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CHANGES IN PHYSICOCHEMICAL AND COOKING QUALITY PROPERTIES OF GERMINATED BROWN RICE AND PIGMENTED RICE

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ABSTRACT

This study evaluated the effect of germination process on selected physico-chemical and cooking quality parameters of brown rice (RNR 29325) and pigmented rice (Navara) in India. These rice varieties were subjected to soaking for 12 hours (brown rice) and 36hrs (pigmented rice) at 28±2ºC, followed by incubation at 28±2ºC. Results showed that germination of the rice lead to significant variations in length, breadth and l*, a*, b* values of grains of both varieties. Germination significantly decreased the bulk and tapped density of grains. A significant decrease in amylose content was observed after germination in brown rice (16.57±0.71 to 15.12±0.41 %) and pigmented rice (19.48±0.41 to 17.44±0.00 %) respectively. Germination also led to significant decrease in cooking time from 36.67±0.47 to 33.67±0.47 min and 41.67±0.47 to 36.67±0.47 min in brown rice and pigmented rice respectively. After germination, the length, breadth and water uptake ratio of the brown rice and pigmented rice grains increased.
Keywords **:** Germination, Brown rice, Amylose, Physico-chemical, Cooking quality

Introduction

For centuries, half of the world's population has relied on rice (*Oryza sativa L.*), one of the most popular cereal foods, as their main source of food (Sun *et al*., 2010). Approximately 21 percent of human calories and up to 76 percent of Southeast Asian calories come from rice, making it one of the world's most important crops (Zhao *et al*., 2020). In the 2022/2023 crop year, China produced about 146 million metric tons of milled rice, a higher volume than any other country. India came in second place with over 135 million metric tons of milled rice in that crop year. As a staple crop, rice is widely consumed across India. Global consumption of rice has seen a slight increase over the last several years. As the most populous country in the world, China consumes more rice than any other country, with about 150 million metric tons consumed in 2023/2024. India ranks second after China, with a rice consumption of 118 million metric tons during the same period. (Sandhya keelery, Statista/2024).

Among the 40,000 varieties of rice cultivated worldwide, only two major species are cultivated widely-*Oryza sativa* or the Asian rice and *Oryza glaberrima* or the African rice (Rathna priya *et al*., 2019). There are genotypes of colored rice with various kinds of pigments and these rice varieties are available in colors such as red, purple and black. After the post-harvest process, all the varieties of rice can be categorized as either white or brown rice (Zareiforoush *et al*., 2016).

Milling rice removes bran and germ, resulting in a uniform white appearance. Brown rice is always a healthier option due to its better nutritional content.

However, brown rice and pigmented rice have poor cooking and sensory properties. Due to the hard fibrous bran layer, cooked brown rice and pigmented rice have chewy, hard texture that makes it unappealing and hence has poor palatability (Rathna priya *et al*., 2019, Das *et al*., 2008).

To soften the texture of cereal grains like rice, before they are dried and cooked, a germination process is performed. During the process of germination, a dry, quiescent seed absorbs water, which causes the embryonic axis to elongate (Bewley *et al*., 1982). Germinated brown rice (GBR) has been shown to have significant benefits. Rice softens during germination, making it suitable for cooking in a rice cooker. According to Bahadur (2003), eating unpolished (brown) rice is preferable since it contains more fiber, iron, vitamins and minerals than milled rice because the bran layer is removed during the milling process. Additionally, the germination of brown rice (and thus GBR) is essential for boosting the nutrients needed for optimal health. The change of staple food from polished rice to GBR can maintain and promote the healthy life and improve the quality of life (Hiroshi 2005). Regular consumption of germinated brown rice has been shown to have several health benefits, including lowering blood pressure, preventing Alzheimer's disease, preventing headaches, relieving constipation, preventing colon cancer, regulating blood sugar levels, preventing heart disease and accelerating brain metabolism (Jiamyangyuen and Ooraikul, 2008).

Compared to regular brown rice, GBR has an abundance of nutrients like ferulic acid and GABA and is considered a functional diet due to its good absorption and digestion. Better shelf life, easier handling, and a great appearance are all provided by dried GBR.

In contrast to white rice, GBR is easier to cook, has a superior texture, more sweetness and a great flavor. Manufactured GBR is mostly sold in dried form (the drying does not affect the superior nutritional value accumulated from germination), which looks very similar to ordinary brown rice (Patil and Khan, 2011).

