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Effect of salinity stress on the growth and yield of mungbean (*Vigna radiata* (L.) R. Wilczek) treated with mangosteen pericarp extract

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ABSTRACT

Salinity stress is one of the environmental factors that limit crop production. The objective was to find out the effect of salinity stress on the growth and yield of mungbean (*Vigna radiata* (L.) R. Wilczek) treated with mangosteen pericarp extract. A randomised block design arranged in factorial pattern with two factors and three replications was used in the experiment. Salinity stress consisted of three levels, namely, 0%, 0.5% and 1%, and mangosteen pericarp extract consisted of two levels, namely, 0% and 1%. Plant height, leaf area, yield components and pod yield were analysed by univariate variance and Duncan's multiple range test at 5% significance level. The results showed that the increase in salinity stress reduced the leaf area, plant height, yield components and yield of mungbean. However, the use of mangosteen pericarp extract could increase the plant height, leaf area, yield components and yield of mungbean. The weight reduction of 100 mungbean seeds at 1% salinity stress could be alleviated by the application of 1% mangosteen pericarp extract. Moreover, mangosteen pericarp extract could mitigate mungbean yield loss caused by salinity stress.

1. Introduction

Agricultural land degradation in Indonesia negatively impacts the production of almost all agricultural commodities, including mungbean. Mungbean is the third important legume in Indonesia after soybean and peanut (Ministry of Agriculture Republic of Indonesia, 2018). It is an important food and cash crop in the rice-based farming systems of South and Southeast Asia (Nair and Schreinemachers, 2020). The harvest area of mungbean decreased from 229 thousand hectares in 2015 to 198 thousand hectares in 2018, and its production also decreased from 271 thousand tons in 2015 to 235 thousand tons in 2018 (Ministry of Agriculture Republic of Indonesia, 2018). Efforts have been made to increase mungbean production, including intensification, extensification and increasing cropping intensity. Mungbean extensification is directed to marginal lands, including saline lands, to avoid its competition with other important commodities. Approximately 12.020 million hectares or 6.29% of the total land area of Indonesia are prone to salinity (Karolinoerita and Yusuf, 2020).

Salinity is one of the main environmental factors that limit plant production (Zorb et al., 2019). Salinity affects almost all the physiological and biochemical processes (Bistgani et al., 2019), as well as morphological characteristics, of plants (Asghari and Ahmadvand, 2018). Salinity stress affects almost all phases of the growth of leguminous plants, namely, the germination, vegetative and reproductive phases (Mansouri and Kheloufi, 2017). Salinity stress causes osmotic stress, nutrient imbalance, ion toxicity, increased reactive oxygen species (ROS) production, decreased photosynthesis and reduced plant productivity (Kordrostami and Rabiei, 2019). The increase in ROS damages biomolecules, such as lipid, protein and DNA; changes membrane integrity and ion transport; decreases enzyme activity; inhibits protein synthesis and leads to cell death (Engwa, 2018; Soundararajan, 2019). Salinity-induced oxidative stress in the form of ROS adversely affects plant growth and productivity (Kumar et al., 2018). Plants trigger an antioxidant defence system through non-enzymatic compounds, such as ascorbic acid, glutathione, α-tocopherol, carotenoids and flavonoids (Caparos et al., 2019).

Mangosteen (*Garcinia mangostana* L.) is one of important fruit-trees in Indonesia. Total production of Indonesian mangosteen in 2020 reached 322,414 ton (Badan Pusat Statistik, 2020), 60% of which (rind or pericarp) is discarded as waste (Cheok et al., 2018). The biological waste threaten the environment, but actually, it can be used as organic fertilizer or soil amendment (Chia et al., 2020). Lately, however, all the

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Fig. 1. Vegetative performance of mungbean.

mangosteen parts, aril, pericarp and other components are utilised (Kaur et al., 2020). The main bioactive compounds contained in the skin and aril are xanthone derivatives (Murthy et al., 2018). Xanthone, a secondary metabolite, has long been known as an antioxidant (Gondokesumo et al., 2019; Ibrahim et al., 2016; Murthy et al., 2018). Xanthone is an anti-inflammatory, anti-allergic, anti-cancer, anti-microbial, anti-parasitic and anti-bacterial agent (Ibrahim et al., 2016; Murthy et al., 2018). The main component of mangosteen pericarp extract shows high antioxidant activity and remarkably reduces oxidative damage to blood proteins because of its ability to neutralise ROS (Suthammarak et al., 2016). Silva et al. (2016) also found that mangosteen pericarp extract is effective as an antioxidant and protects DNA from free radical damage. Detection of DNA using electrochemical biosensors have been developed to get fast and accurate information about plant diseases (Low et al., 2017).

