteria were isolated **(Fig 1).** The pH of soil samples ranged from 6.3-7.25. Cyanobacteria, *Scytonemahyalinum* was isolated form soil with the highest pH. The EC value varied from 25.07 ± 0.97 µS/cm (*Scytonema*sp. (1)) to 736.31± 48.39 µS/cm (*Fischerella*sp.). The morphological identification was done based on the shape and size of vegetative cell along with the presence of heterocysts and akinates of cyanobacteria. In heterocystous cyanobacteria, the maximum size of vegetative cell was noted in *Aphanizomen* sp. (8.3-9.8×8.8-9.2 µm), whereas among the unicellular strains, the maximum size of vegetative cells was observed in *Aphanthece* sp. (7.5-8.7×3.5-5.9 µm). Among the growth parameters, *Scytonema*sp. (1) had the highest cell dry weight (17.20±1.001 µg/ ml). The highest content of chlorophyll *a* (*Anabaena* sp.; 22.23±0.26 µg/ml), carotenoid (*Westiellopsis* sp.; 8.41±0.05 µg/ ml), phycocyanin (*Niveispirillum cyanobacterium*; 4.49±0.07 µg/ml), phycoerythrin (*Niveispirillum cyanobacterium;* 3.10±0.11 µg/ml), allophycocyanin (*Niveispirillum cyanobacterium*; 6.26±0.11 µg/ml), protein (*Scytonema*sp. (2); 29.05±0.19 mg/ml), total carbohydrate (*Anabaena* sp.; 50.23±1.25 mg/ml),

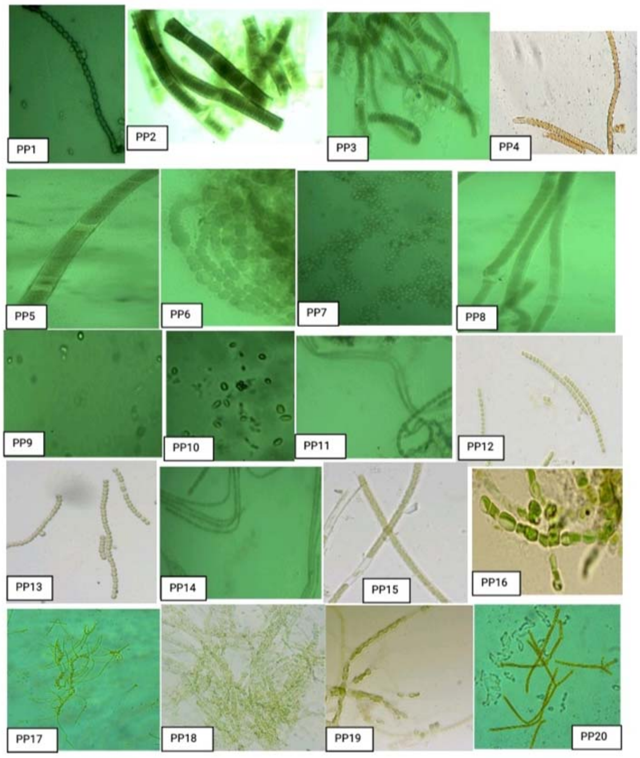

Figure-1 PP1 to PP20 cyanobacteria strains

nitrate reductase activity (*Anabaena* sp.; 32.08±0.103 µmoles/NO_2), and glutamine synthatase (*Scytonema*sp. (1); 106.16±0.146 µmoles³GH/ml) were obtained in the mentioned species. The *Scytonema*sp. (1), *Scytonema*sp. (2), *Anabaena* sp. and *Niveispirillum cyanobacterium* showed the highest content with respect to most of the biochemical parameters. The chlorophyll *a* and carotenoid content varied significantly among the cyanobacterial isolates whereas, phycobiliprotein contents, proteins and carbohydrates did not differ significantly among the strains. The NR and GS content varied among the isolates. Low GS with high NR enzyme activity was found in *Westiellopsis*sp., *Hapalosiphonarboreus*and *Nostoc*sp. and they can be promoted as good quality biofertilizer (Prasanna et al., 2006). They can also be promoted as bioremediating agent. As per the molecular data, PP1- *Anabaena* Sp. (1), PP2- *Scytonema*Sp., PP3-*Scytonema* Sp.(2), PP4-*Hapalosiphon* Sp., PP5- *Brasilonema*sp., PP6- *Anabaena* sp., PP7- *Scynechosystis* sp., PP8-Uncultured cyanobacteria, PP9- *Aphanthece*sp., PP10-*Gloeothece* sp., PP11- *Westiellopsis* sp., PP12- *Hapalosiphonarboreus*, PP13- *Westiellopsisprolifica*, PP14- Uncultured cyanobacteria, PP15- *Niveispirillum*cyanobacterium, PP16- *Nostoc*sp., PP17- *Fischerella*sp., PP18- *Aphanizomen* sp. , PP19-*Westiellopsis* sp. , PP20- *Scytonema hyalinum*. Generally, *Nostoc*and *Anabaena* strains are more dominant than other cyanobacteria strains in paddy field soil. But in these soils, the presence of more *Scytonema*and *Westiellopsis*strains were observed.

CONCLUSION

Based upon the results obtained, it was concluded that abundance of cyanobacteria is adequate in paddy soils. The long term and short term pesticide fields, organic fields and other experimented fields have various cyanobacterial strains. The *Scytonema*and *Westiellopsis*strains can survive in different environmental conditions. They will be further utilized for commercial viability because of their immense genetic potential with regards to nitrogen fixation.

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WEED MANAGEMENT PRACTICES FOR DIFFERENT CULTIVARS IN DRY DIRECT-SEEDED RICE

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The shift in the method of rice establishment from traditional manual transplanting of seedlings to direct seeding has occurred in many Asian countries including India. It is due to water and labour scarcity. Wet seeding and dry seeding are two types of direct-seeded rice (DSR). Weed is the major biotic stress which reduces the yield of dry DSR. Hence, a field investigation was carried out to study the effect of weed management practices for different rice cultivars on weed dynamics and yield of dry direct-seeded rice in coastal deltaic region of Karaikal, Puducherry UT.

METHODOLOGY

A field experiment was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA&RI), Karaikal, Puducherry UT during September 2019 to January 2020 to study the effect of different weed management practices for different cultivars on weed dynamics and rice yield in dry direct -seeded condition. The experiment was laid out in split block design with three replications (Table 1). Rice cultivars were sown with the spacing of 20 cm x 10 cm and all the recommended package of practices except weed control was adopted during the period of experimentation.

Observations on density of individual weeds were recorded with the help of quadrate 0.25 m x 0.25 m placed randomly at four spots at flowering (90 DAS). The data on weed density are analyzed by using square root transformation ("x+0.5) to normalize their distribution. The data collected from the experiments was subjected to the Fisher's method of Analysis of Variance (ANOVA).

RESULTS

Experimental field was dominated by broad leaved weeds (69.70 %), grasses (19.39 %) and sedges (10.91%)). Predominant weeds of the experimental field were *Echinochloacolona* Link., *Leptochloa chinensis* (L.) Nees., *Echinochola crus-galli* (L.), *Cyperus iria* L., *Cyperus difformis*L., *Fimbristylismiliaceae*L., *Bergia capensis* L., *Ludwigia parviflora* L., *Eclipta alba* (L.) Hassk, *Marsilea quadrifolia*L., *Sphaeranthus indicus* L. and *Aeschynomene indica* L. at flowering stage (90 DAS). Among the cultivars, ADT 46 significantly reduced the population of *Bergia capensis* L, *Ludwigia parviflora*L and total weed density (27.1, 20.4 and 96.1 no./m^2, respectively) compared to CO 52 and Improved white ponni. Mahajan *et al.* (2015) observed that cultivars vary in their weed suppressive ability due to their genotypic differences on smothering effect. Weed management practices significantly reduced the weed density at 90 DAS. Sequential application of pendimethalin @ 1 kg/hafollowed by bispyribac-sodium @ 0.02 kg/ha has recorded lower total weed density (102.4 no./m^2), resulted in higher grain yield (3.73 t/ha). Saravanane (2020) indicated that sequential application of pendimethalin *fb*bispyribac-sodium reduced the grasses, sedges and broadleaved weed density in dry DSR. Application of pendimethalin curtailed the early seed germination due to the inhibition of cell division, there by reduced the early flush of weeds. Likewise, post-emergence bispyribac- sodium application inhibits ALS (acetolactate synthase) enzyme in the weeds and thereby restrict the weed growth and

Table 1. Weed management practices for different cultivars on weed dynamics and yield of dry DSR

Treatments	Weed density (No./ m^2)								Grain
	E. colona	*L. chinensis*	*C. iria*	*C. difformis*	*B. capensis*	*L. parviflora*	Other weeds	Total weed density	yield (t/ha)
Cultivars									
ADT 46	2.10(5.3)	1.93(4.0)	2.17(4.8)	1.58(2.4)	5.24(27.1)	4.55(20.4)	5.64(32.1)	9.76(96.1)	3.76
CO 52	2.76(9.0)	2.41(6.6)	2.55(6.4)	2.15(4.6)	5.40(28.8)	4.78(22.4)	6.31(39.8)	10.81(117.6)	3.05
Improved white ponni	2.83(8.2)	2.48(6.1)	2.78(7.4)	2.10(4.2)	6.49(42.0)	6.08(36.8)	7.77(61.3)	12.84(166.0)	2.58
S.Em	0.40	0.32	0.27	0.28	0.23	0.19	0.38	0.57	0.11
LSD (p=0.05)	NS	NS	NS	NS	0.63	0.54	NS	1.59	0.30
Weed management									
Pendimethalin@1 kg ai/ha	2.64 (7.9)	2.34 (6.0)	2.82 (7.6)	2.17 (4.5)	5.70 (32.5)	5.26 (27.7)	6.88 (48.0)	11.52 (134.2)	2.98
Bispyribac - sodium@ 0.02 kg ai/ha	2.44 (6.6)	2.13 (4.8)	2.53 (6.2)	1.86 (3.4)	5.71 (32.5)	5.12 (26.2)	6.69 (45.3)	11.13 (125.0)	3.19
Pendimethalin @1 kg ai/hafbbispyribac - sodium@ 0.02 kg ai/ha	2.06 (4.8)	1.92 (3.6)	2.13 (4.4)	1.84 (3.2)	5.40 (29.1)	4.79 (23.0)	5.80 (34.3)	10.06 (102.4)	3.73
Hand weeding twice (20&40 DAS)	1.96 (4.4)	1.70 (3.0)	2.10 (4.3)	1.54 (2.2)	5.63 (31.6)	4.98 (24.8)	5.90 (35.2)	10.21 (105.5)	3.54
Unweeded control	3.73 (13.7)	3.26 (10.3)	2.91 (8.3)	2.32 (5.4)	6.11 (37.4)	5.52 (30.8)	7.60 (59.1)	12.76 (165.0)	2.21
S.Em	0.23	0.19	0.24	0.27	0.19	0.18	0.30	0.34	0.10
LSD (p=0.05)	0.49	0.40	0.49	NS	0.39	0.37	0.62	0.71	0.23

*Original figures in parenthesis were subjected to square root transformation (“x+0.5) before statistical analysis. NS- Non-significant.

density. Unweeded control recorded higher total weed density (165.0 no./m^2) and resulted in lower rice yield (2.21t/ha) with maximum yield loss of 51.9 % in coastal deltaic region of Karaikal, Puducherry UT.

CONCLUSION

Cultivation of ADT 46 with sequential application of pendimethalin followed by bispyribac-sodium effectively controlled the weeds and improved the yield of dry direct-seeded rice in coastal deltaic region of Karaikal, Puducherry UT.

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IRC/TM-2/PP-77

INFLUENCE OF ESTABLISHMENT METHODS AND IRRIGATION REGIMES ON GRAIN YIELD AND ECONOMICS OF RICE

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Rice is a heavy water consumer about 50–80% of total water input percolates deep into the soil profile and only 30–40% is utilized consumptively.Water is a valuable and scarce natural resource in many regions of the world. The water crisis is threatening the sustainability of the irrigated rice system and food security in Asia. The conventional transplanting method of rice cultivation is the most widely adopted method of rice production, which requires high continuous water inputs and labour, usually at a critical time for labour availability, which often results in shortage and increasing labour costs. Using suitable method of planting, it is possible to increase production, productivity and profitability of rice crop. Continuous flooding is the commonly used practice in traditional irrigation for rice production, but is now regarded as water consuming. One method to save water in irrigated rice cultivation is the intermittent drying of the rice fields instead of keeping them continuously flooded. This method is referred to as alternate wetting and drying irrigation (AWDI).

OBJECTIVES:

To identify best crop establishment technique and irrigation method to realisemaximum grain yield with less water

MATERIAL & METHODS:

Keeping this in view present study was conducted at Regional Sugarcane and Rice Research Station, Rudrur, situated at an altitude of 286.3. m above mean sea level (MSL) at 180 49'41' latitude and 78056'45" E longitude. during kharif & rabi 2018-19 in a split plot design with three replications. The treatments comprised of three methods of crop establishment mechanical transplanting, direct wet sowing on puddled soil with dumseeder and conventional manual transplanting as main plot treatments and three irrigation management practices - flooding through out crop growth, alternate wetting and drying irrigation – AWDI with irrigation of 50 mm when water level falls below 5 cm from soil surface in perforated tube(bouman's water tube) up to panicle initiation stage and when water level in perforated tube falls below 3 cm after panicle initiation up to 21 days after flowering and recommended submergence of 2-5 cm water level as per crop stage .