India stands in second place in production of rice after china and also India has been the largest exporter of rice over the years. There is surplus storage of rice in India as production is more. This excess amount of rice will lead to in-equal supply and demand in the supply chain. In this scenario, converting excess rice to a value-added product through germination, can not only improve nutritional properties but also the physical, functional and cooking quality properties of the rice, thereby creating a new market segment to the GBR. The GBR market is also expected to benefit from changing customer tastes and the growing number of GBR product variants. In India GBR market is still in nascent stage and needs research on suitability of GBR processing with Indian rice varieties. The objective of present study was to determine the effect of germination on physico-chemical and cooking quality parameters of brown rice (RNR 29325) and pigmented rice (Navara) varieties of rice grown in India.

Material and Methods

Plant samples

Pigmented rice variety (Navara) and non-pigmented brown rice (RNR 29325) samples were collected from Telangana State of India during November and December of 2022 and 2023 for conducting the study. Dehusking of the paddy was done to produce brown rice (BR), using Satake THU-10A, lab scale model (Specifications of the machine include rubber roller dehusking mechanism, which runs with 100V, single-phase and motor power of 40 watts).

Germination procedure

BR of RNR 29325 and Navara rice varieties were subjected to soaking for 12 hours at 28±2ºC, followed by incubation at 28±2ºC. RNR 29325 variety was incubated for 24h, as per observations of Mohmmed *et al*., (2021) and Mohmmed *et al*., (2022). The incubation time for germination of pigmented Navara rice was established as 36 h based on a pilot study conducted to evaluate the best germination time with highest GABA content. The pigmented rice was subjected to germination at 28±2ºC for different time intervals of 12, 24, 36, 48 and 72 hours, and it was observed that highest GABA content was observed at 36hrs, and hence 36hrs soaking duration was selected for Navara rice variety. Followed by soaking, GBR samples were dried in a tray dryer at 50±3ºC until moisture content was less than 12%.

1000 grain weight (Sahay and Singh, 2005): 1000 grain weight was determined by counting one hundred Brown rice (RNR 29325 and Navara) seeds manually and weighing in grams using an electronic balance with a sensitivity of 0.001 mg. The obtained values were multiplied by a factor 10 to obtain 1000 grain weight

1000 grain volume (Kamatar *et al*., 2013): Thousand randomly selected brown rice (RNR 29325 and Navara) grains were dropped in a measuring cylinder containing known volume of distilled water. The difference in volume was recorded in ml.

Length-breadth ratio (Sharma and Gujral, 2010): Ten randomly selected brown rice (RNR 29325 and Navara) grains were measured for their length and breadth using a graph sheet. The L/B ratio was calculated by dividing length with breadth.

Colour (AOAC, 1998): The colour of RNR 29325 and Navara grains were measured with a spectro colorimeter (Hunter lab Colour flex, Firmware versions 1.1, Reston, Virginia) with a measuring aperture of 36 mm. Calibration was accomplished prior to each trial with manufacturer supplied white, green and black tiles. A circular glass cuvette was used to contain the sample for measurements. The results were expressed as tristimulus values: L*, lightness (0 = black, 100 = white), a* (−a = greenness, +a = redness) and *b (−b = blueness, +b = yellowness).

Bulk Density (Stojceska *et al.*, 2008): 100 ml measuring cylinder was taken and weighed (W_1). Grain samples were filled into the measuring cylinder up to 100 ml mark. The weight of the sample filled into the measuring cylinder was noted(W_2) and the process was repeated thrice. The unit of measurement was g/ml.

$$\text{Bulk density} = \frac{(W_2 - W_1)\text{ in g}}{\text{Volume (ml)}}$$

Tapped density (Narayana and Narasinga, 1984): Grain samples were weighed (W_1) into a 100ml graduated measuring cylinder and thengently tapped to eliminate spaces between the sample and reweighed (W_2) in triplicates. The unit of measurement is g/ml.

$$\text{Tapped density} = \frac{(W_2 - W_1)\text{ in g}}{\text{Volume of sample before tapping (ml)}}$$

Amylose content: Amylose content of the sample was determined by the method given by Juliano (1971). 100 mg of sample was taken in a beaker and 1 ml 95% ethanol and 9 ml of 1N NaOH was added to the sample and the sample was kept in boiling water bath for 15 minutes. Then the sample was cooled, and volume was made upto100 ml. From this, 5ml of sample was drawn to another conical flask and to that 1ml of 1N acetic acid and 2ml iodine solutions were added and the volume was made up to 100 ml and the samples were kept in dark for 20 minutes. The absorbance of the samples was read at 620 nm in a spectrophotometer and the value of amylose was calculated from the standard graph.

