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NLR RICE 3238: A SHORT DURATION ZINC ENRICHED RICE VARIETY SUITABLE FOR IRRIGATED ECOLOGY OF ANDHRA PRADESH, INDIA

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ABSTRACT

The Study was conducted during 2004-2018 at Agricultural Research Station and continued upto 2022 at farmers fields of Andhra Pradesh with an objective of developing high yielding, short duration, photo-insensitive, blast tolerant rice variety with good cooking quality. The zinc enriched rice variety NLT3238 is a high yielding, early maturing (120-125 days), photoinsensitive with high yield potential (7016 kg/ha) medium slender grain type having moderately resistance to leaf blast disease with better adaptability. The rice variety NLR 3238 was a derivative from the cross between BPT 5204 x MTU 1010 (5695-21-1-3-2-1-1) through conventional pedigree method of breeding. It exhibited an average yield advantage of 35.7% over the popular rice variety NLR 34449 (Nellore Mahsuri) in three years of testing at station yield trials. In the multilocation testing of short duration rice varieties trial it exhibited 6.32% improvement over the common check MTU 1010 during *kharif* season. In AICRIP testing it recorded 5.5% yield increase over BPT 5204 & 13.4% over IR 64 with grain yield of 5466 kg ha^{-1} and it recorded 93 days to 50% flowering possessing medium slender grain ranked first on overall mean. In minikit testing at farmer's fields, it was found 8.13% superior over the check variety. It has strong culm, non-lodging in nature, with medium green foliage, low shattering and complete exertion of panicle. It possesses good cooking and chemical quality as it exhibits intermediate and desired values of ASV, gel consistency, good linear elongation ratio and amylose content. It also possesses 24.7ppm of zinc in polished rice with good head rice recovery and translucent grains which is very much desired for marketing.

Key words : Rice variety, Biofortified, Zinc rice.

Introduction

Rice is staple food for more than one third of world's population. Globally rice crop is estimated to cover 164.7 million acres (Anonymous, 2013). Asia accounts for 90–92% of total rice acreage and is a major producer and consumer of rice (Arouna *et al*., 2021). Rice is the major crop in n Andhra Pradesh state where rice crop was grown in an area of 25 lakh hectares. It is the staple food for 52 million populations where the per-capita consumption of rice is 72 kg $year^{-1}$. With the advent of dwarf gene Dee geo woo gen, the short statured rice varieties played a crucial role in yield improvement especially in case of rice crop (Ramesh Babu, 1999). Today the journey has reached to self-sufficiency level in rice production from starved and great famine conditions. At the time of green revolution, getting more yield is the prime criteria to feed the population. Slowly the concept has become changed to quality concern during 1980s with the development of rice variety like BPT 5204 etc. Finally, we achieved many mile stones in rice production with the great and concerted efforts of scientists. In the present context, development of nutritious rice is getting much attention both at national and international level as rice is the staple food for more than

one third of the world's population (Bouis (2000). If we increase a little quantity of the essential micronutrients in the polished rice, it may fetch a lot to the poorest of the poor (Senguttavel, 2023). Among the essential micro nutrients iron, zinc and protein plays a major role in various essential physiological functions of the body which we can increase in the grain of rice.

According to World Health Organization, iron (Fe) and zinc (Zn) are among the most important micronutrients; however, their availability is inferior in most diets (Anonymous). Nearly 31% of the world's population suffers from Zn deficiency (Hoddinott, 2013). It is the major *viz*., 5th and 11th important cause for illness and diseases in developing countries and in the World respectively (Caballero, 2002). The deficiency of zinc element in soils is estimated to be 12% and it causes respiratory diseases and diarrhoea leading to around 4 lakh death per annum across the globe (Matres, 2021; Yilmaz, 2006). Zinc deficiency is mainly associated with poor growth, loss of appetite, delayed healing of wounds, formation of lesions on skin, delayed sexual maturation, hypogonadism and loss of immune response. (Datta, 2010) India has the highest number (61.7 million of the 162 million in the globe) of stunted children under the age of 5 years (NFHS-5, 2020).

