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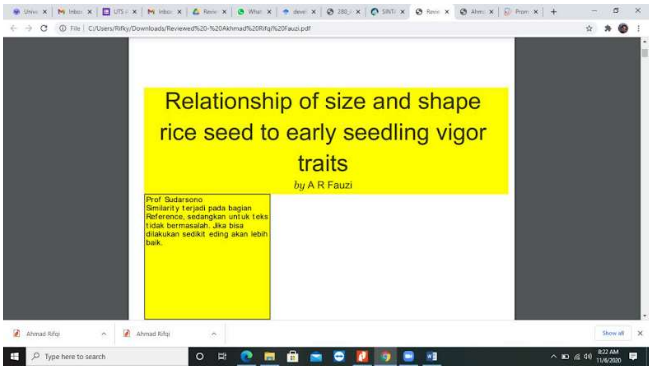

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Relationship of size and shape rice seed to early seedling vigor traits

Abstract. Rice crop improvement program for direct seeded has been directed at identifying the quality of seeds that have rapid uniform germination and biomass accumulation during initial phase of seedling establishment. Seed and embryo size thought as important factors in the emergence of faster and strong seedlings. For the reason, this study was purposed to evaluate the relationship between size and shape of rice seed with embryo size and their effects on germination. This study was designed using rice seeds from 55 genotypes which were grouped in three sizes (medium, long, and extra long) and two shapes (medium and slender). Germination was conducted with the top of paper method in a controlled germinator (24h lighting, 25 ± 2°C, 95%). We have found that size and shape of seed significantly affected ($\alpha < 0.05$) to embryo length, the time of radicles and plumules emergence, and seedling dry weight. Longer seed tend to have longer embryo and emerged of radicles and plumules faster. Meanwhile, longer seeds with slender shape tend to have greater seedling dry weight. The results informed that size and shape rice seeds can be considered as important characters for early seedling vigor traits in direct seeded systems.

1. Introduction

Vigorous crop establishment since early of growth is the success key in further plant growth and development. Huang et al. [1] described that early vigor as a combination between uniformity and emergence of seedling after seeding (seed vigor) with young plant ability to grow and develop after emergence (seedling vigor). Some researchers reported that plants have better early vigor traits reduced losses of rice yield due to competition with weeds and drought [2] and increased biomass and grain dry yield of wheat in Meditteran environtment [3]. Therefore, early vigor has become an agronomic trait and siginifies the potential of seed germination, seedling growth, and tolerance to adverse environtment factors.

Early vigor (EV) was reported to relate with ability of seedling to grow and develop well since their emergence and directly relate to growth and plant yield [4][5][6][7]. One of important characters in determaining the success of crop cultivation is the fast of seedling establishment and development that uniform in various field condition or known as early seedling vigor (ESV) [8][9]. For the reasons, researchers suggested that for direct seeding of rice using variety that have better EV and ESV traits [10][11][12][7].

The success of seedling establishment is determined by size of seed and embryo such as in wheat [13][14][15] barley [16][17], and rice [18][19][2]. It was confirmed by the results of review carried out by Kesavan et al. [20] and Ambika et al. [21] concluded that seed size was one of important indicators from seed quality that affected to vegetative growth (plant height and number of tillers) and often related with crop yield. Thus, seed size is one of important characters to be considered in crop improvement program.

Previous study showed that was correlated between Indica rice seed weight with embryo weight, meanwhile embryo weight had strong correlation with embryo length [22]. Embryo length was positive correlated with seed quality parameters and seedling vigor consist of germination percentage, germination rate, shoot length, root length, and seedling dry weigth [23]. The information indicated that length of embryo could be as variable in improvement of seed quality for Indica rice. However, there are research mentioned that seed size and embryo length of rice not significantly affected to seedling vigor [1]. Therefore, this study aimed to evaluate the relationship size and shape of rice seed to the traits of ESV in germination phase.

2. Materials and methods

2.1. Seed materials

The genetic materials in this study consisted of fifty rice genotypes from rice breeding program of IPB University and five national rice viarieties (Ciherang, INPARI 33, Jatiluhur, IPB 3S, dan IPB 8G). The genotypes were produced at experimental farm of IPB University, Darmaga, Bogor (6°33'52.7"S 106°44'06.4"E) in planting period from April-May 2019 and harvesting period from late August to early September 2019. A total six hills of each genotype were harvested and then dried 3-4 days in the sun. Spikelets was shed by manually and then sorted between filled and empty spikelets using seed blower machine. The sorted seeds were stored in close and dry boxes at room temperature (average 27oC).

