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Water content, resorption of N and P, and the growth of teak *Tectona grandis* L.f. seedlings on four types of growing media under drought stress

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Abstract

Growing media that contain organic materials can provide nutrients and water for plants.This study analyzed the availability and effects of nutrients and water, N and Presorption, and growth of teak seedlings under drought stress. The growing medium was made from ultisol soil (M1), ultisol soil with husk charcoal (M2), ultisol soil with chicken manure (M3), and ultisol soil with compost (M4), then planted with teak seeds. Maintenance was conducted by field capacity watering for 30 days.Teak seedlings were treated with drought stress for 90 days. Based on the analysis, growing media total N ranged from 0.19 to 0.28%, total P ranged from 0.10 to 0.17%, and water ranged from 11.40 to 16.20%. Teak seedling leaves contain N nutrient ranging from 0.34 to 0.95% and P nutrient ranging from 0.04 to 0.16%.The N resorption ability of teak seedlings ranged from 26 to 31%, and P resorption was around 20 to 25%. The height growth of teak seedlings ranged from 80 to 115cm, the stem diameter from 1.4 to 1.8cm, the leaf area from 630 to 650cm^2, and the thickness of the leaves from 545 to 462µm. Growing media made from ultisol soil and chicken manure (M3) produced the best water content, N and P resorption, and the growth of teak seedlings after 3 days of drought stress.

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Introduction

Teak *Tectona grandis* L.f. has a high preference among tropical timbertrees for its superior wood qualities, faster growth, and ease in the establishment. Although there are several ways by which productivity can be increased, the use of superior propagules is the primary and most important one.[1] Teak is a tropical tree species with a wide natural distribution in southeastern Asia.[2] Presently, teak is an important component of many plantation programs throughout the tropical world.[3] Cultivation of teak is generally propagated in a generative way. The generative way is by propagation through seeds that are sown and allowed to grow in growing media. The development and growth of teak seedlings are dependent on nutrients and water in the growing media.[4]

The growing media is one of the external factors affecting plant seeds' growth. The availability of nutrients and water in the growing medium increases the growth rate of plant seedlings. The presence of organic materials in the growing medium increases the availability of nutrients and water. The addition of organic matter causes an increase in porosity so that water content status in the media grows better. Organic matter also causes an increase in nutrients so that the availability of nutrients for plant growth is guaranteed.

Drought stress causes a decrease in the rate of plant growth. Water deficiency will inhibit physiological processes in plants and be a significant problem in young plants (seedlings). It also reduces photosynthetic activities, thus disrupting carbohydrate production, and if it continues, plants will die. The deficiency of water inhibits the metabolic activity, morphology, and growth rate,[5] as well as physiological activities such as photosynthesis, respiration, transpiration, and nutrient storage.[6]

Yellowish discoloration of the leaves indicates water deficiency.[7] The leaves undergo a change in color due to a change in pigment content.[8] Water and nutrients absorbed by roots continue to be transported to the leaves. When transport from the roots is reduced, it will cause aging and discoloration of leaves.[9] There sorption of nutrients from deciduous leaves is a key component of an important nutrient conservation strategy in plants. Resorption is the process of recovering nutrients from leaves before abscission to be stored or used to develop plant tissue.

Growth is a process of increasing the volume and number of plant organs. Growing media and drought stress can influence the growth of the plant. Young plants are more sensitive to deficiency of water. Moreover, teak plants will drop their leaves when they experience water deficiency. This research analyzed husk charcoal, chicken manure, and compost, which can store water in the growing media. The availability of water in the media can be indicated by the content, the N and P resorption, and the plant growth.

Materials and Methods

The research was conducted at the biological experiment garden, the chemical and soil fertility laboratory of Hasanuddin University, Makassar, Indonesia. The research started from the treatment of growing media, teak seedlings, and drought stress treatment, and then analyzed the water content, N and P resorption, and the growth of teak *Tectona grandis* L.f seedlings.

Treatment of growing media

The growing media was made from ultisol soil then mixed with husk charcoal, chicken manure, and compost. Treatment was given on the percentage of materials used in the growing media. The used materials were: ultisol soil 100% (M1); ultisol soil 60% + husk charcoal 40% (M2); ultisol soil 60% + chicken manure 40% (M3); and ultisol soil 60% + compost 40% (M4). The total weight of the media grows to 10 kg in a polybag. The growing media was adapted for 30 days and total N, total P, and water content were analyzed.

