RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 58 Issue 3: 423-430 (June 2024)

An Experimental Study on Productivity and Bio-molecular Compounds of Direct-Seeded Medicinal Rice Varieties as Influenced by Nutrient Sources and Soil Conditions

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10.18805/IJARe.A-6119

ABSTRACT

Background: Rice being staple food has qualities beyond its nutritive value with high digestibility and least allergic properties compared to other cereal grains. Research on exploring the nutritional value of traditional rice varieties with its inherent medicinal values and productivity has poor documentation and hence should be encouraged and supported.

Methods: A field experiment was conducted in the wetland during 2015 *Rabi* season (October-February) at Tamil Nadu Agricultural University, Coimbatore with an objective to study the effect of crop establishment of medicinal rice varieties as influenced nutrient sources (inorganic and organic) and soil conditions (reduced and oxidized) under direct seeded rice. The experiment was laid out in factorial randomized block design with three replications. The treatments consisted of soil conditions (reduced, oxidized) as one factor, sources of nutrients (inorganic, organic) as the second factor and four medicinal rice varieties (*Black Kavuni, Red Kavuni, Local Kavuni* and *Njavara*) as the third factor.

Result: The reduced condition and inorganic source of nutrient recorded higher plant height, maximum tiller population dry matter production, leaf area index, panicle length, higher number of spikelet panicle^{-1}, 1000-grain weight and filled grains. Among the medicinal rice varieties, *Red Kavuni* recorded higher growth parameters and yield attributes. From the above results, it could be concluded that *Red Kavuni* medicinal rice under a reduced condition with inorganic nutrients resulted in higher growth parameters and yield attributes.

Key words: *Black kavuni,* Direct seeded rice (DSR), *Local kavuni*, *Njavara*, *Red kavuni*.

INTRODUCTION

As the world struggles to find a cure for COVID-19, health experts have indicated that boosting the immune system of the body can help to mitigate the effects and accelerate disease recovery. The food products of Ayurveda are potent aids to improve the immunity of the body against harmful viruses. Rice is one of the world's most important medicinal crops and is also a staple food for more than half of the world's population. Worldwide, rice is grown in 165.16 million hectares, with an annual production of 741 million tons and productivity of 4486 kg/ha. About 90% of the world's rice is grown and produced (146.94 million ha area with a production of 671 million tons and productivity of 4566 kg/ha of paddy) in Asia. Rice is grown in 43.94 million ha with a production of 159.2 million tonnes and productivity of 3623 kg/ha in India. Rice is considered as food with carbohydrates and some amount of protein, but has a number of unknown properties of rice, reported in ancient Indian Ayurvedic literature, where apart from consumption, the scientific literature (The 'Susrutha Samhitha' and 'Charaka Samhitha' -1000 BC) had given evidences of a few rice varieties that had the "medicinal properties" and used for treating human ailments since long time in our country and some landraces are still popular in farmer's fields due to their adaptability to different agroclimatic conditions, unique characteristics and

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How to cite this article: Ashraf, A.M., Archana, H.A., Kumar, M.R.N., Iqshanullah, A.M., Rajasekaran, R., Dhinesh, K.S. and Begam, S.N. (2024). An Experimental Study on Productivity and Bio-molecular Compounds of Direct-Seeded Medicinal Rice Varieties as Influenced by Nutrient Sources and Soil Conditions. Indian Journal of Agricultural Research. 58(3): 423-430. doi: 10.18805/IJARe.A-6119.

Submitted: 04-06-2023 **Accepted:** 08-08-2023 **Online:** 23-08-2023

special uses (Ashraf *et al*., 2017a). Recent studies also recommend rice as a novel food due to its high glycemic index for lowering the incidence of lifestyle-related diseases such as heart attack, diabetes and cancer (Ashraf and Lokanadan, 2020).

