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The effect of water hyacinth (*Eichhornia crassipes*) organic fertilizer on the vegetative growth of Manado strain yellow maize (*Zea mays* L.)

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Abstract

Introduction: The invasion of water hyacinth (*Eichhornia crassipes*), a freshwater weed, has been an unsolved problem in many lakes around the world, including in Tondano lake, Indonesia. Since the 2000s, many efforts to eliminate it have turned unsuccessful and uneconomical. Here, we aim to provide a solution and perform a systematic study to utilize water hyacinth as an organic fertilizer for application to local crops, the Manado strain yellow maize.

Methods: Water hyacinth was manually harvested and fermented using an effective microbial fermentation for one month. The resulting compost was analyzed chemically and applied to bedding groups of maize at increasing doses: 0, 100, 150, 200, and 250 grams per plant. All beddings were made in triplicate, consisting of 8-10 plants per repeat. At 2 and 12 weeks post plantation, a series of measurements of plant height, leaf length, and leaf width was performed. Data were analyzed using one- or two-way ANOVA.

Results: The application of water hyacinth organic fertilizer had readily shown beneficial effects on vegetative growth at 2 weeks of age in terms of plant height, leaves length and leaves width at the dose of 200 and 250 grams of fertilizer per plant. This effect persisted up to 12 weeks of age in terms of plant height, but not in leaves length or width.

Conclusion: The application of water hyacinth organic fertilizer is able to increase the vegetative growth of the local Manado strain of yellow maize at the dose of 200 grams per plant.

Keywords: Water Hyacinth; Organic Fertilizer; Maize; Manado; Tondano Lake

1. Introduction

Water hyacinth (*Eichhornia crassipes*) belongs to the family *Pontedericeae* which grows in freshwater as well as in mud [1,2]. It is a free-floating macrophyte but can set its roots in the mud at the base of the water reservoir. Water hyacinth has been regarded as a dangerous aquatic weed worldwide due to its negative impact on people's lives, especially on those who depend on freshwater fisheries and transportation. Many efforts have been put to control or eliminate water hyacinth through mechanical, chemical, and biological methods. Unfortunately, these efforts were not very successful [3,4]. Another attempt to overcome the problem of water hyacinth invasion is by utilizing it as a resource, rather than a liability. One of these approaches is by considering water hyacinth as a valuable source of macro-nutrients such as phosphorus, nitrogen, and potassium, which can be used as a soil fertilizer due to their importance for plant nutrition [5]. In Tondano Lake, Indonesia, the invasion of water hyacinth has been causing an economic and societal burden to the villagers around the lake. The accumulation of water hyacinth began around the year 2000, and its growth has been

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rapidly expanding ever since [6]. The local authorities have launched several rounds of large-scale mechanical elimination efforts, but similar to other places worldwide, with small and non-sustained success [6].

Tondano Lake is situated on the northern peninsula of Sulawesi Island, Indonesia, where most of its habitants work as farmers. Around the lake, there lie abundant crop fields (maize, potatoes), rice fields, and others. Maize (*Zea mays*) is an important food in Indonesia, forming the major component of daily meals. It is also important for cattle food, as well as for human recreational consumption. Maize requires a high amount of macronutrients compared to other cereals, where it needs 100 to 150 kg/ha of N, 40 to 60 kg/ha of phosphoric acid, and 100 to 150 kg/ha of potassium during the vegetative growth period [7]. Around Tondano Lake, most of the farmers planted a local strain of maize called Manado yellow maize, which has not well been characterized [8].

Because of the abundance of water hyacinth in Tondano Lake and its potential application to the crop soul in the vicinity, we asked if water hyacinth can be converted to organic fertilizers that can suit and fulfill the needs of the surrounding crop plantation around Tondano Lake. Similar attempts have been reported previously in Indonesia [9–11] and worldwide [5] with promising results. Water hyacinth rejects were mechanically chopped, fermented, analyzed chemically, and applied to maize plants. We tested several doses and analyzed its effect on the vegetative growth of a local variant of maize, Manado strain yellow maize (jagung lokal Manado kuning).

2. Material and methods

2.1. Sample collection and compost production

Fresh whole-body of water hyacinth was harvested from the nearby collection site in Tondano lake manually, sun-dried, and chopped into small pieces about 3-5 cm. The composting took place inside a plastic chamber using effective microorganism solution (EM4) and sucrose. After 30 days, the compost was examined for gross texture, analyzed chemically, and used for application [12].

2.2. Research design

This research applied a randomized complete block design to minimize variation due to the soil intrinsic variation. At the field, plant beds of 1x2 m^2 were prepared for each block. Three beddings repeats consisting of 8-10 plants were assigned with 100, 150, 200, and 250 gram compost application per plant (P1, P2, P3, and P4, respectively) and compared to a control group with no fertilizer (P0). Compost was applied before the seeds were planted and 3 weeks afterward. Each plant hole contained 1 seed. An interrow spacing of 0.75 m and intra-row spacing of 0.25 m were used.

