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Growth and Yield of Two Tomato Plant Varieties in Dryland Areas with Agronomic Modification Treatments

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Abstract: The yield of tomato plants in dryland areas has been suboptimal due to environmental constraints such as poor soil health and high sunlight intensity. Appropriate agronomic modifications are necessary to improve crop yields while maintaining soil health. This study investigated the impact of various agronomic modification treatments on the growth and yield of tomato plants in dryland regions. The experiment was conducted in Gumantar Village, North Lombok Regency, during the dry season from June to August 2023. The agronomic modifications included a seaweed biochar treatment at a rate of 10 tons per hectare and 45% shading, with a control group that had no modifications. Three treatments were tested on two varieties of tomato plants: hybrid and local superior. The treatments were organized with four replications in a randomized complete block design with split plots, where agronomic modifications served as the main plots and the tomato varieties as the subplots. The results indicated that the interaction of agronomic modifications and plant varieties impacted the growth of tomato plants and various environmental factors. The hybrid variety under shading treatment exhibited the best growth. Additionally, this hybrid variety produced 59.6% more fruit than the local superior variety, yielding an average of 66 fruits and weighing 3.00 kg per plant. This study suggests that incorporating agronomic modifications, such as biochar treatment and selecting the appropriate variety, can enhance tomato yields in dryland areas.

Keywords: hybrid; light intensity; organic matter; seaweed biochar; shading

Introduction

The findings of this study can serve as a valuable reference for dryland farmers seeking to cultivate tomato plants sustainably. Dryland regions are typically characterized by limited water availability and low soil fertility, particularly in eroded areas where the soil layer is thin and lacks organic matter (McLeod et al., 2020; Plaza et al., 2018). This situation is further worsened by the restricted use of organic fertilizers, especially for seasonal food crops. In tropical soils, the organic matter content declines rapidly, reducing by 30-60% within 10-30 years (Deng et al., 2016; Suriadikarta, 2012). The low soil fertility in these dryland areas increases the demand for agricultural inputs needed to achieve optimal productivity (Jaya et al., 2021). This high input demand can result in soil degradation, leading to diminished soil structure, nutrient loss, increased salinity, and a decline in soil microbial populations and activity. These factors ultimately impact soil health and crop productivity

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(Geisseler & Scow, 2014; Hina, 2024; Jote, 2023). Effective dryland management should be integrated and sustainable, adhering to conservation principles (Arrúe et al., 2019). These principles encompass approaches in dryland agriculture that enhance crop productivity, boost agricultural efficiency, and improve environmental quality through long term improvements in soil conditions (Rachman, 2017). Implementing these practices is essential to preventing and mitigating further ecological damage. Various management practices or agronomic modifications can be employed in dryland areas to optimize crop productivity and increase water use efficiency (Moswetsi et al., 2017).

Agronomic modification activities can involve several practices, such as adding organic matter, adjusting planting distances, managing pests, regulating light intensity and temperature for plants, and optimizing water use efficiently. Dryland areas often face biophysical limitations, including poor soil conditions, water scarcity, extreme temperatures, and low nutrient availability, all of which can adversely affect plant growth and yield (Ahmed et al., 2022). To address these challenges, it is essential to implement agronomic modifications in the soil that enhance water and nutrient use efficiency while maintaining soil health. One promising technology currently being developed to tackle these issues in dryland areas is biochar (Yeboah et al., 2020).

Biochar is a promising alternative for enhancing agricultural land and improving crop production. Applying biochar can significantly increase water retention, which is particularly beneficial in sandy soils (Adhikari et al., 2023; Yu et al., 2013). This is especially relevant in the North Lombok region, characterized by dry, sandy land (Jaya, 2021).

Utilizing seaweed as biochar offers an effective solution to environmental challenges, as it is safe for soil microbes and plants and increases economic value (Kaur, 2020). Incorporating algae as biochar can contribute to greater soil fertility and reduce plant mortality compared to fertilizers lacking algae due to its high mineral content. Seaweed biochar is rich in essential nutrients for plants, such as nitrogen (N), phosphorus (P), potassium (K), and calcium (Ca), which are present in high concentrations (Yu et al., 2017).

