Effect of Balanced Nutrient Approaches on Yield, Quality and Economics of Different Rice Varieties Under Direct Seeded Upland Condition in Eastern India

Bhagyashree Phogat[1*]; Seema Sepat[2]; Ram Swaroop Bana[3]; Kajal Arora[4]; Narendra Kumar Pareek[5]

[1-4]Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India;
[1,5]Division of Agronomy, Swami Keshwanand Rajasthan Agriculture University, College of Agriculture, Bikaner-334006;
[2]ICAR –Indian Institute of Maize Research PAU Campus, Ludhiana, Punjab,141027
*Corresponding Author

Received:- 02 November 2024/ Revised:- 10 November 2024/ Accepted:- 20 November 2024/ Published: 30-11-2024

Abstract— *A field experiment was conducted at Central Rain-fed Upland Rice Research Station (CRURRS), Hazaribagh, research station in Jharkhand with the objective to determine better nutrient management practices for zero till upland rice and their effect on yield and nutrient use efficiency. The experiment was laid out in split-plot design with three replications having three rice cultivar Vandana, Anjali and CR Dhan 40 in main plot and four nutrient management practices [soil test fertilizer recommendation meter (STFR), integrated nutrient management (INM), soil test crop response equation (STCR) and recommended dose of fertilizers (RDF)] in sub-plot. Results indicated that CR Dhan 40 recorded higher leaf area index, dry matter accumulation and number of effective tillers at 90 DAS compared to Vandana and Anjali. However, Vandana was better in terms of plant height of rice. Among nutrient management practices, STFR recorded significantly higher plant height, LAI and tillers per plant compared to other practices. Whereas STFR and INM were equally good in terms of DMA of rice at 90 DAS. CR Dhan 40 recorded the highest grain (3.85 t/ha), straw yield (6.22 t/ha), net returns (47.59×10^3 ₹/ha) and B:C ratio (1.98) followed by Anjali and Vandana. STFR enhanced the grain yield by 47% compared to RDF. STFR based NPK recorded the highest net returns (38.20×10^3 ₹/ha) followed by other NM practices. CR Dhan 40 had higher milling (60.3%) and head rice recovery (51.5%) compared to Anjali and Vandana. Whereas STFR based NPK application was better in hulling, milling and head rice recovery. STFR and INM recorded higher values of protein yield followed by STCR. Therefore, based on research findings, it can be concluded that rice cultivar "CR Dhan 40" with STFR and INM based fertilization may enhance the productivity and profitability of upland rice in the Eastern regions of India.*

Keywords— Zero Tillage, INM, Soil Test Crop Response equation, Varieties.

I. INTRODUCTION

Rice (*Oryza sativa* L.) is the second most important grain crop in India and cultivated in 43.38 million hectares (mha), with an annual production of 104.32 million tons (mt)[1]. It is a staple food for the 60 percent population of India. To address the growing demand for the food, feed and industrial sectors, as well as to access the export markets, rice production would still need to increase by additional 143 mt to cope with 40% world population and to raise average food consumption to 3130 kcal/person/day by 2050 [1]. In Asia, rice is commonly grown with wet tillage land preparation (puddled soil) by transplanting seedlings which adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers, and forming hard-pans at shallow depths [2]. Alongside, it is considered one of the major sources of methane (CH_4) emissions and accounts for 10-20% (50-100 Tg/year) of total global annual CH_4 emissions [3]. Puddling and transplanting require large amount of water and labour, both of which are becoming increasingly scarce and expensive. Upland rice grown in rain-fed, naturally well-drained soils, without surface water accumulation could be a better under direct seeded rice method.

Dry–seeding of rice with subsequent aerobic soil conditions eliminates the need of puddling and subsequent submerged soil conditions, thus reducing the overall water demand and providing opportunities for water and labour savings[2]. Direct seeding enables the sowing of rice without any heavy tillage operation under conservation agriculture. Conservation agriculture (CA) has been widely promoted in rice-wheat cropping system to sustain the productivity and soil health in a long run[4]. CA is a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance (*i.e.* zero tillage), and diversification of plant species. ZT rice has several advantages such as it involves low fuel consumption in land preparation, reduced labour costs, improved soil health and quality and conserves soil moisture with higher water use efficiency (WUE) and NUE of about 15-20% along with higher yield.

