Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.5605

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (4):** 1388-1396 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Effect of Eco-Friendly Modified Urea Materials on Growth and Yield of Aerobic and Puddled Rice in Semi-Aerid Tropical Region of Sutheren India

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Received: 28.07.2017 | Revised: 7.08.2017 | Accepted: 8.08.2017

ABSTRACT

A field experiment was conducted during kharif season of 2013 to find out the effect of eco-friendly modified urea materialsunder aerobic and puddled rice cultivation on growth andyield of rice at College Farm, PJTSAU. The results revealed with application of natural nitrification inhibitors (NNI)significantly improved plant growth parameters and inturn grain yield over prilled urea (PU)in both methods of rice cultivation.Puddled rice significantly registered higher leaf area index and drymatter accumulation than aerobic rice at different growth stages with application of NNI as compared with PU.27.5% higher grain yield was recorded in cultivation of puddled rice (5.04 t ha^{-1}) than aerobic rice cultivation (4.51 t ha^{-1}). Significantly grain yield increased by26, 38 and 25% with the application of KCU, VCU and NCCU, respectively than PUin both methods of rice cultivation. Theeco-friendly modified urea materials (NNI)used in present study was equally good and one can choose based upon availability of farmersunder both methods of aerobic and puddled condition.

Key words: *Aerobic rice, Puddled rice, Natural Nitrification Inhibitors, Growth, yield.*

INTRODUCTION

Rice (*Oryza sativa* L.) is the major crop in India as well as in Telangana state. Modern productionagriculture requires efficient, sustainable and environmentally sound management practices. Nitrogen (N) is the most limiting factor in crop production. Hence, application of N fertilizer results in higher biomass yields and protein content in plant tissue[1]. Nitrogen is essential for rice, and usually it is the most yield-limiting nutrient in irrigated rice production around the world[2]. Urea, when applied to soil is hydrolyzed by urease to from NH_4^+ -Nand this is subsequently converted to nitrate (NO_3^- N) during nitrification either by the nitrifying bacteria in aerobic soil condition or denitrifying bacteria under anaerobic soil conditions[3].

Cite this article: Ravi, P., Jayasree, G., Pratibha, G. and Rao, V. P., Effect of Eco-Friendly Modified Urea Materials on Growth and Yield of Aerobic and Puddled Rice in Semi-Aerid Tropical Region of Sutheren India, *Int. J. Pure App. Biosci.* **5(4):** 1388-1396 (2017). doi: http://dx.doi.org/10.18782/2320-7051.5605

Apart from N_2O losses the applied N is lost either through denitrification, runoff, volatilization, immobilization and leaching. These N losses not only cause large economical and resource losses but also results in very serious environmental pollution[4]. Hence,minimizing nitrogen losses is thus a priority area of research to prevent atmosphere and groundwater pollution besides saving in the fertilizer cost to the farmers. In order to reduce these losses of nitrogen and increase its nitrogen use efficiency, one of the mechanisms is to apply ureawith coating of natural nitrification inhibitors. A number of nitrification inhibitors have been developed and used for slowing the urea hydrolysis and bacterial oxidation of ammonium (NH_4^+) over nitrate (NO_3^-) in soil. This affects the persistence of applied N in the soil as well as plant N metabolism and N nutrition. The chemical nitrification inhibitors are available in the soil but since they are expensive, not available in the market and cases environmental pollution. Hence, the natural plant based nitrification inhibitors can be exploited as they are cheap, eco-friendly[5] .Therefore this study deals with the response of Natural Nitrification Inhibitors on growth and yield of aerobic and puddle rice.

