International Journal of Plant & Soil Science

Volume 35, Issue 14, Page 321-329, 2023; Article no.IJPSS.101095
ISSN: 2320-7035

Assessment of Soil Physico-chemical Properties in Direct Seeded Rice and Succeeding Lentil Crop under Integrated Nitrogen and Weed Management Practices in Eastern Uttar Pradesh, India

Shiv Poojan Yadav [a++*], Ramesh Kumar Singh [a#] and Harsita Nayak [a++]

[a] *Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, India.*

Authors' contributions

This work was carried out in collaboration among all authors. Author SPY designed the study, performed the statistical analysis, wrote the first draft of the manuscript and managed the analyses of the study. Author RKS wrote the protocol. Author HN managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i143053

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/101095

Original Research Article

Received: 01/04/2023
Accepted: 03/06/2023
Published: 06/06/2023

[++] *Research Scholar;*
[#] *Professor;*
**Corresponding author: E-mail: shivpoojanyadav65@gmail.com;*

ABSTRACT

An experimentation was conducted during 2019-20 and 2020-21 at Banaras Hindu University, Varanasi, to evaluate the direct and residual effect of organic sources of nitrogen and weed management practices on various soil physico-chemical properties. The experiment was laid out in split plot arrangement having four nitrogen management treatments in main plot *viz.,* Control (only P and K), RDF (150-60-60 kg ha^{-1} N-P_2O_5-K_2O), 75% RDN (Inorganic) + 25% through FYM, 75% RDN (Inorganic) + 25% through Vermicompost and five weed management practices in subplots which consisted of Wheat residue as mulch (4 t ha^{-1}) *fb* bispyribac Na 25 g a.i. ha^{-1} (2-4 leaf stage of weed), Pendimethalin 1 kg a.i. ha^{-1}*fb* bispyribac Na 25 g a.i. ha^{-1} (2-4 leaf stage of weed), *Sesbenia* up to 30 days (Brown manuring), Two hand weeding (20 and 40 DAS) and Weedy check and replicated thrice. Results indicated that application of 25% nitrogen through farmyard manure in combination with 75% nitrogen through urea being at par with 75% RDN (Inorganic) + 25% through Vermicompost, brought significant improvement in soil chemical properties (electrical conductivity and pH) but physical property *i.e.,* Bulk density did not turn significant after harvest of direct seeded rice. The treatment also recorded significantly maximum available soil nitrogen, phosphorus and potassium compared to 100% nitrogen through urea and control treatment though remained comparable with 25% nitrogen through vermicompost along with 75% nitrogen through urea during both years. Whereas, in respect to the residual effect of organic sources, improvement in soil properties after harvest of succeeding residual lentil crop was observed, but failed to touch the level of significance in either year of study. Among weed management practices, maximum improvement in soil physicochemical properties was noticed with the use of *Sesbania* brown manuring for both years after harvest of rice as well as after harvest of succeeding lentil crop but the differences could not reach up to the level of significance.

Keywords: Biological; brown manuring; organic; residual; vermicompost.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is a member of the Poaceae family recognized as the world's second most important cereal crop after wheat which feeds more than half of the world's population" [1]. "It is the staple food crop of people in South, Southeast, and East Asia, which produces and consumes roughly 90% of the world's rice" [2]. "India is the second largest rice producer in the world next to China, which occupies an area of 43.2 M ha (million hectares) and produces 110.15 Mt (million tonnes) with a productivity of 2550 kg ha^{-1} and contributes 40% of total food grain production in the country" [3]. "It is predicted that the demand for rice will be 121.2 million tonnes by the year 2030 and 137.3 million tonnes by the year 2050 for internal consumption. In addition to this, India presently, exports about 3.5 million tonnes of basmati rice and 6.9 million tonnes of non-basmati rice per year, earning valuable foreign exchange for the country. In order to achieve this target, the productivity of rice has to be brought to the level of 3.3 tonnes ha^{-1}, which is only 2.4 tonnes at present" [4]. "In all the Asian countries, transplanting seedlings into puddled soil is the most common practice. Puddling helps in reducing water percolation losses, controlling weeds, enabling easy seedling establishment, and creating anaerobic conditions for microorganisms which enhances nutrient availability" [5]. Unfortunately, water scarcity is threatening the rice ecosystem, which impends global food security [6]. Increased production costs, labour shortages, increased wages, and decreased groundwater availability are the major drivers leading to switchover from traditional paddy transplanting to alternative rice production system in many Asian countries, including India [7,8]. "Repeated puddling also adversely affects soil physical properties by dismantling soil aggregates, reducing permeability in sub-surface layers, and forming hardpans at shallow depths which make land preparation difficult and require more energy to achieve proper tilth for succeeding crops" [9]. "The development of alternative methods that are more water-efficient and less labour intensive is thus important to enable farmers to produce more with lesser input cost. To tackle these problems, direct seeded rice seems to be the most promising option; which not only needs 34% of the total labour requirement but also saves 29% of the total cost in comparison to transplanted crop" [10].

