GENETIC VARIABILITY OF YIELD AND Zn CONTENT OF IRRI LINES UNDER IRRIGATED LOW LAND CONDITION IN INDONESIA

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ABSTRACT

Prevalence of Zn defficient in Indonesia is relatively high spreading accross the country. Rice biofortification for high Zn content would hopefully contribute in combating the problem. IRRI (International Rice Research Institute) had develops lines for high Zn content which were available for testing in collaborating countries. This research aimed to study genetic variability of the 97 introduced lines along with two check varieties under Indonesian irrigated lowland agro ecosystem, especially in Kebumen of Central Java, Indonesia. The research was conducted during WS 2014/2015 followed randomized complete block design with two replications on the plot of 2 × 5 m^2. Transplanting was conducted into 21 days old seedling for 25 × 25 planting spaece, planting 1 – 3 seedlings $hill^{-1}$. The results showed that there was variation on yield and Zn content among the tested genotypes. Genetic variability for the yield was relatively high, but Zn content was low. It indicated that selection for yield was possible to be conducted into the populations, nevertheless for Zn content there was not enough variation for selection. IR 97638-31-3-1-B (14.59 ton ha^{-1}) and IR 97454-44-1-1-B (11.37 ton ha^{-1}) has highest yield, comparable to Ciherang (11.24 ton ha^{-1}). There were other 34 lines having comparable yield with Ciherang. There were 42 IRRI lines with greater than average zinc and IR 97443-80-2-1-B (25.95 ppm), BR7840-54-1-2-5 (25.70 ppm), and IR 97525 - 37-4-1-2-B (25.30 ppm) is a strain with the highest Zn content, equivalent to Ciherang (23.45 ppm).

Keywords: genetic variability, lowland, rice, Zn

INTRODUCTION

Malnutrition is one of major concern of Indonesian government, especially Ministry of Health. Nourish Status Investigation showed that around 3.8% of under 5 year childdren in Indonesia are under nourish (Ministry of Health, 2016). Deshpande *et al.* (2013) reported that Zn is important for maintain human body immune system, shorthen recovery time and severity of diare in children. On the other hand, Zn diare is suspected as risk factor of decreasing of immune system and increasing of sickness vulnerability in adult people.

Hidayati *et al.* (2010) reported thath mal nutrition includes Zn defficiency occured highly in less access people in urban areas. On the other hand, Welch and Graham (2004) reported that Fe and Zn defficient contributed 2/3 of children mortality in the world.

Zn Biofortification on rice would hopefully become one of the solution to overcome the mal nutrition in Indonesia. Mulyaningsih (2009) stated that rice had relatively. Thus, increasing rice Zn content is prospective for the mentioned objective.

IRRI (International Rice Research Institute) had developed rice lines with high Zn content which were ready for testing in collaborating countries. Several lines had been imported and tested in Indonesia. The selected lines again tested to find the best stable one. This research aimed to test 98 IRRI originated lines suspected to have high Zn content, along with two check varieties, under irrigated lowland condition in Indonesia.

MATERIALS AND METHODS

The research was conducted during Wet Season of 2014 in Kebumen, Central Java, Indonesia. As many as 97 IRRI originated lines which were suspected to have high Zn content along with two check verieties, i.e. Ciherang and Inpari 5 Merawu. The experiment was conducted following randomized complete block design with three replications.Transplanting was conducted into 21 days old seedling into 25 cm × 25 cm square planting space of 1 m × 5 m plot size, planted 1 – 3 seedlings hill^{-1}. Plant establishment and protection was conducted intensively following integrated crop management principples.

Observation was conducted into plant height, productive tiller per plant, number of filled and un-filled grain per panilce, seed set, 1000 grain weight, and yield. The Zn content (ppm) of dehulled (brown rice) grains sample was measured using an XRF machine (Oxford Instrument X-Supreme) that had been validated by ICP method. The machine was located in the Plant Breeding Laboratory of ICRR (Indonesian Center for Rice Research) of IAARD (Indonesian Agency of Agricultural Research and Development) in Sukamandi, Subang District, West Java. Approximately 50 g grain samples from each plot were de-hulled using Satake THU Testing Husker. Brown rice samples were then sorted to get only healthy and fully filled grain then used for Zn content measurement using the XRF machine. Minimum of 5 grams samples were put into the cup and run in XRF samples for 15 second per sample. It could test ten samples in one run.