The study on the health benefits of mangosteen has been found elsewhere (Kaur et al., 2020). However, the effect of mangosteen pericarp extract on the performance of mungbean plant under salinity stress condition has not yet been investigated. This study aimed to determine the effect of salinity stress on the growth and yield of mungbean treated with mangosteen pericarp extract. Novelty of this study is mangosteen pericarp extract mitigated mungbean yield loss under salinity stress. Mangosteen pericarp extract increased the growth and yield of mungbean.

2. Material and methods

The experiment was conducted from October to December in West Java, Indonesia at an altitude of 350 m above sea level. Mangosteen pericarp was washed thoroughly, dried in the sun, blended, diluted in 1 L of methanol and stirred until the color turned dark red. The solution was then filtered, and the filtrate was evaporated at 60 °C until a thick extract was obtained.

Mungbean seeds were soaked in 1% mangosteen pericarp extract and water (control) for 12 h. The seeds were planted in polybags that contained an 8 kg mixture of soil and manure (1:1, w/w). Salinity stress treatment was applied by pouring NaCl solution (1%, 0.5% and 0% [control]) every other day from the one week to five weeks after planting. Mungbean plants were maintained (the plants were given inorganic N, P, and K fertilizer, and were hand weeded).

The experiment used a randomised block design with a factorial pattern that is consisted of two factors and four replications. The first factor was salinity level with three levels, namely, 0%, 0.05% and 1% NaCl. The second factor was the concentration of mangosteen pericarp extract, which consisted of two levels, namely, 0% and 1%. The observed data were plant height, leaf area, yield components and yield. The data were analysed using univariate ANOVA and then Duncan's multiple range test at 5% significance level (Steel et al., 1997).

Table 1
ANOVA of plant height, leaf area, number of pod, number of seed per pod, pod weight and the weight of 100 dried mungbean seeds under salinity stress and treatment with mangosteen pericarp extract.

Parameter	Salinity stress	Mangosteen pericarp extract	S × M interaction	CV (%)
Plant height	117.51**	19.96*	0.37	7.22
Leaf area	21.43*	9.34*	2.26	16.47
Number of pod	26.16*	5.52*	3.25	3.67
Number of seed per pod	18.34*	0.40	0.27	4.97
Weight of pod	28.20*	9.98*	3.63	8.25
Weight of 100 seed	30.65*	1.0	4.41*	2.72

Note: * significant, ** highly significant (Steel et al., 1997).

Table 2
Effect of salinity stress on plant height and leaf area of mungbean treated with mangosteen pericarp extract.

Treatments	Plant height (cm)	Leaf area (cm^2)
0% NaCl	57.5^a	1071^a
0.5% NaCl	47.5^b	1176^a
1% NaCl	39.7^c	830^b
0% mangosteen pericarp extract	46.1^b	956^b
1% mangosteen pericarp extract	50.4^a	1096^a

Note: Numbers marked with the same letter in the same column shows no significant difference according to Duncan's Multiple Ranges Test 5% significance level.

3. Results and discussion

The plants experienced salinity stress is indicated by the yellowing leaves. The degree of yellowish color of the leaves indicates the severity level of salinity stress (Fig. 1). Table 1 shows that based on ANOVA, salinity stress and mangosteen pericarp have an interaction effect extract on the weight of 100 mungbean seeds substantial independent effects on the growth and yield of mungbean plants.

Statistical data analysis indicated that salinity stress and mangosteen pericarp extract did not show a remarkable interaction effect on the plant height and leaf area of mungbean. Increased salinity to 0.5% and 1% remarkably reduced the plant height by 17.4% and 30.9%, respectively. Moreover, the leaf area was reduced by 22.5% under 1% NaCl concentration. By contrast, the use of mangosteen pericarp extract increased the plant height and leaf area by 50.4% and 14.6%, respectively (Table 2). Increased salinity hampered the growth process because of the decrease in water absorption by plant roots and the increase in osmotic stress. Salinity affects plants through osmotic effects, ion toxicity and/or nutrient deficiencies (El Sayed et al., 2016). Salinity can reduce leaf photosynthetic activity by affecting stomatal and

Table 3
Effect of salinity stress on number of pods, number of seeds per pod and dry weight of pod treated with mangosteen pericarp extract.