The low productivity of crops in dryland areas is not solely due to a lack of organic matter in the soil; high temperatures and intense light also influence it. High temperatures and light intensity can negatively impact plant growth and yield (López-Marín et al., 2012). One crop that is increasingly cultivated in dryland regions but is sensitive to high light intensity is the tomato plant (*Lycopersicum esculentum*). Tomato plants can thrive in hot environments with light irradiation levels up to 1000 μmol m^{-2} s^{-1} (Bednarczyk et al., 2020), but their optimal light intensity for growth lies between 500 and 800 μmol m^{-2} s^{-1} (Lu et al., 2017). In tropical regions, however, the light intensity can be significantly higher, reaching levels of 1200 to 1800 μmol $m{-2}$ $s{-1}$ (Grace et al., 1998). Therefore, it is necessary to reduce light intensity to help lower temperatures for optimal tomato growth.

High temperatures can lead to significant tomato yield losses, with reductions of up to 70% due to flower drop, which prevents fruiting (Ro et al., 2021). Shading techniques can help mitigate this issue by reducing solar radiation intensity, lowering temperatures, and improving plant water use efficiency (Mohawesh et al., 2022). Shading nets are one of the most used shading materials for horticultural crops. These nets vary in their ability to reduce sunlight intensity and come in different colors. Plants respond differently to various shading levels and shade nets' different colors (Godi et al., 2018).

The response of tomato plants to reduced light intensity caused by shading varies depending on several factors, including the plant variety (Gent, 2007). Generally, local superior varieties exhibit greater tolerance to suboptimal conditions than hybrid varieties (Ficiciyan et al., 2021). On the other hand, hybrid varieties usually demonstrate high productivity when grown under optimal environmental conditions (Carrillo-RodrÃguez et al., 2019). While there has been no reported research on the different responses of tomato plant varieties to biochar treatment, a meta-analysis has documented the effects of biochar on tomato yield and quality (Lei et al., 2024). This study aims to investigate the impact of agronomic modifications on the growth and yield of two tomato plant varieties cultivated in dryland areas.

Method

Location and experimental design

The research method employed in this study was experimental, using field experiments conducted in dryland areas. The experiment took place in Amor-Amor Hamlet, located in Gumantar Village, Kayangan District, North Lombok Regency, West Nusa Tenggara, from June to December 2023.

The experimental design utilized was a Randomized Complete Block Design with split plots consisting of four replications. The main plots focused on agronomic modifications, which included applying seaweed biochar at a rate of 10 tons per hectare, using a 45% shade net, and a control group with no agronomic modifications. The subplots comprised two tomato varieties: the hybrid Servo and the local superior Karuna.

Experimental procedures and crop management

The selected land was first cleared of previous crop residues and then plowed. After plowing, the soil was harrowed to create a smoother surface, and 24 planting beds were established based on the number of treatments. Each bed measures 600 cm in length, with a top surface width of 100 cm, a bottom surface width of 120 cm, and a height of 30 cm. The distance between beds within a block was 50 cm, while the distance between blocks was 75 cm.

Once the beds were prepared, NPK 'Pak Tani' fertilizer (16-16-16) was sprinkled as a base fertilizer at 600 kg ha^{-1}. Following this, seaweed biochar was applied by evenly spreading it along the planting rows at a rate of 6 kg per plot, equivalent to 10 tons per hectare. The seaweed biochar contains 43.60% organic carbon, 1.48% total nitrogen, 0.10% total phosphorus, 2.66% total potassium, 359 ppm total iron, 14 ppm total zinc, and 5.56% humic compounds.

After applying the base fertilizer and seaweed biochar, the plots' surfaces were covered with plastic mulch. The experimental beds were left for two weeks, during which soil moisture was maintained appropriately to allow the base fertilizer to decompose. The next step involved creating planting holes; each bed contained 20 holes with a spacing of 60 cm by 60 cm.

