Seed biomatricconditioning using rhizobacteria for growth promotion and increase the yield of sorghum (*Sorghum bicolor* (L.) Moench) on marginal soil

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**Abstract**

Plant-growth promoting rhizobacteria play an important role in plant health and soil fertility. Application of rhizobacteria as a plant-growth promoting has been shown to increase plants growth and development under field and controlled enviromental condition. Seed biomatricconditioning using rhizobacteria was studied in an attempt to improve seed vigor, growth and yield of sorghum grown on marginal soil. Two matricontioning media *i.e.* ground burned-rice husk and ground brick in combination with three isolates of rhizobacteria namely *Bacillus* sp. CKD061, *Pseudomonas fluorescens* PG01 and *Serratia* sp. CMN175 were tested under laboratory and field condition. In the laboratory, six biomatricconditioning treatments and control were arranged in completely randomized design with three replications; each treatment consisted of 25 sorghum seeds used to observe the seed viability and vigor. In the field test, four biomatricconditioning treatments and control were established as a completely block randomized design in marginal soil to observe plant growth and plant yield. The number of samples observed per experimental unit was three. Results of laboratory test showed that seed biomatricconditioning with *P. fluorescens* PG01 in combination with ground burned rice husk resulted in the highest germination rate, vigor index, relative growth rate and normal seedling dry weight. However, under field condition, treatment with *Bacillus* sp. CKD061 in combination with ground brick showed the best performance than other treatments particularly on plant height, diameter of stem, yield per plant, and harvest index. This treatment increased the yield per plant by 199% when compared to control.

**Keywords:** biomatricconditioning, marginal soil, rhizobacteria, sorghum

**INTRODUCTION**

Suntoro (2006) reported that the area of marginal soil in Indonesia had reached 23.24 million ha and most of which (65%) located outside forest areas. In Southeast Sulawesi, the area had reached 1.2 million ha and 300,000 ha of them are considered very critical (Syafrudin, 2009). The most critical problems to use its are low pH, poor nutrients and low microbial activities. This type of soil is commonly underutilized or even tends to be abandoned. If this soil is not managed well, its condition will become more critical. In order to utilize this soil, it is necessary to find the crop that adaptable to such soil.

*Sorghum* (*Sorghum bicolor* (L.) Moench) is one of the cereal crops that possess a great potential to be grown in Indonesia because it is highly capable of adapting to marginal soil. It is tolerant to drought and flooding, and relatively resistant to pests and diseases (Sirappa, 2003). Besides the utilization of adaptive crops, the availability of viable seeds is also a very important factor in improving marginal soil productivity. The use of a low seed quality will result in a low seed emergence and susceptible young plants to abiotic and biotic pressures which in turn will result in a decreased yield. A failure to prepare or produce viable seeds may reduce crop productivities.

A treatment of pre-planted seed invigoration can be done to overcome the low crop productivity due to low
seed vigor. One of such treatments is seed conditioning which has been proven effective in increasing seed viability and vigor (Ilyas et al. 2002; Moradi & Younesi, 2009; Sutariati et al., 2009). Seed conditioning can be done through matriconditioning (i.e. conditioning of seeds with moist, solid materials). This technology can be integrated with biological agents. The integration of seed invigoration with biological agents is called biomatricconditioning (Ilyas, 2006). Seed matriconditioning technique to be good for both of physiological and biochemical conditions which related to growth rate and uniformity of seed germination by hydration control mechanisms of low matrix potential media (Ilyas, 2006). In other hand, application of biological agents contributed to improving plant growth by phytohormone production, nitrogen fixation, and phosphate solubilisation mechanisms (Park et al. 2009).

The objectives of this study were to know the effects of pre-planted seed biomatricconditioning using two matricontioning media i.e. ground burned-rice husk and ground brick in combination with three isolates of rhizobacteria on seed viability and vigor, growth and yield of sorghum grown on marginal soil.

Materials and Method

Preparation of Rhizobacteria

Rizobacteria used in this study included Bacillus sp. CKD061, Serratia sp. CMN175, and Pseudomonas fluorescens PG01 were isolated from rhizosphere of healthy chilly pepper in the previous study (Sutariati et al., 2009). During times active use Bacillus sp. CKD061 and Serratia sp. CMN175 were routinely cultivated on agar plate of Triphlic Soy Agar (TSA) medium at the room temperature, while Pseudomonas fluorescens PG01 was cultivated on King’s B Medium (KBM). The TSA medium composition (g/l) are Triphlic Soy Broth (difco) 30 g and agar 20 g, while KBM are peptone protease 20 g, K2HPO4 2.5 g, MgSO4.7H2O 6 g, glycerol 15 ml, and agar20 g. After 24 hours the growing bacterium colony was suspended in sterile deinonized water till a population density of 10^5cfu/ml (Bai et al., 2002).

