A-6310
[1-6]

RESEARCH ARTICLE Indian Journal of Agricultural Research

Agronomic Performance of Black Rice under an Organic Ecosystem of North East India

Ashok S. Dambale[1], J. Goswami[2], S.S. Patil[1], Dipti Bisarya[1], R.S. Shinde[3], K. Kurmi[2], R. Das[4]

10.18805/IJARe.A-6310

ABSTRACT

Background: The research on potash management in North East India aims to enhance agronomic performance of black rice in organic habitats through SRI-based potassium management, promoting sustainable agriculture, food security and biodiversity. It underscores the crop's cultural, nutritional and economic importance while offering farmers sustainable production strategies.

Methods: To assess the effects of potash management strategies on organic black rice under system of rice intensification (SRI), a field experiment was carried out at Research Farm of Assam Agricultural University, Jorhat, during the *kharif* seasons of 2019 and 2020. The experiment included twelve distinct treatments with three replications, each arranged in a randomized block design.

Result: The morpho- physiolo, phenological and insect pest resistance were notably influenced by different organic potash management practices under system of rice intensification. From the result it was found that the highest leaf area duration, no of tillers, AGR for dry matter (g day^{-1} plant^{-1}), CGR) for dry matter (g m^{-2} day^{-1}), Phenological attributes, with application of RDK through banana pseudo stem vermicompost with combination of mustard oil cake + 20 kg ha^{-1}) T_8. In case of AGR for plant height (cm plant^{-1} day^{-1}) was more in T_6 (RDK through azolla incorporation + mustard oil cake + 20 kg ha^{-1}). Early flowering and maturity were recorded in treatment T_8 with application of RDK through banana pseudo stem vermicompost along with 20 kg ha^{-1} mustard oil cake. The incidence of insect pest was also observed low under treatment T_8 *i.e.*, application of RDK through banana pseudo stem vermicompost + with mustard oil cake + 20 kg ha^{-1}) and highest pest incidence was found under T_1 (Control).

Key words: Absolute growth rate, Bio-inputs, Black rice, Phenology, Potash, Sustainability.

INTRODUCTION

The vast majority of the world's population depends on rice (*Oryza sativa L.*) as one of the major plants for food. It is regarded as the world's staple food. more than 60 per cent of the world's population depend on rice. Rice is being extensively grown in India reaching a production of 105.31 million tons from a region of 42.75 million hectares and with a productivity of 2462 kg ha^{-1} (Anonynous, 2023). India is the second largest producer of rice in the world after China and stands as the biggest exporter of the same in the list of major rice exporters of the world. Numerous local rice varieties, such as white rice and wild-pigmented paddy, are cultivated on numerous Indian islands. Pigmented rice, which is categorized into four types and belongs to the species Oryza, is black, brown, red and white depending on the pigments it contains (Das *et al.,* 2024).

Due to concerns about long-term sustainability, environmental issues and the production of safe and healthy food, organic agriculture has become a major global focus. In general, the objectives of organic plant nutrition aim to work within the natural systems and cycles by maintaining or increasing the long-term soil fertility, using of renewable resources as much as possible and by producing food that is safe, wholesome and nutritious.

Since there is a lower consumption of inorganic chemicals and fertilizers, the North Eastern Region of India is by default considered to be organic. The average NPK fertilizer use in the NER is reported to be 51.67 kg ha^{-1} against the country's average of 144.33 kg ha^{-1} (Anonynous, 2023). The share of land under food grain production in all NER states is greater than the national average (65%) with

[1]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India.
[2]Department of Agronomy, Assam Agricultural University, Jorhat-785 001, Assam, India.
[3]Department of Agronomy, Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-415 712, Maharashtra, India.
[4]Department of Crop Physiology, Assam Agricultural University, Jorhat-785 001, Assam, India.

Corresponding Author: Ashok S. Dambale, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India.
Email: dambaleashok@gmail.com
ORCIDs: https://orcid.org/0000-0002-1017-7737, https://orcid.org/0000-0001-9663-1277, https://orcid.org/0000-0002-8480-5417, https://orcid.org/0000-0002-2451-786X, https://orcid.org/0009-0003-2609-544X, https://orcid.org/0009-0009-8508-0428, https://orcid.org/0009-0000-2466-1717

How to cite this article: Ashok S. Dambale., Goswami, J., Patil, S.S., Bisarya, D., Shinde, R.S., Kurmi, K. and Das, R. (2025). Agronomic Performance of Black Rice under an Organic Ecosystem of North East India. Indian Journal of Agricultural Research. 1-6. doi: 10.18805/IJARe.A-6310.