RESULTS:

The average data of two seasons recorded indicate that grain and straw yield was non-significant between methods of establishment. Average grain yield was in order of 8480.97kg ha^{-1},8193.33kg ha^{-1}, 8074.39 kg ha^{-1} in mechanical transplanting, direct sowing with drumseeder and conventional manual transplanting respectively. Mechanized transplanting recorded 10% increase in grain yield over conventional manual transplanting and higher water productivity of 5.62 kg ha mm^{-1}over direct seeding with drumseeder which recorded and water productivity 4.91 kg ha mm^{-1} and conventional manual transplanting&water productivity of 4.90kg ha mm^{-1}. There is water saving to the tune of 3.63 percent in mechanical and 6.66 percent in drumseeder method than traditional planting. Net returns were higher (Rs101390.80ha^{-1}) with mechanical transplanting followed by direct sowing with drumseeder (Rs. 99352.34 ha^{-1}) and was least in conventional manual transplanting (Rs. 93215.38ha^{-1}). B:C ratio was significantly higher in direct sowing with drumseeder (2.38) and mechanical transplanting (2.16) over conventional manual transplanting (1.95). The study revealed that the average cost of cultivation in mechanized transplanting was reduced by Rs. 1158 ha^{-1} compared to manual transplanting with an additional benefit of Rs.8175 ha^{-1} due to lower cost of labour for nursery and transplanting in mechanical transplanting. Mohapatra *et. al*., (2012) also reported similar results.

Irrigation methods significantly influenced grain yield and water productivity. Alternate wetting and drying irrigation (AWDI) and recommended submergence of 2-5 cm water level as per crop stage recorded comparable grain yield of8688.06kg ha^{-1}and 8377.75kg ha^{-1} respectively which was significantly superior over flooding throughout crop growth 7682.87 kg ha^{-1}.Similar results were observed by Satyanarayana and Babu (2004). Total water use in AWDI was markedly lower (1417 mm) with saving of 15.40 per cent of total water saving over recommended submergence of 2-5 cm water level as per crop stage ((1675 mm) and 18.12 percent over flooding throughout crop growth (1717 mm) which resulted in significantly higher water productivity 6.08 kg ha mm^{-1}. Lower water productivity was recorded with recommended submergence of 2-5 cm water level as per crop stage (4.98 kg ha mm^{-1}) and flooding throughout crop growth (4.42 kg ha mm^{-1}) due to high total water use.

AWDI was found to be economically viable with markedly higher net returns (Rs.108139.50 ha^{-1}) and B:C ratio (2.47) followed by recommended submergence of 2-5 cm water level as per crop stage (I3) (Rs.99335.96 ha^{-1}.,2.10). The higher net returns were attributed to higher grain and straw yield with lower application of water. Significantly lower net returns and B.C ratio were recorded with continuous flooding (Rs.86483.09 ha^{-1}, 1.97) because of lower grain yield compared to other treatments. The higher benefit cost ratio in AWD was attributed to higher net returns with reduced cost of cultivation compared to other irrigation regimes.

CONCLUSION:

Mechanized rice planting with AWD irrigation can be recommended for rice-rice crop over normal recommended submergence of 2-5 cm water level as per crop stage or flooding throughout crop growth stage for better water management to ensure more water for rice production, and to improve water productivity.

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GENOTYPIC PERFORMANCE UNDER DIFFERENT RICE ESTABLISHMENT METHODS IN DRY SEASON

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Rice (*Oryza sativa* L.) is life and staple food for a majority of people in Asia. Its productivity is getting constrained by several factors including growing water shortage and labour scarcity, escalating input costs and labour wages, *etc*. There is a need to identify alternative crop establishment (CE) methods in place of conventional transplanting of rice (CTR). Direct seeding of rice (DSR) using drum seeder in puddled (wet) soil has emerged as a potential method in different rice growing countries of the world. As a resource-conserving and climate-resilient methodology, the System of Rice Intensification (SRI) has also been gaining widespread popularity. Besides, crop growth and root studies are important pre-requisites for identifying an appropriate CE method to explore the possibility of harnessing the fullest genotypic yield potentialities and exploiting the sub-soil resources. Hence, the present study was taken up to study the performance of rice genotypes under different CE methods in dry season.

METHODOLOGY

A three-year field study was carried out during dry (*boro*) season of 2015-16, 2016-17 and 2017-18 at Rice Research Station, Chinsurah, Hooghly West Bengal ($22^0 52^2$ N latitude and $88^0 24^2$ E longitude with an altitude of 8.62 m above mean sea level) to identify suitable rice genotypes of varying duration groups under different CE methods. Three methods of rice establishment in puddled soil *viz.* SRI, wet-DSR and CTR in main plots and four different rice genotypes *viz. Satabdi* (IET 4786), *Arize Prima* (IET 19511), *Pusa Basmati 1* (IET 10364) and *Anjali* (IET 16430) in sub-plots were assigned in a split-plot design with three replications. The recommended package of practices was followed properly for the management of all the experimental plots from the very beginning of seed sowing and seedling transplanting till harvest. Data were recorded on crop growth (plant height, tiller number m^{-2} and leaf area index), root traits (rooting depth and root volume $hill^{-1}$), yield attributes (panicle number m^{-2}, spikelet number $panicle^{-1}$, grain filling percentage and test weight) and grain yield at harvest using standard procedures.

RESULTS

Among CE methods, SRI maintained its superiority over the others in terms of crop growth, root traits and yield attributes, thereby exhibiting the highest grain yield (5.13 tha^{-1}), irrespective of genotypes. Chapagain*et al.* (2011) were of similar opinion. Of the other methods, wet-DSR (4.72 t ha^{-1}) and CTR (4.69 t ha^{-1}) remained at par with each other in terms of grain yield performance. Plant height was significantly higher under SRI at maturity although wet-DSR plants exhibited more height than those under CTR, irrespective of genotypes. Direct-seeding method was equally effective in registering significantly more number of tillers m^{-2}than those with transplanting methods (CTR and SRI) although the percentage of tillers to form panicles (effective tillers) was more under SRI. About two-third of total tiller count was found to form panicles and finally contribute to the yield of wet-

DSR. The highest leaf area index was recorded under wet-DSR, followed by SRI and CTR at 30 days after sowing/transplanting (DAS/DAT), whereas it was the highest under SRI, followed by wet-DSR and CTR during the period from 45 DAS/DAT till crop harvest. Root proliferation was also better under SRI and wet-DSR due to negative transplantation shock, improved soil aeration and limited root degeneration, compared with the others. There was a general increase in rooting depth and root volume till 75 DAS/DAT, followed by a subsequent decline, regardless of CE methods and genotypes. An early commencement of flowering, 50% flowering and maturity was discernible in wet-DSR, followed by SRI and CTR. Although the variation in test weight was not much wide, there was a trend that the crop transplanted at a wider spacing showed heavier grains than the closely spaced wet-DSR crop. Irrespective of CE methods, *Arize Prima* significantly produced the highest grain yield (6.18 t ha^{-1}) due to significant heterosis in rice hybrid, resulting in improvement of major growth and yield attributes over the inbreds. Bhowmick*et al.* (2016) reported similar findings with the hybrid during wet (*kharif*) season. Among the high-yielding varieties (HYVs), *Satabdi* registered the highest grain yield (5.61 t ha^{-1}), followed by *Anjali* (4.15 t ha^{-1}) and *Pusa Basmati 1* (3.44 t ha^{-1}). The lowest grain yield of *Pusa Basmati 1* was because of its finer grain quality. *Anjali* also recorded lower grain yield because of its shorter duration despite maintaining better crop growth in terms of plant height, rooting depth and root volume. Significantly the highest test weight was registered in *Anjali*, followed by *Arize Prima* and S*atabdi*, whilst it was the lowest in *Pusa Basmati 1*.

CONCLUSION

Growth and yield of rice genotypes were prominently influenced by different management conditions specific for varying CE methods. All the rice genotypes evaluated in the studycould excel under SRI, exhibiting improved growth and yield attributes along with grain yield. Among them, the hybrid performed better than the HYVs. Wet-DSR with increased root growth and comparable productivity also proved to be a viable alternative to CTR during dry season.

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EFFECT OF ZINC AND IRON FERTILIZATION ON GROWTH AND YIELD OF DIRECT SOWN RICE

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Rice (*Oryza sativa* L.) is a staple food for more than one third of the world population. In India, rice occupies one-quarter of the total cropped area contributing to about 40 to 43 per cent of total food grain production and continues to play a vital role in the national food security system.Rice is generally grown by transplanting one month-old seedlings into puddled and continuously flooded soil. Huge water inputs and labour requirements for transplanted rice have reduced the profit margins. During the past one decade or so, there have been numerous efforts to find alternatives to the conventional practice of transplanted rice. Thus, high labour wages and use of more water was observed in transplanting, whereas low wages and low water requirement favour direct seeded rice.DSR is a major opportunity to change production practices to attain optimal plant density and high water efficiency in water scarce areas. In direct seeding, availability of several nutrients including N, P, S and micronutrients such as Zn and Fe, is likely to be a constraint. Nonetheless, farmers are inclining to adopt direct sown rice and the area under direct sown rice is increasing year after year. Hence, keeping in view the importance of Zn and Fe nutrition on growth and yield of direct sown rice crop, the present investigation was conducted at the Agricultural College Farm, Bapatla.

METHODOLOGY

A field experiment was conducted at the Agricultural College Farm, Bapatla situated at Krishna zone of Andhra Pradesh during *kharif*, 2017. The experimental treatments include RDF (180 :60 :40 N-P_2O_5 -K_2O (kg ha^{-1}); RDF + $ZnSO_4$ @ 50kg ha^{-1} through soil application;- RDF + $FeSO_4$ @ 25kg ha^{-1} through soil application; RDF + $ZnSO_4$ @ 50 kg ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1} through soil application; RDF + foliar spray of $ZnSO_4$ @ 0.2% at 20 and 45 DAS; RDF + foliar spray of $FeSO_4$ @0.5% at 20 and 45 DAS; RDF + foliar spray of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% at 20 and 45 DAS. The treatments were laid out in randomized block design and replicated thrice. Recommended dose of phosphorus and potassium were applied uniformly to all the treatments in the form of single super phosphate and muriate of potash as basal. Urea was applied in 3 equal splits *i.e.*, basal, tillering and panicle initiation stage of the crop. $ZnSO_4$ was used as a source of zinc fertilizer and $FeSO_4$ was used as a source of iron fertilizer. Plant and soil samples were collected at different growth stages *viz.*, tillering, panicle initiation and at harvest stages of crop growth. Chemical analysis of soil and plant samples was done as per the procedure described by Jackson, 1967.

RESULTS

Results reveals that the growth parameters *viz.*, plant height, number of tillers m^{-2}, dry matter production of direct seeded rice, RDF + $ZnSO_4$ @ 50 kg ha^{-1}+ $FeSO_4$ @ 25 kg ha^{-1} treatment was significantly superior to the rest of the treatments but on par with RDF + foliar spray of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% at 20 and 45 DAS. RDF applied without Zn and Fe, recorded the lowest growth parameters. The grain yield of direct sown rice was significantly influenced by zinc and iron fertilization The highest grain and straw yield (5312, 7748 kg ha^{-1}) was recorded with RDF + $ZnSO_4$ @50 kg ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1} through soil application which was on par with (4890, 7151 kg

ha^{-1}) RDF+ foliar spray of $ZnSO_4$ @0.2% and $FeSO_4$ @0.5% at 20 and 45 DAS. The lowest grain and straw yield 3736, 5830 kg ha^{-1}) was recorded with RDF where, no zinc and iron were applied The higher grain and straw yield with Zn and Fe application could be attributed due to increased total dry matter production and better uptake of Zn and Fe and their translocation to reproductive parts. Soil application of $ZnSO_4$ and $FeSO_4$ recorded significantly higher grain yield attributed to better performance of growth and yield parameters through adequate availability of major and micro nutrients in soil, which in turn, favourably influenced physiological processes and build up of photosynthates (Tabassum *et al.,* 2013).

The nutrient content (N, P, K, Mn and Cu) of direct sown rice at tillering, panicle initiation and harvest was not significantly influenced by the treatments but zinc and iron contents were significantly influenced by the treatment that received through RDF + $ZnSO_4$ @ 50 kg ha^{-1}+ $FeSO_4$ @ 25 kg ha^{-1} through soil application.Uptake of nutrients at tillering, panicle initiation and at harvest was markedly influenced by the treatment received through RDF + $ZnSO_4$ @ 50 kg ha^{-1}+ $FeSO_4$ @ 25 kg ha^{-1} through soil application and it was on par with RDF + foliar spray of $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.5% at 20 and 45 DAS. This might be due to combined application of iron and zinc nutrients as basal and foliarapplications along with NPK nutrients through which nutrients were available to the crop throughout the growthperiod at required quantities and enhanced the nutrient uptake. Jadhav *et al*., 2014.

CONCLUSION

Based on the above experiment, it can be concluded that the application of zinc and iron along with recommended dose of fertilizer showed remarkable increase in plant growth parameters, yield attributes, yield, plant nutrient content, uptake and soil available zinc and iron status in direct sown rice.

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IRC/TM-2/PP-80

EVALUATION OF NUTRIENT MANAGEMENT OPTIONS UNDER RICE BASED CROPPING SYSTEM IN RAINFED DROUGHT PRONE ECOLOGY

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In the rainfed drought prone areas, growing rice is a major challenge due to uncertainty of rain andsometimes crop (rice) fails due to prolonged drought in the upland condition. It is very much required to adopt rice based cropping system to compensate the loss from one crop by the others. In uplands, rice is cultivated as direct seeded crop (direct seeded rice; DSR) because of water crisis in rainfed areas with irregular rainfall. However, it has a major opportunity to adopt suitable production practices to attain high water productivity (Joshi et al., 2013). In these areas, average grain yieldof upland rice are generally low due to several biotic and abiotic stresses.In direct seeding, availability of several nutrients including nitrogen, phosphorus, sulphurand micronutrients is also a limiting factor (Ponnamperuma 1972). Productivity from rice and rice based cropping system (RBCS) can be increased with suitable soil management options (moisture conservation, enhancing soil fertility, etc.). With this background this experiment was conducted to evaluate the nutrient management options in RBCS.

