Zinc biofortified rice: seed production and targets development, in central java

Cahyati Setiani*, *Indrie* Ambarsari, *Intan Gilang* Cempaka and *Teguh* Prasetyo

National Research and Innovation Agency, Indonesia

Abstract. The aims of this study were to produce Inpari IR Nutri Zinc seeds and determine their development targets. The rice seeds produced in 2000 were 3,090 kg (1 ha), and in 2021, it was 6,155 kg (2 ha). The development location of Inpari IR Nutri Zinc is directed at areas that have a high stunting rate by paying attention to the suitability of agroecosystems. Some of the development obstacles encountered include the availability of seeds, resistance to crackle disease, lower productivity compared to previous varieties, and transaction costs. Policy steps that need to be carried out by the Government include i) producing rice seeds of the Inpari IR Nutri Zinc variety, ii) source seed assistance is given to seed producers, while extension seed assistance is given to farmers and the Agricultural Extension Office / Center for plot demonstration activities, iii) Farmers need to be encouraged to be able to adapt to new habits / plant varieties that are different from before, through socialization with the Multi-Channel Dissemination Spectrum (SDMC) approach, iv) The Government makes the programs to maintain national food security and nutrition a priority.

1 Introduction

One of the strategic programs of the Ministry of Agriculture 2020-2024 is the achievement of sustainable self-sufficiency in rice commodities. Rice production in 2020 is estimated to be around 31.63 million tons, increasing 314.10 thousand tons or 1% compared to 2019 [1]. However, stunting is still a problem in developing countries, including Indonesia. The World Health Organization (WHO) estimates the worldwide prevalence of dwarf toddlers (stunting) by 22% or 149.2 million by 2020. Based on data from the Indonesian Toddler Nutritional Status Survey in 2021, the prevalence of stunting is still at 24.4% or 5.33 million toddlers, and 147,730 thousand of them are in Central Java. This prevalence is higher than the maximum standard established by WHO.

As a staple and functional food, rice contains physiological components for the human body. One of the mineral components in rice, namely Zn (zinc), is a vital nutritional element as a component of more than 300 enzymes for metabolism in the human body [2]. Efforts to increase the zinc (Zn) content in rice to increase added value, nutrition, and public health have been carried out in Indonesia through biofortification to increase the zinc (Zn) content in rice [3]. Biofortification is the process of the number of nutrients in food crops that are added through agronomic practices, conventional plant breeding, or modern biotechnology.

* Corresponding author: cahyati_setiani@yahoo.com

In 2019 the Ministry of Agriculture released a new HYV of Inpari IR Nutri Zinc rice which was determined through the Decree of the Minister of Agriculture Number 168 / HK.540 / C / 01/2019. The advantages of the variety are that it has an average Zn content of 29.54 ppm and potential Zn content of 34.51 ppm, an average yield of 6.21 t ha with a potential yield of 9.98 t ha and has a fluffy rice texture [4]. The Indonesian Agency for Agricultural Research and Development strives that the seeds of the Inpari IR Nutri Zinc variety that have been released can be one of the contributors to the success of the community nutrition improvement program [5]. Therefore, there are nine Assessment Institutes for Agricultural Technology (AIAT) in Indonesia that are tasked with producing and distributing rice seeds of the Inpari IR Nutri Zinc variety. One of them is AIAT of Central Java.

The problem faced in developing new varieties from a technical aspect is the availability of seeds in the field [6]. The development of the use of VUB rice seeds starting from breeder seed (BS) to becoming an extension seed (ES), has been formulated and implemented, but the results have not been as expected [7,8]. Some of the factors that are hindering include; i) Seed producers only produce seeds of popular varieties; ii) Seed producers have not contributed much in disseminating the change of varieties; iii) The use of high-yielding seed direct assistance is still partially using the old variety; iv) The role of Agricultural Field Extension Officer in helping farmers to determine seed direct assistance is not optimal.

