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Research Article

Determine the Effects of Drought Stress on the Cacao Seedlings (*Theobroma cacao* L.) with Rice Straw Compost

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Abstract

Background and Objective: Cocoa (*Theobroma cacao* L.) is one of the leading commodities and has an important role in the Indonesian economy. The purpose of this research was to determine the effect of drought stress and rice straw compost fertilizer and their interactions on the physiology of cocoa seedlings. Drought stress has a major influence on plants including cocoa, which decreases plant turgor pressure. **Materials and Methods:** It used materials such as water (C_0), rice straw (K) compost with 4 treatments (K_0, K_1, K_2 and K_3). This research used factorial Randomized Block Design (RBD) with 2 factors, namely: (1) The first treatment factor is drought stress (C) consisting of 3 levels of treatment (C_0, C_1 and C_2). (2) The second treatment factor is rice straw (K) compost consisting of 4 levels of treatment, namely: K_0, K_1, K_2 and K_3. The parameters observed were planted wet weight, plant dry weight, plant water content, total N-leaf content. **Results:** The results showed that drought stress treatment significantly affected plant wet weight, plant water content and total N-leaf content but did not significantly affect plant dry weight. The treatment of rice straw compost significantly affected the water content of plants but did not significantly affect the wet weight of plants, dry weight of plants and leaf N-total content. **Conclusion:** The drought stress affects the plant's wet weight, water content and N-leaf content but no effects on the dry weight. Rice straw compost significantly affects plants water content but does not influence the wet weight of plants, dry weight and N-leaf content.

Key words: Cacao, drought stress, rice straw compost, plant physiology, animal physiology, photosynthesis, polyphenol

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cocoa (*Theobroma cacao* L.) is a leading commodity and has an important role in the Indonesian economy, such as providing employment, income source for farmers and also a source of foreign exchange. The right climate and land conditions can encourage the development of cocoa plantations in Indonesia, both small and large scale. Cocoa (*Theobroma cacao* L.) is one of the plantation cash crops and has high market opportunities. Indonesia is one of the world's cocoa producers, after Ivory Coast and Ghana. Cocoa plantations area in Indonesia is around 1.462.000 ha, consisting of smallholder plantations (90%) and the rest are private and state plantations with annual production reaching 1.315.800 tons[1].

Plant physiology is a branch of botany that studies how living systems work in the body parts of plants and their response to the environmental effects so that the plant can grow. Like animal physiology, plant physiology also combines various aspects such as physics, chemistry and biology. Physiology science can be applied in agriculture to increase the value of products and yields. Examples of studies in plant physiology applied in agriculture are the application of chemical fertilizers to increase yields and the use of growth regulators in stimulating flowering. The results of plant physiology research are also used to assist plant breeding programs, for example, such as research on drought-resistant cultivars[2].

Water is a very important factor for plants, due to its functions as a nutrient solvent, nutrient translocation and photosynthesis. In the dry season, plants will be experiencing drought stress due to a lack of water supply in the rooting area so the transpiration rate exceeds the rate of water absorption by the plants. If the period of drought stresses prolonged, the plant experiences death[3].

Water also affects the growth of cocoa, both to carry out metabolic processes or the need to maintain cell turgidity, especially for photosynthesis. The photosynthesis process requires water for the formation of photosynthate materials, precisely carbohydrates, where CO_2+ H_2O will form $C_6H_{12}O_6$ with the help of sunlight. Water is also needed in the light phase as a source of electrons to form chemical energy such as $NADPH_2$ and ATP. Chemical energy will then be used to reduce CO in the dark phase to produce $C_6H_{12}O_6$+O_2. If the plants experience water shortages, there will be a decrease in the rate of photosynthesis because plants are not able to form $NADPH_2$ and ATP sufficiently to meet the energy needs in reducing CO[4].

Drought stress has a major effect on plants including cocoa, which can cause a decrease in plant turgor pressure. Turgor pressure affects the enlargement and propagation of plant cells, determining plant body size, stomata opening and closing, leaf development, flower formation and development while indirectly influencing plant physiology processes such as photosynthesis, metabolism, nutrient absorption and photosynthetic translocation[5].