Rice being staple food has qualities beyond its nutritive value with high digestibility and least allergic properties compared to other cereal grains, hence enjoyed by young and old alike (Betrez-Marquez *et al*., 2005). Rice has even been found to have anti-cancer properties. The extract from rice bran has been shown to contain safe and promising anti-cancer properties and it is believed to be, due to its antioxidants. The current paradigm of rice research is shifting towards a farmer-centered one developing along with the principles of food sovereignty and biodiversity based rice ecosystems (Ashraf *et al*., 2017b). This will provide more diverse and nutritious sources of food complementary to rice. Research on exploring the nutritional value of traditional rice varieties with their inherent medicinal values has poor documentation and hence should be encouraged and supported. The demand of nutraceutially rich food is increasing day by day (Thakur *et al*., 2020). *Njavara* is a rice variety endemic to Kerala, famed for its use in Ayurveda. There are two types of *Njavara* rice based on differences in glume colour *viz*., black glumed of 60-90 days maturity and tolerant to drought conditions whereas yellow glumed matures in 60-90 days and is susceptible to lodging and diseases (Ashraf and Lokanadan, 2017). *Kavuni* is a rice variety endemic to Tamil Nadu, cultivated in the outskirts of Tanjore. There are three types of *Kavuni* on the basis of kernel colour *viz*., *Black Kavuni*, *Red Kavuni* and *Local Kavuni*.

In Asia, rice is commonly grown by transplanting seedlings into puddled soil (land preparation with wet tillage). Puddling benefits rice by reducing water percolation losses, controlling weeds, facilitating the easy seedling establishment and creating anaerobic conditions to enhance nutrient availability. The continuous cropping with repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers and forming hard-pans at shallow depths (Agarwal *et al*., 1995) which have a negative effect on the following non-rice upland crop in rotation. Moreover, puddling and transplanting require a large amount of water and labour both of which are becoming increasingly scarce and expensive, making rice production less profitable. All these factors demand a major shift from puddled-transplanted rice production (PTR) to direct seeding of rice (DSR) in irrigated areas. Depending on water and labour scarcity, farmers are changing either their rice establishment methods only (from transplanting to direct seeding in puddled soil, Wet-DSR or both tillage and rice establishment methods (puddled transplanting to dry direct seeding in unpuddled soil (Dry-DSR). Hence, considering the importance, field experiment was conducted with the objective to study the feasibility of the establishment of medicinal rice varieties under reduced and oxidized soil conditions with inorganic and organic nutrient sources under DSR.

MATERIALS AND METHODS

A field experiment was conducted in the wetland farm during 2015 *Rabi* season (October-February) at Tamil Nadu Agricultural University, Coimbatore with an objective to study the effect of crop establishment methods of medicinal rice varieties with different nutrients sources and soil conditions under DSR. The farm is situated at 11°N latitude, 77°E longitude and at an altitude of 426.7 m above mean sea level. The experiment was laid out in factorial randomized block design with three replications.

Treatment details A. Factor 1: Field conditions (2)

C_1: Reduced
C_2: Oxidized

B. Factor 2: Nutrient source (2)

N_1: Inorganic (150: 50: 50, NPK kg/ha)
N_2: Organic (5t/ha as vermicompost)