Submitted: 01-09-2024 **Accepted:** 25-03-2025 **Online:** 10-06-2025

the exception of Sikkim and Tripura. Assam basically a rice centric state mainly due to the fact that during kharif season this state receives heavy rainfall resulting in waterlogging in the low and medium land situations. Under waterlogged condition, rice is the best suitable crop which provides the advantage of less weed menace. Besides this, majority of the people of the state consume rice as staple food. Hence, under favourable agro-climatic condition, farmers of the state cultivate both traditional and high yielding varieties of non-aromatic, aromatic and glutinous rice during the kharif season. In Assam, rice occupies 4.16 million hectares of land under gross cropped area covering three rice growing seasons of the state *viz*., sali or winter rice, ahu or autumn rice and boro and early ahu or summer rice. Rice alone contributes to 96 % of food grain production of the state of Assam. The annual rice production in the state is 51.25 million tonnes with an average productivity of 2087 kg ha^{-1} (Anonynous, 2023).

Organic agriculture emerges as a *via*ble alternative to conventional methods, offering multiple agro-ecosystem benefits while meeting global food demands through mindful consumption (Muller *et al.,* 2017; Niemiec *et al*., 2020). Rice (*Oryza sativa* L.), a staple food, plays a crucial role in global food security (Kumawat *et al*., 2023). However, cereal-centric cropping systems, reliant on chemical inputs, have depleted soil organic carbon and essential nutrients, posing risks to future soil potential and human nutrition (Brevik *et al*., 2020). Micronutrient deficiencies, particularly zinc, in cereal-producing soils necessitate urgent attention to sustain crop and human health (Cakmak, 2008; Dhaliwal *et al*., 2019). Studies demonstrate that organic nutrient management practices significantly improve soil properties and nutritional quality in basmati rice (Dhaliwal *et al*., 2023).

Rice is the primary carbohydrate source for around fifty percent of the world's population. White rice is the most widely consumed variety of rice, with about 95% of the world's production occurring in Asian nations. On the other hand, colored pigment may be present in a few different rice cultivars. One kind of special rice that has a colored pericarp and is rich in nutrients is black rice, or *chak-hao*. The strong antioxidants found in "anthocyanins," which are flavonoid pigments similar to those found in blue and black berries, are what give this rice its black color. Rich in antioxidants, iron and vitamin E, black aromatic rice has a high nutritional profile. It has the power to treat and prevent a broad range of illnesses, including Alzheimer's disease, diabetes mellitus, cancer, cardiovascular disease and allergies. Scientists and experts see it as the most nutritionally complete "super food" found in nature. Black rice needs to be made more widely known in potential areas because it is less common than brown and white rice. A considerable rise in the consumption of black rice could be attained by appropriate technology dissemination and raising knowledge of its health-promoting properties.

Moreover, back rice farming is very lucrative since it fetches a higher price than other types of coarse rice, which benefits the growers. Specialty rice exports may be a major factor in securing India's foreign exchange revenues going forward. During different festivals, different ethnic groups in Manipur enjoy black aromatic rice in different forms such as puddings, bread, or pulao. Not only does the state but the entire nation have a high need for black aromatic rice and the crop's low production prevents it from meeting this demand. In order to improve the production status, suitable nutrient and agronomic practices have to be developed and adopted with immediate attention. The quality of rice is strongly influenced by potassium (K) and more potassium fertilizer is needed for rice than nitrogen (N) and phosphorus (P) fertilizer (Chen *et al*., 2023). According to Vijayakumar *et al.* (2021), potassium is a macronutrient that is necessary for numerous physiological activities in plant cells, including osmotic management, membrane potential maintenance and enzyme activation. By controlling photosynthesis, assimilate transport and carbohydrate metabolism, it also affects crop yields and quality (Pettigrew 2010). Rice yield and quality can be greatly impacted by the appropriate application of K fertilizer, which can also increase the number of tillers available, the rate at which leaves photosynthesize and the accumulation, transformation and transportation of photosynthetic products (Ma *et al.* 2022).

More focus on recent agronomic intervention like SRI may open new avenue for boosting rice production under organic ecosystem with the traditional varieties. The growth, yield and quality advantages under SRI system may be explored to give organic rice production a new momentum. A shift from traditional to scientific cultivation of organic black rice may enhance the productivity of rice and thereby increase income of farmers.