The polished grains of high yielding rice varieties contain lesser amounts of nutrients, polishing reduces the nutrient content like iron and zinc in the grain (Masuda, 2009). The bio fortification means enhancing availability of micronutrient content of food crops through plant breeding. It is the promising and viable strategy to address the nutritional security and provide nutrition to every poor person of the country to overcome malnutrition and lack of essential nutrients in women, children, lactating mothers (Bouis, 2010).

In the changing climate scenario, development of short duration rice varieties (120-125 days) with lodging resistance is the major objective for the modern plant breeders which can fit in various cropping systems where the supply of water is for a limited time (Bagchi *et al*., 2012; Hazell, 2010; Bueno and Lafarge, 2017).

In view of the above, Agricultural Research Station, Nellore, ANGRAU has developed a rice variety NLR 3238 with high zinc content (24.7ppm). whereas in general rice varieties possess zinc content ranges from 14–16 ppm.

Materials and Methods

The study was conducted during 2004-2018 at Agricultural Research Station and continued upto 2022 at farmers fields of Andhra Pradesh. The rice variety NLR 3238 was developed at ARS, Nellore, ANGRAU by following pedigree method of conventional breeding. It is derived from the cross between BPT 5204 (Samba Mahsuri) x MTU 1010 (Cotton Dora Sannalu). It is a short duration rice variety matures in 120–125 days. Being photo-insensitive in nature it can be grown throughout the year i.e., as a summer crop, kharif and rabi crop. It was tested for yield and its attributing traits at Agricultural Research station during 2010–11 to 2012–13 for three years. It was tested in state level multilocation testing in ANGRAU during 2013 and 2018 in early group. NLR 3238 was given for testing in AICRIP during 2014 under Irrigated mid early group (Initial Varietal Trial) and it was tested under bio fortification trial during 2015 and 2016 as IET 24336. It was screened for three years for pests and diseases in NSN-II and NSN I during 2014 and 2015, 2016 respectively. It was tested for agronomic traits like fertilizer responsiveness at ARS, Nellore during 2016, 2017 and 2018 and at AICRIP testing during 2016. Finally, it was given for minikit testing at farmer's fields in ten districts of Andhra Pradesh where paddy crop was grown in rabi season for three years from 2019–2020 to 2021–2022 in 350 locations in each season in comparison with the popular check variety of that area. The quality parameters were checked at ARS, Nellore, IIRR and at RARS, Tirupati. NLR 3238 was deposited as an indigenous culture with NBPGR and got IC number for future reference. The DNA finger printing data was generated by Department of Molecular biology and Biotechnology lab, SV. Agricultural College, Tirupati, India.

Results and Discussion

The crossing between BPT 5204 x MTU 1010 was done during 2003. The best progeny was identified during F_6 generation following pedigree method of breeding. Later on, yield trials were conducted at station level for three consecutive years from 2010–11 to 2012–13 and it was recorded an average grain yield of 7382 kg ha^{-1} as against the check NLR 34449 (5438 kg ha^{-1}), which is 35.7% increase over the check. Yield is an example of quantitative traits whose expressions are strongly influenced by environments (Li *et al*., 2019). For that reason, multi-environment trials (METs) are needed to identify a superior genotype with stable and high yield potential, and as part of the final stages to release a variety. It was tested in multilocation trials during 2013 in 7 centres against the common check MTU 1010, where it recorded an average grain yield of 6408 kg ha^{-1} which is 7.63% increase over the common check (6027 kg ha^{-1}) variety used. In the year 2018–19 again it was tested in MLT at 4 centres against MTU 1121 (Common check variety) where it recorded 6257 kg ha^{-1} which is 3.42%

Table 1 : Performance of NLR 3238 : Grain yield.