DSR has several advantages over puddled transplanted rice. However, certain biotic and abiotic stresses challenge the widespread adoption of DSR. Among all biotic constraints, weeds are the major obstacles that reduce productivity, profitability as well as the sustainability of DSR [11,12]. "Along with weed management practices, balance nutrition of crops is one of the major aspects of rice yield enhancement in direct seeded rice. Nitrogen being a major constituent of amino acids, protein, fatty acids, nucleic acid and many enzymes, affects various physiological, morphological and biochemical processes in plants. Thus, both vegetative and reproductive phases of growth are highly dependent on adequate N supply. However, nitrogen supplied through sole usage of mineral fertilizers in a continuous intensive cropping system may deplete soil fertility, especially micronutrients [13] and organic carbon, because fertilizers have no direct effect on soil physical properties" [14]. Increased use of nitrogenous fertilizers is neither economically feasible nor environmentally friendly [15]. Integrated use of different sources of nitrogen is a sustainable alternative to supply if not complete N requirement, at least a part of it through organic sources. The use of locally well rotten farmyard manure, Vermicompost, compost, etc. to meet the requirement of N by rice has become necessary for the productivity of rice without affecting soil health and environmental quality [16]. Thus, with the above facts, the present study was carried out to compare the combined application of chemical fertilizers with farmyard manure and vermicompost for their direct and residual effects on soil physico-chemical properties after direct seeded rice and succeeding residual lentil crop.

2. MATERIALS AND METHODS

The field trial was conducted during 2019-20 and 2020-21 to study the direct and residual effect of different organic sources along with chemical fertilizers on soil health after the harvest of direct seeded rice and residual lentil crop. The experiment was laid out at Agricultural Research Farm, Banaras Hindu University, Varanasi, under an assured irrigation facility. The experimental site was located at 25^0 18' N latitude, 82^0 36' E longitudes and an altitude of 76 meter above the mean sea level. The region falls under a semi-arid to sub- humid climate, having a mean annual rainfall and potential evapotranspiration (PET) of 1102.4 mm and 1550 mm, respectively, with a moisture deficit index ranging between -20 to -40. The experimental site was homogeneous in fertility with levelled topography, uniform textural class (sandy clay loam) classified as Typic Ustochrept. A proper channel was provided in order to meet crop water requirements and remove the excess water, if any, during the investigation. The field of the trial remained the same during both years of investigation. The initial Physico-chemical properties of the experimental site are presented in Table 1. It was low in available nitrogen (172.25 kg ha^{-1}) and medium in available phosphorus (14.76 kg ha^{-1}) and potassium (196.36 kg ha^{-1}) (Table 1).