Table1: Effect of nutrient management on grain yield (t ha^{-1})

Treatments	Rice (Sole)	Rice-pigeonpea	
	Rice	Rice	Pigeonpea
T_1	1.21^{e}	0.89^{e}	0.10^{e}
T_2	3.18^{a}	2.28^{a}	0.46^{a}
T_3	2.33^{c}	1.69^{c}	0.39^{b}
T_4	2.71^{b}	2.01^{b}	0.36^{bc}
T_5	2.11^{c}	1.62^{c}	0.32^{c}
T_6	1.47^{de}	1.05^{de}	0.30^{cd}
T_7	1.66^{d}	1.20^{d}	0.30^{c}
T_8	1.39^{de}	1.00^{de}	0.24^{d}

METHODOLOGY

To evaluate the nutrient management options, a field experiment was initiated in 2018 in rainfed upland ecology with eight nutrient management options (inorganic, integrated and organic) under rice sole (Sahabhaghidhan) and rice intercropped with pigeon pea (Birsa arhar-1). Nutrient management options were selected to provide the nutrients from both inorganic and organic sources as well as integrated sources. Experiment was conducted in randomized block design (RBD).

RESULTS

It was found that under sole rice system highest grain yield 3.18 t ha^{-1} was recorded in inorganic nutrient management (T_2) (100% RDF (60:30:30) followed 2.71 t ha^{-1}(T_4) (50% RDF +FYM @5 t / ha +VAM 1.5 q/ ha+ PSB 4 kg/ha) and 2.33 t ha^{-1}(T_3) (50% RDF +FYM @5 t / ha). Similar trend was observed in rice pigeon pea system, where rice grain yield (2.28, 2.01, 1.69) and pigeon pea yield (0.46, 0.39,0.36) was recorded respectively. Lowest grain and straw yield was recorded from control (T_1) where no inputs were applied. (table 1). However, yield in organic treatments is also low after two years of experiments.

CONCLUSIONS

It was concluded that highest grain yield (under sole rice and rice pigeon pea system) was recorded in inorganic nutrient management 100% RDF followed by (50% RDF +FYM @5 t / ha +VAM 1.5 q/ ha+ PSB 4 kg/ha) and (50% RDF +FYM @5 t / ha). This implies that integrated nutrient management can be better options to sustain the productivity as well as resources.

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IRC/TM-2/PP-81

EFFECT OF BISPYRIBAC SODIUM ON WEED MANAGEMENT IN AEROBIC RICE

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Aerobic rice system has huge potential as a water-wise technology in the present situation, wherein the crop is established by direct seeding in non-puddled and non-flooded fields (Anwar *et al*., 2010). Weeds grow quickly in direct seeded aerobic rice as compared to transplanted flooded rice. Therefore, developing an effective weed management approach has been a challenge for widespread adoption of aerobic rice technology. Use of herbicides found to be a promising solution for managing weed problem since it is easy, quick, economical and feasible. Application of pre-emergence herbicides mainly control weeds during the earlier stages of crop growth. The second flush of weeds at 25 to 30 days after sowing (DAS) becomes a problem. Keeping these in view, a field investigation was carried out to study the efficacy of bispyribac sodium on weed control and yield of aerobic rice in coastal deltaic region of Karaikal, U.T. of Puducherry.

METHODOLOGY

A field experiment was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA & RI), Karaikal to study the efficacy of bispyribac sodium on weed management and yield of aerobic rice in coastal deltaic region of Karaikal, U.T. of Puducherry. An experiment was conducted during *Rabi*, 2013 in a randomized block design (RBD) replicated thrice with eleven treatments (Table 1). The rice cultivar ADT (R) 46 was sown with the spacing of 20 cm x 10 cm and all the recommended package of practices except weed control was adopted during the period of experimentation.

Table 1. Effect of bispyribac sodium on weed growth and yield of aerobic rice

Treatments	Weed density at 60 DAS (no/m^2)	Weed dry weight at 60 DAS (g/m^2)	Weed control efficiency(%)	Rice Grain yield (kg/ha)	Weed index
Bispyribac sodium 20 g ha^{-1} at 10 DAS	13.9 (201.3)	10.7 (118.5)	79.7	3022	37.8
Bispyribac sodium 25 g ha^{-1} at 10 DAS	12.5 (184.0)	8.0(63.1)	89.2	4678	3.70
Bispyribac sodium 30 g ha^{-1} at 10 DAS	12.9 (169.3)	8.6(74.5)	87.2	2985	38.5
Bispyribac sodium 20 g ha^{-1} at 15 DAS	21.5 (466.7)	14.0 (199.5)	65.8	2582	46.8
Bispyribac sodium 25 g ha^{-1} at 15 DAS	19.8 (390.7)	11.4 (130.2)	77.7	3563	26.6
Bispyribac sodium 30 g ha^{-1} at 15 DAS	20.4 (416.0)	12.8 (165.8)	71.6	2633	45.8
Bispyribac sodium 20 g ha^{-1} at 20 DAS	23.7 (561.3)	14.8 (231.8)	60.2	2363	51.3
Bispyribac sodium 25 g ha^{-1} at 20 DAS	23.0 (526.7)	12.3 (154.2)	73.6	3448	29.0
Bispyribac sodium 30 g ha^{-1} at 20 DAS	23.0 (540.0)	14.0 (197.5)	66.1	2441	49.7
Hand hoeing at 20 and 40 DAS	10.5 (113.3)	5.2(26.9)	92.4	4676	3.70
Unweeded control	35.9 (1290.7)	24.0 (583.0)	-	333	93.1
LSD (p=0.05)	**4.5**	**3.7**	**NA**	**572**	**NA**

*Original figures in parenthesis were subjected to square root transformation ("x+0.5) before statistical analysis. NA- Data statistically not analysed.

Observations on weeds were recorded with the help of quadrate 0.25 m x 0.25 m placed randomly at four spots in each plot at 60 DAS. The data on weed density and dry weight were then analysed by using square root transformation (“x+0.5) to normalize their distribution. The data collected from the experiments was subjected to the Fisher’s method of Analysis of Variance (ANOVA).

RESULTS

The experimental field was infested with diverse weed flora comprising 35.7% grasses (*Echinochloa colona*(L.), *Echinochloa cruss-galli* (L.) Beauv.), 21.8% sedges (*Cyperus difformis*(L), *Cyperus iria* (L.)) and 42.5% broad leaved weeds (*Ludwigiaabyssinica, Linderniaoppositifolia*). Hand weeding twice at 20 and 40 DAS recorded the lowest weed density (10.5 no/m^2), weed dry weight (5.2 g/plant) and weed control efficiency (92.7%) (Table 1). It was found to be on par with the application of bispyribac sodium 25 g/ha at 10 DAS.

However, application of bispyribac sodium 25 g/ha at 10 DAS recorded significantly higher rice yield (4678 kg/ha) which was found to be on par with hand weeding twice at 20 and 40 DAS (4674 kg/ha). Williams (1999) indicated that 20 to 23 g ha^{-1} of bispyribac sodium application at mid- to late-post emergence resulted in higher yields in rice.

Controlling the weeds either manually or through herbicides significantly improved the yield attributing characters as compared to unweeded control. The yield loss caused by weeds was ranged from 3.7 to 51.3 % in bispyribac sodium treated plots. Unchecked weedy aerobic rice recorded the lowest grain yield (333 kg/ha) and maximum yield loss of 93.1%. This is further evident from the regression analysis which indicated that for every g m^{-2} of dry matter produced by weeds, the grain yield decreased by 7.28 kg ha^{-1}.

CONCLUSION

Application of bispyribac sodium 25 g/ha at 10 DAS and manual weeding twice at 20 and 40 DAS effectively controlled the weeds and improved the yield of Aerobic rice in coastal deltaic region of Karaikal, U.T. of Puducherry.

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IRC/TM-2/PP-82

INFLUENCE OF CROP ESTABLISHMENT METHODS AND NITROGEN MANAGEMENT ON PRODUCTIVITY AND PROFITABILITY OF *KHARIF* RICE IN LATERITE SOIL OF WEST BENGAL

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In India, Rice is grown in 43.68million ha,the production level is 104.80 million tonnes and productivity is about 2390 kg/ha.In West Bengal, Rice is grown in 5.38 million ha. area with production 14.68 million tonnes & productivity is 2730 kg/ha which is much lower than world average productivity i.e. 4250 kg/ha. Low yields may be attributed to various factors but faulty rice establishment methods and nutrient management have significant importance in reducing overall productivity of Rice.Manual transplanting requires a large amount of labour and water, which are becoming scarce and expensive. In recent years, the direct seeding method and drum seeding has been promoted as a replacement for transplanting to address this problem of labour scarcity and high water demand. The labour requirement of direct seeding is only about 34% that of transplanted rice (Ho Nai-Kin *et al.*, 2002).The Conventional tilled puddled drum seeding offers some advantages over conventional transplanting such as faster and easier establishment, reduced labour and less drudgery, and often higher profit (Balasubramanian and Hill, 2002). Nitrogen is the most yield-limiting nutrient of rice cultivation and it's efficient use is important for sustainable rice production system.Higher nitrogen use efficiency can be achieved by synchronising the crop demand and supply by adopting efficient nitrogen management tools like LCC,Nutrientexpert,Green seeker.

OBJECTIVES:

1. To study the effect of different crop establishment methods and nitrogen management on productivity of *kharif* rice.
2. To evaluate the economics involved with different crop establishment methods and nitrogen management of *kharif* rice.

METHODOLOGY:

Afield experiment was conducted during *Kharif* 2017 and 2018 at farmer's field of Chella,Birbhum district of West Bengal.The soil of the experimental plot was clay loam in texture, acidic in soil reaction with low level of organic carbon and available nitrogen but medium level of available phosphorus and potassium.The experiment was laid in split plot design with three levels of crop establishment methods(i.e. E_1-Conventional transplanting, E_2-Direct seeded rice and , E_3-Drum seeded rice) as main plot treatment and five levels of nitrogen management (i.e. N_1-Farmer's practice,N_2-State recommended ,N_3-Nutrient expert based,N_4-Green seeker based and N_5-LCC based nitrogen management) as subplot treatment.

In conventional transplanting, 21 days seedling were transplanted manually in puddled main fieldwith spacing 20x10cm.In direct seeded rice fields, dryland ploughing followed by harrowing and leveling was done in the fields before sowing. Dry rice seeds were sown in the soil with spacing 20x10cm before the onset ofmonsoon.In Drum seeded rice, drum seeding involves direct seeding of pre-germinated paddy seeds in drumseeder with spacing 20x8 cm apart in puddled and levelled fields.In subplot treatment (1) N_1 –68 kg N ha{ ^{1} in three equal splits (2) N_2 - 80 kg N ha{ ^{1} in three equal splits (3) N_3 -118 kg N ha{ ^{1} in three splits(30:35:35)(4) N_4 -Basal and 1st top dressing were applied as per nutrient expert based nitrogen management & 2nd top dressing was based on Green seeker reading. (4) N_5-LCC reading was taken from 21 DAT/28DAS at weekly interval until 1 week after PI and when the critical LCC < 3 ,23kg urea urea/ acre was applied.

RESULT:

The maximum number of effective tillers m^{-1} (282.4) was recorded with E_1 followed by E_2 (271.5) but there was no significant difference between E_1& E_2. The percentage increase in number of effective tillersm^{-2} with E_1 and E_2 over E_3 was 16.26 and 11.77% respectively. The maximum number of effective tillers m^{-2}(295.9) was recorded with N_4 which was at par with N_3(280.3) whereasN_5 recorded significantly lower effective tillers m^{-2} (259.8) than N_3 & N_4. On basis of pooled data, the percentage increase in effective tillers m^{-2} with N_1,N_5,N_3 and N_4 over Farmer's practice was 4.36%,7.8%,16.40% &22.88% respectively.

The maximum number of spikelet panicle^{-1} (121.1) was recorded in E_1 which was followed by E_2(113.8) and E_1, E_2 recorded statistically at par result. The percentage increase in number of filled grains panicle^{-1} with N_2,N_5,N_3 &N_4 over N_1 was 2.24,3.0,14.2 & 20.67 respectively.

On the basis of pooled result, the highest grain yield (4751 kg ha^{-1}) was recorded with E_1 which was at par with E_2 (4581.1 kg ha^{-1}).The percentage increase in grain yield with E_2 and E_3 over E_1 was 21.1% and 16.8% respectively. Highest grain yield (4850.6 kg ha^{-1}) was recorded with N_4 but it was at par with N_3(4667.6 kg ha^{-1}). The percentage increase in grain yield with N_4,N_3,N_5,N_2over N_1 was 19.21%,14.71% ,6.49% and 2.52% respectively.

The highest straw yield was recorded with conventional transplanting E_1(6149.6 kg ha^{-1}) which was statistically at par with direct seeded rice (5634.8kg ha^{-1}). The percentage increase in straw yield with N_3,N_4,N_5,N_2over N_1 was 19.19%,14.94% ,10.40% and 6.08% respectively.

Maximum gross return per hectare (Rs.110121 ha^{-1}) was recorded with $E_1$and it was statistically at par with E_2(Rs.104999 ha^{-1}).In respect to nitrogen management, the maximum gross return (Rs.99423 ha^{-1}) was recorded with N_4 which was statistically at par with N_3(Rs.98320 ha^{-1}).