Seed Biomatricconditioning

The sorghum seeds were disinfected with natrium hypoclorit 2% for 5 minutes, rinsed 5 times with sterile water, then air dried in laminar air flow cabinet for one hour. Seed biomatricconditioning were conducted by placing 10 g of seeds into culture bottle which were then mixed with 7.5g of matriconditioning media (i.e. ground burned rice husk or ground brick) and added with 5 ml each of suspensions (10^6CFU/ml concentration) of rhizobacterium Bacillus sp. CKD061, P. fluorescens PG01 or Serratia sp. CMN175. Sterile distilled water was used as control. The bottle was then covered with plastic and tied with rubber bands. To avoid the occurrence of aerobic condition, three small holes were made on the plastic cover by using a needle. The cultures were then incubated for 24 hours at room temperature (28-30 °C) after which the seeds were air dried in the laminar air flow cabinet for 1 hour.

Seed viability dan vigor test

The study were arranged in completely randomized design with six biomatricconditioning treatments plus control and replicated in three times under laboratory condition. The treated seeds were sowed on sterile burned rice husk placed in a plastic box (20 cm x 15 cm x 10 cm. Twenty-five seeds were sowed per box and three boxes were prepared per treatment, and stored in growth chamber during 14 days. The seed viability and vigor were evaluated by measuring their germination rate, vigor index, relative growth rate, and dry weight of normal seedlings. Germination rate (GR), was calculated based on the formula developed by Sadjad et al. (1999) as follows:

\[
GR = \frac{\sum NS \text{ at observation 1} + \sum NS \text{ observation 2}}{\sum \text{Seeds planted}} \times 100\%
\]

NS = Percentage of normal seedlings. Observation 1 = 5 days after sowing. Observation 2 = 7 days after sowing.

Vigor index (VI), depicting the growth rate vigor (Copeland & McDonald, 1995), was measured based on percentage of normal seedlings at the first observation (i.e. 5 dap):

\[
VI = \frac{\sum NS \text{ at observation 1}}{\sum \text{Seeds planted}} \times 100\%
\]

Relative growth rate (K_{CT-R}), depicting seed vigor, is the ratio of K_{CT} to maximum K_{CT}. The maximum K_{CT} itself was obtained from the assumption that at the first observation, normal seedlings had reached 100%. K_{CT} was calculated based on the accumulation of daily growth rate (Sadjad et al, 1999):

\[
K_{CT} = \frac{\sum_{t=0}^{tn} N}{tn}
\]
Where:  
\[ t = \text{time of observation} \]
\[ N = \% \text{NS per observation} \]
\[ t_n = \text{end of observation} \]

\[ K_{CT-R} \text{ for sorghum seeds was calculated by using the following formula:} \]
\[ K_{CT-R} = \frac{K_{CT}}{20} \times 100\% \]

Normal seedling dry weight was measured at the end of observation (7 days after sowing). All normal seedlings were cleaned up with tap water and then wrapped in aluminium foil and dried in an oven at 60°C for 72 h. After being placed in desiccators for ± 30 menit, they were weighed.

**Field experiment**

Based on the preliminary test, the chemical characteristics of the marginal soil used in this research were, as follows, pH \text{H}_{2}O 4.37 (acid), C-organic 3.15% (high), N-Total 0.09% (low), P (Bray) 3.9 ppm (moderate), K\text{O} 0.19 me/100g (very low).

The field test were established as a completely block randomized design in marginal soil of field experimental garden of Haluoleo University in Kendari Southeast Sulawesi. The experiment consist of 4 treatments plus control with 3 replication. Soil cultivation conducted three weeks prior to planting. Soil beds were built in 2m x 4m each plot. The spaces between soil beds in the same plot were 0.3m wide, while those between the neighboring plot were 0.5m wide.

