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Biofortified Red Rice Variety Lalkada Gold (GNR-9) for Cultivation in Gujarat State

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ABSTRACT: Lalkada traditional rice culture cultivated in South Gujarat, known for its nutritional quality traits but poor yielder, prone to lodging and susceptible to disease and pests. To overcome these challenges, we developed an improved, early-maturing variety, GNR 9 (Lalkada Gold). This variety is a result of a cross between IR 28 and Lalkada, achieved through pedigree breeding. GNR 9 retains the superior nutritional traits of Lalkada while offering better resistance to environmental stressors and improved yield potential. Nutritionally rich red rice variety GNR-9 (Lalkada Gold) recorded average grain yield of 4200 kg/ha where it exhibited overall 40.4 and 19.7 % superiority over check varieties Lalkada and GNR-4, respectively. Long slender grain rice variety GNR-9 contains intermediate amylose (21.5%), high head rice recovery (56.24%), high Protein 8.44%, 3.4 ppm Iron and 19.17 ppm Zinc in polished rice. Also variety was tested in AICRIP trials during *Kharif* 2019 showed 0.4, 6.9 and 23.2 per cent yield superiority over national yield check IR 64, DRR Dhan 45 and Chittimuthyalu, respectively.

Keywords: Biofortification, iron, protein, Red rice, yield, zinc, Lalkada Gold.

INTRODUCTION

India's food grain production breaks all its past records and reached new milestone 329.68 MT for year 2022-23 (Anonymous, 2023). India's agriculture exports touched a historic high of USD 50 billion for financial year 2021-22 (Anonymous, 2022). In the Gujarat state rice occupies about 5% of the gross cropped area of the State and account for 14% of the total food grain production is grown in about 9.47 lakh hectare with production of 23.96 lakh tones with the productivity of 2529 kg/ha. Rice accounts for 35-75% of the calories for more than 3 billion Asians. Globally, it provides 27% of dietary energy, 20% of dietary protein and 3% of dietary fat (Pathak *et al.,* 2018).

Green revolution transformed India from a food-deficit nation to a food-surplus country. Though, food security is achieved, breeding for high yielding varieties is remaining core objective due to rising population across India and global level. By 2050, India will surpass China as the most populous country in the world, with an estimated 1.67 billion people (PRB, 2021). Selective breeding for high yield inadvertently bred nutritionally poor food grain due to biological trade-off between yield and mineral concentration. This leads to malnutrition of minerals and protein across population. India loses 4% of its GDP annually due hidden hunger (Seth and Jain 2021). Although various avenues such as dietary-diversification, food-fortification and medical-supplementation are available, biofortification of crop varieties is considered as the most sustainable and cost-effective approach where the nutrients reach the target population in natural way (Chattopadhyay *et al.,* 2018).

Anemia is the most common human nutritional malaise, resulting from iron (Fe) deficiency. The recent finding from NFHS-5 report 2019-21 revealed that, 35.5 per cent of children under five years are stunted and at least 67 per cent children (6-59 months) and half of women population under 49 age are anemic in India. An Anemia is a serious concern for children because it can impair cognitive development, stunt growth, and increase morbidity from infectious diseases. The stunting in children's is due undernourished and anemic mother and it worsens when infants' diets are poor, and when sanitation and hygiene are inadequate (UNICEF India Programme 2021). Zinc biofortification is crucial for growth, immune function, and reducing the risk of diarrhea and respiratory infections, especially in children.

Traditional rice varieties are known for their nutritional benefits and unique quality traits. Among them, "Lalkada," a traditional rice variety grown in South Gujarat, commands a premium price due to its red rice kernels rich in essential nutrients like iron and zinc. However, it has significant drawbacks, including low yield, susceptibility to lodging, and vulnerability to diseases and pests. So there is need for a variety that addresses these issues, providing better yields, resistance to lodging, and tolerance to various biological stresses. To address the issue we released a bio-fortified, semi-dwarf variety, "Lalkada Gold." This new variety not only enhances yield but also plays a

vital role in combating malnutrition through its superior nutritional profile.