The experiment was laid out in split plot design with four integrated nitrogen management *viz*.,N_0Control (only P and K), N_1 (100% RDN inorganic), N_2 (75% RDN through Inorganic + 25% through FYM), N_3 (75% RDN (Inorganic) + 25% through Vermicompost) as main plot treatments and five weed management practices *viz.,*W_0 (Weedy check), W_1 (Two hand weeding at 20 and 40 DAS), W_2 (*Sesbania* co-culture up to 30 days), W_3 (wheat straw mulching 4 t ha^{-1} *followed by* bispyribac Na 25 g a.i. ha^{-1} at 2-4 leaves stage of weed), and W_4 (pendimethalin 1 kg a.i. ha^{-1} at pre-emergence (PE) *fb* bispyribac Na at 25 g a.i. ha^{-1} at 2-4 leaves stage weed) as subplot treatments and replicated thrice. Rice variety HUR-105 was sown in lines at a seed rate of 60 kg ha^{-1} at 20 cm row spacing with solid row planting on 17^{th} and 26^{th} July in 2019 and 2020, respectively. The required quantities of fertilizers were calculated separately as per recommended doses and was met through urea, single super phosphate, muriate of potash and zinc sulphate respectively for each plot. The recommended dose of NPK 150-60-60-25kg NPKZn ha^{-1}. The quantity of FYM and vermicompost was calculated on the basis of their nitrogen content on dry weight basis separately for each treatment. A well decomposed FYM and vermicompost was applied before 20 days of sowing and mixed thoroughly with soil. Half dose of nitrogen and full doses of P, K and Zn were applied at the time of sowing as basal application. The rest half of the nitrogen was divided in two equal splits and top dressed after maximum tillering and panicle initiation stage in the form of urea. Full doses of well decomposed FYM, and vermicompost were applied - two weeks prior to sowing based on their nitrogen content on oven dry weight basis to the experimental plot as per the treatment and mixed thoroughly in soil. The samples of these organic sources were collected and analyzed for the nutrient contents on dry weight basis before application. The required amount of pre-emergence and post-emergence herbicides was

Table 1. Initial physico-chemical properties of experimental soil

Particulars	Value	Method employed
Soil properties (%)	2019	
Mechanical analysis		
Sand	48.73	Hydrometric method [17]
Silt	28.72	
Clay	22.55	
Textural class	Sandy clay loam	
Taxonomy	Ustochrept	
Physical analysis		
Bulk density (Mg m^{-3})	1.33	Core sampler [18]
Chemical analysis		
Soil pH (1:2.5 soil:water suspension)	7.43	Glass electrode pH meter [19]
Electrical Conductivity (dSm^{-1} at 25°C)	0.165	Systronics electrical conductivity meter [19]
Available Nitrogen (kg ha^{-1})	172.25	Alkaline permanganate method [20]
Available Phosphorus (kg ha^{-1})	14.76	0.5 M $NaHCO_3$ Olsen's Colorimetric method [21]
Available Potassium (kg ha^{-1})	196.36	Flame Photometer method [19]

sprayed as per treatment using spray volume of 600 litres of water ha^{-1} with the help of knap sack sprayer fitted with flat fan nozzle. Wheat straw mulch was calculated per plot basis as per treatment and applied at the time of sowing between the line of rice. *Sesbania* was sown at the rate of 20 kg ha^{-1} with the help of kudal between the line of rice. After, 30 days *Sesbania* was knockdown by spraying 0.5 kg a.i. ha^{-1}. The lentil variety 'HUL-57' was sown at a row spacing of 30 cm with solid row spacing as a residual crop without disturbing layout of main crop. The entire set up was repeated next year at the same experimental site to verify results.

The soil samples from 0-15 cm depth were collected before sowing to determine the initial physico-chemical properties and after the harvest of rice and lentil crop to analyze various soil physical and chemical properties. The samples were air-dried, grounded, and sieved through a "2 mm sieve and analyzed for bulk density, pH, EC, available N, P, and K in soil. The soil bulk density, pH and EC were estimated by Core sampler [18], Glass electrode pH meter [19], and Systronics electrical conductivity meter [19], respectively". "The analysis of soil nutrient status was accomplished by following the standard Alkaline permanganate method [20], 0.5 M $NaHCO_3$ Olsen's Colorimetric method [21] and Flame Photometer method [19] for nitrogen, phosphorus and potassium analysis, respectively". "The data of each parameter of the test crop was sorted out, tabulated, and finally analyzed statistically using the analysis of variance technique for split-plot design" described by Gomez et al. [22]. Critical difference values at P =0.05 were used for determining the significance of differences between mean values of treatments.

3. RESULTS AND DISCUSSION

3.1 Direct Effect of Treatments

3.1.1 Soil bulk density (g cc^{-1})

A close examination of the data (Table 2) clearly demonstrated that the application of integrated sources of nitrogen influenced the soil bulk density after harvest of direct seeded rice that followed the trend N_2(75% RDN (inorganic) +25% through FYM) >N_3(75% RDN (inorganic) +25% through VC)> N_1(100% nitrogen through inorganic)>N_0 (only P and K). However, the differences were not found significant in any of the two years of experimentation.