C. Factor 3. Varieties (4) (Fig 1)

V_1: *Black kavuni*
V_2: *Red kavuni*
V_3: *Local kavuni*
V_4: *Njavara*

The soil of the experimental field was deep clay loam, moderately drained and grouped under *Vertic Ustochrep* (belonging to *Noyyal* series) taxonomical classification. In the soil the available nitrogen, alkaline permanganate method (Subbiah and Asija, 1956) was low, the available phosphorus, olsen's method (Olsen *et al*., 1954) was medium and the available potassium, neutral normal ammonium acetate method (Stanford and English, 1949) was high. The medicinal rice varieties were dry sown in the field at a spacing of 22 cm × 15 cm at the rate of two seeds per hill. The field was maintained at the saturated condition with no standing water at the time of sowing and gap filling was done within a week and the plant population per unit area was maintained in the whole field. Irrigation was regulated in such a manner that the field was maintained at saturated condition with thin film of water with alternate wetting to 2.5 cm and drying till formation of hair line cracks during the vegetative stage. At flowering stage, 1-2 cm water level was maintained at any point of time till maturity and water was drained two weeks before harvest. Observations were recorded on growth parameters such as plant height, tillers, dry matter production and leaf area index. The yield attributes *viz;* productive tillers, spikelet number, 1000-grain weight, filled grains and harvest index were recorded at the time of harvest. Biochemical medicinal parameters like total phenol content (Bray *et al*., 1954) and β-carotene content (Jensen, 1978) were recorded.

RESULTS AND DISCUSSION

Growth parameters

Growth parameters like plant height, tillers and dry matter production of medicinal rice varieties were higher under reduced soil conditions (C_1) and inorganic sources of nutrients (N_1). *Red Kavuni* (V_2) recorded higher plant height (99.5 cm)

at the maturity stage of the crop growth. The plant height increased gradually with the advancement of growth under different water regimes. A taller plant was observed under flooded conditions. However, rice growth under saturated was comparable (Zulkarnain *et al*., 2009). Taller plant height was observed with inorganic nutrients in all the medicinal rice varieties [*Red Kavuni* (V_2)*, Local Kavuni* (V_3)*, Black Kavuni* (V_1) and *Njavara* (V_4)]. Similar findings were reported by (Usman *et al*., 2003) stating that the application of mineral fertilizers increased the plant height significantly over organic sources when applied separately. The plant height is having a positive correlation with panicle weight and hence increases the yield (Bhattacharya and Ghosh, 2004). The number of functional leaves, leaf area and the total number of tillers $hill^{-1}$ were higher which increased the photosynthetic rate leading to taller plants (Shrirame *et al*., 2000).

Tiller production was also influenced by soil conditions. More tillers were observed under flooded and saturated conditions than field capacity conditions (Zulkarnain *et al*., 2009). The number of productive tillers was found to be higher with the inorganic application of nutrient (N_1) compared to the organic nutrient source (N_2). *Red Kavuni* (V_2) variety recorded higher number of tillers $hill^{-1}$. The *Njavara* (V_4) recorded a lower number of tillers $hill^{-1}$ during the crop growth stage. Attributing that the individual plants could have effectively utilized the available resources such as space, foraging area for the root system, light utilization, higher utilization of nutrients during initial crop growth stages, increased cell division, improved metabolic activity and higher tillers. The usefulness of increased nutrient application on the growth attributes like plant height, tiller production, leaf area and dry matter production was also



Fig 1: Medicinal rice landraces in the study.

observed by Singh *et al.* (2006). The dry matter production (DMP) of the crop increased with age of the crop. Total DMP increased steadily with time and reached the maximum at harvest with the application of an inorganic source of nutrients. Among the varieties, *Red Kavuni* (V_2) performed better than *Njavara* (V_4). The *Red Kavuni* (V_2) produced maximum dry matter production (8.79 t ha^{-1}) at maturity stages of the crop growth and *Njavara* (V_4) recorded the lowest (5.95 t ha^{-1}). With the ability to absorb adequate nutrients with the large photosynthesizing surface area, the dry matter accumulation was at a rapid rate. Higher uptake was mainly attributed to better root activity and increased DMP in all the medicinal rice varieties. Similar findings were reported by Kumari and Kumar (2006).

A higher leaf area index was recorded with the inorganic source of nutrients (N_1) in all the medicinal rice varieties. The *Local Kavuni* recorded maximum LAI at different stages of the crop growth, *Njavara* recorded minimum at different stages of the crop growth. Availability of macro and micronutrients might have enhanced the metabolism of rice by way of production of different growth promoting substances that regulates stem elongation and cell enlargement. Similar findings were given by Selvarasu *et al.* (2005) and Laxminarayana (2007) (Table 1, 2, 3 and 4).