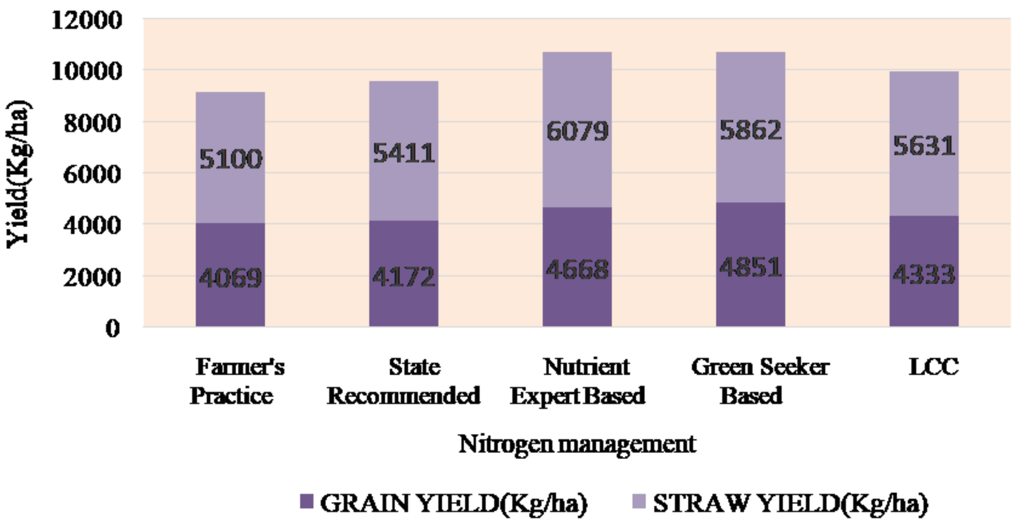

Fig1:Effect of nitrogen management on grain yield (Kg ha^{-1}) and straw yield(Kg ha^{-1}) of *Kharif* rice.

Highest net return per hectare (Rs. 63624 ha^{-1}) was recorded with E_2 and it was statistically at par with E_1(Rs. 62079 ha^{-1}). Highest net return (Rs. 66497 ha^{-1}) was recorded with N_4 which was statistically at par with N_3(Rs.63301ha $^{-1}$).

Maximum return per rupee invested (2.54) was recorded with $E_1$and it was statistically at parwith E_2(2.29). In respect to nitrogen management the maximum return per rupee invested (2.50) was recorded in N_4 which was statistically at par with N_3(2.41).

CONCLUSION

From the present investigations, it is concluded that conventional transplanting and direct seeded rice with greenseeker based nitrogen and nutrient expert based nitrogen management may be recommended for higher productive & profitability in *Kharif* Rice.

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Theme - II : Sustainable rice farming

IRC/TM-2/PP-83

IMPACT OF CLIMATE CHANGE ON RICE PRODUCTION IN ANDHRA PRADESH USING ORYZA 2000 MODEL

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Climate change temperature, CO_2 level changes, precipitation is expected to impact on agricultural productivity. Global warming, in Asia, will affect scheduling of cropping season as well as duration of the growing period of the crop in all the major crop producing areas. Rice crop in India is susceptible to an increase in minimum temperature, resulting in a net decline in yield. Simulation analysis by using different models has shown that increasing CO_2 concentration in the atmosphere has a positive effect on crop biomass production, but its net effect on rice yield depends on the rising of the temperature. In Andhra Pradesh the temperatures are projected to increase by at least 3^0C throughout the state due to climate change during 2041 to 2060 (Sreenivas and Raji Reddy, 2009). This increase may occur across the seasons of the year. This study was under taken to assess the impact of climate change on rice yield using ORYZA 2000 model in Guntur and Visakhapatnam districts of Andhra Pradesh.

MATERIALS AND METHODS

Crop growth simulation models are simplified mathematical representations of the biological phenomena involved in crop growth and production. ORYZA2000 (Bouman*et al.*, 2001) model is an ecophysiological crop model to simulate the growth and development of a rice crop in situations of potential production, water limitation and nitrogen limitations. This study attempts to determine the potential impact of climate change, namely changes in CO2 and temperature, on the rice yield in Guntur and Visakhapatnam districts of Andhra Pradesh. ORYZA 2000 crop growth model was used to simulate rice yield with different levels of temperature (1°C, 2°C, 3°C and 4°C of above mean temperature) and CO_2 (340, 383, 415, 490, 565 and 640 ppm) where nutrient and water are assumed to be non-limiting under three scenarios (different levels of CO_2 concentrations, raise in mean annual temperature from 1°C to 4°C and combined effects of CO_2 concentrations and raise in mean annual temperature).

RESULTS AND DISCUSSION:

The impact of temperature on rice yield in Guntur and Visakhapatnam districts resulted in decrease in yield with increase in temperature from 1°C to 4°C above the mean temperature. When temperature increase to from 1°C to 4°Cabove the mean temperature, the per cent decrease in rice yield varied from -2.3 to -55.2 and -6.3 to -39.6 in Guntur and Visakhapatnam district, respectively. The increased temperature will lead to forced maturity and poor harvest index due to limited water supply, at flowering inhibits swelling of the pollen grains which is the driving force behind anther dehiscence and therefore high temperature would induce spikelet sterility and increase in instability of the rice yield (Matsui and Omasa, 2002).

The impact of CO_2 levels in rice yield was recorded in Guntur and Visakhapatnam districts with increase in CO_2 concentration without change in temperature. Since 383 ppm is present CO_2 level in atmosphere is used to compare the simulated yields with different levels of CO_2. With increase in CO_2 concentration from 340 to 640 ppm, the percent change in simulated yield of rice is from -5.6 to 20.0 and -5.2

to 22.0 respectively in Guntur and Visakhapatnam districts. The high CO_2 concentration to be present in the atmosphere under global warming could be harnessed to increase the productivity of the rice crop. Studies found that with increase in atmospheric CO_2 concentration (Parry *et al.*, 2004), could produce beneficial effects in grain production, photosynthetic rates and decrease in stomata conductance and transpiration rates (Vaghefi*et al.*, 2011).

The interaction effects of temperature and CO_2 concentration on simulated rice yield resulted that change in per cent grain yield increased with increased levels of CO_2 from 340 to 640 ppm up to increase in temperature up to 1^0C and 2^0C (-10.4 to 21.6 and -7.6 to 30.7). The per cent change in grain yield was -35.6 to -8.8 and -52.2 to -32.6 with increase in temperature 3° and 4°C above mean and CO_2 concentration increased from 340 to 640ppm, respectively in Guntur district. With the increase in CO_2 concentration from 340 to 640 ppm the grain yield increased from -10.9 to 8.0 and -14.0 to 3.1 per cent, respectively at both increased temperature 1 and 2°C. The per cent change in grain yield was -18.7 to -6.4 and -24.1 to -9.1 with increase in temperature 3° and 4°C above mean and CO_2 concentration increased from 340 to 640ppm, respectively. Increasing atmospheric CO_2 concentration could only have beneficial effects on rice production. Potentially great negative effects are also possible, if maximum daily atmospheric temperatures also rise. With increasing temperatures at higher CO_2 levels the decline in rice production will be much higher. Substantial reduction in rice yield as a result of increased temperature will not usually compensated by increased level of CO_2.

CONCLUSION:

The analysis showed that the model is sensitive to the changes in temperature and CO_2 concentration, and therefore, could be used for simulating the effect of changes in weather parameters on rice yields.ORYZA 2000 could successfully use weather data to predict the future crop yields under different management practices. The results indicated that there would be negative effects on rice production and yield as well as on future food supply. Thus policies on mitigation need to be formulated to mitigate climate change and farm practices need to be adopted to overcome the adverse effects of climate change to ensure sustainable farm income and self- sufficiency level.

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IRC/TM-2/PP-84

IRON PULSING: A NOVEL RICE SEED INVIGORATION TECHNIQUE TO ENHANCE YIELD BY ENHANCING NITROGEN AND CARBON ASSIMILATION

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Rice is one of the major staple food for majority of the world's population. With continuous growth in population, global demand for milled rice is projected to reach 555 million tons by 2035. To meet up with this increasing food demand, augmenting rice yield especially through sustainable means appears to be the need of the moment. Farmers are leaned towards use of bulk fertilizers and pesticides to achieve enhanced yield but rampant use of these chemicals are detrimental to our environment and causes consumer health menace. Micronutrients have immense significance in ensuring proper plant growth and development. Application of micronutrients through soil treatment has been widely accepted but it requires huge resource requirement and inflicts residual effects due to leaching. Besides, foliar application of micronutrients is also used butfails to impart long lasting effects and requires multiple rounds of application. Seed treatments like seed priming and coating has been a promising area to achieve higher yield but are often challenged with storage problems of such seeds (Farooq et al., 2012). Iron is one of the most essential micronutrient. Iron(Fe) deficiency is a common nutritional problem faced by many crops, and it is the availability not the abundance that needs to be addressed. Moreover, Fe is susceptible to a series of reactions that alters its mobility, solubility thus sequential availability of it.We have implemented a novel seed invigoration technique termed as *iron pulsing*, that obliterates the difficulties associated with the present techniques of micronutrient application, yet delivers optimum results in terms of improving growth and yield attributes of treated rice plants.

Iron is a key co-factor for the enzymes associated in nitrogen assimilation and photosynthesis. Besides, seed germination requires a steady supply of energy in form of ATP and iron plays a crucial role as it is an essential element required for proper functioning of the enzymes involved in the mitochondrial electron transport chain. We intend to improve the growth of the plants through iron nutrition delivered through seed treatment, that would lead to enhanced yield without the aid of any fertilizers or chemicals. As iron is an inevitable component for optimum functioning of a variety of crucial enzymes associated with plant physiological processes, iron treatment would be effective in upregulating them and result in uplifted growth. This initial hike in growth, nitrogen and carbon assimilation would be reflected in the yield of the treated plants.

Thus, the objective of our work encompasses increasing the germination, growth and yield related attributes of the rice plants using an affordable, user friendly strategy without incurring an environmental cost.

METHODOLOGY

We have implemented a novel technique termed as iron pulsing where we treat rice seeds with different concentrations (2.5, 5 & 10 mM) of iron salts ($FeCl_3$ and $FeSO_4$) for 72h and grow them till maturity (Dey et al., 2019). The germination parameters were analysed. At 14 day of plant growth, we analysed the key enzymes and intermediates of the nitrogen assimilation pathways. The chlorophyll content, activity and other photosynthetic parameters were also studied.

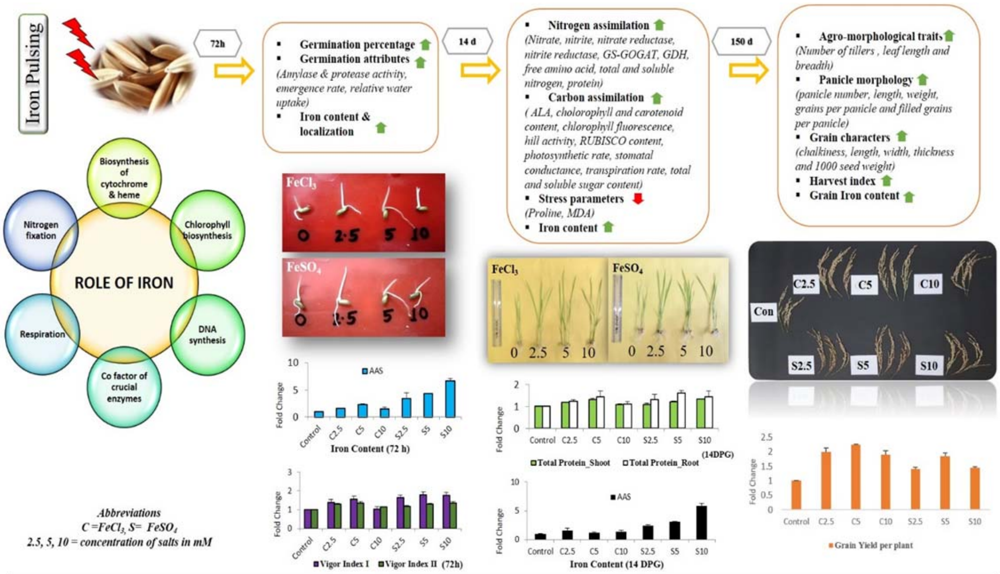

Fig: Summary of iron pulsing and its impact on plant growth, vigour, carbon and nitrogen assimilation and yield related traits

To check that the treatment did not elicit any toxicity, the antioxidant parameters and stress markers were monitored. The plants were grown in field till harvest, and after harvest the agro-morphological traits and yield attributes were recorded. The iron content of the plants (through AAS) and their localization (through Perl Staining) was also analysed.

RESULT

Iron supplementation for 72h, improved germination rates, relative water uptake by the seeds and phenotypical characters like length of radical and plumule. The iron content of the treated seeds also increased significantly. The treatment enhanced the nitrogen assimilation and photosynthetic efficiency of the plants as evident from higher protein and sugar contents (Dey et al., 2019). This helped in boosting the plant growth and vigour that ultimately enhanced the agro-morphological traits and yield of the treated plants. The treated plants also accumulated higher amount of iron in its vegetative parts and also the grains. This treatment did not cause any toxicity, rather improved the functioning of the antioxidant enzymes as iron serves as a cofactor for them as well. All the data were statistically significant and a PCA analysis revealed that the best dose for treatment was C5 (5 mM $FeCl_3$) and S5 (5 mM $FeSO_4$).

CONCLUSION

Iron pulsing is a propitious approach that might serve as a promising tool in modern agriculture that would be helpful in increasing the yield of the rice crops. It will not only be beneficial in ensuring food security for the teeming millions but would also reduce over use of the fertilizers and other harmful chemical supplements that are detrimental to the environment and also the consumer health.

