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Increasing Tomato Yield in a Sandy Dryland Through the Application of UV Plastic Shade and Soil Amendment

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Abstract: Cultivating tomato plants in dry, sandy soils aims to achieve high yields while enhancing or maintaining soil fertility. This study investigates the effects of soil amendments and ultraviolet (UV) plastic shade on tomato yield and various indicators of soil fertility. The experiment was conducted in the dryland of Gumantar village, North Lombok Regency, Indonesia, during the dry season from May to August 2024. The soil amendment factor included three levels: no soil amendment, chicken manure, and seaweed biochar. Meanwhile, the shading factor consisted of two levels: no shading and shading with UV plastic (200-micron thickness, which transmits 86% of UV light). All treatments received inorganic NPK fertilizer (16-16-16) at a rate of 1,200 kg per hectare. Treatments were arranged factorially using a randomized block design with three replications. Results showed an interaction between soil amendments and shading that affected soil pH, the number of fruits, and fruit weight per plant and plot. The highest fruit weight per plant, recorded at 4.2 kg with 100.7 fruits, was achieved using seaweed biochar and shading. The treatments slightly improved soil fertility indicators, such as soil organic carbon (C-organic), total microbial count, and cation exchange capacity. Applying soil amendment and UV plastic shading can be a sustainable practice for tomato crops production in sandy dryland soils.

Keywords: Agronomic Management; Chicken Manure; Seaweed Biochar; Soil fertility; ultraviolet

Introduction

This study significantly contributes to advancing tomato crop production in sandy dryland soils. Dryland regions, home to over two billion people, have an aridity index ranging from 0.05 to 0.65 (Huang et al., 2017). Typically, many arid areas have already undergone deterioration, making them susceptible to turning into deserts. This occurs when the soil in these regions loses its ability to bind and retain water and nutrients and has diminished water infiltration capacity and nutrient recycling ability. Variousmfactors, including inadequate land management, cause the degradation of these dry areas (Sterk & Stoorvogel, 2020) and climate change (Burrell et al., 2020). The tangible impact of unsatisfactory land management and climate change in these areas is the decrease in organic carbon in the soil, resulting in reduced soil fertility or soil health (Li et al., 2018). If this trend continues, these dry regions may transform into deserts, rendering them unsuitable for agriculture.

Dry areas in the North Lombok Regency (NLR) region, part of the Rinjani Geopark, have low levels of organic carbon (C-organic). Mostly, the C-organic content in NLR drylands ranges from 0.87 to 1.27% (Jaya, 2021), significantly below the minimum C-organic threshold for healthy soil, which is around 1.5-2.0% around the root zone, and ideally should be higher to enhance soil fertility (Lal, 2016). Fertility, in this context, pertains to good soil binding ability, excellent water and nutrient retention capacity to improve usage efficiency, and the creation of optimal conditions for beneficial microbes in the area around plant roots.

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The low C-organic content in NLR drylands necessitates high agricultural inputs (fertilizers) for optimal crop production. However, the use of substantial amounts of inorganic fertilizers not only leads to high production costs and environmental damage but also harms soil microorganisms (Wei et al., 2024). If the use of inorganic fertilizers is not curbed and soil conditions are not improved, there is a potential risk of desertification of drylands (Sun et al., 2023). This occurs due to the continual decrease in organic matter in the soil (Lal, 2020). Therefore, agricultural management actions that create optimal plant growth and development conditions while maintaining environmental sustainability are crucial for utilizing drylands.

Agronomic modifications can be executed in various ways, such as incorporating organic matter and fertilizers into the soil, adjusting planting distances, managing plant pests, regulating light intensity and temperature around plants, and optimizing and efficiently using water. For drylands, like those in NLR, a swift measure that could be taken to raise the soil's organic matter content is applying soil amendments, such as manure and biochar. Augmenting organic matter in the soil can enhance the soil's physical, chemical, and biological properties (Singh et al., 2022), thereby increasing the efficiency of water and fertilizer utilization (Voltr et al., 2021). The consortium of soil microbes that aid nutrient cycling or protect plants also increases due to heightened organic matter content in the soil (Gryta et al., 2020).