2.2. Laboratorium experiments

A total of 400 seeds of each genotype and variety were taken to observe size and shape characters by image analysis using SmartGrain software application [24]. Eigth seeds from 400 seeds were hulled and carried out observation of embryo length using flourescence microscope (Olympus microscope BX-51 series; Olympus Corp.) at 1.25x magnification. Measurement were carried out in September-November 2019. Seed size (length of seed) and seed shape (length-to-width ratio) data used as a bases for grouping the characters. The grouping was according to handbook of rice standard evaluation system (SES) from International Rice Research Institute [25] which classified into four groups seed size: short (< 5.50 mm), medium (5.51 – 6.60 mm), long (6.61 – 7.50 mm), and extra long (> 7.51 mm). Meanwhile, seed shape grouped into round (< 1.0), bold (1.0-2.0), medium (2.1 – 3.0), dan slender (> 3.0).

Germination test was carried out at Seed Quality Analysis Laboratory, Departement of Agronomy and Horticulture, Faculty of Agriculture, IPB University. The fifty seeds (replicated three times) which healty taken from each genotype and variety. Germination test conducted by top of paper method using paper towel [26]. Fifty seeds were arranged top of paper in transparent box measuring 145 mm x 90 mm and then germinated in controlled germinator with 24 h illumination, T 25±2 °C, and RH 95% (seedburo germinator; Seedburo Equipment Company) for 13 days (21 February – 4 March 2020). Seed vigor was measured with radicle emergence analysis according to method used by Onwimol et al. [27]. Radicle and plumule emergence (2 mm in length and healty) were measured at 12 hours interval.

Normal seedling was assessed refer to handbook seedling evaluation issued by International Seed Testing Association [26]. The variables observed consist of vigor index (%) counted at 5 days after seeding/DAS (number of normal seedling / total number of seeds), germination percentage (%) calculated form first count at 5 DAS) and final count at 13 DAS ((first count+final count)/Total number of seeds x 100%), and germination velocity (% day-1). Length of radicle and plumule were determined by taking 3 samples from each replication using caliper on 13th day, while seedling dry weight was determined using electronical balance after dried by oven at 60oC for 72 hours.

Table 1. Means of seed length (mm) and seed shape (length to width ratio) of 55 rice genotypes

