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An experimental study on the growth performance, surface morphology and therapeutic properties of unique medicinal rice (*Oryza sativa* L.) landraces of Tamil Nadu

A Mohammed Ashraf[a,*] & Subbalakshmi Lokanadan[b]

[a]Department of Agronomy, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal 609 603, India
[b]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
E-mail: ashrafbsa09040@gmail.com

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A field experiment was conducted during the *Samba* season at the Tamil Nadu Agricultural University, Coimbatore wetland farm with the objective of studying surface morphology and growth output of medicinal rice varieties in the western zone of Tamil Nadu under the irrigated rice ecosystem. The experiment was conducted with five replications in a Randomized Block Design (RBD). The treatment consists of three medicinal rice varieties and one high yielding variety of Tamil Nadu viz., Red *kavuni*, Black *Kavuni* and *Njavara and* CO(R)50. The observations were recorded on growth parameters like plant height, tillers, dry matter production and the physiological parameters like Leaf Area Index (LAI), Crop growth rate, Relative growth rate (CGR) and Net assimilation rate (NAR). The yield attributes like productive tillers/m^2, total spikelet, filled grains, unfilled grains, thousand grain weight, grain yield and straw yield were recorded at the time of harvest. Physical, cooking, bio chemical parameters like amylose per cent, total phenol content, total protein and β - carotene was also recorded. The surface morphology of the grain and husk shape and appearance were also studied and examined under Scanning Electron Microscope (SEM). The study concludes that among the medicinal rice varieties, *Red Kavuni* recorded enhanced growth characters, yield attributes, yield (2,391 kg/ha), B:C ratio and optimum cooking quality parameters as compared to *Black Kavuni* and *Njavara*. *Njavara* recorded higher gross return and net return. With respect to nutritive and medicinal properties, *Black Kavuni* recorded higher phenol content, protein content and β-carotene when compared to other varieties.

Keywords: Bio chemical parameters, Medicinal rice varieties, Nutritional properties, Surface morphology

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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[1].

Rice, as a staple food, has characteristics that go beyond its nutritional value, such as high digestion and low allergy potential when compared to other cereal grains. Due to the development of contemporary high yielding varieties (HYVs), hybrids and genetically modified rice traditional rice landraces in India and Asia are in grave danger of extinction[2].

Rice is the major constituent of life-saving Oral Rehydration Arrangements (ORS) and utilized for this reason since time immemorial. In India, the restorative esteem of rice have been reported in Charaka Samhita (700 BC) and Susruta Samhita (400 BC), for treating different ailments such as diarrhoea, vomiting, fever, haemorrhage, chest pain, wounds, and burns.

In an evaluation programme for biotic stresses, among 12,750 entries reported by Indian Institute of Rice Research (Hyderabad, India), 28.31% of entries were coloured rice. Of these 10.48%, 9.41% and

*Corresponding author

8.40% were red, brown and purple pericarps. The collection from National Rice Research Institute, (Cuttack, Odisha) was 2,960 entries, mainly from the Eastern states of India, had a relatively high number of red rice of which 20% were coloured rice. Of which, 17%, 3.44% and 2.50% were red, purple and brown rice, respectively. A survey conducted by the NBPGR from 1991 to 1998 recorded about 35% and 21% of rice as traditional red rice varieties in Orissa and Manipur[3]. This coloured rice is rich in minerals like iron, zinc and polyphenol content with antioxidant properties. So, these landraces are gaining interest for research studies.

According to Sathya[4], more than one hundred different varieties of rice prevailed in North Arcot district alone of Tamil Nadu, of which *Munagada* (submerged) warrants a special mention and *Vaigunda* a fast growing traditional rice surpassing weeds. In certain pockets of Karnataka, Madhya Pradesh, Kerala, Tamil Nadu, Uttar Pradesh, Himachal Pradesh and the Western Ghats, many rice varieties with medicinal values are cultivated and used to treat skin disease, blood pressure, fever, paralysis, rheumatism, leucorrhea, lactation and as a health tonic. *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[5].