Teak seedlings and drought stress treatment

Teak seeds were taken from teak plantations that grow in the city forest of Hasanuddin University, Makassar, Indonesia. Old and large teak seeds were taken and dried under sunlight for three days. Then the teak seeds were soaked in water for four days, then removed and drained for one day. After that, the seeds were sown on seedling media made of top soil and fine sand. After the teak seeds have grown,they were ready to be transferred to the growing media in polybags. The teak seeds aged 14 days were planted in four types of growing media and maintained by field capacity watering every morning. The field capacity water was calculated using the gravimetric method and obtained that each watering relates to 3 liters of water. Watering the field capacity of teak seeds was only done for 30 days. Furthermore, teak seedlings were treated under drought stress with watering intervals of 3, 7, 14, and 21 days for 90 days.

Analysis of content and resorption of N and P

The teak seedlings' mature leaves (green leaf) and senescing leaves (yellow leaf) were analyzed for N and P content. Teak leaves were dried until a constant dry weight was achieved, milled, and analyzed for N and P content.The total N content was analyzed using the Kjeldhal method, and the total P content was analyzed using a Morgan-Wolf extractor. While the N and P resorption abilities of teak leaves were analyzed using the following formula:[10]

$$\textit{Resorption of N} = \frac{\text{(N content of mature leaves-N content of senescing leaves)}}{\text{(N content of mature leaves)}} \times 100\%$$

Analysis of teak seedling growth

The growth of teak seedlings was evaluated by analyzing height, stem diameter, area and leaf thickness. The plant height growth was measured using a meter, while the stem's diameter was measured using a caliper. The leaf area was analyzed by measuring the total leaf area with paper. Then, the leaf thickness was measured by semi-permanent preparations using the paraffin method.

Research design

The study used a randomized design of factorial groups with two factors. The first factor was growing media with fourty pes and the second factor was drought stress with four watering intervals. The observed parameters included the content, resorption of N and P, height, the diameter of stems, leaf area, and thickness of teak seed leaves.The obtained data were analyzed with analysis of variance and continued with the Duncan Multiple Range Test at the 95% level.

Results

Content of N and P in the growing medium and teak seedling leaves

The results of this study indicate that the total N in growing media ranged from 0.19 to 0.28%, and total P ranged from 0.10 to 0.17%. Growing media made from ultisol soil mixture with husk charcoal (M2), ultisol soil with chicken manure (M3) and ultisol soil with compost (M4) contained higher N and P than just only ultisol soil (M1). M3 contained the highest total N and total P and M1 the lowest (Table 1). The results of this study also showed that the total N and total P content of the growing medium affected the N and P content of the teak seedling leaves. The results of the analysis ofN content of teak seedling leaves ranged from 0.34 to 0.95% and the P content ranged from 0.04 to 0.16% in the 4 types of growing media under drought stress (Table 2). The N content of teak seedling leaves is highest (0.95%) in M3 growing medium with three days of drought stress. The P content of teak seedling leaves is highest (0.16%) in M3 growing medium with 3 and 7 days of drought stress and in M2 and M4 growing media with three

Table 1. Content of total N, total P, and water in growing media.

Parameter	M1	M2	M3	M4
Total N (%)	0.19	0.21	0.28	0.24
Total P (%)	0.10	0.15	0.17	0.14
Water (%)	11.40	15.00	16.20	16.00

days of drought stress. While the N content and P content of teak seedling leaves is lowest (0.34%, and 0.04%,respectively) in M1 growing medium with 14 and 21 days of drought stress. This study showed that the longer drought stress caused the lower N and P content of teak seedling leaves in the 4 types of growing media (Table 2).

