Assessment of seed yield and quality traits of zinc biofortified advanced breeding lines of Rice

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By

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CERTIFICATE- I

This is to certify that the thesis entitled **"Assessment of seed yield and quality traits of zinc biofortified advanced breeding lines of Rice"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Seed Science and Technology)** to the Odisha University of Agriculture and Technology is an faithful record of *bona fide* and original research work carried out by **Yashobanta Barik (Adm. No. 191222402)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help obtained by him from various sources during the course of investigation has been duly acknowledged.

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(Dr. S. K. Tripathy)
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CERTIFICATE- II

This is to certify that the thesis entitled **"Assessment of seed yield and quality traits of zinc biofortified advanced breeding lines of Rice"** submitted by **Yasobanta Barik (Adm. No. 191222402)** to Odisha University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Seed Science and Technology)** has been approved by the Students' Advisory Committee and the External Examiner.

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Yashobanta Barik

Bhubaneswar

(Yashobanta Barik)

Date: 13.09.2021

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ABBREVIATIONS USED

AA	: accelerated ageing
ANOVA	: analysis of variance
^0C	: degree Celsius
Cm	: centimetre
CV	: coefficient of variation
CD	: critical difference
dS/m	: DeciSiemens per metre
et al.	: co-workers
etc.	: et cetera (and other things)
e.g.	: exampli gratia (for example)
Fig.	: Figure
G	: gram
Ha	: hectare
i.e	. : that is
Kg	: kilogram
Kg ha-1	: kilogram per hectare
Mg	: milligram
%	: percentage
SVI-I	: Seed Vigour Index-I
SVI-II	: Seed Vigour Index-II
SEm	: standard error of mean
viz.	: videlicet (namely)
ppm	: parts per million

ANTI-PLAGIARISM CERTIFICATE

(For PG Thesis)

This is to certify that the thesis entitled "***Assessment of Seed Yield And Quality Traits Of Zinc Biofortified Advanced Breeding Lines Of Rice***" submitted by **Sri Yashobanta Barik**, Master of Science in Agriculture (Dept of seed science and Technology, bearing Adm. No.191222402 is plagiarism checked and has not crossed the limit as per the Anti-Plagiarism Policy of OUAT.

(Chairman) | **(Professor and Head)** | (Signature of the student)

(Yashobanta Barik)

ABSTRACT

A set of 76 zinc biofotrified advanced breeding lines of rice are collected from the Central Research Farm, Regional Research and Technology Transfer Station, Coastal Zone, OUAT. The grounded seed samples of each genotype were estimated for grain Zn content at Central Instrumentation Facility (CIF), OUAT, Bhubaneswar after digestion with di-acid mixture followed by filtration. The Zn- dense genotypes showing more than 30 ppm zinc content were sorted out for field trial in Kharif, 2021 with a standard check variety (Swarna). The field experiment was conducted at Central Research Farm, Regional Research and Technology Transfer Station, Coastal Zone, OUAT. The selected zinc biofortified advanced breeding lines were laid out in RBD with three replications and the following 15 genotypes served as treatments viz., T0- Swarna (check), T1- ORCZ 98, T2 - ORCZ 181, T3 - ORCZ 114, T4- ORCZ 176, T5- ORCZ 135, T6- ORCZ 175, T7 - ORCZ 148, T8 - ORCZ 174, T9 - ORCZ 156, T10 - ORCZ 169, T11- ORCZ 161, T12- ORCZ 167, T13- ORCZ 162 and T14- ORCZ 165. During the course of investigation, each treatment (genotype) was studied with respect to plant growth and seed yield. The treatment ORCZ 135(T5) shows the earliest maturity among all the selected zinc biofortified advanced breeding lines and check variety Swarna. Yield components were shown to be positively influenced by grain zinc content except some characters. EBT/m^2 was recorded maximum in Swarna as a check variety followed by ORCZ 161, ORCZ 181, ORCZ 162. ORCZ135. These breeding lines also showed compact panicle feature (with 158.0 number of grains/panicle) as compared to the check cv. Swarna (135.8 number of grains/panicle). All the varieties except ORCZ 167 recorded 1000-seed weight more than 22.0g. ORCZ 135 and ORCZ 114 recorded better seed yield potential (47 -50q/ha) attributable to higher tiller number, grains/panicle, grain weight and higher Zn content(>30ppm) compared to Swarna (40q/ha, 11.30ppm Zn). Seed quality parameters including storability of seeds of the above advanced zinc biofortified breeding lines were tested at Seed Physiology Laboratory, Dept. of Seed Science and Technology, College of Agriculture, OUAT, Bhubaneswar and Dr. G. V. Chalam Seed Testing & Research Laboratory, AICRP on Seed Technology Research, NSP (Crops), OUAT, Bhubaneswar. Most of the seed quality parameters, such as germination, field emergence, final count, root length, shoot length, dry weight and both vigour indices (SVI- I & II) were shown to be influenced by seed zinc content. However, grain Zn content revealed significant negative association with EC indicating that Zn is incredably helpful for initial growth and development starting from germination process. Further, the negative relationship of Zn with EC signifies that, Zn content has improved the seed quality leading to lower amount of seed leachate, in the present set of variety as compared to Swarna (high leachate) in the solution. Among the test genotypes ORCZ 148, ORCZ 181 and ORCZ 135 retained high Zn content along with high yield potential. However, ORCS 135 emerged as the best test entry with excellent seed and seedling quality parameters (germination percentage, field emergence, first count, seedling growth, seedling dry weight as well as both vigour indices:SVI-I and SVI-II).

INTRODUCTION

Rice (*Oryza sativa* L.), family- Poaceae, is one of the most important cereal crops of the world, grown in wide range of climatic zones, to nourish the mankind. Rice is the second most consumed cereal worldwide and is one of the world's major crops, especially in Asia, because it contains proteins, carbohydrates, vitamins and many important nutrients and compounds that have a significant impact on health and reduce the risk of diseases (Aguilar-Garcia et al. 2007 and Liu 2007).

Rice is an important food grain for majority of the world population and in India. It provides about 31% calories, 17% protein & 7.3% protein in milled rice, for which it is considered as a staple food for 88.2%of Indian population. Within rice growing countries, India has the largest area 100m.ha under rice in the world. In respect of production, India stands second with 116.42mtons of paddy which is 22.25% of the total world production. However, the average yield potentiality in India is lowest, i.e,2.66 tons/ha (Directorate of Economics and Statistics, DAC&FW,2019).

In India rice is grown in almost all the states under widely varying conditions of altitudes and climates. Its cultivation in India is extended from 19º48′N latitude from the mean sea level to as high as 6 metres. Odisha is an agrarian state accounts for 3.71mha area (8.47% of all India) with 7.31m.tons (6.28% of all India production) and yield potential is 1.97tons/ha(Directorate of Economics and Statistics, DAC&FW, 2019).

The misfortune of natural calamities always imposes threat to the production and productivity of crops in Odisha state. In the present scenario, with increasing population and decreasing per capita land area, the productivity of the crops will be reaching to the bottom soon. Increase in quality seed production of crops will be a definite solution for the enhancement of the social and economic status of the farming community. The chief task of Seed Science is to produce quality seed with high vigour to conquer this peril.

Considering the increasing population growth of India, the expected rice requirement must be reached to a level of 160million metric tons by 2050AD (Swain *et al.,*2017).

The rice varieties commonly grown by farmers have relatively low levels of Zn (<12–14 mg/kg) in polished rice and cannot meet the daily dietary requirement of Zn. Rice aleurone layer harbour 25–30 % of the total Zn, and this is lost during processing, while the endosperm has 60–75 % of Zn, which is retained even after polishing (Hansen et al. 2009).Grain Zn concentrations in rice plants grown in the Philippines were unchanged by Zn fertilization (15 kg Zn·ha−1), while the Zn fertilization increased straw Zn concentrations by 43%–95% (Wissuwa *et al.*, 2008). With even 20 % Zn absorption, and retention of 90 % in the blood serum, a daily ration of 422gm rice (having Zn conc. @28mg Zn/kg kernel) can afford at least 25% of daily requirement (HarvestPlus, 2014).Zn serves as a co-factor for more than 300 enzymes involved in the metabolism of carbohydrates, lipids, proteins, and nucleic acids, hence its importance in normal growth and development of plants and animals (Roohani *et al.*, 2013).

Genetic basis: grain Zn has a moderate to high broad-sense heritability and can be improved by breeding (Norton et al. 2010; Zhang et al.2014), while reports of narrow sense heritability clearly indicated significant additive and dominant genetic effects. In black pericarp indica rice, both genetic and cytoplasmic effects contributes towards Zn content in grain. The heritability of seed Zn content was highly significant and narrow-sense heritability was very high, suggesting single plant selection as an effective approach for improving Zn content. There are reports indicating high correlations between Zn deficiency tolerance and high grain Zn in rice. Since there are many QTLs/ genes responsible for grain Zn concentration located on different chromosomes(Ch. 7,11 and 12), QTL pyramiding (using three way and double crosses of Zn-dense varieties or by intermating of high Zn lines or plants), Marker Assisted Recurrent Selection (MARS) and Genomics Assisted Breeding approaches are worth trying to develop high-Zn rice. BRRI Dhan 64 (with 25 mg Zn/kg grains with a yield potential of 6t/ha) has been released for cultivation in Bangladesh (HarvestPlus 2014). A few high zinc rice varieties have been tested and released in India and Bangladesh for commercial cultivation.

Rice wild relatives e.g., *O. nivara, O. rufipogon, O. latifolia, O. officinalis, and O. granulata* are rich source of Zn (37 mg/kg to 55 mg/kg in non-polished grains), around 2–3 fold higher than in the cultivated rice. Landraces, aus and aromatic accessions, deep water rice and colored rice are the best sources of high grain Zn. High grain Zn trait was found to be tightly linked with aroma under Zn-deficient soil (Gregorio 2002). In some cases, genetic factors increasing Zn also co-segregate with genetic factors that increase Fe and other mineral elements (Gregorio 2002;Jiang et al.2007).

Biofortification is a combined approach of conventional plant breeding and modern biotechnology to enrich vital nutrients (minerals, vitamins and proteins) in staple crops . Nagina22, Annada and Jalmagna harbours more than 20ppm Zn in grain. However, the best candidate genotypes selected for biofortification programme should fulfill the criteria of high productivity; show considerable health impact for micronutrient enrichment levels; the trait for micronutrient must be relatively stable across various environmental conditions and climatic zones and consumer acceptance for taste and cooking quality (Welch and Graham; 2004, Martinez *et al.*, 2007). According to Harvest Plus Challenge Programme, a minimum increment of 8mg Zn/kg kernel against a base line of 16 mg Zn/kg of polished rice may result considerable biological impact on human health. Among 1000 rice genotypes, concentration of Zn in the brown rice ranged from 15.3 to 58.4 ppm while Fe concentration ranged from 6.3 to 24.4 ppm. A trait for high iron and zinc has been linked to aromatic varieties such as Jasmine and Basmati type. On the basis of grain zinc content, rice genotypes could be grouped into three categories, low (lessthan 14 ppm), moderate (14 ppm –24ppm) and high (greater than 25 ppm). Gregorio (2002) in IRRI reported the presence of the correlation for Fe and Zn accumulation in the grains of rice among 1,138 genotypes studied.

Johnson et al.(2011) made it possible for constitutive over expression of OsNAS (osmotically regulated nicotianamine synthase) gene family as a single gene strategy for effective zinc and iron biofortification of rice endosperm. At present, biofortified indica rice attains iron and zinc nutrition dietary targets in the field (Trijatmiko et al. 2016)).

A thorough characterization of genotype and environmental interactions is essential to identify key environmental factors influencing grain Zn(Sadeghzadeh et al 2013).Several researchers have reported genetic differences of mineral elements in rice grain.Zn content ranges from 10-33ppm. However, modern high yielding rice varieties are deficient in Zn. Brown rice usually contains 17.4–33.1ppmZn. 5% polished rice contains11.0–28.3 ppm Zn. In general, Basmati genotypes, deepwater rices and landraces were found to have highzinc contents in the grains. Some of the Zn-dense rice varieties are Poornima (31.3%), Ranbir Basmati (30.9%), ADT 43 (30.9%), Chittimutyalu (30.5%) and Type 3 (30.3%) and promising genotypeswith less loss after polishing are White Ponni, Bas 386, Kanishk, Giri and Karjat 4.

The interaction among the plant nutrients can be either synergistic, antagonistic, zero-interactive and/or Liebig-synergistic. Combined foliar application of Zn and Fe (0.5% ZnSO4 and 1% FeSO4) is recommended to enhance the productivity of wheat crop with good quality of grains. Zn and Fe foliar supplement increased seed yield and other yield components. Sole application of Zn increased grain Zn content. Interestingly, grain Zn content is antagonistic to Fe content, when Zn content increased Fe content decreased, vice versa. Besides, there was increase in height of plants, number of tillers, spike length, number of spikelets per spike, number of grains per spike, thousand grain weight, economical yield, biological yield and harvesting index, calcium, magnesium, iron, zinc, copper and protein contents. Sharma reported higher protein content with foliar supplied Zn plants, because Cu and Zn are involved in higher protein content. Zn application also increased the number of grains per spike in wheat (Soleimani 2006) possibly due its contribution in the cellular enlargement, elongation and cell division process . Micronutrients and their interactions affect the physiological and biochemical processes of plants, which significantly influence the quality and grain yield .