S. no.	Name of the Trial	Year and season of testing	Grain yield (Kg/ha)			Percentage increase over check
			NLR 3238	Name of the Check	Check yield	
	Station trials					
1	OVT-E	2010 EK	7405	NLR 34449	5190	42.6
2	PVT-E	2011 EK	7157	NLR 34449	5190	37.8
3	AVT –E	2012 EK	7586	NLR 34449	5934	27.8
		Average	**7383**		**5438**	**35.7**
1	**Mulilocation testing**	2013-14	6408	MTU 1010	6027	6.3
2		2018-19	6257	MTU 1121	6050	3.4
		Average	**6333**		**6039**	**4.9**
1	**AICRIP testing**	2014	5235	BPT 5204	5008	4.5
2		2015	4598	IR 64	4278	7.5
3		2016	5466	IR 64	4900	11.55
		Average	**5100**		**4728**	**7.9**
1	**Minikit testing**	2019-20	7118	NLR 34449/ MTU 1010/ MTU 1121/ RNR 15048	6628	7.70
2		2020-21	7223		6669	9.49
3		2021-22	6708		6272	7.20
		Average	**7016**		**6523**	**8.13**

superior over the check (6198 kg ha^{-1}).

The capability of any variety was proven when it was tested under large scale area in the farmer's field. The culture was given for testing for three consecutive years from 2019–20, 2020–21 and 2021–22 under minikit testing in each 350 locations per annum in the farmer's fields. In minikit testing the culture was evaluated against respective rice varieties grown in that particular area in different districts of Andhra Pradesh where it recorded an average grain yield of 7016 kg ha^{-1}against the checks 6523 kg ha^{-1} which is 8.13% increase over the check. (Table 1).

During 2014 *kharif* season NLR3238 was nominated and tested as IET24336 along with 63 entries under IVT-IME trial in 32 centres all over India under AICRIP testing. It was tested along with three checks where it recorded an average grain yield of 5312 kg ha^{-1} as against the national check 4875 kg ha^{-1}. During 2015 it was tested in AVT-I bio fortification trial at 19 locations along with 4 checks viz., BPT 5204 (Yield- late duration), IR 64 (Yield – Mid early duration), Kalanamak & Chittimuthyalu (micro nutrient check) and the entry IET 24336 recorded 4248 (kg ha^{-1}) as against the national check variety check variety BPT 5204 (4278 kg ha^{-1}), Kalanamak (3159 kg ha^{-1}), Chittimuthyalu (3122 kg ha^{-1} and IR 64 (3872 kg ha^{-1}). (AICRIP annual progress report 2015).

Advance Variety Trial -2 Biofortification was constituted with 12 test entries promoted from AVT 1-Biofortification and the experiment was conducted at 23 locations. The zinc and iron contents in the polished grain were evaluated using XRF method. However, the locations with mean of 15.5 ppm and above were only considered. They are Ludhiana, Cuttack, Raipur, Sakoli, Karjat, Navasari, Shirgaon, Maruteru, Aduthurai, Moncompu and Brahmavar; while the data from IIRR, Nawagam, Rewa, Kolkata, Malan and Coimbatore were not included in the mean since the location mean was less than 15.5 ppm at these locations. On overall mean, two entries IETs 24336 and 24783 recorded the required yield superiority over the best check. IET 24336 found promising in Gujarat and Chhattisgarh (Annual progress report, 2016).

Disease and pest reaction

The culture was tested for various diseases at Agricultural Research Station, Nellore from 2010–2012 and it showed prominent tolerant reaction to leaf blast disease (Table 3) In AICRIP testing during 2014 it was tested in NSN 2 nursery, and during 2015 and 2016 under NSN 1 nursery where it was found tolerant for leaf blast disease (Table 2).

Table 2 : Reaction of NLR 3238 to different diseases at ARS, Nellore.

Year	Genotype	Leaf Blast	Neck blast	Bacterial Blight
2010	NLR3238	5.0	3.0	5.0
	NLR 34242 ©	8.0	7.0	7.0
2011	NLR3238	6.0	5.0	5.0
	NLR 34242 ©	9.0	9.0	9.0
2012	NLR3238	5.0	3.0	5.0
	NLR 34242 ©	9.0	7.0	9.0

- In the station screening trials it was found tolerant to leaf blast.