Resorption ability of N and P

The resorption is a way for plants to keep nutrient stability due to nutrient loss through leaf abscission. Before the leaf abscission, the existing nutrients are absorbed and stored in the tissue. The results of the N resorption ability analysis of teak seedlings ranged from 26 to 31%, and P resorption was around 20 to 25% in the 4 types of growing media under drought stress. The N resorption ability of teak seedlings is highest (31%) in M3 growing medium with 3 days of drought stress. The P resorption ability of teak seedlings is highest (25%) in M3 growing medium with 3 and 7 days drought stress and in M2 and M4 growing media with 3 days drought stress. While the N and P resorption ability is lowest (26% and 20%) in M1 growing medium with 14 and 21 days drought stress. The N and P resorption ability of teak seedlings decreased with the length of the drought stress (Figure 1).

Growth of teak seedlings

The results of the growth analysis of teak seedlings aged 120 days showed an average height ranging from 80 to 115cm, an average stem diameter from 1.4 to 1.8cm, an average leaf area from 630 to 650cm^2, and an average leaf thickness from 454 to 460µm with thefour types of growing media under drought stress (Table 3). This study showed the growth of teak seedlings is highest (115cm) in M3 growing medium with 3 days of drought stress. The growth of stem diameter, leaf area, and leaf thickness of teak seedlings are largest in M3 and M4 growing media with 3 days of drought stress. While the growth of height and leaf areas of teak seedlings were lowest inM1 growing medium under drought stress.

The growth of stem diameter and leaf thickness of teak seedlings is lowestin M1 and M2 growing media under drought stresses. The results of the statistical analysis showed that the height growth of teak seedlings in M3 growing media was significantly different from the height in M1, M2, and M4 growing media under drought stress. While the growth of stem diameter, area, and thickness of teak leaves was not significantly different in all growing media under drought stress (Table 3). The leaf area growth of teak seedlings did not appear different from the results of leaf shape in the four types of growing media (Figure 2).

Table 2. Content ofN and P of teak seedling leaves in 4 types of growing media under drought stress.

Drought Stress (days)	Leaves	Content of N (%)				Content of P (%)			
		M1	M2	M3	M4	M1	M2	M3	M4
3	Green	0.53	0.84	0.95	0.85	0.09	0.16	0.16	0.16
	Yellow	0.38	0.60	0.66	0.60	0.07	0.12	0.12	0.12
7	Green	0.49	0.84	0.93	0.86	0.09	0.13	0.16	0.13
	Yellow	0.36	0.61	0.65	0.62	0.07	0.10	0.12	0.10
14	Green	0.46	0.84	0.88	0.83	0.05	0.13	0.13	0.13
	Yellow	0.34	0.61	0.62	0.60	0.04	0.10	0.10	0.10
21	Green	0.46	0.82	0.86	0.82	0.05	0.09	0.13	0.13
	Yellow	0.34	0.60	0.62	0.60	0.04	0.07	0.10	0.10

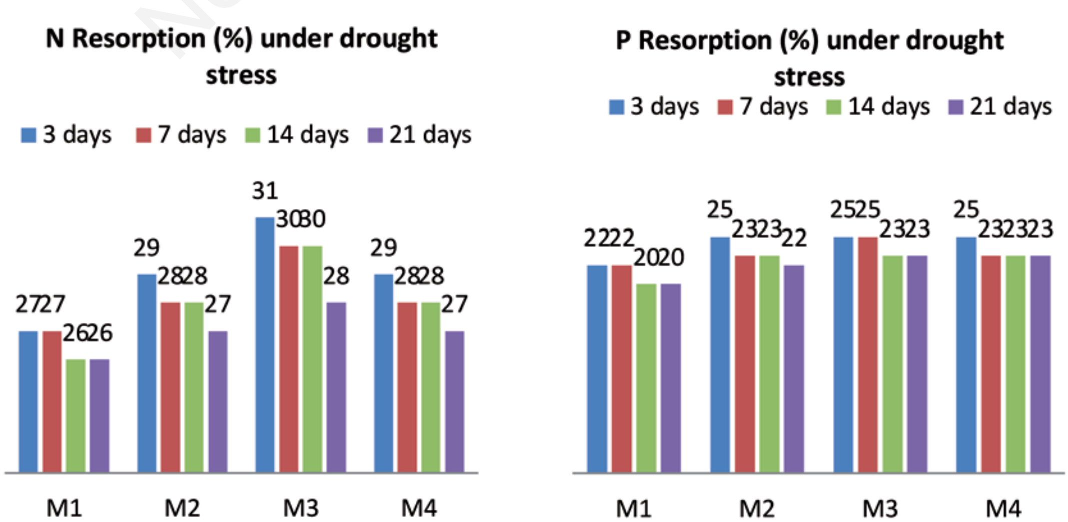

Figure 1. N and P resorption ability of teak seedlings on four types of growing media under drought stress.

