Current Applied Science and Technology e-ISSN: 2586-9396

Curr. Appl. Sci. Technol. 2025, Vol. 25 (No. 4), e0259673

Research article

Net Assimilation Rate and Mean Relative Growth Rate of Horticulture Plants on Swamp Land under Control of Organic Compounds

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Received: 23 January 2024, Revised: 2 April 2024, Accepted: 12 December 2024, Published: 27 January 2025

Abstract

This research involved two experiments and was conducted in the experiment station of Faculty of Agriculture, Islamic University of Riau, Indonesia. This experiment was arranged with a randomly simple design with two factors. First, the effects of water hyacinth (*Eichhornia crassipes*) compost and rice husk ash on *Brassica juncea*, and secondly the effects of water hyacinth compost and *Rhizobium* inoculant on soybean (*Glycine max*) were investigated. The data analysis was performed with Duncan's multiple range test with significant differences at $p < 0.05$. The net assimilation rate and mean relative growth rate were used as indicators for the dry weight accumulation of plants. The combination of water hyacinth compost and rice husk ash had an interacting effect on soybean and *Brassica juncea*. An increase of net assimilation rate was followed by an increase in mean relative growth and a significant increase in dry matter weight was also observed. A combination of water hyacinth compost and rice husk ash had a significant positive effect on plant growth in swamp land. Rice husk ash can potentially balance excess iron and aluminum levels in soil impedes the absorption of essential minerals in swamp land. Rice husk ash can potentially balance excess iron and aluminum levels in soil that impedes the absorption of essential minerals in swamp land. The combination of water hyacinth compost and rice husk ash in swamp land increased the production of seed dry weight of soybean and crop dry weight of *Brassica juncea.*

Keywords: assimilation; compound; growth; organic; swamp land

1. Introduction

Swamp land in Indonesia is distributed in most of the big islands and mainly in the coastal areas of Papua, Sulawesi, Kalimantan and Sumatra. On those great islands, swamp land is spread about 34.12 million hectares and only 41% of the swamp land has the potential for agricultural land (Sulaiman et al., 2018; Sakir et al., 2021). The water hyacinth (*Eichhornia crassipes*) lives on the surface and requires no direct soil. Most water hyacinth lives on

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https://doi.org/10.55003/cast.2025.259673

water that is opaque and does not flow. Water hyacinth has covered most of the rivers and lakes in the western region of Indonesia (Sakir et al., 2021). Water hyacinth is an invasive plant that has become increasingly dangerous to agriculture land and fisheries (Ilo et al., 2020). Water hyacinth is water wild plant that poses threats to other water plants. Various efforts to exploit water hyacinth have been made. One such strategy is to use the aquatic wild plants as compost. Researchers have reported its use as an organic fertilizer (Su et al., 2018; Ilo et al., 2020).

Chemical contents and the quantities on the percentage shown that water hyacinth possessed various essential minerals for plants. Water hyacinth is significantly dominated by potassium (K) and followed by calcium (Ca) and other essential minerals. Chemical substances including carbon (C), oxygen (O), sodium (Na), magnesium (Mg), aluminum (Al), zirconium (Zr),chlorine (Cl), potassium (K), calcium (Ca), silicon (Si), titanium (Ti), and iron (Fe). (Sukarni et al., 2018)

Waste produced by rice milling contains contaminants that can potentially damage agricultural land, particularly rice husk ash or chaff. Because it takes a long time to undergo nitrification, most farmers burn the chaff to ashes. Previous research indicated that rice husk ash contained essential elements such as calcium, magnesium and other minerals (Jumin et al., 2017; Jumin et al., 2020; Jumin et al., 2021; Jumin et al., 2024). Moreover, chaff ash can increase the availability of other essential elements in the soil, such as nitrogen, phosphorus, calcium, magnesium. Calcium and magnesium can suppress harmful iron and aluminum levels in agricultural land (de Oliveira et al., 2013). As for water hyacinth, there is an opportunity to be used as an alternative organic fertilizer and in such applications it has the added function of decreasing material poisoning due to excess aluminum and iron levels in swamp land (Costa et al., 2004).