2.3. Parameter reading and statistical calculations

We observed three vegetative growth indicators: plant height, leaf length, and leaf width as previously described (9). Data were analyzed using Microsoft Excel and Graphpad Prism. One- or two-way ANOVA was applied as appropriate, followed by post-hoc Tukey's or Dunnett's test, where the significance level was set to 0.05.

3. Results

The application of water hyacinth organic fertilizer (WHOF) had readily shown beneficial effects on the vegetative growth at 2 weeks of age (Figure 1) in terms of plant height ($F(4, 10) = 3192$, $p<0.0001$), leaves length ($F(4, 10) = 9.616$; $p=0.0019$), and leaves width ($F(4, 10) = 9.616$, $p=0.0019$). A post-hoc analysis revealed that the addition of 200 and 250 grams WHOF per plant (treatment P3 and P4, respectively), increased the plant height, leaves length, and leaves width significantly compared to no treatment (P0) or lower doses (P1, 100 gram per pant; P2, 150 gram per plant) (Figure 1). The positive effect of P3 and P4 persisted up to 12 weeks of age in terms of plant height ($F(4, 10) = 165.2$, $p<0.0001$), but not in leaves length ($F(4, 10) = 2.773$, $p=0.0869$) and width ($F(4, 10) = 0.006903$, $p=0.9999$) (Figure 2).

To summarize the vegetative growth from 2 to 12 weeks of the treatment groups, a growth curve of the plant height is displayed in Figure 3. Statistical calculation with two-way ANOVA revealed a significant effect of treatments ($F(4, 60) = 77.45$, $p<0.0001$) and age ($F(5, 60) = 438.8$, $p<0.0001$) on the plant height, with $p<0.005$ in P3 and P4 vs. P0 across all age time points as revealed by Dunnett's multiple comparison test.

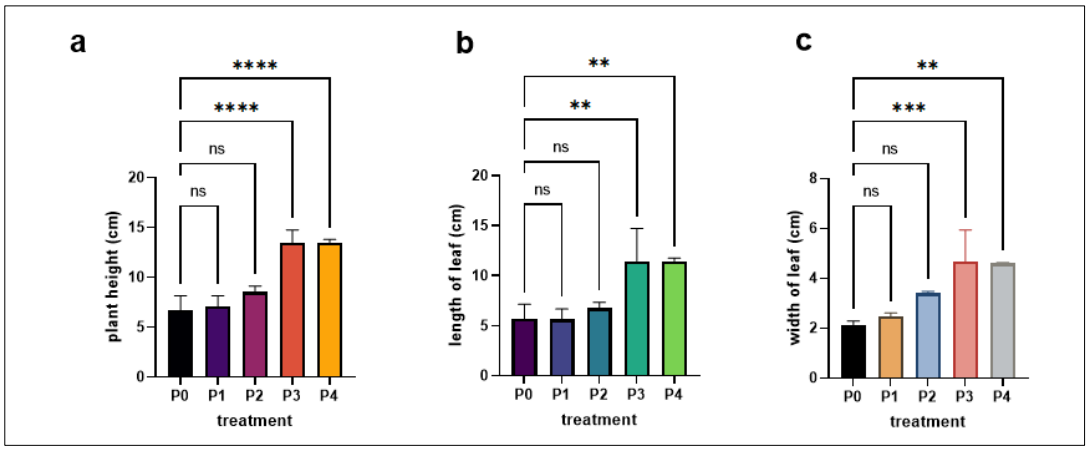

Figure 1 The effect of WHOF on maize vegetative growth at 2 weeks of age. (a) plant height, (b) leaves length, (c) leaves width. ns: non-significant; ** p<0.01; *** p<0.005; **** p<0.001 by one-way ANOVA and post-hoc Tukey's test, n=3 groups. Error bars are SDs