The biomatriconditioned seeds in each treatment were planted with a planting space of 70 cm x 40 cm in pre-dug holes of 3 cm deep after which each hole was covered with 10g of organic fertilizer. Plant maintenance included: (1) Watering, done twice a day namely in the morning and in the afternoon when it didn’t rain by using a watering can until the soil become mist but not flooded, (2) Replanting, done 7 days after panting (dap) to replace the dead or missing plants, and (3) Weeding, done when weeds grew on the surrounding plant root area.

The parameters that were observed were: (1) plant growth including plant height, stem diameter, plant dry weight, (2) plant yield including time of anthesis, sorghum product per plant, and 1000-grain weight, (3) plant growth analysis including leaf area index (LAI), plant growth rate (PGR), net assimilation rate (NAR) and harvest index (HI). The number of samples observed per experimental unit was 3.

Plant height (cm) at 75 days after planting (dap), measured from root neck (soil surface) to the highest growing point. Stem diameter (mm) at 75 (dap), measured at 5 cm above the root neck. Plant dry weight (g), samples were collected destructively by up-rooting the plants. The roots were freed from dirt, ovened at 80°C for 2x24 hours, then weighed. Measurement was conducted at 30, 45, 60, 75 dpa and at harvest time. The data were then used for the calculation of PGR, NAR and HI. Time of anthesis (day), observed when the number of blooming flowers in each experimental unit had reached 80%.

Sorghum yield per plant (g), conducted after harvest by weighing all grains on each plant that had been dried under sun for 3 days. The plants were harvested at 95-105 dpa. A 1000-grain weight (g), conducted when the grain water content had reached 12%. The sorghum grains were dried under the sun for 3 days of 4 hours a day (from 10.00 to 14.00) to achieve such a water content.

**Plant Growth Analysis**

Leaf Area Index (LAI) is a leaf area (A) on every unit of soil area (P) that can be expressed in a mathematical formula as follows:

\[ \text{LAI} = \frac{A}{P} \]

Plant Growth Rate (PGR) is every increased dry weight per every unit of soil area (W) that can be expressed in a mathematical formula as follows:

\[ \text{LTP} = \frac{W_2 - W_1}{T_2 - T_1} \]

where:

W1 = total plant dry weight at the 1st observation
W2 = total plant dry weight at the 2nd observation
T1 = observation 1st day
T2 = observation 2nd day

Net Assimilation Rate (NAR) is the rate of plant dry weight increase at a particular time (T) per unit of soil area (L) that can be expressed in a mathematical formula as follows:

\[ \text{LAB} = \frac{\ln L_2 - \ln L_1}{L_2 - L_1} \times \frac{W_2 - W_1}{T_2 - T_1} \]
The data were analysed by using ANOVA and when it showed significant effect, it was furtherly tested with Duncan’s Multiple Range Test (DMRT) at α=0.05. All data analysis was conducted by using SAS.

RESULTS AND DISCUSSION

Results

Seed biomatriconditioning on sorghum seed viability and vigor

Compared to control, treatments of seed biomatriconditioning were more effective in improving sorghum seed germination percentage, vigor index, relative growth rate and normal seedling dry weight. Among the three rhizobacteria studied, *Bacillus* sp. CKD061 and *P. fluorescens* PG01 either integrated with ground burned rice husk or ground brick showed a higher germination percentage, vigor index, relative growth rate and normal seedling dry weight compared to *Serratia* sp. CMN175. The lowest germination percentage was found on control which was significantly different from the other treatments except *Serratia* sp. CMN175 (Table 1).

Based on the seed viability and vigor test, rhizobacterium *Serratia* sp. CMN175 was less effective in improving the sorghum seed viability and vigor compared to *Bacillus* sp. CKD061 and *P. fluorescens* PG01. Therefore, *Serratia* sp. CMN175 was not tested in the field study as the other two.

Seed biomatriconditioning on sorghum growth and yield in the field

**Plant height, stem diameter, and leaf area index**

Treatments of seed biomatriconditioning were effective in improving plant height, stem diameter, and leaf area index compared to control (Table 2). Among the three parameters, biomatriconditioning *Bacillus* sp. CKD061 + ground brick showed the highest yield. It was significantly different from control but not significantly different from *P. fluorescens* sp. PG01 + ground burned rice husk (i.e. plant height and stem diameter) or *Bacillus* sp. CKD061 + ground burned rice husk (i.e. stem diameter) (Table 2).

