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Full Length Research Paper

Germination capacity, growth and yield of three upland rice varieties increased following seed invigoration treatments

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Abstract

One of the major causes of low productivity of upland rice in Indonesia is the use of low-quality seeds. Little information is available on the effects of seed invigoration treatments on seed germination of upland rice varieties. The information is necessary to identify appropriate technologies to improve upland rice seed germination capacity at farmers' level. A study was carried out in the Makariki Experimental Station, Assessment Institute for Agricultural Technology of Maluku, Central Maluku from December 2010 up to May 2011, to determine the effects of seed invigoration treatments (GA_3 and coconut water) and seed viability levels (60, 80, and 100%) of three upland rice varieties (Situ Patenggang, Limboto, and Batutegi) on the germination behavior, rice growth and yield. The results showed that the seed invigoration treatments employed affected seed germination of Situ Patenggang and Limboto upland rice varieties. Seed invigoration with young coconut water, 100 ppm GA_3 or 100 ppm GA_3 + young coconut water can be used as a pre-planting seed treatment to overcome the problem of low seed viability (the grain yields were 5.63 t/ha, 5.51 t/ha, and 5.98 t/ha, respectively). In addition, seedling establishment of Situ Patenggang and Limboto upland rice varieties with 6-10 seeds per planting hole can be used as an alternative to overcome the low seed viability. This treatment might give a high grain yield (up to 5.03 t/ha).

Keywords: Seed, invigoration, viability level, upland rice varieties.

INTRODUCTION

The demand of rice in Indonesia is increasing in line, with the population increased (Sembiring, 2011). During the period of 2004-2008, the decline in irrigated rice fields, especially in Java Island reached about 100.000 ha/yr. This condition would not support the achievement of the national rice production target, because more than 50% of the supply of rice produced in Java Island. Dry land is one potential alternative to agricultural development, in order to maintain rice self-sufficiency and improve other food products. Dry land area in Indonesia that is potential for upland rice is estimated about 5.1 million ha. The average productivity of upland rice at the national level is still about 2.97 t/h, only 59% of the average productivity of paddy rice which reached 5.00 t/ha (MOA, 2009, 2010).

The use of low-quality seeds is one of the major causes of low productivity of upland rice in Indonesia. Farmers generally use their own seeds from previous harvest stored in the improper storage and packaging conditions. So, the seed germination and the vigor were poor already (MOA, 2009). Therefore, it is imperative to have appropriate techniques in order to improve the rice seed germination and vigor. Seed priming (invigoration treatment) has the potential to overcome poor germination and poor crop establishment, since invigoration persists under less optimum conditions. The seed priming is defined as pre-sowing treatment in water or in an osmotic solution that allows seed to imbibe water to proceed to the first and second stages of germination, but the radicle protrusion through the seed coat is not occurred yet. Osmopriming and hydropriming are the

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most important priming treatments. Osmopriming is carried out by soaking seed in solutions, such as sugars, polyethylene glycol (PEG), glycerol, sorbitol or fertilizers solutions. Then the seed was dried before sowing. Whereas, hydropriming is done by soaking of seed in water before sowing (Al-Mudaris and Jutzi, 1999; Ashraf and Foolad, 2005).

By application of seed priming, the metabolic processes necessary for germination is occurred without actual germination. This pre-sowing treatment usually results in an increase of germination rate, greater germination uniformity, and greater germination percentage (Basra *et al*., 2005).