MATERIALS AND METHODS

Details of locationand treatments of the experiment

A field experiment was conducted during *kharif* season of 2013 at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana state, India (17°19' N and 78°23' E at 542.3 m above mean sea level). It comes under Southern Telangana agro-climatic zone of Telangana. According to Troll's climatic classification, it falls under semi-arid tropics (SAT). The soil is sandy clay loam in texture with 34.89% clay, 13.04% silt and 52.06% sand. The soil was slightly alkaline in reaction (7.95) with low electrical conductivity (1.19 dsm^{-1}),medium in organic carbon content (0.48%), low in available N (238.34 kg ha^{-1}), mediumin available P_2O_5 (18.21 kg ha^{-1}) and high in available K_2O (480.61 kg ha^{-1}).Rice variety MTU-1010 was cultivated in split plot design with puddled and aerobic methods as main treatments and subplots treatments were Control *i.e.,* without addition of any N fertilizer; Nitrogen in the form of prilled urea (PU); Neem coated urea (NCCU); Karanj coated urea (KCU); *Vitexnegundo* leaf extract coated urea (VCU). The treatments were replicated thrice and the plot size was 6 x 4 m. Recommended dose of 60 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O were commonly applied for all the treatments. Half of the N (60 kg ha^{-1}) was applied as basal dose. Ferrous sulphate @ 0.5 % was sprayed in aerobic rice as per normal package of practice.

Preparation of different Coated Urea Fertilizers with using of Eco-Friendly Modified Urea Materials or Natural Nitrification Inhibitors

Neem Cake Coated Urea (NCCU)

A solution containing 5 g of coal tar in 10 ml of kerosene was prepared and mixed with 1 kg urea and kept aside for 30 minutes for proper soaking of urea. Then 250 g of finely powdered and sieved neem cake was mixed with urea[6].

Karanj Coated Urea (KCU)

For preparing KCU, 85 ml of castor oil was poured on 1 kg urea and kept aside for soaking for a period of 24 hours. To this 250 g of finely powdered and sieved Karanj cake was added and mixed till uniform coating over urea was obtained[7].

Vitexnegundo Leaf Coated Urea (VCU)

For preparing VCU, 85 ml of castor oil was poured on 1 kg urea and kept aside for soaking for a period of 24 hours. To this 250 g of shade dried leaf powder of *Vitexnegundo* was added and mixed till uniform coating over urea was obtained[8].

GROWTH PARAMETERS OF RICE

Leaf area index (LAI)

Leaf area was estimated on two plants in each plot at maximum tillering, panicle initiation and milky stage of crop respectively. The area of total leaves was measured by using LI-3100 Leaf area meter (LICOR-Lincoln, Nebraska, USA) and expressed in cm^2. Leaf area index was calculated by using the formula as proposed by Watson[9].

$$LAI = \frac{\text{Leaf area}}{\text{Unit ground area}}$$

Dry matter production (g ha^{-1}):

Dry matter of the plant was recorded at fortnightly interval by uprooting of 5 hills in the third row of every plot. Component parts were separated after shade drying, the samples were subjected to 60^0C temperatures in a hot air oven till constant weight were obtained and expressed as g ha^{-1}.

RESULTS AND DISCUSSION

Response of natural nitrification inhibitors on growth parameters of aerobic and puddle rice at different growth stages

Leaf Area Index (LAI)

The leaf area of rice is a factor closely related to grain production because the total leaf area at flowering greatly affects the amount of photosynthates available to the panicle [10]. The leaf area index of rice was significantly influenced by the methods of rice cultivation, nitrification inhibitors but was not significantly influenced by interaction of methods of rice cultivation and natural nitrification inhibitors (Fig. 1).Leaf area index of the rice crop increased up to maximum tillering stage, thereafter the rate of increase was marginal up to panicle initiation stage and decreased towards harvest as evident from the decrease in leaf area due to leaf senescence.Mean over methods of rice cultivation, puddled rice recorded significantly higher leaf area index (2.50, 4.52 and 4.43) than aerobic rice (2.18, 3.42 and 3.28) at maximum tillering, panicle initiation and milky stages, respectively. Lower LAI values in aerobic method were correlated with reduced total biomass and grain yield at the end of the growing season. The results were in corroboration with the results of [11]. [12] reported that transplanted rice (3.5) had higher LAI than direct seeded rice (3.2) at flowering stage, as observed in present study. Among the eco-friendly modified urea materials (*i.e.*, NCCU, KCU and VCU), application of KCU recorded significantly higher leaf area index (4.51, 4.36) followed by VCU (4.03, 3.91) and NCCU (3.93, 3.81) at panicle initiation and milky stage, respectively. However, at maximum tillering stage PU application recorded significantly higher leaf area index (2.71) than natural NNI. Similar results were observed by [13] and [14].