Rice grown under upland condition is generally low in nutrient availability. In addition, the imbalance and indiscriminate use of fertilizer is one of the most important factors for low productivity and nutrient use efficiency in rice crop [5].The development of early maturing varieties and improved nutrient management techniques along with integrated weed management methods have encouraged many farmers in the Philippines, Thailand and India to switch from Transplanted Rice (TPR) to Direct Seeded Rice (DSR) [6].Conjunctive use of organic manure along with fertilizer has been proved to be an efficient source of nutrient supply. Organic residue recycling is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Returning residues like green manure to the soil is necessary for maintaining soil organic matter, which is important for favorable soil structure, soil water retention and soil microflora and fauna activities. To enhance farm profitability under different soil-climate conditions, it is necessary to determine the optimum fertilizer doses and appropriate method of fertilizer application on the basis of soil test and crop response studies [7]. In order to achieve the higher and sustained yield over long period by maintaining the soil fertility level and preventing the environmental contamination, it is very much necessary to maintain balance between nutrient requirement of crops and nutrient reserves in soil. Managing the location specific variability in nutrient supply is a key strategy to overcome the current mismatch of fertilizer rates and crop nutrient demand in upland rice environments. The soil test crop response (STCR) approach is a novel approach wherein fertilizer recommendations are made by considering nutrient use efficiency (NUE) of the crop and nutrient contribution of soil. STCR approach could be a strategy to enhance rice productivity (15-35%) and NUE in rice–wheat cropping system [7]. Besides this, soil test fertilizer recommendation (STFR) meter can give nutrient-specific fertilizer requirement to crop. It addresses the site-specific nutrient management (SSNM) principles and utilizes information of the growing environment to provide balanced fertilizer recommendations for rice which are tailored for a particular location, cropping system, rice ecology, season, and farmer resource availability [8]. Despite the huge vast scope of growing rice under zero-till upland conditions in Jharkhand, with fertilizer recommendations by STFR meter and STCR approach, very limited research has been done for evaluating these management practices. Therefore, it need to be tested in various ecologies for sustainable production in Jharkhand region. With respect to it, the current study is planned on the topic entitled "Developing nutrient management options for different rice cultivars under zero-till upland conditions**.**

II. MATERIAL AND METHODS

A field experiment was conducted during *kharif* season, 2018 at Mashipirhi farm, Central Rainfed Upland Rice Research Institute, Hazaribagh, Jharkhand is characterized by humid and sub-humid tropical climate. The average temperature of Hazaribagh was 23.7 °C and 1274 mm respectively during crop duration. The average rainfall of the district is 783 mm of which 700 mm of rainfall is precipitated during the months of June to September (Figure1). The experimental field was under rice-fallow cropping system during the last five years. The initial soil physical characteristics reveals the mechanical composition (Hydrometer method Bouyocos 1962 [9]) as red with textural class as Sandy clay loam. Moisture at 1/3 and 15 bar tension is 28.72 and 14.87 % respectively (Pressure plate apparatus, Richards and Weaver, 1943 [10]). Bulk density (0–15 cm layer) is 1.5 (Mg/m^3). Soil chemical characteristics were as pH 5.2 (Piper, 1966 [11]), EC is 0.29 (m mhos cm^{-1}) organic carbon 0.39 % (Walkley and Black, 1934 [12]), available-N 220 kg/ha (Subbiah & Asija, 1956 [13]), available-P 15.6 kg/ha (Bray's No.1 Method [14]) and available-K 420 kg/ha (Hanway and Heidel, 1952 [15]) were recorded as per the procedures mentioned.