No	Genotipe	Seed length (mm)	Length to Width Ratio	No	Genotipe	Seed length (mm)	Length to Width Ratio
1	IPB187-F-101-2-1	7.01 ± 0.07 j-q	2.79 ± 0.05 l-s	29	IPB191-F-27-1-3	7.60 ± 0.15 b-f	3.31 ± 0.06 abc
2	IPB187-F-102-1-1	7.55 ± 0.05 b-g	3.17 ± 0.01 a-i	30	IPB193-F-17-2-3	7.16 ± 0.24 g-p	3.17 ± 0.06 a-i
3	IPB187-F-37-1-3	7.70 ± 0.09 abc	3.11 ± 0.02 c-l	31	IPB193-F-18-1-1	7.40 ± 0.04 b-j	3.11 ± 0.07 c-l
4	IPB187-F-41-2-1	7.68 ± 0.02 a-d	3.44 ± 0.14 ab	32	IPB193-F-19-1-3	7.18 ± 0.03 g-o	3.13 ± 0.10 b-k
5	IPB187-F-43-1-1	7.70 ± 0.13 abc	3.21 ± 0.14 a-g	33	IPB193-F-20-1-3	7.48 ± 0.09 b-i	3.26 ± 0.01 a-e
6	IPB187-F-45-1-1	7.63 ± 0.12 b-e	3.21 ± 0.08 a-g	34	IPB193-F-38-2-1	7.34 ± 0.02 c-m	2.82 ± 0.07 k-s
7	IPB187-F-46-2-2	7.61 ± 0.12 b-f	3.22 ± 0.06 a-f	35	IPB194-F-36-2-3	6.78 ± 0.38 o-s	2.84 ± 0.15 j-s
8	IPB187-F-46-2-3	7.51 ± 0.06 b-g	2.89 ± 0.04 g-r	36	IPB194-F-40-2-1	7.40 ± 0.03 b-j	3.14 ± 0.04 b-k
9	IPB187-F-49-1-2	6.18 ± 0.05 u	2.92 ± 0.04 f-r	37	IPB194-F-40-2-2	6.85 ± 0.07 n-s	2.75 ± 0.01 o-s
10	IPB187-F-52-2-2	7.58 ± 0.05 b-f	2.96 ± 0.05 d-r	38	IPB194-F-40-2-3	7.49 ± 0.07 b-h	3.05 ± 0.12 c-o
11	IPB187-F-5-2-3	7.43 ± 0.02 b-i	3.06 ± 0.04 c-o	39	IPB194-F-41-1-1	6.98 ± 0.19 l-r	3.03 ± 0.06 c-p
12	IPB187-F-55-2-1	7.22 ± 0.09 f-n	2.68 ± 0.02 rst	40	IPB194-F-41-1-2	7.59 ± 0.03 b-f	3.14 ± 0.13 b-j
13	IPB187-F-68-3-2	7.33 ± 0.14 c-m	2.98 ± 0.04 d-r	41	IPB194-F-50-1-3	7.74 ± 0.05 ab	3.25 ± 0.07 a-e
14	IPB187-F-74-1-3	7.65 ± 0.13 b-e	3.03 ± 0.07 c-p	42	IPB194-F-58-3-3	6.99 ± 0.04 k-r	2.81 ± 0.03 l-s
15	IPB187-F-75-1-3	6.95 ± 0.06 m-r	3.09 ± 0.12 c-m	43	IPB194-F-62-1-2	7.37 ± 0.03 b-l	3.00 ± 0.04 c-q
16	IPB187-F-76-1-1	7.36 ± 0.04 b-l	3.20 ± 0.15 a-g	44	IPB194-F-65-2-2	7.29 ± 0.05 d-m	3.24 ± 0.13 a-e
17	IPB187-F-85-1-1	7.40 ± 0.18 b-j	2.68 ± 0.04 q-s	45	IPB194-F-65-2-3	7.37 ± 0.23 b-k	3.19 ± 0.07 a-h
18	IPB187-F-88-1-2	7.29 ± 0.03 d-m	2.79 ± 0.02 m-s	46	IPB194-F-68-1-3	8.06 ± 0.13 a	3.42 ± 0.12 ab
19	IPB189-F-18-2-1	6.77 ± 0.10 p-s	2.77 ± 0.06 n-s	47	IPB194-F-70-1-3	7.27 ± 0.06 e-m	3.46 ± 0.09 a
20	IPB189-F-31-1-2	6.81 ± 0.37 o-s	2.94 ± 0.08 e-r	48	IPB194-F-92-3-1	7.16 ± 0.02 g-p	2.83 ± 0.04 j-s
21	IPB189-F-35-1-1	7.03 ± 0.06 j-q	2.87 ± 0.03 i-s	49	IPB194-F-93-1-1	7.29 ± 0.01 d-m	3.19 ± 0.10 a-h
22	IPB189-F-42-1-1	7.55 ± 0.12 b-g	3.19 ± 0.42 a-h	50	IPB194-F-96-2-1	7.46 ± 0.01 b-i	3.07 ± 0.06 c-n
23	IPB189-F-6-2-3	7.55 ± 0.04 b-g	2.88 ± 0.02 h-r	51	CIHERANG	6.73 ± 0.02 qrs	2.80 ± 0.02 l-s
24	IPB190-F-10-3-1	7.41 ± 0.01 b-j	3.18 ± 0.08 a-i	52	JATILUHUR	6.21 ± 0.04 tu	2.40 ± 0.01 t
25	IPB190-F-12-1-2	7.08 ± 0.16 i-q	3.07 ± 0.06 c-n	53	INPARI 33	6.94 ± 0.09 m-q	2.95 ± 0.04 e-r
26	IPB190-F-17-1-2	7.10 ± 0.17 h-q	3.04 ± 0.07 c-o	54	IPB3S	6.61 ± 0.04 rst	2.72 ± 0.02 p-s
27	IPB191-F-17-2-3	7.26 ± 0.06 e-m	3.27 ± 0.08 a-d	55	IPB 8G	6.60 ± 0.01 rst	2.56 ± 0.04 st
28	IPB191-F-24-2-1	6.55 ± 0.03 stu	2.70 ± 0.02 q-s		Average	7.240 ± 0.107	3.018 ± 0.226

Note: the numbers with the same letters in same variable are not significantly different at 5% level Tukey/HSD test

2.3. Statistical analysis

Data were analyzed by analysis of variance (ANOVA) and Pearson correlation using Minitab (17th version). Means compared followed by calculation of honest significance difference or tukey test at a siginificance level of $p \leq 0.05$.