Kavuni is a rice variety native to Tamil Nadu, cultivated in certain pockets of Thanjavur, Thirunelveli, Kanniyakumari and is of two types viz., *Black Kavuni* and *Red Kavuni*. *Kavuni* rice was consumed by Tamil kings during Chola period. The South Indian Chettinad community, in the ancient days, widely used this Karuppu Kavuni Arisi. Rice has even been found to have anti-cancer properties and it is believed to be due to its antioxidant properties[6-8].

Research on exploring the nutritional value of traditional rice varieties with its inherent medicinal values has poor documentation and hence should be encouraged and supported. Hence, the present study was planned to find the feasibility of medicinal rice cultivation of *Njavara* and *Kavuni* and their surface morphology, quality parameters under irrigated rice ecosystem under irrigated rice ecosystem.

Materials and Methods

A field experiment was conducted during the *Samba* seasons (Aug 2014 to Jan 2015) at the Tamil Nadu Agricultural University, Coimbatore wetland farm with the objective of studying surface morphology and growth output of medicinal rice varieties in the western zone of Tamil Nadu under the irrigated rice ecosystem. The experimental field's soil was a deep clay loam that was fairly drained and classified as Vertic Ustochrep (belonging to the *Noyyal* series). The available nitrogen in the soil was low, the available phosphorus was medium and the available potassium was high. All of the cultivation practices were carried out in accordance with the guidelines of provided[9]. The experiment was performed with five replications in a Randomized Block Design. The treatment consisted of three medicinal rice varieties and one high yielding variety of Tamil Nadu viz., Red *kavuni*, Black *Kavuni* and *Njavara* and CO(R)50 (Table 1 and Fig. 1, 2).

In the net plot area, five sample plants were selected randomly and tagged for recording biometric observations. The observations on growth parameters like plant height, tillers, dry matter production and the physiological parameters were also recorded. The yield attributes like productive tillers m^{-2}, total spikelet, filled grains, unfilled grains, thousand grain weight, grain and straw yield were recorded at the time of harvest. The nutritional parameters like total phenol content[10], total protein[11] and β – carotenes[12] were recorded. Bio-chemical characters like amylose content[13], gelatinization temperature (GT)[14] and gel consistency (GC)[15] were also recorded.

Table 1 — Details of landraces/rice variety in the experiment

SI. No.	Landraces/Varieties	Pedigree source	Special characters
1.	*Black kavuni*	Chettinadu, Tamilnadu	Lower yielding, tillering as poor, long duration photosensitive, brownish black kernel, used for medicinal purpose with crop duration 130-135 days.
2.	*Red kavuni*	Chettinadu, Tamilnadu	Lower yielding, tillering as poor, long duration photosensitive, reddish black kernel, used for medicinal purpose with crop duration 130-135 days.
3.	*Njavara*	Palaghat, Kerala	Medicinal rice variety, used in Ayurveda and susceptible to lodging.
4.	CO(R)50	CO 43 X ADT 48 TNAU, Coimbatore, India	High yielding, tolerant to bacterial leaf blight, photo insensitive, tall, white medium kernel with new plant type characteristics, green leaf sheath, long compact droopy panicle with crop duration 130-135 days.

Fig. 1 — Medicinal Rice Landraces in the study

Fig. 2 —Panicle position of Medicinal Rice Landraces in the study

Equipment used for grain surface characters and elemental composition analysis

Energy Dispersive X-ray spectroscopy in conjunction with scanning electron microscope was used for analyzing the grain surface characters and elemental composition. The samples were recorded using EDAX attached in the FEI ESEM model "QUANTA 250" FEI ESEM Model "QUANTA 250" available in the Department of Nano Science and Technology, Tamil Nadu Agricultural University, Coimbatore.

Results and Discussion

Climate influence on crop growth

Weather elements play an important role in exploiting the growth and yield potential of any crop. Weather variability is considered as one of the major factors in annual variability of crop growth and biological yield. The variations are mostly attributed to the effect of seasonal weather conditions on plant growth. Rice requires submerged conditions from seedling to milky stage with an average water requirement of 1250 mm for low land rice ecosystem. The weather conditions prevailing during the crop growth period (Aug. 2014 - Jan. 2015) were normal with total rainfall of 463 mm received in 23 rainy days during the crop period. Besides rainfall, temperature influenced rice yield by directly affecting the physiological processes involved in grain production and indirectly through the incidence of pest and diseases. The crop requires high temperature, ample water supply and high atmospheric humidity during the growth period.