Dry mater production (g m^{-2})

The dry matter production was significantly influenced by methods of rice cultivation, nitrification inhibitors and their interaction at different crop growth stages *viz.*, maximum tillering, panicle initiation and milky stage (Table 1). However, at harvest dry matter production was not significantly influenced by methods of rice cultivation where as NNI significantly improved the dry matter production. In all the treatments a linear increase in dry biomass was observed from maximum tillering to milky stage and attained maximum at maturity. Similar results were observed by [10]. Average over methods of rice cultivation, puddled rice has registered significantly higher dry matter production (207.10, 484.13 and 687.44 g m^{-2}) than the aerobic rice (187.33, 436.86 and 640.72) at maximum tillering, panicle initiation and milky stage, respectively. Similar increase dry matter production in puddled rice was reported by [11].

Among the NNI, application of KCU significantly improved dry matter production (543.47, 780.38 and 1158.01 g m^{-2}) over the other treatments at panicle initiation, milky stage and at harvest respectively, followed by

VUC (503.05, 732.29 and 1076.55 g m^{-2}) and NCCU (501.94, 730.31 and 1083.51 g m^{-2}). Among all the treatments control (without nitrogen) has recorded lowest dry matter production at all crop growth stages. Whereas initially at maximum tillering stage PU recorded higher dry matter (234.36 g m^{-2}) than NNI. But nitrification inhibitors produced significantly more dry matter at later stage of crop growth *i.e.*, panicle initiation, milky stage and at harvest as compared to PU and control. This could be due the sustained availability of nitrogen due to slow release of nitrogen from coated urea [15]. The increase in dry matter production with application of nitrification inhibitors was reported by [13]. [14] also reported higher dry matter production with PU than neem cake coated urea (1.9 t ha^{-1}) and pusaneem golden urea (1.8 t ha^{-1}) at 30 DAT, while at 60 DAT, more dry matter was recorded with application of PNGU (7.2 t ha^{-1}) and NCU (7.0 t ha^{-1}) as compared to PU (6.4 t ha^{-1}).[16] reported that neem cake had nitrification inhibiting effect on urea-N for a period of two weeks and this helped in supplying N as ammonical form to the crop for a longer period due to continuous availability of N in the soil. Application of KCU under puddled rice recorded significantly higher dry matter production (563.31, 816.05 and 1216.30 g m^{-2}) at panicle initiation, milky stage and at harvest, respectively than other combinations.

Effect of methods of rice cultivation and nitrification inhibitors on grain, straw yield and harvest index of rice

Grain yield (tonnes ha^{-1})