3. Results

The ANOVA result on seed length and seed shape of 50 genotypes and 5 national varieties showed that the genotypes had significant effect on both characters at an error rate of 5%. The average size (seed length) and shape (length-width ratio) of 50 genotypes had longer (7.30±0.09 mm) and larger (3.05±0.07) than five national varieties tested, 6.62±0.04 and 2.69±0.03, respectively (Table 1). This variation could be basis for seed grouping according to the criteria issued by International Rice Research Institute. Based on the standar evaluation system in rice[25], 55 genotypes tested, was grouped in three groups of seed size (medium, long, and extra long) and two groups of seed shape (medium and slender). The seed size consist of five genotypes grouped in medium seed, 36 genotypes were long seed, and 14 genotypes was extra long seed. Meanwhile for seed shape consist of 29 genotypes grouped in medium shape and 26 genotypes were grouped in slender shape (Table 2). Based on the groups, there were five combination that long and extra long seeds had both of seed shape while all medium-sized genotypes only had medium shape. The combination informed that seeds which long-extra long size have a different shape. Meanwhile, the uniform shape of medium-sized genotypes might be not surely accurate to describe all genotypes of the all medium genotypes because the small number of genotypes that tested. Therefore, exploration and evaluation of the seed shape variation from medium-sized genotypes need to be done with a larger number of genotypes.

Table 2. Group of size and shape rice seeds from 55 genotypes

Seed Shape (length-to-width ratio)	No	Seed Length (mm)		
		Medium (S1) (5.51-6.60 mm)	Long (S2) (6.61–7.50 mm)	Extra Long (S3) (> 7.50 mm)
Medium (B1) (LWR 2.1 – 3.0)	1	IPB3S	IPB187-F-55-2-1	IPB189-F-6-2-3
	2	IPB191-F-24-2-1	IPB187-F-85-1-1	IPB187-F-52-2-2
	3	IPB187-F-49-1-2	IPB194-F-40-2-2	IPB187-F-74-1-3
	4	JATILUHUR	IPB189-F-18-2-1	
	5	IPB 8G	IPB187-F-88-1-2	
	6		IPB187-F-101-2-1	
	7		CIHERANG	
	8		IPB194-F-58-3-3	
	9		IPB193-F-38-2-1	
	10		IPB194-F-92-3-1	
	11		IPB194-F-36-2-3	
	12		IPB189-F-35-1-1	
	13		IPB187-F-46-2-3	
	14		IPB189-F-31-1-2	
	15		INPARI 33	
	16		IPB187-F-68-3-2	
	17		IPB194-F-62-1-2	
	18		IPB194-F-41-1-1	
	19		IPB190-F-17-1-2	
	20		IPB194-F-40-2-3	
	21		IPB187-F-5-2-3	
Slender (B2) (LWR > 3.0)	1		IPB190-F-12-1-2	IPB187-F-37-1-3
	2		IPB194-F-96-2-1	IPB194-F-41-1-2
	3		IPB187-F-75-1-3	IPB187-F-102-1-1
	4		IPB193-F-18-1-1	IPB189-F-42-1-1
	5		IPB193-F-19-1-3	IPB187-F-45-1-1
Slender (B2)	6		IPB194-F-40-2-1	IPB187-F-43-1-1

Seed Shape (length-to-width ratio) (LWR > 3.0)	No	Seed Length (mm) Medium (S1) (5.51-6.60 mm)	Long (S2) (6.61–7.50 mm)	Extra Long (S3) (> 7.50 mm)
	7		IPB193-F-17-2-3	IPB187-F-46-2-2
	8		IPB190-F-10-3-1	IPB194-F-50-1-3
	9		IPB194-F-93-1-1	IPB191-F-27-1-3
	10		IPB194-F-65-2-3	IPB194-F-68-1-3
	11		IPB187-F-76-1-1	IPB187-F-41-2-1
	12		IPB194-F-65-2-2	
	13		IPB193-F-20-1-3	
	14		IPB191-F-17-2-3	
	15		IPB194-F-70-1-3	