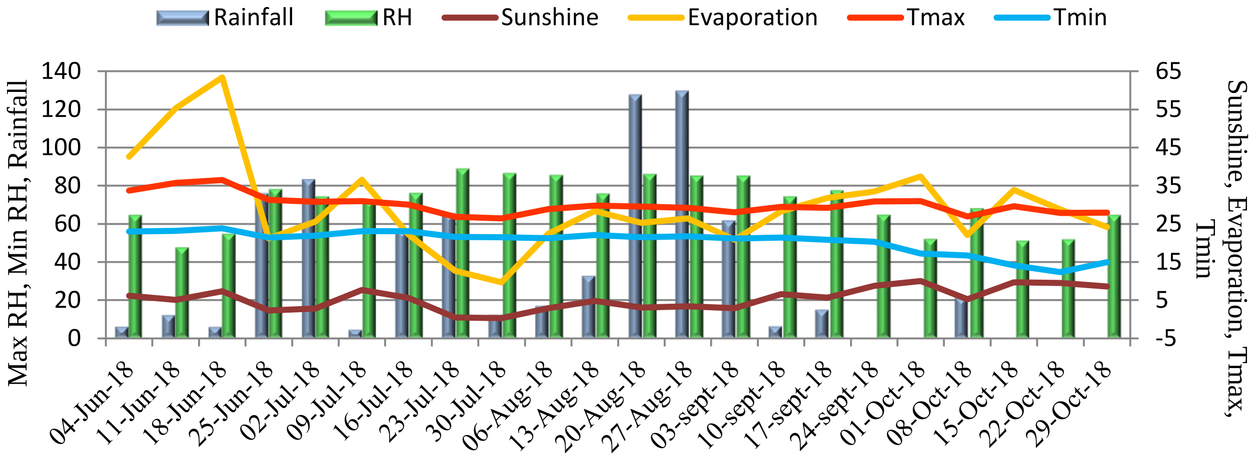


FIGURE 1: Agro–meteorological parameters recorded during *kharif* 2018

2.1 Description of imposed treatments:

The experiment was laid out in split-plot design with three replications having three rice cultivars Vandana, Anjali and CR Dhan 40 in main plots and four nutrient management practices soil test fertilizer recommendation meter (STFR), integrated nutrient management (INM), soil-test crop response equation (STCR) and recommended dose of fertilizers (RDF) in sub-plots. Treatments were allocated randomly on the experimental units. The experimental field was kept under zero-till conditions. The sowing was done with the help of seed drill at row spacing of 22.5 cm using seed 50 kg/ ha.

2.2 Soil test crop response (STCR):

Soil test crop response (STCR) equations for soil test-based fertilizer were as

- FN= 6.14T-0.55SN (FN= Fertilizer N), (T=Targeted yield), (SN= Soil available N)
- FP_2O_5= 2.83T-2.16SP_2O_5 (FP_2O_5 = Fertilizer P), (SP_2O_5 = Soil available P_2O_5)
- FK_2O= 3.73T- 0.70SK_2O (FK_2O= Fertilizer K), (SK_2O= Soil available K_2O) for N, P and K respectively. Based on above equations Fertilizer dose required calculated and analyzed further.

TABLE 1
SOIL TEST-BASED ANALYSIS FOR SOIL TEST CROP RESPONSE (STCR) EQUATION

STCR general equation for Jharkhand	Variety	Targeted yield (t/ha)	Soil test value of nutrient (kg/ha)	Recommended dose (kg/ha)
FN= 6.14T-0.55SN	Vandana Anjali CR Dhan 40	3.5 3.5 3.5	220	87
FK_2O=3.73T-0.70SK_2O	Vandana Anjali CR Dhan 40	3.5 3.5 3.5	420	Not required
FP_2O_5=2.83T-2.16SP_2O_5	Vandana Anjali CR Dhan 40	3.5 3.5 3.5	15.6	44

2.3 Soil test-based fertilizer recommendation (STFR) meter:

Plot-wise soil samples were collected before sowing of crop from 0–15 cm and 0-30 depth of soil and evaluated. Based on analysis, the STFR meter recommended the amount of fertilizers DAP, MOP, urea as 98, 15 and 217 kg/ha along with manure (6.5 t/ha) and lime (6 t/ha) according to soil pH, soil organic carbon and available NPK of the site.