The aim of this research was to study seed and grain characteristics of a set of advance breeding lines focusing on the following:

1. Assessment of grain zinc content and identification of Zn fortified rice genotypes.
2. Association analysis of growth parameters and physico-chemical quality traits with seed yield of selected zinc rich rice genotypes.
3. Indentification of high yielding Zn rich advanced breeding lines under field condition.

REVIEW OF LITERATURE

Mainly India soils are deficient of Zn. Zn is a important constituent in paddy seed. Zn also integral part of Proteins, Enzymes, influence various chemical reactions and other yield attributing characters. Huge population of world affected by various type of diseases every year due to deficiency of Zn. It can be improved through growing of Zn-efficient varieties, use of breeding techniques, nano fertilizers and other process. Out of these, Zn-efficient varieties developed through Biofortification is a cost effective process. Zn influences the seed quality parameters like germination, seedling growth, vigour, viability etc.

In this chapter, The litrerature collected from different sources with respect to "*Assessment of Seed yield And quality traits of zinc biofortified advanced breeding lines of rice*" has been reviewed to understand the importance of Zn in quality parameters and yield influencing characters of rice. Literatures on Zn biofortified rice in relation of seed quality and yield is limited, therefore some other micronutrients and Zn application in both soil, foliar cases has been included in this chapter to emphasize certain point of view.

2.1 Assessment of grain zinc content and identification of Zn fortified rice genotypes

Micro nutrient content is a highly variable trait and it is largely influenced by the environment at which the crop is grown. A major priority for any breeding initiative is to have in place effective tools for assessing the genetic variation of the trait of interest. Ideally, these technologies should be relatively low in cost and also rapid in their analysis to allow for high throughput. A preliminary qualitative estimation of zinc content can be done using Dithizone stain for mass screening of germplasm and initial breeding materials. But, its quantification requires colorimetric or spectrophotometric estimation. For that colour development while sample preparation is required. However, the estimation of zinc using Atomic Absorption spectrophotometer(AAS) or more specifically by inductive coupled plasma-optical emission spectrophotometer (ICP-OES) is more reliable.

Choi et al., (2007) developed semi-quantitative screening methods for plant breeding purposes to identify zinc (Zn) and Fe-dense genotypes in germplasm, elite lines and early generation progeny. Methods included colour image analysis for Zn in wheat and rice grains and spectrophotometric analysis of Zn in ground flour of rice, wheat, potato, sweet potato and cassava.They developed a colorimetric method for Zn analysis using 1.56mM Dithizone (DTZ) solution and subsequent quantification by image analysis with Adobe Photoshops. The results highly correlated with ICP-OES analysis and successfully separated low and high Zn and Fe-grain germplasm. However, the Harvest Plus programme has relied heavily on ICP-OES forits micronutrient analysis as it has very good sensitivity, can have a throughput of around 500 samples per day and is able to detect Al and Ti which are seen as indicators of soil contamination in plant tissue samples. The down-side to the technology is the high cost of analysis and the degree of specialization needed to run the equipment. Newer technologies are also being explored and they include NIRS and both hand-held and bench-top XRF. Results are promising and research in this area is continuing. Research into ways of minimizing harvest and post-harvest soil contamination of plant tissues has also lead to more robust protocols and development of "contaminant-free" equipment for use by all research disciplines working in biofortification(James Stangoulis et al., (2010).

Patil et al., (2015) studied on Sixty one rice accessions include local genotypes and improved lines were used to estimate grain (brown rice) Zn content. The variation in grain Zn content ranged from 14.03 to 31.94 ppm with an average of 24.3 ppm.

Gande et al., (2014) evaluated grain zinc content in recombinant inbred lines (RIL) derived from IRRI38 X Jeerigesanna. Grain zinc content ranged from 16.1 to 35.5 ppm with an average of 23.7 ppm.

Gregorio et al., (2000) carried out germplasm screening which showed large genetic variation for iron and zinc concentrations in brown rice. Common cultivars contain about 12 mg of iron and 25 mg of zinc per kilogram. Some traditional varieties have double these amounts. One IRRI breeding line, IR68144-4B-2-2-3 had about 80%

more iron than IR64. Genetic x environmental interactions are sufficiently moderate that breeding for higher iron and zinc content is considered worthwhile. He showed large genetic variation for Fe and Zn in brown rice. Common cultivars contain about 12 mg Fe kg-1 to 25 mg Zn kg-1. Some traditional varieties have double these amounts.

Mallikarjuna swamy et al., (2016) evaluated IRRI rice germplasm and found significant variation for grain Zn in IRRI rice germplasm and efforts are being directed at exploiting this variation through breeding to develop high Zn rice varieties.

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Lee et al., (2008) studied 246 rice germplasm for iron and zinc content, wherein iron content ranged from 2.02 to 12.0 (mg kg-1) and zinc content varied from 10.0 to 33.0 (mg kg-1), with mean values of 4.3 and 22.8 (mg kg-1) respectively.

Banerjee et al., (2010) analyzed diversity in grain protein and Fe/Zn levels in 46 rice lines including indica and japonica rice cultivars, germplasm accessions, advanced breeding lines and wild rice genotypes and found greater diversity for grain protein and micronutrient levels among the tested rice genotypes, which ranged from 6.19 to 10.75 percent for grain protein content, 4.82 to 22.69 mg/kg for grain Fe and 13.95 to 41.73 mg/kg for grain Zn content.

Moraes et al., (2010) conducted experiment to evaluate the relationships among Cd, zinc (Zn),iron (Fe), and selenium (Se) concentrations in grains of upland rice cultivars. Thirty-five upland rice cultivars were grown to maturity in a pot soil experiment under greenhouse conditions. Micronutrient concentrations in grains ranged widely, among 35 genotypes higher Fe (31.4 mg/kg) and Zn (45.1 mg/kg) concentration in grains were recorded in genotypes catetosedo and primavera respectively.

Brar et al., (2011) observed large variation for iron and zinc contents in a collection of 220 rice genotypes. Iron content varied between 5.1 (IR6387 2-4-2-2-1) - 41.50 μg/g (HKR95-157) and zinc content varied between 2.12 (KBR466) to 39.4 μg/g (Taraori Basmati). Notably, there was about eighty-fold difference in Fe content and nineteen fold differences in Zn concentration in the present set of 220 rice genotypes suggesting the existence of genetic potential to increase the concentration of these micronutrients in rice grain. These results also indicate that, there is significant genetic diversity for Fe and Zn in the available rice germplasm and it should be feasible to plan a breeding program to develop high-yielding, mineral-rich rice genotypes.

Anandan et al., (2011) assessed the extent of genotypic differences among rice genotypes for mineral contents of Fe, Zn, Mn and Cu in unpolished rice varieties. The results showed that the visible difference could be found in the mineral contents among rice genotypes studied. The contents of Fe and Zn in traditional genotypes were significantly higher than those of improved cultivars.

Anuradha et al., (2012a) analyzed for Fe and Zn concentration in brown rice of 126 accessions including cultivated indicaand japonicarice cultivars. Iron concentration ranged from 6.2 to 71.6 ppm and zinc from 26.2 to 67.3 ppm. Both Fe and Zn were high in wild rice genotypes and least in japonica.

Babu et al., (2013) evaluated twenty one popular rice hybrids for the micronutrients content. Mean iron concentration of hybrids (68.4 ppm) was found to be 1.83 times that of zinc (37.3 ppm). Two hybrids with both high iron and zinc concentration (DRRH-2 with 125.8 ppm and 43.8 ppm and Sahyadri-4 with 104.8 and 43.0 ppm) were identified.

Pulagam et al., (2015) estimated the iron and zinc content in F8 (Recombinant Inbreed Line) population developed by crossing between BPT 5204 and Chittimutyalu. The iron content in brown rice ranged from 4.4 ppm to 32.6 ppm and in polished rice 1.3-12.6 ppm, while the zinc content was 8.1-57.5 ppm in brown rice and 5.8-37.4 ppm in polished rice. Loss of iron during polishing is many times more than zinc. Out of 300 populations six lines had high zinc content in endosperm with good yield.

2.2 Effect of Biofortification on plant growth parameters and yield

Abdul Rashid et al., (2019) investigated effects of low-Zn and high-Zn seeds (biofortified) of wheat (*Tritcum aestivum* L.), rice (*Oryza sativa* L.), and common bean (*Phaseolus vulgaris* L.) on seedling density, grain yield and grain Zn concentration. Zn-biofortified wheat seeds increased plant population by 26.8% and grain yield by 5.37%. paddy yield increase was 5.3% by Zn-biofortified seeds when compared to the control treatment.

Yilmaz et al., (2008) studied the effect of seed zinc content on grain yield and zinc concentration of wheat grown in zinc deficient calcareous soils. The results show that wheat plants grown from seed with high Zn content can achieve higher grain yields than those grown from the low- Zn seed when Zn was not applied to the soil.

Application of Zn fertilizers to soils is a general strategy to cope with Zn deficiency (Rengelet al., 1999) and to increase grain Zn concentration (Yilmazet al., 1997; Jiang et al., 2008; Hussainet al., 2012 a, b). Therefore, Zn fertilization of crop plants is a rapid solution to on-going human deficiency, with an added benefit of increased grain yield (Cakmak, 2009)

Soil or foliar application of Zn-containing fertilizers greatly improved grain Zn concentrations in both durum and bread wheat (Cakmak, 2008). In field trials in Central Anatolia, a well-known highly Zn-deficient region of Turkey (Cakmak et al., 1996), applying $ZnSO_4$ to soil enhanced both grain yield (Yilmazet al., 1997; Ekizet al., 1998) and grain Zn concentration of durum wheat. An increase in grain Zn concentration by soil Zn application was almost two fold, whereas combined application of Zn through soil and foliar was more effective and resulted in a more than threefold increase in Zn concentration in durum wheat grain. Similar increases in grain concentrations of Zn in wheat following soil Zn application were also seen in Australia (Graham et al., 1992).

Shahidullah et al. (2009) studied the phenological characters of rice cultivars to determine their yield potential. They noticed days to 1stheading, days to 50 per centflowering, days to complete heading and days to maturity varied in a wide range 65 to 85, 77 to 110, 86 to 122, 92 to 123, 116 to 138 days, respectively. Among these genotypes, BR28 proved better.

In two-year field experiments, Khanda and Dixit (1996) compared ZnSO4and Zn-EDTA via soil and foliar application in combination with four N levels (0, 30, 60, 90 kg ha-1) in sandy loam soil with suboptimal soil Zn (0.84 mg kg-1) under lowland rice conditions. However, maximum gain in yield, nutrient uptake and economic returns was observed with combined application of N and Zn, particularly with 90 kg N ha-1. Among the Zn application methods, soil application was considered superior (Khanda and Dixit, 1996).

Zdenko Rengal et al., (1995) studied the importance of seed Zn content for wheat growth on Zn-deficient soil. It is concluded that higher seed Zn content acted similar to a starter-fertiliser effect by improving vegetative growth (root and shoot growth) and dissipating differences in Zn efficiency of wheat genotypes.

Cakmak, et al., (2017) clearly demonstrates very significant financial returns from Zn biofortified based on improvements in both grain yield and public health where soil Zn deficiency and dietary Zn deficiency are prevalent.

Slaton et al., (2005a) reported that an increase in dry mater accumulation of rice by application of 13.5 kg Zn ha-1. They have also reported that rice dry matter accumulation increased linearly with Zn application rate and was not affected by the source.

Slaton et al., (2005b) reported that the dry matter accumulation increased due to application of 13.5 kg Zn ha-1. The response of dry matter yield of rice to added Zn was higher (13.6%) under pre-flooding compared with the control (9.4%) treatment.

SK Choudhary et al., (2017) conducted A field experiment was conducted during the rainy (*kharif)* seasons of 2010 and 2011 to study the effect of micronutrients on yield and nutrient uptake in sorghum [*Sorghum bicolour* (L.) Moench]. The results showed that methods of micronutrient application through combined soil + foliar spray significantly increased grain (14.15 and 12.13%), stover (10.75 and 8.60%) and biological yields (11.37 and 9.31%) over soil and foliar application, respectively. Combined application of micronutrient (Fe+ Zn+ B) was significantly increased grain (25.33%), stover (15.44 %) and biological yield (17.42 %) over control. The combined applications of soil + foliar application significantly uptake of N, P & K by 14.12 & 11.75%,13.98 & 10.86% and 12.33 & 9.57% over soil and foliar application, respectively. Improvement of N, P and K uptake with Fe+ Zn+ B was noticed of 33.25, 33.14 & 18.51 percent over control. Micronutrient significantly improvement of Zn, (47.90, 18.32 %) Fe(30.20, 16.11%) and B (25.60, 19.75%) uptake were also noticed with soil + foliar and (Fe+ Zn+ B) over control.

Pandey et al., (2018) found no direct positive or negative effect of zinc and iron content in different parts of rice grain on grain yield. Number of tillers exhibited highest direct positive effect and hence, selection based on total number of tillers for grain yield per plant would be the most effective strategy.

Enrichment of commonly applied compound fertilizers with Zn is a further fertilizer practice useful for increasing Zn concentration of plants. In India, application of Zn-coated urea fertilizer significantly improved both grain yield and grain Zn concentrations (Shivay et al., 2008 a, b).

Foliar application of Zn has a positive effect on plant growth and its reproductive development. Zn deficiency leads to loss of pollen function, impairment in fertilization, and poor development of the seed, which contribute to poor seed yield of legumes grown on low Zn soils. This can be alleviated through foliar Zn fertilization of crops at the onset of reproductive phase, especially in Zn deficient areas. Foliar fertilization not only enhances productivity, but it is an important strategy for increasing Zn density ins seeds improved for human consumption (Pathaket al., 2012).