Criteria of Grouping from Standar Evaluation System of Rice (SES) by IRRI 2002

Table 3. Means of embryo length (EL), vigor index (VI), germination velocity (GV) and germination percentage (GP), length of radicule (RL) and plumule (PL), ratio of plumule and radicle length (RPR), and seedling dry weight (SDW)

Seed Group	EL (mm)	VI (%)	GV (%/day^{-1})	GP (%)	RL (cm)	PL (cm)	RPR	SDW (g)
Size (S)								
Medium (S1)	1.52±0.1^{b}	86.39±13.2	16.90±1.1	90.81±7.3	8.80±1.6	7.82±1.4	0.92±0.3	0.44±0.02^{b}
Long (S2)	1.67±0.1^{a}	87.73±11.0	17.00±1.0	91.05±6.4	9.08±2.8	8.17±1.3	0.99±0.4	0.45±0.04^{b}
Extra Long (S3)	1.63±0.1^{a}	82.07±23.5	16.50±1.9	88.96±12.6	9.36±3.1	7.89±1.3	0.91±0.3	0.47±0.04^{a}
Shape (B)								
Medium (B1)	1.63±0.2	88.08±10.6	16.90±1.1	91.35±6.0	8.69±2.5^{b}	8.07±1.3	1.01±0.4^{a}	0.44±0.03^{b}
Slender (B2)	1.66±0.1	83.77±19.7	16.70±1.6	89.43±10.8	9.64±3.0^{a}	8.05±1.3	0.90±0.3^{b}	0.46±0.05^{a}
S	**	ns	ns	ns	ns	ns	ns	**
B	ns	ns	ns	ns	*	ns	*	**
SxB	*	ns	ns	ns	ns	ns	ns	**
CV (%)	4.8	17.9	7.9	9.2	30.8	16.1	34.7	8.3

*Note: the numbers with the same letters in same variable are not significantly different at 5% level Tukey/HSD test; *significant at α 5%; **significant at α 1%; ^{ns}not significant*

The variation in seed size had a significant effect on embryo length (Table 3). The longer seeds (long and extra long) had longer embryo than medium seed, while seed shape had no significant effect (Tukey test $p < 5\%$). Embryo length also significantly affected by the combination of seed size and shape. The result of tukey test ($\alpha < 5\%$) showed that long-sized rice seed with both of shape had longer embryo than medium seeds, but not significantly difference with extra long seed. These result indicate that the longer seeds tend to have longer embryo compared with other size of rice seeds.

Analysis of variance on the germination test for both characters of rice seeds had significant effect on the emergence time of radicle and plumule, also seedling dry weigth (Figure 1 and Table 3). Different size of rice seed produced germination percentage, germination velocity, and vigor index not difference significant each other. It means that all seed lots had germination ability (seed vigor) that were as good. But, different size resulted different emergence of radicle and plumule. Longer seed (long and extra long) emerged radicle 4-5 hours faster for 50% of total seeds (TRE50) and 7-10 hours faster for maximum of total seed number (TREMax) than medium size. As well as the emergence of plumule, which the medium-sized seeds was latest to emerge of plumule than other size (Figure 1). The slender shape emerged radicle faster than medium shape (Table 3) and also had greater seedling dry weigth in both size, long and extra long (Table 4). The different of seed shape resulted different radicle length which slender seeds had 10% longer than medium, but both of shape not different for plumule length (Tabel 3 and Figure 2). The results indicate that the physical character of seeds such as size and shape contributed to rapidly emerge of radicle and plumule also accumulate greater the biomass so that they have potential to grow and develop faster and stronger. This traits is needed for direct seeded system to suppress weed growth and can rapidly adapt to sub-optimum conditions.