One third of nitrogen (i.e. 29, 34, 27, 23 kg/ha from STCR, STFR, 50% RDF + 50% Organics, and RDF respectively are applied through urea, full dose of phosphorus through diammonium phosphate (DAP) and potassium through muriate of potash

(MOP) were applied as basal at the time of sowing in all the treatments. Further nitrogen was top dressed in splits at one third dose at 30 & 60 DAS respectively. Lime application was done 15 days before sowing of the crop.

2.4 Recording growth parameters and grain yield:

Five plants randomly selected were tagged permanently in each plot for recording plant height, total number of tillers and effective tillers. The number of effective tillers were counted over meter square area at crop harvest stage. Plants from one square meter length from second row onwards were uprooted and sun dried for 2-3 days followed by drying in oven at 60-65 ± 2°C for 24 hours to get dry matter accumulation in grams/m^2. Leaf area meter (LI-COR Model LI-3100) was used to record leaf area (cm^2) then leaf area index of selected plants was calculated by using the leaf area Index formula. Grain yield was calculated from the area by leaving 2 border rows on each side and reported at 12.5% moisture content. Straw yield was obtained by subtracting grain yield from respective total biomass yield (grain + straw). Crude protein content in rice grain was calculated by multiplying N concentration of grain with a coefficient factor 5.95 and multiplied with grain yield to get protein yield. Sun dried paddy samples weighing 100 g were hulled in a mini "Satake Rice Mill", weight of brown rice was recorded and hulling percentage was calculated. The hulled brown grains of rice were passed through Satake Rice Whitening and Caking Machine for 2 minutes. Weight of polished rice was obtained and milling percentage was computed. The milled rice was sieved to separate whole kernels from broken grains to record head rice recovery in percentage.

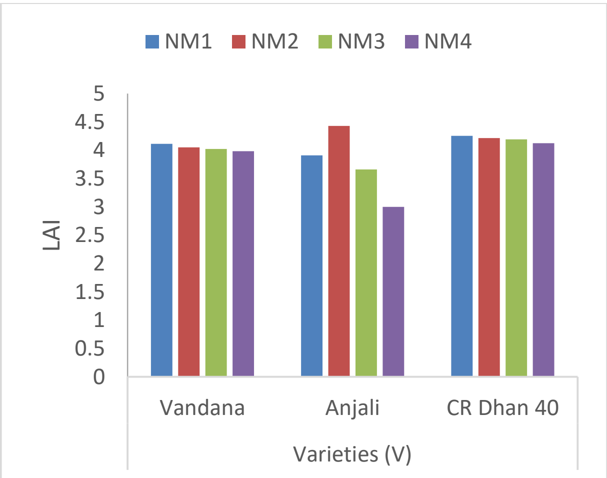
III. RESULT AND DISCUSSION

3.1 Growth parameters:

3.1.1 Plant height, LAI, Dry-matter accumulation and Tiller production:

The growth parameters viz. plant height, LAI, dry-matter accumulation and tiller production were significantly influenced by different varieties at 90 DAS (Table 2). Vandana recorded higher plant height as compared to Anjali and CR Dhan 40 at 90 DAS. However, variety CR Dhan 40 recorded the highest number of tillers (344) followed by Anjali (308) and Vandana (282). Similarly CR Dhan 40 have highest DMA (1125 g/m^2) and LAI (3.87) among all the varieties whereas among Anjali and Vandana were found to be at par. The plant varieties show a difference in plant height due to genetic makeup. The plant height and grain yield of different cultivars were inversely related due to more erectness, which lead to more height in Vandana [16].