By supplying plants with Zn, either through soil application, foliar spray, or seed treatment, increased yield, quality, and Zn use efficiency. In consideration of the important role of Zn in promoting and maintaining human health, more research is needed to determine the advantages of using the optimum level of Zn (Malakouti, 2008).

Drostkar et al., (2016) stated that foliar application of nano (Zn, Fe and NPK)@2L/plot in chickpea and resulted plant height(28.75 cm) and number of secondary branches (8.62) with nano (NPK+ Zn+ Fe), day to flowering(60.87) with nano Fe, number of primary branches (2.93) with nano NPK foliar application compared to control.

Kumar et al., (2014) studied the effect of nano-fertilizers of gypsum and rock phosphate tagged with urea at the rate of 3 kg/ha on the wheat and found that application of nano-materials and fertilizers significantly increased tillers/m2, dry matter accumulation and the days taken to 50 % flowering, physiological maturity and harvest maturity than control and other treatments in comparison.

Nilgun candan et al., (2018) indentified that high zinc (Zn) concentration of seeds has beneficial effects both on seed vigor and human nutrition in durum wheat. The seeds differing in Zn were tested for germination rate, seedling height, shoot dry matter production, and shoot Zn concentration under limited and well irrigated conditions in a Zn-deficient soil with and without Zn application. Low seed Zn concentration resulted in decreased seedling height, seed germination under limited water supply condition. Increased seed Zn content show better seed vigour, seedling growth better germination.

Ezatollah Esfandiari and Majid Abdoli (2017) identified Salt stress as a major adverse factor can lower germination, imbalance of the cellular ions resulting in ion toxicity, reduction in enzymatic and photo- synthetic efficiency and cause other physiological disorders and ultimately lower crop productivity in salinity zones. Zinc (Zn) is an important essential micro- element for wheat. In the present study the role of Zn (low 199 ng Zn seed-1 and high 595 ng Zn seed-1) under different levels (0, 50, 100 and 150 mM) of NaCl with three replications were determined. The results of this study indicate, that salinity decreased the shoot, seminal root and seedling length and also shoot, seminal root and seedling dry matter weight, seed germination and seedling vigor index. Seed Zn content significantly ($P<0.01$) increased the shoot length (15.5%), seedling length (17%), final germination percentage (10.1%) and seedling vigor index (26%).

Imran Muhammad et al., (2021) studied in spinach that Low temperature during germination hinders germination speed and early seedling development. Zn seed priming is a useful and cost-effective tool to improve germination rate and resistance to low temperature stress during germination and early seedling development. Spinach was tested to improve germination and seedling development with Zn seed priming under low temperature stress conditions.

Mary Ann Inabangan-Asilo et al., (2019) evaluated eight high-Zn rice breeding lines along with checks in several locations across the Philippines during 2014 wet season (WS), 2015 dry season (DS) and 2015WS, and 2016DS. Individual and combined analysis of variance revealed significant genotypic effects and G × E interactions for all the traits studied. Significant positive correlations between grain iron (Fe) and Zn, days to maturity, and plant height were observed, whereas grain yield and Zn were negatively correlated. Stability analysis using Kang's stability index, additive main effects and multiplicative interaction, and genotype main effects plus G × E (GGE) consistently identified IR10M300 as the most stable genotype across seasons in terms of yield and grain Zn.

Most. Aysha Siddika et al., (2016) conducted an experiment to determine the effect of different micronutrients including zinc (Zn), copper (Cu), manganese (Mn) and boron (B) on growth and yield of rice (BRRI dhan29). The treatment (NPKS+Zn + Cu) produced the tallest plant (44.67 cm, 61.00 cm,72.07 cm and 92.13 cm at 30, 45, 60 DAT and at harvest respectively), highest number of tillers (10.80, 20.90, 21.67 and 18.40 at 30, 45, 60 DAT and at harvest respectively) and dry matter yield (2.04 g, 3.70 g, 8.16 g and 8.44 g at 30, 45, 60 DAT and at harvest respectively) over the other treatments. The highest panicle length (25.00 cm), number of filled grains per panicle (105.50), grains per panicle (128.50) and thousand grain weight (22.10 g) were also observed in treatment (NPKS+Zn + Cu). The lowest values of all the parameters were obtained from control (NPKS). Grain yield (6.13 t ha-1) and straw yield (7.23 t ha-1) of boro rice were also highest due to treatment (NPKS+Zn + Cu).

Muhammad Zahir Aziz et al., (2019) evaluated the effects of foliar application of a micronutrient mixture (MNM) consisting of zinc (Zn), iron (Fe), copper (Cu), manganese (Mn) and boron (B) on yield and flour quality of wheat. The results show the effectiveness of foliar feeding for growth and yield parameters, in addition to the enriching of wheat grains with Zn, Cu, Fe, Mn and B. Compared to the control without foliar feeding, foliar application on wheat crop increased tillering ability, spike length, grain yield and the contents of Zn, Cu, Mn, Fe and B by 21, 47, 22, 22 and 25% in wheat flour, respectively.

Moazam et al., (2017) studied foliar application of zinc nano oxide at five levels (S1: Non-sprayed, S2: Spraying 20 ppm in mid-tillering and panicle initiation, S3: spraying 20 ppm in panicle initiation and full heading, S4: Spraying 40 ppm in mid-tillering and panicle initiation and S5: Spraying 40 ppm in panicle initiation and full heading) in two of the rice cultivars. The highest plant height (151.9 and 154.5cm), maximum grain weight (28.16 and 28.80g), panicle length (30.25 cm), number of tillers per hill (25.95) and number of spikelets per spike (125.2 and 128.9) were obtained with S2 and S4 treatments respectively.

Chanakan Prom-u-thai et al., (2012) studied the Zn priming promotes seed germination and seedling vigour of rice. The result shown that priming rice seed with Zn can improve germination and seedling vigour and also improve the germination of rice seed.

2.3 Effect of Zn biofortification on seed quality parameters

Anandaraj and Natarajan (2017) studied on seed quality enhancement of onion seeds which are highly prone to deterioration in storage (aged seeds) and concluded that enhancement in seed quality parameters like- highest germination of 72%, maximum shoot length (7.5 cm), higher root length (6.4cm), highest vigour Index(998) with ZnO. NPs treated seeds @ 1000mg kg-1 and also reported that nanoparticles treatment did not influence the seed physiology immediately after treatment but has significant effect after six months of aged seed compared to control(60%, 6.0, 5.4 and 692) respectively.

Bahareh Daneshbakhsh et al., (2012) identified plant having adequate amount of Zn can tolerate the adverse effect of salinity by altering the membrane permeability , sulfhydryl group (–SH groups) content of root cells and antioxidative defense mechanisms, super oxide dismutage, root activity of catalase.

Anuradha et al., (2012) analyzed 126 accessions of rice genotypes for Fe and Zn content. Iron concentration ranged from 6.2 ppm to 71.6 ppm and zinc from 26.2 ppm to 67.3 ppm. Zn concentration and grain elongation was significantly correlated.

Hajiboland R. and Amirazad H. (2010) examined drought tolerance in Zn deficit red cabbage (Brassica oleracea L. var. capitata f. rubra) plants. Impairment of growth due to Zn deficiency was higher under drought compared with well-watered conditions. Drought stress caused a drastic decline in Zn content and led to a damage of photosynthetic apparatus in Zn-deficient but not Zn-sufficient leaves. Zn adequate plants more tolerant to drought as compaired to the low Zn content.

Parma Nanda Sharma et al., (2004) identified Anti-oxidative defense systems in wheat plants were studied as a function of zinc deficiency in solution culture under glasshouse conditions. Zinc (Zn) deficiency enhanced cyanide-insensitive super- oxide dismutase activity significantly, and decreased the activity of cyanide-sensitive superoxide dismutase before the appearance of visible effects of Zn deficiency. The plants with incipient deficiency of Zn also had significantly higher activities of nonspecific peroxidase, ascorbate peroxidase, and glutathione reductase.

Prasad et al., (2012) suggested that ZnO nanoparticles at a concentration of 1000 ppm improved the germination (99 %), root growth (11.81 cm), shoot growth (8.71 cm), pod dry weight (5.39 g) and pod yield (3763 kg ha-1) in groundnut.

Fiaz Ahmad et al., (2009) studied the impact of Zn fertilization on gas exchange characteristics and water use efficiency (WUE) of cotton crop in arid condition. It was found that the positive correlation between Zn doses and net photosynthetic rate , transpiration rate and stomatal conductance, WUE and negatively correlated in intercellular CO_2.

Hening Hu and Darrell Sparks (1991) identified leaves of “Stuart” pecan [Carya illinoensis (wangenh) C. Koch] with various level of Zn deficiency were analysed for physiological indicator of leaf vigour, leaf chlorophyll content, stomatal conductance, and net photosynthesis were adversely affected by Zn deficiency but stabilised as leaf Zn approached the sufficiency.

Zed Rengel et al., (2004) studied zinc fertilization and water stress affects plant water relations, stomatal conductance and osmotic adjustment in chickpea (*Cicer arientinum* L.). In conclusion, zinc-deficiency reduced the efficiency with which the water was used for biomass production and compromised the plant's capacity to respond to water stress by osmotic adjustment.

K. Ohki (2006) studied Photosynthesis, respiration, carbonic anhydrase activity and chlorophyll concentrations were correlated with zinc nutrition in cotton (*Gossypium hirsutum* L.). The critical zinc level during early plant growth was 13 µg/g dry weight in recently matured leaves (blade three). Photosynthesis and chlorophyll concentration required a minimum Zn of 13 and 14 µg/g dry weight, respectively, in blade three for maximum activity and synthesis. Respiration was not influenced by zinc status. Carbonic anhydrase activity increased curvilinearly as zinc status improved from deficiency to adequacy.

P.N. Sharma et. al., (1995) tested for Zn requirement for stomatal opening in cauliflower. Zn deficiency induced increases in epicuticular wax deposits, lamina thickness, degree of succulence, water saturation deficit, diffusive resistance, and proline accumulation and decreases in carbonic anhydrase activity, water potential, stomatal aperture, and transpiration in the leaves of cauliflower (*Brassica oleracea* L. var botrytis cv Pusa) plants.

H. wang and JY Jin (2005) studied the Photosynthetic rate, chlorophyll fluorescence parameters, and lipid peroxidation of maize leaves as affected by zinc deficiency. Pot trial in greenhouse was conducted using cumulic cinnamon soil from North China to study the effects of zinc deficiency on CO_2 exchange, chlorophyll fluorescence, the intensity of lipid peroxidation, and the activity of superoxide dismutase (SOD) in leaves of maize seedlings. Zn deficiency resulted in a reduction of net photosynthetic rate and stomatal conductance to H_2O. The maximum quantum efficiency of photosystem 2 (PS2) and the PS2 activity were depressed, while the pool size of the plastoquinone molecules was not affected by Zn deficiency. The content of super oxygen anion radical (O^{2-}) and the intensity of lipid peroxidation as assessed by malonyldi aldehyde content in Zn-deficient leaves were higher than those in Zn-sufficient leaves. The activity of SOD increased with Zn application. The adverse influence of Zn-deficiency on the light stage of photosynthesis is probably one of possible reasons for the limitation of photosynthetic capacity in maize leaves.

Horst Marschner and Ismail cakmak (1988) studied the Zn deficiency increased root exudation (net efflux) of K+, amino acids, sugars and phenolics. Resupply of Zn to deficient plants for 8, 12 or 27 h increased the Zn concentration in the roots and simultaneously decreased the root exudation.

Jyunget et al., (1975) reported that, Zn was involved in the carbohydrate and protein metabolism. Cakmak et al., (1989) stated that, Zn is required for the synthesis of tryptophan, a precursor for the synthesis of IAA. Zn plays multiple roles in basic biochemical processes such as enzyme catalysis or activation, protein synthesis, carbohydrate and auxin metabolism, chlorophyll production, pollen formation, cytochrome and nucleotide synthesis, maintenance of membrane integrity and energy dissipation (Alloway, 2009).

Cakmak (2000) proved that Zn has a role in protecting cells by both controlling regeneration as well as detoxification of reactive oxygen species. A large diversity of essential cellular functions and metabolic pathways are directly influenced by Zn including function and structural stability of proteins, integrity of biological membranes and protection against reactive oxygen species. Nearly 2,800 proteins in biological systems require Zn for their activity and structural stability (Andreiniet al., 2009).

The role of Zn in higher plants is as a divalent cation (Zn++) which acts either as a functional, structural and a regulatory co-factor of a large number of enzymes (Brown et al., 1993).

Shuman et al., (1995) indicated the involvement of Zn in stomatal opening, possibly as a constituent of carbonic anhydrase needed to maintain adequate bicarbonate in the guard cell and also Zn affected in the influx of K^+ uptake into guard cells.

Fox and Guerinot (1998) asserted that, Zn is required for functioning of more than 300 enzymes. Zn is a structural part of carbonic anhydrase, alcohol dehydrogenase, Cu / Zn-superoxide dismutase and RNA polymerase (Marschner, 1986) and serves as a cofactor for all 6 classes of enzymes viz. oxidoreductases, transferases, hydrolases, lyases, isomerase and ligases (Broadley et al., 2007).