Agronomic and Zn data was analyzed for variance by using Excel and Crop Stat Ver. 6.1. (IRRI, 2007). Histogram figuring used Minitab Ver. 14 (McKenzie, 2004). Variance components, genetic variability and heritabiity was conducted followed Singh and Chaudhary (1979) (Table 1).

Table 1. Variance and variance components of randomized complete block design

Source of variability	Degrees of freedom	Mean square	Expected mean square	F-value
Replication	r-1	M3	$\sigma_e^2 + n\sigma_g^2$	M3/M1
Genotype	g-1	M2	$\sigma_e^2 + r\sigma_g^2$	M2/M1
Error	(r-1)(g-1)	M1	σ_e^2	
Corrected total	n-1			

Heritability value was calculated by formula as follows.

$\sigma^2{}_{\varepsilon}$= M1

$\sigma^2{}_{G}$ = (M2-M1)/r

$\sigma^2{}_{P} = \sigma^2{}_{G} + \sigma^2{}_{\varepsilon}$

$h^2{}_{bs} = \sigma^2{}_{G} / \sigma^2{}_{P}$

Remarks:

$\sigma^2{}_{\varepsilon}$= Error = environmental variance

$\sigma^2{}_{G}$ = Genotipic variance

$\sigma^2{}_{P}$ = Phenotipic variance

H^2 = Broad sense heritability

Criteria of heritability is as follows (Stanfield, 1991):

Low : $H^2 < 0.2$

Medium : $0.2 < H^2 \leq 0.5$

High : $H^2 > 0.5$

Genetic and phenotipic variability was calculated as follows (Falconer & Mackay, 1996):

$$\sigma_{\sigma^2 G} = \sqrt{\frac{2}{r^2}\left\{\frac{MS_g{}^2}{db_g + 2} + \frac{MS_e{}^2}{db_e + 2}\right\}}$$

$$\sigma_{\sigma^2 P} = \sqrt{\frac{2}{r^2}\left\{\frac{MS_g{}^2}{db_g + 2}\right\}}$$

Genetic variability was categorized as follows.

Wide : $\sigma^2{}_{G} \geq 2\sigma_{\sigma^2_G}$

Narrow : $\sigma^2{}_{G} < 2\sigma_{\sigma^2_G}$.

Phenotipic variability was categorized as follows.

Wide : $\sigma^2{}_{P} \geq 2\sigma_{\sigma^2_P}$

Narrow : $\sigma^2{}_{P} < 2\sigma_{\sigma^2_P}$.

RESULTS AND DISCUSSION

Variance Analysis

There was variation on all the observed traits, except fo Fe content and heading date (Table 2). Coefficient of variation of all the traits were lower than 30% which indicate that the quality of the data is relatively good (Gomez & Gomez, 2010). Among the observed traits, un-filled grain had the highest CV (27.09%) indicating that the trait is stongly affected by environment. On the other hand, heading date, 1000 grain weight, and Zn content had lower CV (<10%) which indicating that the traits were less affected by environment. In this trial, plant height had low CV (4.5%). It match with other experiments results, such as Kartina *et al.* (2014) at hybrids (4.06%) also Safitri *et al.* (2011)

and Mahmud *et al.* (2014) at haploid lines (3.46%) and developed varieties (3.78%).