Among nutrient management (NM) practices, STFR recorded the highest plant height (105 cm) LAI (3.92) and tillers/m2 (331) followed by STCR and INM dose. RDF performed significantly poor in these growth parameters. However, STFR (1074 g/m^2) and INM (1062 g/m^2) were equally good in respect to the DMA followed by STCR and RDF. While, STCR (1046 g/m^2) was also at par with INM (1039 g/m^2). NPK application was balanced and as per the demand in STFR treatment which might have enhanced nutrient uptake from the soil by cultivars which lead to higher growth of rice plants[17].



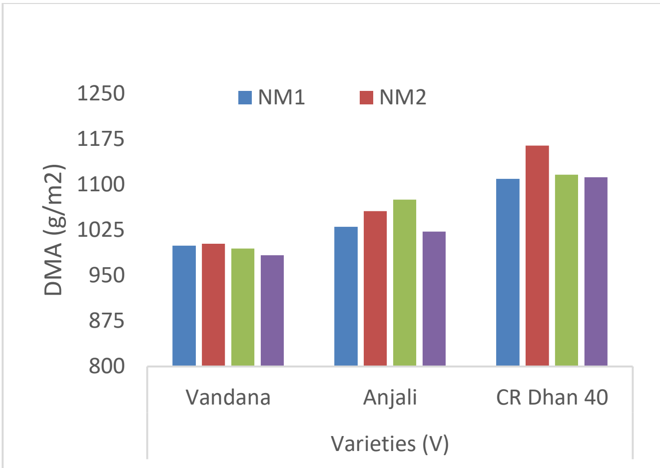


FIGURE 2: Interaction effect of rice varieties and nutrient management on DMA and LAI of direct-seeded upland rice
(NM 1: STCR), (NM 2: STFR), (NM 3: INM), (NM 4: RDF)

Interaction results for Table 2 and Figure 2 shows that fertilizer application based on NM3 in the varieties Vandana and CR Dhan 40 decreased the dry matter accumulation by 4.1% and 3.2% respectively than NM2, whereas the fertilizer application based on NM3 in variety Anjali increased the dry mater accumulation by 9 %. Similarly, NM4 in the variety Vandana decreased the DMA by 6.6% than NM3, whereas it was decreased by 13.2% in the CR Dhan 40. In terms of LAI adoption of NM2 in the variety Vandana and CR Dhan 40 decreased the leaf area index by 1.46 % and 0.94% respectively than adoption of NM1, whereas the adoption of NM1 in variety Anjali increased the leaf area index by 13.2% than NM2. Similarly, the adoption of NM4 in the variety Vandana decreased the LAI by 0.99 % than NM3, whereas it was decreased by 1.67 % in the CR Dhan 40. It might have happened due to uniform rainfall solubilized lime in soil which increased the availability of nutrients according to the plant requirement [17].

TABLE 2
EFFECT OF RICE VARIETIES AND NUTRIENT MANAGEMENT ON GROWTH AND QUALITY PARAMETERS OF DIRECT-SEEDED UPLAND RICE

Treatment	Hulling (%)	Milling (%)	Head rice recovery (%)	Crude protein (%)	At 90 DAS			
					Plant height (cm)	DMA (g/m^2)	LAI	Plant tiller/m^2
Varieties (V)								
Vandana	62.5	53.5	48.9	7.2	104	994	3.6	282
Anjali	64.3	54.8	47.9	7.3	97.2	1046	3.4	308
CR Dhan 40	69.5	60.3	51.5	7.7	96.3	1125	3.9	344
SEm±	1.84	1.04	1.27	0.07	1.4	15.8	0.1	1.88
CD (P=0.05)	7.21	4.07	4.97	0.27	5.56	62.2	0.2	7.36
Nutrient management (NM)								
STCR	64.8	55.7	48.3	7.43	99.3	1046	3.8	311
STFR	69.7	59.4	50.8	7.73	105	1074	3.9	331
INM	68.8	56.6	49.2	7.69	96.2	1062	3.6	320
RDF	59	52.8	45.3	6.84	93.3	1039	3.2	284
SEm±	0.89	0.72	0.31	0.1	0.9	7.58	0.1	1.28
CD (P=0.05)	2.64	2.13	0.92	0.3	2.7	22.5	0.2	3.8
V×NM	NS	NS	NS	NS	NS	S	S	S