The rice crop prefers to have brighter sunshine for an enhanced photosynthetic activity and higher yield. Bright days associated with gentle winds are the best condition which regulates the maximum supply and utilization of CO_2. Crop growth mainly depends on environmental factors and fluctuations in weather conditions greatly influence it. In the present experiment, the average maximum temperature recorded during the cropping season was 30°C and minimum temperature was 21.5°C. The average mean relative humidity at 0722 hrs was 88.5% and at 1422 h was 58%, respectively. The mean sunshine hour was 4.9 hrs day^{-1}. The weather conditions prevailing throughout the cropping period were favourable and facilitated the rice crop for better growth and to attain higher yield.

Effect on growth parameters and yield attributes

When compared to Black *Kavuni*, *Njavara* and CO(R)50, *Red Kavuni* recorded higher plant height (137.5 cm), tillers/m^2 (536), Leaf Area Index (LAI) (4.46) and dry matter production (11.91 t/ha). Plant height varies among traditional varieties, which could be attributed to changes in their genetic makeup. This outcome was similar with previous findings[16,17] who observed variable plant height in the rice varieties. Among the rice landraces, *Red Kavuni* recorded higher crop growth rate of 2.83 g/m^2/day at flowering to maturity stage (Table 2 and 3). The number of functional leaves, leaf area and total number of tillers $hill^{-1}$ were higher, which increased the photosynthetic rate, leading to higher crop growth rate[18].

Among rice landraces, *Red kavuni* (24.9 g) recorded higher thousand grain weight followed by

Table 2 — Growth parameters of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Plant height (cm)	Tillers/m^2	Dry matter production (DMP) (t/ha)
Black Kavuni	129.2	442	11.45
Red Kavuni	137.5	536	11.91
Njavara	123.0	464	8.42
CO(R)50	107.0	403	10.34
Mean	124.2	461.	10.53
SEd	1.3	18.12	0.52
CD (p=0.05)	2.7	36.44	1.05

Table 3 — Physiological parameters (flowering-maturity stage) of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Leaf Area Index (LAI) (flowering stage)	Crop growth rate (CGR) (g/m^2/day)	Relative growth rate (RGR) (g/g/day)	Net assimilation rate (NAR) (mg/cm^2/day)
Black Kavuni	3.36	2.27	0.013	0.45
Red Kavuni	4.46	2.83	0.017	0.56
Njavara	3.12	2.47	0.014	0.45
CO(R)50	2.75	2.54	0.015	0.44
Mean	3.42	2.53	0.015	0.48
SEd	0.13	0.13	0.001	0.01
CD (p=0.05)	0.25	0.25	0.002	0.04

Table 4 — Yield attributes and Yield of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Productive tillers/m^2	Thousand grain weight (g)	Total spikelet/ panicle	Filled grains/ panicle	Number of unfilled grains/ panicle	Grain yield (kg/ha)	Straw yield (kg/ha)
Black Kavuni	348	23.2	116	88	28	2,212	7,229
Red Kavuni	418	24.9	122	93	29	2,391	7,469
Njavara	337	17.0	89	65	24	1,342	4,842
CO(R)50	352	19.3	136	116	20	4,868	6,619
Mean	364	21	116	91	25	2,703	6,540
SEd	17.98	1.14	5.44	4.16	1.33	129	326
CD (p=0.05)	36.15	2.29	10.94	8.37	2.67	259	655

Table 5 — Economics of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B: C ratio
Black kavuni	36,586	1,40,280	1,03,694	3.83
Red kavuni	36,586	1,52,760	1,16,174	4.18
Njavara	41,786	1,71,000	1,29,214	4.09
CO(R)50	34,506	71,372	36,866	2.07
Mean	36,586	1,40,280	1,03,694	3.83

*Data statistically not analysed

Black *Kavuni* and *Njavara*. This result is found to be in concurrence with previous studies[19]. Many native varieties have greater grain weight than most HYVs. Varieties like *Ashphal*, *Bakul phool*, *Bokva*, *Ganga sal*, *Patnai*, *etc*. have heavy grains.