Central Java Provincial Government issues governor regulation for stunting prevention program in Central Jawa No. 19 Of 2019. Accelerating stunting reduction is not only the task of the central government, but the provincial government also certainly has a role in accelerating stunting reduction, one of which is to socialize policies to accelerate stunting prevention, to facilitate guidance, monitoring and control, evaluation, and follow-up on policies for implementing programs and budgets for priority nutrition interventions in the region district/city. This effort is also carried out with the Convergence Action activity where the convergence action is an instrument in the form of activities used to improve the implementation of the integration of nutrition interventions in the prevention and reduction of stunting. This action is used to improve the quality of program implementation approaches and cross-sectoral behavior so that nutrition intervention programs and activities can be used by target families, namely 1,000 households more effectively. Based on this, the aims of this study were to produce Inpari IR Nutri Zinc biofortic seeds and determine their development targets in Central Java.

2 Methods

Research on Zinc Biofortified Rice: Seed Production and targets development includes 2 activities, namely producing and developing Inpari IR Nutri Zinc seeds. Seed production was conducted for 2 years (2020-2021). In 2020, it was carried out at the Agricultural Technology Research and Assessment Installation (ATRAI) Magelang on a land area of 1 ha. In 2021 it was carried out on the land of the Sidowayah village head, Polanharjo District, Klaten Regency on an area of 2 ha. During the production process of prospective seeds until its become seeds, supervision is carried out by officers from SCCI in accordance with Minister of Agriculture Regulation No. 12 of 2018 concerning Production, Certification, and Distribution of Plant Seeds. The production of prospective seeds in the research area was counted entirely. The data collected includes the production of prospective rice seeds, seed production after processing, and yield. The data were analyzed descriptively. Assessment of Seed Production and Biofortification Development Targets of Inpari IR Nutri Zinc in Central Java carried out in Magelang and Klaten Regency in 2020-2021 (Table 1).

Table 1. Location, area, and the production time of Inpari IR Nutri Zinc grade ES seeds 2020-2021

Location	Area (Ha)	Production Time
Bandongan Village, Bandongan District, Magelang Regency.	1	Januari-Juni 2020
Sidowayah Village, Polanharjo District, Klaten Regency.	2	Februari-Juni 2021

Seed Production Technology is presented in Table 2. During the production process of prospective seeds, until they become seeds, supervision is carried out by Seed Control and Certification Institutions (SCCI) officers following the Regulation of the Minister of Agriculture of the Republic of Indonesia Number: 56/Permentan/PK.110/11/2015 concerning Production, Certification, and Circulation of Seeds Fostered by Food Crops and Fodder Forage Crops and Regulation of the Minister of Agriculture No.12 Of 2018 concerning Production, Certification, and Circulation of Plant Seeds. The data collected in seed production activities include: the productivity of prospective seeds (dry threshed paddy) and the volume of seeds declared passed. The data were analyzed descriptively.

Table 2. Inpari Nutri Zinc rice seed production technology 2020-2021.

Description	Technology
Seedbed	Beds (height 5-10 cm, width 110 cm, length size depending on location)
Fertilizer dosage (seedbed)	Urea, SP 36, dan KCL @ 15 g/m2
Tillage	Deep ploughing
Seedling/planting age	15-21 hst
Planting distance	Jajar legowo 2: 1
Fertilizer dosage	Urea 200 kg/ha; Ponskha 300 kg/ha; Petroganics 500-1000kg/ha
Irrigation	Seedling, heading, panicle forming, ripeing
Weeding	Three times
Pest Control	IPM
Roguing	Three times (vegetative, generative, before harvest)
Harvest	115 DAP
Moisture Content	11-12%

To find out the problems, targets, and draft policies for the development of Inpari IR Nutrizinc rice seeds are being conducted through the Focus Group Discussion (FGD) on October 27, 2020, at the Agriculture and Food Security Office of Banyumas Regency with with 43 participants the Public Health Service, Department of Agriculture, Extension Workers, SCCI Banyumas Region, farmer groups, and multidisciplinary researchers. The collected data and information were analyzed descriptively.