Figure 1. Effect of size (i) and shape (ii) rice seeds to time of 50% radicule and plumule emergence (TRE50, TPE50) and time of maximum radicle and plumule emergence (TREMax, TPE Max)

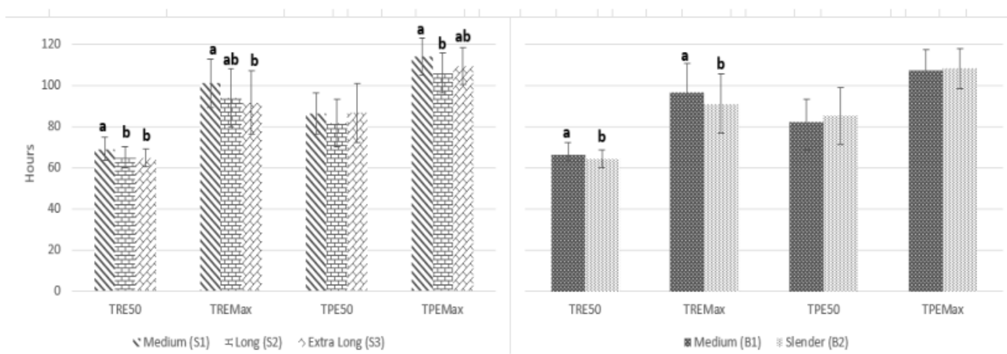

Table 4. Effect of combination between size and shape of rice seeds to embryo length, emergence time of radicle (TRE) and plumule (TPE), and seedling dry weight

Treatment	Length of Embryo (mm)	TRE50 (hour)	TREmax (hour)	TPE50 (hour)	SDW (g)
S1B1	1.53 b	69.31 a	101.99 a	86.37 ab	0.44 b
S2B1	1.65 a	66.06 ab	96.51 ab	83.01 b	0.44 b
S2B2	1.68 a	64.37 b	91.24 b	81.20 b	0.45 ab
S3B1	1.64 ab	68.25 ab	94.27 ab	75.34 b	0.47 ab
S3B2	1.63 ab	64.21 b	91.37 b	90.21 a	0.48 a

Note: the numbers with the same letters in same variable are not significantly different at 5% level Tukey/HSD test

The result of ANOVA on the germination test for both characters of rice seeds had significant effect on the emergence time of radicle and plumule, also seedling dry weigth (Figure 1 and Table 3). Different size of rice seed produced germination percentage, germination velocity, and vigor index not difference significant each other. It means that all seed lots had germination ability (seed vigor) that were as good. But, different size resulted different emergence of radicle and plumule. Longer seed (long and extra long) emerged radicle 4-5 hours faster for 50% of total seeds (TRE50) and 7-10 hours faster for maximum of total seed number (TREMax) than medium size. As well as the emergence of plumule, which the medium-sized seeds was latest to emerge of plumule than other size (Figure 1). The slender shape emerged radicle faster than medium shape (Table 3) and also had greater seedling dry weigth in both size, long and extra long (Table 4). The different of seed shape resulted different radicle length which slender seeds had 10% longer than medium, but both of shape not different for plumule length (Tabel 3 and Figure 2). The results indicate that the physical character of seeds such as size and shape contributed to rapidly emerge of radicle and plumule also accumulate greater the biomass so that they have potential to grow and develop faster and stronger. This traits is needed for direct seeded system to suppress weed growth and can rapidly adapt to sub-optimum conditions.

4. Discussion

Rice varieties that have the ability rapid germination and produce strong seedling are suitable for the direct seeded (DSR) system. Rapid growing and strong seedling could support well plant growth and adaptive to environtmental changes [28]. Varieties with these traits have become a priority in crop improvement program especially rice variety for DSR system [9]. The ability of rapid seedling form has been reported to be closely related to seed physical characters [29][30]. This study focused on evaluating the relationship between early seedling vigor traits and seed physical characters consist of three sizes (medium, long, and extra long) and two shapes (medium and slender) on germination ability on a laboratory scale.

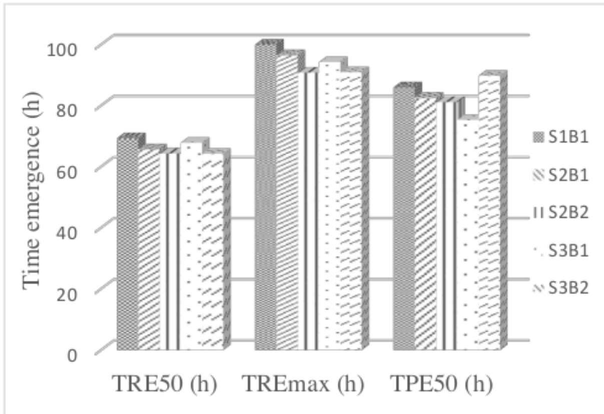

Figure 2. Effect of size and shape combination of rice seeds to time of 50% radicle and plumule emergence, and time of maximum radicle emergence

