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Organic fertilizer: How it can support the growth and development of *Picrasmajavanica* Blume under drought

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Abstract:
Background*: Picrasmajavanica can be categorized as a medicinal plant due to its chemical components. This study was performed to analyze the effect of fertilizer to P.javanica Bl. in order to improve the yield of this plant grown under drought stress conditions. Drought is a major environmental constraint for agriculture that affects the growth and development of plants.*
Materials and Methods*: The research was arranged in a completely randomized design with two factor treatments, drought stress and organic fertilizers. The drought stress treatment was comprised in the four levels of watering period, i.e watering every day, 4 days, and 7 days. The organic fertilizer treatments consisted of three type of growth medium, i.e soil only without organic fertilizer (control), a mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ (v/v/v), and a mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ (v/v/v). The observation was performed on 24-weeks P.javanica plants.*
Results*: The watering period treatments affected the water potential status of the growth medium. The lowest water potential of the growth medium was generated by the treatment of watering period in every 7 days. Compost and animal manure supplied on the growth medium of P.javanica (M2 and M3) decreased the negative level of soil water potential during water deficit conditions. The negative effect of drought towards RWC of P.javanica leaves was reduced by the application of compost and animal manure on the growth medium. Furthermore, compost and animal manure presented the positive effects on the parameters of vegetative growth, such as plant height, biomass, leaves number, and leave weight ratio.*
Key Word*:animal manure, compost, drought stress, P.javanica, vegetativegrowth.*

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I. Introduction

Improved soil fertility is a pre-requisite requirement for increasing plant productivity. The synergy of soil fertility and the availability of plant nutrients supported by fertilizers is necessary to achieve global green growth and sustainable development. The reduction of soil organic matter content due to cultivation and erosion are being the major concerns related to agricultural sustainability1. Therefore, the management of soil nutrients becomes one of the most important things to maintain the soil health2. Nowadays, the trend of using the organic fertilizers in agricultural intensification increases significantly regarding to unexpected effects of chemical fertilizers in the continuous long-term use and an increase in demand for organic agriculture yield3. In general, the application of fertilizer in agricultural land has been used for the main purpose, such as to provide high level nutrition for plants, to maintain optimum soil fertility, and to improve crop quality4.

Picrasmajavanica Blume is a species of flowering plant which is being a member of Simaroubaceae family. Almost all parts of P.javanica has a bitter taste due to its quassinoid derivative and glycosides compounds5,6. In several part of Indonesia, this plant has local names which meanings refer to the bitter wood, such as ´kayupaik` in Bukittinggi West Sumatera and ´kayupahit` or ´kipahit` in Java. Many studies showed that P.javanicaBl can be used for medicines, such as for antimalarial, anticancer, antidysentery, antibacterial, and insecticides7,8.

Regarding to plant growth conditions, water stress is a term used to describe the lack of sufficient water resources to meet water needs by the plant. It occurs when the available of soil water is reduced, thereby limiting the water supply to the roots, or when the transpiration rate becomes intense9. Nowadays, water stress is being a major environmental stress affecting the plant growth in agricultural field10,11. The reduction of water intake by the plant during water deficit leads to the reduction of the plant yield and productivity as its effect during plant´s life cycle, such as in the vegetative phase, the reproductive phase, and the end of plant cycle phase12. Many reports stated that the effect of fertilizers can improve the plant growth under water stress. Fertilizers have the positive effect to the quality and yield of sunflower under water stress13. Organic fertilizer also has a significant effect on yield of Cuminumcyminum L. as an economical medicinal plant14. Meanwhile, compost as one of organic fertilizers has been reported to increase the growth of Bruceajavanica under drought15.

Plants developed a wide range of adaptation mechanisms in the morphological, physiological, cellular, and molecular levels during stress conditions16,17. Under water deficit, decreasing cell growth is considered as one of the most effects caused by water deficit in plants18. Water shortage can inhibit the cell enlargement by suppressing cell expansion and cell growth due to a low turgor pressure during water deficit19. Therefore, the reduction in turgor pressure caused by reduced water potential will induce the interruption of the water flow from the xylem to the surrounding of elongating cells. However, the maintenance of turgor pressure above a particular threshold seems to be essential for plant to continuous growth under water stress20.