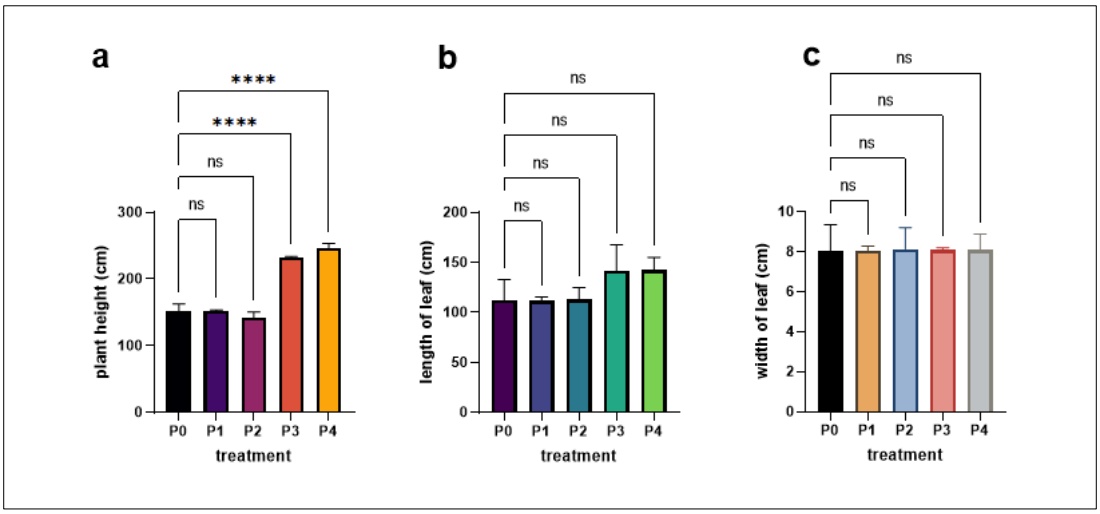

Figure 2 The effect of WHOF on maize vegetative growth at 12 weeks of age. (a) plant height, (b) leaves length, (c) leaves width. ns: non-significant; ** p<0.01; *** p<0.005; **** p<0.001 by one-way ANOVA and post-hoc Tukey's test, n=3 groups. Error bars are SDs

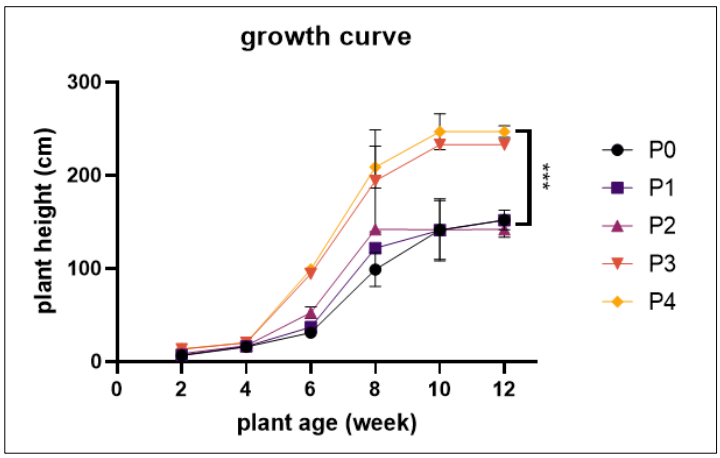

Figure 3 Growth curve across age and treatment groups, showing a positive and significant effect of P3 and P4 on the plant height. *** p<0.005 by two-way ANOVA followed by Dunnett's multiple comparison test. n=3 repeats. Error bars are SDs

4. Discussions

Water hyacinth is an invasive fresh water weed and has caused worldwide problem, such as in India [13], Mexico [14], and South Africa [15]. To overcome this, water hyacinth can be eliminated using mechanical extraction as well as biological and chemical control. Alternatively, water hyacinth can be utilized as a raw material for secondary products such as handicraft, fiber, and fertilizer [5,16].

Water hyacinth-based organic fertilizer (WHOF) contains abundant organic materials (78%), mainly carbon (21%), nitrogen (0.28%), phosphor (0.001%) and potassium (0.016%) [17]. These values may vary based on the origin/location of growth as well as the technics used to produce the organic fertilizer. Omondi, et al in Kenya found C=15%, N=1.6%, P=0.05%, and K=0.1% [18], while in this current research, we found that N=0.98%, P=0.22%, and K=0.17% (primary data). Regardless of the variation, all previous research found that carbon and nitrogen are the two most abundant organic materials available in WHOF.

Since nitrogen is a critical substance for chlorophyll production, protein synthesis, and vegetative growth [19], the positive effects of WHOF on maize vegetative growth as shown by us and others is expected. Interestingly, this positive effect is preserved across maize variants in Indonesia [11], onto which this current research has added a new variant (Manado strain yellow maize). Thus, WHOF can be an alternative solution to overcome the water hyacinth invasion by converting them into organic fertilizers. However, it seems that WHOF is mostly beneficial during the vegetative stage, while the production stage is less affected [20]. Apzani, et al [21] observed a positive effect of WHOF on the vegetative growth of salad (*Lactuca sativa*) , which is also equivalent to its production because salads were cultivated for harvesting their leaves.

When determining the optimum dose for characterizing the effect of an organic fertilizer, it is critical to perform a dose titration. In this current experiment, the dose of 200 and and 250 gram per plant have yielded a similar, positive effects on maize vegetative growth, while other lower doses (100 and 150 gram per plant) have not. Interestingly, there is no further increase of the plant height when given 250 gram of WHOF compared to 200 gram (Figure 4), indicating that 200 gram is the optimum dose for our preparation of WHOF. Further increase of the fertilizer dose may be not only unnecessary, but also detrimental for the plant growth and the soil composition.

5. Conclusion

In conclusion, we have reported a positive effect of water hyacinth organic fertilizer application on the vegetative growth of a local strain of maize (Manado strain yellow maize). An optimum dose, based on our preparations, was reached at 200 gram per plant. This approach can serve as a solution for the invasion problem of water hyacinth, while providing a local-resourced organic fertilizer for the surrounding farms in Lake Tondano, Indonesia, as well as worldwide.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared no conflict of interest.

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