MATERIALS AND METHODS

Description of experimental site

The field experiment was carried out in a rainfed medium land setting on a certified organic block at research farm of the Assam Agricultural University, Jorhat, during the 2019 and 2020 *kharif* seasons. The pH of the sandy loam soil at the experimental location was 5.3; it had a medium level of organic carbon (0.72%) and low levels of accessible potassium (144.80 kg ha^{-1}), phosphorus (21.02 kg ha^{-1}) and nitrogen (246.45 kg ha^{-1}). Twelve different treatments were used in the experiment. The treatments includes such as Control (T_1), Potash solubilizing bacteria (KSB) + 3.5 kg ha^{-1} as root dip treatment (T_2), RDK through azolla incorporation (T_3), RDK through water hyacinth incorporation (T_4), RDK through banana pseudo stem vermicompost (T_5), RDK through azolla incorporation along with mustard oil cake + 20 kg ha^{-1} (T_6), RDK through water hyacinth incorporation with mustard oil cake + 20 kg ha^{-1} (T_7), RDK through banana pseudo stem vermicompost + mustard oil cake + 20 kg ha^{-1} (T_8), RDK through azolla incorporation + Potash solubilizing bacteria (KSB) + 3.5 kg ha^{-1} as rood dip treatment (T_9), RDK through water hyacinth incorporation + Potash solubilizing bacteria (KSB) + 3.5 kg ha^{-1} (T_{10}), RDK through banana pseudo stem vermicompost

+ Potash solubilizing bacteria (KSB) + 3.5 kg ha^{-1} (T_{11}) and ITK (T_{12}). Three replications of the experiment were set up using a randomized block design (RBD).

RESULTS AND DISCUSSION

Growth and physiological attributes

Leaf area duration

The leaf area duration of black rice was ranging from 156.60 to 118.50. among all the treatments, Application of recommended dose of potassium through banana pseudo stem vermicompost in combination with 20 kg ha^{-1} mustard oil cake recorded significantly higher LAD at 120 DAT (156.60 days during 2019 and 157.95 days during 2020) over the other treatments followed by T6 (RDK through azolla incorporation + mustard oil cake + 20 kg ha^{-1}), The lowest was recorded in control (118.50 days during 2019 and 120.60 days during 2020). The higher leaf area of traditional black rice genome may be due to the more availability of nitrogen and other essential nutrients that is received from banana pseudo stem vermicompost (Table 1).

Number of tillers hill^{-1}

Application of RDK through banana pseudo stem vermicompost along with mustard oil cake + 20 kg ha^{-1} (T_8) registered significantly highest number of tillers hill^{-1} 22.67 during 2019 and 23.44 during 2020 and were remained at par with T_6 (RDK through azolla incorporation with mustard oil cake + 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation with mustard oil cake + 20 kg ha^{-1}). The highest tillers hill^{-1} under the treatment T_8 might be due to the availability of more nutrients from applied organic inputs like banana pseudo stem compost and mustard oil cake which will ultimately a good source of macro and micro nutrients and also it provides some growth promoting enzymes that will enhance the growth of crop plant (Table 1).

AGR for plant height (cm plant^{-1} day^{-1})

The maximum values of absolute growth rate (AGR) for plant height were recorded in between 60-90 under T_6 treatment (RDK through azolla incorporation + mustard oil cake + 20 kg ha^{-1}) during both the years respectively and which was at par with T_9 (application of RDK through azolla incorporation + Potash solubilizing bacteria (KSB) + 3.5 kg ha^{-1} as root dip treatment). The lowest value of absolute growth rate (AGR) for plant height was recorded under control (T_1) in all the growth stages of crop in both the years of study. Higher plant height under treatment T_6 might be due to the availability of more nitrogen through azolla incorporation and 20 kg ha^{-1} mustard oil cake (Table 1).

AGR for dry matter (g day^{-1} plant^{-1})

For the first 0 to 30 days, the AGR based on the dry matter accumulation per plant per day was extremely slow. moderate during 30-60 and rapid during 60-90 days and decreased at 91-120 days and it was declined from 120 to harvest. The highest AGR values for the dry matter

Table 1: Growth and physiological parameters as influenced by different organic inputs during 2019-2020 and 2020-2021.