The seeds were planted in seedling trays filled with a growing medium made from a 1:1:1 mixture of manure, husks, and soil. Tomato seeds from the Servo variety (produced by PT. East West Seed) and the Karuna variety (produced by PT. Bintang Asia) are soaked in warm water for two hours. After soaking, one seed was placed in each hole of the seedling trays. Before planting, the growing medium was moistened to field capacity.

Once the seeds were planted, the seedling trays were covered with cloth for two days and placed in a shaded area to promote germination. The trays were moved to a nursery house covered with a shade net when the seeds germinated.

Regular maintenance includes watering, fertilizing (using a solution of 2.5 g NPK Pak Tani in 1 liter), and removing any weeds that grew in the nursery medium. Additionally, pesticide spraying was conducted to prevent aphids or leafhoppers that could transmit yellow or curly viruses. The seedlings were transplanted to the field after developing four leaves or 21 days after sowing.

Plant maintenance involves several essential tasks, including staking, irrigation, supplementary fertilization, and pest and disease control. For tomato plants, staking should be performed one week after transplanting to prevent damage to the roots when the stakes are inserted.

The stakes were set up triangular, with their tops tied together. Each stake was inserted 15 cm away from the plant on each side, reaching a depth of about 25 cm and standing 85 cm above the ground.

The next step was to install a bamboo shading frame. This dome-shaped frame was covered with a shade net 150 cm high at the center, 100 cm wide at the sides, and 120 cm wide at the top. The shade net should be installed one week after planting.

Irrigation was carried out using the drip irrigation method. The installation of the irrigation system involved arranging pipes and emitters to deliver water directly to the plant roots. The condition of the plants was monitored daily to ensure they received adequate water from the irrigation system. Supplementary fertilization for tomato plants was performed every two weeks by diluting the NPK fertilizer at a concentration of 5.68 g l^{-1}, and each plant received 250 ml of fertilizer solution. Pest and disease control was managed by spraying 30% spiropidion and 24% acetamiprid to prevent virus vectors such as thrips.

Observation parameters and data analysis

Observations and laboratory analyses were conducted on various parameters before planting, including pH, macronutrient content (nitrogen, phosphorus, potassium, calcium, and organic carbon), micronutrient content (magnesium), cation exchange capacity (CEC), and soil texture. Nutrient uptake was assessed by measuring the macronutrient content in plant tissues just before the first harvest. Additionally, the number of bacterial colonies in the treatment plots was recorded just before the first harvest, along with the chlorophyll content in the plant leaves.

During the first harvest, key growth variables for the tomato plants, such as plant height, number of leaves, branches, and stem diameter, were observed. Yield variables, including the number of fruits, fruit weight per plant, and total fruit weight per plot, were recorded at each harvest. Microenvironmental variables, such as temperature and humidity around the experimental site, were monitored periodically.

The collected data were analyzed using Analysis of Variance (ANOVA) at a 5% significance level. Simultaneously, Duncan's Multiple Range Test (DMRT) further examined significant interaction effects. In contrast, significant main effects were assessed with the Honest Significant Difference (HSD) test, also at the 5% significance level.

Result and Discussion

General Overview of Experimental Conditions

The recorded air temperature during the experiment was relatively high for tomato plants. The highest air temperature experienced during the experiment was 38°C, and the lowest was 20°C, with an average of 29.1°C. Such temperature conditions are not optimal for the growth and development of tomato plants. Previous studies have stated that the optimum temperature for the growth and development of tomato plants is between 15°C and 32°C, and pollen fertility decreases when the air temperature exceeds 35°C (Lu et al., 2017). Meanwhile, the air humidity during the experiment ranged from 52% to 80%. However, studies show that air humidity does not affect the growth or fertility of pollen, thus not affecting crop yield. A general overview of the experimental conditions is presented in Figure 1.