(1: Highly resistant; 3: Resistant; 5: Moderately resistant; 7: susceptible; 9: Highly susceptible. Scale: 0–9 of SES given by IRRI, 1996).

Table 3 : Agronomic Evaluation of NLR Rice 3238.
Response of NLR 3238 to Nitrogen fertilizer at ARS, Nellore.

N level	2016	2017	2018	Mean	Yield increase for every 40 KgN
N 40	5187	5284	5049	5173	0
N 80	5288	5359	5463	5370	197
N 120	5517	5739	5502	5586	216
N 160	5594	5830	5586	5670	84
Mean	5396.5	5553	5400	5450	

Agronomic evaluation

Among the four levels of nitrogen tested, NLR 3238 responds even up to 160kg N. the optimum dosage is 120 kg ha^{-1}. During 2016, in AVT2, 12 bio fortified cultures were evaluated in eleven locations in comparison with high yielding cultivars (Chittimuthyalu, IR 64 and Kalanamak and local check of respectively) under three recommended doses of N (RDN) i.e., 50,100 and 150% of RDN. Grain yields of the test cultures differed significantly at all locations except Nagina. IET 24336 recorded 6.77 t ha^{-1} at Kaul, 6.49 t ha^{-1} at Raipur and 5.03 t ha^{-1} at Maruteru locations and found to be significantly superior over the checks in the respective locations. Application of 150% N of RDN was found promising in all locations except Coimbatore and Maruteru while N dose of 100% of RDN was effective in most of the locations in terms of higher N response (Table 3).

Morphological features

The morphological features of the culture were given in the table 6. Important agronomic trait, earliness (120–125 days) is one of the objectives of the modern breeders, has an advantage of varieties to suit various cropping

Table 4 : Morphological description of NLR 3238.

S. no.	Trait / Character	Description
1.	Plant height	90-100 cm
2.	Habit	Erect
3.	Days to 50 % flowering	90-95 days
4.	Lodging	Non lodging
5.	Leaf blade colour	Medium Green
6.	Basal leaf sheath colour	Medium Green
7.	Leaf angle	Erect
8.	Flag leaf angle	Erect
9.	Leaf length	28 cm (medium)
10.	Leaf width	1.2 cm (medium)
11.	Leaf blade pubescence	medium
12.	Ligule colour	White
13.	Ligule shape	Split
14.	Ligule length	2.7 mm
15.	Auricle colour	Pale green
16.	Collar colour	Pale green
17.	Culm angle	Erect
18.	Flag leaf angle	Erect
19.	Culm internode colour	Green
20.	Panicle length	22cm
21.	Panicle type	Compact
22.	Panicle exertion	Well exerted
23.	Awns	Absent
24.	Apiculus colour	Straw
25.	Stigma colour	White
26.	Lemma palea colour	Straw
27.	Lemma palea pubescence	Slightly present
28.	Seed coat colour (bran)	Straw
29.	Sterile lemma colour	Straw
30.	Senescence	Late
31.	Grain type	Medium slender
32.	Grain length (mm)	8.8
33.	Grain breadth (mm)	2.3
34.	Kernel length (mm)	5.9
35.	Kernel Breadth (mm)	2.1
36.	L/B ratio	2.8
37.	Hulling (%)	78
38.	Milling (%)	70
39.	Head Rice Recovery	62
40.	1000 grain weight	20g
41.	Chalkiness	Absent
42.	Gelatinization temperature	Intermediate
43.	Kernel elongation ratio	2.1
44.	Keeping quality	Good
45.	Grain shattering	<2%
46.	Flowering duration (days)	8-10
47.	Dormancy (weeks)	-
48.	Harvest index	60-65
49.	Filled grains/panicle	200-220
50.	Tillering ability	Moderate (7-14)

Table 5 : Grain Quality data of NLR Rice 3238.