MATERIAL AND METHODS

The Lalkada Gold is a derivative of cross between IR 28 × Lalkada developed through pedigree breeding at Regional Rice Research Station, Navsari Agricultural University, Vyara. The F1 was made during the year *Kharif* 2014. From F2 to F5 handled as pedigree breeding. Single panicle per plant selected for desired characteristics was carried out during this period. Furthermore it is forwarded as single plant to progeny rows. This culture was evaluated with checks in Preliminary Evaluation Trial (PET) at Vyara and in Small Scale Varietal Trial (SSVT) and Large Scale Varietal Trial (LSVT) at Vyara, Navsari, and Bardoli during *Kharif* 2017-2020. This culture was also tested in AICRIP trial (IVT-Biofort) overall 19 locations during Kharif 2019. Days to 50 percent flowering, productive tillers per plant, panicle length and grain and straw yield data was collected by different research station across state in biofortified segment trials. This culture was screened for major diseases and pests reactions under protected and unprotected conditions. Statistical analysis for Randomized Block Design (RBD) was carried out for comparison with checks varieties for test of significance. Grain quality data generated by following Standard Evaluation System for Rice (SES) developed by International Rice Research Institute (IRRI).

RESULTS AND DISCUSSION

Yield and Quality: The yield and its contributing traits evaluation was carried out during 2017-2020 and data are presented in Table 1. In *Kharif* 2017 Preliminary Evaluation Trial (PET-Biofort) conducted at Vyara, GNR-9 recorded 3390 kg/ha grain yield which was significantly higher than both lalkada and GNR-4. In *Kharif* 2018 SSVT Trial conducted at three locations Vyara, Waghai and Bardoli. GNR-9 recorded yield 5156 kg/ha which was significantly higher than lalkada at Vyara location but statistically at par with GNR-4 at all three locations. In *Kharif* 2019 LSVT trial GNR-9 average percent increase in yield over GNR-4 was 36.9 percent which is exhibit genetic potential of GNR-9 over checks varieties. Nutritionally rich red rice variety GNR-9 (Lalkada Gold) recorded overall average grain yield of 4200 kg/ha where it exhibited overall 40.4 and 19.7 % superiority over check varieties Lalkada and GNR-4, respectively. Long slender grain rice variety GNR-9 contains intermediate amylose (21.5%), high head rice recovery (56.24%), hulling recovery (76.27 %) and milling recovery (71.18%). In all India co-ordinated trials during year *Kharif* 2019, it tested as IET 28699 across 19 locations in IVT-Biofort trial and showed 0.4, 6.9 and 23.2 per cent yield superiority over national yield check IR 64, DRR Dhan 45 and Chittimuthyalu, respectively (Table 2). GNR-9 contains high Protein (8.44%) which was higher than micronutrient checks DRR Dhan 45 (6.43%) and Chittimuthyalu (8.30%) in AICRIP Trials. GNR-9 recorded 3.4 ppm Iron and 19.17 ppm Zinc in polished rice (Table 3). Similarly, Chattopadhyay *et al.* (2018); Krishna Veni *et al.* (2024) improved protein content by conventional pedigree breeding method.

It possesses 6.67 mm kernel length with the kernel breadth of 2.21 mm having the L/B ratio of 3.02 categorize it in to long slender grain.

Reaction to Pest and Diseases: The newly developed strain shows moderate resistance to leaf blast, with a blast score of 3 under unprotected conditions. In comparison, the check varieties Lalkada and GNR-4 have a significantly higher score of 9, indicating greater susceptibility. This blast resistance in the proposed strain offers better protection against leaf blast, contributing to healthier crops and improved yields. Molecular marker screening for blast resistance was conducted, identifying key resistance genes *Pi54*, *Pitp(t)*, and *Pi67*. These genes were linked to the molecular markers RM 206, RM 246, and YL 87/155, respectively. This association highlights the genetic loci responsible for blast resistance. GNR-9 is moderately tolerant to stem borer, Leaf folder and sheath mite. Similar field screening for disease and pests was conducted by Jyoti *et al.* (2022).