Two aspects of water hyacinth and the rice chaff are the most detrimental factors in the growth and productivity of other plants. This can be clearly seen in the rate of plant growth. Less light in the leaves causes a drop in the growth and sensitivity of enzymes in the photosynthesis cycle, a key enzyme of which is ribulose-1.5-bisphosphate carboxylase/oxygenase (de Oliveira et al., 2013). When the main activity in leaves decreases, there must be a decrease in bimass accumulation (de Oliveira et al., 2013).

In swamp land the effectiveness of *Rhizobium* decreases due to decrease in the availability of calcium and magnesium (Adlim et al., 2020). The drop of photosynthesis activity can be seen as an average indicator of mean relative growth rate and net assimilation rate.The rate of accumulation of dry weight material or the net assimilation rate depends largely on the leaf area. It compresses the sun's energy and accelerates the water and carbon dioxide (CO_2) to produce the glucose in the plants. The availability of carbon dioxide and an abundance of water and oxygen is closely linked to the availability of light energy emitted by the sun to the plant leaf.

This paper aimed to firstly study the effects of the interaction of rice husk ash and water hyacinth compost on the net assimilation rate and mean relative growth rate of *Brassica juncea* cultivated in swamp land. Secondly, the interaction between *Rhizobium* inoculant and water hyacinth compost on the mean relative growth and the net assimilation rate of soybean (*Glycine max*) growing in swamp land was also investgated.

2. Materials and Methods

2.1 Study area

This research was conducted from August 2022 to July 2023. Two experiments were conducted. Firstly, the experiment on *Brassica juncea* was arranged to factorial with a randomly simple design with two factors. Treatments were repeated three times. The data analysis was based on Duncan's multiple range test with significant differences at p <0.05. The first factor was the dose of rice husk ash, which was as follows: 0.0 g/polybag, 125 g/polybag, 250 g /polybag, and 375+ g/polybag. The second factor was water hyacinth compost at doses 0.0 g/polybag, 250 g/polybag, 500 g/polybag, and 750 g/polybag. The plants were maintained under the light condition and photoperiod of the equation region. The plants were irrigated in the morning and afternoon every day, except on rainy days.

Secondly, an experiment with the soybean (*Glycine max*) was performed, arranged with a randomly simple design with two factors. The treatments were repeated three times. The first factor was with *Rhizobium* inoculant; 0.0 g/kg seed/plot, 1.5 g g/kg seed, 3.0 g/kg seed/plot and 4.5 g/kg seed/plot. The second factor was water hyacinth compost at 0.0 kg/plot, 1.5 kg/plot, 3.0 kg/plot, and 4.5 kg/kg seed/plot. The plants were maintained under the light conditions and photoperiod of the equation region. The plants were irrigated in the morning and afternoon every day, except on rainy days.

2.2 Mean relative growth rate (MRGR)

Dry weight (W) data for *Glycine max* and *Brassica juncea* biomass were collected by sampling a total of 4 times, at 7 days intervals, beginning from 7 days after planting. The data were analysis followed the equation (South, 1995), as below:

$$\text{MRGR} = \frac{\ln W2 - \ln W1}{t2 - t1} \quad \text{g/day}$$

All data analysis was done with Duncan's multiple range test with significant differences at p <0.05.

2.3 Net assimilation rate (NAR)

Data for net assimilation rate were collected from total dry weight per unit area of leaf and were sampled a total of 4 times, at 7 days intervals, beginning 7 days after planting. The data collected analysis followed the (Vernon & Allison, 1963) equation, as follows;

$$\text{NAR} = \frac{W2 - W1}{t2 - t1} \, X \, \frac{\log W2 - \log W1}{A2 - A1} \quad mg/\text{cm}^2/\text{day}$$

All data analysis was done with Duncan's multiple range test with significant differences at p <0.05.

3. Results and Discussion

3.1 The effect of rice husk ash and *Brassica juncea* compost on swamp land

Addition of rice husk ash and compost of *Brassica juncea* could repair the ravaged swamp land. The vegetative growth continued to juvenile plants and during this vegetative growth the analyses of net assimilation rate and mean relative growth rate were done. The results of the treatments are shown in Figures 1, 2 and 3.