Yield attributes

Yield components like productive tillers, number of grains per panicle, filled grains, panicle weight and panicle length

Table 1: Plant height (cm) at maturity stage as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	45.4	43.9	44.6	45.8	33.4	38.6	45.6	38.6	42.1
V_2	47.3	40.5	43.9	38.8	41.1	40.8	43.1	40.8	41.9
V_3	47.8	41.2	44.5	43.4	36.7	39.0	45.6	39.0	42.3
V_4	55.8	49.1	52.5	59.8	45.3	47.2	57.8	47.2	52.5
Mean	49.1	43.7	46.4	43.7	39.1	43.0	48.0	41.4	44.7
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	1.3	1.3	1.9	1.9	2.7	2.7		3.8	
CD (P=0.05)	2.7	2.7	3.9	NS	NS	NS		NS	

Table 2: DMP (t ha^{-1}) at maturity stage as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	8.55	8.34	8.44	9.11	5.47	7.29	8.83	6.90	7.87
V_2	10.71	8.42	9.56	10.43	5.61	8.02	10.57	7.01	8.79
V_3	9.55	9.31	9.43	9.23	4.99	7.11	9.39	7.15	8.27
V_4	7.77	5.05	6.41	6.14	4.84	5.49	6.95	4.94	5.95
Mean	9.14	7.78	8.46	8.73	5.23	6.98	8.93	6.50	7.72
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	0.25	0.25	0.35	0.35	0.50	0.50		0.70	
CD (P=0.05)	0.51	0.51	0.72	0.72	NS	NS		1.40	

Table 3: LAI at flowering stage as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	3.92	2.39	3.16	2.81	2.32	2.57	3.37	2.36	2.86
V_2	4.20	3.08	3.68	2.96	2.42	2.69	3.62	2.75	3.18
V_3	3.88	2.58	3.23	2.88	2.78	2.83	3.38	2.68	3.03
V_4	2.76	2.55	2.65	2.70	2.23	2.46	2.73	2.39	2.56
Mean	3.71	2.65	3.18	2.84	2.44	2.64	3.27	2.54	2.91
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	0.10	0.10	0.14	0.14	0.20	0.20		0.29	
CD (P=0.05)	0.21	0.21	0.30	0.30	NS	NS		NS	

of rice were positively influenced by soil conditions, nutrient sources in all the four medicinal rice varieties *Black Kavuni* (V_1), *Red Kavuni* (V_2), *Local Kavuni* (V_3) and *Njavara* (V_4). Number of tillers m^{-2}, number of grains $panicle^{-1}$, filled grains, 1000-grain weight and sterility percentage was found higher in flooded conditions rather than saturated conditions. The panicle length and panicle weight was, however comparable between flooded and saturated conditions. There was a 10% yield reduction when grown in saturated condition as compared to flooded condition. However, the grain yield of rice grown under field capacity conditions was significantly lower as compared to saturated and flooded conditions. The percentage of filled grain was significantly affected by water regimes. A significantly higher percentage of filled grain was observed under flooded conditions compared to saturated conditions (Zulkarnain *et al*., 2009).

Availability of nutrients during the crop growth period might have promoted assimilates to sink, increasing the length of panicle with more number of filled grains and higher grain weight. This might be the reason for the improved yield attributes with more productive tillers and filled grains recorded with an inorganic nutrient application (N_1). Increased nutrient supply would have improved the metabolic activity and cell division resulting in higher plant height, more number of leaves which consequently increased the yield attributes and grain yield in rice. The ability of spikelets to accept the carbohydrates, translocation of assimilates from leaves to spikelets and the source activity relative to sink size influenced the filled spikelet percentage. Higher accumulation ability of the rice with the optimum supply of macro and micronutrients induced the test weight (Bakhsh *et al.* 2008) (Table 5, 6 and 7).