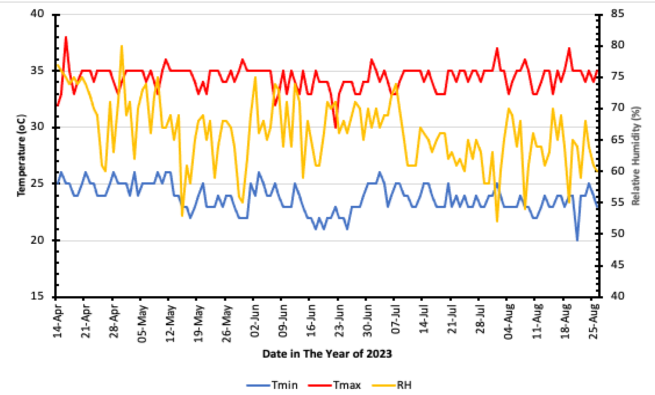

Figure 1. Ambient temperatures and relative humidity at the experimental site during the experiment

Both tomato plant varieties grew well at the experimental site but did not perform optimally. A decline in the appearance of tomato plants began around 45 days after planting (DAP) with symptoms such as upward curling leaves and brown spots on the leaves, indicating thrips infestation. Some young leaves or leaves at the tips show yellowing and curling, characteristic of viral infection. It was suspected that the tomato plants, after entering the generative phase, started to be infected by the tomato yellow leaf curl virus (TYLC), which commonly affects tomato plants in this climate change condition (Ramos et al., 2019). The primary vector of this virus is the insect *Bemisia tabaci*, also known as the white fly (Li et al., 2021).

The plants exhibited calcium (Ca) deficiency symptoms during the fruit development phase. This was evident from the appearance of rot at the bottom (base) of the tomato fruits, known as bottom end rot (BER). This condition was quite ironic because the levels of exchangeable Ca and Mg in the soil at the experimental site were categorized as high (Table 1). It was suspected that the drip irrigation used could not dissolve the calcium compounds in the soil, preventing their absorption by the plants. This issue could be immediately addressed by applying fertilizers with high calcium content.

The land at the experimental site can be categorized as less fertile with deficient levels of organic C, nitrogen, and cation exchange capacity (CEC) (Table 1). The soil acidity level (pH) was neutral, maintaining nutrient availability. Surprisingly, the phosphorus (P), potassium (K), and calcium (Ca and Mg) contents fell into the high to very high categories. The intensive use of NPK Phonska (15-15-15) fertilizer at the experimental site during previous crop cultivation is suspected to cause a high P and K content. Meanwhile, the soil texture is classified as sandy loam with sand, silt, and clay percentages of 56.7%, 30.0%, and 13.3%, respectively.

Table 1. Some soil chemical properties at the experimental site before the trial

Parameter	Method	Unit	Results	Catagory
pH (H_2O)	Elektrode		6.5	Neutral
C-Organik	Spectro	%	0.64	Very low
N-Total	Kjeldalh	%	0.06	Very low
P-Available	Spektro	ppm	26.86	Very high
K-Exchangeable	(amon. acetate) AAS	me/100 g	0.61	High
Ca- Exchangeable	(amon. acetate) AAS	me/100 g	16.94	High
Mg- Exchangeable	(amon. acetate) AAS	me/100g	2.45	High
KTK	(amon. acetate)	me/100 g	4.8	Very low

The effect of treatments on the microenvironment conditions of plants

The variance analysis (ANOVA) results show that the variety had no significant effect on soil temperature and bacterial population (Table 2). However, agronomic modification treatments, including applying biochar and shading with 45% shade net, showed significantly different effects. Both in-soil modifications (biochar) and above-soil modifications (shading) could reduce soil temperature significantly. The lowest temperature was obtained with the shading treatment using a shade net, and the control treatment produced the highest temperature. The reduction in solar energy reaching the soil surface due to the shade net treatment caused lower temperatures under the shade (Masabni et al., 2016) compared to other treatments. Meanwhile, organic matter in the soil can reduce heat transfer from solar energy (Zhu et al., 2019), resulting in lower soil temperatures in the biochar treatment compared to the control treatment.

A significantly higher number of bacterial colonies were found in the hybrid tomato variety (Servo F1) environment than in the local tomato variety, Karuna. No apparent reason was found for this phenomenon because the observed bacteria were total colonies. There were no observations related to bacterial species that might have a specific association with tomato varieties.

