

Growth of celery (*Apium graveolens* L.) in the red-yellow podzolic soils as inoculated by earthworms *Pontoscolex corethrurus*

Pertumbuhan tanaman seledri (*Apium graveolens* L.) pada tanah podsolik merah-kuning yang diinokulasi cacing tanah *Pontoscolex corethrurus*

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ABSTRACT

In this study, the inoculation effect of earthworms *Pontoscolex corethrurus* on celery growth (*Apium graveolens* L.) has been carried out in red-yellow podzolic (RYP) soils. The research studied in a pot experiment using a completely randomized design (CRD) with 6 (six) treatments and 3 (three) replications. One-pot consists of 4 (four) plants. The treatments carried out were as follows: I_0 (without inoculum of earthworm), I_1 (inoculum of 5 earthworms pot^{-1}), I_2 (inoculum of 10 earthworms pot^{-1}), I_3 (inoculum of 15 earthworms pot^{-1}), I_4 (inoculum of 20 earthworms pot^{-1}) and I_5 (inoculum of 25 earthworms pot^{-1}). Observation parameters were the number of tillers clumps^{-1} , fresh biomass clumps^{-1} (g clump^{-1}), and root volume (mL). The observations were statistically analyzed using variance (one-way ANOVA) and followed by the Duncan Multiple Range Test (DMRT) with a level of 5%. Treatment I_5 gave the best results on celery crop in all parameters, i.e., 20.33 tillers per hill; fresh biomass per clump 113.93 g; and a root volume of 10 mL. The results showed that earthworms' inoculation into RYP soils significantly affected all parameters. There was also an increase in pH in each treatment that was inoculated with earthworms.

INTRODUCTION

In the culinary world, celery is a ubiquitous ingredient and used as a popular vegetable. Celery (*Apium graveolens* L.), a plant from the Apiaceae family, is known by the public as a spice or flavor enhancer for food. With a slightly spicy taste and distinctive aroma, celery is widely used in seasoning various food products (Sowbhagya, 2014). In Indonesia, celery is added for more flavors to traditional foods like *bakso*, *soto*, and soup in several cities.

Traditional medicine also utilized celery for ailments *viz.* fever, asthma, and high blood pressure (Kooti & Daraei, 2017; Malhotra, 2006). The presence of compounds such as limonene, selinene, furanocoumarin, glycosides, flavonoids, vitamins A, and C is why celery is also used as a medicinal plant (Malhotra, 2006). The previous study reports that celery can be used as a medicinal plant in fighting against SARS-CoV-2 (Rupasinghe, 2020; Shawky et al., 2020; Thakur

et al., 2020). It makes celery will be a significant prospect for cultivated.

Fertile soil with a good nutrient content is one of the determining factors for celery crops. Besides, loose soil and pH 5.5 - 6.7 are the conditions for the success of celery cultivation (Malhotra, 2006; Sumpena & Permana, 2020). The soil in Riau, Indonesia, is dominated by ultisol soils in the form of red-yellow podzolic (RYP) soils (Anggraini et al., 2019; Foller & Silvina, 2017), which has unsuitable physical, chemical, and biological properties for celery cultivation.

RYP soil has a compacted structure, poor porosity, low pH, low microorganisms, and poor nutrient content of N, P, and alkalis (Ca, Mg, K, Na). Also, RYP soil contains high Al, which is toxic to plants and will fixate essential soil elements such as phosphorus (P) (Sri & Karnilawati, 2018). To overcome the problem of RYP soil, many researchers treat RYP soil or

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other marginal soils so that it can be used in celery cultivation, such as adding alkaline fertilizer (Wu et al., 2019), organic fertilizers (Duaja, 2019), and even cultivated without the

soil, just by using growing media (Adawiyah & Afa, 2018). It is assumed that the inoculation of earthworms in RYP soil can also improve the soil properties to provide nutrients for a celery crop.