Recently, seaweed extracts have been reported to have properties that can stimulate plant growth (Ali et al., 2021), protect plants from pathogen (Mamede et al., 2023), as well as improve fruit quality, such as in apple (Yang et al., 2023). Another study suggests that seaweed-based fertilizer can increase and improve the quality of crop yield as well as improve microbe's consortium in the soil (Pei et al., 2024; Prasedya et al., 2022). Seaweed biochar has also begun to be used because it can provide high macro nutrients and carbon (Katakula et al., 2020) and be used as a soil amendment (Roberts et al., 2015)(Robert et al., 2015). Based on those and other studies' results, the applications of seaweed products in agriculture are considered as the move toward sustainable crop production (Kaur, 2020) because seaweed is a renewable product and has the ability to sequester carbon (Veeragurunathan et al., 2023). The application of manure and biochar to the soil is one of the agricultural management approaches to improve the plant-growing environment so that the genetic potential of the plants can be well expressed. Applying biochar to the soil, in addition to enhancing the soil's physical, chemical, and biological properties, is also able to lower soil temperature (Ahmad Bhat et al., 2022).

Another factor that impacts plant productivity in drylands is climate change which leads to high intensity of light and temperature (Ahmed et al., 2022). Plants like tomatoes with a C3 photosynthesis cycle are not tolerant of high temperatures and light intensity due to high photorespiration (Lu et al., 2017). High temperatures can cause up to 70% yield loss in tomatoes due to flower drop, preventing fruiting (Ro et al., 2021). It was reported earlier that heat stress can have adverse effects on fertilization that lead to a low reproduction rate (Resentini et al., 2023). Meanwhile, the optimum light intensity for tomato plants is 500 to 800 μmol m^{-2} s^{-1} (Lu et al., 2017), far below the sunlight intensity in tropical areas that can reach 1200 to1800 μmol m^{-2} s^{-1} (Grace et al., 1998; Tripathi et al., 2020). In addition to the high light intensity, the sunlight in the tropics also carry high ultraviolet (UV) radiation due to ozone depletion in the atmosphere (Bais et al., 2019; Barnes et al., 2022). High UV radiation can reduce the photosynthetic capacity of some plants (Z. Chen et al., 2022) and can cause oxidative stress (Correa et al., 2023). Agronomic modifications must be made to attain optimal tomato yields, such as reducing sunlight intensity and UV radiation. The interaction between UV plastic shading and soil amendments can synergistically impact both factors in influencing the microclimate around tomato plant growing areas. This study examined the impact of reducing sunlight intensity using UV plastic and increasing organic matter in sandy dryland soil on tomato yields.

Method

Site Description and Experimental Design

One field experiment was conducted on a dryland owned by a farmer in the hamlet of Amor-amor, Gumantar village, North Lombok Regency (NLR) (latitude -8.253208, longitude 116.288624). The experimental site is situated approximately 40 meters above sea level. The experiment occurred during the dry season, from May to September 2024.

The study tested three soil amendment treatments: no soil amendment, chicken manure soil amendment, and seaweed biochar soil amendment, with a dosage of 10 tons per hectare for each amendment. Additionally, the experiment included shading treatments carried out at two levels: without and with shading. The shading material used was polyethylene UV plastic, with a thickness of 200 microns and a UV radiation rejection capability of 14%. All treatments were arranged factorially using a randomized block design, with three replications for each treatment combination. The procedure of the experiment is presented in Figure 1.