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Theme - II : Sustainable rice farming

IRC/TM-2/PP-85

SOIL AMENDMENT OF NANOSCALE ZERO-VALENT IRON FOR CADMIUM STRESS MITIGATION IN *ORYZA SATIVA* L. CV SWARNA

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Cadmium (Cd) being a carcinogen, is ranked 7th among the top 20 hazardous substances. Due to anthropogenic activities, Cd contamination of agricultural land is increasing. The presence of Cd in agricultural soil reduces crop yield. Phyto-accumulation and subsequent trophic transfer of Cd occur easilyleading to various health issues.Rice, a staple food crop among Asians, acts as major source of Cd intake. In India, Cd contamination is a major concern because Cd concentrations in rice grains of Indica variety are 2–3folds higher than that of Japonica varieties.

Applications of nanotechnology as plant growth promoter are being encouraged since nanoparticles can increase plant fitness under stress conditions through modification of plant metabolic responses.Nanoscale zero-valent iron (nZVI) has gained immense popularity asnano-remediation tool due to its potential for broader application, higher reactivity and cost-effectiveness compared to other iron compounds as well as in-situ methods. Almost 60% of sites remediated with nanomaterials are done with nZVI and nZVI can reduce bioavailable Cd, Zn and Cr in soil (Zhu et al. 2019). However, nZVI is yet to be utilized commercially in agricultural sector because most of the reports regarding plant-nZVI interactions are restricted in lab based study and reports regarding long term effects of nZVI in soil systems are still scarce.

In our present work, we have analyzed the effectiveness of nZVI in alleviating Cd induced oxidative stress in *Oryza sativa* L. cv. Swarna. From extensive dose screening, we found that 100mg L^{-1}nZVI was most suitable for remediation of 10 ìM Cd. Our objective in the present study was toevaluatethe mechanism of reduced Cd uptake in rice grains by application of nZVI in Cd contaminated soil.

METHODOLOGY

Synthesis of nZVI (diameter: 33.8 ± 3.59 nm) was done by sodium borohydride method. Rice seeds were sterilized and after germination, seedlings were grown in hydroponics for 7 days and thenthe seedlings were treated with Cd and nZVI for 10 days. 4 treatment sets viz; control, 10 ìM Cd, 100 mg L^{-1}nZVIand 10 ìM Cd + 100 mg L^{-1}nZVIwere maintained separatelyunder lab conditions. Thereafter, plant growth parameters, stress parameters (MDA, Proline and root dehydrogenase activity), antioxidant status (CAT, SOD, GPOD, Glutathione cycle) were analyzed. SEM images were taken to investigate formation of iron plaques. In-vivo imaging of ROS and Cd localization were done by confocal microscopy and lastly, gene expression level of some transporters involved in Cd uptake were checked by qRT-PCR.

Pot experiments were also conducted from June to October 2018. Here 21 days old seedlings were transplanted to respective pots with 5 kg farm soil mixed with 1lit of respective Cd and nZVI treatment solutions and grown till maturity under natural conditions with regular watering. Several agronomic traits, grain nutrient status of rice were evaluated and sequential extraction analysis of soil was conducted to confirm Cd immobilization by nZVI.

RESULTS

From our lab experiments, it is evident that nZVI can alleviate Cd-induced toxic effects by enhancing plant antioxidant defense mechanisms and other physiological processes. nZVI treated rice seedlings also showed upregulation of phytochelatins which caused a higher proportion of absorbed Cd to be fixed within roots as a Cd-phytochelatin complex and accumulated within the vacuole. Cd localization assay with leadmium proved that Cd translocation was reduced with nZVI treatment. EDX results showed formation of iron plaques in nZVI treated seedling root surface.

Study of root morphology with scanning electron microscopy and ROS imaging with confocal microscopy confirmed that nZVI could alleviate oxidative stress due to Cd uptake. In nZVI treated rice seedlings, expressions of iron (Fe) transporters (like, *IRT1-2*, *YSL 2-15*) which are responsible for both Fe and Cd uptake were significantly down-regulated and *OsVIT1* and *OsCAX4* genes were overexpressed which lead to sequestration of Cd in vacuoles.

To further validate our findings a pot experiment was carried out. Cd treatment significantly inhibited the growth of rice. With the addition of both nZVI and Cd in pot soil, growth and biomass were increased significantly. Panicle number and grain number per

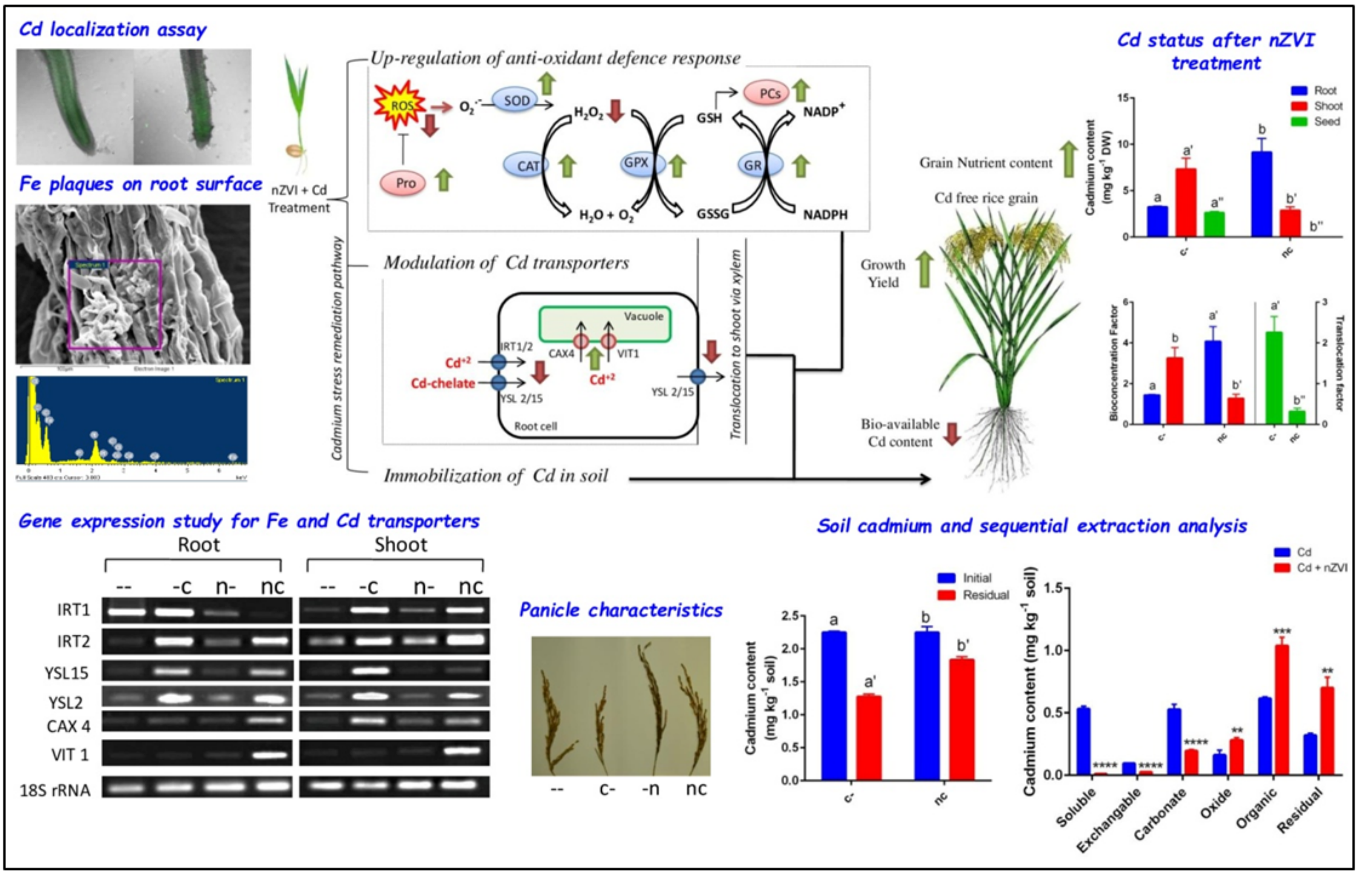

Figure 1. Schematic representation of the plausible mechanism of Cd stress amelioration by nZVI. nZVI induces up-regulation of anti-oxidant defence responses ameliorating Cd induced oxidative stress. Phytochelatin levels being higher in the nZVI treated plants facilitate vacuole sequestration of cadmium. Confocal images also confirmed restriction of Cd in root region afternZVI treatment. Iron plaques were formed on root surface which can prevent Cd uptake. nZVI treatment also down-regulated expression levels of Fe/Cd transporters. Upon pot study, it was verified that nZVI can reverse negative effects of Cd and prevented Cd translocation in rice grains. Soil study also confirmed immobilization of soil Cd. ('—'Control; 'c-' 10 ìM Cd; 'n-' 100 mg L^{-1}nZVI, 'nc' 100 mg L^{-1} nZVI+10 ìM Cd treatment.)

panicle in Cd treated sets were lower than the control sets by 28.8 and 48.75 % respectively but with nZVI treatments, 39.8% increase in panicle number was observed and there was an overall enhancement of grain yield by 2.6 fold. The Cd treatment severely reduced mineral uptake in rice root, shoot and grains which was rescued by nZVI treatment.

Cd treated plants had higher Cd level in shoot, and Cd level in grain was 30ìg kg^{-1} DW. However, nZVI could restrict Cd in root region and prevented the accumulation of Cd in rice grains.

Soil which was treated only with Cd, had higher levels of Cd in exchangeable and carbonate fractions but with nZVI treatment, exchangeable soil Cd level was decreased by 74.04% and 62.89% of Cd was also removed from carbonate fraction. On the other hand, oxidized Cd level was enhanced by 72%. Similarly, Cd contents in the organic and residual fractions increased by 68% and 218% respectively. These confirmed that nZVI can lead to Cd immobilization in soil.

CONCLUSION

In conclusion, it can be said that soil amendment with nZVI can be helpful in mitigation of Cd stress in rice. Physiological and biochemical parameters that were studied in the nZVI and Cd treated plants suggested that nZVIupregulated plant growth, root metabolism, photosynthetic efficiency and antioxidant enzyme activities. nZVI was also capable of modulating Cd transporters which included down-regulation of plasma membrane-localized iron-transporters like *IRT* and *YSL* genes and up-regulation of transporters involved in sequestration of Cd into vacuoles like *CAX*, *VIT* genes. In addition to this phytochelatin level was also higher in nZVI + Cd treated seedlings. All of these mediated restrictions of Cd to the root tip area as detected under confocal microscope. Lastly, from pot study, it was confirmed that nZVI can prevent transport of Cd to the grains, and immobilized Cd in the soils. Thus, in future nZVI can play a significant role in in-situ soil remediation by immobilizing Cd and improving plant growth.

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IRC/TM-2/PP-86

SELECTION OF RICE GENOTYPES FOR CADMIUM TOLERANCE UTILIZING LOCAL LANDRACES AND CULTIVARS

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Cadmium is one of the most widespread and potent toxic element (Gallego et al., 2012). As Cd has long biological half-life, and cannot be degraded, remains within the system. Cd is toxic, non-nutritive, having adverse effects on both plants and animals. Being highly mobile Cdis easily taken up by the rice plants (*Oryza sativa* L.), and causes growth impairment, chlorosis, tissue damage and even cell death.Cd generated ROS can either enhance or diminish cellular antioxidant levels in species, in a variety dependent manner. In most cases activity of SOD, CAT and GPOD increase to scavenge cellular ROS, depending on the tolerance potential of the cultivar. Cd induced ROS causes lipid peroxidation leading to membrane damage. In the mature plants, Cd toxicity can negatively affect the crop yield. Cd contaminated rice is a threat to human health, as it causes osteomalacia and kidney dysfunction.

West Bengal is the home of large numbers of rice varieties (more than 5000 genotypes) and is well known as a rice diversity region. These cultivars vary in their morphological, physiological, yield parameters as well as tolerance and uptake potential to heavy metal toxicity.

Our objective of the present study is to identify rice cultivars tolerant to Cd stress as well as, to select cultivars which can accumulate low/no Cd in their grains. Based on morphological, physiological and biochemical stress parameters (root shoot length, photosynthetic pigment content, lipid peroxidation, proline contents and activities of antioxidant enzymes) two pairs of rice genotypes, with contrasting stress responses were chosen for further studies. Pot experiment was conducted with these genotypes till maturity to study the agronomic traits (plant final height, leaf length, leaf breath, total tiller number, effective tiller numbers) and grain Cduptake under moderate Cdstress.

METHODOLOGY

Seeds of ten rice cultivars were collected from Chinsurah Rice Research Station, West Bengal, India and surface sterilized with 0.2% dithane M-45(anti-fungal agent Dow Agro-Science) for 5 min. Seeds were washed 5-6 times by deionized water and allowed to soak overnight in dark condition and plated for germination.Seven days old seedlings were subjected to treatment with 10µM $CdCl_2$ (1.81 mg/kg). Plants were grown in hydroponic condition and harvested on their 14^{th} day old condition. Root and shoot length, dry bio-mass, Root tolerance index (RTI), Photosynthetic pigment content and relative water content (RWC) were measured. Different stress markers (Proline and MDA level) were estimated. Localization of ROS and antioxidative defense responses were also studied.

On that basis, four cultivars were selected for their contrasting responses to Cd. To study further (agronomic traits, grain Cd), selected genotypes were grown in pots till maturity. Different agronomic traits, yield components and grain Cd content were estimated.