The combination of water hyacinth compost and rice husk ash gave a positive effect on the net assimilation rate and mean relative growth rate of *Brassica juncea*. The relationship between rice husk ash and water hyacinth compost on mean relative growth rate of *Brassica juncea* lwas described by a linear equation $y = 1{,}067x – 30925$ $R^2 = 0{,}9631$ *. Linear pattern interaction refers to the increasing effect of one factor, followed by the effect of another factor. In this research, the effect of increasing the rice husk ash on the mean relative growth rate was simultaneously followed by the effect of water hyacinth compost on the mean relative growth rate (Figures 1, 4).

The relationship between net assimilation rate and mean relative growth rate, under the influence of rice husk ash and water hyacinth compost was linear. That meant an increase of net assimilation rate was followed by an increase in mean relative growth as well. Based on this research, the suitable increase in doses of water hyacinth compost and rice husk ash waste had a positive effect on the net assimilation rate and mean relative growth rate. However, a high dose of water hyacinth will increase the risk to damage the farmland in the swamp land.

The research indicated that the plant was more tolerant to swamp land conditions after being treated with water hyacinth compost and and rice husk ash waste. This was only natural because swamp land was of low pH and contained less calcium and magnesium (Table 1). Rice husk ash waste contained calcium and magnesium compounds (Table 2). Calcium and magnesium are essential plant nutrients and these sources of nutrition in swamp land suppressed by excessive iron levels.

The influence of water hyacinth compost and rhizobium inoculant on soybean was examined and the results are shown in Figure 4. Water hyacinth has been known as waste (Su et al., 2018), but it is regarded as a sorce of fertilizer in this study due to its various nutrients essential for plant growth. The results in this studies indicated that the organic compost of water hyacinth made land profitable over soybean growth, because of pH increase, and the excessive iron and aluminum suppressed the availability of calcium and magnesium. Furthermore, *Rhizobium* was activated in the land microclimate around root hairs, and therefore, the land was certainly suitable for availability of nitrogen and other nutrients for soybean growth. Water hyacinth compost contains nitrogen and magnesium and other minerals that can help make up for the shortage of such elements in swamp land, and make the swamp land productive or more suitable for horticulture plants.

3.2 Interaction between mean relative growth rate and net assimilation rate

The relationship between net assimilation rate and mean relative growth rate was revealed to be an interdependent one for soybean (Figure 3). This means that an increase of net assimilation rate was followed by an increase of mean relative growth rate (Figure 4), and they were connected to each other in a linear pattern. As a result, there was an improvement in the dry matter weight and also increased yield for the plant soybean (Figure 5).

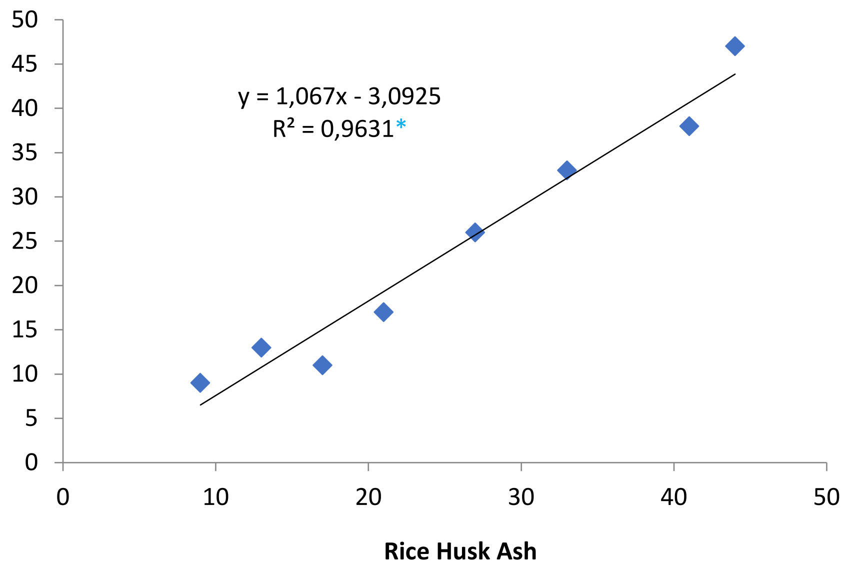

Figure 1. Mean relative growth rate x (0.01 g/day) of *Brassica juncea* after treatments with rice husk ash and compost of water hyacinth