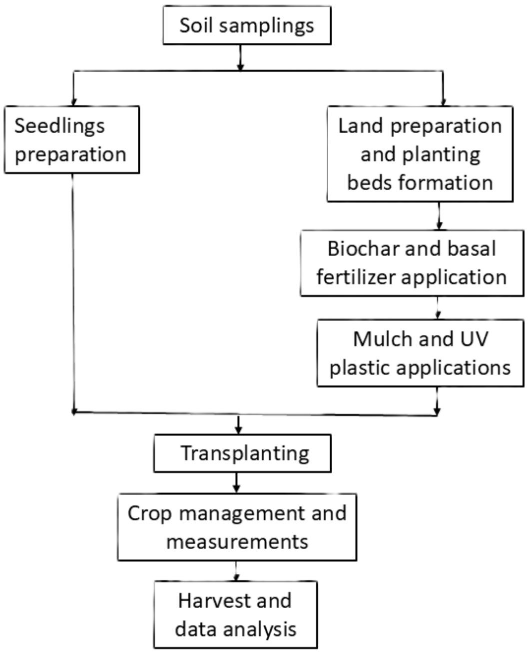

Figure 1. The process of the experiment

Planting beds Preparation

The initial steps of this experiment involved selecting three rows of existing beds from the previous tomato planting that could accommodate all the planned treatments. These three chosen rows were then divided into six beds each, resulting in a total of 18 beds, with each bed measuring 6 meters in length. The beds have a base width of 120 cm and a top width of 100 cm, with a height of 20 cm. The distance between each bed within a block was 50 cm, while the distance between blocks was 75 cm. The beds' top surfaces were already covered with plastic mulch from the previous planting. The existing planting holes were spaced 60 cm apart between rows and 60 cm apart within rows.

Cleaning the planting beds involved removing the remnants of the previous tomato plants and any weeds growing along the edges. After that, minimal soil tillage was performed using a hoe along the rows of planting holes and alternately lifting the plastic mulch on one side. On the prepared beds, NPK (16-16-16) *Pak Tani* fertilizer was applied as a base fertilizer at a 760 kg ha^{-1} rate, equivalent to 456 g $plot^{-1}$. This fertilizer was mixed evenly into the soil. The total amount of fertilizer applied, including base and supplementary fertilizers, was 1,200 kg ha^{-1}. This high fertilizer dosage referred to the standard local farmers' practice for growing tomatoes on sandy dryland soil.

Chicken manure and seaweed biochar were added to each treatment in the planting holes and mixed well with the soil. Each planting hole in the soil amendment treatments received 300 g of either chicken manure or seaweed biochar. After applying the base fertilizer and soil amendments, the surface of the experimental plots was covered again with the previously used plastic mulch. The chicken manure nutrient properties were organic carbon (C) 29.15%, total nitrogen (N) 1.15%, total phosphorus (P) 4.44%, total potassium (K) 2.58%, total magnesium (Mg) 1169.4 ppm, calcium (Ca) 3.87%, and boron (B) 182.38 ppm. On the other hand, the seaweed biochar nutrients composition was organic carbon (C) 43.60%, total nitrogen (N) 1.48%, total phosphorus (P) 0.10%, total potassium (K) 2.66%, total iron (Fe) 359 ppm, total zinc (Zn) 14 ppm, and humic compounds 5.56%.

Plants Culture and Management

Servo tomato seeds produced by PT. East West Seed was soaked in warm water for two hours. After soaking, only the seeds that sank were planted, one per hole, in seedling trays. The growing medium consisted of a mixture of chicken manure, husk, and soil in a 1:1:1 ratio. Before planting the seeds, the growing medium was moistened to field capacity. After planting, the seedling trays were covered with a cloth for two days and placed in a shaded area to promote germination.

Once germination occurred, the seedling trays were moved to a nursery house covered with black shade netting with 45% light interception. The maintenance involved regular watering and applying a fertilizer solution (2.5 g of NPK *Pak Tani* dissolved in 1 liter of water) 20 days after sowing. Additionally, weeds growing in the seedling medium were removed, and pesticides were sprayed to prevent aphids or thrips that could potentially spread the yellow virus or curly virus.