Length–breadth ratio of cooked grain (Hamid *et al.*, 2016): The cumulative length and breadth of ten cooked grains was measured after cooking for minimum cooking time using a graph sheet.

Water uptake ratio (Subedi *et al.*, 2016): BR, GBR and CPT GBR grains weighing 5.0 g were cooked in 100.0 ml distilled water for minimum cooking time. The cooked grains were strained to drain the excess cooking water and the adhering superficial water present on the cooked grain was removed by lightly pressing the cooked samples between filter paper. The samples were weighed and water uptake ratio was calculated as the ratio of weight gained after cooking to weight before cooking.

Cooking time (Wani *et al.*, 2013): 20.0 g of BR, GBR and CPT GBR grains were added to 500.0 ml boiling water in a beaker. The boiling continued and softness of seeds was tested by pressing between finger and thumb at regular intervals. The time from addition of seeds till achievement of the desired softness was noted down as the cooking time.

Statistical analysis

The generated data was subjected to completely randomized design (CRD) using SPSS version 23 (SPSS, IBM, Chicago USA) and means were separated using the Duncan multiple range test. The values obtained are presented as mean ± standard deviation of three parallel measurements. Significant differences among different treatments were accepted at 95% confidence interval ($p< 0.05$).

Results and Discussion

Physico chemical properties

The corresponding 1000 grain weight of BR and GBR are (17.71±0.03 g, 16.95±0.03 g) and (16.36±0.11 g, 16.16±0.01 g) whereas volume of BR and GBR were (15.63±0.06 ml, 14.50±0.41 ml) and (13.00±0.82 ml, 13.00±0.00) respectively as given in tables 1 and 2 of RNR 29325 and Navara varieties. Statistically there was significant difference ($p \leq 0.05$) between the samples due to drying of grains after germination. The 1000 grains weight indicated the density of grains and was directly related to bulk density (Rao *et al.*, 2019). The decreased GBR count than BR indicated that grain density was lowered after germination as complex components were reduced to simpler and easily digestible ones. The grain length of RNR 29325 was 6.67±0.09 mm, which was longer than the grain length of Navara (5.53±0.02 mm). Figure 1 shows the relative breadths of RNR 29325 and Navara, which are 1.93±0.01 mm and 2.40±0.01 mm. The length and breadth of RNR 29325 and Navara grains increased after germination, resulting in significant changes in the length-to-breadth ratios of the grains.

Compared to brown rice, germination showed significant variations in 1000 kernel weight, volume, length and breadth of rice grains. Jiamyangyuen and Ooraikul, (2008) stated that rice soaked for 12 h and germinated for 24 h showed size expansion in length and breadth compared to ungerminated rice.

Color is a crucial criterion for sensory quality, as it is the first factor consumers consider when evaluating a food. According to Dury *et al.* (2007), grain quality is initially determined by this measure.

Hunter parameter L* represents (lightness ranging from 0 to 100 indicating black to white), a* (a* redness and -a greenness) and b* represents (b*; yellowness and -b; blueness). The maximum value for lightness is 100 indicating white. L* value of RNR 29325 and Navara grain was 61.90±0.25 and 37.53±0.40, whereas decreased L* value was observed after germination (57.68±0.71 and 34.73±0.14 respectively). L* is an approximate measurement of luminosity, which is the property according to which each colour can be considered as equivalent to a member of the greyscale, between black and white. The L* value shows that RNR 29325 and Navara are two distinct colors of grains. a* values of of RNR 29325 and Navara ranged from 4.35±0.04 to 4.57±0.17 and 15.00±0.58 to 16.30±0.21 respectively. The parameter a* is positive for reddish colours and negative for greenish colours. In this approach, pigmented grain (red color), Navara has the highest a* value compared to RNR 29325 (brown rice). b* values of RNR 29325 and Navara grains were 20.53±0.27 and 15.23±0.61 respectively. b* takes positive values for yellowish colours and negative values for the bluish ones. The results of b* values (positive values) of both the samples indicate presence of yellowness in the RNR 29325 and Navara grains. It was observed that germination increased the b* value of RNR 29325 (21.71±0.17) and Navara (16.49±0.18). These results found that the germination process greatly influenced grain color of RNR 29325 and Navara varieties. Enzymatic processes during germination may cause starch and protein breakdown into simple sugars and amino acids. Sugar and amino acids can cause the maillard reaction, resulting in lightness and yellowness values in GBR (Islam *et al.*, 2012).