Methods of rice cultivation and nitrification inhibitors significantly influenced grain yield (Table 2). Among methods of rice cultivation, significantly higher grain yield was recorded in puddled cultivation of rice (5.04 t ha^{-1}) as compared to aerobic cultivation (4.51 t ha^{-1}). Grain yield of rice under aerobic cultivation was recorded 27.5% lower than puddled rice cultivation. The higher yield in puddled rice can be attributed to higher leaf area and biomass which might have helped in increasing the yields than aerobic rice. This may be attributed to three main reasons. In general water stress under aerobic condition led to reduced N demand of the crop. More N_2O losses due to drastic changes in redox potentials which resulted in N losses via nitrification - denitrification and also N volatilization which was evident from 39.4% more N_2O more emission under aerobic rice than in puddled rice and hence N use efficiency was also low under aerobic rice than puddled. The potentiality of direct sown rice in obtaining slightly lower or comparable yields as that of transplanted rice was reported by [17] and [18]. The grain yield of rice was higher at saturated soil moisture content than in intermittent wetting and drying. Whereas, grain yield of upland rice was on par with that of lowland rice was recorded in Bangladesh [19]. 33.3% Lower yields in direct seeded rice (4.3 t ha^{-1}) than transplanted rice (5.6 t ha^{-1}) are due to higher panicle sterility due to moisture stress and higher weed growth ([20] and [21]). [22] reported 32 and 22% lower yield under aerobic conditions over puddled rice in the dry and wet seasons, respectively. The yield difference between aerobic and flooded rice ranged from 8 to 69% depending on the number of seasons that aerobic rice has been continuously grown, dry and wet seasons, respectively [23]. Grain yield of rice under aerobic treatment was 27.5% lower than flooded condition. The yield difference between aerobic (average yield, 1.67 t ha^{-1}) and flooded rice (average yield, 2.31 t ha^{-1}) ranged from 18.4 to 37.8% [24]. Mean over methods of rice cultivation (aerobic and puddled), indicated that application of KCU recorded significantly higher grain yield (5.91 t ha^{-1}) followed by VCU (5.4 t ha^{-1}) and NCCU (5.38 t ha^{-1}) than PU (4.27 t ha^{-1}). In terms of percentage increase it was 38.4, 26.0 and 25.0% with application of KCU, NCCU and VCU respectively, over PU. Irrespective of method of cultivation 25 to 38.4% increase in grain yield was realised by the application eco-friendly modified urea materials over PU application. This suggests that application of natural nitrification inhibitors not only improved the grain yield but also eco-friendly (mitigation of greenhouse gas emissions), cheap and easily available.In aerobic rice, application of PU showed significantly higher yield (4.02 t ha^{-1}) than the plots without nitrogen fertilizer application (2.87 t ha^{-1}) and significantly lower yield than all nitrification inhibitors. Significant difference among the NNI was not observed though highest grain yield was recorded in KCU (5.48 t ha^{-1}) followed by VCU (5.13 t ha^{-1}) and NCCU (5.08 t ha^{-1}). The percentage increase in grain yield was 36.3, 27.6 and 26.4 with the application of KCU, VCU and NCCU, respectively over PU. The results suggest that the three nitrification inhibitors used in the present study are equally good and one can choose any one of them depending upon the availability of plant materials under aerobic condition.In puddled rice, significant difference could not be observed among nitrification inhibitors. Application of PU recorded significantly higher grain yield (4.52 t ha^{-1}) than control (3.09 t ha^{-1}) and significantly lower yield than nitrification inhibitors. Application of KCU registered significantly higher grain yield (6.35 t ha^{-1}) than NCCU (5.68) and VCU (5.55 t ha^{-1}) which were on par with each other. An increase in grain yield percentage of 40.5, 25.7 and 22.8 was revealed by application of KCU, NCCU and VCU, respectively over PU. The results were in line with the results of [15] who found that more grain yield was recorded in NCU (5.2 t ha^{-1}) and PNGU (5.3 t ha^{-1}) than PU (4.8 t ha^{-1}).The increase in grain yield due to NNI may be attributed to the reduced dissolved inorganic nitrogen losses like leaching and less nitrous oxide emissions due to sustained nitrogen release in coated fertilizers. [14] reported that increase in grain yield in rice was observed by application of neem bitter coated urea (9.53%) and pusaneem golden urea (15.29%) over PU. This sustained availability of nitrogen helped in higher nutrient content which helped in increasing biomass and yield attributes which increase rice grain yield ([25], [26] and [27]). The results in the present study have evidently proved the advantage of natural nitrification inhibitors in increasing grain yield of rice. The possibility of reduction of dissolved nitrogen leaching was due to slow release of nitrates by nitrification inhibitors. Leaching and gaseous loss of nitrogen are greatly controlled by net rate of microbial nitrification and these process was delayed by nitrification inhibitors.Neem cake has the potential to slow down the nitrification process by reducing the microbial oxidation of NH_4^+ -N to NO_3^- -N due to the prescence of meliacins *ie.,* epinimbin, nimbin, salannin, nimin and nimbidin, which are active ingredients present in neem seed have been reported to be responsible for the inhibition of nitrification process ([3] and [27]). Whereas the nitrification inhibition in karanjin was observed for a longer period of approximately 6 weeks, and was due to prescence of Karanjin, a furanoflavonoid (3-methoxy furano-2, 3, 7, 8-flavone, $C_{18}H_{12}O_4$) as reported by [5]. With regard to *Vitexnegundo* leaf powder coated urea, there was significant nitrification inhibition up to 60 days. The slow release of NH_4^+-N in VCU which might be due to the effect of vitex leaf coatings on population of nitrifiers and inhibition or reduction of the ongoing nitrification mechanism. The essential and volatile oils present in this vitex leaf has antibacterial activity due to the prescence of phenols, terpenoids, flavonoids, anthraquinones and carotenoids ([26]; [29] and [30]).