3 Results and Discussion

3.1 Rice Seed Production

The yield of prospective seeds in 2020 was 4,399 kg/ha, which is higher than in 2021, which was 3,948 kg/ha (Table 3), but still lower than the potential rice yield of the Inpari IR Nutrizinc variety. The potential yield of Inpari IR Nutri Zinc amounts to ± 9.98 Tons / Ha with an average yield of ± 6.21 Tons / Ha [6]. Research by Pebriandi [9] also showed a higher yield of 6.91 t/ha. One of the main factors for the low yield at the assessment site is that before the harvest, prospective rice seeds of the Inpari IR Nutri Zinc variety were attacked by bacterial leaf blight/crackle (BLB) disease. The disease is caused by the gram-negative bacterium Xanthomonas oryzae pv. oryzae [10]. In Indonesia, BLB was first reported in

1950. BLB attacks caused crop losses in the rainy season by 21-29% and in the dry season by 18-28%. In 2010 the widespread transmission of BLB disease reached more than 110,248 ha, 12 ha of which caused puso [10–12]. The high level of BLB attacks occurred in West Java, covering an area of 40,486 ha, Central Java 30,029 ha, East Java 23,504 ha, Banten 3,745 ha, and Southeast Sulawesi 2,678 ha. The character of the tropical climate also causes many pathogens to be discovered [13]. Descriptively Inpari IR Nutri Zinc is somewhat resistant to bacterial blight of pathotype III and susceptible to pathogens IV and VIII [4].

Post-harvest processing is by drying until it gets a moisture content of 11-12%, then using a blower to remove empty grain / other impurities until it is declared ready to be sampled (blower seeds). The yield of Inpari IR Nutri Zinc seeds was 70.24% (2020) and 77.95% (2021). According to Satoto [7], seed management can be good if the yield obtained ranges 70–80%.

Table 3. Planting area, prospective seed yield, seed yield, and rendemen of Inpari IR Nutri Zinc 2020-2021.

Description	**Seed Production**	
	2020	**2021**
Planting Area (ha)	1.0	2.0
The Yield of Prospective Seeds (kg/GKP)	4,399	7,896
Seed Yield (kg)	3,090	6,155
Rendemen	70.24	77.95

Laboratory testing is carried out to determine the quality of seeds consisting of physical, physiological quality, and the suitability of the quality of the seeds produced with the established seed quality standards. Genetic purity is taken from the results of field examinations. The seed group is declared to have passed laboratory tests if it meets the applicable quality standards [14]. The laboratory tests on the quality of prospective rice seeds of Inpari IR Nutri Zinc variety show that all seed quality indicators have values higher than the established standards (Table 4).

Table 4. The quality of rice seeds of Inpari IR Nutri Zinc variety is based on laboratory test standards for rice seeds of extentionseeds/ES grade, 2020 and 2021.

Seed Grade	**Maximum Moisture Content (%)**	**Minimal Pure Seed (%)**	**Minimal Seed Manure (%)**	**Maximum Seeds of Other Varieties (%)**	**Maximum Seeds of Other Plants (%)**	**Maximum Growing Power (%)**
Extention Seed/ES Grade Rice Seed Laboratory test Standarts	13.0	98.0	2.0	0.2	0.2	80.0
Quality Test Results (2020)	11.7	99.9	0.1	0.1	0.0	89.0
Quality Test Results (2021)	11.8	99.9	0.1	0.0	0.0	94.0

3.2 Inpari IR Nutri Zinc Development Target in Central Java

The target of developing Inpari IR Nutri zinc is in areas that have stunting cases. Efforts to accelerate the spread of Inpari IR Nutri Zinc have been carried out since its release in 2019. In 2020, biofortification was included in the priority program of the 2020-2024 Medium-Term Development Plan set by National Development Planning Agency (NDPA). The Ministry of Agriculture targets to grow 10,000 ha of Inpari IR Nutri Zinc variety rice in nine provinces by 2020.The nine provinces are Riau, Lampung, West Java, Central Java, West Kalimantan, Gorontalo, West Nusa Tenggara, Maluku, and Papua. The Inpari IR Nutri Zinc variety planting program is expected to gradually increase to 50,000 ha in 2021 and 200,000 ha in 2024. NDPA, the Ministry of Agriculture, Local Government, National Logistical Supply Organization, and other parties are expected to be able to synergize to make the program successful [15].