Bulk density determines storage and transportation capacity, packaging requirements and the weight of grains. It was observed that germination led to significant ($p \leq 0.05$) reduction in the bulk and tapped density of RNR 29325 (0.76±0.01 to 0.64±0.01 g/ml, 0.85±0.01 to 0.81±0.01 g/ml) and Navara (0.81±0.01 to 0.75±0.00 g/ml, 0.89±0.00 to 0.80±0.00 g/ml) respectively. Abioye *et al.* (2018) found that after 24 hours of germination, the bulk density of finger millet decreased from 0.48 to 0.46 g/ml listed in tables 1 and 2. Desikachar (1980) found that germination is an effective way to prepare low-bulk weaning foods. Tapped density along with bulk density can be used to measure anatomy and packing of grains for transportation and storage (Singh and Goswami, 1996).

Amylose content

Amylose content plays a significant role in determining eating quality of rice and it is used as a parameter for the texture of cooked rice (Suwannaporn *et al.*, 2007). A significant ($p < 0.05$) decrease in amylose content was observed in GBR of RNR 29325 (16.57±0.71 to 15.12±0.41 %) and Navara (19.48±0.41 to 17.44±0.00 %). Our findings are consistent with Wu *et al.*, (2013), who discovered a decrease in amylose content during brown rice germination. Amylose content is an important parameter for rice quality as it directly affects kernel firmness and inversely affects stickiness and glossiness of the cooked grain (Sujatha *et al.*, 2004). It has been found that the amount of amylose has a negative link with stickiness and a positive correlation with hardness (Juliano, 1992; Windham *et al.* 1998). These results showed that germination might actually increase the stickiness of BR while decreasing its hardness, indicating that GBR would be more palatable than BR when the amylose content was reduced.

Cooking quality parameters

After germination, the length, breadth and water uptake ratio of the RNR 29325 and Navara grains increased, while the cooking time reduced. Water absorbed by kernels during germination resulted in size expansion. Juliano (1979) reported that the elongation of the rice kernel may be due to the starch swelling during cooking with the water uptake. After germination water uptake ratio increased in RNR 29325 from 3.03±0.01 to 3.55±0.01 and in Navara 3.45±0.01 to 3.96±0.01. In RNR 29325 cooking time reduced from 36.67±0.47 to 33.67±0.47 minutes. Navara (41 min) took more time for cooking than RNR 29325 (36 min), germination reduced cooking time in Navara from 41.67±0.47 to 36.67±0.47 minutes. According to Gai (2003), rapid cooking is helpful because it avoids exposing grains to high temperatures for extended periods, which can cause protein breakdown. Cooking time significantly impacts the tenderness and stickiness of cooked grains. Germinated brown rice require less cooking time because of its lower grain hardness, relatively porous grain structure that facilitates faster water absorption into the kernel and the dissociation of complex nutrients into simpler ones, which speeds up cooking (Patil and Khan, 2012; Mridula *et al.*, 2015). The results obtained were on par with the findings of Jiamyangyuen and Ooraikul, (2008), where the cooking time of brown rice decreased from (19.2 to 12.8 minutes) after germination.

Conclusion

Germination had a significant effect ($p < 0.05$) on physico-chemical and cooking quality parameters of RNR 29325 and Navara grains, as it was confirmed from the results obtained from the study. It was observed that increase in length and breadth of the grains, indicating water absorbed by kernels during germination resulted in size expansion. A significant decrease in 1000 grain weight, volume, bulk density and tapped density was observed in GBR grains compared to their respective BR's of RNR 29325 and Navara. Amylose content and cooking time reduced in GBR indicating that GBR would be more palatable than BR as these impacts the tenderness and stickiness of cooked grains. Results from this study may be used to promote a greater consumption of GBR. The intake of GBR ameliorates health in many ways, due to its nutritional composition as compared to ordinary BR or polished rice. The change of staple food from polished rice to GBR can maintain and promote the healthy life and improve the quality of life.