Studies have been done on the effects of priming treatments on germination of lowland rice seeds (Basra *et al.,* 2003, 2004, 2005; Farooq *et al.,* 2004, 2005, 2006ab, 2007). These treatments were able to shorten the time between planting and emergence (Farooq *et el.* 2004, 2005, 2006ab). In addition, during critical phase of seedling establishment, the employed treatments may also protect the seeds from biotic and abiotic factors (Senaratna *et al.,* 2000; Du and Toung, 2002; Shakirova *et al.,* 2003). Finally, as the priming treatments synchronized emergence, hence, they resulted in uniform seedling and increased yield (Harris *et al.,* 2002; Du and Toung, 2002). Du and Tuong (2002), who studied the effects of 14% KCl solution and saturated $CaHPO_4$ solution as priming treatments on rice seeds, reported that when rice is seeded in very dry soil, priming increased plant density, tiller number, and grain yield. Meanwhile, Farooq *et al.* (2007) suggested that fine rice (cv. Super-basmati) seeds which were soaked in 10, 20 and 30 ppm aerated solutions of salicylicate for 48 h at 28°C gave earlier, synchronized and enhanced germination. In addition, Mulsanti and Wahyuni (2011) reported that invigoration treatment with NaCl increased rice seed germination, vigor, and growth rate of Ciherang variety, a lowland rice variety. However, up to now little information is available on the invigoration of upland rice seeds, especially for local superior varieties of Indonesia. This information is necessary to identify appropriate technology in order to improve upland rice seed germination capacity.

Rini *et al*. (2005), who studied the response of *Sorghum bicolour* (L) to priming treatments, reported that the success of osmoconditioning method is largely determined by the type of osmotic solution used. They found also that the osmotic potential, the temperature, and the duration of incubation will have different effects between species, between varieties, and even between seed lots. In addition, Mercado and Fernandez (2001) investigated the response of four rice seed varieties (IR64, C4-63(G), Sampaguita and Turdagol) to hydration-dehydration (HD) treatment for enhancing the seed germinability and vigor. They reported that the seed response to HD treatment significantly varied with variety and seed viability level.

The present study was, therefore, carried out with the objectives to determine the effects of seed invigoration and viability levels of three upland rice varieties (Situ Patenggang, Limboto, and Batutegi) on the percent emergence, growth and yield.

MATERIALS AND METHODS

Seeds and chemical description

The experiments were carried out in the Makariki Experimental Station, Assessment Institute for Agricultural Technology, Central Maluku from December 2010 up to May 2011. Three upland rice varieties (Situ Patenggang, Limboto, and Batutegi) were used in the study. The seeds were obtained from Muara Research Station. In the station, the seeds were harvested in August 2009 and stored 12 months in the storage room with the temperature of 22^{o}C.

Gibberellin (GA_3) used in the present study was a powder having technical grade with a content of 10%. Gibberellin solution of 100 ppm was made by dissolving 1gr of gibberellin with 10 cc of 70% alcohol, and then added by water to a volume of 1 L. Young coconut water used was taken from green coconut fruits. The criteria of young coconut were a green coconut with ¼ of the fruit was still transparent and the bottom of shell had not changed in color (white). The coconut water used for soaking the rice seeds was undiluted.

Experimental design and treatments

The trials were arranged factorially in Randomized Block Design (RBD) with three replications. The first factor was seed invigoration (I), consisted of five levels of seed treatments, namely: I_1 - Soaked in water, 3-5 seeds/hole, I_2 - Soaked in water, 6-10 seeds/hole, I_3 - Soaked in young coconut water, 3-5 seeds/hole, I_4 - Soaked in 100 ppm GA_3 solution, 3-5 seeds/hole, and I_5 - Soaked in 100 ppm GA_3 solution + young coconut water, 3-5 seeds/hole. The second factor was the level of seed viability (V), consisted of three levels, namely: V_1 - High viability (± 100%), V_2 - Moderate viability (± 80%), and V_3 - Low viability (± 60%). The third factor was upland rice varieties (G), namely: G_1 - Situ Patenggang, G_2 - Limboto, and G_3 - Batutegi.

For the three varieties, seeds of high viability (100%), moderate viability (80%), and low viability (60%) were used. To obtain seeds with high, moderate, and low viability, artificial ageing techniques were done (Delouche and Baskin, 1973; ISTA, 1985). Invigoration treatments were employed to all seed lots by soaking the seeds for 6 hours in the corresponding solutions. Afterwards, the seeds were drained and air-dried. At the end, the seeds were directly planted in the fields.