Before transplanting, bamboo stakes measuring 120 cm in length and 4 cm in width were placed around each planting hole in a crosswise position relative to the adjacent planting holes between rows. The final arrangement of the stakes resembled the letter 'X' and stood approximately 80 cm above the ground. After installing the stakes, the next step was to set up the bamboo shade frame. This shade frame was constructed in a dome shape, with a center height of 150 cm and a width of 120 cm.

Tomato seedlings with four leaves (24 days after sowing) were planted in the existing planting holes in the late afternoon and watered adequately. One week after planting, the shaded UV plastic was installed, measuring 6 meters in length and 3 meters in width. To ensure good air circulation underneath the shade, the UV plastic at the bottom of the shade was folded up by 30 cm.

Plant maintenance involves several vital activities: irrigation, supplementary fertilization, and pest and disease control. Irrigation was tailored to the plant's specific needs and was accomplished through gravity irrigation. This method flooded the beds to about half their height for approximately 15 minutes. The irrigation water was sourced from a deep well pump near the experimental site. Supplementary fertilization was performed using the same NPK fertilizer as the base fertilizer. This process was conducted three times: the first application occurred 15 days after transplanting (DAT) with a dosage of 80 kg ha^{-1}, the second at 35 DAT with 120 kg ha^{-1}, and the third at 56 DAT with 240 kg ha^{-1}. Pest control was handled by spraying pesticides that contained 30% spiropidion and 24% acetamiprid. This spraying primarily targeted virus vectors, such as aphids and thrips. The pesticide was applied routinely once a week until the plants reached 49 days of age.

Measurements and Data Management

Laboratory observations and analyses assessed various factors, including pH levels, macro and micronutrient content (nitrogen, phosphorus, potassium, calcium, magnesium, and organic carbon), cation exchange capacity (CEC), and soil texture before planting. Daily ambient temperature data (maximum and minimum) and relative humidity at the experimental site were recorded using a thermo-hygrometer. Additionally, rainfall data were collected with a rain gauge installed at the site.

The soil fertility indicators measured at the first harvest included pH, organic carbon, CEC, and total microbial content. Growth and yield indicators for the tomato plants included plant height, stem diameter, number of productive branches, percentage of flowers that developed into fruits (fruit set), overall yield, and yield components. Leaf chlorophyll was also measured as a supporting parameter.

The collected data were analyzed using Analysis of Variance (ANOVA) at a significance level of 5%. If significant treatment effects were detected for the measured parameters, these were further examined using the Honestly Significant Difference (HSD) test at the same significance level. Duncan's Multiple Range Test (DMRT) was applied in cases of significant interaction effects at a 5% significance level.Research design and method should be clearly defined**.**

Result and Discussion

Microclimate and general effects of treatments

The tomato plants grew well up to the first harvest. Pest disturbances, particularly thrips sp., began to appear after the first harvest, causing some plant leaves to curl upwards, a uniform symptom across all treatment plots. Besides thrips pest disturbances, no significant pest and disease problems could reduce plant yields.

Environmental conditions, including air temperature and relative humidity (RH), were optimal for the Servo tomato variety to grow and develop. The average maximum air temperature during the experiment reached 34^0C, while the minimum was 25.3^0C. Such temperatures were still optimal for the Servo tomato variety, developed for planting in tropical lowlands. Some studies mention the optimal temperature for tomato plants is 26^0C, and temperatures 10^0C above this optimum can cause flower failure in pollination (Mubarok et al., 2023). Meanwhile, the average RH during the experiment was 68.3%. Such humidity levels are pretty optimal for tomato plants to grow. Earlier research results in a controlled environment also showed that humidity levels like those at the experimental site are still within the optimal conditions for tomato plants to grow (Jankauskienė & Laužikė, 2023).