Due to its high benefit as a medicinal plant, P.javanica Bl. is much exploited. Currently, the existence of this plant is also rarely found in nature21. Therefore, the cultivation aspects of this plant certainly need to get serious attention. This research was conducted to study the effect of organic fertilizer to P.javanica Bl. in order to improve the yield of this plant grown under water stress conditions. The value of this medicinal plant supported by its ability to adapt under water deficit conditions, make P.javanica Bl. plant as a suitable plant grown in dry lands.

II. Material And Methods

Plant materials and treatments

Seeds of *P.javanica*.used in this study are the germplasm collection of Division of Botany, Research Center for Biology, Indonesian Institute of Sciences (LIPI). The mature seeds were germinated for 2 weeks in the germination chamber. Afterwards, the seedlings were transferred in the pot-based system and acclimatized in the green house with temperature 30^0 C ± 5^0 C, relative humidity 60% ± 20%, and the natural photoperiod.

This experiment in this study was arranged in a completely randomized design with two factors treatments, namely drought stress and organic fertilizers, with four replications in each factor combination. The water deficit treatments were performed by dehydration cycle and comprised of three levels of the watering period, i.e., W1 = watering every day as a control treatment, W2 = watering every 4 days, and W3 = watering every 7 days. The watering treatment was given to the growth media until it reached the field capacity of pot-based system. The fertilizer treatments consist of three types of fertilizer on growth medium, namely M1 = soil without organic fertilizer application (Control), M2 = a mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ (v/v/v), and M3 = a mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ (v/v/v). Each treatment was represented by a single plant in every pot-based system. The physico-chemical characters of growth medium used in this study are presented in Table 1.

Table 1. Physico-chemical parameters governing the growth medium of *P.javanica*

Parameters	M1	M2	M3
Cation Exchange Capacity (cmol/100g)	8.02	9.125	11.90
C organic (%)	7.87	8.27	9.33
Total K (cmol/100g)	0.48	0.73	0.92
Total N (cmol/100g)	1.64	1.99	2.84
Na (ppm)	1.17	1.56	1.81
P (ppm)	24.07	25.43	26.88
Mn (ppm)	90.32	112.55	124.32
Cu (ppm)	128.99	137.83	150.43
Fe (ppm)	35.76	38.31	42.02
Zn (ppm)	289.98	328.78	352.16

M1 = soil without organic fertilizer, M2 = a mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ (v/v/v), and M3 = a mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ (v/v/v).

Water potential status and the temperature of the growth medium

The status of water potential (PA) and the temperature on growth medium a long this experiment were measured by using DewpointPotentiaMeter WP4. For this purpose, 10 g of growth medium at the depth of 15 – 20 cm was needed for the measurement. The data was recorded at the end of dehydration period before the subsequent re-watering treatment was subjected to the growth medium. The observation was conducted only in the growth medium, without destructing the plants.

Relative Water Content (RWC)

Relative water content in leaves was determined according to Turner[22]by using this following formula :

$$\text{RWC (100\%)} = \frac{(\text{FW} - \text{DW})}{(\text{TW} - \text{DW})} \times 100\%$$

Five fully-developed leaves per-plants were sampled, weighed (FW), and placed in distillated water to reach full turgidity for 48 hours. Then, the turgidity of leaves (TW) were measured and dried in an oven with temperature of 60^0 C for 48 hours to determine the dry weight of leaves. The abbreviations of the formula are as follows :Fw = fresh weight of leaves, DW = dry weight of leaves, TW = turgid weight of leaves. RWC of leaves was calculated by using 5 leaves in every treatment.

Growth Parameters

Growth parameters in this study were measured at the vegetative stage on 24-week plants. The characters observed were numbers of leaves, height of plants, fresh weight and dry weight of leaves, length of roots, fresh weight and dry weight of roots. The number of leaves was counted on all leaves developed by the plant. The height of plant was measured from the base of the plant up to the tip of the shoot. The length of root was measured on primary root, from the base of the root that borders to the base of plant to the tip of the root. The fresh weight of shoot and roots were measured on fresh weight shoot and roots at harvesting time. The dry weight of shoot and root were analyzed on shoot and root after being dried in an oven at 60^0 C for 3 days until it reached a constant weight.