Planting and maintenance of trial

The experimental site was cleared of weeds, and then plowed twice using hand tractor. The second plowing was performed two weeks after the first plowing. After the second plowing, the land was flattened using hoe. Plots were developed with size 4 m x 3 m. The distance between plots within the same replicate was 75 cm and the distance between replicates was 100 cm. Planting was done by drilling (numbers of seeds depended on the corresponding treatments). Planting distance was set using a marked rope with spacing of 30 cm x 15 cm.

NPK fertilizer at the rate of 45 kg/ha was applied twice. The first half was given at 15 days after planting and the second half was given 35 days after planting. In addition, N fertilizer at the rate of 45 kg/ha were also applied at the time of panicle initiation. Insecticides to control pests and diseases were applied when necessary. Parameter measurements were conducted to five samples per plot determined randomly to determine: percent emergence, number of maximum tillers per hill, number of productive tillers per hill, 1,000-grain weight, and grain yield. To measure percent emergence, the first observation was performed 5 days after planting (DAP) and the second observation was performed 7 (seven) days after planting. The percent emergence was obtained by summing the normal germinated seeds at first count and the second by using the following formula:

$$\% \text{ Emergence} = \frac{(NG_1 + NG_2)}{\sum \text{seeds}} \times 100\%$$

where: NG_1 = number of normal seedlings at the first count

NG_2 = number of normal seedlings at the second count

Statistical analysis

Data were subjected to analysis of variance (ANOVA). The Duncan's multiple range test (DMRT) at $p = 0.05$, unless otherwise stated, was used to separate the means when ANOVA results indicated there were significant treatment effects (Steel *et al.,* 1997).

RESULTS AND DISCUSSION

Emergence percentage

The results in Table 1 showed that seed invigoration treatments with young coconut water, 100 ppm GA_3 or 100 ppm GA_3 solution + young coconut water significantly enhanced the emergence percentage of the three upland rice varieties (Situ Patenggang, Limboto and Batutegi) for the seed lot of low viability (± 60%). For instance, Situ Patenggang variety at the seed lot of low viability (± 60%), the invigoration treatment of GA_3 100 ppm increased emergence percentage up to 91.3%. Similarly, the application of these treatments to the seed lot of Limboto and Batutegi varieties with low viability (60%) also increased the emergence percentage.

Gibberellins are a group of tetracyclic diterpene acids that are well-known for their capability to promote plant growth. GA_3 (gibberellic acid) is most frequently used to trigger seed germination (Hedden and Kamiya, 1997; Yan *et al.*, 2004). During the seed germination process, the gibberellins push hydrolytic enzymes activities. This enzyme hydrolyzes starch and protein in the seed endosperm, which are food sources for embryonic development (Weiss and Ori, 2007). Miyoshi and Sato (1997), who studied the effects of gibberellins on the germination of dehusked seeds of indica and japonica rice under aerobic and anaerobic conditions, reported that there were stimulatory effects of gibberellins on the germination of indica and japonica rice seeds under both conditions.

The emergence percentages of the three upland rice varieties (Situ Patenggang, Limboto and Batutegi) were also enhanced by invigoration treatment using coconut water. In accordance with this result, studies have shown that coconut water enhanced seed germination of orchid species in vitro (Lo *et al*., 2004; Sylvia *et al*., 2005). The enhancement of germination in the present study could be related to the presence of a plant growth hormone like cytokinin (Leetham, 1974), carbohydrate, vitamin, acid amino and organic acid, and organic ion in the coconut water (Nitsch, 1951).