Straw yield (tonnes ha^{-1})

In contrast to grain yield, straw yield was not significantly influenced by methods of rice cultivation but affected by nitrification inhibitors and their interaction (Table 2). However, a significant difference in straw yield was not observed due to methods of rice cultivation. Application of NNI resulted in significantly higher straw yield than over control as well as PU. The results were in line with the results of [21]; [24]; [19] and [17] who found improvement in straw yield with nitrification inhibitors compared to PU application in rice.In aerobic rice, application of PU (4.34 t ha^{-1}) showed significantly higher straw yield than the control (3.28 t ha^{-1}) and significantly lower yield than all the nitrification inhibitors. Significant difference with in the nitrification inhibitors were not observed though highest straw yield was recorded with KCU application (5.52 t ha^{-1}) followed by VCU (5.41t ha^{-1}) and NCCU (5.18 t ha^{-1}).In puddled rice, application of PU recorded significantly higher straw yield (4.64 t ha^{-1}) than control (3.48 t ha^{-1}) and however, significantly lower straw yield than nitrification inhibitors. Among nitrification inhibitors, KCU recorded significantly higher straw yield (5.82 t ha^{-1}) followed by NCCU (5.59 t ha^{-1}) and VCU (5.48 t ha^{-1}) as compared to PU treated plots. The percentage increase in straw yield due to nitrification inhibitors is 23.73% in aerobic rice and 21.3% in puddled rice thanapplication of PU. The per cent increase in straw yield of KCU applied plots was 25.4 over PU plots and the per cent increase was 20.5% in VCU and 18.1% NCCU. The increasing straw yield due to nitrification inhibitors may be attributed to the reduced dissolved inorganic nitrogen leaching and nitrous oxide emissions and the latter was discussed in 4.1.7.3. The results were in support of [25]; [15]; [31] and [26].

Harvest Index

The perusal of harvest index (Table 2) showed that methods of rice cultivation, nitrification inhibitors and their interaction had no significant impact on harvest index of the rice, however, under methods of rice cultivation, puddled rice recorded the higher harvest index (49.85) than the aerobic rice (48.64). Among nitrification inhibitors, KCU recorded highest harvest index (51.04) followed by VCU (49.96) and NCCU (49.54) were at par with each other.

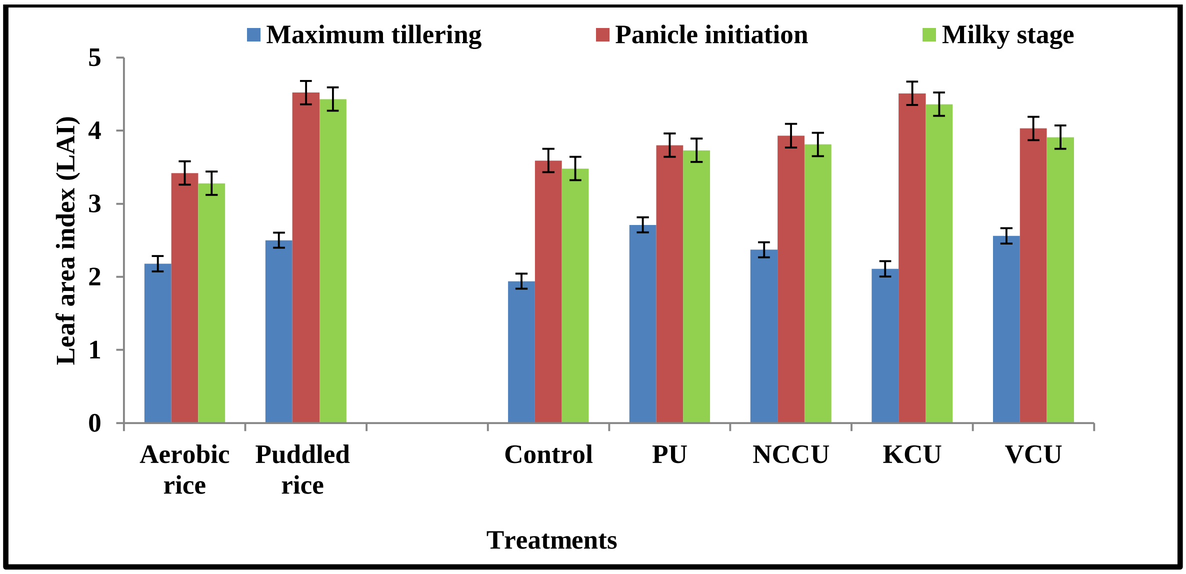

Fig. 1: Impact of cultivation methods and nitrification inhibitors on LAI of aerobic and puddled rice. Vertical bars represent the standard error