3.1.2 Yield:

Grain and straw yield were significantly influenced by different rice varieties (Table 3). CR Dhan 40 recorded the highest grain (3.85 t/ha) and straw (6.22 t/ha) following Anjali and Vandana which remained at par. The variation in yield of CR Dhan 40 might be due to more number of effective tillers and dry matter production. Further, higher weed competitiveness and higher yield potential of CR Dhan 40 contributed towards higher yield.

3.1.3 Harvest index:

The harvest index was not influenced with different rice varieties (Table 3). In different nutrient management practices, STFR based NPK dose, INM and STCR remained at par with each other in terms of harvest index i.e. (40.5 %, 39.5 % and 38.9 %) respectively. RDF practice recorded the lowest harvest index values (34.6%).

TABLE 3
EFFECT OF RICE VARIETIES AND NUTRIENT MANAGEMENT ON YIELD AND ECONOMICS OF DIRECT-SEEDED UPLAND RICE

Treatment	Yield (t/ha)				Cost of Cultivation (×10³ ₹/ha)	Net Return (×10³ ₹/ha)	Net B:C
	Grain	Straw	Protein yield (kg/ha)	HI (%)			
Varieties(V)							
Vandana	3.20	5.61	230	38.2	23.67	29.25	1.24
Anjali	3.40	5.56	248	37.8	23.67	29.83	1.26
CR Dhan 40	3.85	6.22	309	38.8	24.07	47.59	1.98
SEm±	0.10	0.11	4.54	0.65	-	0.08	0.04
CD (P=0.05)	0.41	0.46	17.79	NS	-	0.31	0.15
Nutrient management (NM)							
STCR	3.50	5.80	274	38.9	24.00	36.56	1.52
STFR	4.02	6.06	309	40.5	26.07	38.20	1.46
INM	3.68	6.05	301	39.5	24.13	36.75	1.52
RDF	2.73	5.30	205	34.6	21.00	30.72	1.46
SEm±	0.13	0.13	1.35	1.32	-	0.10	0.68
CD (P=0.05)	0.38	0.38	4.00	3.9	-	0.29	NS
Interactions (C×NM)	NS	NS	NS	NS			

3.1.4 Quality parameters:

Rice varieties had non-significant impact on hulling percentage. However milling and head rice recovery was significantly affected by different rice varieties. CR Dhan 40 had higher milling (60.3%) and head rice recovery (51.5%) compared to Anjali and Vandana. Whereas Anjali and Vandana remained on par in both all quality parameters. The main reason could be the genetic characteristics and genetic yield potential of the different varieties. Further, a higher strength of aleurone layer in rice grain in CR Dhan 40 might be the reason for higher head rice recovery [20,21].

Nutrient management (NM) practices shown significant influence on the hulling, milling and head rice recovery percentage (Table 2). In different nutrient management practices, STFR and INM based NPK dose remained at par with respect to hulling followed by STCR and RDF. In terms of milling percentage, STFR based fertilization recorded the highest values (59.4%) followed by INM (56.6%), STCR based fertilization (55.7%) and RDF practice (52.8%). STFR based NPK dose had highest head rice recovery. Moreover, INM and STCR were on par and INM was found to have lowest percent head rice recovery values. The optimum and balanced dose of NPK fertilization and application of fertilizers based on soil nutrient status with various nutrient management options in site specific manner might be the reason for increased quality parameters [22]. Furthermore, mobilization of nutrients might be the reason for higher protein yield [23].