On the other hand, for the seed lots of high viability levels (± 80 and 100%), the invigoration treatments in the present study had no effect on germination of the three upland rice varieties. Probably, this could be due to at medium and high seed viability levels, the energy in the seeds was available enough to support the germination. Therefore, the effects of seed invigoration using young coconut water, GA_3 or 100 ppm GA_3 solution + young coconut water were not significant on the emergence percentage of the three upland rice varieties. Moreover, it could be also due to the integrity of cell organelles in the seeds was in good conditions to support the processes in cells, hence, no additional compound was needed to repair and maintain the stability of the cell structure.

Maximum tillers

The results in Table 2 showed that the invigoration treatments employed to the seeds of Situ Patenggang variety at the lowest viability (± 60%) significantly increased the number of maximum tillers per hill. The obtained values of these treatments were not significantly different from the values obtained from the control treatments at the moderate and high seed viability levels

Table 1. Effects of interaction of seed invigoration, viability level and variety on germination percentage

Seed treatment		Emergence (%)					
		Situ Patenggang		Limboto		Batutegi	
V1	Control	91.33*	abc	88.67	ab	90.67	ab
V1	Young coconut water	95.33	a	84.67	abc	95.33	a
V1	100 ppm GA_3	90.00	abcd	89.33	ab	95.33	a
V1	100 ppm GA_3 + Young coconut water	91.33	abc	83.33	bc	96.00	a
V2	Control	81.33	bcde	81.33	C	80.67	bc
V2	Young coconut water	85.33	abcde	85.33	abc	74.00	c
V2	100 ppm GA_3	84.00	abcde	88.67	ab	91.33	ab
V2	100 ppm GA_3 + Young coconut water	92.00	abc	90.00	ab	86.00	abc
V3	Control	58.00	f	61.33	e	60.67	d
V3	Young coconut water	77.33	de	84.00	abc	94.00	a
V3	100 ppm GA_3	91.33	abc	74.67	d	94.67	a
V3	100 ppm GA_3 + Young coconut water	88.67	abcde	85.33	abc	96.67	a

Note: *Numbers within the same column followed by the same letter are not different at $p < 0.05$, by Duncan's Test.
V1 = seed viability ± 100%, V2 = seed viability ± 80%, V3 = seed viability ± 60%

Table 2. Effects of seed invigoration, viability level and variety on number of maximum tillers per hill

Seed treatment		Maximum tiller number per hill					
		Situ Patenggang		Limboto		Batutegi	
V1	Soaked in water, 3-5 seeds/hole	26.9	a	27.8	ab	24.5	a
V1	Soaked in water, 6-10 seeds/hole	21.9	ab	27.5	ab	21.9	abc
V1	Soaked in young coconut water, 3-5 seeds/hole	21.9	ab	23.7	abcd	24.1	ab
V1	Soaked in 100 ppm GA_3, 3-5 seeds/hole	24.3	ab	22.5	bcd	14.8	d
V1	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	23.3	ab	24.8	abcd	22.3	abc
V2	Soaked in water, 3-5 seeds/hole	22.3	ab	19.4	d	21.2	abc
V2	Soaked in water, 6-10 seeds/hole	26.1	ab	27.7	ab	24.6	a
V2	Soaked in young coconut water, 3-5 seeds/hole	23.0	ab	22.0	bcd	22.9	ab
V2	Soaked in 100 ppm GA_3, 3-5 seeds/hole	22.3	ab	29.0	a	22.9	ab
V2	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	23.9	ab	26.3	abc	22.7	ab
V3	Soaked in water, 3-5 seeds/hole	20.3	b	20.0	cd	16.4	cd
V3	Soaked in water, 6-10 seeds/hole	24.4	ab	23.7	abcd	19.9	abcd
V3	Soaked in young coconut water, 3-5 seeds/hole	22.1	ab	25.9	abc	24.3	a
V3	Soaked in 100 ppm GA_3, 3-5 seeds/hole	23.1	ab	21.1	cb	25.9	a
V3	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	24.8	ab	23.9	abcd	17.9	bcd

Note: *Numbers within the same column followed by the same letter are not different at $p < 0.05$, by Duncan's Test.
V1 = seed viability ± 100%, V2 = seed viability ± 80%, V3 = seed viability ± 60%

(± 80 and 100%). These results most likely due to, the energy in the seeds was available enough to support the germination at the medium and high seed viability levels. Moreover, it could also be due to the integrity of cell organelles in the seeds was in good conditions to support the processes in cells, hence, no additional compound was needed to repair and maintain the stability of the cell structure.