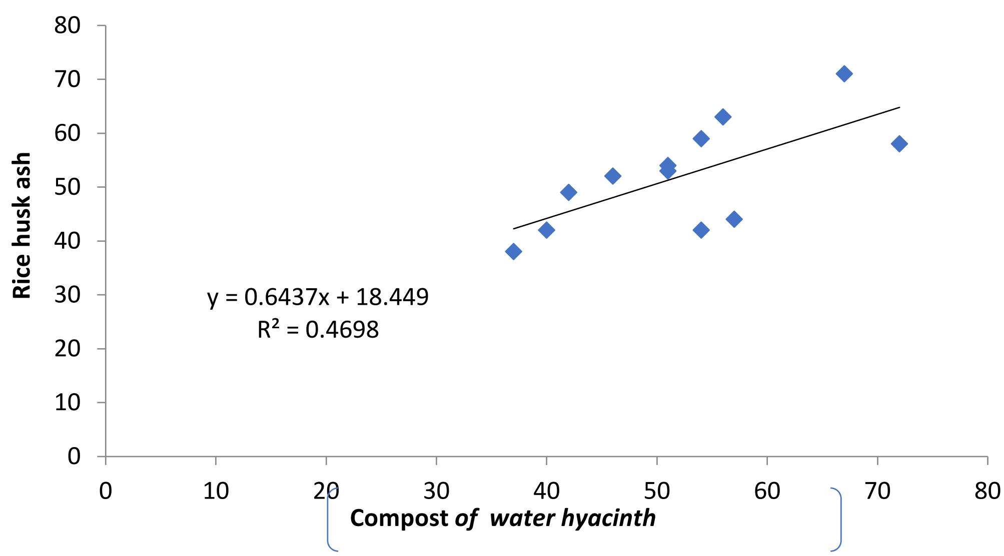

Figure 2. Net assimilation rate x (0.001 mg/cm^2/day) of *Brassica juncea* after treatments with rice husk ash and water hyacinth compost

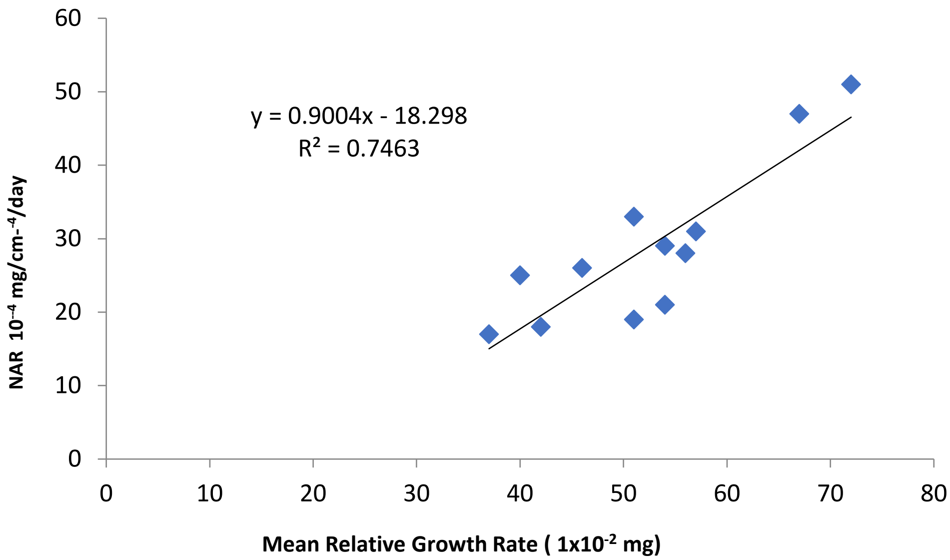

Figure 3. Relationship between net assimilation rate x (mg/cm^{-2}/day) and mean relative growth rate x (0.01g/day) of *Brassica juncea* under the influence of rice husk ash and water hyacinth compost