Table 2. Variance analysis of agronomic and Zn content of 97 IRRI originated lines along with Ciherang and Inpari 5 in Merawu, Kebumen, WS 2014

Trait	Mean	Std. dev.	Mean square	F-value	Prob.	Coef. of var. (%)
Heading date (days after sowing)	86.232	7.05	53.024	1.19	0.193	7.74
Plant height (cm)	120.890	10.57	174.235	5.85**	0.000	4.52
Productive tiller number	14.694	2.85	9.729	1.61**	0.009	16.66
Filled grain/panicle	81.979	**19.01**	533.259	2.75**	0.000	17.01
Un-filled grain/panicle	49.395	**18.30**	488.827	2.73**	0.000	27.09
Seed set (%)	62.622	11.80	203.229	2.72**	0.000	13.80
1000 graing weight (gr)	25.803	2.45	9.236	3.37**	0.000	6.43
Yield (ton ha^{-1})	7.345	2.22	6.692	2.07**	0.000	24.48
Fe (ppm)	13.445	3.37	10.136	1.18	0.213	21.90
Zn (ppm)	20.788	2.21	6.891	2.42**	0.000	8.11

Remark: * = significant at α level of 5%, ** = significant at α level of 1%.

The traits having highest variance value were number of filled grain per panicle (19.01) and un-filled grain per panicle (18.3). It is indicating that there is big variation among genotypes in these traits. On the other hand, yield and Zn content had low variance, i.e. 3.35 and 3.45 respectively.

Means and Different among Means of the Traits

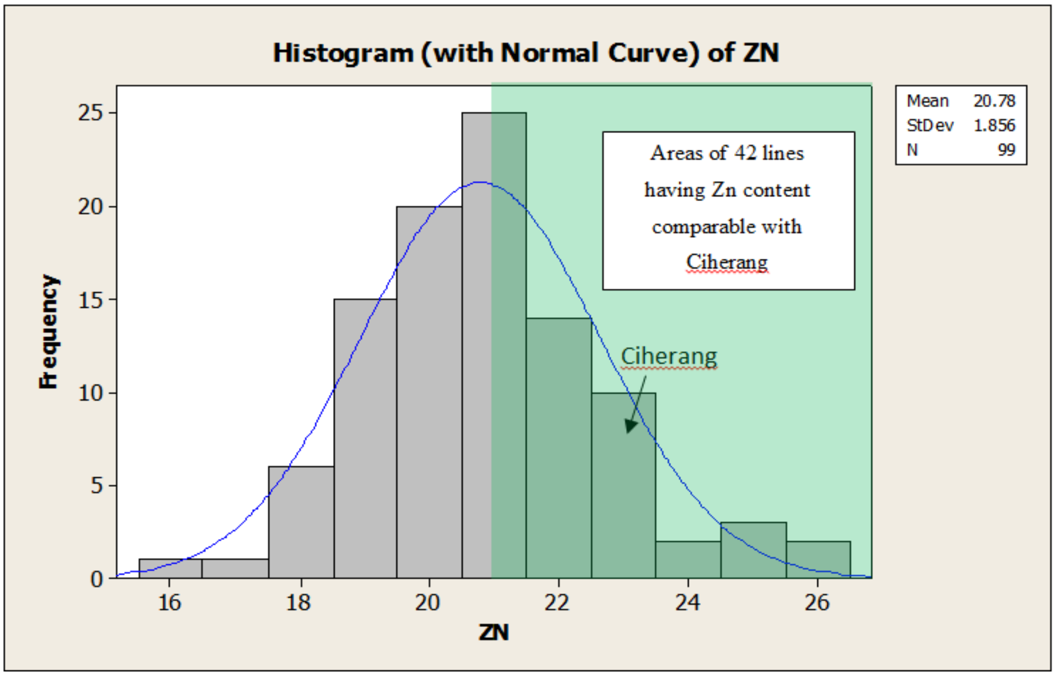

Figure 1. Frequency distribution of Zn Content of 97 IRRI originated lines along with Ciherang and Inpari 5 in Merawu, Kebumen, WS 2014

Mean of the traits in this trial were 86 days after sowing for heading date, 120.89 cm for plant height, and 14 for tiller number. The mean for filled grain per panicle was 82 grains, un-filled grain was 49 grains, 1000 grain weight was 25.8 g. The average yield in this trial was 7.34 ton ha^{-1}.