Treatments	Number of pod	Number of seed per pod	Weight of pod (g)
0% NaCl	12.62^a	8.19^a	16.60^a
0.5% NaCl	10.33^b	8.62^a	12.58^b
1% NaCl	7.70^c	6.90^b	7.78^c
0% mangosteen pericarp extract	9.55^b	7.58^b	10.80^b
1% mangosteen pericarp extract	10.88^a	8.20^a	13.83^a

Note: Numbers marked with the same letter in the same column show no significant difference according to Duncan's multiple range test at 5% significance level.

Table 4
Effect of salinity stress on the weight of 100 mungbean seeds treated with mangosteen pericarp extract.

Salinity stress	Mangosteen pericarp extract	
	0%	1%
	(g)	
NaCl 0%	8.89^{a} A	8.94^{a} A
NaCl 0.5%	8.10^{b} A	7.62^{b} A
NaCl 1%	6.94^{c} B	7.76^{b} A

Note: Numbers marked with lowercase letters in the same column and uppercase letters in the same line are not significantly different according to Duncan's multiple range test at 5% significance level.

non-stomatal factors (Lotfi et al., 2020). It also affects the initial growth of plant, causes oxidative stress and reduces chlorophyl content (Kordrostami and Rabiei, 2019). Thus, salinity reduces plant height, leaf area and plant dry weight (Setiawati et al., 2018).

Xanthone derivatives, including α-mangostin, can scavenge free radicals, which disrupt or inhibit the growth process (Ibrahim et al., 2016), as indicated by the increase in plant height and leaf area. The increase in salinity stress from 0% to 1% decreased the number of pods, the number of seeds and dry pod weight. In comparison, mangosteen pericarp extract increased the number of pods, number of seeds per pod and the dry pod weight (Table 3).

Salinity stress reduced the number of pods, the number of seeds per pod and pod weight of by 39%, 16% and 53%, respectively, compared with those of control. The energy conversion to yield is reduced under stress conditions, because part of the energy is used for stress alleviation in addition to growth and maintenance (Munns and Gilliham, 2015; Zorb et al., 2019). Salinity stress reduces the photosynthesis rate and limits the allocation of photosynthate to the reproductive part (Farooq et al., 2015). The limitation of photosynthate translocation into sinks under salinity stress causes the failure of grain filling and reduces the number of seeds; thus, salinity stress hampers physicochemical processes during the grain filling stage (Razzaq et al., 2020). The decrease in assimilate content is due to the shortening of the grain filling stage as salinity stress causes early plant senescence (Prathap et al., 2019). Mangosteen pericarp extract remarkably increased the yield component and yield of mungbean. Mangosteen pericarp extract increased the number of pods, the number of seeds and pod weight by 14%, 8% and 28%, respectively, compared with those of the control. The antioxidative properties of xanthone and flavonoid compounds contained in mangosteen pericarp are able to capture free radicals by transferring labile H atoms to radical oxygen species (Chew and Lim, 2018; Kaurinovic and Vastag, 2019).

Salinity stress caused a remarkable interaction effect with mangosteen pericarp extract on the weight of 100 dried mungbean seeds (Table 4). An increase in salinity stress from 0% to 1% was followed by the decrease in weight of 100 mungbean seeds with or without 1% mangosteen pericarp extract treatment. Mangosteen pericarp extract (1%) can prevent a decrease in the weight of 100 mungbean seeds under 1% salinity stress condition. Salinity stress increased ROS production, which will further damage the cell membrane, reduce chlorophyll content and decrease the photosynthesis rate. However, mangosteen pericarp extract is able to neutralise ROS and suppress the damage (Farooq et al., 2015). The oxidative effect suffered by mungbean plant subjected to salinity stress was alleviated by xanthone and flavonoid compounds contained in the mangosteen pericarp extract.

4. Conclusion

Increased salinity stress reduced the leaf area, plant height, yield components and yield of mungbean. However, the use of mangosteen pericarp extract could increase the plant height, leaf area, yield components and yield of mungbean. The weight reduction of 100 mungbean seeds at 1% salinity stress could be alleviated by the application of 1% mangosteen pericarp extract. Mangosteen pericarp extract could mitigate mungbean yield loss under salinity stress.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bcab.2021.102132.

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Glossary

g: gram
M: Mangosteen
S: Salinity
CV: Coefficient of Variation
DNA: Deoxyribonucleic Acid
ROS: Reactive Oxygen Species