Further study of the data revealed that execution of various weed management practices did not turn significant with respect to bulk density during both the years. Although, it was found in the order of W_2> W_3> W_4> W_1> W_0.

3.1.2 Electrical conductivity (dSm^{-1})

A critical inspection of data (Table 2) connoted that maximum value of soil electrical conductivity (EC) was recorded in treatmentN_2 (75% RDN (inorganic) +25% through FYM) being on par withN_3 (75% RDN (inorganic) +25% through VC) and N_1 (100% nitrogen through inorganic). Lowest value of EC was observed in N_0 (only P and K) during both years of study. The increase in soil EC could be ascribed to the decomposition of organic materials releasing acids or acid-forming compounds that reacted with the sparingly soluble salts already present in the soil and either converted them into soluble salts or at least increased their solubility thereby increasing EC of soil. Since, the mineralization process was very slow in the case of FYM, it attained a more pronounced effect than VC. These results were corroborated with the findings of Katkar et al.; Zayed et al. and Kumar et al., [23-25].

Among weed management practices, it is evident from the data that the soil EC was found maximum with the W_2 (*Sesbania* co-culture) followed by W_3 (wheat straw mulch 4 t ha^{-1} *fb*bispyribac Na 25 g a.i. ha^{-1} at 2-4 leaves stage of weed), W_4(pendimethalin 1 kg a.i. ha^{-1} as PE *fb* application of bispyribac Na 25 g a.i. ha^{-1} at 2-4 leaves stage of weed), W_1 (hand weeding twice at 20 and 40 DAS) and weedy check (W_0) respectively. However, the differences could not reach up to the level of significance with the execution of different weed management practices during both years trial.

3.1.3 Soil pH

Data shown in Table 2 indicated decrease in soil pH with the application of organic manure along with inorganic fertilizers whereas, it increased with the application of 100% RDN and control in 2020 over 2019 in. The minimum soil pH was envisaged with the application of 75% RDN by chemical with 25% by FYM in comparison to 100% RDN by chemical fertilizer and control (only RDF of P and K). However, it remained at par with 75% RDN by chemical with 25% by VC during both years of study.

The decrease in pH value in organic manure treatments could be attributed to the fact that various organic acids (amino acid, glycine, cysteine, and humic acid) would have released in the mineralization (amminization and ammonification) of organic materials by heterotrophs and nitrification by autotrophs, replacing basic ions present on the surface of soil micelles by hydrogen ions. Similar results were also reported by Sarwar et al.; Katkar et al. and Zayed et al. [26,23,24].

Further, the data indicated that among the different weed management practices, pH value found in the order of W_2 (*Sesbania* co-culture) <W_3 (wheat straw mulch4 t ha^{-1}*fb*bispyribac Na 25 g a.i. ha^{-1} at 2-4 leaves stage of weed)<W_4(pendimethalin 1 kg a.i. ha^{-1} as PE *fb* application of bispyribac Na 25 g a.i. ha^{-1} at 2-4 leaves stage of weed)<W_1 (hand weeding twice at 20 and 40 DAS) <weedy check (W_0) during two years of trial. Nevertheless, Differences among different treatment failed to reach the level of significance during 2019 as well as 2020.

3.1.4 Soil available nitrogen (kg ha^{-1})

The combined use of organics along with inorganic sources of nitrogen caused significant variations in available nitrogen during both years (Table 2). Application of 75% RDN through chemical fertilizer + 25% N through FYM recorded significantly maximum available nitrogen which was statistically at par with75% RDN through chemical fertilizer+ 25% N through VC treatment, though both were found superior over control and 100% RDN by fertilizer during both years. This might be due to the retention and availability of nutrients in the soil. Organic matter had the capacity to withhold nutrients due to improved physicochemical properties of soil. The increase in available N may be through the direct addition of organic matter from farmyard manure and vermicompost in combination with 75% RDN which might have helped in the multiplication of soil microbes, ultimately enhancing the conversion of organically bound N to mineral form. Katkar et al. [23] reported that farmyard manure is not only rich in carbon but also in nitrogen and other macro and micronutrients.