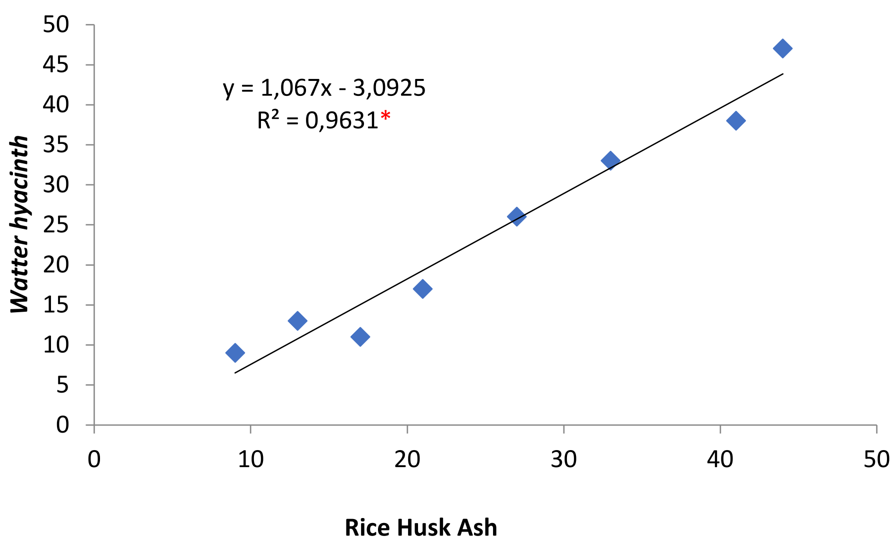

Figure 4. Mean relative growth rate x (0.001g/cm^2/day) and net assimilation rate x (0.001mg/cm$^{2.}$/day) on soybean under control of *Rhizobium* inoculant and compost of water hyacinth

Table 1. Chemical composition of water hyacinth (Sukarni, 2018)

Chemical Elements	Composition (wt%)
C	14±6.81
O	49±6.70
Na	0.58±0.40
Mg	1.96±1.04
Al	2.32±1.71
Zr	2.24±1.33
Cl	5.58±1.94
K	5.26±2.62
Ca	4.73±0.63
Si	5.33±4.52
Ti	0.27±0.24
Ti	4.71±4.32

Table 2. Rice husk ash compositions

Chemical Compounds	(Jumin, 2024)	(Costa et al., 2004)
CaO	1.85	0.77
MgO	0.45	0.53
Fe_2O_3	-	0.25
P_2O_5	0.16	1
Nitrogen	1.15	-
SiO_2	68.79	97
C/N	36	-
Los of- ignition	1.05	0.2