Tabel 1. Some soil chemical properties at the experimental site prior to treatments

Parameters	Value	Grade
pH H_2O (Electrometry)	6.81	Neutral
C-organic % (Wakey & Black)	1.11	Low
N total % (Kjeldahl)	0.09	Very low
P available ppm (Bray)	149.01	Very high
K total % (AAS)	0.67	High
Ca exchange meq/100g (Ammonium Acetate)	4.75	Low
Mg exchange meq/100g (Ammonium Acetate)	1.26	Moderate
Cation Exchange Capacity meq/100g (Ammonium Acetate)	12.47	Low

The soil texture at the experimental site is sandy loam with a composition of 15% clay, 15% silt, and 70% sand, with a fertility level classified as low. This can be seen in Table 1, where the organic C content, which significantly determines other soil chemical properties such as nitrogen content, pH, and CEC, was very low to low. However, the available phosphorus content was very high, while the soil potassium content was also high. Intensive land used for growing chili and tomato plants using NPK compound fertilizer likely resulted in high P and K residues in the soil.

Agronomic modification treatments through UV plastic shading and soil amendments did not affect tomato plants' growth and growing environment conditions. The treatments only affected yield and some yield components of tomato plants. Interaction between shading and soil amendment treatment influenced parameters such as the number of productive branches, number of fruits per plant, fruit weight per plant, and fruit weight per plot. Meanwhile, the single factors of shading and soil amendments significantly affected almost all tomato plants' growth, yield, and yield components. However, the agronomic modification treatments did not significantly affect the percentage of flowers turning into fruits (fruit set), total chlorophyll, total soil microbes, organic C, and soil CEC.

Effect shading and soil amendment interaction on some parameters

The interaction between UV plastic shading and soil amendments affects soil pH. The optimal soil pH value (6.6) was obtained from the no shading treatment combined with seaweed biochar (Table 2). The activity of decomposer microbes in the soil is greatly influenced by UV radiation (Paul et al., 2012). Reducing UV radiation can slow down the soil's decomposition process of unstable organic matter, such as chicken manure, and hence slowing the process of improving soil pH. Moreover, the impact of UV radiation on the decomposition process is affected by many biotic and abiotic factors (Hussain et al., 2023). As is well known, biochar is a stable organic soil amendment that can increase soil pH (Hailegnaw et al., 2019).

Table 2. Effect of shading and soil amendment interaction on some measured parameters

Parameters		Soil amendments		
	Shading	No Amendment	Chicken manure	Seaweed biochar
Productive branches	No shading	7.8[a*]	9.6[c]	8.0[ab]
	Shading	8.7[abc]	8.2[abc]	11.4[d]
Fruits per plant	No shading	56.3[a]	63.7[ab]	60.0[ab]
	Shading	68.7[ab]	71.7[b]	100.7[c]
Fruits weight per plant (g)	No shading	1,861.2[a]	2,221.7[ab]	2,358.0[b]
	Shading	2,808.3[c]	2,888.5[c]	4,228.0[d]
Fruits weight per plot (kg)	No shading	36.3[a]	41.5[ab]	47.0[b]
	Shading	55.0[c]	65.9[d]	80.7[e]
Soil pH	No shading	4.9[a]	5.3[b]	6.6[c]
	Shading	5.3[b]	5.2[b]	5.4[b]

*Values in the same parameter followed by different superscript letters significantly differ according to DMRT at a 5% level.

Meanwhile, organic materials like chicken manure sometimes have unstable properties depending on their level of composting. Chicken manure can lower soil pH if nitrification by microbes still occurs (Rayne & Aula, 2020). Such conditions might have happened in this study, resulting in the highest pH value from the UV plastic shading treatment combined with biochar.

Soil amendments not only improve physical soil properties such as aggregation, porosity, and water-holding capacity but also increase the availability of nutrients in the soil (Ahmad Bhat et al., 2022). The optimal conditions in the soil were reinforced by the reduced solar radiation and remarkably ultraviolet light above the soil surface, leading to optimal plant growth. This optimal plant growth can support the development of many branches and increase the number of leaves on the plants.