Discussion

This study showed a different N and P content in each growing medium. The results of the chemical analysis showed that the M3 growing medium made from a mixture of ultisol soil with chicken manure contained a total N of 0.28% and total P of 0.17%, which are highest values compared to M1, M2, and M4 growing media (Table 1). The difference in total N and total P content was thought to be influenced by the mixture of organic materials used in growing media. The organic matter of chicken manure, compost and husk charcoal contains different total N and total P amounts. According to Sabran *et al.*,[11] chicken manure contains a total N of 1.27% and a total P of 0.15%. According to Indrawan *et al.*[12] compost contains a total N of 1.00% and a total P of 0.23%. According to Nasrulloh *et al.*[13] husk charcoal contains a total N of 0.30% and a total P of 0.15%. While according to Syahputra *et al.*[14] ultisol soils containsa total N of 0.18% and a total P of 0.05%. This study also analyzed the water content in the growing media, the amount of which was also different. The M3 growing medium contained the highest percentage of water which was 16.20%, compared to the M1, M2, and M4 growing media (Table 1).The presence of water in the media is very important. Because the water functions as a nutrient solvent, so that itis easily absorbed by roots and carries media to the leaves. According to Marjenah[15] the water has a function as a nutrient solvent, transportation medium, and the main ingredient in the photosynthesis process.

Growing media containing total N and total P were absorbed by roots of teak seedlings and distributed to the leaves. The results of this study showed that the leaves of teak seedlings contained N ranging from 0.36 to 0.95%, and P ranging from 0.04 to 0.16% in M1, M2, M3, and M4 growing media under drought stress (Table 2). The N and P content of teak seedling leaves was highest in M3 growing medium, which turned out to contain the highest total N,

Table 3. Growth of teak seedlings on four types of growing media under drought stress. The numbers followed by the same letters: a, b, c, or d are not significantly different at the 95% level.

Growth of Teak seedlings	Drought Stress (days)	M1	M2	M3	M4
Height (cm)	3	95a	100a	115c	110d
	7	90a	95b	105c	100d
	14	85a	95b	100c	95b
	21	80a	90b	95c	90b
Stem Diameter (cm)	3	1.7a	1.7a	1.8a	1.8a
	7	1.6a	1.6a	1.7a	1.7a
	14	1.5a	1.5a	1.6a	1.6a
	21	1.4a	1.4a	1.5a	1.5a
Leaf Area (cm^2)	3	646a	648a	650a	650a
	7	640a	644a	646a	646a
	14	634a	636a	638a	636a
	21	630a	632a	634a	632a
Leaf thickness (µm)	3	460a	460a	462a	460a
	7	460a	460a	460a	460a
	14	456a	456a	458a	458a
	21	454a	454a	458a	456a