S. no.	Character	NLR 3238	BPT 5204
1.	Grain type	Medium slender	Medium slender
2.	Kernel length (mm)	5.9	4.98
3.	Kernel Breadth (mm)	2.1	1.85
4.	L/B ratio	2.8	2.69
5.	Hulling %	78	75.67
6.	Milling %	70	67.21
7.	Head Rice Recovery	62	60.37
8.	Test Weight (gm)	20	14.6
9.	Rice Grain Type	Medium slender	Medium slender
10.	Grain Chalkiness	VOC	VOC
11.	Amylose content	24	23.4
12.	Alkali spreading value	3.5	4.0
13.	Water uptake	250	130
14.	Volume expansion ratio	4.5	3.3
15.	Kernal elongation ratio	2.1	1.74
16.	Gel consistency	40	24
17.	Aroma	NS	NS
18.	Zinc content (ppm)	24.72	16

(Zinc content was estimated at soil science lab, RARS, Tirupati through AAS method)

situations, especially where the water supply is a limited period of time (Bueno and Lafarge, 2017; Siddi *et al.*, 2022). The culture flowered 90–95 days after sowing and it grows upto a height of 90–100cm and bearing 12–15 tillers plant^{-1} which possess medium green leaves. The panicle length is 22cm and the grains were in straw colour. The leaves were erect and showing delayed senescence at the time of maturity. Each leaf is 28cm long and having a width of 12mm. Each panicle was fully exerted from the boot leaf and comprises 220 grains panicle^{-1}. The harvest index ranges from 60–65% (Table 4).

Quality features

In countries where rice is widely consumed, grain quality has a central role in the adoption of new varieties (Nirmaladevi *et al.*, 2015). Consumer preferences for grain quality vary from region to region (Custodio *et al.*, 2019). The grain quality is determined by physical and chemical properties which are highly influenced by genetics, aside from environmental factors (Han *et al.*,

Table 6 : Results of Organoleptic Test (No. of participants: 50).

1.	Appearance	Creamish
2.	Cohesiveness	Partially separated
3.	Tenderness	
a)	Touching	Medium soft
b)	Chewing	Soft
4.	Taste	Desirable
5.	Aroma	Absent
6.	Elongation	Moderate
7.	Acceptance	Good

The quality of cooked rice is very good with flaky, fluffy, non-glutinous and medium soft in nature.

Table 7 : Nutritional composition of NLR Rice 3238.

S. no.	% Matter	NLR 3238	BPT 5204
1	Zinc	24.72 ppm	16 ppm
2	Crude Protein	10.47	8.13
3	Total carbohydrate	76.23	80.86
4	Crude fat	0.98	0.48
5	Crude fibre	0.72	0.81
6	Moisture	10.88	10.28
7	Ash	0.72	0.25

2021). Grain size is a key breeding target as it influences yield and quality (Wang *et al.*, 2012). The grain length-width ratio fundamentally shape is classified as bold, medium, and slender. Most genotypes had the grain shape slender which is the preferred shape by consumers from India (Velasco *et al.*, 2015 and Aswidinnoor *et al.*, 2023). Chalky is an opaque area in the grains, resulting in a lower eating quality and higher than 2% of chalkiness is not accepted in markets (Lisle *et al.*, 2000). Amylose is hydrophobic due to its straight molecular shape. The genotypes with low amylose content had higher water uptake and makes the texture fluffier, as it easier to leach out during cooking time. Such grain texture has been widely accepted by consumers in South Asia (Mackill and Khush, 2018).

The culture NLR 3238 is a medium slender culture with a grain length of 8.8mm, width 2.3mm and the kernel length of 5.9mm, breadth 2.1 whereas the kernel L/B ratio was 2.8. Quality wise, it recorded 62.0% head rice recovery, which is in similar to the findings of Robin *et al*. (2019), who reported a significant positive association of head rice recovery with milling outturn. Absence of grain chalkiness and good kernel elongation ratio of 2.1 and volume expansion of 3.3 shows the good sign for cooking quality of the rice. The grain size belongs to medium slender group and the amylose content (24) and

gel consistency (40mm) were also under desirable limits (Table 5). In the organoleptic test conducted by the group of people and it was found to that the rice was flaky, non-sticky and good compatibility with curries while eating i.e., good relish ability. Sanjeeva Rao *et al.* (2020) also reported that the culture IET 24336 possess a good head rice recovery of more than 60%, intermediate amylose content and soft gel consistency provided having good yielding ability.