CO(R)50 rice variety recorded maximum number of filled grains/panicle (116). In rice landraces, filled grains/panicle was higher (93) in *Red Kavuni* (Table 4). A negative correlation between yield and percentage sterility of rice genotype was observed. Hence, to increase grain yield, it is important to reduce spikelet sterility or increase the number of filled grains/panicle. Higher accumulation ability of the rice with optimum supply of macro and micro nutrients induced the grain weight[20].

Effect on grain and straw yield

There is a positive correlation between grain yield and yield components such as productive tillers, number of grains/panicle, filled grain percentage and grain weight, enhancing the partitioning of assimilates from vegetative tissues to grains. The vegetative part ceases growing after flowering and as a result, most of the net assimilate is translocated to the panicle. Therefore, increase in total dry matter and carbohydrate during the grain filling period usually shows a close correlation with grain yield. The rice variety CO(R)50 observed the highest grain yield of 4,868 kg/ha in this study, followed by Red *Kavuni* and Black *Kavuni*, which yielded 2,391 and 2,212 kg/ha respectively. The same has also been previously reported by[21-23]. *Red Kavuni* recorded higher grain yield compared to *Black Kavuni* and *Njavara*. *Red Kavuni* recorded higher straw yield of 7,469 kg/ha, but was on par with *Black Kavuni* 7,229 kg/ha. *Njavara* recorded lower grain yield and straw yield of 1,342 kg/ha and 4,842 kg/ha respectively during the crop growth period.

Economic analysis

In rice landraces, *Njavara* recorded higher cost of cultivation (41,786 ₹/ha), higher gross return (1,71,000 ₹/ha) and net return (1,29,214 ₹/ha) followed by *Red Kavuni* and *Black Kavuni*. The B:C ratio was higher in *Red Kavuni* (4.18) followed by *Njavara* (4.09) (Table 5). Rice landraces recorded higher returns; because price is four to five times higher than normal rice varieties. Income from a crop is determined by its yield level, market price of the produce and cost incurred on its cultivation.

Cooking quality parameters of rice landraces

Rice is the most effective cereal and it can be eaten whole, milled, or boiled. Although a number of quality attributes are valued by growers, millers and consumers, each of them place a distinct focus on different factors. Millers, for example, desire a high percentage of head recovery during milling. Customers need good quality of grain with respect to look, length and form of the grain, tenderness and flavor after cooking. The quality parameters to be evaluated for rice landraces can be discussed in terms of physical, cooking and bio chemical parameters.

Table 6 — Physical quality parameters of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Kernel length (mm)	Kernel breadth (mm)	Kernel length/ breadth ratio	Grain size and shape	Hulling (%)	Milling (%)	Head Rice Recovery (%)
Black kavuni	6.0	2.1	2.9	Medium	75.6	71.0	51.6
Red kavuni	6.2	2.2	2.9	Medium	77.1	72.0	53.0
Njavara	5.8	2.0	2.9	Medium	78.2	73.1	30.3
CO(R)50	5.9	2.1	2.8	Medium	81.4	72.2	60.1
Mean	6.0	2.1	2.9	Medium	78.1	72.1	48.8

*Data statistically not analysed

Table 7 — Cooking quality parameters of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Kernel length after cooking (mm)	Kernel breadth after Cooking (mm)	Linear elongation ratio	Breadth wise elongation ratio	Volume expansion ratio
Black kavuni	7.7	2.6	1.27	1.24	2.4
Red kavuni	8.1	2.7	1.30	1.25	2.6
Njavara	6.6	2.5	1.14	1.23	2.2
CO(R)50	9.2	3.2	1.57	1.57	3.4
Mean	7.9	2.8	1.32	1.32	2.7

*Data statistically not analysed

Kernel length, breadth, length/breadth ratio, milling percentage and hulling percentage are under physical qualities. Elongation ratio and volume expansion ratio are under cooking parameters. Amylose content and gelatinization temperature are the bio chemical parameters. Kernel length, kernel breadth and length/breadth ratio did not show higher variation in rice landraces; the grain comes under the medium category in shape and size (Table 6). This could be due to genetic constitution. The grain size and shape of rice varieties in general is short to medium slender with translucent appearance[24].