Ali et al.,(2003)conducted the effect of ageing on the germination characteristics at 21^0C as an indicator of physiological quality of seed lots of fourteen rice. The result showed the differences in germination after ageing is the indication of the differences in initial seed quality and seed vigour of the cultivar. They also found the variability of germination among seed lots of fourteen rice cultivars that cause the reduction of field emergence. Seed lots with low final germination percentage after deterioration or ageing are said to be a low vigour with poor field emergence and storage potential.

Gangwar and Kanaujia (2006)studied on accelerated ageing test for evaluating the vigour, viability and storability of ten rice cultivars viz., Usar 1, Type 3, Ashwani, Mahsuri Saket-4, Type 9, Sarju 52, Basmati 370, Prasad and NDR 118. For this purpose,they subjected seeds of ten rice cultivars to accelerated ageing for 0,3,5,7,9,12,15 and 20 days and found that germination, seedling length and seed vigour index were significantly reduced with advancement of accelerated ageing. They recorded minimum germination and vigour after 20 days of accelerated ageing.

Ahamed-Sabir and Vanangamudi (2011)determined the progressive decline in seed germination and seedling growth as increasing the period of ageing on two cultivars of rice hybrids. They found that seed germination was reduced as increased ageing, due to increase in electrical conductivity, free sugar content and free amino acids content.

MATERIALS AND METHODS

The present investigation entitled "*Assessment of Seed Yield And Quality Traits Of Zinc Biofortified Advanced Breeding Lines of Rice "* **was conducted at Central Research Farm, Regional Research and Technology Transfer Station, OUAT and** Dr. G. V. Chalam Seed Testing & Research Laboratory, AICRP on Seed Technology Research, NSP (Crops), OUAT, Bhubaneswar. The materials used and methodologies followed are described in this chapter.

3.1 Experimental Site

3.1.1 Field Experiment

The experiment was conducted at Central Research Farm, Regional Research and Technology Transfer Station, OUAT, Bhubaneswar between latitude 20.2961°N and longitude 85.8245°E with an average altitude of 45 m (148 ft) mean sea level. This particular location comes under the East & South Eastern coastal Plain Zone of agro-climatic zone of Odisha.

3.1.2 Laboratory Experiment

Laboratory evaluation of Zn is carried out in Central Instrumentation Facility, OUAT and seed quality attributes were done in Seed Physiology Laboratory, Dept. of Seed Science and Technology, College of Agriculture, OUAT, Bhubaneswar and Dr. G. V. Chalam Seed Testing & Research Laboratory, AICRP on Seed Technology Research, NSP (Crops), OUAT, Bhubaneswar.

3.2 Soil of the experimental field

Composite soil samples from the top 0-15 cm were collected from the experimental site before sowing and they were analyzed for "N" by Alkaline Permanganate method (Subbaiah and Asija, 1956), "P" by Bray's Extractant method (Bray's and Kurtz, 1945), "K" by flame photometery method (Jackson, 1973) & pH by pH meter (Piper, 1996), sand, silt & clay by International Pipette method (Piper,1996), Electrical Conductivity (ds/m) by Conductivity Bridge method (Jackson, 1967) and Organic Carbon (%) by Wet Oxidation method. The soil nutrient status are presented in Table 1.

Table 1. Initial nutrient status of soil of the experimental plot.

Sl No.	Parameters	Value
1.	Sand (%)	72.7
	Silt (%)	12.5
	Clay (%)	14.7
	Textural class	Loamy Sand
2.	Bulk density(g/cc)	1.57
3.	pH	5.27
4.	E.C (dS/m)	0.004
5.	Organic Carbon (g/Kg)	4.26
6.	Available N (Kg/ha)	228
7.	Available P (Kg/ha)	14
8.	Available K (Kg/ha)	67

3.3 SEED MATERIALS

Total 76 Zn biofortified of rice genotypes (Table 3) were collected from Central Research Farm, Region**al** Research and Technology Transfer Station, OUAT, Bhubaneswar. The samples were tested in the Central Instrumentation Facility, OUAT, Bhubaneswar for the amount of Zn content.

Table 2. List of genotypes with their pedigrees

Sl. No.	ORCZ Designation	Pedigree
1	ORCZ 98	IR-91143- AC 239-1 x BG 102
2	ORCZ 105	DRR Dhan 45/MTU 1010
3	ORCZ 110	IR 15M 1537 / CGZR 1
4	ORCZ 113	IR 85850-AC 157-1 mutant
5	ORCZ 114	-do-
6	ORCZ 115	-do-
7	ORCZ 116-1	BRRI Dhan 64 mutant
8	ORCZ 116-2	-do-
9	ORCZ 117	IR 82475-110-2-2-1-2/BG 102
10	ORCZ 118	IR 82475-110-2-2-1-2/BG 102
11	ORCZ 119	R-RHZ-SM-14/N22
12	ORCZ 121	Sambamahsuri/N22
13	ORCZ 122	RP 5115-111-24-3-1-1/BG102
14	ORCZ 124	IR-AC 239-1 x MTU 1010
15	ORCZ 125	R 99642-57-1-1-1-B/MTU 1010
16	ORCZ 126	R-RHZ-SM-14/N22
17	ORCZ 127	BRRI Dhan 64 mutant
18	ORCZ128	R-RHZ-SD-94/MTU 1010
19	ORCZ129	IR 128788-91-1-2B/BRRI Dhan 64
20	ORCZ130	IR 85850-AC 157-1/URG 24//CGZR-1 /IR 95133: 1B-16-14-10-P1-2-3
21	ORCZ 131	RP 5115-111-24-3-1-1/BG102
22	ORCZ 132	BRRI Dhan 64 mutant
23	ORCZ 133	HH -25-DT-20/Chak Hao
24	ORCZ 134-1	R-RHZ-7/N22
25	ORCZ 134-2	-do-
26	ORCZ 134-3	-do-
27	ORCZ 135	OR(CZ)- 77 Selection
28	ORCZ 136	-do-
29	ORCZ 137	BRRI Dhan 72/N22
30	ORCZ 138	-do-
31	ORCZ 139	CGZR 1/ Dudh Kandar
32	ORCZ 140-1	-do-
33	ORCZ 140-2	-do-
34	ORCZ 140-3	-do-
35	ORCZ 141	OR(CZ) 75-3-1 Sel.
36	ORCZ 142	IR 91143-AC-239-1/N22
37	ORCZ 143-1	R-RHZ-SM-14/N22
38	ORCZ 143-2	-do-

39	ORCZ 145	-do-
40	ORCZ 146	-do-
41	ORCZ 148	IR 82475-110-2-2-1-2/BG 102
42	ORCZ 149	IR 82475-110-2-2-1-2/BG 102
43	ORCZ 150	-do-
44	ORCZ 152	-do-
45	ORCZ 153	IR 91143-AC-239-1/MTU 1010
46	ORCZ 154	IR 85850-AC 157-1/URG 24//CGZR-1 /IR 95133:1B-16-14-10-P1-2-3
47	ORCZ 155	RP 5115-111-24-3-1-1/BG102
48	ORCZ 156	-do-
49	ORCZ 157	-do-
50	ORCZ 158	OR(T) -31 Sel.
51	ORCZ 159	-do-
52	ORCZ 160	-do-
53	ORCZ 161	-do-
54	ORCZ 162	R-RHZ-7/BG 102
55	ORCZ 163	-do-
56	ORCZ 164	-do-
57	ORCZ 165	N22/Dudh Kandar//BRRI Dhan 64 /IR 12877-4-4-2-2B
58	ORCZ 166	IR 82475-110-2-2-1-2/BG 102
59	ORCZ 167	-do-
60	ORCZ 168	IR 15M 1537 / CGZR 1
61	ORCZ 169	BRRI Dhan 64 mutant
62	ORCZ 170	-do-
63	ORCZ 171	-do-
64	ORCZ 172	-do-
65	ORCZ 173	BRRI Dhan 72/Kalanamak
66	ORCZ 174	HH-25-DT-20/OR(CZ) 66
67	ORCZ 175	-do-
68	ORCZ 176	N22 / BRRI Dhan 72
69	ORCZ 177	IR 95133: 1B-16-14-10 GBS-P1-2-3/DRR DHAN 45
70	ORCZ 178	N22/ Dudh Kandar
71	ORCZ 179	HH-25-DT-20/OR(CZ) 66
72	ORCZ 180	DRR Dhan 45/MTU 1010
73	ORCZ 181	IR 82475-110-2-2-1-2 / DRR Dhan 72
74	ORCZ 182	-do-
75	ORCZ 183	-do-
76	ORCZ 184	IR 49642-57-1-1-1-/MTU1010

3.4 Recording of Observation

10 plants were taken randomly from treatment and control plots from each of replications and were tagged separately to record the following observations.

3.4.1 **Grain yield and yield component traits:**

Data on ten random plants from middle row of each plot were recorded for six morpho-economic traits, while days to 50% flowering and days to maturity (days to attend physiological maturity + 4-5 days) were recorded on plot basis. Whereas, 100 –grain weight was recorded (g) from random sample of seeds of each plot respectively

3.4.1.1 Days to maturity (DM) :

Period from date of sowing to date of 50% flowering and physiological maturity + 4 to 5 days respectively.

3.4.1.2 Plant height (PHT):

Height of the plant from the base of the plant to the panicle tip of the mother tiller at maturity and expressed in cm.

3.4.1.3 Effective bearing tillers per hill (EBT):

Average number of effective bearing tillers per hill at maturity.

3.4.1.4 Panicle length (PL):

Length of panicle from the ciliate base to the tip of the panicle of the main culm measured in the centimeter.

3.4.1.5 Grain number per panicle (GN/P):

Average number of filled grains per panicle across 5 top most panicles.

3.4.1.6 1000-grain weight (GW):

Weight of 100-filled grains from random sample of seeds of each plot (expressed in gram).

3.4.1.7 **Seed yield per plant (SY/P):**

Weight of cleanly threshed dry seeds per plant expressed in gram.

3.4.2 Seed quality parameters

3.4.2.1 Seed moisture content

Moisture content of rice seeds was determined by Air Oven Method (ISTA, 1985) taking duplicate samples. The seed material was grinded in a seed grinder into a fine powder. About 5 g of finely ground seed material was taken separately from each treatment in a pre-weighed (M1) moisture box and the weight was recorded (M2). The moisture boxes were then placed in a hot air oven maintained at 103°C for 17 hours. After that the moisture boxes were taken out and allowed to cool to room temperature in a desiccator. The final weight (M3) was recorded. The moisture content was calculated using the following formula and expressed as percentage on wet weight basis.

$$\text{Seed moisture content (\%)} = \frac{\text{Loss in weight}}{Initial\ weight\ of\ seed} \times 100 = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M1 = Weight of empty moisture box + its lid

M2 = Weight of moisture box + lid +seed before drying

M3 = Weight of moisture box + lid + seed after drying

3.4.2.2 Germination percentage

The germination percentage of freshly harvested seeds (100 seeds) of each treatment and replication was calculated by using Between Paper method(Anon, 1999) and expressed in percentage. Germination percentage was calculated as:

$$\text{Seed germination (\%)} = \frac{Number\ of\ normal\ seedling}{Total\ number\ of\ seeds\ put\ for\ germination} \times 100$$

3.4.2.3 Field emergence

One hundred seeds produced under each treatment were sown in rows of 5 m length with a spacing of 20 cm x 10 cm in a leveled field. Water was sprinkled at intervals to maintain proper soil moisture condition. After 14 days the number of seedlings emerged from soil were counted and the field emergence percentage was calculated.

3.4.2.4 Mean seedling length(cm)

Ten no. of normal seedlings were selected randomly in each replication after taking the final count in germination test. The seedling length was measured from the tip of the primary leaf to the root tip with the help of a scale and mean seedling length was expressed in centimetre.

3.4.2.5 Root length (cm)

The length of the roots was measured on ten randomly selected seedlings from the 14th day of germination test and the average was expressed in centimeter.

3.4.2.6 Shoot length (cm)

The shoots length (collar region to tip of topmost leaf) was measured on the same ten random seedlings whose root length was measured earlier and was expressed in centimeter.

3.4.2.7 Mean seedling dry weight(mg)

The ten normal seedlings used for seedling length measurement were used for measurement of seedling dry weight. After removing the remnant portion of the endosperm, only the plumule and radicle were put in butter paper packet and kept in hot air oven at $110\pm1^{0}C$ for 24 hours. Weight of the oven-dried seedlings was taken in an electronic balance and their mean value expressed in gram.

3.4.2.8 Seedling vigour indices

After germination test and measurement of seedling length and seedling dry weight, seed vigour indices I & II were calculated using the formulae given by AbdulBaki and Anderson (1973).

Seedling Vigour Index-I = Germination (%) x Mean seedling length (cm)

Seedling Vigour Index-II = Germination (%) x Mean seedling dry weight (g)

3.4.2.9 Conductivity of seed leachate

Conductivity of seed leachate was measured by adopting the procedure of Sahoo et al., (2006). Eight grams of rice seeds were weighed accurately with the help of an electronic balance and were kept separately in beaker of 100 ml capacity. To the beaker 40 ml of distilled water was added. The beaker was kept in an incubator at 30˚C for 6 hrs. Then the beaker was brought out of the incubator and water was decanted to another beaker and the conductivity of seed leachate was measured by the help of conductivity meter and the value was expressed as deci Siemens per metre (dS/m).

3.4.2.10 Accelerated aging test

The storability of rice seeds produced under different treatments were studied by accelerated ageing method. Here hundred seeds from each treatment of the three replications were exposed to 45ºC and 95% relative humidity for 96 hours in an ageing chamber. The treated seeds were brought out of the ageing chamber under laboratory condition for germination test by using "Between Paper" method as per ISTA rule (Anon, 1999). Then, the germination percentage, root length, shoot length, seed vigour index I & II were assessed and recorded.