Zn content of the tested lines in this trial was ranged from 15.95 ppm to 25.95 ppm with the average of 20.78 ppm (Figure 1). There were 42 lines had comparable Zn content with Ciherang (23.45 ppm). Three lines with the highest Zn content were IR97443-80-2-1-B (25.95 ppm), BR7840-54-1-2-5 (25.70 ppm), and IR97525-37-4-1-2-B (25.30 ppm). Zn content of rice grains was suspected to be affected by environment. Rohaeni et al. (2016) reported that Ciherang in Sukamandi during DS 2015 had Zn content of 27.2 ppm.

On yield trait, it ranged 3.47 ton ha^{-1} to 14.59 ton ha^{-1} with the mean of 7.30 ton ha^{-1} (Figure 2).There were 34 lines having comparable yield with Ciherang (11.24 ton ha^{-1}). Some of the highest yield bearing lines were: IR97638-31-3-1-B (14.59 ton ha^{-1}), IR97454-44-1-1-B (11.37 ton ha^{-1}), IR97454-38-3-3-B (10.79 ton ha^{-1}), IR97454-38-1-3-B (10.54 ton ha^{-1}), and IR97633-56-1-2-B (10.13 ton ha^{-1}). Nevertheless, coincident of high Zn and high yield was seem to be low. IR97633-56-1-2-B had < 20 ppm of Zn content, while IR97443-80-2-1-B (had the highest Zn content) had relatively low yield (5.54 ton ha^{-1}). IR84750-12-1-2-3-1 (9.63 ton ha^{-1}, 23.20 ppm) had relatively high yield and Zn content along with Ciherang (11.24 ton ha^{-1}, 23.45 ppm) (Tabel 3).

Genetic Variability and Heritability of Yield and Zn Content

Genetic variability is defined by the presence of genotypically different individuals, in contrast to environmentally induced differences which, as a rule, cause only temporary, non-heritable changes of the phenotype (Rieger *et al.*, 1968). Heritability refered to the proportion of a trait is inherited into th enext generations based on the observed phenotypical observation. High value of heritability indicating that genetic factor contribute stongly to the expression and inheritence into the next generations of a trait (Sabu *et al.*, 2009).

Genetic variability of Zn content in the tested lines in this trial was categorized as narrow, which it has σ^2_G of -0.29 and $\sigma_{\sigma^2_G}$ of 1.26 (Table 3). Heritability of Zn content is categorized as medium (Stanfield, 1991) or low (Ishak, 2012). It indicated that selection for Zn content is not so effective into this population. The Zn content among the genotypes was ranged from 15.95 ppm to 25.95 ppm (around 10 ppm difference), while the check variaty at 23.45 ppm (Ciherang), more than the population mean (20.61 ppm). Selection of the best line however, might be effective for high Zn content.

Table 3. Genetic variability and heritability of yield and Zn content of 97 IRRI originated lines along with Ciherang and Inpari 5 in Merawu, Kebumen, WS 2014

Characters	σ^2_G	σ^2_F	$2\sigma_{\sigma^2_G}$	Category	H^2	Category
Yield (ton ha^{-1})	3.345	4.961	2.804	Wide	0.674	High
Zn content	-0.291	1.130	2.516	Narrow	-0.258	Medium

Table 4. Agronomic characteristics and Zn content of 17 lines selected based on yield or Zn content in Kebumen, WS 2014