According to the Governor's Regulation, there are five pillars of stunting prevention. One of them is to encourage a nutritional food security policy. State Losses Due to Lack of Zn elements: 2 – 3 % of GDP/year; Indonesia's GDP = 13,000 T IDR/year; Loss due to Zn deficiency = 260 – 390 T IDR/year. Based on Basic Health Research conducted in 2018, the percentage of very short toddlers of 0-59 months in Central Java Province is 11.15%, while the percentage of short toddlers is 20.06 percent [16]. According to the head of the Central Java Provincial Health Office, in February 2020, the stunting rate in Central Java reached 14.9%. There are three regions in Central Java that have a fairly high number of stunted babies. Namely, Wonosobo Regency with 27.17%, Banjarnegara with 24.31%, and Rembang Regency with 24.15% [17].

Development sites are mainly directed at areas with a reasonably high stunting rate. Nevertheless, it should still pay attention to the suitability of agroecosystems. Based on the description of rice varieties Inpari IR Nutri Zinc, irrigated rice fields are located at an altitude of 0-600 m above sea level (m.asl). Based on the height of the place in the three regions, it is possible to cultivate rice plants of the Inpari IR Nutri Zinc variety.

Based on information from the Agriculture and Plantation Service of Central Java Province, the development of Inpari Nutri Zinc in 2020 was carried out in Sukoharjo Regency, covering an area of 325 ha and Pemalang covering an area of 1000 ha. The assistance provided to farmers is seeds and NPK and pesticides. In 2021, the Inpari IR Nutri Zinc planting program covered an area of 5,000 ha, which is carried out in five districts, namely in Blora Regency (1,000 ha), Grobogan (350 ha), Demak (295 ha), Wonosobo 91,000 ha and Brebes 2,355 ha, the assistance provided by seeds, urea and pesticides. The seeds produced from the assessment of 9,245 tons have also been distributed to 6 Regencies, namely: 1) Semarang; 2) Boyolali; 3. Banyumas; 4. Pati; 5. Semarang City; and 6. Kendal. The seeds are assisted as a tangible manifestation of development through dissemination in overcoming the scarcity of Inpari IR Nutri Zinc seeds that are not yet available in the free market because they are a new variety.

Table 5. Inpari IR Nutri Zinc rice development target in Central Java.

Regency	Height of the premises (m.asl)	Area of irrigated paddy fields (ha)
Wonosobo	275-2250	12,066
Banjarnegara	298-2093	11,070
Rembang	100-1000	8,158

3.3 Challenges, Development Strategies, and Policies

The Ministry of Agriculture hopes that farmers can use the rice seeds that have been released soon to replace old varieties. But what is happening today is that it is still difficult for farmers to replace varieties that have been in circulation for a long time. In 2018 there were 43

varieties of rice grown by farmers in Central Java. The five varieties that dominated were Ciherang and IR 64 by 30.54% and 15.08%, then the Situ Bagendit variety by 10.21%, Mikongga by 6.31%, and Inpari by 6.01%. Other varieties that are also widely found are Membramo, Sidenuk, Bestari, Sunggal, Pepe, Logawa, and Wayapo Buru [18]. The information suggests that replacing the varieties that farmers are used to growing takes quite a long time. An example is that the IR 64, released in 1986, is still quite dominant in the field, as is Ciherang, released in 2000, Situ Bagendit in 2000, and Mekongga in 2004 (Table 6).

Based on the FGD results, there are two fundamental obstacles in the development of Inpari IR Nutri Zinc, namely farmers' complaints about the Inpari IR Nutri Zinc variety that is not resistant to BLB and lower productivity than previously grown varieties (IR 64; Ciherang; Mekongga; and Inpari 32). This condition significantly affects seed producers, and they are also reluctant to produce these seeds. According to Husman [19], in addition to technical factors (resistance to pest diseases and productivity), farmers do not adopt new varieties due to the presence of transaction costs that are not taken into account. Transaction fees are costs that cannot be avoided in any exchange, whether the exchange of goods/services or the exchange of information [20]. More broadly opinion [21], what is essentially not adopted by technology is the presence of imperfect information, the phenomenon of free riders, and transaction costs that are not taken into account. This arises because of bounded rationality and opportunistic behaviour. Bounded rationality refers to the degree or limit of an individual's ability to receive, store, retrieve and process information without error. In contrast, opportunistic behaviour refers to the individual's efforts only to pursue profit in carrying out activities [22].