3.4.2.10.1 Seed germination after accelerated ageing

Seed of each treatment was kept in accelerated ageing chamber and subjected to accelerated ageing conditions such as high temperature (45^0C) and high humidity (95%) for a period of 96 hours. After that the standard germination test was test as in 3.5.2.2 and the normal seedling count taken after seven days. The germination percentage after accelerated ageing was calculated as:

$$\text{Seed germination after AA (\%)} = \frac{Number\ of\ normal\ seedling}{Total\ number\ of\ seeds\ put\ for\ germination} \times 100$$

3.4.2.10.2 Seedling length and dry weight after accelerated aging

Ten normal seedlings of the aged seeds were selected randomly in each replication after taking the final count in germination test. The seedling length was measured from the tip of the primary leaf to the root tip with the help of a scale and mean seedling length was expressed in centimetres. Weight of the ten random oven-dried seedlings was taken in an electronic balance and their mean value expressed in milligram.

3.4.2.10.3 Seed vigour indices after accelerated ageing

From the germination and seedling growth data, seed vigour indices were calculated as per the following formulae suggested by Abdul-Baki and Anderson (1973):

Seedling vigour index-I = Germination (%) x Mean seedling length (cm)

Seedling vigour index-II=Germination (%) x Mean seedling dry weight (g)

3.5 Micronutrient content:

Brown rice samples of selelcted rice genotypes in triplicates were grounded to fine powder and digested with 3:2 nitric acid (HNO_3) and perchloric acid ($HClO_4$)(Jahan *et al.* 2013) with minor modification.. The atoms of zinc (Zn) absorb energy under flame condition and converted to radiation. The Zn content is proportional to the amount of radiation absorbed as measured by Selective Inductive Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES) at 206.2nm at Central Instrumentation Facility (CIF), OUAT, Bhubaneswar. The replication variation of each sample did not exceed ± 1ppm. The average of three replicates indicate Zn-content of each genotype.

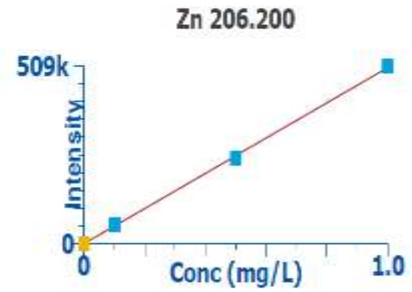

Fig 1. Calibration of standard curve for grain Zn content using ICP-OES

A standard curve was drawn and from this curve, the zinc content of each genotype was estimated as ppm or mg/kg rice kernel.

3.6 Stastical analysis:

Statistical analysis on the data recorded were carried out based on sample means of all traits. Data of each character in randomized block design were subjected for analysis of variance (ANOVA) as per Panse and Sukhatme (1985).

Mean value of each trait was derived by dividing the total observed values by the total number of observations. Critical difference (√ 2EMS/r x t value) for each trait was calculated at error degrees of freedom at probability level of $P_{0.05}$.

Coefficients of correlation were estimated for each pair of characters using SPSS (version 16.0) as per formula of Panse and Sukhateme (1985) to assess inter-relationship among characters under observation.

Besides, *inter se* varietal genetic distances between genotypes were estimated following SPSS software (Version 16) and dendrogram was constructed based on morpho-economic traits and quality traits to assess genotypic relationship among the test genotypes.

RESULTS

The investigation on "*Assessment of Seed Yield and Quality Traits Of Zinc Biofortified Advanced Breeding Lines of Rice*" was conducted in Kharif season of 2020 at Central Farm, Regional Research and Technology Transfer Station, Coastal Zone, OUAT, Bhubaneswar and Dr. G. V. Chalam Seed Testing & Research Laboratory, AICRP on Seed Technology Research, NSP (Crops), OUAT, Bhubaneswar and the results have been presented in this chapter**.**

In this investigation, the parameters relevant to the plant growth, seed yield and yield components and different seed quality attributes including storability have been studied in zinc biofortified rice varieties. Data pertaining to the observations from the present investigation recorded on plant growth parameters, yield & yield components and seed quality parameters were analysed statistically and described with the help of relevant tables and figures along with detailed description of the data.

Grain Zinc content

Brown rice samples of selected rice genotypes in triplicates were grounded to fine powder and digested with 3:2 nitric acid (HNO_3): and perchloric acid ($HClO_4$)(Jahan *et al.* 2013) with minor modification.. The atoms of zinc (Zn) absorb energy under flame condition and converted to radiation. The Zn content is proportional to the amount of radiation absorbed as measured by Selective Inductive Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES) at 206.2nm at Central Instrumentation Facility (CIF), OUAT, Bhubaneswar. The replication variation of each sample did not exceed ± 1ppm. The average of three replicates indicates Zn-content of each genotype.

Table 3. Zn content of brown rice of a set of 76 rice cultures using ICP-OES facility at CIF, OUAT, Bhubaneswar

Sl. No.	ORCZ Designation	Pedigree	Zn content (mg/kg)	Elite High Zn (>30mg/kg)
1	ORCZ 98	IR-91143- AC 239-1 x BG 102	31.27	High Zn
2	ORCZ 105	DRR Dhan 45/MTU 1010	23.23	
3	ORCZ 110	IR 15M 1537 / CGZR 1	24.92	
4	ORCZ 113	IR 85850-AC 157-1 mutant	22.73	
5	ORCZ 114	-do-	31.71	High Zn
6	ORCZ 115	-do-	27.06	
7	ORCZ 116-1	BRRI Dhan 64 mutant	20.13	
8	ORCZ 116-2	-do-	25.32	
9	ORCZ 117	IR 82475-110-2-2-1-2/BG 102	24.42	
10	ORCZ 118	IR 82475-110-2-2-1-2/BG 102	19.42	
11	ORCZ 119	R-RHZ-SM-14/N22	15.24	
12	ORCZ 121	Sambamahsuri/N22	17.35	
13	ORCZ 122	RP 5115-111-24-3-1-1/BG102	10.43	
14	ORCZ 124	IR-AC 239-1 x MTU 1010	27.07	
15	ORCZ 125	R 99642-57-1-1-1-B/MTU 1010	14.92	
16	ORCZ 126	R-RHZ-SM-14/N22	22.78	
17	ORCZ 127	BRRI Dhan 64 mutant	19.31	
18	ORCZ128	R-RHZ-SD-94/MTU 1010	20.55	
19	ORCZ129	IR 128788-91-1-2B/BRRI Dhan 64	11.14	
20	ORCZ130	IR 85850-AC 157-1/URG 24//CGZR-1 /IR 95133:1B-16-14-10-P1-2-3	12.05	
21	ORCZ 131	RP 5115-111-24-3-1-1/BG102	24.52	
22	ORCZ 132	BRRI Dhan 64 mutant	21.17	
23	ORCZ 133	HH -25-DT-20/Chak Hao	17.71	
24	ORCZ 134-1	R-RHZ-7/N22	23.01	
25	ORCZ 134-2	-do-	17.89	
26	ORCZ 134-3	-do-	16.58	
27	ORCZ 135	OR(CZ)- 77 Selection	49.87	High Zn
28	ORCZ 136	-do-	15.10	
29	ORCZ 137	BRRI Dhan 72/N22	15.14	
30	ORCZ 138	-do-	17.81	
31	ORCZ 139	CGZR 1/ Dudh Kandar	18.17	
32	ORCZ 140-1	-do-	14.13	
33	ORCZ 140-2	-do-	14.82	
34	ORCZ 140-3	-do-	15.90	
35	ORCZ 141	OR(CZ) 75-3-1 Sel.	28.19	
36	ORCZ 142	IR 91143-AC-239-1/N22	19.62	
37	ORCZ 143-1	R-RHZ-SM-14/N22	18.09	
38	ORCZ 143-2	-do-	20.68	
39	ORCZ 145	-do-	17.40	
40	ORCZ 146	-do-	21.60	

41	ORCZ 148	IR 82475-110-2-2-1-2/BG 102	69.7	High Zn
42	ORCZ 149	IR 82475-110-2-2-1-2/BG 102	26.70	
43	ORCZ 150	-do-	13.80	
44	ORCZ 152	-do-	25.40	
45	ORCZ 153	IR 91143-AC-239-1/MTU 1010	24.60	
46	ORCZ 154	IR 85850-AC 157-1/URG 24//CGZR-1 /IR 95133:1B-16-14-10-P1-2-3	23.70	
47	ORCZ 155	RP 5115-111-24-3-1-1/BG102	20.50	
48	ORCZ 156	-do-	34.60	High Zn
49	ORCZ 157	-do-	27.90	
50	ORCZ 158	OR(T) -31 Sel.	18.20	
51	ORCZ 159	-do-	19.70	
52	ORCZ 160	-do-	22.30	
53	ORCZ 161	-do-	30.40	High Zn
54	ORCZ 162	R-RHZ-7/BG 102	35.00	High Zn
55	ORCZ 163	-do-	16.90	
56	ORCZ 164	-do-	8.80	
57	ORCZ 165	N22/Dudh Kandar//BRRI Dhan 64 /IR 12877-4-4-2-2B	35.30	High Zn
58	ORCZ 166	IR 82475-110-2-2-1-2/BG 102	19.80	
59	ORCZ 167	-do-	38.40	High Zn
60	ORCZ 168	IR 15M 1537 / CGZR 1	17.60	
61	ORCZ 169	BRRI Dhan 64 mutant	40.00	High Zn
62	ORCZ 170	-do-	17.60	
63	ORCZ 171	-do-	28.80	
64	ORCZ 172	-do-	19.00	
65	ORCZ 173	BRRI Dhan 72/Kalanamak	21.60	
66	ORCZ 174	HH-25-DT-20/OR(CZ) 66	33.10	High Zn
67	ORCZ 175	-do-	31.20	High Zn
68	ORCZ 176	N22 / BRRI Dhan 72	31.30	High Zn
69	ORCZ 177	IR 95133: 1B-16-14-10 GBS-P1-2-3/DRR DHAN 45	20.50	
70	ORCZ 178	N22/ Dudh Kandar	21.70	
71	ORCZ 179	HH-25-DT-20/OR(CZ) 66	23.00	
72	ORCZ 180	DRR Dhan 45/MTU 1010	22.70	
73	ORCZ 181	IR 82475-110-2-2-1-2 / DRR Dhan 72	58.00	High Zn
74	ORCZ 182	-do-	20.50	
75	ORCZ 183	-do-	27.50	
76	ORCZ 184	IR 49642-57-1-1-1-/MTU1010	28.20	

The top Zn dense (≥30ppm) genotypes, identified as compared to check variety Swarna (11.30ppm) in the present investigation (**Table 3**) were ORCZ 148 (69.7ppm) followed by ORCZ 181 (58.0ppm), ORCZ 135(49.87 ppm), ORCZ 169 (40.0 ppm), ORCZ 167(38.40ppm),

ORCZ 165, (35.30ppm), ORCZ 162(35.0ppm), ORCZ 156(34.60ppm), ORCZ 174 (33.10ppm), ORCZ 114 (31.71ppm), ORCZ 176 (31.30ppm), ORCZ 98(31.27ppm), ORCZ 175(31.20ppm) and ORCZ 161 (30.40ppm) (Table 3).

Table 4. Performance of elite high- Zn rice cultures for agro-morphological traits

ORCZ Designation	Days to maturity	Plant height (cm)	EBT /m^2	No. of grains /panicle	1000-seed weight (g)	Seed yield (q/ha)	Grain Zn content (mg/kg)
T_0:Swarna (check)	144.5	75.5	420.4	135.8	22.5	40.35	11.30
T_1 : ORCZ 98	136.5	96.4	402.5	130.2	23.0	39.9	31.27
T_2 : ORCZ 181	138.0	90.6	410.0	128.0	23.4	37.0	58.0
T_3 : ORCZ 114	145.0	130.0	388.0	140.4	25.6	49.8	31.71
T_4 : ORCZ 176	130.6	92.8	405.0	124.6	24.4	40.2	31.30
T_5 : ORCZ 135	120.5	120.0	389.4	158.0	24.8	47.2	49.87
T_6 : ORCZ 175	128.0	125.5	340.0	129.8	23.0	35.8	31.20
T_7 : ORCZ 148	120.8	110.6	380.8	130.2	23.8	40.9	69.7
T_8 : ORCZ 174	130.9	108.2	395.0	128.9	23.2	38.8	33.10
T_9 : ORCZ 156	132.0	102.0	398.0	134.0	23.4	42.8	34.60
T_{10} : ORCZ 169	140.0	105.0	402.5	135.7	23.0	42.8	40.0
T_{11} : ORCZ 161	135.8	94.8	420.4	140.2	22.9	40.2	30.40
T_{12} : ORCZ 167	134.4	90.5	401.9	132.6	13.0	38.3	38.40
T_{13} : ORCZ 162	145.0	118.0	408.6	130.2	23.8	40.0	35.0
T_{14} : ORCZ 165	135.0	118	392.8	135	22.8	39.6	35.30
Mean	**134.4**	**105.2**	**397.0**	**134.2**	**23.5**	**40.9**	**37.4**
CD(5%)	**8.4**	**12.2**	**16.2**	**20.8**	**1.03**	**5.40**	**6.50**

The stable morphological traits are most important for varietal identification. A systematic and meticulous effort was therefore, undertaken to assess all the relevant stable morphological traits. Mean performance of all rice varieties for seed yield and its component traits have been shown in Table 4.