The GBR technology transfer should be planned for empowerment of rural people, rice processors and producers, which in turn could transform them into successful entrepreneurs with GBR processing units. The method for making GBR is quite simple, as depicted in the study. South Indian states which produce high volumes of rice, should ensure production of GBR as a value-added product instead of promoting BR. If successful on its generation and dissemination part, this technology will prove to be boon for the rice growers in India.

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Table 1 : Physico chemical and cooking quality parameters of RNR 29325 variety

Variety RNR 29325	1000 grain		Length (L) mm	Breadth (B) mm	L/B ratio	Colour			Bulk Density (g/ml)	Tapped Density (g/ml)
	Weight (g)	Volume (ml)				L*	a*	b*		
BR	17.71±0.03[b]	15.63±0.06[b]	6.67±0.09[a]	1.93±0.01[a]	3.44±0.03[a]	61.90±0.25[b]	4.57±0.17[b]	20.53±0.27[a]	0.76±0.01[b]	0.85±0.01[b]
GBR	16.36±0.11[a]	13.00±0.82[a]	7.27±0.09[b]	2.00±0.01[b]	3.63±0.05[b]	57.68±0.71[a]	4.35±0.04[a]	21.71±0.17[b]	0.64±0.01[a]	0.81±0.01[a]
Grand Mean	17.03	14.31	6.96	1.96	3.53	59.79	4.45	21.11	0.69	0.83
SE of Mean	0.30	0.64	0.14	0.01	0.04	0.97	0.07	0.28	0.02	0.01
C.D	0.43	2.61	0.49	0.05	0.17	1.39	0.37	1.25	0.01	0.01
CV (%)	0.72	5.19	2.03	0.83	1.44	0.66	2.38	1.68	0.58	0.61

Variety RNR 29325	Amylose content (%)	Kernel length after cooking mm	Kernel breadth after cooking mm	Water uptake ratio	Cooking time (minutes)
BR	16.57±0.71[b]	8.32±0.08[a]	2.10±0.12[a]	3.03±0.01[a]	36.67±0.47[b]
GBR	15.12±0.41[a]	8.63±0.12[b]	2.40±0.08[b]	3.55±0.01[b]	33.67±0.47[a]
Grand Mean	15.84	8.47	2.25	3.29	35.16
SE of Mean	0.32	0.06	0.06	0.11	0.67
C.D	0.02	0.04	0.04	0.01	0.00
CV (%)	0.04	0.14	0.54	0.12	0.00

Note: Values are expressed as mean ± standard deviation of three determinations. Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$

L* (whiteness/brightness), a* (redness/greenness), b* (yellowness/blueness)