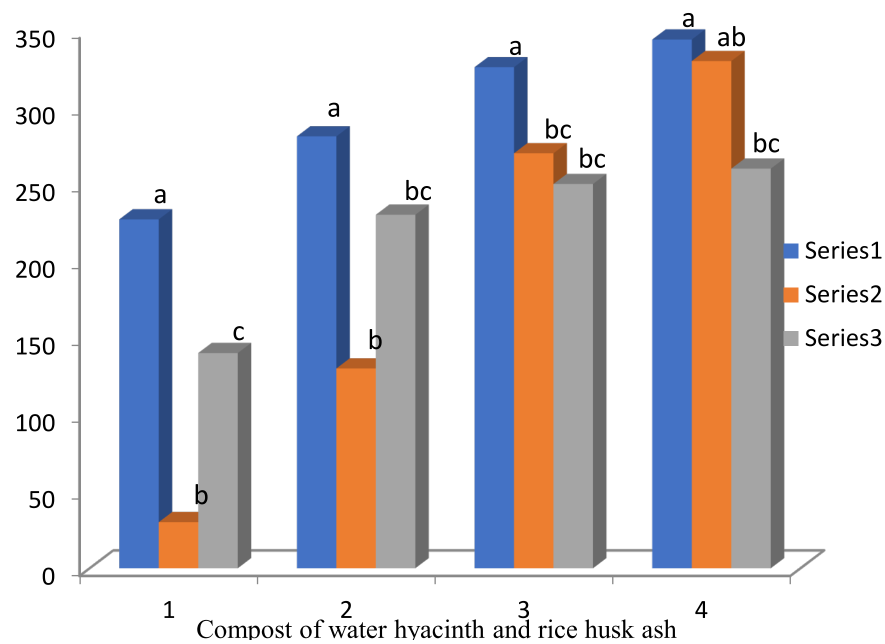

Figure 5. Relationship between net assimilation rate and mean relative growth rate of *Brassica juncea* (g/plant) after treated with water hyacinth and rice husk ash at 80 days age [series 1 is NAR x(0.01mg/cm^2/day), series 2 is dry weight (g/plant), and series 3 is MRGR x (0.01g/day)]. Mean values followed by different letters on the same series differ significantly at $P < 0.05$ by Duncan multiple range test.

The abundance accumulation of plant dry weight on net assimilation rate depends on the two factors. The first factor is the wide berth of leaves where the sunlight falls. Another factor influencing the photosynthesis activity of plants is light intensity. Both of these factors contribute to the vegetative growth of plants, and further to the net accumulation rate velocity.

Decreased leaf expansion affects the degeneration of the leaf's capacity to absorb light energy. Polluting materials in the land cause a shortage of chlorophyll in the leaves, meaning that the photosynthesis rate is also suppressed. The addition of the rice husk ash in swamp land contributed to the rise of calcium and magnesium in the soil, while at the same time suppressing the availability of plants that absorbed iron and aluminum. Chlorophyll in leaf tissues functions as a photosynthetic antenna that accumulates light onto the leaf. The light energy that falls on the leaves is used in the photolysis process, is beneficial in the conversion of light to organic compounds, and thereafter is harvested as glucose (Pezeshki, 2018).

The mean relative growth rate (South, 1995) is an indicator of plant growth over a certain time, without considering the role of leaf efficiency. Whereas the net assimilation rate is an accurate calculation of photosynthetic activity in every square cm of leaf per day. Thus, mean relative growth is a beginning and speey calculation of the growth of plant per day (Vernon & Allison, 1963; Shipley, 2006). However, it is important to analyze the plant's growth and to detect any obstructions to growth at an early time.

The organic material in water hyacinth compost can reduce excess iron and aluminum by pushing down the absorption by plants, mainly in peat and acid soil (Khamidah & Saputr, 2020). On the other hand, in swamp land, water hyacinth compost may absorb the excess iron and aluminum and make them unavailable for soybean.

Thus, the interaction between water hyacinth and rice husk ash represses the overbalance of iron and aluminum. While the calcium and magnesium in rice husk ash and in water hyacinth compost can together increase the pH of land into the normal range, further increasing plant growth.

After 80 days of rice husk ash and water hyacinth compost treatment of *Brassica juncea* (Figure 5) and soybean (Figure 6), it was apparently the interaction between rice husk ash and water hyacinth compost significantly increased the net assimilation rate, mean relative growth rate, and plant dry weight in *Brassica juncea*, and the seed dry weight of soybean, compared to no treatment.

Gage (2004) mentioned that microorganisms that grow in the soil as free-living bacteria can also live as nitrogen-fixing symbionts in the tissues of the root nodule cells of soybean. The symbiotic relationship between soybean and bacteria (rhizobium) is profitable to both individuals. The need for nitrogen can be met by rhizobium to the soybean through free nitrogen bonds in the atmosphere via nitrogen fixation process. Therefore, the inside of the root nodules of the soybean contain nitrogen, and this nitrogen is usable by the soybean. Brewin (2010) mentions that in soybean, under the support of microclimate, the rhizobium infection proceeds through the intercellular root hairs and infection threads were detected in trans-cellular channels. At the same time, cells in the root cortex are induced to divide and generate the tissues of the nodule.