The mean performance of genotypes clearly spelt out the abundant scope for selection of valuable genotypes. Wide array of range variation in almost all characters further strengthens the probable effectiveness of selection. The best entries with regard to specific traits may be utilized as donors in future breeding programme.

Zn biofortification is targeted to develop variety with high grain zinc content with better agro-morphological character. 14 zinc biofortified breeding lines along with Swarna as a check variety are tested in the field condition. Days to maturity ranged from 120.5 days in ORCZ 135 to 144.5 days in Swarna as the standard check variety (Table-6). Semidwarf to intermediate plant types are needed to prevent the crop from lodging and to retain physical quality features. Plant height of the test entities ranged from dwarf plant type as in Swarna (75.5 cm) to as tall as ORCZ 114 (130 cm).

Number of effective bearing tillers (EBT), grain number/panicle, Test weight status determined yield potential of the advanced breeding lines. In the present investigation, EBT/m^2 was recorded maximum in Swarna as a check variety followed by ORCZ 161, ORCZ 181, ORCZ 162. ORCZ 135 show compact panicle (with 158.0 number of grains/panicle) as compared to the check variety Swarna (135.8 number of grains/panicle). All the varieties except ORCZ 167 recorded 1000-seed weight more than 22.0g.

Farmers are sceptic for realization of more produce from each penny invested so as to earn more profit per unit area of cultivation and to suffice their food requirement. Therefore, a biofortified crop variety should retain high yield potential besides being rich in micronutrient. In the present investigation, ORCZ 135 and ORCZ 114 give better yield potential (47 – 50q/ha) compaired to Swarna (40Q/ha) as a check variety.

Seed Moisture Content

The analysis of variance for seed moisture content indicated non-significant variation among various treatments. The treatments means varied from 11.24% (T_{12}) to

12.22% (T_9) with an overall mean of 11.79% (Table 5). Numerically higher percentage of seed moisture content was indicated in the treatment T_9 (12.22%) followed by T_{10} (12.21%), T_5 (12.21%), T_{11} (12.08%), T_3 (11.95%), T_6 (11.89%), T_4 (11.86%), T_{13} (11.79%), T_8 (11.77%), T_{14} (11.6%), T_2 (11.51%), T_1 (11.43%), T_7 (11.42%), T_{12}(11.24%) whereas lowest seed moisture content was recorded in the treatment T_{12} (11.24 %).

Table 5. Assessment of seed moisture content and electrical conductivity of a set of elite high Zn rice cultures.

ORCZ Designation	Seed moisture %	Electrical conductivity (EC) (ds/m)
T_0:Swarna (check)	11.67	0.074
T_1 : ORCZ 98	11.43	0.066
T_2 : ORCZ 181	11.51	0.053
T_3 : ORCZ 114	11.95	0.061
T_4 : ORCZ 176	11.86	0.058
T_5 : ORCZ 135	12.21	0.051
T_6 : ORCZ 175	11.89	0.054
T_7 : ORCZ 148	11.42	0.052
T_8 : ORCZ 174	11.77	0.053
T_9 : ORCZ 156	12.22	0.066
T_{10} : ORCZ 169	12.21	0.061
T_{11} : ORCZ 161	12.08	0.053
T_{12} : ORCZ 167	11.24	0.061
T_{13} : ORCZ 162	11.79	0.052
T_{14} : ORCZ 165	11.6	0.053
Mean	11.79	0.062
SEm(±)	0.51	0.005
CD(5%)	NS	0.01

Electrical conductivity of seed leachate (dS/m)

Electrical conductivity (EC) of seed leachate is an accurate indicator of seed vigour. Strong and negative relationship between EC and seed vigour have been reported by many workers in many crops (Hamdi and Elemery, 1996).

The ANOVA for EC showed significant variation among the different treatments for the study of their effect of seed zinc content on electrical conductivity of seed leachate. The mean value of the treatments ranged from 0.051 dS/m (T_5) to 0.074 dS/m (T_0) with an overall mean of 0.062 dS/m (Table 5). All treatments except T_1 and T_9 had significantly lower values than T_0 (0.074 dS/m). The treatments except T_1 and T_9 are at par with T_5, T_1 and T_9 are at par with each other. So we conclude that T5 is highest vigour than all other treatments.

Table 6. Seedling parameters following germination of fresh seeds after breaking dormancy.

ORCZ Designation	G(%)	FE (%)	FC(%)	Shoot length (cm)	Root Length (cm)	Seedling length (cm)	SDW (mg)	SVI-I	SVI-II
T_0:Swarna (check)	85.67 (9.25)	80.67 (8.98)	68.33 (55.76)	7.73	12.67	20.4	63.1	1749.7	5.42
T_1 : ORCZ 98	90.33 (90.5)	85.67 (9.25)	71.00 (57.42)	7.90	13.20	21.1	68.5	1953.4	6.29
T_2 : ORCZ 181	91.67 (9.57)	88.33 (9.40)	73.67 (59.15)	8.20	14.50	22.70	71.9	2066.7	6.52
T_3 : ORCZ 114	90.67 (9.52)	86.33 (9.29)	71.33 (57.63)	8.27	13.30	21.27	69.1	1955.5	6.29
T_4 : ORCZ 176	91.33 (9.56)	88.00(9.38)	73.00 (58.72)	8.33	13.73	22.07	70.1	2022.9	6.50
T_5 : ORCZ 135	93.33 (9.66)	91.00(9.54)	76.00 (60.69)	7.87	16.10	23.97	75.3	2188.6	6.88
T_6 : ORCZ	91.00	86.3	71.33	8.30	13.07	21.37	72.2	1958.	6.32

175	(9.54)	3(9.29)	(57.63)					4	
T_7 : ORCZ 148	91.67 (9.57)	89.67(9.47)	74.00 (59.37)	8.07	15.60	23.67	73.1	2147.5	6.65
T_8 : ORCZ 174	92.00 (9.59)	90.67(9.52)	75.33 (60.23)	8.83	15.00	23.83	74.0	2179.1	6.73
T_9 : ORCZ 156	90.00 (9.49)	85.00(9.22)	70.33 (57.01)	7.77	13.30	21.07	65.5	1924.0	5.96
T_{10} : ORCZ 169	91.00 (9.54)	88.00(9.38)	72.67 (58.48)	8.47	13.23	21.7	69.9	1980.7	6.49
T_{11} : ORCZ 161	91.33 (9.56)	88.33(9.40)	74.00 (59.37)	8.43	14.87	23.3	71.2	2120.4	6.54
T_{12} : ORCZ 167	91.00 (9.54)	86.33(9.29)	71.67 (57.84)	8.03	13.50	21.53	69.5	1969.5	6.41
T_{13} : ORCZ 162	91.67 (9.57)	89.00(9.43)	74.00 (59.37)	7.80	15.80	23.6	72.2	2145.4	6.62
T_{14} : ORCZ 165	92.00 (9.59)	90.00(9.49)	75.00 (60.03)	8.30	15.47	23.77	73.0	2152.1	6.72
Mean	90.98 (9.54)	85.67(9.36)	72.78 (58.58)	8.15	14.20	22.36	70.5	2034.2	6.42
SEm(±)	0.084	0.093	1.262	0.302	0.57	0.62	1.461	67.40	0.18
CD(5%)	0.17	0.191	2.57	0.61	1.17	2.04	2.9	137.64	0.367

Note: G-Germination % , FE- Field emergence , FC- First count, SDW-Seedling dry weight, SVI: Seed vigour index-I and SVI: Seed vigour index-II (The figures of parenthesis like G%, FC %, FE% indicates the square root transformation values)

Seed germination (%)

Germination percentage is the standard physiological parameter which is commonly used to assess the planting value of seeds. In the present study, germination tests were conducted by between paper (BP) method using fresh seeds after breaking dormancy.

The analysis of variance for germination percentage indicated significant variation among the different treatments. The mean value of the treatments ranged from 85.67% (T_0) to 93.33% (T_5) with an overall mean of 90.98% (Table 6). All treatments showed significantly higher values over check variety T_0. The maximum seed germination was recorded in the treatment T_5 (93.33 %) which was 8.94% % higher than check variety (85.67 %). All treatments except T_0 are at par with T_5.

Field emergence(%) :-

Field emergence gives a realistic picture about assessment of stand establishment potential of seed lots. The condition of field where seeds germinate and seedlings emerge out from the soil are less favourable than the condition during germination tests under laboratory, hence low seed vigour seeds perish under field condition.

The analysis of variance for this character indicated significant variation among the different treatments for the study of their effect of seed zinc content on field emergence. The mean value of the treatments ranged from 80.67% (T_0) to 91.00%% (T_5) with an overall mean of 85.67% (Table 6). All treatments had shown significantly higher values over T_0 (80.67%) for this trait. The maximum field emergence was recorded in the treatments T_5 (91.00%). T_4, T_{10},T_2,T_{11},T_3,T_{14} and T_8 treatments are at par with T_5 (91.00%). T_{11},T_{13},T_7,T_{14},T_8 and T_5 treatments have significantly higher field emergence than T_9. The lowest field emergence was recorded in treatment T_0 (80.67 %).

First count (%):-

The vigour parameter first count exhibited significant variation among the different treatments. It ranged from 68.33% ($T_{0)}$ to 76.00% (T_5) with an overall mean of

72.78% (Table 6). All treatments except T_9, T_1, T_3, T_6, T_{12} have significantly higher values over check variety (68.33%). The maximum first count value was recorded in the treatment T_5 (76.00%) which was 11.22 % higher than control (68.33%). All treatments except T_{14}, T_8, T_5 are at par with T_9, T_{14}, T_8 and T_5 are at par with each other. The lowest first count value was recorded in check variety T_0(68.33 %).

Seedling shoot length (cm)

Shoot length is an important parameter which reflects early seedling growth during germination of crop seeds. In the present investigation, this parameter was measured on the final day of germination count, i.e, final count.

The analysis of variance for seedling shoot length indicated presence of significant variation among various treatments. The mean value of the treatments varied from 7.73cm (T_0) to 8.83 cm (T_8) with an overall mean of 8.15 cm (Table 6). T_{11}, T_{10}, T_8 treatments have significantly higher value than the check variety (T_0). T_9, T_{13}, T_5, T_1, T_{12}, T_7, T_2 treatments have significantly lower than T_8 and these treatments are at par with each others.

Seedling root length (cm)

Seedling root length exhibited significant variation among the various treatments. It ranged from 12.67cm (T_0) to 16.10 cm (T_5) between treatments with an overall mean of 14.20 cm (Table 6). T_2, T_{11}, T_8, T_{14}, T_7, T_{13} and T_5 are significantly higher than T_0 and other treatments are at par with T_0. All treatments except T_8, T_{14}, T_7 and T_{13} are significantly lower than T_5.

Seedling length (cm)

The ANOVA for this character indicated significant variation among the different treatments. The mean value of the treatments ranged from 20.4 cm (T0) to 23.97 cm (T5) with an overall mean of 23.36 cm (Table 6). All treatments showed significantly higher values over check variety (20.4 cm). The treatments T5 (23.97 cm) recorded maximum seedling length. Treatments T9, T1, T3, T6, T12, T10 are significantly lower than T5 and others treatments are at par with T5. T5 showed 17.5% higher value than the check variety. The lowest seedling length was recorded in control 20.4 cm.

The analysis of variance for seedling dry weight revealed the presence of significant variation among various treatments. The mean value of the treatments varied from 63.1mg (T0) to 75.3 mg (T5) with an overall mean of 70.5mg (Table 6). All treatments except T9 showed significantly higher values over check variety (63.1 mg). The highest seedling dry weight was recorded in the treatment T5 (75.3 mg) with 19.33% higher value than check variety. All treatments except T14, T7, T8, have significantly lower dry weight than T5. T14, T7, T8, T5 are at par with each other.

Seedling vigour index-I

The performance of crop varieties also largely depend upon seed vigour (Mathews, 1993). Therefore any study involving seed production and quality assessment, due emphasis is given on seed vigour. The ANOVA for seedling vigour index-I which was the product of seed germination and seedling length indicated significant variation among the different treatments. Its mean values for various treatments ranged from 1749.7 (T_0) to 2188.6 (T_5) with an overall mean of 2034.2 (Table 6). All treatments showed significantly higher values over T_0 (1749.7). The maximum SVI-I was recorded in the treatment T_5 (2188.6) with 25.08% higher value than control. All the treatments are significantly higher than T_0. All the treatments except T_9, T_1, T_3,$T_{6,}$$T_{12}$, T_{10},T_4 are at par with T_5 and T_9, T_1, $T_{3,}$$T_6$,$T_{12}$, T_{10},T_4 are at par with each other.

Seedling vigour index-II

The analysis of variance for seedling vigour index-II (germination % x seedling dry weight in mg) indicated significant variation among various treatments on this trait. The mean values of various treatments varied from 5.42 (T0) to 6.88 (T5) with an overall mean of 6.42 (Table 6). All treatments showed significantly higher values over check variety (5.42). The highest SVI-II was recorded in the treatment T5 (6.88) with 26.93% higher value than check variety). All . The lowest SVI-II was recorded in control (5.42). All the treatments are significantly higher than T0. All the treatment except T2, T11, T13, T7, T14,T8 are significantly lower than T5 and T2, T11, T13, T7, T14,T8 are at par with each other. All the treatments except T3, T1, T6 have significantly higher SVI-II than T9 and T3. T1, T6 are significantly at par with each other.

Table 7. Seedling parameters after Ageing Test.