The highest number of productive branches in tomato plants tested was obtained from the shading treatment with the addition of biochar soil amendments, as shown in Table 2. The number of productive branches from this treatment was much higher than the other treatments. Shading treatment can increase the number of productive branches when combined with soil amendments, either biochar or chicken manure.

The increase in the number of leaves with the rise in the number of branches allows for an increase in the plant's leaf area index (LAI). Previous research has shown a strong positive relationship between LAI and tomato yield (Xiao et al., 2022). Another study also showed that an increase in the leaf area index leads to a rise in the number of fruits per plant (Jo & Shin, 2020). This study also had a strong positive relationship between the number of productive branches and the number of fruits per plant, with an r^2 value of 0.86. As seen in Table 2, the highest number of fruits and fruit weight per plant were produced from the shading treatment combined with seaweed biochar. The shading treatment combined with chicken manure also produced a higher fruit weight per plant than all treatments without shading, whether given soil amendments or not. This shows the role of UV plastic shading in creating optimal environmental conditions for tomato plants grown in dry lands. High UV radiation can inhibit plant development and metabolism (Z. Chen et al., 2022). It was previously reported that UV radiation in dryland areas has increased significantly since 2010 due to the depletion of the ozone layer in the atmosphere (Xie et al., 2023). These optimal conditions, combined with soil amendment treatments, produced several fruits and fruit weights per plant that exceeded the yield potential listed in the description of the Servo tomato variety. Table 2 shows that the number of fruits and fruit weight per plant were 100.7 and 4.22 kg, respectively. Meanwhile, the highest number of fruits per plant listed in the variety description is 53, with a maximum weight of 3.49 kg plant^{-1}. As previously mentioned, the maximum and minimum temperatures at the experimental site are still within the optimum range for tropical tomatoes suitable for planting in lowland areas.

On sandy soils, biochar is reported to improve soil structure and increase water-holding capacity (Bekchanova et al., 2024). With biochar's high CEC, its ability to provide nutrients increases (Das et al., 2021). This condition, along with creating optimal conditions above the soil surface by reducing sunlight intensity and ultraviolet radiation through UV plastic, results in tomato yield components (number of fruits and fruit weight per plant) far exceeding the yields from other treatments. In conditions without shading, the increase in the number of fruits due to chicken manure and seaweed biochar treatments was 13.28% and 6.65%, respectively. Meanwhile, under UV plastic shading, the increase observed in the seaweed biochar treatment was more than tenfold compared to the chicken manure treatment. This fact shows that seaweed biochar provides more benefits than chicken manure for tomato plants grown on sandy, dry lands when combined with UV plastic shading.

The weight of tomato fruit per plot, which is the accumulation of six harvests, is also influenced by the interaction between shading treatment and soil amendments. Like the number and weight of fruit per plant, the highest fruit weight per plot was obtained from the shading treatment combined with seaweed biochar soil amendment. The trend of fruit weight data per plot is similar to that of fruit weight data. Correlation test results show a solid relationship (r^2= 0.94) between fruit weight per plant and plot.

Effect of shading on some measured parameters

Statistical test results show that the UV plastic shading treatment significantly affected plant height, stem diameter, number of leaves, fruit weight per fruit, and diameter. This treatment did not substantially affect other observed parameters, such as the percentage of flowers turning into fruits (fruit set), total chlorophyll in leaves, total soil microbes, organic C content, and CEC.

Ultraviolet radiation with a wavelength of <350 nm is carried along with solar radiation reaching the earth's surface. In tropical regions with high sunlight intensity, this high UV radiation can inhibit plant growth (Correa et al., 2023). Plant growth inhibition can occur due to DNA damage, inhibition of photosynthesis, or triggering reactive oxygen species (ROS) that require a lot of energy from the plant (B. Chen et al., 2022). Therefore, reducing UV radiation by 14% through UV plastic shading could enhance tomato plant growth by increasing plant height, stem diameter, and the number of leaves (Table 3). This good growth resulted in larger fruit sizes in tomato plants, increasing fruit weight per fruit. As seen in Table 4, the higher fruit diameter and fruit weight per tomato plant were obtained from the shading treatment with UV plastic. Previous study showed that UV plastic shading can increase the size of tomato fruits (Holcman et al., 2017).