Physiologically, plants that grow in drought stress conditions will reduce the number of stomata thereby reducing the rate of water loss and also followed by stomatal closure and a decrease in net CO_2 uptake in leaves. This causes a decrease in the photosynthesis rate and photosynthates produced. Testing the nature of plant tolerance to drought is generally done by planting in the field when there is limited water for example at the end of the dry season. Given the difficulty of controlling environmental variations in the field, new research methods have been used to induce drought with better control in the greenhouse. One such method is by planting plants in polybags accompanied by water supply arrangements based on the time and amount of water given to plants[6].

Generally, plant cultivation can lead to land degradation if not balanced with proper fertilization and proper damage control. Land degradation can be caused by reduced fertility, physical and biological properties damage and depletion of soil thickness. Reduced fertility is caused by nutrients lost from the rooting area through harvesting and erosion. Damaging soil physical and biological properties are due to reduced organic matter and reduced amount and activity of living in the soil. Therefore, it is necessary to increase soil nutrients by providing organic fertilizer[7].

Fertilization aims to add certain nutrients in the soil that are not sufficient for the needs of the cultivated plant while cocoa is to provide nutrients for vegetative growth. Good vegetative growth is expected to support the generative phase to grow perfectly[8]. Rice straw compost is one of the organic fertilizers derived from crop residues through a composting process. The use of rice straw compost which has a high C/N ratio, polyphenol and lignin content can increase nutrient availability and soil organic matter content that can increase the ability of the soil to retain water[9].

This research was aimed at finding the effects of drought stress and rice straw compost fertilizer and their interactions on the physiology of cocoa seedlings.

MATERIALS AND METHODS

Study area: This research was carried out in the Experimental Farm of the Faculty of Agriculture, Islamic University of North

Sumatra, Karya Wisata Street, District of Medan Johor. The altitude of place ±25 m above sea level with flat topography. This research was conducted from March-June, 2019.

Instruments: The tools used in this study were: Hoes, brushes, hammers, knives, machetes, fan sticks, gauges, measuring cups, cameras, stationery and other tools. The materials used were: Cocoa seedlings TSH 858, polybags 35×40, rice straw compost, transparent plastic, bamboo, rope and other materials.

Methodology: This research uses factorial Randomized Block Design (RBD) with 2 factors, namely:

- The first treatment factor is drought stress (C) consisting of 3 levels of treatment, namely: C_0 (watered every day), C_1 (watered every 2 days), C_2 (watered every 3 days)
- The second treatment factor is rice straw (K) compost consisting of 4 levels of treatment, namely: K_0 (control (without fertilizer)), K_1 (5 t ha^{-1} (25 g per polybag)), K_2 (10 t ha^{-1} (50 g per polybag)), K_3 (15 t ha^{-1} (75 g per polybag)). The parameters observed were planted wet weight, plant dry weight, plant water content and total N-leaf content

RESULTS AND DISCUSSION

Effects of drought stress and rice straw compost on the growth of cocoa seedlings are presented in Table 1.

Plant wet weight (g): Analysis showed that the treatment of drought stress significantly affected the wet weight of the cocoa plants while the treatment of rice straw compost did not significantly affect the wet weight. Interaction between the 2 treatments did not significantly affect the wet weight of the plant at 12 Weeks After Planting (WAPs). Table 1 shows that drought stress treatment significantly affects the wet weight of the cocoa plant at 12 WAPs. The highest yield of plant wet weight was found in treatment C_0 (watered every day) namely 98.65 g, which was significantly different than treatment C_2 (watered every 3 days) namely 84.02 g and also with treatment C_1 (watered every 2 days) namely 90.55 g.

Interaction of the 2 treatments had no significant effect on the wet weight of cocoa. The highest wet weight found in treatment C_0K_1 (watered every day and 25 g per polybag of straw compost fertilizer) namely 105.22 g, while the lowest wet weight found in treatment C_2K_0 (watered every 3 days and without straw compost (control) 0 g per polybag) namely 77.33 g.

Plant dry weight (g): Analysis showed that the treatment of drought stress and rice straw compost did not significantly affect the dry weight of cocoa plants. Interaction of the 2 treatments had no significant effect on plant dry weight at 12 WAPs. This can be seen in Table 1 that shows that the treatment of drought stress and rice straw compost did not significantly affect the dry weight of cocoa plants. The interaction between the 2 treatments had no significant effect on plant dry weight. The highest dry weight of the cocoa plant was found in treatment C_0K_0 (watered every day and without fertilizer compost), namely 30.49 g, while the lowest dry weight was found in treatment C_2K_3 (watered every three days and compost fertilizer rice straw 75 g per polybag) namely 23.64 g.