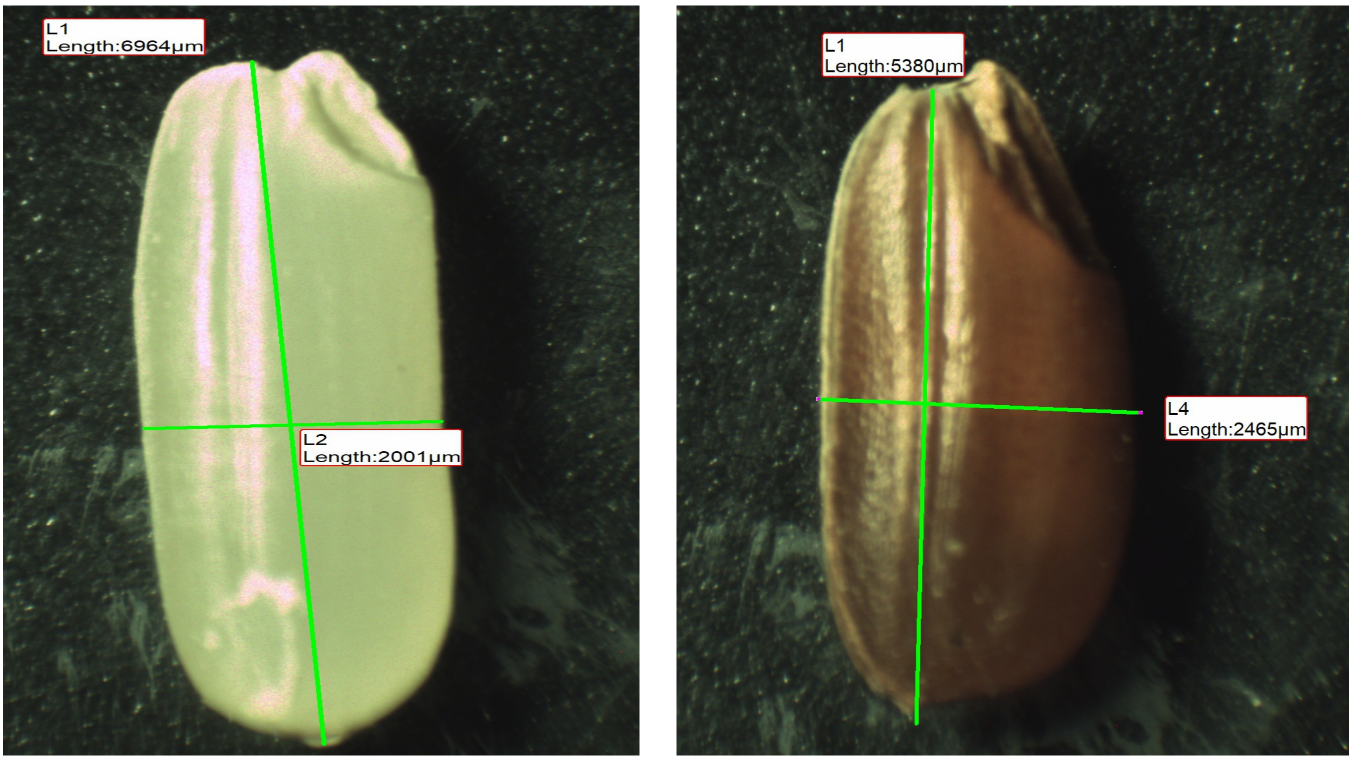
L/B ratio = Length/Breadth ratio

Table 2 : Physico chemical and cooking quality parameters of Navara variety

Variety NAVARA	1000 grain		Length (L) mm	Breadth (B) mm	L/B ratio	Colour			Bulk Density (g/ml)	Tapped Density (g/ml)
	Weight (g)	Volume (ml)				L*	a*	b*		
BR	16.95 ± 0.03^{b}	14.50 ± 0.41^{b}	5.53 ± 0.02^{a}	2.42 ± 0.02^{a}	2.28 ± 0.01^{b}	37.53 ± 0.40^{a}	15.00 ± 0.58^{a}	15.23 ± 0.61^{a}	0.81 ± 0.01^{b}	0.89 ± 0.00^{b}
GBR	16.16 ± 0.01^{a}	13.00 ± 0.00^{a}	5.65 ± 0.04^{b}	2.52 ± 0.02^{b}	2.24 ± 0.01^{a}	34.73 ± 0.14^{b}	16.30 ± 0.21^{b}	16.49 ± 0.18^{b}	0.75 ± 0.00^{a}	0.80 ± 0.00^{a}
Grand Mean	16.55	13.75	5.59	2.47	2.26	36.13	15.65	15.85	0.78	0.84
SE of Mean	0.17	0.35	0.03	0.02	0.00	0.64	0.35	0.34	0.01	0.01
C.D	0.08	1.24	0.17	0.05	0.01	1.22	1.13	1.41	0.04	0.06
CV (%)	0.15	2.57	0.88	0.59	0.18	0.96	2.06	2.53	1.56	1.58

Variety NAVARA	Amylose content (%)	Kernel length after cooking mm	Kernel breadth after cooking mm	Water uptake ratio	Cooking time (minutes)
BR	19.48 ± 0.41^{b}	6.63 ± 0.09^{a}	2.53 ± 0.05^{a}	3.45 ± 0.01^{a}	41.67 ± 0.47^{b}
GBR	17.44 ± 0.00^{a}	7.27 ± 0.09^{b}	3.17 ± 0.05^{b}	3.96 ± 0.01^{b}	36.67 ± 0.47^{a}
Grand Mean	18.46	6.95	2.85	3.70	39.16
SE of Mean	0.47	0.14	0.14	0.11	1.13
C.D	1.24	0.28	0.14	0.02	0.00
CV (%)	1.92	1.17	1.43	0.19	0.00

Note: Values are expressed as mean ± standard deviation of three determinations. Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$
L* (whiteness/brightness), a* (redness/greenness), b* (yellowness/blueness)
L/B ratio = Length/Breadth ratio



RNR 29325 **NAVARA**

Fig. 1: Length and breadth of RNR 29325 and Navara grain in μm

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