The dehulling of rice is one of the important post-harvest processes. In the rice landraces, CO(R)50 obtained higher hulling percentage (81.4) followed by *Njavara* (78.2), *Red Kavuni* (77.1) and *Black Kavuni* (75.6). More than seventy percent is the desirable hulling characteristic for rice[25]. The farmers' and millers' difficulty is to get high price that is decided through market quality standards comprising of shape, size, coloration of rice, percentage of milling, hulling and head rice restoration[26].

During course of cooking, rice kernels absorb water and increase in volume via increase in length or breadth. Breadth increase is not applicable while, length wise increase without increase in girth is the desirable characteristic in high premium quality rice[27-29]. In the rice landraces, CO(R)50 (9.2 mm), *Red Kavuni* (77.1 mm) and *Black Kavuni* (75.6 mm) registered higher KLAC values. *Njavara* obtained lower KLAC (6.6 mm) (Table 7).

Biochemical parameters

The cooking temperature at which water is absorbed and the starch granules swell irreversibly in hot water with a simultaneous loss of crystallinity and birefringence is referred to as the gelatinization temperature of the endosperm starch, a helpful measure of cooking quality. The time required for cooking is determined by the gelatinization temperature (GT). The alkali spreading value was calculated as low, intermediate and high. In rice landraces, *Black Kavuni* was grouped in the rating 3 and 4 described as kernel swollen, collar complete/ incomplete or wide based on the alkali digestion value. *Red Kavuni* and CO(R)50 was grouped in the rating 5 described as kernel split or segmented collar complete and wide. *Njavara* has high alkali digestion value and grouped under 6th category described as kernel dispersed, merged with collar. The different range of drying also affects the GT[30]. The intermediate GT is suitable for cooking purpose. In rice landraces, CO(R)50 and *Njavara* have higher length of gel consistency (>60 mm) and they were classified as soft rice. *Black Kavuni* and *Red Kavuni* have gel consistency lower than 60 mm and classified as flaky rice (Table 8).

Amylose content can play a significant role in determining the overall cooking, eating and pasting properties of a rice variety[31,32]. Rice with intermediate amylose content has been reported to cook moist and remain soft (when cool) and is widely preferred than rice with high or low amylose contents. The amylose content in percentage of *Black Kavuni* (20.3), Red

Table 8 — Bio chemical parameters of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Alkali digestion	Length of Gel (mm)	Amylose content (%)
Black kavuni	Kernel swollen, collar complete or wide	56	20.3
Red kavuni	Kernel split or segmented collar complete and wide	58	21.1
Njavara	Kernel dispersed, merged with collar	61	18.5
CO(R)50	Kernel split or segmented collar complete and wide	83	21.6

*Data statistically not analysed

Table 9 — Nutritional quality parameters of medicinal rice varieties under irrigated rice ecosystem

Landraces/Varieties	Total phenol content (mg/100 g)	Total protein content (%)	β – Carotene (µg /100 g)
Black Kavuni	14.79	6.87	288.91
Red Kavuni	12.69	5.83	208.59
Njavara	10.0	6.25	450.25
CO(R)50	5.93	4.08	140.07
Mean	10.85	5.76	271.97