The enhancement of the number of maximum tillers per hill for Situ Patenggang variety at low seed viability is most probably related to physiological effects of GA_3, that affects plant growth, photosynthesis, and cell expansion (Yuan and Xu, 2001; Yan *et al*., 2004), and to the presence of a plant growth hormone like cytokinin (Leetham, 1974), carbohydrate, vitamin, acid amino and organic acid, and organic ion in the coconut water (Nitsch, 1951).

For the Batutegi variety, at the lowest viability level (± 60%), seed invigoration treatments with 100 ppm GA_3 and young coconut water significantly increased the number of maximum tillers per hill. However, at the moderate viability level, the seed invigoration treatments did not affect number of maximum tillers per hill. Meanwhile, for the Limboto variety, at the lowest seed viability (± 60%), the invigoration treatments had no effect on the number of maximum tillers per hill. While, at moderate seed viability (± 80%), the seed invigoration treatment with 6-10 seeds per hole, 100 ppm GA_3, and 100 ppm GA_3 + young coconut water gave significantly higher number of maximum tillers per hill than the control treatment (3-5 seeds per hole). These results showed that there were differences in the response to the invigoration treatments employed among the three upland varieties. In addition, it is likely that the response also varied to seed viability levels. In accordance with the results of the present study, Mercado and Fernandez (2001) reported that the response of four rice seed varieties to hydration-dehydration (HD) treatment significantly varied with variety and seed vigor level.

Productive tillers

The results of analysis of variance showed that there was no interaction effect among invigoration treatments, seed viability levels and varieties on the number of productive tillers per hill.

For Situ Patenggang variety at low viability (± 60%), the invigoration treatments significantly increased number of productive tillers per hill. Du and Tuong (2002), in their study of seed invigoration treatments using 14% KCl and saturated $CaHPO_4$ solution, proved also that the invigoration enhanced rice crop density along with the tiller number. Whereas, for Limboto and Batutegi varieties at all seed viability levels, the invigoration treatments had no effect on number of productive tillers per hill. These indicated that at low seed viability, Situ Patenggang variety had more responsive to the invigoration treatments compared with Limboto and Batutegi varieties. One reason for the more responsive of Situ Patenggang variety is probably related the presence of growth hormones, in which the role of these hormones was influenced by variety, age and development phase of plant tissue. As mentioned earlier, Mercado and Fernandez (2001), in their study found the similar tendency with the present study. They observed that the response of four rice seed varieties to hydration-dehydration treatment significantly varied with variety and seed vigor level. Moreover, Yan *et al*. (2004), who studied the effects of GA_3 acid on rice germination (9 semidwarf cultivars and 12 tall cultivars) reported that under stress conditions the semidwarfs responded more to GA_3 than taller cultivars, although taller cultivars germinated and emerged faster than the semidwarf.

Thousand-grain weight

There was no interaction effect of invigoration treatment and seed viability on 1000-grain weight of the three upland rice varieties.

In general, at any invigoration treatment and seed viability, Situ Patenggang and Limboto varieties had higher 1000-grain weight than Batutegi variety. However, at high seed viability (± 100%), invigoration application by soaking the seed in 100 ppm GA_3 gave no significantly different in 1000-grain weight to the three upland rice (Situ Patenggang, Limboto and Batutegi). It is likely that Situ Patenggang variety was more responsive to the invigoration treatments compared with Limboto and Batutegi varieties. One reason for this more responsive is most probably related to the role of growth hormones that influenced by the variety, age, and tissue development phase in the plant (Nitsch, 1951; Leetham, 1974; Yuan and Xu, 2001; Yan *et al*., 2004).