RESULTS

From our experiments, we found marked difference in physiological and biochemical and parameters under Cd toxicity. Root, shoot length, RWC and dry bio mass reduced considerably in all genotypes compared to untreated plants. RTI values were found to be much higher for rice cultivars Netiya, Maharaj, Khandagiri (<0.90) and for the cultivars I.E.T-4786, Jamini the value was low (>0.80), indicating susceptibility towards Cd toxicity. Higher lipid peroxidation was observed in the cultivars I.E.T-4786, Jamini. The cultivars I.E.T-4786, Jamini, M.T.U-1010 showed higher proline (an osmolyte) content, whereas, a significant depletion of proline content was found in cultivars Khandagiri (38.63%), Mali-4 (44%), compared with their untreated counterparts. To cope with the environmental stress, plant produces antioxidative enzymes, which scavenge Reactive Oxygen Spices (ROS), thus preventing oxidative damage. In this experiment, Cd toxicity has led to significant increase and decrease of antioxidative enzyme activities both in the root and shoot samples. Significantly, much higher level of SOD activity was observed in I.E.T-4786 (75.23%), Jamini (93.66%), Khandagiri (61.81%). The activity of Guaiacol peroxidase (GPOD) was also analysed in the rice cultivars (both Cd treated and untreated plants) and found higher activity in M.T.U-1010, Nilima, Maharaj. However, rice cultivars Netiya, Maharaj, showed significant reduction in GPOD activity after treatment. Rice cultivars I.E.T-4786 and Jamini showed dark blue spots (indicating presence of $O_2ÿ^-$) and brown polymerization (indicating presence of H_2O_2), all over the leaf lamina. In both cases, stained regions were much more abundant on the leaves than the rest of the two cultivars Netiya and Maharaj, which showed less blue and brown spots. Crop production is highly related

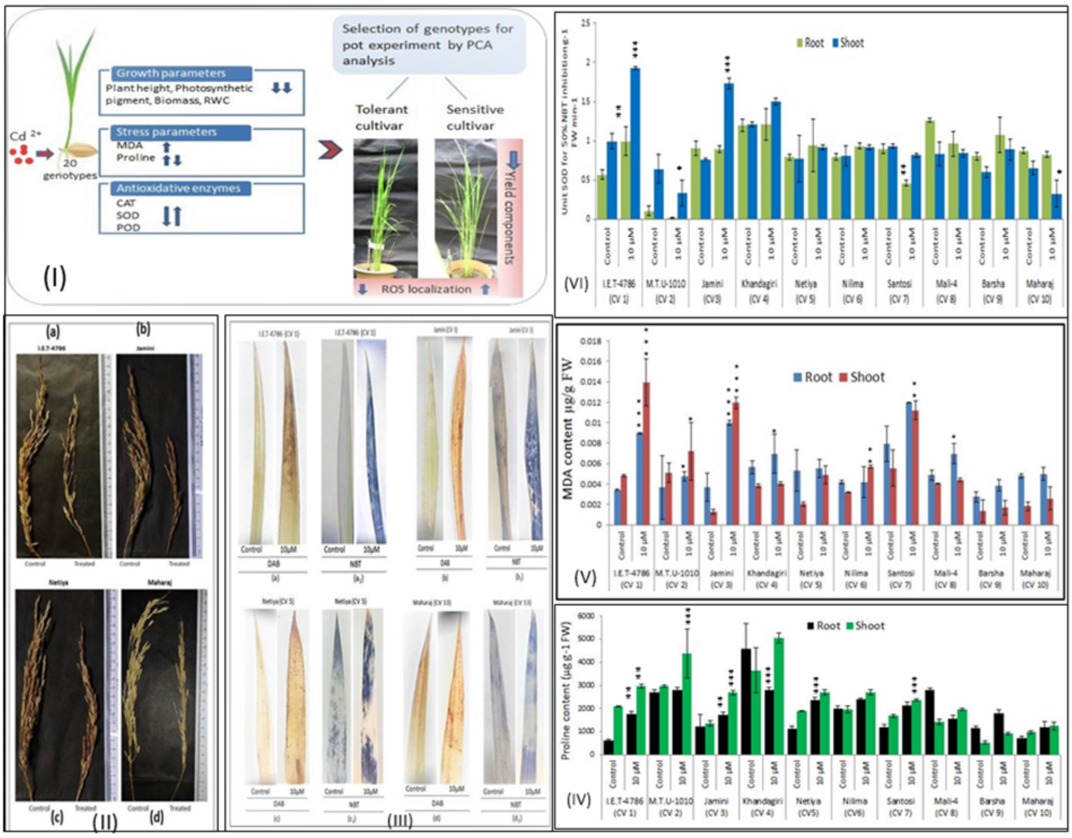

Fig. 1 Schematic representation showing Graphical abstract (I), Panicle length under Cd toxicity (II), H_2O_2 and O^-_2 localization (III), Bar graph showing different stress parameters and antioxidant content of 10 rice cultivars under Cadmium toxicity. Proline content (IV), MDA content (V) and SOD (VI).

to plant agronomic traits. Reduced growth was observed indicating toxic effect of Cd on rice during the vegetative and reproductive phase. I.E.T-4786 and Jamini showed reduction in effective tiller and total tiller percentages (53.33%, 60.00% and 56.25%, 60.00% respectively), indicating susceptibility towards Cd stress. Grain Cd content analysis showed that, cultivars Netiya and Maharaj have significant amount of grain Cd accumulation (33µg/kg and 29µg/kg), while the other two cultivars I.E.T-4786 and Jamini have no Cd accumulation in grains and therefore can be identified as non-accumulators. The estimated daily Cd intake would be 16.5µg and 14.5µg for Netiya and Maharaj cultivars respectively, if a 60kg adult person consumes approximately 500gm grains of these cultivars daily, the estimated monthly intake would be 8.25 and 7.25 µg/kg BW/month, which is much lower than the permissible limit of Cd consumption (according to WHO permissible tolerable monthly intake of Cd is 25 µg/kg BW/month).

CONCLUSION

Based on various parameters studied, it was found that rice cultivars Maharaj and Netiya are tolerant towards Cd stress with low Cd content (below the PTMI level) in grains. However,Jamini and I.E.T-4786 are susceptible and has no Cd content in grain.I.E.T-4786 and Jamini can be used in future as allele donor for developing Cd non-accumulating rice genotypes. Whereas, the other two landraces Netiya and Maharaj can be used for phytoremediation purposes.

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IRC/TM-2/PP-87

DEVELOPMENT AND EVALUATION OF BATTERY ASSISTED WEEDER FOR REDUCING DRUDGERY OF RICE FARMER

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Weeds are the most serious and important cause of yield loss in rice. In Rice, initial stages weeds are more competitive (2-6 weeks after planting) with crops.Manual hand weeding is the most common and it is a very efficient method but the time required for manual weeding (2-3 times in a season)is more than 100 man-days per hectare. Weed control during this time is very essential for maximum crop yield. Because of this, the mechanical and chemical weed control method is rapidly gaining ground due to its high efficiency. The chemical application requires more than once and the wastage of weedicide/herbicide due to widespread spraying which results significantly reduces the yield in comparison to mechanical weedingand other hand raising several environmental concerns. Weeding operation consumes a large amount of energy in form of chemicals and manual labours. Mechanical methods of weeding are preferred over other methods of weed control because of their added advantages of simple construction, low cost, and environmental friendly. But the drudgery due to engine vibration while operating the machine is a major concern. To eliminate drudgery due to engine vibration a battery-powered weeder was designed and developed. It is a lightweight (17 kg) single row battery-assisted rice weeder for weeding between the row and row to row spacing of greater than 20 cm. The average field capacity with this machine was 0.03 $ha.h^{-1}$ at a walking speed of 2.5 $km.h^{-1}$ with 85.7% weeding efficiency. The machine is gender-friendly with simple design and technology and has the potential to be adopted by small and medium farmers.

METHODOLOGY

The concept of mechanical and electronics (mechatronics) was used to design and develop a battery-powered paddy weeder (<20 cm row to row distance). It consists of a DC motor, two sets of batteries, a controller, frame, power transmission system, and handle with a speed control unit. A geared

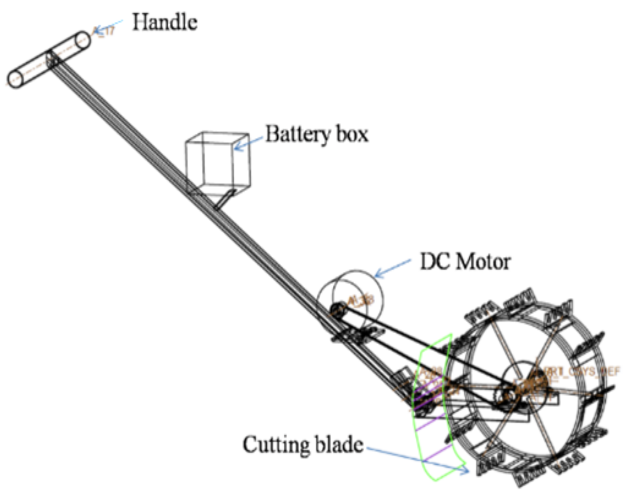

Fig 1. Developed prototype of battery-powered weeder

Table 1: Field performance of different weeding machine/implement for rice crop

Implements	Actual field capacity, ha/h		Field efficiency		Weeding efficiency		Plant damage, %	
Weeding after planting	25 DAT	40 DAT	25 DAT	40 DAT	25 DAT	40 DAT	25 DAT	40 DAT
Finger weeder	0.010	0.012	69.82	72.34	78.67	84.77	1.6	1.4
Star cono-weeder	0.015	0.016	61.32	64.7	64.77	66.22	2.6	2.8
Power weeder	0.076	0.075	78.14	77.49	67.22	68.48	2.94	2.99
Battery powered weeder	0.030	0.029	85.70	84.00	77.32	76.17	0.00	0.5
Hand weeding	0.003	0.005	NA	NA	96.66	97.20	0.6	0.1

DC motor (24 V, 250 watts) with gear reduction unit ratio of 9.8, which provides high torque and better efficiency with less operating and maintenance cost over fossil fuels. To supply a rated current of 14 A two 12 V (DC) batteries connected in series were provided. DC batteries were used because of the moving unit. The power switch/lock was used to start or stop to cutting unit and the throttle was used to increase or decrease the speed of the cutting unit. A controller was used to connect and regulate all the functioning of the weeder. The weeding unit was designed to operate in between the row greater than 20 cm distance and cutting unit width14 cm with 16 blades attached on the periphery of the cutting unit for better weeding without clogging and shrinking. The ergonomically designed handle length and grip were provided for better balancing and reduce vibration, which eliminates drudgery due to engine vibration while operating in the field. The power transmission system is designed to transmit the power from the motor to the cutting unit with the help of a chain and chain sprocket with a gear ratio of 1.5:1 for weeding and walk behind the weeder (fig. 1).

RESULT AND DISCUSSION

The developed battery-powered weeder was evaluated at the NRRI field. Different parameters were taken plant row spacing (20 cm, 22.5 cm, and 25 cm), weeding date after transplanting/planting (25 and 40 DAT), and cutting unit speed of 150-200 rpm. The ideal power consumption of a developed weeder in the range of 2-4 A. The power consumption of the DC motor increases with an increase in the speed of the cutting unit and the maximum power delivered by the DC motor at its rated speed was 250 watts (at 14 A current). The average current required for weeding operation was 6-8 A and a set of batteries (14 Ah) run the developed prototype at stretch for 2 h. The actual field capacity of the weeder was observed 0.030 $ha.h^{-1}$ at a row spacing of 20 cm and the depth of cut was 4 cm. The weeding efficiency of battery power weeder was found highest (77.32%) in plant spacing 20 cm with cutting unit width of 14 cm. the performance evaluation of developed battery power weeder in comparison to different weeding machine/implement (Table 1) and cost economics and energy required in weeding operation in rice cultivation (Table 2). The cost of the machine and the cost of operation was found Rs. 15000/- ha^{-1}, and Rs. 1062/- ha^{-1} with an energy requirement of 112.46 $MJ.ha^{-1}$.

Table 2: Effect of weeding implement/methods on energy and cost of weeding in rice cultivation

Treatments	Average labour required man. h/ha	Total cost Rs./ha	Energy MJ/ha
Finger weeder	100	3125.00	384.10
Star cono-weeder	63	1954.00	444.16
Power weeder (Two rows)	14	1389.00	556.72
Battery-powered weeder	34	1062.00	112.46
Hand weeding	250	7813.00	490.00

CONCLUSION

The manually operated weeding implement required muscle power so it cannot be operated for a long time. Mechanical weed control is very effective but due to exposure engine vibration causesthe dynamic disorder, damaging hand tissue, touch sensation, and vascular diseases which are eliminated by battery-powered weeder. Battery assisted weeder helps to reduce the drudgery involved in manual and mechanical weeding and it saves labour cost, weeding cost, and also save time required for weeding operation as compared to other weeding methods. Renewable energy-based agricultural machinery will be an option to reduce the use of fossil fuels in agricultural operations.

Theme - II : Sustainable rice farming

IRC/TM-2/PP-88

IMPACT OF SEASONAL CLIMATIC VARIABILITY ON *KHARIF* RICE YIELD OF GANJAM, ODISHA, INDIA

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Rice (*Oryza sativa* L.) is the most important food crop in the world. India has 43.2 million hectares area of rice cultivation and ranks second with respect to production. In Odisha, rice covers about 69% of cultivated area, where it is grown mainly in *kharif* season.Ganjam district of Odisha, which lies in East and South Eastern Coastal Plain Zone, contributes about 6.70% of total area. Climatic variables such as rainfall, temperature, solar radiation and carbon dioxide concentration are most important factors affecting crop variability and productivity. Temperature controls the duration of crop growth. Increased temperature accelerates plant phenological development; however it can decrease grain filling period. Hence temperature increases may shorten the length of growing period.Climatic change may modify precipitation, runoff, evaporation and soil moisture which in term can affect duration of growth through effect on leaf area duration and also may affect the photosynthetic efficiency through stomatal closure.It is therefore extremely important to know the future scenarios of climate change at regional as well as global level and mitigation measures to solve problems of crop sustainability and food security. Here in this context Marksim weather generator has been used to project future change in climatic parameters such as temperature, rainfall, solar radiation. Representation Concentration Pathways (RCP) data for Ganjam were used for three future years, namely 2030, 2050 and 2070 which were used in Fifth Assessment Report of IPCC (VanVuuren, *et al*., 2011).