ORCZ Designation	G (%)	FE(%)	SVI-I	SVI-II
T_0:Swarna (check)	74.33(8.60)[a]	73.33(8.56)[b]	1560.4	4.64
T_1 : ORCZ 98	84.33(9.18)	82.00(9.05)	1784.6	5.52
T_2 : ORCZ 181	85.67(9.26)	84.00(9.16)	1907.9	5.82
T_3 : ORCZ 114	84.67(9.20)	81.00(9.00)	1789.9	5.57
T_4 : ORCZ 176	85.33(9.24)	83.33(9.13)	1860.1	5.79
T_5 : ORCZ 135	87.33(9.34)	86.00(9.27)	2046.1	6.27
T_6 : ORCZ 175	85.00(9.22)	82.33(9.07)	1794.8	5.57
T_7 : ORCZ 148	86.33(9.29)	84.67(9.20)	1989.4	5.98
T_8 : ORCZ 174	87.33(9.34)	85.67(9.26)	2027.9	6.07
T_9 : ORCZ 156	83.67(9.15)	80.67(8.98)	1755.8	5.18
T_{10} : ORCZ 169	85.33(9.24)	82.67(9.09)	1819.3	5.75
T_{11} : ORCZ 161	86.00(9.27)	84.00(9.16)	1961.6	5.84
T_{12} : ORCZ 167	85.33(9.24)	82.33(9.07)	1806.4	5.66
T_{13} : ORCZ 162	86.00(9.27)	84.33(9.16)	1986.2	5.92
T_{14} : ORCZ 165	86.67(9.31)	85.33(9.24)	1994.6	6.08
Mean	84.89(9.21)	82.78(9.09)	1872.3	5.71
SEm(±)	0.095	0.106	61.6	0.16
CD(5%)	0.19	0.21	125.7	0.32

Note: G-Germination(%), SVI-I: Seedling vigour index-I, SVI-II: Seedling vigour index II (The parameters like G%, FE% indicates the arcsine transformation value).

Seed germination (%) after accelerated ageing

The accelerated ageing (AA) vigour test provides valuable information on both seed storability and field seedling emergence potentials. The AA stress exposes seeds for relatively short period to high to high temperature (41ºC) and RH (about 95%) followed by a germination test. This combination of raised seed water content and high temperature causes rapid seed ageing. High vigour seeds are more tolerant to these stressful conditions and produce a higher percentage of normal seedlings.

The ANOVA for seed germination after accelerated ageing indicated significant variation among the different treatments. The mean value of the treatments ranged from

74.33% (T_0) to 87.33 % (T_5) with an overall mean of 84.89 % (Table 7). All treatments showed significantly higher values compared with check variety (74.33 %).The maximum seed germination was recorded in the treatment T_5 (87.33 %) which was 17.48 % higher than control, whereas the lowest seed germination was recorded in check variety (74.33 %).The treatment except T_0 (74.33%) was statistically at par with T_5.

Field emergence (%) after accelerated ageing

The ANOVA for seedling field emergence after accelerated ageing indicated significant variation among the different treatments. The mean value of the treatments ranged from 73.33 % (T0) to 86.00 % (T5) with an overall mean of 82.78 % (Table 7). All treatments showed significantly higher emergence compared with control (73.67 %).The maximum emergence was recorded in the treatment T5 (86.00 %) which was 17.27 % higher than check variety, whereas the lowest seed germination was recorded in check variety(73.33 %). T9,T3,T1 are significantly lower than T5 and all other treatments are at par with T5.

Seedling vigour index-I after accelerated ageing

Seedling vigour index-I after accelerated ageing also exhibited significant variation among the various treatments. Its mean values for the treatments ranged from 1560.4 (T0) to 2064.1 (T5) with an overall mean of 1873.3 (Table 7). All treatments had significantly higher values than control (1471.02). All treatments are significantly higher than check variety (T0). The maximum SVI-I was recorded in the treatment T5 (2046.1) which was 23.7 % higher than check variety (1560.4). T9,T1,T3,T6,T12,T10,T4 and T2 are significantly lower than T5 and these treatments are at par with each other. The lowest seedling vigour index-I was recorded in check variety (1560.4).

Seedling vigour index-II after accelerated ageing

The ANOVA for seedling vigour index-II after accelerated ageing exhibited significant variation among the various treatments. Its mean values for the treatments ranged from 4.64 (T0) to 6.27 (T5) with an overall mean of 5.71(Table 7). All treatments had significantly higher values than T0 (4.64). All treatments except T7, T8, T14 were significantly lower than T5. The maximum SVI-II was recorded in the treatment T5 (6.27) which was 25.9 % higher than check variety (4.64). The lowest seedling vigour index-II was recorded in check variety (4.64).

Table 8. Inter-relationship of seedling and agro-morphological traits with grain Zn content.

Traits	Zn content	DM	PHT	EBT	GN/P	1000-SW	SY	SM	EC	G^a	FE^a	FC	SL	RL	DW	$SVI\text{-}I^a$	$SVI\text{-}II^a$	G^b	FE^b	SVI^b	$SVII^b$
Zn	1.00																				
DM	-0.45	1.00																			
PHT	0.24	0.04	1.00																		
EBT	-0.22	0.42	-0.7**	1.00																	
GN/P	0.04	0.22	0.29	0.02	1.00																
1000-SW	0.06	0.50	0.40	-0.11	0.16	1.00															
SY	0.03	0.38	0.39	0.07	0.69**	0.40	1.00														
SM	-0.19	0.36	0.32	-0.05	0.51	0.53*	0.52*	1.00													
EC	-0.60*	0.27	-0.54*	0.32	-0.09	-0.19	0.13	-0.05	1.00												
G^a	0.62*	-0.33	0.57*	-0.30	0.17	0.10	0.08	0.13	-0.87**	1.00											
FE^a	0.63*	-0.26	0.51	-0.18	0.16	0.20	0.05	0.10	-0.91**	0.93**	1.00										
FC	0.55*	-0.17	0.41	-0.05	0.24	0.21	0.03	0.10	-0.89**	0.86**	0.97**	1.00									
SL	0.04	-0.15	0.19	-0.17	-0.22	0.09	-0.17	0.12	-0.43	0.40	0.48	0.44	1.00								
RL	0.55*	-0.11	0.37	0.04	0.29	0.22	0.06	-0.00	-0.81**	0.68**	0.83**	0.89**	0.08	1.00							
DW	0.60*	-0.29	0.58*	-0.38	0.17	0.16	-0.07	-0.00	-0.95**	0.89**	0.94**	0.92**	0.46	0.79**	1.00						
$SVI\text{-}I^a$	0.58*	-0.22	0.46	-0.09	0.17	0.20	0.00	0.04	-0.92**	0.87**	0.97**	0.97**	0.38	0.92**	0.91**	1.00					
$SVI\text{-}II^a$	0.61*	-0.28	0.51	-0.20	0.15	0.10	0.03	0.02	-0.90**	0.96**	0.98**	0.94**	0.46	0.77**	0.94**	0.93**	1.00				
G^b	0.60*	-0.37	0.56*	-0.31	0.04	0.05	0.02	0.08	-0.82**	0.98**	0.89**	0.79**	0.46	0.59*	0.83**	0.83**	0.93**	1.00			
FE^b	0.62*	-0.36	0.50	-0.24	0.07	0.11	-0.04	0.04	-0.89**	0.98**	0.97**	0.91**	0.47	0.73**	0.91**	0.93**	0.97**	0.97**	1.00		
$SVI\text{-}I^b$	0.59*	-0.23	0.47	-0.10	0.18	0.20	0.01	0.05	-0.92**	0.88**	0.97**	0.98**	0.38	0.92**	0.92**	1.00**	0.94**	0.84**	0.93**	1.00	
$SVI\text{-}II^b$	0.61*	-0.27	0.51	-0.19	0.18	0.13	0.05	0.03	-0.90**	0.95**	0.98**	0.96**	0.45	0.80**	0.95**	0.95**	1.00**	0.90**	0.97**	0.95**	1.00

Note : *, ** denote significant at $P_{0.05}$ and $P_{0.01}$

Correlation with Grain Zinc content

Zinc is a cofactor for more than 300 enzymes, participating in a number of cellular reaction including those involved in growth and development. In the present study, an attempt was did to assess inter relationship of grain Zn content with seedling parameters and agro-morphological traits including seed yield (Table 8)

Zn is found to have significant positive relationship with all seedling parameters such as germination (%), FE(%), FC(%), Root length, Shoot length, Seedling dry weight as well as both vigour index (fresh seeds and aged seeds).

It significantly negatively correlated with EC. This indicates that Zn is incredably helpful for initial growth and development starting from germination process. The negative relationship of Zn with EC signifies that, Zn content has improved the seed quality leading to lower amount of seed leachate, in the present set of variety as compaired to Swarna (high lechate) in the solution (Table 8)

Correlation of component traits with yield

The number of effective bearing tillers was found to maintain significant negative correlation with plant height owing to fact that the similar plant types relationship status of high yield potential. (Table 8)

Among the component traits grain number per Panicle was shown to have significant positive relationship with yield and other components traits. In this context, days to maturity, plant height and seed weight exhibit a positive relationship though not significant.

Correlation of seed quality parameters with agro- morphological traits

Seed moisture content revealed significant positive relationship with seed yield. Electrical conductivity signifies the extent of seed quality deterioration. In the present study, electrical conductivity maintained significant inverse relationship with plant height (Table 8) indicating more deterioration of seed quality derived from dwarf to semi dwarf plant type. While seedling dry weight and germination (%) (both fresh and aged seed) has been revealed significant relationship with plant height. Thus the seed quality in terms of germination is expected to be improved in semi tall to tall types plants.

Correlation among seed and seedling quality parameters

Seed moisture above the critical limit (12%) is an crucial factor for seed quality deterioration. It revealed no significant relationship with none of the seed and seedling parameters under the study (Table 8). Similar Shoot length also have no significant relationship with any of the seed and seedling parameters. Although, it has feeble negative correlation with EC and weak the relationship with germination (%).

It is worth to note that EC revealed significantly negative relationship with almost all the quality parameters and the study (Table 8) indicating its role in seed quality deterioration. In contrast germination (%), field emergency, fast count, root length, dry matter, vigour index (both fresh and age seed) show a positive relationship among themselves. This envisaged strong correlation response for growth and development among the Seedling quality traits for the better survival and Seedling establishment.

Seed vigour index (SVI-I and SVI-II) based on fresh seed after breaking seed dormancy and vigour index after a aging process revealed perfect relationship (r = 1) among respective vigour index- I and II. This indicates that the status of seed quality can be maintained to a substantial period without seed detoriation in the presence of zinc biofortified materials.

The present 14 zinc biofortified rice fixed breeding lines were evaluated in the field for seed yield and yield contributing traits. Among the varieties ORCZ 114 and ORCZ 135 give better yield potential (47-50Q/ha). While ORCZ 176, ORCZ 148, ORCZ 156, ORCZ 169, ORCZ 161, ORCZ 162 exhibited seed yield more than 40Q/ha, Which is comparable to the mega variety Swarna. The significant high yield performance of the above fixed breeding lines may be attributed to important yield contributing traits such as tiller number, seeds/panicle, grain weight. Among the test genotypes ORCZ 148, ORCZ 181, ORCZ 135 retain high Zn content along with high yield potential ORCZ 181. These may be considered for seed multiplication and multilocational testing.

DISCUSSION

The results of the present investigation on "*Assessment of Seed Yield and Quality Traits Of Zinc Biofortified Advanced Breeding Lines of Rice*" conducted during kharif season of 2020 at Central Research Farm, Regional Research and Technology Transfer Station, Coastal Zone, OUAT, Bhubaneswar using zinc biofortified advance breeding lines of rice. The effect of zinc biofortified rice on seed yield and seed quality parameters have been discussed in this chapter.

5.1 Assessment of grain zinc content and identification of Zn fortified rice genotypes.

In the present studies, Seventy six zinc biofortified advanced breeding lines of rice were collected from Central Farm, Regional Research and Technology Transfer Station, Coastal Zone, OUAT, Bhubaneswar, Odisha. These samples were tested for zinc content in Central Instrumentation Facility (CIF), OUAT, Bhubaneswar. The top Zn dense (≥30ppm) varieties, identified as compared to check variety Swarna (11.30ppm) in the present investigation were ORCZ 148 (69.7ppm) followed by ORCZ 181 (58.0ppm), ORCZ 135(49.87ppm), ORCZ 169 (40.0ppm),ORCZ 167(38.40ppm), ORCZ 165 (35.30ppm), ORCZ 162(35.0ppm), ORCZ 156(34.60ppm), ORCZ 174 (33.10ppm), ORCZ 114 (31.71ppm), ORCZ 176 (31.30ppm), ORCZ 98(31.27ppm), ORCZ 175(31.20ppm), ORCZ 161 (30.40ppm). The obtained results is similar to the findings obtained by Babu et al., (2013), Anuradha *et al.*, (2012a) in related studies.

5.2 Assessment of of growth parameters and Identification of high yielding advanced breeding lines of rice

Determination of days of maturity maturity is crucial to maintain seed quality, since over-maturity affects the sowing quality of seeds. Days of maturity is achieved when the seed moisture content is reduced to safe limits to take up further postharvest operations. The days of maturity ranged from 120.5 days in ORCZ 135 to 144.5 days in Swarna as the standard check variety. If the days of maturity reduces then the yield of the crop does not affected by the many types of environmental disasters and Semidwarf to intermediate plant types are needed to prevent the crop from lodging and to retain physical quality features. Plant height of the test entities ranged from dwarf plant types as in swarna (75.5 cm) to as tall as ORCZ 114 (130 cm).