Grain yield

The seed invigoration treatments applied to the three varieties in general (Table 5) showed that the treatment of young coconut water and 100 ppm GA_3 had higher dry grain yield than the control (soaked in water, 3-5 seeds/hole). However, the treatment of soaked in water, 6-10 seeds/hole had no significantly different in the grain yield (5.03 t/ha) compared with these treatments. Moreover, the seeds soaked in 100 ppm GA_3 + young coconut water significantly increased the production of grain yield.

Furthermore, the results in Table 5 also showed that the higher seed viability level, the higher the dry grain yield produced by the three upland varieties. The significant effects of seed invigoration with young coconut water on the grain yield most probably related to the presence of cytokines. This result was supported by the increased of germination percentage due to the application of the same invigoration treatment (Table 1). In line with the results in the present study, other studies proved also that invigoration treatments applied to the rice seeds increased grain yield (Harris *et al.,* 2002; Du and Toung, 2002).

Table 3. Effects of interaction of seed invigoration, viability level and variety on number of productive tillers per hill

Seed treatment		Number of productive tillers per hill					
		Situ Patenggang		Limboto		Batutegi	
V1	Soaked in water, 3-5 seeds/hole	18.20	a	16.67	ab	15.13	ab
V1	Soaked in water, 6-10 seeds/hole	12.17	bc	14.87	abcd	12.63	ab
V1	Soaked in young coconut water, 3-5 seeds/hole	11.37	bc	15.00	abcd	13.93	ab
V1	Soaked in 100 ppm GA_3, 3-5 seeds/hole	14.90	abc	15.47	abcd	12.13	ab
V1	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	13.10	bc	15.00	abcd	15.27	ab
V2	Soaked in water, 3-5 seeds/hole	12.93	b	12.47	cd	12.40	ab
V2	Soaked in water, 6-10 seeds/hole	11.67	bc	16.47	abc	13.93	ab
V2	Soaked in young coconut water, 3-5 seeds/hole	13.67	bc	13.70	abcd	14.07	ab
V2	Soaked in 100 ppm GA_3, 3-5 seeds/hole	14.33	abc	17.67	a	12.87	ab
V2	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	13.93	bc	14.13	abcd	11.43	ab
V3	Soaked in water, 3-5 seeds/hole	11.03	c	12.93	bcd	12.00	ab
V3	Soaked in water, 6-10 seeds/hole	18.27	a	15.07	abcd	12.43	ab
V3	Soaked in young coconut water, 3-5 seeds/hole	15.33	ab	12.07	b	11.13	b
V3	Soaked in 100 ppm GA_3, 3-5 seeds/hole	14.40	abc	14.30	abcd	15.47	a
V3	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	15.27	ab	12.83	bcd	13.53	ab

Note: *Numbers within the same column followed by the same letter are not different at $p < 0.05$, by Duncan's Test. V1 = seed viability ± 100%, V2 = seed viability ± 80%, V3 = seed viability ± 60%.

Table 4. Effects of seed invigoration, viability level and variety on 1000-grain weight at 14% moisture content