Table 6. Distribution of Rice Varieties in Central Java, 2015-2019.

Varieties	**Percentage (%)**				
	2015	**2016**	**2017**	**2018**	**2019**
Inpari Sidenuk	-	1.19	-	-	-
Siam Mutiara	-	0.93	-	-	-
Cigeulis	4.36	3.41	3.23	2.98	-
Cilamaya Muncul	-	-	1.52	-	-
Inpari 33	-	-	-	-	1.6
Ciliwung	-	-	2.60	3.13	-
Lokal	9.56	-	7.68	8.34	6.9
Cibogo	-	1.37	-	-	-
Inpari 30 Ciherang Sub 1	-	2.97	5.06	5.96	4.5
Mekongga	10.69	15.24	12.10	12.79	13.0
IR 64	-	6.93	7.95	7.00	6.3
Sembada 168	-	-	-	-	1.6
IR 42	-	-	-	-	1.7
IR 46	11.94	-	-	-	-
Situ Bagendit	6.58	4.23	5.39	5.49	5.4
Inpari 32 HDB	-	-	-	3.64	5.8
Ciherang	30.31	31.92	29.74	30.80	27.4
Other varieties	26.56	18,06	25.95	19.86	25.9
Total	100.00	100.00	100.00	100.00	100.00
Area (ha)	13,836,990	14,731,252	15,333,923	16,270,642	12,843,274

The development strategy that needs to be done is to eliminate existing obstacles. The problem of BLB disease requires chemical bactericides, biological agents, and chitosan [23]. The reduction of transaction costs can be made by bringing the availability closer and guaranteeing the quality of the seeds, as by eliminating bounded rationality and opportunistic behaviour by conducting socialization through continuous dissemination of seed advantages with the Multi-Channel Dissemination Spectrum (MCDS) model approach [24]. The

development target is not only user farmers but also policymakers, seed producers, and Extension Agencies.

The policy applied in developing Nutri Zinc rice seeds is responsive policy, namely by providing responses or alternatives to the actual problem. One of the habits related to stunting problems is the assistance of Inpari IR Nutri Zinc seeds. Seed assistance also needs to be carried out to rice seed producers in the form of source seeds and needs to touch on price protection for both grain and the price of Inpari IR Nutri Zinc rice seeds. The protection policy aims to control the price of grain and rice seeds of Inpari IR Nutri Zinc. The price of rice variety Inpari IR Nutri Zinc is encouraged to be at a higher level when compared to the price of other rice varieties. On the other hand, rice seed producers must produce and circulate rice seeds of the Inpari IR Nutri Zinc variety so that their availability in the free market and for programs can be guaranteed.

4 Conclussion and suggestions

Inpari IR Nutri Zinc seeds produced in this study amounted to 9,245 tons and were disseminated in areas with moderate-high stunting rates. Unavailability of seeds was a challenge for Inpari IR Nutri Zinc seed development. The production of new varieties of rice seeds (Inpari IR Nutri Zinc) needs to be carried out by the government, and the results are given as assistance until the seed stage has been guaranteed availability in the field. Source seed assistance is given to seed producers, while extension seed is given to farmers and the agricultural extension office/center for demonstration plot activities. Farmers need to continue to be encouraged to be willing and able to adapt to new habits / planting different varieties from before through socialization with the Multi-Channel Dissemination Spectrum (MCDS) model approach. The government made programs to maintain national food security and nutrition a priority.