METHODOLOGY

The present study was carried out during *kharif* season of 2018 at Research field of Krishi Vigyan Kendra, Ganjam district of Odisha. Ganjam is situated at an elevation of 3m above sea level, 19.38 °N latitude and 85.07 °E longitude. There were 16 treatments combination consisting of four transplanting dates in main plot and four rice varieties in sub-plots. The design was split plot with three replications. The study variety taken was "Hasanta". Data on height of the plants, number of tillers, total number of leaves and number of leaves in main shoot, dry weight of root, shoot and leaf were recorded in 15 days interval from

Table 1- Projected change in seasonal Climate

Variable	Present weather scenario	DIFFERENCE FROM PRESENT WEATHER SCENARIO											
		RCP 2.6			RCP 4.5			RCP 6.0			RCP 8.5		
		2030	2050	2070	2030	2050	2070	2030	2050	2070	2030	2050	2070
Rainfall, mm	1103.2	1118.5	1135.7	964.9	1106.3	1133.6	994.2	1110.9	1124.1	976.4	1118.9	1132.3	988.8
Mean Maximum Temperature, ^{0}C	30.8	31.3	31.5	31.1	31.5	31.9	31.7	31.4	31.8	31.8	31.6	32.3	32.7
Mean Minimum Temperature, ^{0}C	23.9	24.1	24.3	23.7	24.2	24.6	24.4	24.1	24.5	24.4	24.3	25.1	25.3
Mean Solar Radiation, MJ/day	14.2	17.9	17.8	17.3	17.9	17.8	17.2	18	17.9	17.1	17.9	17.9	17.1

Table 2- Observed and Simulated grain yield of cv. Hasanta of four transplanting dates under four RCP projections for the year 2030, 2050 and 2070

Grain Yield at harvest maturity, kg/ha	Planted on 12th July					Planted on 27th July					Planted on 11th August					Planted on 26th August				
	Observed	Simulated				Observed	Simulated				Observed	Simulated				Observed	Simulated			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2030	3675	3759	3985	3865	3965	4035	4126	4056	4256	4532	5990	6032	6326	5998	6125	3275	3364	3589	3412	3012
2050	3657	3689	3789	3986	3512	4035	3965	3989	4129	4026	5990	5899	5910	5980	6012	3275	3280	3282	3280	3270
2070	3657	3365	3965	3678	3548	4035	3233	3233	3713	3713	5990	3345	3345	3347	3347	3275	3276	3270	3280	3270

three tagged hills. Phenological stages such as tillering, panicle initiation, heading, 50% flowering, 100% flowering, soft dough, hard dough, physiological maturity were visually noted. Yield and yield attributes were recorded at the time of harvest.

The climatic projection for Ganjam district in four RCPs scenarios (2.6, 4.5, 6.0, 8.5) are done for rainfall, Tmax, Tmin, radiation using MarkSim GCM-DSSAT weather file generator (Jones & Thornton 2000, Jones *et al*., 2002) working off a 30 arc-second climate surface derived from WorldClim.

The climatic projection for Ganjam district in four RCPs scenarios (2.6,4.5,6.0,8.5) are done for rainfall, Tmax, Tmin, radiation using MarkSim GCM-DSSAT weather file generator (Jones & Thornton 2000, Jones *et al*., 2002) working off a 30 arc-second climate surface derived from WorldClim.

RESULTS AND DISCUSSION

For the year 2030, RCP 2.0, 4.5, 6.0, 8.5 scenarios are likely to cause an increase in seasonal maximum temperature, seasonal minimum temperature but the increase in maximum temperature is slightly more than the minimum temperature, seasonal rainfall shows increasing trend up to 2050 but decreasing afterwards in all four RCPs scenarios. Solar radiation also shows an increasing trend in RCPs 2.6, 4.5, 6.0 and 8.5 from present scenario. The grain yield of Hasanta is likely to increase under four scenarios in 2030 but to decrease in yield by 2050 in and in case of 2070 the yield is likely to decrease in early and late planting but shows no significant change for mid season planting under all RCPs scenarios. It was also found that production potential of Hasanta was higher than other varieties. In mid season planting, all the varieties performed well whereas their performance was poor in earliest and latest transplanting dates.

CONCLUSION

The RCP projection of climate change showed an increase in seasonal maximum temperature, minimum temperature, increase in solar radiation and rain fall increases up to 2050 but it shows a declining trend in 2070. It was also found that production potential of Hasanta was higher in mid-season planting, whereas the performance was poor in earliest and latest transplanting dates.

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INFLUENCE OF LONG-TERM USE OF MANURES AND FERTILIZERS ON YIELD TREND, NUTRIENT CHANGE AND SUSTAINABLE YIELD INDEX IN RICE-RICE CROPPING SEQUENCE OF ASSAM

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Long-term fertilizer experiments were conducted across the country at fixed site in different agro-ecological zones (AEZ) and on important cropping system to monitor the changes in yield responses in soil environments which are influenced by continuous use of organic and inorganic sources of nutrients. This is a classical experiment which intends to formulate the rational use of fertilizers (Janzen, 1995). Further, this type of experiments also studies the dynamics of soil and crop productivity in different cropping system and relates to management for identifying the constraints that affect the sustainability of a given production system.

This paper intends to focus on the crop yield in different years of cultivation as influenced by continuous use of manures and fertilizers and its sustainability issue reflected by change in soil fertility parameters.

METHOLOGY

This long-term experiment was initiated during the year 1989 at RARS, AAU, Titabor (26°352 E and 96°102 N) and is being continued till date. There are 14 treatments in total which are as follows: T1 (Control), T2 (100%PK), T3 (100%NK), T4 (100%NP), T5 (100%NPK+Zn), T6 (100%NPK+Zn+FYM @ 5t/ha), T7 (100%NPK-Zn), T8 (100%NPK-S), T9 (100%N+50%PK), T10 (50%NPK), T11 (50%NPK+50% GM-N), T12 (50%NPK+50% FYM-N), T13 (50%NPK+25%GM-N+25%FYM-N), T14 (FYM@10t/ha). Here, 100%NPK implies the fertilizer dose of 40kg N: 20 kg P_2O_5 and 20 kg K_2O /ha. The plot size of individual treatment was 10m x10m with 4 replication using RBD. All the standard package of practices was followed during experimentation. Some of the selective treatments were considered for their study namely: T1 (Control),T5 (100%NPK+Zn), T6 (100%NPK+Zn+FYM @ 5t/ha), T13 (50%NPK+25%GM-N+25%FYM-N), T14 (FYM@10t/ha).

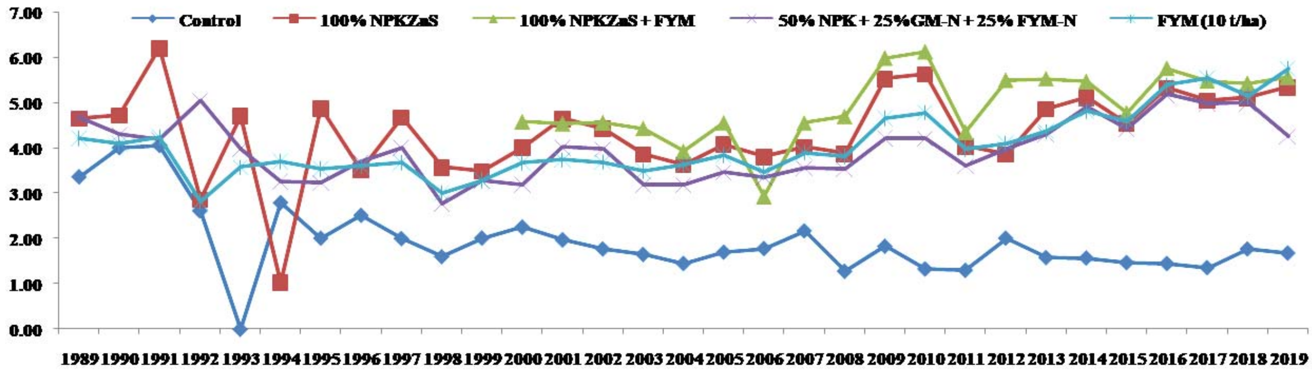

Fig 1: Crop productivity in different years of cultivation

Further, the available yield data in terms of sustainable yield index (SYI) and its relationship with some of the important soil fertility parameters like organic-C, available P_2O_5 and available K_2O status of the soil were done. The data in terms of sustainable yield index (SYI) was worked out by using the following formula (Singh *et.al*, 1990)

SYI= (A-Y) x 100/ Ymax

Where,

A= Mean yield of a particular treatment

Y= Standard deviation of the treatment and

Ymax= The maximum yield recorded in different years and treatments.

RESULTS

Crop productivity in different years of cultivation as depicted in the Fig 1 showed variation over the years both in Rabi and Kharif season. The range of yield between the years varies significantly. Regarding grain yield during 2019, it ranged from 2.02 (control) to 4.94 t/ha (RDF+FYM) with an average increase of 14%. Linear trends of productivity over the years with current RDF indicated positive growth rate in this acid alluvial soils (35 kg/ha/yr). Additional dose of FYM @ 5 t/ha along with RDF improved the growth rate substantially with 79 kg /ha/yr. During rabi also, RDF+5 t/ha FYM recorded maximum mean grain yield (4.34 t/ha) and this treatment recorded growth rate of 54kg/ha/yr. Higher growth rate was observed in Kharif season compared to rabi season. The trends in mean grain yield over 31 years (1989-2019) in kharif and rabi were assessed by filling to linear function using actual yield.

Changes in soil fertility compared to initial values:

The organic carbon content increased in all the aforesaid treatments compared to initial values. The organic carbon content at Titabor decreased in control but increased in RDF, RDF+FYM and in other integrated treatments. Maximum increase was in sole application of FYM. In case of the available P, there was a buildup of P content in all treatments except on initial control plots. In case of available K, there was decrease in control plot and increase in other treatments.

Sustainability of soil and crop productivity

Sustainability refers to the maintenance or enhancement of productivity on a long term basis through integrated land management. In order to monitor the changes in soil fertility and yield response due to continuous application of plant nutrients from fertilizers and organic manures, an attempt has been made to evaluate the yield data in terms of sustainable yield index (SYI) and its relationship with some of the important soil fertility parameters like organic carbon,

Table 1: Influence of continuous use of manures and fertilizer on sustainable yield index (SYI) and percent of nutrient change in selective treatment of rice-rice cropping sequence

Treatments	SYI (%) 2012	Mean yield (kg/ha)	SYI (%) 2019	Mean yield (kg/ha)	% changes SOC	Avg. P	Avg. K
Control	22.0	2156	18.60	2020	-41.1	-14.2	-40.6
100% NPK+Zn	50.4	4161	4235	4320	28.4	16.7.	10.4
100% NPK+Zn+FYM	60.7	4600	6465	4900	60	198	12.5
50%NPK+25%GM-N +25% FYM-N	51.3	3700	56.04	3950	57.9	187	15.10
FYM 10 t/ha	53.5	3750	57.10	4010	65.4	194	16.8
Correlation (r)	0.90		0.94		0.78	0.82	0.78
Regression coefficient (R^2)	0.82		0.88		0.60	0.69	0.62

available P_2O_5 and available K_2O (Table 1). In this rice-rice cropping system the SYI for rice range from 20.60- 64.65% during the current year (2019) and during the year of 2012 SYI values varied from 22 to 60.7%. The treatment receiving 100% NPK+Zn+FYM maintained the highest SYI values. Besides there was increase of organic carbon content in treatments receiving organic manures as well as in INM treatments. In case of K, the buildup of available K was marginal.

Correlation of SYI values with available soil data on changes in nutrient status indicated a moderate to high level of relationship between SYI and the soil parameters. Most of the variations in SYI could be related to changes in soil carbon P and K availability in this acid alluvial soil. The percent of change in soil organic carbon varied from 28.4 to 68.4%, for P it ranged between 167 to 194%. While for K the change was marginal ie., 10.4 to 16.8%.

CONCLUSION

From the results of 31st year of study on longterm soil fertility management in rice-rice sequence indicated superior performance of RDF+FYM over the other treatments in both wet and dry season. In general, INM and other organic treatments alone resulted in improvement of soil fertility parameters which reflected positively in rice productivity and SYI as an when compared between the year 2012 and 2019.

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ENERGY AND CARBON FOOTPRINT FROM DIFFERENT RICE CULTIVATION METHODS IN EASTERN INDIA

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Changing climate is a major threat to agriculture affecting food security and livelihood of millions of people across the world. The conventional agriculture is believed to be contributing to the greenhouse gases emission and also reducing carbon stored in the soil and in vegetation. Climate-smart agricultural (CSA) technologies are now propagated due to their effect on enhancing productivity and resilience to climatic stresses, and reducing the greenhouse gas emissions. Agricultural systems are producers and consumers of energy. Large quantities of non-commercial and commercial energies are used in agriculture in direct and indirect forms, such as mineral fertilizers, biocides, machinery, diesel fuel, electricity, manure, animals and seeds. Sustainable development can be achieved by increasing the energy efficiency which reduces the cost of cultivation as well as environmental pollution. Keeping the above facts in mind, following objectives were set for this study (1) to evaluateenergy input-output balance and energy efficiency of different CSA cultivation practices (2) to analyse carbon footprint of different CSA cultivation practices

METHODOLOGY

The experimental site for this project is situated in Cuttack district of Odisha. The district lies on the east coast of India in the state of Odishabetween 20° 3'N and 85° 49' 60'' E, and has an average elevation of 36 m above sea level. Rice is the predominant crop grown during the wet season, and is cultivated in both rainfed and irrigated areas. The frequency of dry and wet spells is very high in the region, causing floods and droughts in alternate years or even in the same year. Abhayapur and Badakusunpur of Tangi-Choudwar block; Sundarda and Juanga of Niali block were selected a study sites based on frequency of occurance of the abiotic stresses. Tangi block was having upland and medium land situations whereas Niali comprised of lowland ecologies. CSA technologies tested includes crop establishment practices of rice in *kharif* season which are 1. Dry-Direct Seeded Rice (D-DSR) ,Wet-Direct Seeded Rice (W-DSR), Mechanical Transplanting (MT) and compared against the farmers practice (FP) of manual transplanting. All the data about fertilizers, seeds, plant protection chemicals, fuels, human labor, and machinery power were recorded in different cultivation practices right from sowing to harvesting of crops and input and output energy of individual cropping systems were calculated (Devasenapathy et al., 2009). Similarly, the carbon footprint was also calculated. Statistical analysis has also been done of different crop establishment practices implemented across the villages.