*Data statistically not analysed

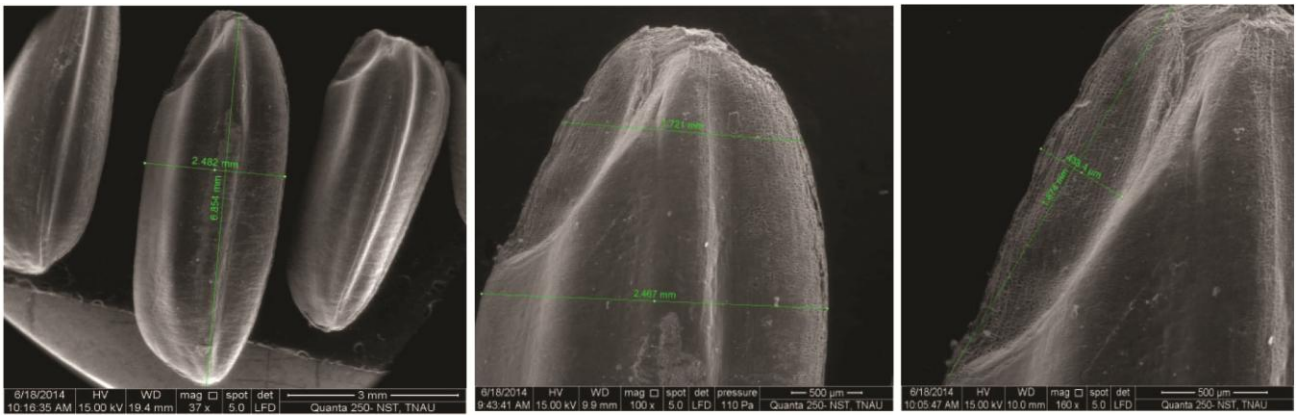

Fig. 3 —Electron microscope image (*Black Kavuni*); Embryo length: 1.87 mm and Embryo breadth: 433.4 µm; Kernel length: 6.85 mm and Kernel breadth: 2.48 mm

Kavuni (21.1), *Njavara* (18.5) and CO(R)50 (21.6) were grouped under intermediate amylose content category. *Black Kavuni* recorded higher total phenol content of 14.79 mg/100 g and protein of 6.87% and β-carotene of 288.91 µg/100 g. *Njavara* recorded higher β-carotene (450.25 µg/100 g) (Table 9). This might be due to the genetic characteristics of traditional land races[33]. The data also suggests that the biomolecular properties of *Kavuni* landrace had higher health benefits in preventing oxidative stress and diabetic complications.

Energy dispersive X-ray spectroscopy (EDAX) of grain length and width

The surface morphology of all the three medicinal rice varieties viz., Red *kavuni*, Black *Kavuni* and *Njavara* was examined under Scanning Electron Microscope (SEM) and the image of rice husk depicted in Figures 3, 4 and 5. Rice husk or body is fundamentally the outer layer of the rice or paddy grain. It gets isolated from most of the rice grain during the process of milling. Rice husk, which is also known as lemma, covers the whole rice seed which contains the embryo containing plumule and radical as well as endosperm and a variety of other important components of the rice seed. The outer surface of lemma is ridged and the ridged structures have a linear profile. The epidermal cells of lemma are arranged in linear ridges and furrows and the ridges are punctuated with distinguished conical protrusions. The outer floor of lemma additionally contains papillae and hairs of various sizes; however, they have been regularly broken. It is interesting to observe that a clear distinction on the dentate square elements was present over the exterior surface of the rice husk

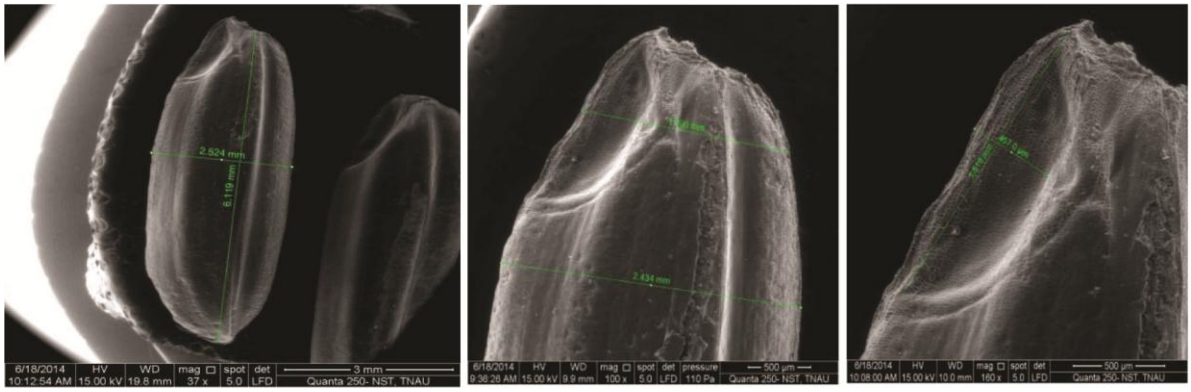

Fig. 4 —Electron microscope image (*Red Kavuni*); Embryo length: 1.51 mm and Embryo breadth: 457.0 µm; Kernel length: 6.19 mm and Kernel breadth: 2.52 mm