As mentioned above, longer seeds tend to had longer embryo. This was confirmed by a correlation that seed size had a positive correlation with embryo length (Table 5). The result also completed the statement of Namuco *et al*. [2] stated that larger seeds tend to had bigger embryos. Longer seeds and longer embryos reported to have good germination ability [22][23]. However, the results of our study showed that seed vigor characters such as vigor index, germination velocity, and germination percentage were not significantly different from both the size and shape of seed (Tabel 3). Seed ability to germinate is related to many factors such as the storage period of seeds, germination environtment, and physiological activity in seeds [31][32]. Physiological traits of seeds might have an effect on germination ability, including the influence of starch content and enzyme activity where seeds that amylose content and high α-amilase enzyme activities can increase rice seeds vigor [33].

The speed and uniformity of seedling emergence are important keys for assessment of early seedling vigor varieties [9]. Both of these traits could be measured quickly through the radicle emergence [34] and percentage of normal seedling in the first count at 5 days after seeding (DAS) or called vigor index. According to Figure 1 dan Tabel 3, genotypes that have a longer and slender seeds were faster to emerge radicle either single factor or in combination factor (Figure 2). Onwimol et al. [27] and Luo et al. [35] reported that radicle emergence time of rice seeds has been a good parameter for the classification of rice seed vigor. On the other hand, long seeds resulted higher germination percentage than other size (Table 3). It showed that long seeds have better germination uniformity.

Table 5. Correlation between size and shape of rice seeds and embryo length with seedling vigor traits

	EL	GP	GV	TRE50	TREMax	TPE50	TPEMax	SDW
Seed size	*	ns	ns	**	**	ns	ns	**
Seed shape	ns	ns	ns	**	**	ns	ns	**
Embryo length		ns	ns	**	*	ns	ns	ns

**significant at α 5%; **significant at α 1%; ^{ns}not significant*

The strong morphological and physiological characters of seedling are also important traits for early seedling vigor varieties [1]. The longer radicle length of slender seeds (Table 3) indicated that slender seeds had potential better adaptation in sub-optimum conditions. Whereas medium-shaped seed group had a higher plumule-radicle length ratio which indicated that more seed reserves mobilized from seeds to seedling shoot. According to Huang et al. [1], higher ratio of plumule-radicle length indicated seed had strong vigor. However, combination of long-sized and medium-shaped gave a plumule-radicle length ratio > 1.0 (data not shown) higher than other combinations. Nutrient mobilization also depends on environtmental factors during germination phase. Unfortunately, this study was conducted on laboratory scale under optimum conditions so that our results cannot be generalized to stress conditions.

Another important trait that early seedling vigor genotypes is the biomass accumulation of seedling in the early stage of growth. This accumulation reflect strong seedling vigor. Biomass accumulation in this study is reflected by seedling dry weight (SDW) parameter (Table 3 and Figure 2). The longer and slender seeds produced the highest SDW, but not significantly different with the medium ones. The result was not the same as with previous study that mentioned SDW was not influenced by seed size and seed shape (width) [36]. Accumulation of biomass at germination stage can be able to support the seedling to grow photosynthetic organs, so that it will be able to suppress competition with weeds in direct seeded system. Banik et al. [37] mentioned that rice cultivar that have high seedling vigor traits and rapid leaf area development at early vegetative growth could suppress weeds growth. Correlation analysis in this study showed that SDW was positively correlated with size and shape of seeds, but not with embryo length (Table 5). These result reinforce the information that size and shape of seeds are closely related to early seedling vigor traits of rice plants.

5. Conclusion

Evaluation of rice genotypes with various sizes and shapes of seeds on seedling vigor characters provides valuable information. We conclude from our results that rice genotypes have various sizes and shapes of seeds potential to become varieties that have ability to early seedling. The genotypes which has longer size and slender seeds has shown superior early seedling vigor characters in terms of the rapid emergence of radicle and plumule and biomass accumulation. These superior characters can be used to increase early seedling vigor after further testing. The genotypes identified are included in superior early seedling vigor group, need to be validated in field conditions before being applied in plant improvement program.

Acknowledgement

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