**Sorghum growth rate and net assimilation rate**

Treatments of seed biomatriconditioning were effective in improving plant growth rate and net assimilation rate compared to control (Table 3). An increase of plant growth rate was observed on plants treated with *Bacillus* sp. CKD061 + ground brick either at 30-45 dap or 46-60 dap. The increase was significantly different from control and other treatments but not significantly different from *P. fluorescens* sp. PG01. The increase of plant growth rate was less significant when *Bacillus* sp. CKD061 + ground brick was treated at 60-75 dap. The increase was significantly different from control but not significantly different from other treatments (Table 3).
Table 2. The effects of sorghum seed biomatriconditioning on plant height, stem diameter, and leaf area index

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Stem diameter (mm)</th>
<th>Leaf area index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>217.72</td>
<td>c</td>
<td>10.22</td>
</tr>
<tr>
<td>CKD061+AS</td>
<td>244.63</td>
<td>b</td>
<td>19.56</td>
</tr>
<tr>
<td>CKD061+BM</td>
<td>259.17</td>
<td>a</td>
<td>21.11</td>
</tr>
<tr>
<td>PG01+AS</td>
<td>258.83</td>
<td>a</td>
<td>19.67</td>
</tr>
<tr>
<td>PG01+BM</td>
<td>231.39</td>
<td>c</td>
<td>17.78</td>
</tr>
</tbody>
</table>

Notes: Means in the same column suffixed with different letters are different at 5% levels of significance according to DMRT.

Table 3. The effects of seed biomatriconditioning on plant growth rate (PGR) and net assimilation rate (NAR)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PGR 30-45 dap (g/plant/d)</th>
<th>PGR 46-60 dap (g/plant/d)</th>
<th>PGR 61-75 dap (g/plant/d)</th>
<th>NAR 30-45 dap (g/cm²/d)</th>
<th>NAR 46-60 dap (g/cm²/d)</th>
<th>NAR 61-75 dap (g/cm²/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.230</td>
<td>c</td>
<td>1.668</td>
<td>d</td>
<td>5.458</td>
<td>a</td>
</tr>
<tr>
<td>CKD061+AS</td>
<td>0.372</td>
<td>b</td>
<td>9.470</td>
<td>b</td>
<td>2.257</td>
<td>b</td>
</tr>
<tr>
<td>CKD061+BM</td>
<td>0.530</td>
<td>a</td>
<td>11.439</td>
<td>a</td>
<td>2.435</td>
<td>b</td>
</tr>
<tr>
<td>PG01+AS</td>
<td>0.467</td>
<td>ab</td>
<td>10.022</td>
<td>b</td>
<td>2.032</td>
<td>b</td>
</tr>
<tr>
<td>PG01+BM</td>
<td>0.378</td>
<td>b</td>
<td>8.061</td>
<td>c</td>
<td>0.386</td>
<td>c</td>
</tr>
</tbody>
</table>

Notes: Means in the same column suffixed with different letters are different at 5% levels of significance according to DMRT.

*flourescens* sp. PG01 + ground burned rice husk at 30-45 dap. However, at 61-75 dap, the highest plant growth rate was observed on control which was significantly different from all other treatments (Table 3).

Meanwhile, net assimilation rate at 30-45 dap on control was higher than biomatriconditioning *Bacillus* sp. CKD061 + ground burned rice husk, but it was not significantly different from the other treatments. At 46-60 dap, all other biomatriconditioning resulted in a similar net assimilation rate and significantly different from control. In contrast, at 61-75 dap, only did control showed a relatively high net assimilation rate which was significantly different from that of all other treatments (Table 3).

Time of anthesis, yield per plant, 1000-grain weight and harvest index of sorghum

Treatments of seed biomatriconditioning were effective in improving time of anthesis, sorghum yield per plant, 1000-grain weight and harvest index. Compared to control, treatments *Bacillus* sp. CKD061 + ground brick and *P. fluorescens* sp. PG01 + ground burned rice husk or ground brick significantly shortened sorghum time of anthesis. Biomatriconditioning *Bacillus* sp. CKD061 + ground brick also increased yield per plant which was significantly different from control and other treatments but it was not significantly different from *Bacillus* sp. CKD061 + ground burned rice husk. The highest 1000-
grain weight was found on biomatriconditioning Bacillus sp. CKD061 + ground brick significantly different from control but it was not significantly different from P. fluorescens sp. PG01 + ground burned rice husk. Meanwhile, all seed biomatriconditioning either Bacillus sp. CKD061 or P. fluorescens sp. PG01 + ground burned rice husk or ground brick resulted in a higher harvest index and significantly different from control (Table 4).