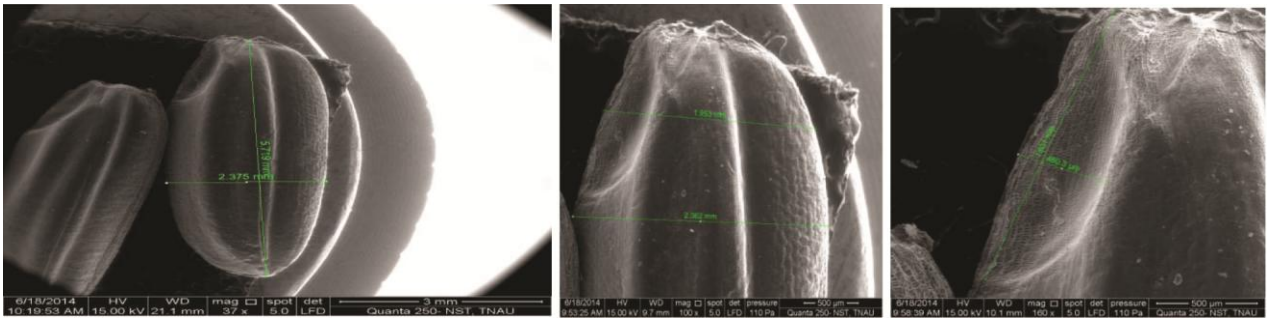

Fig. 5 —Electron microscope image (*Njavara*); Embryo length: 1.63 mm and Embryo breadth: 460.3 µm; Kernel length: 5.71 mm and Kernel breadth: 2.37 mm

and few of those had mechanical indentations. It changed into determined that there have been some of longitudinal fibers which had been interspaced in the indoors of the matrix of lignin and glucose. This structure was observed to be quite analogous to that of a composite material wherein fibers are placed frequently inside the matrix. All grains with husk were having hairs with varying lengths, whereas grain looks alike with rough surface. Dehusked grains of kavuni had been broken along the natural fracture planes and established on round aluminum stubs with the aid of double facet adhesive tape.

According to length, the grains of *Black Kavuni* (6.85 mm) and Red *kavuni* (6.19 mm) and *Njavara* (5.71 mm) are classified as medium or intermediate rice grains. The grains kernel length, grains kernel breadth and grains length/breadth ratio did not show higher variation in all the three medicinal rice landraces and they were classified as medium in grain shape and size. This could be due to genetic constitution. This result was in conformity with saravanan[34]. The SEM-EDAX study revealed that the rice landraces are rich in boron, potassium, zinc, iron, sodium, molybdenum and copper.

Conclusion

The present attempt revealed that among the medicinal varieties, higher growth parameters, yield attributes, grain, straw yield and B:C ratio were obtained in *Red Kavuni*. *Njavara* recorded higher gross return and net return. Based on higher grain yield CO(R)50 > *Red Kavuni* > *Black Kavuni* > *Njavara*. With respect to nutritive and medicinal properties, the land race *Black Kavuni* was found to be superior when compared to other varieties. Hence, these two varieties can be suggested for all rice belts districts of Tamil Nadu and it would be more profitable for small and marginal farmers. The study revealed that *Kavuni* traditional rice varieties are with rich nutritive and therapeutic characteristics, more yield producing ability which could be used in breeding programme and development of new varieties.

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Conflict of Interest

Authors declare they do not have any conflict of interest.

Authors' Contributions

A M A planned and conducted research work' and drafted the manuscript. S L, guided the research.

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