Yield

In medicinal rice varieties, *Njavara* (V_4) recorded 1.31 t ha^{-1} and *Local Kavuni* (V_3) recorded 2.90 t ha^{-1} grain yields. C_1 (reduced condition) and C_2 (oxidized condition) resulted with 2.53 t ha^{-1} and 2.14 t ha^{-1} of grain yield. In nutrient sources, inorganic nutrients (N_1) recorded 3.28 t ha^{-1} and organic nutrients (N_2) 1.51 t ha^{-1} of grain yield. Increased grain yield was obtained in C_1 (reduced) and it was comparable with C_2 (oxidized). The results obtained suggest that it is not necessary to flood rice to obtain a high grain yield as maintaining a saturated soil throughout the growing season results in a non-significant reduction in rice yield. Grain yield, however, decreased significantly when water was reduced to field capacity condition and this is in agreement with previous findings of Grigg *et al.* (2000).

There is a positive correlation between grain yield and yield components such as productive tillers, number of grains $panicle^{-1}$, filled grain percentage and grain weight, enhancing the partitioning of assimilates from vegetative tissues to grains. This is in line with the findings of Zhang *et al.* (2008) and Ashraf and Lokanadan (2020). Rice grain yield obtained was higher from an inorganic source of nutrient (N_1) in

Table 4: Number of productive tillers m^{-2} as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	351	270	310	310	220	265	330	245	287
V_2	390	280	335	330	220	275	360	250	305
V_3	370	260	315	290	220	255	330	240	285
V_4	240	220	230	240	180	210	240	200	220
Mean	337	257	297	292	210	251	315	233	274
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	7	7	10	10	14	14		20	
CD (P=0.05)	15	15	21	NS	NS	30		NS	

Table 5: Number of spikelet $panicle^{-1}$ as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	90	84	87	78	72	75	84	78	81
V_2	89	84	86	82	76	79	85	80	83
V_3	94	89	91	80	74	77	87	81	84
V_4	59	38	48	54	35	44	56	36	46
Mean	83	74	78	73	64	69	78	69	73
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	2	2	2	2	4	4		5	
CD (P=0.05)	4	4	5	NS	NS	8		NS	

comparison to organic (N_2) in all the four medicinal rice varieties [(*Red Kavuni* (V_2), *Local Kavuni* (V_1), *Black Kavuni* (V_3) and *Njavara* (V_4)]. This might be due to the continuous and quick release of nutrients into the soil solution to meet the required nutrient demand by the crop at the required stages. The straw yield was also higher in C_1 (reduced condition) compared to C_2 (oxidized condition). The harvest index was recorded higher in C_1 (reduced condition) compared to C_2 (oxidized conditions). Inorganic source (N_1) recorded a higher straw yield and harvest index compared to organic source (N_2). All the above-focussed factors might have helped to enhance the nutrient use efficiency and thereby contribute to higher grain yield directly or indirectly in all the four medicinal rice varieties tested (Ashraf and Lokanadan, 2022a) (Table 8).

Biochemical parameters

The bio-molecular compounds in the medicinal rice recorded more variation with nutrients (Ashraf *et al*., 2015). The organic sources of nutrient (N_2) recorded higher bio-chemical compounds. *Black Kavuni* (V_1) recorded total phenol content of 11.83 mg/100 g and β-carotene (420.37 µg/100 g). *Njavara* (V_4) recorded 9.42 mg/100 g total phenol content and 508.09 µg/100 g β-carotene. Ragaee *et al*. (2006) reported total phenolic content of other whole cereals like wheat, barley, millet and rye as 0.562, 0.879, 1.387 and 1.026 respectively (Table 9 and 10).