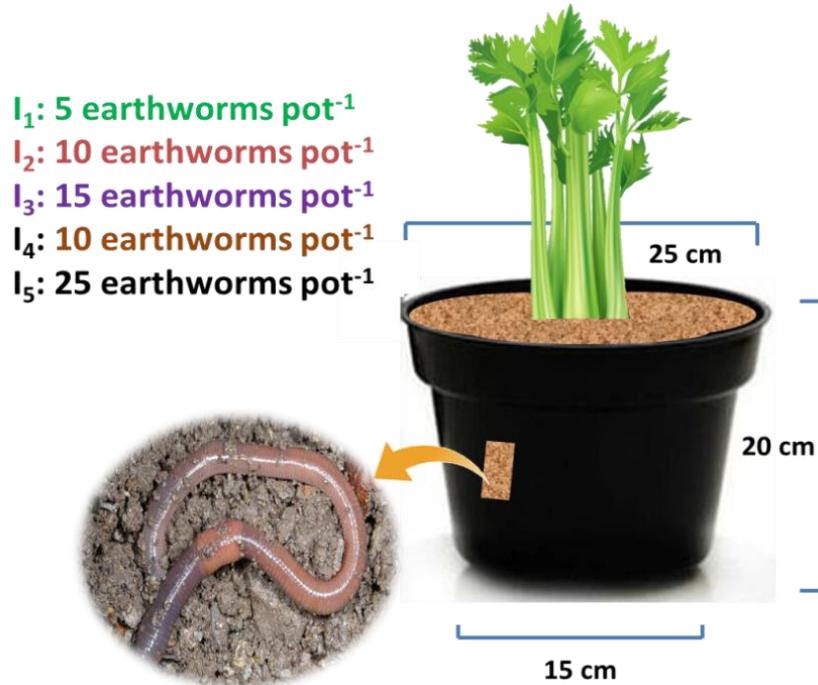


Figure 1. An illustration of the pot experiment in this study; I_0 as a control (without earthworm)

Earthworms are soil macrofauna that has a vital role in the soil ecosystem. Earthworms' existence is an indicator of soil fertility because, through their activities, earthworms can improve soil properties physically and chemically (Vidal et al., 2019; Wu et al., 2020). Physically, earthworms can improve soil texture and aeration, while chemically, through their digestive mechanism, remove dirt in the soil to increase the soil's availability (Sharma et al., 2017).

P. corethrurus, an earthworm species, is commonly found in agricultural lands, which has wide adaptability and tolerance of various environmental conditions (Lv et al., 2016, 2020). Some of the plants reported to have shown significant results due to the inoculation of earthworms are pak choi (Lidar & Surtinah, 2020), common bean (Barbosa et al., 2017), cabbage (Nurhidayati et al., 2016), and strawberries (Infante et al., 2018). So, based on the literature review so far, no study has been accomplished regarding the effect of earthworm inoculation in RYP soils for celery production. Therefore, the experiment was designed to find out the effect of earthworm inoculation in RYP soil on celery production.

MATERIALS AND METHODS

Materials

The variety of celery seed was Amigo. For earthworms, the species was *P. corethrurus* FR. Mull. *Baglog* (waste from oyster mushroom media) was utilized as a mixing material for RYP soils. The food source for earthworms used chicken manure during the preparation phase. Garlic extract was applied as natural pesticides. This study was performed with the pot experiment; gauze covered each hole at the bottom.

Field site description

The research was conducted at the experimental garden at the Faculty of Agriculture, Universitas Lancang Kuning Pekanbaru, Indonesia (0.5779567, 101.4250067) with an altitude of 16 masl. The type of soil was RYP soils, taken from the top (0-20 cm) with a pH measurement of 4.5 measured using Soil Tester DM-13.

Soil samples and *baglog* wastes were air-dried and sieved through a 2 mm sieve as followed previous study (Purnama et al., 2015). The highest average temperature was 33 °C, and

the lowest average temperature was 23 °C. Meanwhile, the rainfall was around 2000 mm.

Earthworm preparation

Earthworms were obtained from the experimental garden and reared in a bucket with soil. The bucket was protected from direct sunlight and rain. Earthworms were nurtured for about three months by keeping the soil moist and feeding with the chicken manure (dried and finely ground). Earthworms *P. corethrurus* were selected uniformly, i.e., the adults were

characterized by the presence of clitellum, length (0.6 – 0.7 cm), and weight (0.58 – 0.68 g).

Experimental design

The research was conducted by a pot experiment (as shown in Figure 1) using a completely randomized design (CRD) with 6 (six) treatments and 3 (three) replications. In total, there were 18 experimental pots. The experimental pots were prepared as follows: I_0 (without earthworm), I_1 (5 earthworms pot^{-1}), I_2 (10 earthworms pot^{-1}), I_3 (15 earthworms pot^{-1}), I_4 (10 earthworms pot^{-1}), and I_5 (25 earthworms pot^{-1}).

Table 1. Effect of earthworm inoculation on the number tillers $clump^{-1}$, fresh biomass ($g clump^{-1}$), and root volume (mL) in a factorial pot experiment

Treatments (earthworms pot^{-1})	Number (tillers $clump^{-1}$)	Fresh biomass ($g clump^{-1}$)	Root volume (ml)
$I_0 = 0$	12.00 c	47.10 c	4.16 c
$I_1 = 5$	14.50 c	55.91 c	5.00 c
$I_2 = 10$	15.66 c	57.43 c	6.50 c
$I_3 = 15$	15.83 c	79.78 c	7.50 c
$I_4 = 20$	17.33 b	88.26 b	8.30 b
$I_5 = 25$	20.33 a	113.93 a	10.00 a

Numbers followed by the same letter were not significantly different based on the Duncan Test $p < 0.05$

The growing media (4 kg pot^{-1}) was a mixture of RYP soil and *baglog* waste (5:1), incubated for a week to ensure a perfect mixing of the RYP soil and *baglog* before use in the pot experiment. The holes in the bottom of the pot had previously been covered by gauze. Then each pot was inoculated with earthworms according to the design.