RESULT AND DISCUSSIONS

Among different treatment, grain yield was significantly higher in D-DSR, W-DSR and MT compared to FP. The grain yield in MT and D-DSR was at par whereas W-DSR recorded significantly higher yield compared to both D-DSR and MT but energy productivity was significantly higher in case of D-DSR compared to all other treatments. The treatment D-DSR was significantly lower than W-DSR & Mechanical transplanting in terms of energy input, but in energy output both were at par with each other. The treatments D-DSR, W-DSR and MT were having significantly higher energy output compared to farmer's practice (FP). If we compare between the different rice ecologies, Sundarda&Juanga with medium and lowland rice ecologies were having significantly higher energy output compared with Abhaypur and Badakusunpurhaving upland and medium land ecologies

Table1 Grain yield, carbon and energy footprint from different rice cultivation methods

Treatement/Village		Grain yield (t/ha)	Carbon footprint		Energy budgeting		
			Carbon input (kg Ce/ ha)	Carbon Yield (t/ha)	Energy Output (MJ/ha)	Net energy Return (MJ/ ha)	Energy productivity (EP)
Treatment	D-DSR	4.7[b]	1319.34[a]	4.20[a]	90355.91[a]	76994.96[a]	0.35[a]
	W-DSR	5.1[a]	1563.26[b]	4.61[a]	99106.27[a]	82538.66[b]	0.31[b]
	MT	4.6[b]	1681.53[c]	4.16[a]	89426.62[a]	69578.97[bc]	0.24[c]
	FP	3.6[c]	1411.91[d]	3.26[b]	70099.56[b]	55295.55[d]	0.25[c]
Village (Ecology)	Badakusunpur	4.4[c]	1409.73[a]	3.67[a]	78930.49[a]	64916.73[a]	0.29[a]
	Abhaypur	4.2[c]	1437.38[a]	3.60[a]	77408.53[a]	61489.59[a]	0.26[a]
	Sundarda	5.9[a]	1480.10[ab]	4.67[b]	100556.6[b]	84562.82[b]	0.33[a]
	Juanga	4.7[b]	1637.2[c]	3.9[c]	84022.8[c]	65531.4[c]	0.2[a]

DDSR: Dry direct seeded rice; WDSR: Wet direct seeded rice; MT: Mechanical transplanting; FP: Farmer's practice

respectively. Net energy return in case of W-DSR was significantly higher (6.7%) than D-DSR. The net energy in D-DSR was significantly higher than that in MT & FP. Energy ratio in D-DSR was significantly higher that all the three studied treatments i.e. W-DSR, MT and FP. Averaged over all treatments, the villages in Niali block (Sundarda and Juanga) with lowland ecologies recorded significantly higher in grain yield and energy output compared with that in Tangi block (Badakusunpur&Abhaypur) with mostly upland and medium lands. Energy ratio was significantly higher in villages from Niali block compared with villages in Tangi, whereas highest energy ratio was recorded in Sundarda. Similarly, in case of carbon input, all the studied treatments across the villages were significantly different from each other whereas carbon yield (t/ha) in FP was significantly lower than other treatments. Similar to energy ratio, Sundarda and Juanga with lowland ecology recorded significantly higher carbon yield compared with Badakusunpur&Abhaypur. Lal et al. (2020) also observed that D-DSR method of rice cultivation saved the significant amount of energy (18.4%) as compared to transplanted rice, in which major energy-saving was in diesel (160%), machinery and labor (66%) making dry-DSR more energy profitable system with minor yield penalty which will be sustainable in long-run.

CONCLUSION

Out of all the methods implemented in the villages,itwas found that D-DSR was more efficient in terms of energy and carbon output parameters. W-DSR was found to be energy efficient and carbon saving technology compared with conventional farmers practice particularly in lowland ecology. These practices are energy efficient and help in conserving and maintaining carbon buildup in the soil. These climate smart practices should be disseminated for conserving energy, enhancing crop yield & income of small holder farmers under climatic stress conditions.

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IRC/TM-2/PP-91

PERFORMANCE EVALUATION OF PADDY TRANSPLANTER IN NORTH COASTAL DISTRICTS OF ANDHRA PRADESH

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Rice is the major crop grown in the North coastal districts of Andhra Pradesh consisting of Srikakulam,Vizianagaram and Visakhapatnam districts. In North coastal zone, rice is cultivated traditionally by manual transplanting which requires a lot of labour besides involving drudgery. Also, the scarcity of labour especially during paddy season adversely affects the timely agricultural operations thereby reducing the crop yield. The manual transplanting takes about 250-300 man hours/ha which is roughly about 25 per cent of the total labor requirement of the crop (Behera et al., 2009). The mechanical transplanting of paddy has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity (Behera and varsheny, 2003). Hence, the present study was conducted to test the performance evaluation of walk behind four row paddy transplanter in the soils of North Coastal region of Andhra Pradesh.

METHODOLOGY

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle, Visakhapatnam district, Andhra Pradesh (160 30'N latitude and 180 20' E longitude) to study the economic feasibility of four row paddy transplanter for transplanting of paddy. For this Kubota paddy transplanter (Model NSP -4W) was used and compared with manual transplanting. The seed rate, labour requirement, total time required to cover an acre of land and the fuel consumption during mechanical transplanting were recorded. Mechanical transplanting requires a special type of seedlings raised on mat type nursery. The mat nursery was raised in plastic trays using paddy variety RGL 2538. Soil free of stones, clods etc was mixed with equal proportions of vermicompost and sand and placed in the trays and soaked paddy was spread uniformly in a thin layer either manually or mechanically. After 15 days, the seedlings mats were fed to the mechanical four row paddy transplanter. In case of manual transplanting method, paddy nursery was raised following the recommended package of practices. Transplanting was done using mechanical transplanter by running lengthwise of the field on the puddled and leveled land with water level in the field kept up to 2 cm only to avoid floating of the seedlings.

RESULTS

The performance evaluation of walking behind four row paddy transplanter is evaluated. The field capacity of the transplanter was found to be 0.13 ha/h at 75 percent field efficiency. The economic analysis of paddy transplanter over manual transplanting was given in Table 2. The cost of transplanting the paddy nursery using mechanical transplanter was Rs. 1240 whereas it was Rs 4800 with manual method of transplanting at wage rate of Rs. 300 and Rs.200 per day for men and women respectively. Under mechanical planting of paddy, there is saving of 74% on labour cost, 40% saving in seed rate and 50% saving in time compared

Table 1.Technical Specifications of Paddy Transplanter

Model	Kubota
Number of rows	4
Row spacing (cm)	30
Hill space (cm)	14
Seedling type	Mat type
Seedling height (cm)	20

Table 2. Economics of Manual vis-s-vis Mechanical Transplanting (per acre)

S.No	Method of Planting					
	Manual			Mechanical		
	Men	Women	Total	Men	Women	Total
Labour (Number)	6	15	21	3	1	
Amount incurred on labour (Rs)	1800	3000	4800	900	200	1100
Fuel cost (Rs)			-			140
Total cost of operation			4800			1240
Saving in labour cost (%)	-		-			74
Seed requirement (kg)			25			15
Saving in seed quantity (%)						40
Time taken for planting (hr)	6			3		
Saving in time (%)						50
Yield (t/ha)	4.72			4.98		

*Labour charges for men Rs.300/- and women Rs.200/- per day of 6 hours

to manual transplanting. Hence, mechanical transplanting of paddy using walk behind transplanter was found to be the most promising option for the soils of North coastal districts of Andhra Pradesh as it saves labour costs, minimizes stress and drudgery, ensures timely transplanting compared to manual transplanting.

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IRC/TM-2/PP-92

EFFECT OF LIQUID BIOFERTILIZERS ON NITROGEN FRACTIONS UNDER DIRECT SOWN RICE

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Unlike conventionally transplanted rice, direct sown rice avoids puddling, transplanting and standing water at initial growth stages. At present, 26 and 28 per cent of rice is direct-seeded in south Asia and in India, respectively (Rao *et al.* 2007).Nitrogen is the key element among the major nutrients which governs the plant growth and nutrition and most of the Indian soils are low in this nutrient. Most of nitrogen present in organic form and partly of it in inorganic form. The efficiency of nitrogen fertilizer utilization by rice is directly related to the chemical transformations of nitrogen after the application in soil (Fageria *et al.*, 2003). Liquid biofertilizer (LBF) facilitates a long survival of the organism by providing suitable medium which is sufficient for the entire crop. In this view, a field experiment was conducted during *kharif*, 2019-20 at Agricultural College Farm, Bapatla with the following objectives

1. To study the effect of liquid biofertilizers *viz. Azospirillum*, PSB and KRB on growth, yield and quality of direct sown rice.

2. To study the effect of liquid biofertilizers *viz. Azospirillum*, PSB and KRB on N, P and K transformations in soil.

3. To study the effect of liquid biofertilizers *viz.Azospirillum*, PSB and KRB on biological properties of soil.

METHODOLOGY

The experiment was laid out in RBD with eleven treatments replicated thrice. The experimental soil was sandy clay loam in texture, slightly alkaline in nature (7.74). The soil was medium in organic carbon (0.50%), low in available nitrogen(261 kg ha^{-1}), medium in available phosphorus (46 kg ha^{-1}), high in available potassium (389 kg ha^{-1}) and sufficient in all available divalent cationic micronutrients. The treatments comprised of T_1 – Control, T_2 -100% Recommended Dose of Fertilizer (RDF), T_3 - 100% RDF +*Azospirillum*, T_4 - 100% RDF + *Azospirillum* + ria (PSB), T_5 - 100% RDF + *Azospirillum* + Potassium releasing bacteria (KRB), T_6 -100% RD + *Azospirillum* +PSB+ KRB, T_7 - 75% RDF + *Azospirillum*, T_8 - 75% RDF + *Azospirillum* +PSB, T_9 - 75% RDF + *Azospirillum* + KRB, T_{10} - 75%RDF + *Azospirillum* +PSB+ KRB, T_{11} - *Azospirillum* +PSB+ KRB. The soil samples were estimated for nitrogen fractions *viz.*,ammonical, nitrate and total nitrogen as per outline given by Page *et al.*, (1982) and available nitrogen estimated as outlined by Subbaiah and Asija (1956).

RESULTS

Available nitrogen

Among the different treatments the highest available nitrogen content (299, 290 and 278 kg ha^{-1}) were recorded in the treatment T_6 (100% RDF + *Azospirillum* + PSB+ KRB) followed by T_4 (100% RDF +*Azospirillum* + PSB) (297, 285 and 276 kg ha^{-1}respectively) at maximum tillering panicle initiation and harvest stages of crop growth.and these were on par with each other. The lowest available nitrogen content (235, 221 and 210 kg ha^{-1}) was recorded in the treatment T_1 (Control).In present study, the combined application of inorganic fertilizers and biofertilizers increased the available nitrogen in soil. The *Azospirillum* will excrete ammonia in the rhizosphere in the presence of root exudates. Similar results were found by Narula & Gupta (1986) and Wu *et al.*,(2005).

Ammonical nitrogen

Among the different treatments, the highest ammonical nitrogen content (45.87, 43.16 and 41.78 mg kg^{-1}) were recorded in the treatment T_6 (100% RDF + *Azospirillum* + PSB+ KRB) followed by T_4 (100% RDF +*Azospirillum* + PSB) (45.59, 42.75 and 41.11 mg kg^{-1} respectively)at maximum tillering panicle initiation and harvest stages of crop growth and these were on par with each other. The lowest ammonical nitrogen content (32.65, 30.98 and 29.74 mg kg^{-1}) were recorded in the treatment T_1 (Control) This could be attributed that by utilizing inorganic fertilizers with the biofertilizers like *Azopspirillum* which has the capacity to fix the free nitrogen that present in the soil to ammonical form there was an increase in ammonical nitrogen. Same resultswere observed bySubbaiah*et al.*,(2013) and Faujdar and Mahendrasharma (2014).

Nitrate nitrogen

The highest nitrate nitrogen content (24.89, 22.90 and 21.32 mg kg^{-1}) was recorded in the treatment T_6 (100% RDF + *Azospirillum* + PSB+ KRB) followed by T_5 (100% RDF +*Azospirillum* + KRB) (24.76, 22.56 and 20.69 mg kg^{-1} respectively) respectively) at maximum tillering, panicle initiation and harvest stages of crop growth.and these were on par with each other. The lowest nitrate nitrogen content (12.14, 11.67 and 10.86 mg kg^{-1}) was recorded in the treatment T_1 (Control). Similar results were observed by Subbaiah*et al.,(*2013) and Faujdar and Mahendrasharma (2014).

CONCLUSIONS

The results of the experiment indicated that higher nitrogen fractions were recorded with the application of 100% rdf+ *azospirillum*+ psb+ krb (t_6) which was on par with t_5 (100% rdf + *azospirillum*+ krb) and t_4 (100% rdf + *azospirillum*+ psb). The treatments that received 75% rdf along with liquid biofertilizers were on par with 100% rdf along with liquid biofertilizers in direct sown rice.

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