Plant water content (%): Analysis showed that the treatment of drought stress and rice straw compost significantly affect the water content of cocoa seedlings. Interaction of the 2 treatments significantly affects the water content of plants in cocoa seedlings at 12 WAPs. This can be seen in Table 1.

The data in Table 1 shows that treatment of drought stress significantly affects the water content of cocoa seedlings. The highest yield of drought stress was found in treatment C_0 (watered every day) namely 70.50%, which was significantly different than treatment C_2 (watered every 3 days) namely 66.46% but not significantly different than treatment C_1 (watered every two days) namely 70.00%.

Treatment of rice straw compost has a significant effect on the water content of cocoa seedlings. The highest yield of rice straw compost found in treatment K_3 (75 g per polybag) namely 72.01%, which is significantly different than treatment K_0 (control 0 g per polybag) namely 66.86% and with treatment K_1 (25 g per polybag) namely 66.92% but not significantly different than treatment K_2 (50 g per polybag) namely 70.16%.

Interaction of the two treatments significantly affects the water content of the cocoa seedlings. The highest interaction of plant water content analysis was found in treatment C_1K_3 (watered every day and compost fertilizer 75 g per polybag), namely 73.21%, which was significantly different than treatment C_2K_0 (watered every 3 days and without composted rice straw) namely 60.67%.

Total N-leave content (%): Analysis showed that the treatment of drought stress significantly affects the total N-leave content of the cocoa plant while the treatment of

Table 1: Effect of drought stress and rice straw compost treatment on growth of cocoa seedlings

Treatments	Plant wet weight (g)	Plant dry weight (g)	Plant water content (%)	Content N-total (%)
Drought stress (C)				
C_0	98.65^b	28.96	70.50^b	1.89^a
C_1	90.55^a	26.78	70.00^b	2.11^b
C_2	84.02^a	27.78	66.46^a	2.14^b
Compost (K)				
K_0	87.93	28.68	66.86^a	2.07
K_1	89.43	29.15	66.92^a	1.99
K_2	91.11	27.13	70.16^b	2.01
K_3	95.83	26.41	72.01^b	2.11
Interaction (C×K)				
$C_0 K_0$	94.24	30.49	67.65^{bcd}	1.88
$C_0 K_1$	105.22	29.90	71.24^{cd}	1.86
$C_0 K_2$	93.53	26.68	71.49^{cd}	1.91
$C_0 K_3$	101.62	28.74	71.61^{cd}	1.91
C1K_0	92.21	25.57	72.26^{cd}	2.11
$C_1 K_1$	80.60	29.20	63.75^{ab}	2.02
$C_1 K_2$	87.24	25.52	70.78^{cd}	2.15
$C_1 K_3$	102.14	26.85	73.21^d	2.17
$C_2 K_0$	77.33	29.97	60.67^a	2.23
$C_2 K_1$	82.47	28.34	65.76^{abc}	2.09
$C_2 K_2$	92.55	29.19	68.19^{bcd}	1.98
$C_2 K_3$	83.72	23.64	71.20^{cd}	2.25
KK (%)	12.910	11.433	5.241	7.605

Values followed by not the same letters in the same treatment group are significantly different at the 5% level based on the DMRT test

rice straw compost did not significantly affect the total N-leave. Interaction of the two treatments did not significantly affect the total N-leave content of the cocoa plant at 12 WAPs. This can be seen in Table 1.

The data in Table 1 shows that treatment of drought stress significantly affects the total N-leave content of cocoa at 12 WAP. The highest yield of total N-leave content was found at treatment C_2 (watered every three days) namely 2.14%, which was significantly different than treatment C_0 (watered every day) namely 1.89% but not significantly different than treatment C_1 (Watered 2 days) namely 2.11%.

Treatment of rice straw compost did not significantly affect the total N-leave content of cocoa at 12 WAPs. The highest yield of compost found in treatment K_3 (75 g per polybag) namely 2.11%, which was not significantly different than treatment K_2 (50 g per polybag) namely 2.01%, treatment K_1 (25 g per polybag) namely 1.99 % and treatment K_0 (0 g per polybag control), 2.07%.