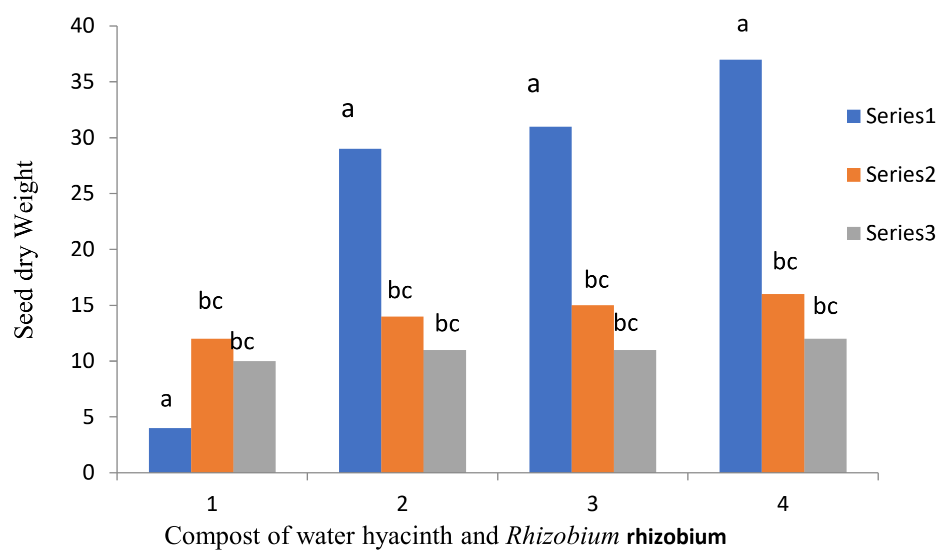

Figure 6. Relationship between seed dry weight, net assimilation rate and mean relative growth of soybean after treated with water hyacinth compost and *Rhizobium* inoculant (series 1 is seed dry weight (g/plant), series 2 is MRGR x (0.01 mg/day), series 3 is NAR x (0.003 mg/cm^2/day). Mean values followed by different letters of same series differ significantly at P < 0.05 (Duncan multiple range test).

The result pattern of net assimilation rate is always parallel to the result of mean relative growth rate because the accumulation of plant dry weight is constituted to implement photosynthetic activities. Net assimilation rate is an indicator of chlorophyll's role to absorb the sun's energy in leaves and the result of this activity is glucose. While the mean relative growth rate constitues to total accumulation of plant dry weight at any time range. Therefore, net assimilation rate and mean relative growth rate correspond to the representation of photosynthesis activity.

Under healthy conditions, the leaves fully react to absorb solar energy and collectively synthesize glucose. When the leaves are affected by a disease or a leaf infestation, the leaves are abnormal, and photosynthesis activity is lacking. As a result, the process of conversion of solar energy is insufficient, resulting in low net assimilation rate, while mean relative growth may be still higher, and thus the correlation between net assimilation rate and mean relative growth rate is not linear.

The important reason for the linear relationship between net assimilation rate and mean relative growth rate is that the soil should promote the healthy raising of plants. This means that the addition of water hyacinth compost and rice husk ash resulted in soil that promoted growth and supported an accumulation of plant dry weight.

4. Conclusions

The interactive treatment of water hyacinth compost and rice husk ash produced significant differences in the net assimilation rate and mean relative growth rate of *Brassica juncea* in swamp land. Second, the interaction between rhizobium inoculant and water hyacinth compost also produced significant differences in net assimilation rate and mean relative growth rate. This study provides the idea that although water hyacinth has become a pollutant and has disrupted various water bodies, it can also be seen as a beneficial source of organic nutrients. Similarly, rice husk ash can act as garbage and damage farmland, but it can also be used as organic fertilizer.

In healthy plants or plants not affected by diseases or pests, the relationship between net assimilation rate and mean relative growth rate is always linear. When the leaves become infected with bacteria or fungi, the net assimilation rate tends to decline but the mean relative growth rate may remain satisfactory. At such times, the relationshp between net assimilation rate and mean relative growth rate is no longer linear. Therefore net assimilation rate and mean relative growth rate can be used as physiological indicators, particularly in swamp land.

5. Acknowledgements

We wish to thank the Rector Islamic University of Riau for financial support for this research and publication. Special thanks to Director of Post Graduate Studies in Agronomy Department for assistance with the administrative affairs.

6. Conflicts of Interest

The authors declare no conflicts of interest.

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