References

1. I. N. Khasanah, O. R. Prasetyo, I. Wirawati, N. Rahmadhani, R. Poerwaningsih, D. M. Ramdhani, and Y. Bimantara, *Luas Panen Dan Produksi Padi Di Indonesia* (Badan Pusat Statistik, Jakarta, 2020).
2. Y. D. Hastuty and M. Ariska, J. Midwifery Nurs. **4**, 63 (2022).
3. M.-Y. Jou, X. Du, C. Hotz, and B. Lönnerdal, J. Agric. Food Chem. **60**, 3650 (2012).
4. Badan Penelitian dan Pengembangan Pertanian, *Deskripsi Varietas Unggul Padi: Inbrida Padi Sawah Irigasi (INPARI), Hibrida Padi (HIPA), Inbrida Padi Gogo (INPAGO), Dan Inbrida Padi Rawa (INPARA)* (Badan Penelitian dan Pengembangan Pertanian Kementerian Pertanian, Jakarta, 2020).
5. Gesha, Balitbangtan Siap Kembangkan Inpari IR Nutri Zinc untuk Atasi Stunting. Tabloidsinartani.com (2019).
6. N. S. Nazuri and N. Man, Acad. J. Interdiscip. Stud. **5**, (2016).
7. Satoto, Pengenalan Varietas Padi. Materi Workshop Penguatan Kapasitas Peneglola Benih Sumber (UPBS), 17-23 November 2013, Balai Besar Penelitian Tanaman Padi, Sukamandi. 12 hal
8. T. Prasetyo. Posisi Benih Padi dalam Kerangka Kebijakan Swasembada Beras Berkelanjutan. Badan Penelitian dan Pengembanga Pertanian, Kementerian Pertanian, Jakarta, (2015).
9. A. Pebriandi, Sulhan, and Setyawan, J. Daun **8**, 74 (2021).

10. Wahyudi, A. T. and Meliah, S. and Nawangsih, and A. Asih, Makara J. Sci. (2011).
11. Marlina, L. Hakim, Mapegau, and A. Nizori, Int. J. Adv. Sci. Technol. **29**, 6673 (2020).
12. S. A. H. Naqvi, Pakistan J. Agric. Res. **32**, (2019).
13. R. H. Wening, U. Susanto, and Satoto, Iptek Tanam. Pangan **11**, (2016).
14. Balai Pengawasan dan Sertifikasi Benih Jawa Tengah, *Peraturan Perbenihan Tanaman Pangan. Pembinaan Produsen/Pengedar Benih Tanaman Pangan* (Pemerintah Provinsi Jawa Tengah, Dinas Pertanian dan Perkebunan, Balai Pengawasan dan Sertifikasi Benih Jawa Tengah, Sukoharjo, 2018).
15. Kementerian Pertanian, *Rencana Strategis Kementerian Pertanian 2020-2024* (Kementerian Pertanian – Republik Indonesia, Jakarta, 2020).
16. Kementerian Kesehatan Republik Indonesia, *Laporan Provinsi Jawa Tengah Riskesdas 2018* (Lembaga Penerbit Badan Penelitian dan Pengembanan Kesehatan, Jakarta, 2019).
17. A. Arif, Ini 3 Daerah di Jateng dengan Kasus Stunting Tinggi. ayosemarang.com, (2020).
18. Dinas Pertanian Tanaman Pangan dan Hortikultura Provinsi Jawa Tengah, Program Perbenihan Tanaman Pangan di Jawa Tengah 2019. Makalah disampaikan pada acara Forum Komunikasi Produsen Benih Tanaman Pangan Jawa Tengah, Tanggal 16 Agustus, 2019 di Solo, (2019).
19. C. Husmann, Q. J. Int. Agric. **54**, 59 (2015).
20. Deogratias Lwezaura, Agness Ndunguu, Ruth Madulu, Betty Chalamila, and Charles Paul, J. Food Sci. Eng. **7**, (2017).
21. A. Muja and S. Gunar, IFAC-PapersOnLine **52**, 287 (2019).
22. J. Křečková and H. Brožová, Agris On-Line Pap. Econ. Informatics **09**, 91 (2017).
23. S.-I. Kim, J. T. Song, J.-Y. Jeong, and H. S. Seo, Sci. Rep. **6**, 21209 (2016).
24. R. Rahmawati, A. Saleh, M. Hubeis, and N. Purnaningsih, Int. J. Sci. Basic Appl. Res. **34**, (2017).