Statistical analysis

The data obtanied in this study were analyzed statistically by using JMP 11 software. ANOVA test was performed to determine the single and interaction effects of the treatments. Means generated then were compared by The Tukey`s HSD test at the probability level of 5%.

III. Result

Water potential status and the temperature of the growth medium

The status of soil water potential (ψs) is an effective parameter used to determine the level of drought stress in the environmental constraint[23]. This parameter also describes the availability of water and its movement in the soil-plant system (ψs-r)[24]. In this study, the growth medium subjected by every day watering period treatment, shows the value of the water potential which is close to zero. Meanwhile, increasing of drought stress treatment by using an increased watering period treatment resulted in a reduction of water potential status of the growth medium (Fig. 1). Growth medium containing organic fertilizers presents higher water potential values as compared to the control. However, this observation has corresponded to the data of soil-plant system of *B. javanica* showing lower ψs by increasing the duration of dehydration period[15]. As organic fertilizers, compost and animal manure in the solid forms used in this study has function to conserve soil water, and therefore maintain the moisture of the growth medium subjected by water stress conditions by increasing water holding capacity[25,26].

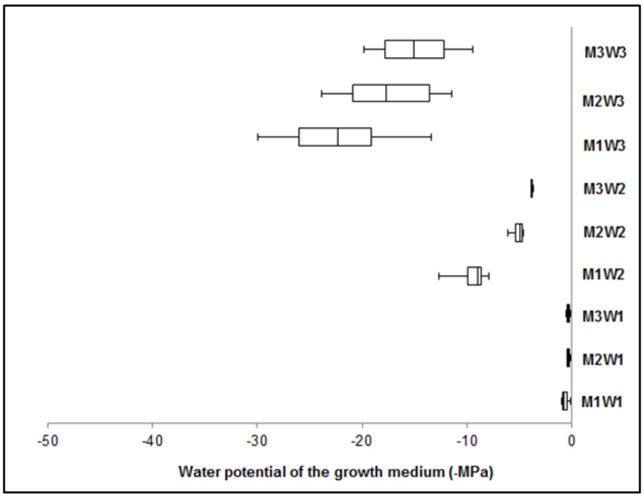

Figure 1.The water potential status of the growth medium used in this study.The data was collected in every single pot-based system. M1W1 = soil without organic fertilizers in every day watering periods, M2W1 = mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ in every day watering period, M3W1 = mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ in every day watering period., M1W2 = soil without organic fertilizers in every 4 days watering periods, M2W2 = mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ in every 4 days watering period, M3W2 = mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ in every 4 days watering period., M1W3 = soil without organic fertilizers in every 7 days watering periods, M2W1 = mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ in every 7 days watering period, M3W1 = mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ in every 7 days watering period.

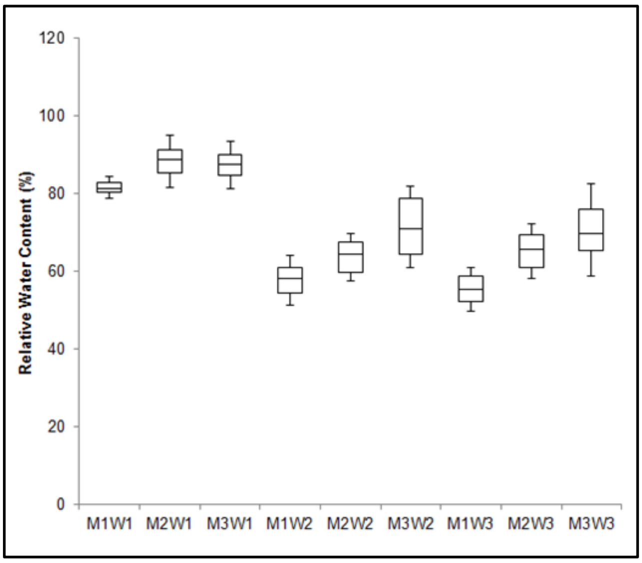

Figure 2. Relative Water Content (RWC) of *P.javanica* leaves. M1W1 = soil without organic fertilizers in every day watering periods, M2W1 = mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ in every day watering period, M3W1 = mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ in every day watering period., M1W2 = soil without organic fertilizers in every 4 days watering periods, M2W2 = mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ in every 4 days watering period, M3W2 = mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ in every 4 days watering period., M1W3 = soil without organic fertilizers in every 7 days watering periods, M2W1 = mixture of soil, compost, and animal manure at a ratio 1 : ¼ : ¼ in every 7 days watering period, M3W1 = mixture of soil, compost, and animal manure at a ratio 1 : ½ : ½ in every 7 days watering period.