In the agronomic modification treatments, the highest microbial population (bacteria and fungi) was observed in the biochar treatment (Table 2). This is common because microbes require organic matter to grow and develop well. Biochar also provides a growth environment for microbes due to its porous structure with numerous macro pores (Palansooriya et al., 2019). Adding organic matter through applying seaweed biochar can serve as a food source for microbes, allowing them to grow and develop better than other treatments. Previous studies have shown that adding biochar can increase microbial populations in agricultural land (Blackwell et al., 2015). Meanwhile, the microbial population, especially bacteria, in the control treatment was higher than in the shading treatment. This is likely related to soil temperature, as soil temperature determines the rate of organic matter decomposition in the soil (Conant et al., 2011). It is suspected that soil temperature under the shading treatment was less optimal for the decomposition activity of organic matter in the soil, leading to less available organic matter, which serves as food for soil microbes.

Table 2. Effect of treatments on soil temperature, total microbes and total chlorophyl in leaves measured at 60 DAT

Treatments		Measured parameters	
Variety	Soil temperature (^oC)	Total microbes (CFU) × 10^6	Total chlorophyl (mg l^{-1})
Hybrid	29.9	1.52b*	19.64
Local superior	30.8	1.02a	19.20
BNT	-	*0.49*	-
Agronomic Modification			
Without	31.6c	1.31ab	17.4
Seaweed biochar	30.1b	1.54b	17.2
Shading	28.3a	0.97a	23.6
LSD	*1.00*	*0.54*	-

*Values in the same column and the same treatment followed by different letters are significantly different according to Least Significant Different (LSD) at 5% level.

The leaves' chlorophyll content was influenced by agronomic modifications but not by the variety (Table 2). The plants produced the highest chlorophyll A, B, and total chlorophyll content under the shade net. The reduction in sunlight intensity by 45% due to the shade net made the leaves appear greener than plants in other treatments. This was reflected in the high amounts of chlorophyll A, B, and total chlorophyll in the shaded plants. According to (Delgado-Vargas et al., 2023), tomato plants grown in areas with high light intensity will grow more optimally if sunlight intensity is reduced using shading materials, such as the shade net used in this study. Studies on sage (*Salvia officinalis*) have also shown that chlorophyll increases with shading treatments (Rezai et al., 2018). In this case, if certain plant species grow under light intensity conditions exceeding their optimum needs, reducing light or shading can increase the plant's chlorophyll content.

The effect of treatments on plant growth and yield variables

The significant differences in the effects of variety and agronomic modifications on soil bacterial populations did not significantly affect the macronutrient content in the plant leaf tissues. The data in Table 3 show that the nitrogen, phosphorus, and potassium content in the leaf tissues of both tomato plant varieties did not differ significantly. This indicates that the supplementary fertilization applied every two weeks had a more dominant influence than the agronomic modifications applied. The increase in the microbial population in the biochar treatment could not increase the macronutrient content in the plant leaves.

Table 3. Effect of treatments on total nitrogen (N), phosphorous (P) and potassium (K) in leaves measured at 60 DAT

Treatments			Measured parameters
Variety	Total N (%)	Total P (ppm)	Total K (ppm)
Hybrid	1.59	0.34	0.82
Local superior	1.61	0.30	0.87
BNT	-	-	-
Agronomic Modification			
Without	1.56	0.31ab	0.81
Seaweed biochar	1.59	0.30a	0.82
Shading	1.65	0.36b	0.90
LSD	-	*0.05*	-

*Values in the same column and the same treatment followed by different letters are significantly different according to Least Significant Different (LSD) at 5% level.

Tomato plants grown under high light intensity conditions, if provided with 50% shading, will become taller, with broader leaves and more extensive root systems (Delgado-Vargas et al., 2023). High sunlight intensity causes high evapotranspiration in tomato plants (Yang et al., 2022), especially in dryland areas where water is limited. Shading provided a favorable environment for tomato plants to grow (Masabni et al., 2016). The same phenomenon was observed in this study, where the size of the plants (height and stem diameter) under 45% shading was significantly larger than those in other treatments (Table 4). Unfortunately, this study did not measure leaf area, but field observations showed that shaded plants also had larger leaf sizes than non-shaded plants.