Treatment	Leaf area duration		Number of tillers hill^{-}		AGR for plant height (cm plant^{-1} day^{-1})		AGR for dry matter (g day^{-1} plant^{-1})		CGR) for dry matter (g/m^2/day)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1	118.50	120.60	12.00	12.44	1.999	1.995	2.572	2.748	2.572	2.648
T_2	127.20	128.70	14.11	13.89	2.031	2.033	2.827	3.149	2.827	2.882
T_3	130.65	132.60	15.56	15.11	2.401	2.399	3.412	3.415	3.412	3.415
T_4	129.00	130.95	14.67	14.44	2.069	2.065	3.371	3.085	3.371	3.413
T_5	133.50	135.30	16.11	16.00	2.197	2.201	3.413	3.475	3.413	3.475
T_6	151.80	153.45	20.44	21.56	2.530	2.537	4.078	4.212	4.078	4.145
T_7	148.80	150.15	18.78	20.00	2.131	2.132	3.948	4.125	3.948	4.025
T_8	156.60	157.95	22.67	23.44	2.297	2.300	4.208	4.325	4.208	4.291
T_9	142.65	144.30	16.89	17.67	2.499	2.499	3.704	3.844	3.703	3.777
T_{10}	139.50	141.00	16.56	17.00	2.102	2.100	3.510	3.835	3.510	3.535
T_{11}	145.65	147.15	18.22	18.78	2.270	2.265	3.893	4.034	3.893	3.934
T_{12}	135.30	137.25	16.33	16.44	2.169	2.166	3.519	3.696	3.519	3.596
S.Ed (±)	4.79	5.58	0.67	1.66	-	-	-	-	-	-
CD at 5 %	14.04	16.37	1.97	4.87	-	-	-	-	-	-
General mean	138.26	139.95	16.86	17.23	2.224	2.224	3.54	3.66	3.54	3.59

accumulation 4.208 during 2019 and 4.325 during 2020 were observed at 60-90 days under treatment T_8 application of RDK through banana pseudo stem vermicompost + mustard oil cake + 20 kg ha^{-1} followed by treatment T_6 (application of RDK through azolla incorporation along with mustard oil cake + 20 kg ha^{-1}) (Table 1).

CGR for dry matter (g m^{-2} day^{-1})

Among the different crop growth stages, the highest value of crop growth rate for dry matter (4.208 and 4.291 g m^{-2} day^{-1}) was recorded at 60-90 DAT under the treatment T8 (application of RDK through banana pseudo stem vermicompost + mustard oil cake + 20 kg ha^{-1}) during the year of 2019 and 2020, respectively. The lowest value of CGR was recorded under control (T_1) in all the growth stages of crop in both the years of study (Table 1).

Phenological attributes

Days to 50 per cent flowering

Flowering is very important parameter as flowering leads to grain formation. Flowering behaviour serves as a criteria for identifying appropriate time of sowing and planting of rice genotypes in a particular agro climatic region. The mean for 50 per cent flowering period was 97.75 and 98.31 respectively, during 2019 and 2020. The early 50 per cent flowering was observed at 95.67 and 96.33 DAT during both the years of experimentation with application of RDK through banana pseudo stem vermicompost + mustard oil cake + 20 kg ha^{-1} (T_8) which was found statistically at par with T_6 (RDK through azolla incorporation + mustard oil cake + 20 kg ha^{-1}) and significantly superior over rest of the treatments.

Days to 100 per cent flowering

The 100 per cent flowering observed during 2019 and 2020 at 100.67 and 101.33 DAT respectively in T_8 treatment due to the application of RDK through banana pseudo stem vermicompost along + mustard oil cake 20 kg ha^{-1} which was found statistically at par with T6 (RDK through azolla incorporation + mustard oil cake + 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake + 20 kg ha^{-1}).

Days to maturity

Different potash management practices did not bring about any significant influence on maturity in both the years (Table 2), However, under T_8 treatment plant shown early maturity than other treatments followed by T_6 (RDK through azolla incorporation + mustard oil cake + 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake + 20 kg ha^{-1}).