3.1.5 Protein concentration and yield:

The protein concentration and yield were significantly influenced with different rice varieties (Table 2). The rice variety CR Dhan 40 recorded the highest protein concentration and yield followed by Anjali and Vandana. In different nutrient management practices, STFR based NPK dose, INM based NPK dose, STCR based fertilization and RDF practices remained at par with protein concentration. However, STFR based fertilization and INM recorded higher values of protein yield followed by STCR and RDF.

3.1.6 Economics:

Cost of cultivation variation is not large in different rice varieties (Table 3). The rice variety CR Dhan 40 costs the highest cultivation charges (24.07×10^3 ₹/ha) followed by Vandana and Anjali. Among nutrient management (NM) practices, STFR based NPK dose recorded the highest cost of cultivation (26.07×10^3 ₹/ha), while lowest in RDF practice. The net return and benefit: cost (B:C) were significantly varied with different rice varieties (Table 3). The rice variety CR Dhan 40 recorded the highest net returns (47.59 ×10^3 ₹/ha) and Net B:C ratio (1.98) followed by Vandana and Anjali. The higher grain and straw yield of CR Dhan 40 might have contributed to higher gross and net return. Nutrient management (NM) practices shown non-significant impact on the B:C ratio results. However net return was significantly influenced by different nutrient management practices. STFR based NPK dose recorded the highest net returns (38.20 ×10^3 ₹/ha) followed by other NM practices. INM based NPK dose remained at par with STCR based fertilization in terms of net returns followed by RDF practice.

IV. CONCLUSION

The different rice cultivars and various nutrient management practices significantly influenced the growth parameters, yield attributes and yield of upland rice under rain-fed conditions in Jharkhand. The rice cultivar CR Dhan 40 recorded vigrous growth, yield attributes and yield followed by Anjali and Vandana. STFR based NPK fertilization recorded the highest growth parameters, yield attributes and yield which remained at par with INM (50 % RDF+ 50% Organics) and STCR (87 kg N, 44 kg P_2O_5, 0 K + 1.5 t/ha lime) followed by RDF application (70 kg N, 40 kg P_2O_5, 20 kg K_2O).

Based on the research findings, it can be concluded that rice cultivar CR Dhan 40 was the best cultivar in terms of yield and economics. STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t/ha lime) and INM (50% RDF+50% organics) NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha] were found optimum in terms of yield, economics and use efficiency of applied NPK. Therefore, based on research findings, it can be concluded that rice cultivar “CR Dhan 40” with STFR and INM based fertilization may enhance the productivity and profitability of upland rice in the Eastern regions of India.

AUTHOR CONTRIBUTIONS

Conceptualization, S.S. , R. B. and N.K.P., methodology, B.S.P and K.A.; software, B.S.P.,.; Validation B.P.,. and K.A.; formal analysis, B.P. and S.S; investigation, B.P. and R.B..; resources, S.S.; data curation, B.S.P and K.A.; writing-B.S.P.; writing-review and editing, S.S.; and N.K.P. visualization. S.S.; supervision, S.S. and N.K.P.; project administration, S.S.; funding acquisition S.S.;. All authors have read and agreed to the published version of the manuscript.

FUNDING

The research was supported by ICAR-IARI Pusa.

INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable

DATA AVAILABILITY STATEMENT

All the data are included within the manuscript and supplementary table.

ACKNOWLEDGEMENT

The first author is grateful to ICAR for providing a Junior Research Fellowship for M.Sc. Program.

CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

[1] Borah, D., Ghosh, M., Ghosh, D.C. and Gohain, T. 2016. Integrated Nutrient management in rainfed upland rice in the North-Eastern region of India. *Agriculture research* **5**(3):252–260.

[2] FAO, Food and Agriculture Organization, 2017. FAOSTAT database, 2017. FAO, Rome.

[3] Sharma, P., Tripathi, R.P., Singh, S. and Kumar, R. 2004. Effects of tillage on soil physical properties and crop performance under rice-wheat system. *Journal of the Indian Society of Soil Science* **52**:12–16.

[4] IPCC. 2001. Climate change 2001: The scientific basis. Contribution of working group 1 to the third assessment report of the intergovernmental panel on climate change (J. T. Houghton).