### Discussion

The results of the study showed that techniques of seed invigoration through biomatriconditioning using rhizobacteria Bacillus sp. CKD061 or P. fluorescens PG01 were significantly capable of improving sorghum seed viability and vigor compared to control. The results were in accordance with those of the previous studies. As reported by Ilyas (2006); Sutariati, (2009), the use rhizobacteria as PGPR can also significantly increase seed production, and physiological and pathological quality of chili pepper seed compared to those untreated with bio-agents. Bio-agents-seed inoculation is also reported to increase chili pepper seed production and the seed protein content compared to those untreated ones (Ilyas et al. 2002).

Observation on several seed viability and vigor parameters showed that Bacillus sp.CKD061 and P. fluorescens PG01 were more responsive to sorghum seeds than Serratia CMN175. Rhizobacterium colonization into a host plant is started when a seed is germinating. At the same time, the rhizobacteria also require adequate nutrition for their growth and development. Generally, the nutrition is derived from organic acids exuded by the host plant and the type of the organic acid is different from one host to another. Therefore, a reduced contribution of rhizobacteria may be caused by a limited nutrition provided by the host plant.

Based on the field study results, seed biomatriconditioning was effective enough to increase the growth and yield of sorghum crop indicated by an increased value of all observed parameters, either on the growth (plant height, stem diameter, leaf area index, growth rate, and net assimilation rate) or yield (time of anthesis, yield per plant, 1000-grain weight, and harvest index) compared to control.

In general, the utilization of Bacillus sp.CKD061 or P. fluorescens PG01 integrated with matriconditioning of ground burned rice husk or ground brick resulted in a higher yield and more effective in increasing the growth and yield of sorghum compared to control. However, from several observed parameters, Bacillus sp.CKD061 was more responsive to ground brick, while P. fluorescens PG01 was more responsive to ground burned rice husk. It is not clearly known the correlation between ground brick and Bacillus sp.CKD061 or between grounds burned rice husk and P. fluorescens PG01, but it is assumed that this was correlated to rhizobacterium-carrier compatibility. Bacillus sp.CKD061 was more compatible to ground brick whose basic material was from clay mineral. Bacillus sp.CKD061 belongs to gram positive bacteria that possess a thicker cell wall than those of gram negative, therefore, the former is more suitable to ground brick that is heavier, more compacted and less porous physical structure. Meanwhile, P. fluorescens PG01 possesses a thinner cell wall so that it is more compatible to ground burned rice husk that is lighter, less compacted and more porous physical structure. Generally, clay mineral with its high water holding capacity and adhering property is more capable of protecting microorganisms. As stated by Marshall (1975), due to its high water holding capacity and adhering property, the drying rate of clay is slower therefore microorganisms willalways be at an ideal condition for their growth and development.

An improved and increased growth and yield of sorghum resulted from the utilization of Bacillus sp. CKD061 or P. fluorescens PG01 integrated with seed matriconditioning was presumably caused by the ability of both rhizobacteria to produce IAA and to dissolve phosphate. Bacillus sp.CKD061 produced 375 ppm of IAA, while P. fluorescens PG01 produced 100 ppm.

### Table 4. The effects of sorghum seed biomatriconditioning on time of anthesis (TA), yield per plant (YPP), 1000-grain weight (W1000) and harvest index (HI)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>TA (day)</th>
<th>YPP g/plant</th>
<th>W1000 (g)</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>85.67</td>
<td>a</td>
<td>30.86</td>
<td>c</td>
</tr>
<tr>
<td>CKD061+AS</td>
<td>73.00</td>
<td>b</td>
<td>34.85</td>
<td>b</td>
</tr>
<tr>
<td>CKD061+BM</td>
<td>68.33</td>
<td>c</td>
<td>36.56</td>
<td>a</td>
</tr>
<tr>
<td>PG01+AS</td>
<td>68.67</td>
<td>c</td>
<td>35.07</td>
<td>ab</td>
</tr>
<tr>
<td>PG01+BM</td>
<td>70.00</td>
<td>c</td>
<td>34.49</td>
<td>b</td>
</tr>
</tbody>
</table>