Table 4. Effect of treatments on plant height, leaves number, stem diameter dan number of branches of tomato plants measured at 60 DAT

Treatments				Measured parameters
Variety	Plant height (cm)	Leaves number	Stem diameter (mm)	Number of branches
Hybrid	123.9b	29.6	14.8b	8.4
Local superior	85.8a	31.8	12.1a	7.3
LSD	*13.86*	-	*0.45*	-
Agronomic modification				
Without	89.3a	29.8	12.7a	8.2
Seaweed biochar	92.1a	30.7	13.1a	8.0
Shading	133.1b	31.5	14.5b	7.3
LSD	*13.86*	-	*0.45*	-

*Values in the same column and the same treatment followed by different letters are significantly different according to Least Significant Different (LSD) at 5% level.

In addition to being influenced by agronomic modifications, plant height and stem diameter were also affected by variety (Table 4). The hybrid variety Servo was taller than the Karuna variety and had a larger stem diameter. Compared to the variety descriptions of these two tomato varieties, both were within the height category described. However, in terms of stem diameter, the Karuna variety had a much smaller stem than expected, which was 20.0 to 25.0 mm. Meanwhile, the Servo variety produced a stem diameter much more significant than described, 12.0 mm. This indicates that the hybrid variety Servo could better adapt to light intensity and temperatures that exceed the optimal conditions for tomato plants than Karuna. However, regarding the number of leaves and productive branches, neither variety nor agronomic modifications had a significant effect (Table 4).

The fact that the Servo variety could better adapt to sub-optimal growing conditions was shown by the yield and yield components of the tomato plants (Table 5). The crop yield (fruit weight per plot) and yield components, which include the percentage of flowers turned into fruits, the number of fruits per plant, and the fruit weight per plant, were higher for the Servo variety. The number of fruits per plant produced by the Servo variety was higher than the range described, which was 31 to 53 fruits per plant. According to the variety description, the fruit weight per plant falls into the high category, with a weight between 2.11 and 3.49 kg per plant. However, the Karuna variety produced a much lower number of fruits per plant than its potential yield of 72 to 80. Similarly, the fruit weight per plant was below its potential of 3.0 to 3.5 kg per plant. This is suspected to be due to sub-optimal growing conditions. It is known that the Karuna tomato variety is recommended to be planted at an altitude of 100 to 350 meters above sea level (masl). Meanwhile, the experimental site was at an altitude of 40 masl.

Table 5. Effect of treatments on fruit set, yield and yield components

Treatments				Measured parameters
Variety	Fruit set (%)	Fruit number plant^{-1}	Fruit weight plant^{-1} (g)	Fruit weight plot^{-1} (kg)
Hybrid	40.3	66.4b*	3003.6b	16.8b
Local superior	22.0	48.2a	1879.8a	12.0a
LSD	-	*15.90*	*845.71*	*3.92*
Agronomi modification				
Without	32.0	55.8	2087.9	14.3ab
Seaweed biochar	33.5	64.0	2805.6	16.5b
Shading	27.9	52.2	2431.7	12.5a
LSD	-	-		*3.92*

*Values in the same column and the same treatment followed by different letters are significantly different according to Least Significant Different (LSD) at 5% level.

The percentage of flowers that turn into fruit (fruit set) in both varieties was meager, but the Servo variety had a higher percentage (Table 5). According to existing theories, daytime temperatures exceeding 29°C or nighttime temperatures exceeding 21°C can cause flower drop. This was also influenced by the low availability of nitrogen in the soil (Ozores-Hampton & McAvoy, 2010). Referring to the temperature data at the experimental site in Figure 1, the maximum and minimum air temperatures consistently exceeded the optimum range for fruiting. Additionally, fertilization was done using a balanced compound fertilizer with percentages of N, P, and K at 16-16-16. Data in Table 1 show that the soil at the experimental site was impoverished in nitrogen but rich in phosphorus and potassium. This suggests that the high percentage of flower drops was likely due to the high-temperature conditions and the lack of applied nitrogen fertilizer. (Luo et al., 2023) state that under high-temperature conditions, the nitrogen needs of tomato plants should be optimized to ensure high yields.