3.1.5 Soil available phosphorus (kg ha^{-1})

Data shown in Table 2 revealed lucid influence of integrated nitrogen management treatments on soil available phosphorus during both years. It was noticed that though 75% RDN through chemical fertilizer+ 25% N through FYM was at par with 75% RDN through chemical fertilizer+ 25% N through VC both recorded significantly higher available phosphorus in comparison to control and 100% RDN by fertilizer during both the years.

Table 2. Effect of integrated nitrogen and weed management practices on soil properties after harvest of direct seeded rice

Treatments	EC (dSm^{-1})		pH		BD ($g\ cc^{-1}$)		Available N ($kg\ ha^{-1}$)		Available P ($kg\ ha^{-1}$)		Available K ($kg\ ha^{-1}$)	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Integrated Nitrogen Management												
N_{0}- Control (Only P and K)	0.157	0.150	7.78	7.86	1.38	1.40	157.79	154.66	14.26	14.18	184.84	180.22
N_1-RDN (150-60-60 kg NPK ha^{-1})	0.159	0.158	7.76	7.80	1.35	1.37	168.34	166.79	14.67	14.64	190.92	189.30
N_2-75% RDN (Inorganic) +25% FYM	0.178	0.183	7.20	7.14	1.33	1.30	182.14	184.92	15.66	15.91	206.82	212.56
N_3-75% RDN (Inorganic)+25% Vermicompost	0.170	0.176	7.23	7.19	1.34	1.32	174.74	176.83	15.40	15.77	205.36	207.00
SEm±	0.003	0.004	0.14	0.15	0.03	0.03	3.71	3.29	0.28	0.34	4.44	4.06
CD (P=0.05)	0.011	0.014	0.50	0.50	NS	NS	12.84	11.40	0.96	1.18	15.35	14.06
Weed management												
W_0-Weedy check	0.163	0.164	7.51	7.51	1.33	1.33	168.19	168.25	14.79	14.83	193.98	193.99
W_1-Two hand weeding (20 and 40 DAS)	0.164	0.164	7.50	7.51	1.37	1.37	169.60	169.57	14.90	14.93	196.83	195.92
W_2-*Sesbenia* up to 30 days (30 DAS 2,4-D 0.5 kg a.i. ha^{-1})	0.172	0.173	7.47	7.45	1.34	1.33	172.97	173.11	15.34	15.45	197.99	200.62
W_3-Wheat residue as mulch (4 t ha^{-1}) *fb* bispyribac sodium 25 g a.i. ha^{-1} (2-4 leaf stage of weed)	0.167	0.167	7.48	7.49	1.35	1.34	171.99	172.00	15.03	15.33	197.08	198.83
W_4-Pendimethalin 1 kg a.i. ha^{-1} *fb* bispyribac sodium 25 g a.i. ha^{-1} (2-4 leaf stage of weed)	0.166	0.166	7.49	7.51	1.36	1.35	171.01	171.07	14.94	15.08	199.03	196.99
SEm±	0.003	0.003	0.12	0.08	0.02	0.02	2.88	3.30	0.20	0.23	2.88	3.23
CD (*P* =0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of integrated nitrogen and weed management practices on soil properties after harvest of residual lentil crop

Treatments	EC (dSm^{-1})		pH		Available N ($kg\ ha^{-1}$)		Available P ($kg\ ha^{-1}$)		Available K ($kg\ ha^{-1}$)	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Integrated nitrogen management										
N_0- Control (Only P and K)	0.173	0.181	7.60	7.32	175.76	179.83	15.40	15.79	197.92	202.22
N_1-RDN (150-60-60 kg NPK ha^{-1})	0.175	0.183	7.59	7.30	179.91	180.97	15.46	15.89	203.84	205.50
N_2-75% RDN (Inorganic) +25% FYM	0.188	0.196	7.17	7.14	189.20	193.25	16.61	16.96	211.82	215.56
N_3-75% RDN (Inorganic)+25% Vermicompost	0.178	0.186	7.21	7.19	183.05	188.12	15.68	16.62	207.36	212.00
SEm±	0.004	0.004	0.14	0.14	3.92	4.33	0.36	0.34	4.44	4.06
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management										
W_0-Weedy check	0.174	0.181	7.42	7.26	179.41	183.02	15.46	16.02	203.23	206.24
W_1-Two hand weeding (20 and 40 DAS)	0.176	0.183	7.41	7.25	180.84	185.81	15.70	16.27	205.24	209.24
W_2-*Sesbenia* up to 30 days (30 DAS 2,4-D 0.5 kg a.i. ha^{-1})	0.186	0.195	7.37	7.21	184.20	187.73	16.30	16.64	207.08	212.87
W_3-Wheat residue as mulch (4 t ha^{-1}) *fb* bispyribac sodium 25 g a.i. ha^{-1} (2-4 leaf stage of weed)	0.178	0.187	7.39	7.23	183.22	186.81	15.94	16.52	206.28	211.08
W_4-Pendimethalin 1 kg a.i. ha^{-1}*fb* bispyribac sodium 25 g a.i. ha^{-1} (2-4 leaf stage of weed)	0.178	0.186	7.40	7.24	182.25	184.35	15.53	16.12	204.33	204.67
SEm±	0.003	0.003	0.10	0.10	2.72	3.24	0.29	0.23	2.88	3.23
CD (*P* =0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