Notes: Means in the same column suffixed with different letters are different at 5% levels of significance according to DMRT.
Several previous studies also showed that the role of Bacillus spp. or _P. fluorescens_ as PGPR (Plant Growth Promoting Rhizobacteria) were correlated to their ability to synthesize plant growth regulator substances, to fix nitrogen or to dissolve phosphate (Sutariati et al., 2009). Kang _et al._ (2007), also reported that _Bacillus_ spp. can fix nitrogen and dissolve phosphate. _Bacillus_ spp. can also synthesize IAA (ElSorra _et al._, 2007; Sutariati, 2006), gibberellins (Joo _et al._, 2005), and cytokinins (Timmus _et al._, 2005). Like _Bacillus_ spp. _P. fluorescens_ can also produce IAA (Ashrafuzzaman _et al._, 2009), gibberellins and cytokinins (Ahmad _et al._, 2005), fix nitrogen (Mehrab _et al._, 2010) and dissolve phosphate (Park _et al._, 2009).

_Nadeem et al._ (2010) added that the main contribution of rhizobacterium _Bacillus_ spp. or _P. fluorescens_ associated with host plants was to increase the availability of regulator growth substances, such as, IAA that functions to promote plant growth and increase the availability of plant nutrition such as P that is highly required during the plant growth and development. The utilization of P-dissolving rhizobacteria that can substitute a part or all plant P-requirement results in an increased plant growth and yield. This P-dissolving is brought about by bacteria that produce phosphates that can release bound P from organic substances, and therefore, it can fulfill plant requirement (Vleesschauwer _et al._, 2009; Koo & Cho, 2009).

Besides an improvement brought about by the utilization of rhizobacterium alone, the application of invigoration techniques as rhizobacterium inoculating media, it also provides a great positive role on seeds. As discussed previously, invigoration techniques are treatments for seeds (seed conditioning) intended to increase the plant growth and uniformity, and increase the percentage of seedling and young plant emergence. _Seed conditioning_ is a physiological and biochemical improvement related to the rate and uniformity, improvement and increase of germinating potential during their delayed germination by media having a low matrix potential (matriconditioning) (Ilyas, 2006). The utilization of seed invigoration techniques has been proven effective in improving seed viability and vigor (Ilyas _et al._, 2002). The utilization of such technology combined with rhizobacterium can also protect planted seeds from seed-and soil-born fungi (Sutariati, 2006; Moradi & Younesi, 2009).

A decrease of plant growth rate or net assimilation rate soon before 61-75 dap showed that the plants had reached senescent phase, therefore, the produced assimilates were mostly allocated for generative organs (i.e. seeds) resulted in a reduced vegetative organ growth. Gardner _et al._, (1991) explains that net assimilation rate is the rate of accumulating dry weight per unit of leaf area per unit of time. Net assimilation rate is not constant with time but it will decrease along with the plant age and especially when it has reached its generative phase. In addition, the accumulation of dry weight determines plant ability to fix the solar energy through photosynthesis and its interaction with other environmental factors. The distribution of dry weight in plant parts such as roots, stem, leaves and generative parts can determine the plant productivity. Meanwhile, plant growth rate pattern and net assimilation rate of control plants that increased at 8-10 weeks after planting showed that such plants still experienced an active vegetative growth, therefore, the accumulation of dry weight still happened on roots, stem, leaves or other vegetative organs.

An improvement of the early stage of plant growth resulted in a significant effect on speeding up the plant generative phase. This can be seen from the observation on the time of anthesis (Table 4). Regardless their genetic differences of the harvest time for both varieties, treatments of seed biomatriconditioning can significantly shorten time to anthesis. Time to anthesis time is the period required by a plant to reach pollination phase which is depicted by the blooming of its flowers. Compared to control, all seed biomatriconditioning flowered faster. The observation of anthesis time was conducted to predict or study the effect of the applied treatment on time of plant to initiate flower which in turn can shorten its harvest time.

**CONCLUSION**

The utilization of rhizobacterium _Bacillus_ sp. CKD061 or _P. fluorescens_ PG01 integrated with matriconditioning using ground burned rice husk or ground brick can improve sorghum seed quality, growth and yield compared to control. _Bacillus_ sp.CKD061 was more responsive to ground brick, while _P. fluorescens_ PG01 was more responsive to ground burned rice husk. However, rhizobacterium _Bacillus_ sp. CKD061 integrated with ground brick was the most effective treatment to obtain a maximum yield. The treatment increased yield (yield per plant) by 199% compared to control.

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