No	Genotype	Hdg	PH	TN	FG	SS	1000 GW	Yld	Rank Yld	Zn	Rank Zn
1	IR97638-31-3-1-B	83	125.90	14	115	73.21	23.72	14.59	1	21.05	38
2	IR97454-44-1-1-B	84	126.70	15	93	73.14	25.41	11.37	2	21.60	29
3	Ciherang	86	115.70	15	92	70.45	26.70	11.24	3	23.45	8
4	IR97454-38-3-3-B	83	125.30	18	86	62.97	22.75	10.79	4	21.70	27
5	IR97454-38-1-3-B	95	116.60	16	86	67.52	23.24	10.54	5	20.45	57
6	IR97633-56-1-2-B	83	121.00	16	75	61.57	27.95	10.13	6	17.75	97
7	IR92978-91-1-1-3-3-B	83	118.00	16	60	63.45	27.21	9.84	7	17.90	95
8	IR97632-68-1-6-B	83	121.20	14	103	64.75	25.92	9.84	8	22.90	12
9	IR97629-98-2-3-B	84	111.90	16	84	66.80	27.81	9.82	9	20.25	63
10	IR97443-80-2-1-B	84	**131.50**	15	60	47.58	26.14	5.54	85	25.95	1
11	BR7840-54-1-2-5	88	119.50	11	74	50.16	27.16	5.07	91	25.70	2
12	IR97525-37-4-1-2-B	94	107.80	**21**	39	31.34	23.00	8.72	25	25.30	3
13	IR97483-81-2-1-B	85	**130.10**	15	46	41.13	20.83	6.42	66	25.15	4
14	IR97483-81-3-1-B	81	125.80	13	69	65.27	27.75	8.12	34	25.00	5
15	IR97483-81-3-5-B	83	123.70	13	69	57.50	27.72	6.99	54	24.30	6
16	BR7840-54-2-5-1	88	114.00	12	74	62.87	24.69	3.47	99	23.55	7
17	IR84750-12-1-2-3-1	87	110.60	14	112	78.17	27.44	9.63	10	23.20	9
18	IR97454-78-2-1-B	84	120.60	18	73	74.07	25.91	8.71	26	22.95	10

Hdg = Heading date (days after sowing), PH = Plant height (cm), TN = Tiller number per plant, FG = Filled grain per panicle; SS = Seed set (Percent of filled grain per panicle), 1000GW = 1000 grain weight (g), Yld = Yield (ton ha^{-1}), Rank Yld = Rank of yield, Zn = Zn content (ppm).

Selection for yield from this materials seem to be more effective. It has wide genetic variability with the value of σ^2_G of 3.23 and $\sigma_{\sigma^2_G}$ of 1.40 (Table 3). It has high broad sense heritability (67.43%). There are promising lines having comparable yield with Ciherang. Selection of the best line would hopefully find the stable high yielding lines, comparable with Ciherang. Nevertheless, there is still lacking of materials having combination of best yield and best Zn content in a single line.

Heritability value of yield trait in this trial is probably stable accross environments. Heritability for yield is mostly around medium. Zen (2012) reported that heritability of yield increased by increasing elevation. Location of this trial is categorized as low elevation (below 200 m asl), thus the yield heritability might increase in higher elevation.

IR97638-31-3-1-B is a high yielding line (14.59 ton ha^{-1}). This yield might be supported by number of filled grain per panicle (115 grain) and seed set (73.21%) (Table 4). Nevertheless, it has relatively low Zn content (21.05 ppm). Improvement of Zn content by crossing it with the highest Zn content line would hopefully combine the superiorities. Considering that the heriability value of Zn content is relatively low, selection in the advance generation is suspected to be more effective.

Genetic variabity of Zn content need to be increased. Exploration of new donor for high Zn content is needed. Indonesia has thousands of local landraces. ICABIOGRAD has around 3,563 accessions of rice germ plasm and 100 accessions of rice wild relatives (Silitonga, 2004). It is a good source for the exploration.

Zn content in rice grains is affected by constitution of soil nutrient (Yustisia *et al*., 2012). Zn content in rice grains is also affected by climate and weather condition (Dianawati & Sugiarso, 2015). On the other hand, genetic variability of quality related in rice is some times low, such as mentioned by Kristamtini *et al.* (2016) that genetic variability of coloring in rice is categorized as low.

CONCLUSION

Genetic variability of yield was categorized as high, but for zn content was low. It indicated that selection for yield is feasible from the tested lines. Nevertheless, selection for Zn content would not be so effective. IR97638-31-3-1-B (14.59 ton ha^{-1}) and IR97454-44-1-1-B (11.37 ton ha^{-1}) had the highest yield, comparable with Ciherang (11.24 ton ha^{-1}). There were additionally 34 lines having comparable yield with Ciherang. IR97443-80-2-1-B (25.95 ppm), BR7840-54-1-2-5 (25.70 ppm) and IR97525-37-4-1-2-B (25.30 ppm) had the highest Zn content, comparable with Ciherang (23.45 ppm). There were additionally 42 lines having comparable Zn content with Ciherang.

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