Seed treatment		1000-grain weight					
		Situ Patenggang		Limboto		Batutegi	
V1	Soaked in water, 3-5 seeds/hole	27.80	ab	27.87	ab	24.63	de
V1	Soaked in water, 6-10 seeds/hole	28.70	a	28.20	a	24.20	de
V1	Soaked in young coconut water, 3-5 seeds/hole	27.87	ab	27.67	ab	25.30	c
V1	Soaked in 100 ppm GA_3, 3-5 seeds/hole	27.57	ab	27.07	abc	26.93	abc
V1	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	27.03	abc	28.33	a	24.30	de
V2	Soaked in water, 3-5 seeds/hole	27.03	abc	28.50	a	24.80	de
V2	Soaked in water, 6-10 seeds/hole	26.80	abc	28.57	a	24.33	de
V2	Soaked in young coconut water, 3-5 seeds/hole	28.13	ab	27.40	ab	25.30	cde
V2	Soaked in 100 ppm GA_3, 3-5 seeds/hole	27.07	abc	28.93	a	23.37	e
V2	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	27.57	ab	27.90	ab	26.00	bcd
V3	Soaked in water, 3-5 seeds/hole	28.13	ab	27.10	abc	25.07	de
V3	Soaked in water, 6-10 seeds/hole	27.93	ab	28.07	ab	24.53	de
V3	Soaked in young coconut water, 3-5 seeds/hole	27.93	ab	28.10	ab	24.50	de
V3	Soaked in 100 ppm GA_3, 3-5 seeds/hole	27.60	ab	27.13	abc	24.20	de
V3	Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	28.71	a	26.83	abc	24.40	de

Note: *Numbers within the same column followed by the same letter are not different at $p < 0.05$, by Duncan's Test.
V1 = seed viability ± 100%, V2 = seed viability ± 80%, V3 = seed viability ± 60%.

For all invigoration treatments, the seed lots having higher viability had higher grain yield than that having lower viability. This could be due to the availability of energy for metabolism that was high enough in the seeds having high viability to support the plant growth and cell development (Nonogaki *et al.,* 2010).

The results of Duncan Multiple Range Test in Table 6 showed that there were significantly different in grain

Table 5. Effects of seed invigoration and viability level on dry grain weight (t/ha) at 14% moisture content

Seed treatment	Grain weight (t/ha)			
	V1	V2	V3	Mean
Soaked in water, 3-5 seeds/hole	6.25	3.83	3.41	4.49 c
Soaked in water, 6-10 seeds/hole	5.80	4.74	4.54	5.03 bc
Soaked in young coconut water, 3-5 seeds/hole	6.25	5.63	5.01	5.63 ab
Soaked in 100 ppm GA_3, 3-5 seeds/hole	5.65	5.53	5.33	5.51 ab
Soaked in 100 ppm GA_3 + young coconut water, 3-5 seeds/hole	6.77	6.22	4.96	5.98 a
Mean	6.14 a	5.19 b	4.65 c	

Note: *Means within the same column or row followed by the same letter are not different at $p < 0.05$, by Duncan's Test.
V1 = seed viability ± 100%, V2 = seed viability ± 80%, V3 = seed viability ± 60%.

Table 6. Effects of variety and seed viability level on dry grain weight (t/ha) at 14% moisture content

Seed treatment	Dry grain weight (t/ha)			
	V1	V2	V3	Mean
Situ Patenggang	6.27	6.02	4.86	5.71 b
Limboto	7.54	5.89	5.86	6.43 a
Batutegi	4.62	3.66	3.22	3.84 c
Mean	6.14 a	5.19 b	4.65 c	

Note: *Means within the same column or row followed by the same letter are not different at $p < 0.05$, by Duncan's Test.
V1 = seed viability ± 100%, V2 = seed viability ± 80%, V3 = seed viability ± 60%.

yields among the three upland rice varieties. The Limboto variety had the highest grain yield, followed by Situ Patenggang and Batutegi varieties. This suggests that the ability of recovery among the three upland rice varieties were different.

CONCLUSIONS

Invigoration treatments affected seed germination of Situ Patenggang and Limboto upland rice varieties. Seed invigoration treatments either with young coconut water, 100 ppm GA_3 or 100 ppm GA_3 + young coconut water can be used as a pre-planting seed treatment to overcome the problem of low seed viability (the grain yields were 5.63 t/ha, 5.51 t/ha, and 5.98 t/ha, respectively).

Seedling establishment of Situ Patenggang and Limboto upland rice varieties with 6-10 seeds per planting hole (equivalent to 80 kg/ha) can be used as an alternative to overcome the low seed viability. This treatment might give a high grain yield (up to 5.03 t/ha).

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