Insect pest incidence in black rice ecosystem

The data in respect to insect pest incidence in black rice ecosystem are depicted in Table 3. Data showed that the insect pest incidence in black rice ecosystem was significantly influenced by different potash management practices during different growth stages. The incidence of stem borer attack during PI stage in black rice ecosystem was reported to vary from 0.91 per cent to 11.86 per cent during 2019 and 1.82 per cent to 11.86 per cent during 2020. The lowest incidence of stem borer attack during at PI stage was reported under T8 treatment with application of RDK through banana pseudo stem vermicompost + mustard oil cake + 20 kg ha^{-1}) followed by T_{11} treatment (application of RDK through banana pseudo stem vermicompost + potash solubilising bacteria + 3.5 kg ha^{-1} as root dip treatment) and T_5 treatment (application of RDK through banana pseudo stem vermicompost).The higher incidence of stem borer attack (11.86 per cent during 2019 and 11.86 per cent during 2020) was recorded under T_1 treatment (Control). The low stem borer incidence at PI stage under T_8 treatment was observed and that may be due to more supply of all major nutrients as well as micro nutrients through banana pseudo stem compost and also

Table 2: Phenological attributes as influenced by different potash management practices during 2019-2020 and 2020-2021.

Treatment	Days to 50 per cent flowering (DAS)		Days to 100 per cent flowering (DAS)		Days to maturity (DAS)	
	2019	2020	2019	2020	2019	2020
T_1	102.33	103.00	107.33	108.00	138.33	139.00
T_2	99.00	99.67	104.00	104.67	135.00	135.67
T_3	98.33	98.67	103.33	104.00	134.33	135.00
T_4	98.67	99.00	103.67	104.33	134.67	135.33
T_5	98.00	98.33	103.00	103.33	134.00	135.00
T_6	96.00	96.67	101.00	101.67	132.00	132.67
T_7	96.33	97.00	101.33	102.00	132.33	133.00
T_8	95.67	96.33	100.67	101.33	131.67	132.33
T_9	97.00	97.67	102.00	102.67	133.00	133.33
T_{10}	97.33	98.00	102.33	103.00	133.33	133.67
T_{11}	96.67	97.33	101.67	102.33	132.67	133.00
T_{12}	97.67	98.00	102.67	103.33	133.67	134.00
S.Ed (±)	0.94	1.03	1.12	1.23	8.51	8.54
CD at 5%	2.75	3.03	2.42	2.50	NS	NS
General mean	97.75	98.31	102.75	103.39	133.75	134.33

Table 3: Effect of different K management practices against insect pest incidence in black rice ecosystem.

Treatment	Stem borer				Leaf folder				Gandhi bug	
	at PI stage		Grain filling stage		at PI stage		Grain filling stage		Milky stage	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1	11.86	11.86	22.27	20.41	23.73	22.03	40.82	33.96	12.99	9.39
T_2	9.23	9.23	18.33	15.00	20.00	18.46	35.00	29.23	10.00	7.14
T_3	5.26	5.26	9.65	9.65	14.47	13.16	23.44	19.35	5.52	3.64
T_4	7.35	7.35	14.34	12.74	17.65	16.18	30.27	25.08	7.96	5.50
T_5	1.18	2.35	6.25	5.00	9.41	8.24	18.75	15.29	2.50	1.11
T_6	2.50	3.75	8.00	8.00	11.25	10.00	21.33	17.50	4.00	2.35
T_7	5.26	6.58	11.34	9.92	14.47	13.16	25.51	21.18	5.67	3.72
T_8	0.91	0.82	2.92	2.92	7.27	6.36	12.65	10.21	1.95	0.89
T_9	3.85	3.85	9.62	8.24	12.82	11.54	23.36	19.29	5.50	3.62
T_{10}	5.48	6.85	11.80	10.33	15.07	13.70	26.56	21.98	7.38	5.14
T_{11}	1.04	1.04	3.29	3.29	8.33	7.29	14.27	11.45	2.20	0.99
T_{12}	2.37	2.37	6.29	6.29	10.66	8.94	18.88	15.39	3.78	2.24
S.Ed (±)	0.38	0.40	0.78	0.69	0.95	0.86	1.67	1.38	0.44	0.31
CD at 5%	1.11	1.18	2.28	2.03	2.78	2.54	4.90	4.05	1.30	0.90
General mean	4.69	5.11	10.34	9.32	13.76	12.42	24.24	19.99	5.79	3.81

banana pseudo stem compost supply more potassium so that ultimately it enhances the resistance power of growing plant against insect pest attack. The higher stem borer incidence was recorded under T_1 treatment may be due to less supply of essential nutrients and due to that plant may suffer more with least resistance against insect pest attack. In case of stem borer attach incidence during grain filling stage of black rice it is revealed that the lowest incidence (2.92 per cent during both the years) of stem borer at grain filling stage was reported under T_8 treatment followed by T_{11} (3.29 per cent during both the years) and highest in case of T_1 treatment (control). In case of leaf folder attack incidence (%) at PI and grain filling stage it was observed that the application of RDK through banana pseudo stem vermicompost + 20 kg ha^{-1} of mustard oil cake less attack of leaf folder during PI and grain filling stage and higher incidence was in control plot. Gandhi bug incidence during milky stage was also influenced by various potash management practices. Lower incidence of Gandhi bug at milky stage was found under treatment (T_8) application of RDK through banana pseudo stem vermicompost + 20 kg ha^{-1} of mustard oil cake and higher incidence under control treatment (T_1).