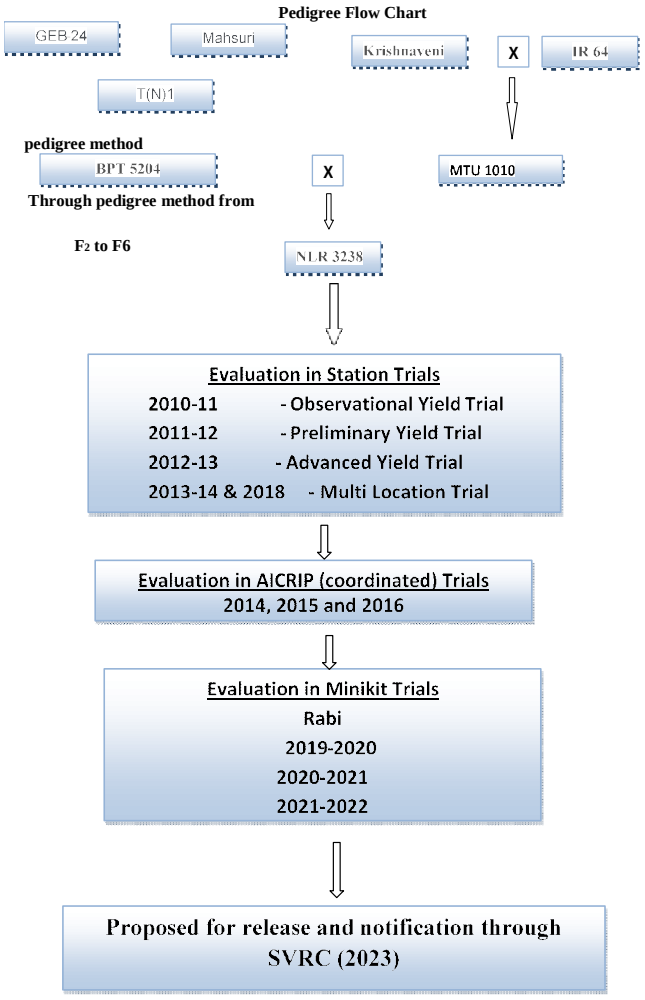
A small quantity of micronutrient increase in polished grain leads to much impact while consumption especially in case of rice (Swamy *et al.*, 2016). Nutritional composition of NLR 3238 revealed that it has a carbohydrate of 76.23%, 10.47% of crude protein, 24.7ppm of zinc, 0.98% fat and 0.72% fibre was present in 100g polished rice (10% polished rice) (Table 6).

Monetary benefits

Additional advantage of 7.5ppm zinc in polished grain over the best popular rice variety. The culture is non-lodging in nature, saves labour cost and cost incurred in machine harvesting 5000 ha^{-1}. It has tolerance to blast disease which can reduce the 2–3 sprays cost 1750 ha^{-1}.

Moreover 5–7% yield improvement which in-turn fetches better price to the farmers at 9000 ha^{-1}.

Flow chart details of NLR 3238



Conclusion

NLR 3238 is a short duration variety possess good yielding ability at station level and also at farmers' fields, good milling and cooking quality traits along with blast resistance, possessing good nutritional qualities in polished rice, suitable to sow during early kharif and rabi seasons it was found to be suitable to cultivate in the irrigated rice ecology of Andhra Pradesh state.

Further Research

NLR 3238 may be utilized directly as a biofortified rice variety for consumption. It may be utilized for further breeding programmes to improve yielding ability as well as micronutrient simultaneously.

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