Agronomic modification treatments did not affect the yield (fruit weight per plot) and yield components (percentage of flowers turning into fruits, number of fruits per plant, and fruit weight per plant), as shown in Table 4. This differs from the theory that a significant reduction in sunlight intensity can increase tomato plant yields (Ilić et al., 2012). It is suspected that other factors, such as the high air temperature around the experimental site, were affecting the plant yields besides the treatments applied. Similarly, using biochar in tomato plants can increase crop yields due to enhanced water retention capacity (Akhtar et al., 2014). However, with biochar applied only once and over a very short period, its potential effects may vary, as (Lehmann & Joseph, 2015) discussed.

The effect of treatments on the availability of nutrients in the soil

The variety and agronomic modification treatments did not affect the availability of macronutrients in the soil 60 days after planting (DAP) (Table 6). Previously, Table 3 showed no significant differences in the macronutrient content (N, P, and K) in the plant leaf tissues at 60 DAP. This fact indicates that the availability of these macronutrients was relatively the same in the plant growth environment, as shown in Table 6. This means that the differences in plant growth (plant height and stem diameter) in the two tested varieties were due to the increased efficiency of nutrient utilization in the shading treatment and not due to the increased availability of nutrients in the soil due to the biochar treatment.

Table 6. Effect of treatments on the availability of soil macronutrients at 60 DAP

Treatments			Measured parameters
Variety	N-total (%)	P-available (%)	K-exchangeable (ppm)
Hybrid	0.04	45.82	0.82
Local superior	0.04	47.59	0.87
LSD	-	-	-
Agronomic modification			
Without	0.04	41.13	0.81
Seaweed biochar	0.04	56.22	0.82
Shading	0.04	42.77	0.90
LSD	-	-	-

Laboratory studies have shown that biochar can increase cation exchange capacity and the availability of certain nutrients in the soil (Hailegnaw et al., 2019). However, in field conditions, the effects of biochar can vary significantly regarding growth, yield, and nutrient availability in the soil, as described by (Lehmann & Joseph, 2015). This variability could also be due to differences in the raw materials used for biochar compared to those reported in previous studies, affecting the impact of biochar on soil nutrient availability. According to the data in Table 6, the effect of agronomic modifications on the availability of macronutrients in the soil is highly variable, particularly concerning phosphorus and potassium availability. For phosphorus availability, the biochar treatment shows the highest values, while the shading treatment yields the highest values for potassium availability. However, it should be noted that none of the applied agronomic modifications significantly affected the availability of macronutrients in the soil.

Conclusion

There is no interaction between the variety and agronomic modifications in affecting environmental variables, growth, yield, and nutrient conditions (nutrients) in plant tissues. The hybrid tomato variety Servo is more adaptive to sub-optimal growing conditions for dryland tomato plants than the open-pollinated variety Karuna—the better growth and yield of the Servo variety evidence this. Meanwhile, agronomic modifications can alter soil temperature, microbial populations, and plant growth but have yet to be able to increase crop yield. Tomato plants given biochar produced better yields than control plants or plants given shading, although shaded plants showed the best growth.

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Author Contributions
Idea and methodology of the study, I Komang Damar Jaya and Baiq Eliza Prizma Mahardhika; field establishment and coordinating for data collection, Baiq Eliza Prizma Mahardhika, Sudirman and I Gede Putu Wirarama Wedashwara Wirawan; data analysis and interpretation Bambang Budi Santoso. Preparation of the draft, I Komang Damar Jaya and Baiq Eliza Prizma Mahardhika; writing-review, Bambang Budi Santoso and editing, Baiq Eliza Prizma Mahardhika.

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Conflicts of Interest
The authors declare no conflict of interest.

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