CONCLUSION

Based on the two-year experiment study data it is concluded that using RDK through banana pseudo stem vermicompost + mustard oil cake at 20 kg ha-¹ (T8) optimized growth, physiological parameters and reduced insect pest incidence in the System of Rice Intensification. This treatment outperformed others in promoting leaf area, tiller number and growth rates while also lowering pest damage compared to the control.

ACKNOWLEDGEMENT

The authors acknowledge Assam Agricultural University, Jorhat, for supporting the research work.

Conflict in interest

The authors declare that they have no conflicts of interest.

REFERENCES

Anonymous, (2023). First advance estimates of production of food grains for 2020-21 directorate of economics and statistics. ministry of Agriculture and Farmers Welfare Department of Agriculture, Cooperation and Farmers Welfare. Government of India. https://agricoop.nic.in.

Brevik, E.C., Slaughter, L., Singh, B.R., Steffan, J.J., Collier, D., Barnhart, P. and Pereira, P. (2020). Soil and human health: Current status and future needs. Air, Soil and Water Research. 13: 1178622120934441.

Cakmak, I. (2008). Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant Soil. 302(1): 1-17.

Chen, G.Y., Peng, L.G., Li, C.M., Tu, Y.B., Yan, L.A.N., Wu, C.Y., Qiang, D.U.A.N., Zhang, Q.Q., Hong, Y.A.N.G. and Tian, L.I., (2023). Effects of the potassium application rate on lipid synthesis

and eating quality of two rice cultivars. Journal of Integrative Agriculture. 22(7): 2025-2040.

Das, S., Acharya, B.S., (2024). Soil Health Gap: A concept to establish a benchmark for soil health management. Glob. Ecol. Conserv.

Dhaliwal, S.S., Ram, H., Walia, S.S., Walia, M.K., Kumar, B., Dhaliwal, M.K., (2019). Long- term influence of nutrient management on carbon and nutrients in Typic-*Ustochrept* soils. Commun. Soil Sci. Plant Anal. 50: 2420-2428.

Dhaliwal, S.S., Sharma, V., Shukla, A.K., Verma, V., Kaur, M., Singh, P., Gaber, A., Hossain, A., (2023). Effect of addition of organic manures on basmati yield, nutrient content and soil fertility status in north-western India. Heliyon. 9(3): e14514.

Kumawat, A., Kumar, D., Shivay, Y.S., Bhatia, A., Rashmi, I., Yadav, D., Kumar, A., (2023). Long-term impact of biofertilization on soil health and nutritional quality of organic basmati rice in a typic Ustchrept soil of India. Front. Environ. Sci. 11: 1031844.

Muller, A., Schader, C., Scialabba, N.E.H., Brüggemann, J., Isensee, A., Erb, K.H., Smith, P., locke, K., Leiber, P., Stolze, F., Niggli, U.M., (2017). Strategies for feeding the world more sustainably with organic agriculture. Nat. Commun. 8(1): 1-13.

Ma, J., Tingting, C., Jie, L., Weimeng, F. U., Baohua, F., Guangyan, L. and Guanfu, F. (2022). Functions of nitrogen, phosphorus and potassium in energy status and their influences on rice growth and development. Rice Science. 29(2): 166.

Niemiec, M., Chowaniak, M., Sikora, J., Szel¹g-Sikora, A., Grodek-Szostak, Z., Komorowska, M., (2020). Selected properties of soils for long-term use in organic farming. Sustainability. 12(6): 2509.

Pettigrew, W.T. (2010). Potassium influences on yield and quality production for maize, wheat, soybean and cotton. Physiologia Plantarum. 133: 670-681.

Vijayakumar, S., Kumar, D., Ramesh, K., Kulasekaran, R., Prabhu, G., Dinesh, J., Rubina, K., Saravanane, P., Subramanian, E., Ekta, J., Sharma, V.K,, Sudhir, K.R. (2021). Potassium nutrition in rice: A review. *ORYZA* - An International Journal on Rice. 58: 341-353.