Planting was completed two weeks after earthworm inoculation. The seeds were selected based on the seedling time (three weeks old after seedling), healthy, and the number of leaves (five pieces). Furthermore, watering was achieved until moist.

Every day the pots were watered with the same volume of water. Watering was stopped during the rains. Weed control was performed manually, while pests and diseases were controlled using natural pesticide prepared from garlic. NPK fertilizer (16:16:16) was applied at a dose of 2 g $plant^{-1}$ when the plants were 15 days old. Celery harvesting was carried out after three months of rearing when they produced tillers.

Parameters & statistical analysis

During the study, the parameters observed were the number of tillers $clump^{-1}$, fresh biomass $clump^{-1}$ ($g clump^{-1}$), root volume (mL), and the earthworm population and soil pH of RYP at the end of the experiment.

The one-way ANOVA test was used for data analysis and followed by the DMCT test with a 5% level using Microsoft Excel 2010.

RESULTS AND DISCUSSIONS

The growing media with a mixture of 5 parts RYP soils and 1 part *baglog* waste was an effort to add nutrients in the RYP soil uniformly. *Baglog* is another term for oyster mushroom growing media. *Baglog* waste can no longer be used because it contains an exceptionally high amount of calcium (Ca); due to the addition of lime ($CaCO_3$) during the *baglog*-making process (Fitri et al., 2019). On the other hand, chicken manure fertilizer was mainly used for breeding earthworms in preparation (Ngosong et al., 2020; Vodounou et al., 2016).

In this study, to control pests and diseases, natural pesticides were prepared from garlic. As is known, garlic containing active ingredients such as saponins, polyphenol flavonoids, and essential oils to control pests and diseases celery (Khairan et al., 2019). Malhotra (2006) revealed that insects pose comparatively less of a celery crop problem than do diseases. The primary disease of celery is early blight (*Cercospora apii*). Khairan et al. (2019) and Pande et al. (2017) have studied the fungicidal activity of garlic extract on *Cercospora apii*. The natural pesticide from garlic was prepared by following a previous study

(Pande et al., 2017). Meanwhile, gauze was intended to cover the hole at the bottom of the plastic pot to prevent the entry of new earthworms from outside and also to prevent water stagnation in the pot.

Based on Table 1, it is clear that the inoculation of earthworms to RYP soil significantly affected all the parameters, including the number of tillers clump^{-1} , fresh biomass clump^{-1} and root volume. The number of tillers clump^{-1} increased with the increase in numbers of inoculated earthworms. Treatment I_0 , I_1 , I_2 , and treatment I_3 showed significant difference with treatment I_4 and I_5 . The highest number of tillers clump^{-1} was found in treatment I_5 (20.33 tillers clump^{-1}), while the lowest was found in treatment I_0 , which was 12.00 tillers clump^{-1} . Fresh biomass clump^{-1} (g) also showed a significant increase with the addition of earthworms. The increase in the number of earthworms inoculated into RYP soils also caused an increase in the root volume.

The observations on celery crops without earthworm inoculation showed the lowest performance in all experimental parameters. It is perhaps due to RYP soils' properties like compact structure, low pH, and less nutrient available for celery crops. Also, low base cations and base saturation are responsible for making nutrient-poor soil, resulting in an inadequate celery yield. A study conducted by Wu et al. (2019) revealed celery crops in acidic soil, when added calcium cyanamide fertilizer (an alkaline), showed a highly significant increase in production. Meanwhile, when acidic soils only used urea, no significant effect in production was observed.

Celery crops that were inoculated with the earthworm had a significant effect on all the experimental parameters. With the inoculation of earthworms to RYP soil, the soil structure improves (Sharma et al., 2017). As a result, the water retention capacity and soil aeration also increase (Barbosa et al., 2017), which causes a better environment for organisms' lives in the soil. These organisms decompose organic matters in the soil smoothly and provide nutrients that are readily absorbed by celery crops.

Earthworms are one of the invertebrates in the soil which are decomposers and can increase soil fertility. The type of earthworm inoculated in this study is *P. corethrurus*, a type of worm beneficial to the soil and is widely found. Earthworms' role in increasing soil fertility through their activities, i.e., earthworm activity through movement in the soil, will increase soil porosity, so aeration and drainage conditions can be better. It will improve root performance in the soil, thereby increasing growth and production. Making burrows in the soil is not only to support

the movement of earthworms and avoid environmental stress but also to store and digest food. After digestion, the remains of the ingested material are released back as solid waste (casting).