Nutritional Deficiency and Bio Fortified Red Rice: In India people depend mostly on polished rice based foods as daily diet which is generally deficient in Iron and Zinc. Poor people can't afford to buy supplementary foods as well as fortified processed foods to have adequate supply of Fe and Zn. Diet involving biofortified rice helps in meeting daily requirement of Fe (8-11 mg per day for adults) and Zn (7–13 mg per day for adults) and thereby improving the health of human beings (Abbaspour *et al.*, 2014). Fortified red rice "Lalkada Gold" variety also have more protein (8.44%) than other variety. It gives additive advantages over other variety to consumer by cutting down other expense incurring due buying of supplementary foods for Fe and Zn. It acts as natural supplement for Fe and Zn without changing food habit of people. So fortified red rice variety Lalkada Gold is good alternative to mitigate iron and zinc deficiency among children, adolescent girls and boys, and pregnant or lactating womens. Sheoran *et al.* (2022) highlighted that biofortified crops have demonstrated positive outcomes in nutritional status. For instance, iron-biofortified rice has improved iron levels in women in the Philippines, and iron-biofortified beans have shown similar benefits in Rwandan women.

Sahu (2018) reported that anemia is more prevalent in rural and tribal area of India and Gujarat. Rice is main staple food of majority of Indian tribal people. So diets which include fortified mineral rich rice "Lalkada Gold" are boon for nutritionally poor people. It also serves the purpose of Sustainable Development Goals-2 Zero Hunger, target 2.2 talk about End all forms of malnutrition by 2030 (Abbaspour *et al.*, 2014). Biofortified varieties not only offer health benefits but also maintain good agronomic performance, making them appealing to farmers. The adoption of this variety by farmers creates a win-win scenario, benefiting both farmers and the public alike.

Table 1: Yield performance of rice variety GNR-9 (Lalkada Gold) in comparison with check varieties in the Gujarat State.

Season	Trial Name	Location	GNR-9	GNR-4 (C)	Lal Kada	S. Em. ±	CD	CV%
K-2017	**PET- Biofort**	Vyara	3390[ab]	2454	2310	308	881	15.0
		% In. Over	-	**38.1**	**46.7**	-	-	-
K-2018	**SSVT-Biofort**	Vyara	5156[b]	4468	2689	400	1153	15.8
		Waghai	4277	4095	3702	212	610	8.5
		Bardoli	4390	4856	3555	371	1084	17.3
		Mean	**4608**	**4473**	**3315**	-	-	-
		% In. Over	**-**	**3.01**	**39.00**	-	-	-
K -2019	**LSVT-Biofort**	Navsari	4617	4243	-	247	708	9.1
		Vyara	3685[a]	2382	-	321	919	14.7
		Waghai	3667[a]	2121	-	234	671	12.2
		Mean	**3990**	**2915**	**-**	-	-	-
		% In. Over	**-**	**36.9**	**-**	-	-	-
K-2020	**LSVT-Biofort**	Vyara	4425[a]	3450	-	234.7	664.5	14.7
		Navsari	3364	4196	-	383	1107	12.8
		Waghai	2038	2038	-	160	463	10.4
		Mean	**3276**	**3228**	**-**	-	-	-
		% In. Over	**-**	**1.49**	**-**	-	-	-
Overall mean(M1)			**4200**	**3508**	**-**	-		
% increase over GNR-4			**-**	**19.7**	**-**			
Overall mean(M2)			**4303**	**-**	**3064**			
% increase over Lal Kada			**-**	**-**	**40.4**			

[a] Statistically superior than GNR 4 and [b] Statistically superior than Lal Kada at 5% level of significance

Table 2: Performance of IET-28699 (Lalkada Gold) under IVT-Biofort trial at National Level (AICRIP) - 19 locations during *kharif* 2019.

Expt. & year	Name of entry	Grain yield (kg/ha)	% increase Over Chittimuthyalu (MNC)	Grain yield Zone III (kg/ha)	% increase over		
					NC	DRR Dhan 45	Chittimuthyalu
IVT-MS *Kharif*-2019	**IET 28699 (Lalkada Gold)**	**4298**	17.08	**4561**	0.4	6.9	23.2
	IR 64 (NC)	4484		4540			
	DRR Dhan 45 (YC & MNC)	5006		4268			
	Chittimuthyalu (MNC)	3671		3701			

Table 3: Protein and micronutrient contents in polished rice in IVT-Biofort (AICRIP trial) during *kharif* 2019.