Table 6: Number of filled grains panicle^{-1} as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	86	83	84	76	69	72	81	76	78
V_2	85	85	85	79	74	76	82	79	81
V_3	89	86	88	78	73	75	83	80	81
V_4	54	33	44	49	30	40	52	32	42
Mean	79	72	75	70	61	66	74	66	70
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	2	2	3	3	4	4		6	
CD (P=0.05)	4	4	6	NS	NS	8		NS	

Table 7: 1000-grain weight (g) as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	21.92	21.56	21.74	21.50	22.12	21.81	21.71	21.84	21.77
V_2	22.98	22.09	22.54	22.62	21.91	22.26	22.80	22.00	22.40
V_3	22.95	22.83	22.89	21.82	22.57	22.20	22.39	22.70	22.54
V_4	19.70	19.54	19.62	20.22	19.50	19.86	19.96	19.52	19.74
Mean	21.88	21.50	21.69	21.54	21.52	21.53	21.71	21.51	21.61
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	0.13	0.13	0.19	0.19	0.27	0.27		0.38	
CD (P=0.05)	NS	NS	0.39	NS	NS	0.55		NS	

Table 8: Grain yield (t ha^{-1}) as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	C_1			C_2			N × V		
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	Mean
V_1	3.81	1.73	2.77	2.94	1.30	2.12	3.38	1.52	2.45
V_2	4.25	2.31	3.28	3.95	1.35	2.65	4.32	1.83	3.08
V_3	4.02	1.51	2.76	3.35	1.57	2.46	3.97	1.54	2.76
V_4	1.42	1.20	1.31	1.48	1.14	1.31	1.45	1.17	1.31
Mean	3.37	1.69	2.53	2.93	1.34	2.14	3.28	1.51	2.40
	C	**N**	**V**	**C × N**	**C × V**	**N × V**		**C × N × V**	
SEd	0.14	0.14	0.19	0.19	0.27	0.27		0.39	
CD (P=0.05)	0.28	0.28	0.40	NS	NS	0.56		0.80	

Table 9: The total phenol content (mg/100g) as influenced by soil conditions and nutrient source in medicinal rice varieties under direct seeded rice (DSR).

Treatment	Reduced condition (C_1)		Oxidized condition (C_2)		
	Inorganic nutrient (N_1)	Organic nutrient (N_2)	Inorganic nutrient (N_1)	Organic nutrient (N_2)	Mean
Black Kavuni (V_1)	14.79	9.59	13.68	9.29	11.83
Red Kavuni (V_2)	12.69	7.60	11.78	7.30	9.84
Local Kavuni (V_3)	9.60	6.38	9.54	8.18	8.42
Njavara (V_4)	10.0	9.23	9.38	9.08	9.42
Mean	11.77	8.20	11.09	8.46	11.83
Mean	9.98		9.78		

Table 10: The β-carotene (µg 100 g^{-1}) as influenced by soil conditions and nutrient source in medicinal rice varieties under DSR.

Treatment	Reduced condition (C_1)		Oxidized condition (C_2)		
	Inorganic nutrient (N_1)	Organic nutrient (N_2)	Inorganic nutrient (N_1)	Organic nutrient (N_2)	Mean
Black Kavuni (V_1)	288.91	553.38	288.71	550.48	420.37
Red Kavuni (V_2)	208.59	310.83	206.87	310.83	259.28
Local Kavuni (V_3)	280.92	489.56	280.92	480.68	383.02
Njavara (V_4)	450.25	570.68	448.12	563.34	508.09
Mean	307.16	481.11	306.15	476.33	
Mean	394.13		391.12		

CONCLUSION

Application of inorganic sources of nutrients (N_1) and reduced soil condition (C_1) recorded higher bio-metric characters, physiological characters and yield attributes in all the four medicinal rice varieties. In medicinal rice varieties, *Red Kavuni* (V_2) recorded enhanced growth characters and yield attributes compared to *Black Kavuni* (V_1), *Local Kavuni* (V_3) and *Njavara* (V_4). *Black Kavuni* (V_1) recorded higher total phenol content of 11.83 mg/100 g and β-carotene of 420.37 µg/100 g. Hence, these *Kavuni* varieties can be suggested for cultivation and it would be more profitable for small and marginal farmers.

Conflict of interest

All authors declare that they have no conflict of interest.

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