Worm casting, or better known as vermicast, contains beneficial microorganisms and nutrient elements that can be absorbed directly by plants so that the results could be seen in the experimental parameters. In line with studies conducted by Sinha (2011) and Vidal et al. (2019), casting can be an organic fertilizer that is proven to increase soil fertility, crop yields, soil microbial population, and reduce plant disease. Furthermore, Aladesida et al. (2014) stated that the soil with a high density of earthworm populations would be fertile because casting mixed with the soil are fertilizers: rich in organic nitrate, phosphate, and potassium, which make it plants easy to accept fertilizers given to the soil.

Overall, it can be seen that the highest results are found in treatment I_5 . It is thought that the more the number of earthworms that are inoculated, the soil becomes looser and fertile, so the growth and yield of celery crops will be more significant. Also, to the activity and nutrient content that is readily absorbed by plants, earthworm manure contains plant growth substances that can accelerate the absorption of nutrients for celery so that the measurement results of the experimental parameters are even more refined.

Tabel 2. Number of cocoons and juveniles produced by *P. corethrurus* at the end of the experiment (n=3)

Treatments	Total cocoons (grain $^{-1}$)	Total juvenile (tail $^{-1}$)
I_0	0.0	0.0
I_1	2.7	3.7
I_2	3.0	4.0
I_3	3.3	4.7
I_4	3.7	5.7
I_5	4.0	6.0

Based on observations of the earthworm population at the end of the experiment (see Table 2), it was founded cocoons and juveniles. It is assumed that earthworms are incredibly tolerant in RYP soil, even in acidic conditions with high exchangeable-Al content. Due to tolerance with various conditions, earthworms are also used in reducing waste or heavy metals in the environment (Bongoua-Devisme et al., 2019; Sanchez-Hernandez et al., 2019).

Table 2 shows that the number of cocoons and juveniles from earthworms will increase in

line with the number of adult earthworms in the pot. However, the more earthworms inoculated into the soil, the increase in the number of juveniles and cocoons was insignificant. It was presumably due to the more inoculated earthworms had a limited space to move, so their reproduction was not as smooth as the number of earthworms was relatively less (Barbosa et al., 2017).

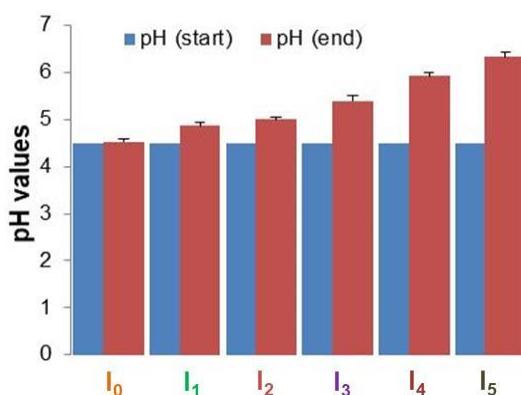


Figure 2. Soil pH influenced by earthworm in different treatments (I₀: control soil/without earthworm; I₁: 5 earthworms inoculation pot⁻¹; I₂: 10 earthworms inoculation pot⁻¹; I₃: 15 earthworms inoculation pot⁻¹; I₄: 10 earthworms inoculation pot⁻¹; and I₅: 25 earthworms inoculation pot⁻¹).

The proliferation of earthworms in treated RYP soils also increased RYP soils' pH, as seen in Figure 2. The same phenomenon also occurred in previous studies (Wu et al., 2020), the strong ability of the earthworm in reducing soil acidification due to the presence of calciferous glands (Ayten Karaca, 2011; García-Montero et al., 2013) and skin mucous secretions, including urine, NH⁴⁺, and exchangeable Ca²⁺, Mg²⁺, K⁺ (Sizmur & Hodson, 2009). The ability of earthworms to increase pH is thought to have modified the exchangeable Al fraction in the RYP soil to reduce the bio-toxicity of exchangeable Al. It is in line with a study conducted by Wu et al. (2020), increased pH of acidic soil due to inoculation of earthworms impacts reducing exchangeable Al by up to 61.7%.

CONCLUSIONS

Inoculation of earthworm *P. corethrurus* significantly increased the total number of tillers, fresh biomass, and the celery crop's root volume in RYP soils compared with the control that absence of earthworms. Treatment I₅ gave the best results on the celery crop. Treatment I₅ gave the best results on celery crop in all parameters, i.e., 20.33 tillers per hill; fresh biomass per clump 113.93 g; and a root volume of 10 mL. This research shows that RYP can also be used as a

growing media when earthworms are inoculated apart from fertilizers. This study also reveals that earthworms can improve the properties and structure of the soil. Further research is needed to analyze the soil's physical and chemical properties at the beginning and the end of the experiment.

DECLARATION

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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