Relative Water Content (RWC)

RWC is considered as an indicator to determine plant water status[27,28].Figure 2 shows that watering period treatments causing drought stress in the growth medium perform a negative effect on RWC of *P.javanica* leaves. Increasing the watering period treatment in all types of growth medium will decrease RWC status of *P.javanica*leaves. However, the application of organic fertilizer (compost and animal manure) in the growth medium has the ability to increase RWC of leaves in all watering period treatment as compare to the control. Regarding to this case, compost and animal manure function to decrease the soil evaporation[29] and increase water-holding capacity in the soil[30]. Organic fertilizers assist the growth medium to preserve water, therefore the root can absorb the more water for the plant growth process.

Growth characters in the vegetative phase

The growth characters of *P.javanica* plants were measured at the harvesting time on 24-weeks plants. Organic fertilizers, such as animal manure and compost, in optimal levels can affect the temporal dynamics of soil nutrient availability through their influence on soil physical and chemical properties (Paul and Beauchamp, 1993).

Table 2. Vegetative growth parameters of *P.javanica* plants

Treatment	Plant height (cm)	Root length (cm)	Plant biomass (g)	Leaves number	Leaf weight ratio
M (organic fertilizers)					
M1	31,58 a	21,79 a	16,08 a	30,33 a	0,72 a
M2	33,08 a	19,68 a	25,09 b	35,00 a	0,76 a
M3	52,96 b	25,61 a	47,13 c	51,25 b	0,87 b
W (watering periods)					
W1	39,00 a	19,96 a	17,18 a	35,83 a	0,77 a
W2	38,97 a	21,92 a	30,27 b	39,75 a	0,78 a
W3	39,66 a	25,21 a	30,86 b	41,00 a	0,77 a
M x W					
M1W1	31,50 a	22,13 a	14,28 a	30,50 a	0,73 a
M1W2	31,45 a	22,75 ab	17,93 ab	31,25 a	0,73 a
M1W3	31,80 a	20,50 b	16,05 ab	29,25 ab	0,69 a
M2W1	33,25 a	19,67 a	21,55 ab	34,50 ab	0,75 ab
M2W2	33,43 a	19,75 a	25,30 ab	35,25 ab	0,76 ab
M2W3	32,58 a	19,63 a	28,43 b	35,25 ab	0,78 ab
M3W1	52,25 b	18,09 a	45,73 c	42,50 ab	0,82 b
M3W2	52,03 b	23,25 ab	47,58 c	52,75 ab	0,85 b
M3W3	54,60 b	35,50 b	48,10 c	58,50 b	0,84 b

Means followed by the same letter in the same column, are not significantly different at the 5% level by Tukey HSD test, (n = 4).

As informed in Table 2, organic fertilizers show a significant contribution in several parameters of vegetative growth of *P.javanica* plants under drought. The organic fertilizer treatment on the growth medium, in a single factor, presents a significantly effect on plant height, plant biomass, leaves number, and leave weight ratio. Compos and animal manure in the growth medium provide the important nutrient (Table 1) required for plant growth and development. A lower soil fertility in M1 (Table 1) leads to the lower vegetative growth parameters of plant height, biomass, leaves number, and leaf weight ratio as compared to the growth medium containing compost and animal manure (M2 and M3). Meanwhile, the single factor of watering period treatment presented the significantly different in the biomass production of*P.javanica* plants. This result corresponds with the finding of increasing the biomass production of *B.javanica* by the application of compost under drought stress[15]. Regarding to the interaction of M and W treatments, the organic fertilizers is capable of overcoming the negative effect of drought stress administrated to the growth medium in all of the vegetative growth observed in this study (Table 2).