This might be attributed to the build-up of P in soil and the solubilization of native phosphorus in the soil through the release of organic acids from farmyard manure and vermicompost [26,27].

3.1.6 Soil available potassium (kg ha^{-1})

Application of 75% RDN through chemical fertilizer with 25% N through FYM recorded the highest available potassium in soil (Table 2) and it was statistically at par with 75% RDN through chemical fertilizer with 25% N through VC treatment during both the years. The increase in available K might be due to the direct addition to the available K pool of the soil, besides reduced K fixation and release of K due to the interaction of organic matter with clay. These findings are in conformity with the findings of Choudhary and Suri [27].

3.1.7 Residual effect of treatments

Data pertaining to physico-chemical properties of soil after harvest of lentil as affected by residual effect of organic sources along with inorganic sources of nitrogen have been summarized in Table 3. Soil organic carbon, pH and EC and status of soil available N, P and K after harvest of residual crop slightly improved but could not differ significantly due to application of various treatments in preceding rice crop throughout the period of investigation.

4. CONCLUSION

Based on the above findings, it can be concluded that the application of 25% nitrogen through farmyard manure in combination with 75% nitrogen through urea in preceding rice crop had significant effect on soil chemical properties *viz.,* electrical conductivity and pH, soil available nitrogen, phosphorus and potassium after harvest of rice crop. Whereas, in respect to the residual effect of organic sources, improvement in soil health after harvest of succeeding residual lentil crop was observed however, all the treatments failed to touch the level of significance in either year of study. Similarly, among weed management practices maximum improvement in soil physicochemical properties were noticed with the use of *Sesbania* brown manuring for both years after harvest of rice as well as succeeding lentil but all the weed management practices could not reach up to the level of significance. Therefore, the application of 25% RDN through farmyard manure along with 75% RDN through urea can be practiced to maintain soil health in eastern Uttar Pradesh.

ACKNOWLEDGEMENTS

I am highly thankful to the whole staff of Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University for their support and cooperation during the course of study and ICAR-New Delhi for providing ICAR-JRF/SRF fellowship for Ph. D. programme and contingent grant for research. I also extend thanks to my supervisor for his needful guidance and advice during the entire period of experimentation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chauhan BS, Johnson DE. Row spacing and weed control timing affect yield of aerobic rice. Field Crops Research. 2011;121(2):226-231.
2. FAO, 2017, Rice Market Monitor. 2017; 20(4).
3. GOI. Annual Report 2017-18, Department of Agriculture, Cooperation and Farmers Welfare, Govt of India, New Delhi; 2017-18.
4. Vision 2050, Central Rice Research Institute-Indian Council of Agricultural Research Cuttack, Odisha, India; 2013.
5. Sanchez PA. Puddling tropical soils, effects on water losses. Soil Science. 1973; 115:303-308.
6. Singh V, Jat ML, Ganie ZA, Chauhan BS, Gupta, RK. Herbicide options for effective weed management in dry direct-seeded rice under scented rice-wheat rotation of western Indo-Gangetic Plains. Crop Protection. 2016;81:168-176.
7. Mahajan G, Chauhan BS, Gill MS. Dry-seeded rice culture in Punjab State of India, lessons learned from farmers. Field Crops Research. 2013;144:89-99.
8. Chaudhary, BK, Singh, JP, Verma, SK, Nayak, H, & Yadav, SP. Conservation Agriculture-Based Planting Techniques and Weed Management Practices Influence on Nutrient Content and Their Uptake in Dry Direct-Seeded Rice (*Oryza sativa* L.). International Journal of Plant & Soil Science. 2022;34(14), 117-124.
9. Sharma PK, Ladha JK, Bhushan L. Soil physical effects of puddling in rice-wheat cropping systems. In "Improving the Productivity and Sustainability of Rice-