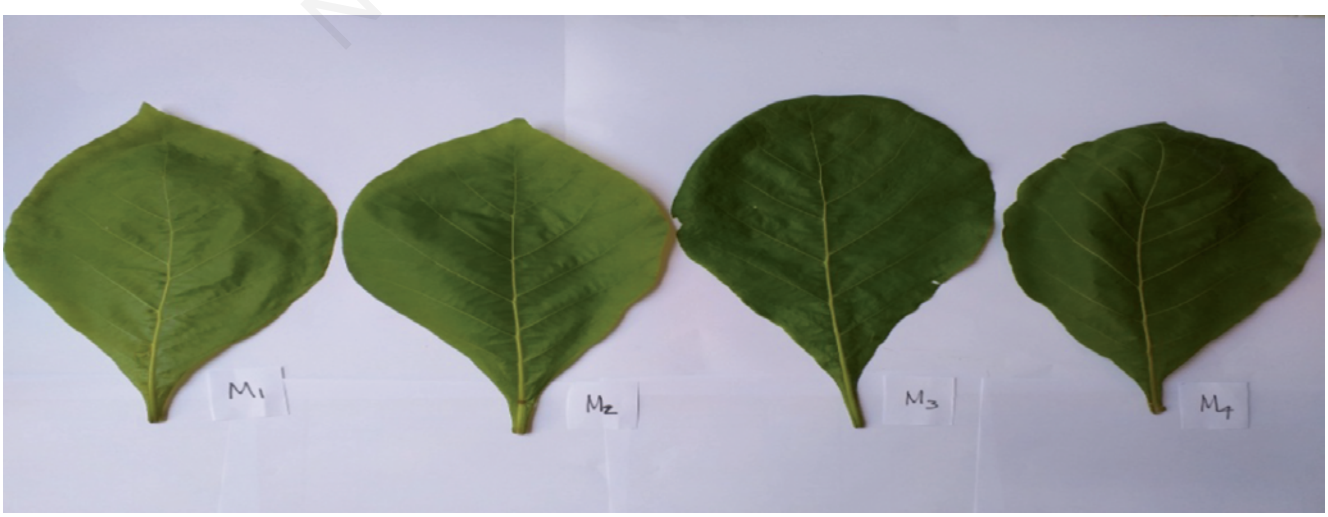

Figure 2. Appearance of teak seedling leaves on four types of growing media under drought stress.

total P, and water (Table 1). The results of the analysis of N and P content of teak seedling leaves were included in the moderate category after 120 days under drought stress. According to Luangjame *et al.*[16] the N content in teak leaves ranged from 1.02 to 1.36%. According to Drechsel *et al.*[17] the mature teak leaves contained N ranging from 1.35 to 2.20%, included in the high category and P content ranged from 0.10 to 0.21%, included inthe moderate category. According to Husni *et al.*[18] the P content of teak leaves ranged from 0.11 to 0.13%. Then the results of research by Supriyo *et al.*[19] show that the mature teak leaves contained N ranging from 0.52 to 1.28%, included in the moderate category and P content ranging from 0.04 to 0.10%, included in the moderate category.

In this study, the drought stress treatment caused water deficiency in growing media so that leaves of teak seedlings became yellow. Yellowing leaves will fall, and naturally, the plant maintains nutrient stability due to the loss of nutrients through the fall of the leaves. The response of the teak seedlings to water deficiency is shown by the color of yellowing leaves. Protein synthesis, cell wall synthesis, and chlorophyll synthesis are inhibited when water is deficient. The leaf discoloration is a process of aging and will eventually induce leaf abscission.[20] There is an internal nutrient cycle in leaves, where some nutrients are mobilized and pulled before leaf abscission.[21] Nutrient resorption indicates nutrients that are reabsorbed by plants during leaf aging. Absorption of nutrients during the process of leaf abscission is a nutrient conservation mechanism that is important in maintaining the condition of plant nutrient status (stand-level nutrient economy). According to Distel *et al.*[22] nutrient resorption from leaves that are undergoing aging allows plants to hold and reuse nutrients.

Based on results of the analysis of N resorption capacity of teak seedling leaves a range from 26 to 31% in M1, M2, M3, and M4 growing media under drought stress was shown (Figure 1). N resorption of teak seed leaves was influenced by the total N content in the growing media. According to Aerts *et al.*[23] the soil which is high in nutrients causes an increase in leaf nutrient content. If the leaves undergo an aging process, they will reabsorb nutrients. Then research by Frak *et al.*[24] showed that N resorption is strongly influenced by the availability of N in the soil.

The ability of P resorption of teak seedlings leaves ranged from 20 to 25%, which was lower than N resorption (Figure 1). This resorption of P was also related to the availability of total P in the growing media. This study shows that increasingly long drought stress causes a decrease in P resorption ability. The low efficiency of P resorption in the dry season results from drought stress which causes imperfect P resorption in aging leaves. The research by Prihastanti *et al.*[25] show that the resorption of P tends to decrease compared to N resorption in cocoa plants. The decrease in P resorption tends to be higher in plants that are exposed to drought stress. According to Drenovsky *et al.*[26] the mobility of nutrients differs following the speed and intensity of drought. The nutrient resorption efficiency increases with the increasing availability of N nutrients, but there is no response to P nutrients.