The results show the similar types finding obtained by Shahidullah *et al*., (2009), Drostkar *et al*., (2006) and Kumar *et al*., (2014) in related this study.

In the present investigation, Number of effective bearing tillers (EBT), grain number/panicle, Test weight status determined yield potential of the any variety. In the present investigation, EBT/m^2 was recorded maximum in Swarna as a check variety followed by ORCZ 161, ORCZ 181, ORCZ 162. ORCZ 135 show compact panicle (with 158.0 number of grains/panicle) as compared to the check variety Swarna (135.8 number of grains/panicle). All the varieties except ORCZ 167 recorded 1000-seed weight more than 22.0g. Farmers are sceptic for realization of more produce from each penny invested so as to earn more profit per unit area of cultivation and to suffice their food requirement. Therefore, a biofortified crop variety should retain high yield potential besides being rich in micronutrient. In the present investigation, ORCZ 135 and ORCZ 114 give better yield potential (47 – 50q/ha) compaired to Swarna (40Q/ha) as a check variety. The results show the similar types finding by Abdul Rashid *et al.*, (2019), Yilmaz *et al.*, (2008) and Moazam *et al.*, (2017) in the related studies.

5.3 Assessment of Seed quality parameters of zinc biofortified advanced breeding lines of rice.

In any seed production program, maintenance of sowing quality of seed is the most important consideration. Various physiological parameters accounts for the planting value of seed, most of which are influenced by the environment prevalent during crop growth and post-harvest period. Knowledge of the relationship between nutritional status of soil and plants and the sowing quality of seed is important for the seed production and maintenance of better seed quality. In the present study, the seed quality was assessed by different quality parameters, the results were discussed here under.

All the selected zinc biofortified advanced breeding lines influenced significantly the seed quality parameters such as germination, field emergence, shoot-root length and dry weight, SVI- I & II as compared to the control. In almost all cases, ORCZ 135 recorded the highest and the check variety had show the lowest value, suggesting that ORCZ 135 zinc biofortified advanced breeding line enhances the seed quality parameters. The results show the similar types finding by Andreiniet at el., (2009), Ezatollah Esfandiari and Majid Abdoli

(2017), Chanakan Prom-u-thai *et al.*, (2012), Zdenko Rengal *et al.*, (1995), Slaton *et al.*, (2005a), Slaton *et al.*, (2005b), Nilgumcandan *et al.*, (2018) in related studies.

5.4 Effect of Zinc biofortified varieties on Storability of seed.

In any seed production program, maintenance of sowing quality of seed is the most important consideration. Various physiological parameters accounts for the planting value of seed, most of which are influenced by the environment prevalent during crop growth and post-harvest period. Knowledge of the relationship between nutritional status of soil and plants and the sowing quality of seed is important for the seed production and maintenance of better seed quality. In the present study, the seed quality was assessed by different quality parameters, the results were discussed hereunder.

In this study, all treatments after AA showed reduced values as compared to normal fresh seeds and the parameters such as seed germination(%), field emergence, SV-I & II were positively influenced by all the treatments compared with control. In all parameters, ORCZ 135 recorded the highest value and the check variety gave the lowest. This suggested that the seed vigour of treatments of ORCZ 135 and hence more storability period seeds. Similar results were obtained by Anandaraj and Natarajan (2017), Ali *et al.*, (2003), Gangwar and Kanaujia (2006), Ahamed- Sabir and Vanangamundi (2011) in related studies.

SUMMARY AND CONCLUSION

Seventy six zinc biofortified advanced breeding lines of rice were collected from Central Farm, Regional Research and Technology Transfer Station, Coastal Zone, OUAT, Bhubaneswar, Odisha. These samples were tested for zinc content in Central Instrumentation Facility (CIF), OUAT, Bhubaneswar. The top Zn dense (≥30ppm) varieties, identified as compared to check variety Swarna (11.30ppm) in the present investigation were ORCZ 148 (69.7ppm) followed by ORCZ 181 (58.0ppm), ORCZ 135(49.87ppm), ORCZ 169 (40.0ppm),ORCZ 167(38.40ppm), ORCZ 165 (35.30ppm), ORCZ 162(35.0ppm), ORCZ 156(34.60ppm), ORCZ 174 (33.10ppm), ORCZ 114 (31.71ppm), ORCZ 176 (31.30ppm), ORCZ 98(31.27ppm), ORCZ 175(31.20ppm), ORCZ 161 (30.40ppm). These selected varieties are treated as treatments for the experimental purpose. These 14 selected varieties along with check variety Swarna are sown in the field at Central Farm, Regional Research and Technology Transfer Station, Coastal Zone OUAT, Bhubaneswar, Odisha. The field experiment was laid with 15 treatments in RBD with 3 replications. The field experiment was conducted during Kharif season of 2020 to study yield performance and quality of rice (*Oryza sativa* L.).

Observations were recorded on agro-morphological traits viz., days to maturity, plant height (cm),effective tillers/hill, no of grains/panicle,1000-seed weight(g), seed yield(kg)/ha, and seed quality parameters viz., seed moisture content, electrical conductivity of seed leachate, germination percentage, first count, field emergence, seedling root & shoot length, mean seedling length, mean seedling dry weight, SVI-I and SVI-II. On accelerated aged seeds, observations on germination percentage, seedling root & shoot length, mean seedling length, mean seedling dry weight, SVI-I and SVI-II. The salient outcomes of the investigation are summarized below.

Significant difference was observed in days to Maturity ranged from 120.5 days in ORCZ 135 to 144.5 days in Swarna as the standard check variety. Semidwarf to intermediate plant types are needed to prevent the crop from lodging and to retain physical quality features. Plant height of the test entities ranged from dwarf plant type as in Swarna (75.5 cm) to as tall as ORCZ 114 (130 cm).

Number of effective bearing tillers (EBT), grain number/panicle, Test weight status determined yield potential of the advanced breeding lines. In the present investigation, EBT/m^2 was recorded maximum in Swarna as a check variety followed by ORCZ 161, ORCZ 181, ORCZ 162. ORCZ 135 show compact panicle (with 158.0 number of grains/panicle) as compaired to the check variety Swarna (135.8 number of grains/panicle). All the varieties except ORCZ 167 recorded 1000-seed weight more than 22.0g. In the present investigation, ORCZ 135 and ORCZ 114 give better yield potential (47 – 50Q/ha) compaired to Swarna (40Q/ha) as a check variety.

The seed moisture content indicated non-significant variation among various treatments. The treatments means varied from 11.24% (T_{12}) to 12.22% (T_9) with an overall mean of 11.79%. Numerically higher percentage of seed moisture content was indicated in the treatment T_9 (12.22%) followed by T_{10} (12.21%), T_5 (12.21%), T_{11} (12.08%); whereas, lowest seed moisture content was recorded in the treatment T_{12} (11.24 %).

The EC varied significantly and the mean value of the treatments ranged from 0.051 dS/m (T_5) to 0.074 dS/m (T_0) with an overall mean of 0.062 dS/m. All treatments except T_1 and T_9 had significantly lower values than T_0 (0.074 dS/m). The treatments except T_1 and T_9 are at par with T_5, T_1 and T_9 are at par with each other. So we conclude that T5 is highest vigour than all other treatments.

In the present study for germination percentage indicated significant variation among the different treatments. The mean value of the treatments ranged from 85.67% (T_0) to 93.33% (T_5) with an overall mean of 90.98%. All treatments showed significantly higher values over check variety T_0. The maximum seed germination was recorded in the treatment T_5 (93.33 %) which was 8.94% % higher than check variety (85.67 %). All treatments except T_0 are at par with T_5.

The analysis of variance indicated significant variation among varieties for field emergence. The mean value of the treatments ranged from 80.67% (T_0) to 91.00%% (T_5) with an overall mean of 85.67%. All treatments had shown significantly higher values over T_0 (80.67%) for this trait. The maximum field emergence was recorded in the treatments T_5 (91.00%). T_4, T_{10},, T_2, T_{11}, T_3, T_{14} and T_8 are at par with T_5 (91.00%). T_{11}, T_{13}, T_7, T_{14}, T_8 and

T_5 have significantly higher field emergence than T_9. The lowest field emergence was recorded in treatment T_0 (80.67 %).

The first count exhibited significant variation among the different treatments. It ranged from 68.33% ($T_{0)}$ to 76.00% (T_5) with an overall mean of 72.78%. All treatments except T_9, T_1, T_3, T_6, T_{12} have significantly higher values over check variety (68.33%). The maximum first count value was recorded in the treatment T_5 (76.00%) which was 11.22 % higher than control (68.33%). All treatments except T_{14}, T_8 and T_5 are at par with $T_{9,}$ T_{14}, T_8 and T_5. The lowest first count value was recorded in check variety T_0 (68.33 %).

Shoot length indicated presence of significant variation among various treatments. The mean value of the treatments varied from 7.73cm (T_0) to 8.83 cm (T_8) with an overall mean of 8.15 cm (Table 4). T_{11}, T_{10}, T_8 treatments have significantly higher value than the check variety (T_0). T_9, T_{13}, T_5, T_1, T_{12}, T_7, T_2 treatments have significantly lower than T_8 and these treatments are at par with each others.

Seedling root length exhibited significant variation among the various treatments. It ranged from 12.67cm (T_0) to 16.10 cm (T_5) between treatments with an overall mean of 14.20 cm. T_2, T_{11}, T_8, T_{14}, T_7, T_{13} and T_5 are significantly higher than T_0 and other treatments are at par with T_0. All treatments except T_8, T_{14}, T_7 and T_{13} are significantly lower than T_5.

The character seedling length indicated significant variation among the different treatments. The mean value of the treatments ranged from 20.4 cm (T_0) to 23.97 cm (T_5) with an overall mean of 23.36 cm. All treatments showed significantly higher values over check variety (20.4 cm). The treatments T_5 (23.97 cm) recorded maximum seedling length. Treatments T_9, T_1, T_3, T_6, T_{12}, $T1_0$ are significantly lower than T_5 and others treatments are at par with T_5. T_5 showed 17.5% higher value than the check variety. The lowest seedling length was recorded in control 20.4 cm.

The mean value of the seedling dry weight varied from 63.1mg (T_0) to 75.3 mg (T_5) with an overall mean of 70.5mg. All treatments except T_9 showed significantly higher values over check variety (63.1 mg). The highest seedling dry weight was recorded in the treatment T_5 (75.3 mg) with 19.33% higher value than check variety. All treatments except T_{14}, T_7 and T_8, have significantly lower dry weight than T_5. Whereas, T_{14}, T_7, T_8, T_5 are at par with each other.

The performance of crop varieties also largely depend upon seed vigour. Therefore, any study involving seed production and quality assessment, due emphasis is given on seed vigour. The common parameter used to represent seed vigour is the seed vigour index (SVI) which is measured by integrating two other physiological quality parameters viz., germination percent and seedlings length (SVI-I) or dry weight (SVI-II). In the present investigation both the parameters like SVI-I & II showed maximum and minimum value with the treatment T5 and T0 as (2188.6 & 6.88) and (1749.7 & 5.42) respectively.

The accelerated ageing (AA) vigour test provides valuable information on both seed storability and field seedling emergence potentials. The mean value of seed germination after AA ranged from 74.33% (T_0) to 87.33 % (T_5) with an overall mean of 84.89 % (Table 5). All treatments showed significantly higher values compared with check variety (74.33 %).The maximum seed germination upon aging was recorded in the treatment T_5 (87.33 %) which was 17.48 % higher than control, whereas the lowest seed germination was recorded in check variety (74.33 %).The treatments except T_0 (74.33%) was statistically at par with T_5.

Seedling field emergence after accelerated ageing indicated significant variation among the different treatments. The mean value of the treatments ranged from 73.33 % (T_0) to 86.00 % ($T_{5)}$ with an overall mean of 82.78 %. All treatments showed significantly higher emergence compared to check (73.67 %).The maximum emergence was recorded in the treatment T_5 (86.00 %), whereas the lowest seed germination was recorded in check variety (73.33 %). The maximum and minimum value for SVI-I & II after AA test was recorded in the treatment T5 as 2046.1 & 6.27 whereas in check as 1471.02 & 4.64 respectively.

CONCLUSION

The present investigation on "***Assessment of seed yield and quality traits of Zn biofortified advanced breeding lines of rice***" revealed important and valuable information for the rice researchers to be utilized in good quality seed production.

- Top Zn dense(≥30ppm) advanced breeding lines (ORCZ 148, ORCZ 181, ORCZ 135, ORCZ 169 ,ORCZ 167, ORCZ 165, ORCZ 162, ORCZ 156, ORCZ 174, ORCZ 114, ORCZ 176, ORCZ 98, ORCZ 175, ORCZ 161) are selected from the collected 76 samples.

- Among the varieties ORCZ 114 and ORCZ 135 revealed better yield potential (47-50Q/ha). While ORCZ 176, ORCZ 148, ORCZ 156, ORCZ 169, ORCZ 161 and ORCZ 162 also exhibited seed yield comparable to the mega variety Swarna. The significantly high yielding fixed breeding lines may be attributed to important yield contributing traits such as tiller number, seeds/panicle, grain weight. Among the test genotypes ORCZ 148, ORCZ 181, ORCZ 135 retain high Zn content along with high yield potential ORCZ 181. These may be considered for seed multiplication and multi-locational testing.
- Out of these selected varieties ORCZ 135 showed better seed quality parameters.

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