Wheat Systems: Issues and Impacts" (Ladha, JK, Hill, JE, Duxbury, JM, Gupta, RK and Buresh, RJ, Eds.), ASA, CSSA, SSSA, Madison, WI, ASA Special Publication 65. 2003;97-113.

10. Ho Nan-Kin, Romli Z. Impact of direct seeding on rice cultivation, lessons from the Muda area of Malaysia, In: Proceedings of Workshop on Direct Seeding, Research Strategies and Opportunities, held during 25-28 January 2000, at Bangkok, Thailand; 2000.
11. Chauhan BS. Weed ecology and weed management strategies for dry-seeded rice in Asia. Weed Technology. 2012;26:1-13.
12. Chauhan BS, Johnson, DE. The role of seed ecology in improving weed management strategies in the tropics. Advances in Agronomy. 2010;105:221-262.
13. Swarup A, Ganeshamurthy A. Emerging nutrient deficiencies under intensive cropping systems and remedial measures for sustainable high productivity. Fertil News. 1998;43:37-52.
14. Sheeba S, Kumarasamy K. Influence of continuous cropping and fertilization on physical properties of rice soil. Madras Agr J. 2001;88:728-730.
15. Cassman KG, Pingali PL. Extrapolating trends from long-term experiments to farmers fields: The case of irrigated rice systems in Asia". Paper presented at the Working Conference on "Measuring Sustainability Using Long Term Experiments", Rothamsted Experimental Station, funded by the Agricultural Science Division, The Rockefeller Foundation; 1993.
16. Nayak, H, Bohra, JS, Yadav, SP, Singh, T, & Saha, P. Physico-chemical Properties of Soil as Influenced by Combined Application of Organic and Inorganic Sources to Fodder Oat and Succeeding Residual Fodder Maize. International Journal of Plant & Soil Science 2022;34(20):739-747.
17. Bouyoucos GJ. Hydrometer method improved for making particle size analyses of soils. Agronomy Journal. 1962;54: 464-465.
18. Piper CS. Soil and Plant Analysis. Academic Press, New York. 1966;47-77.
19. Jackson ML. Soil chemical analysis. Prentice-Hall of India, private limited: New Delhi, India; 1973.
20. Subbaiah BB, Asija GL. A rapid procedure for estimation of available nitrogen in soil. Current Science. 1956;5:656-659.
21. Olsen SR, Culs CV, Wortanade FS, Deam LA. Estimation of available phosphorus by extraction with sodium bicarbonate. United States Department of Agriculture. 1954; 939:19-23.
22. Gomez KA and Gomez AA. Statistical procedures for agricultural research. John Wiley and Sons: New York, USA; 1984.
23. Katkar RN, Sonune BA, Kadu PR. Long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum-wheat system in Vertisols. Annals of Plant and Soil Research. 2011;2:32-34.
24. Zayed BA, Elkhoby WM, Salem AK, Ceesay M, Uphoff NT. Effect of integrated nitrogen fertilizer on rice productivity and soil fertility under saline soil conditions. Journal of Plant Biology Research. 2013;2(1):14-24.
25. Kumar A, Dhyani BP, Rai A, Kumar V. Effect of timing of vermicompost application and different level of NPK on growth, yield attributing characters and yield of rice in rice-wheat cropping system. International Journal of Chemical Studies. 2017;5(5):2034-2038.
26. Sarwar G, Schmeisky H, Hussain N, Muhammad S, Ibrahim M, Safdar E. Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. Pakistan Journal of Botany. 2008;40(1):275-282.
27. Choudhary AK, Suri VK. Integrated nutrient management technology for direct-seeded upland rice (*Oryza sativa*) in Northwestern Himalayas. Communications in Soil Science and Plant Analysis. 2014;45: 777-784.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/101095