Table 3. Correlation coefficient of growth medium and plant growth responses

	ψs	RWC	PH	RL	PB	LN	LWR
ψs	1						
RWC	-0.7207*	1					
PH	-0.0327	0.3692	1				
RL	-0.3061	0.2208	0,2779	1			
PB	-0.0394	0.4269	0.8759*	0.2865	1		
LN	-0.1178	0.2688	0.6593*	0.3402	0.6667*	1	
LWR	-0.0013	0.3106	0.5514*	0.1826	0.6235*	0.4568*	1

ψs= Water potential of growth medium, RWC = relative water content, PH = plant height, RL = root length, PB = plant biomass, LN = leaves number, LWR = leaf weight ratio, * Correlation is significant at $\rho < 0.05$.

The parameters shown in Table 3, are either positively or negatively correlated to others. Some of them are significant, while others are not. The significant positive correlation is presented by the parameters of PH and PB, PH and LN, PH and LWR, PB and LN, PB and LWR, LN and LWR. Meanwhile, the significant negative correlation is observed by (ψs) and RWC, which means that the valued increase of (ψs) directly leads to the decrease of RWC.

IV. Discussion

Regarding its function in agricultural sustainability, organic fertilizers serve as beneficial componentsfor improving soil health and fertility. Organic fertilizers are types of fertilizer derived from natural raw materials, such as vegetable and animal waste, or human execrate. Among the types of organic fertilizers, compost and animal manure are commonly used on a large scale in the agricultural field. Both have been known to increase soil physical, chemical, and biological properties by increasing soil structure and water-holding capacity, improving the amount of oxygen, promoting microbial activity and cation exchange capacity, and decreasing evaporation rate[31,32,33]. These fertilizers also consist of macro and micro-elements, therefore both have the ability to fulfill the significant amount of nutrients for plant growth and development. As seen in Table 1, an increased concentration of compost and animal manure administered to the growth medium can improve the cation exchange capacity, and the amount of C-organic, K-total, N-total, and other minerals, such as, P, Na, Mn, Cu, Fe, and Zn.

Drought stress is considered as one of the most important environmental constraints that adversely affect plant growth and productivity. In regard to the presence of drought stress in plant`s living environment, the soil water potential (ψs) is performed as a significant parameter to determine the soil water status. This parameter describes the soil property affecting a large variety of bio-physical process required for plant growth and development[34]. It has been reported that declining values of soil water potential occurs during water deficit conditions[15,35,36,37]. As shown in Figure 1, the increasing of dehydration periods subjected to the growth medium of *P.javanica* leads to decreasing soil water potential level. However, compost and animal manure as organic fertilizers, both play in a role to reduce the negative effect of drought stress by increasing the moisture holding capacity and decreasing the evaporation rate in the soil[38,39,40], thereby affecting the level of soil water potential on the growth medium of *P.javanica* (Fig. 1).

In plants, water deficit affects various physiological processes that are complex and interrelated to one another.As a significant physiological parameter revealing the water status in plants, RWC (Relative Water Content) on leaves reflects the balance between water supply from the environment to the leaf tissue and transpiration rate[41]. In this study, increasing dehydration periods on the growth medium decreased the level of RWC on plant leaves. This result has corresponded to other findings in terms of drought effects to RWC of the plants[42,43]. Yet, the presence of compost and animal manure in the growth medium was able to increase RWC on leaves of *P.javanica* during drought stress (Fig. 2). Compost and animal manure contain many properties in term of their ability to improve RWC under water deficit conditions. Both function to increase water retention capacity and the movement of water in the growth medium, thereby decreasing water stress intensity[39,44].

In dry soil conditions, macro and micro-nutrients are less mobile, mainly because soil pores are filled with air, and the pathways for nutrient flux from the soil to the root surface is obstructed[45]. Table 1 presents that an increase concentration of organic fertilizers in the soil affects the availability of macro and micro-nutrients from compost and animal manure which varies with respect to their composition in the growth medium of *P.javanica*. The application of compost and animal manure improved the vegetative growth parameters, such as plant height, plant biomass, leaves number, and leave weight ratio, in *P.javanica* plants. It means that organic fertilizers support the growth and development of plants through fulfillment of nutrient-rich amendments which are available in synchrony with the plants need[46].

V. Conclusion

An increased amount of organic fertilizers reduced the negative effects of drought stress subjected to the growth medium of P.javanica. Compost and animal manure also functioned to improve the decreasing of RWC value during the periods of water deficit. Moreover, macro and micro-nutrients supplied by compost and animal manure improved the vegetative growth of P.javanica under drought.

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