Sr. No.	Name of the culture	Protein %	Zinc (ppm)	Iron (ppm)
1.	**IET 28699 (Lalkada Gold)**	8.44	19.17	3.4
2.	IR 64 National check	6.67	18.87	2.9
3.	DRR Dhan 45 (YC & MNC)	6.43	19.06	3.2
4.	Chittimuthyalu (MNC)	8.30	21.94	3.9

Table 4: BLB and Blast screening under protected and unprotected condition.

Disease	Year and season	Name of trial	Varieties		
			NVSR 2756	Lal kada	GNR 4
BLB (Protected condi.)	*Kharif*-2018	SSVT-Biofort	0	0	0
	Kharif-2019	LSVT- Biofort	5	-	5
	Kharif-2020	LSVT- Biofort	1	-	3
	Range		**0-5**	**0**	**0-5**
BLB (Unprotected condi.)	*Kharif*-2019	LSVT- Biofort	5	-	7
	Kharif-2020	LSVT- Biofort	5	9	7
	Range		**5**	**9**	**7**
LB (Protected condi.)	*Kharif*-2018	SSVT-Biofort	1	1	1
	Kharif-2019	LSVT- Biofort	0	-	3
	Kharif-2020	LSVT- Biofort	1	-	3
	Range		**0-1**	**1**	**1-3**
LB (Unprotected condi.)	*Kharif*-2019	LSVT- Biofort	3	9	9
	Kharif-2020	LSVT- Biofort	2	3	9
	Range		**2-3**	**3-9**	**9**

Table 5: Ancillary observations and economic attributeof GNR-9 along with checks.

Sr. No.	Name of culture	Productive tillers/sq.m	Grains /Panicle	1000 grain weight (g)
1.	**GNR-9**	338 (300-350)	175 (150-200)	23.79 (23.3-25.8)
2.	Lal Kada(C)	250 (230-260)	121 (100-140)	29.48 (28.5-29.5)
3.	GNR-4(C)	330 (300-350)	220 (200-240)	17.54 (17.2-18.2)

Table 6: Morphological characters of variety GNR-9 along with checks.

Sr. No.	Name of culture	DFF (Days)	Plant height (cm)	Panicle length (cm)	Grain length (mm)	Grain breadth (mm)	Straw Yield (kg/ha)
1.	**GNR-9**	81-86	105-115	21-24	8.58	2.77	5700-6500
2.	Lal Kada(C)	80-83	125-135	20-23	9.00	3.01	5700-6200
3.	GNR-4(C)	105-110	95-105	19-22	7.63	2.47	5500-6000

Table 7: Grain quality characteristics of the variety GNR-9.

Sr. No.	Name of the culture	Aroma test	Vol. Exp	Water uptake (ml)	Amylose content (%)	Hulling Recovery (%)	Milling recovery (%)	HRR (%)
1.	**GNR-9**	Absent	4.76	250	21.5	76.27	71.18	56.24
2.	Lal Kada(C)	Absent	4.20	310	24.6	76.43	74.82	42.67
3.	GNR-4(C)	Absent	4.12	290	24.4	79.19	75.81	63.22

Sr. No.	Name of the culture	KL (mm)	KB (mm)	L/B Ratio	Grain Chalkiness	KLAC (mm)	Alkali spreading value	Grain type
1.	**GNR-9**	6.67	2.21	3.02	Absent	7.6	5.0	LS
2.	Lal Kada(C)	6.49	2.68	2.42	Absent	6.9	5.0	LB
3.	GNR-4(C)	5.70	2.01	2.83	Absent	6.4	5.0	MS

CONCLUSIONS

The biofortified rice variety "Lalkada Gold" represents a significant advancement in addressing nutritional deficiencies in Gujarat state. Developed through pedigree breeding, this variety demonstrates substantial improvements in yield and nutritional content, with notable increases in protein, iron, and zinc levels compared to traditional varieties. Its superior performance in yield trials and resistance to key pests and diseases underscores its potential for widespread adoption by farmers. By integrating "Lalkada Gold" into staple diets, it offers a sustainable, cost-effective solution to combat iron and zinc deficiencies, thereby contributing to the broader goal of eliminating malnutrition and hunger.

FUTURE SCOPE

The promising variety GNR-9 (Lalkada Gold) can be further improved for grain quality parameters and disease pest reactions by population improvement approach or by markers assisted breeding.

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Conflict of Interest. None.

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