Table 1: Influence of methods of cultivation and nitrification inhibitors on dry mater production (g m^{-2}) of rice at different crop growth stages

Nitrification inhibitors	Dry matter production (g m^{-2})											
	Maximum tillering			Panicle initiation			Milky stage			Harvest		
	Aerobic rice	Puddled rice	Mean	Aerobic rice	Puddled rice	Mean	Aerobic rice	Puddled rice	Mean	Aerobic rice	Puddled rice	Mean
Control	159.53	186.13	**172.83**	326.32	361.6	**343.96**	479.51	484.54	**482.02**	614	614.2	**635.24**
PU	212.75	255.97	**234.36**	376.71	443.34	**410.03**	559.8	631.02	**595.41**	835.6	915.1	**875.38**
NCCU	198.4	239.43	**218.92**	485.46	520.63	**503.05**	714.61	746.01	**730.31**	1064	1103	**1083.5**
KCU	168.3	208.44	**188.37**	523.64	563.31	**543.47**	744.71	816.05	**780.38**	1100	1216	**1158**
VCU	197.66	245.52	**221.59**	472.15	531.74	**501.94**	705	759.59	**732.29**	1026	1127	**1076.6**
Mean	**187.33**	**207.1**	**207.21**	**436.86**	**484.13**	**460.49**	**640.72**	**687.44**	**664.08**	**927.9**	**1004.0**	**965.74**
	SEm ±	**CD (p=0.05)**		**SEm ±**	**CD (p=0.05)**		**SEm ±**	**CD (p=0.05)**		**SEm ±**	**CD (p=0.05)**	
M	0.61	3.7		3.15	19.16		1.13	6.87		19.81	NS	
S	2.29	6.85		3.82	11.46		3	9.01		30.01	89.97	
M x S	14.78	46.23		28.85	113.02		19.82	64.39		214.1	NS	

Table 2: Grain yield, straw yield and harvest index of rice as influenced by methods of rice cultivation and eco-friendly modified urea materials

Treatments	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index		
	Aerobic rice	Puddled rice	Mean	Aerobic rice	Puddled rice	Mean	Aerobic rice	Puddled rice	Mean
Control	2.87	3.09	**2.98**	3.28	3.48	**3.38**	47.15	47.12	**47.14**
PU	4.02	4.52	**4.27**	4.34	4.64	**4.49**	48.05	49.04	**48.54**
NCCU	5.08	5.68	**5.38**	5.18	5.59	**5.39**	48.68	50.4	**49.54**
KCU	5.48	6.35	**5.91**	5.52	5.82	**5.67**	49.82	52.27	**51.04**
VCU	5.13	5.55	**5.34**	5.41	5.48	**5.44**	49.51	50.42	**49.96**
Mean	**4.51**	**5.04**	**4.78**	**4.75**	**5.00**	**4.87**	**48.64**	**49.85**	**49.25**
	SEm ±	**CD (p=0.05)**		**SEm ±**	**CD (p=0.05)**		**SEm±**	**CD (p=0.05)**	
M	0.08	0.52		0.14	NS		0.37	NS	
S	0.21	0.64		0.22	0.65		1.99	NS	
M x S	1.42	NS		1.53	5.6		12.72	NS	

CONCLUSIONS

Significant improvement in LAI and dry biomass were observed under puddled rice than in aerobic rice. Application of eco-friendly modified materials significantly improved plant growth parameters and in turn grain yield than PU applied plots under both cultivation methods of puddle rice and aerobic rice.The results suggest that eco-friendly modified urea materials used in present study were equally good and one can choose based upon availability under cultivation of aerobic and puddled rice.Under limited water resources, one can choose aerobic rice with addition of eco-friendly modified urea materialswhich resulted more yield than puddled rice with PU application. Hence, water can be saved without losing grain yield and also reduces global warming potential.

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