This study showed that teak seedlings aged 120 days had an average height growth ranging from 80 to 115cm, an average stem diameter ranging from 1.4 to1.8cm, an average leaf area ranging from 630 to 650cm^2, and an average leaf thickness ranging from 454 to 460µm usingfour types of growing media under drought stress (Table 3). The growth of teak seedlings was relatively similar to theresearch by Ridwan *et al.,*[27] which examined the growth of tetraploid and diploid teak aged 120 days. The research showed an average height ranging from 78 to 115cm, the diameter of the stem ranging from 1.4 to 1.8cm, the leaf area ranging from 580 to 760cm^2, and the thickness of the leaves ranging from 480-500µm under drought stress. The analysis showed that the M3 growing medium with the highest N and water content caused the highest growth of teak seedlings (115cm).

The high availability of nitrogen causes the process of cell division and enlargement, thus encouraging the growth of teak seedlings. Nitrogen plays a rolein the height growth and development of plant tissue. The growth of plant height begins with the process of cell division and enlargement for shoot formation. The cell division and enlargement process will occur when the cell experiences turgidity, which is the main element of water availability. High growth depends on the availability of nutrients, groundwater content, and sunlight.[28] The results of research by Tampubolon *et al.*[29] showed that the use of plastic mulch and rock mulch cancon serve water, causing a significant increase in teak height compared to other mulch. The average height increase was 49.35 and 44.46cm in a period of 6 months, while the control were only 32.93 and 32.96cm.

The height growth of teak seedlings decreased linearly with drought stress (Table 3). Teak seeds were young plants that were sensitive to water deficiency.[30] The plants that were not affected by drought stress will produce the highest plant height compared to those stressed. Declining plant growth in drought stress conditions was caused by low water availability. The deficiency of water decreases the pressure of the turgor cells. Decreased cell turgor pressure can inhibit cell division. Water available in sufficient quantities can control the occurrence of turgor pressure. Turgor pressure causes normal cell enlargement and division, so plant growth is also normal. Conversely, if water availability is low, the turgor pressure will be disrupted and cause cell enlargement so that the division can be disturbed. The resultsof research by Gopikumar and Varghese[31] show thatnitrogen deficiency affects the growth of teak seedlings on sand culture. All the chlorophyll fractions of treated seedlings, particularly nitrogen-deficient seedlings, reduced considerably. Visual symptoms of nitrogen-deficient seedlings also coincided with the reduced foliar levels of the concerned element.

While the growth of stem diameter, area, and thickness of teak seedlings leaves was not significantly different in the four types of growing media under drought stress (Table 3), the addition of husk charcoal (M2), chicken manure (M3), and compost (M4) as a mixture of growing media did not significantly affect the growth of stem diameter, area, and leaf thickness. Symptoms of nutrient-deficient teak seedlings in sand culture include leaf discoloration, necrosis, scorch, defoliation, and stunted growth. According to Palupi *et al.*[32] an increasingly drought stress caused a decrease in the growth rate of stem diameter, area, and thickness of teak seedlings leaves. The deficiency of water caused a decrease instem diameter rate. The reduced leaf area was a plant mechanism to suppress water loss and reduce transpiration. Plants experience a decrease in total leaf area in response to water deficits. The amount of reduction in total leaf area on plant growth depends on the amount of water lost and the rate and duration of stress conditions. Drought conditions with a lower cell water potential can limit cell enlargement, leading to decreased growth.[33] Decreased soil moisture causes a decrease in leaf size and dry weight production. Meanwhile, leaf thickness is also influenced by water availability. In the results of research by Kofidis and Bosabalidis[34] showed that the *Nepetanuda* (Labiatae) plant experienced changes in leaf tissue thickness with changes in height due to a deficiency of water. The thickness of leaves in some plant species of the Fabaceae family decreased in polluted areas and water deficiency.[35]

Conclusions

The mixture of organic material was influenced water content, total N and total P content in the growing media. Content of N and P of teak seedlings leaves was influenced by the content of total Nand total Pinthe growing media.The resorption of N and P ability of teak seedlings leaves was ranged from 26 to 31% and ranged from 20 to 25%. The water availability and nutrients in the growing media can affect the growth of teak seedlings. Water content, N and P resorption, and the growth of teak *Tectona grandis* L.f. seedlings were the best in M3 growing medium with three days of drought stress.

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