[5] FAO. Food and Agriculture Organization, 2012. Available online at:
http://www.fao. org/ag/ca/doc/FLYER_Conservation_Agriculture.pdf (verified 23 January 2012).

[6] Borah, D., Ghosh, M., Ghosh, D.C. and Gohain, T. 2016. Integrated Nutrient management in rainfed upland rice in the North-Eastern region of India. *Agriculture research* **5**(3):252–260

[7] Farooq, M., Siddique, K.H.M., Rehman, H., Aziz, T., Lee. D.J. and Wahid, A. 2011. Rice direct seeding: Experiences, challenges and opportunities. *Soil and Tillage Research* **111**: 87–98.

[8] Sahu, V., Mishra, V.N and Sahu, P.K. 2017. Soil test based Fertilizer recommendation for targeted yield of crops. *International Journal of Chemical Studies* **5**(5):1298–1303.

[9] IARI. 2015. Annual Report. Division of Soil Science & Agricultural Chemistry, IARI, New Delhi-12. P-87.

[10] Bouyoucos, C.J., 1962. Hydrometer method improved for making particle size analysis of soil. *Agronomy Journal,* **54**: 464-465.

[11] Richards, L.A. and Weaver, L.R., 1943. Fifteen-atmosphere percentage as related to the permanent wilting percentage. *Soil Science,* **56** (5): 331-340.

[12] Piper, C.S., 1966. Soil and Plant Analysis Hans Publishers Bombay. *Asia Edition.*

[13] Walkley, A.J. and Black, I.A., 1934. An examination of the Degtjareff method for determination of soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science,* **37** :29-38.

[14] Subbiah, B.V. and Asija, G.L., 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science,* **25**(8): 259-260.

[15] Bray, R. H. and Kurtz, L. T. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil science* **59** (1): 39-46.

[16] Hanway, J.J. and Heidel, H., 1952. Soil analysis methods as used in Iowa State College Soil Testing Laboratory. Bulletin 57, Iowa State College of Agriculture, Iowa, USA **2**(1) : 131.

[17] Singh, Y. V., Singh, K. K., and Sharma, S. K. 2013. Influence of crop nutrition on grain yield, seed quality and water productivity under two rice cultivation systems. *Rice Science* **20**(2):129-138.

[18] Kumar, G.R., Konde, N.M., Tamgadge, D.B., Jadhao, S.D. and Paslawar, A.N. 2018. Effect of STCR equation on soil characters and nutrient availability in cotton under rain-fed condition in vertisols. *International Journal of Chemical studies* **6**(3):723–726.

[19] Mahajan, G., Ramesha, M. S., and Chauhan, B. S. 2014. Response of rice genotypes to weed competition in dry direct-seeded rice in India. *The Scientific World Journal* **1** :140-148.

[20] Ekeleme, F., Omoigui, L. O., Oikeh, S. O., Chikoye, D. and Tegbaru, A. 2010. Response of upland rice cultivars to nitrogen fertilizer in the savannas of Nigeria. *Agronomy journal* **102**(1):333-339.

[21] Haq, M.T., Sattar M.A., Hossain M.M. and M. M. Hasan. 2002. Effects of Fertilizers and Pesticides on growth and yield of Rice. *Journal of Biological Sciences* **2***:84-88.*

[22] Jagtap, D. N., Mahadkar, U. V. And Chavan, S. A. 2017. Response of rice varieties to different sowing windows under Konkan conditions. *Agricultural Science Digest* **37**(1):78-80.

[23] Chaubay, A.K., Parganiha, O.P. and Paraye, P.M. 2015. Effect of STCR technology for Targeted yield in rice. *Plant Archives* **15**(1):267–269.

[24] Vijayakumar, M., Santhi, R. and Jalaluddin, S.M. 2017. Refinement of fertilizer recommendation based on soil Test Crop Response Technology for rice under system of Rice intensification. *Journal of applied and Natural Science* **9**(2):855–859.