Interaction of the two treatments did not significantly affect the total N-leave content of cocoa. The highest total N-leave content of cocoa is in treatment C_2K_3 (watered every 3 days and 75 g per polybag of straw compost) namely 2.25%, while the lowest is in treatment C_0K_1 (watered every day and straw compost 25 g per polybag), namely 1.86%.

Cacao (*Theobroma cacao* L.) is a tropical perennial crop that is of great economic importance to the confectionery industry and to the economies of many countries of the humid tropics where it is grown. Some recent studies have suggested that climate change could severely impact cacao production[10]. It is essential to incorporate our understanding of the physiology and genetic variation within cacao germplasm when discussing the implications of climate change on cacao productivity and developing strategies for climate resilience in cacao production. Drought stress can change the physiology, morphology, biochemistry and molecular of plants. Water stress drought affects the parameter number of leaves, seedling height, leaf area, fresh weight and dry seeds, stem diameter and root[11]. Length seeds groundnut to 4 weeks seedlings. Drought stress occurred when water availability in soil decrease due to low soil moisture at a certain period. Water deficiency in plants occurred when transpiration is higher than water taken by the roots[12].

Research by Azmin *et al.*[13] showed that compost fermented by rot fungi gave a significant effect on the growth of cocoa seedlings. Nevertheless, the difference in varieties of cocoa did not affect the growth of cocoa seedlings. Cocoa pod husk waste composted by *Tremella* sp. and *Pleurotus* sp. gave the significant effect on Leaf Area Index (LAI), Net Assimilation Rate (NAR), Crop Growth Rate (CGR), Root-shoot ratio and root dry weight of Cocoa seedling. While the research results of Haryanti *et al.*[14] showed that the administration of biochar and decomposers did not accelerate the composting process. Application of organic fertilizer with biochar or without biochar on the inoculant treatment factors of BPF A and BPF B significantly increased the diameter of the cocoa seedling stem. Application of organic fertilizer increases the stem diameter, plant height, number of leaves of cocoa seedlings, root dry weight and dry weight of a stem of cocoa seedlings. Chemura[15] in their study showed that the administration of husk biochar rice and coffee husk compost affected seedling height, the number of leaves, stem diameter, total leaf area, root dry weight, shoot dry weight and root crown ratio. Giving 25% coffee husk compost generally gave a good response to the growth of cocoa seedlings. According to the study of Sasmita *et al.*[16], the application of rice husk biochar significantly increased the acid phosphatase activity of growing media. Meanwhile, organic fertilizer increased the soil pH, acid phosphatase and available P activity and decreased Al-dd growing media. Bahrun *et al.*[17] stated that the dose of rice straw compost could improve the seedling height, stem diameter, number of leaves, leaf area, root volume, the ratio of the canopy and root and dry weight. The dose of rice straw compost at 125 g per polybag produced the best growth of the cocoa seedling.

Good cocoa seeds for planting in the field must meet the standard quality of seeds ready to be planted, namely: seedling age 4-5 months, seedling height 50-60 cm, number of leaves 20-24 sheets and a minimum of 4 old leaves, stem diameter the bottom seedling is about 8 mm and the seedlings are in good health (not attacked by pests and diseases) and intact (not broken and so on) and growing normally (not bent and so on)[18]. The plant generally has a mechanism to minimize water loss during stress conditions. Stomatal closure is a strategy of the cocoa plant for diminishing water loss through the transpiration process by regulating stomatal conductance[19]. This study has implied that the usage of water and rice straw treatments to overcome the drought stress of cocoa seeds. Researchers and farmers may apply the water and rice straw treatments to keep the cocoa seeds experience stress if the temperature and climate to hot. The limitation of this study is the number of samples that took only 75 polybags of cocoa seeds as a frontier way to test the drought stress of cocoa seeds with the water and rice straw treatments, it needs a larger sample for further study.

CONCLUSION

The drought stress of cocoa seeds has been overcome with water and rice straw compost treatments. Two variables significantly affect the water content of plants. Although watering every day shows the highest yield but not too far that is only 0.50% in the parameters of plant water content.

SIGNIFICANCE STATEMENT

Treatment of rice straw compost has a significant effect on the water content of cocoa seedlings. The highest yield of rice straw compost was found in treatment K_3 (75 g per polybag) namely 72.01%. The novelty of this study concerning the treatment for cocoa stress and rice straw compost effects.

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