Table 3. Effect of treatments on the growth of tomato plants

Treatments	Parameters			
	Plant height (cm)	Stem diameter (cm)	Leaves number	Total Chlorophyll (mg l^{-1})
Shading				
No shading	125.1^{a*}	0.9^{a}	33.3^{a}	53.89
Shading	139.6^{b}	1.0^{a}	43.2^{b}	61.04
BNJ 5%	*10.67*	*0.13*	*4.74*	-
Soil amendment				
No amendment	129.6	0.9a	36.6a	51.69
Chicken manure	132.8	0.9a	38.4a	55.92
Seaweed biochar	134.6	1.0b	39.8a	64.80
HSD 5%	-	*0.13*	*4.74*	-

*Values in the same treatment and parameter followed by different superscript letters significantly differ according to HSD at a 5% level.

The fruit set was not affected by the UV plastic shading treatment. The average fruit set under the UV plastic shading treatment was still less than 70% (Table 4), indicating a high flower drop rate. As mentioned earlier, previous research results show that the maximum air temperature at the experimental site reached 36^{0}C, much higher than the optimum air temperature needed for tomato plants, which is 26^{0}C (Sato et al., 2000). Maximum air temperatures above 32^{0}C have been reported to cause pollination failure, reducing tomato yields (Ayankojo & Morgan, 2020).

The UV plastic covering treatment did not affect the total chlorophyll of tomato leaves observed at the first harvest. The total chlorophyll values obtained varied widely, from 51.69 μmol cm^{-2} to 64.80 μmol cm^{-2}. Total chlorophyll, which determines a plant's photosynthetic capacity, generally ranges from 5.0 μmol cm^{-2} to 80.0 μmol cm^{-2} for field plants. Nitrogen nutrients and environmental stress determine the total chlorophyll value, such as drought or pest and disease attacks (Zhang et al., 2022). In the study, the plants received relatively the same nutrients and did not experience stress, as previously mentioned, resulting in relatively high total leaf chlorophyll.

The soil's total microbes (bacteria and fungi) were not affected by the UV plastic shading treatment (Table 4). The total colonies in the shading treatment were slightly higher than in the non-shading treatment, although not significantly different. Changes in soil microbial populations are influenced by soil temperature (Wang et al., 2024) as well as soil pH. In this study, shading treatment had no significant effect on soil temperature (Table 4), but soil pH was greatly influenced by the interaction between shading and soil amendments (Table 2). The impact of soil pH changes on microbial populations generally occurs gradually (Wang et al., 2024). Meanwhile, this study was conducted for only one season, so shading treatment had no significant effect on soil microbial populations.

Table 4. Effect of treatments on soil temperature, C-organic, CEC, and total microbes in the soil

Treatments	Parameters			
	Soil temperature (^{0}C)	C-organic (%)	CEC	Total microbes (CFU) ×10^6
Shading				
No shading	28.6	1.41	10.44	1.14
Shading	29.3	1.45	10.13	1.25
Soil amendment				
No amendment	29.3	1.38	9.99	1.20
Chicken manure	29.7	1.49	10.53	1.10
Seaweed biochar	27.8	1.43	10.35	1.28

The UV plastic shading treatment also unaffected the soil's cation exchange capacity (CEC) and organic C content (Table 4). CEC and organic C content in the soil are generally influenced by soil texture and depth (Sani et al., 2019). No studies have reported the effect of UV plastic shading on CEC and organic C content in the soil, especially over very short research periods. In this study, all soil samples were taken from the same soil texture (sandy loam) and the same depth, 5 cm to 10 cm from the soil surface.

Applying seaweed biochar and soil amendments can increase growth (stem diameter and number of leaves) and yield components (fruit weight per fruit and diameter). A literature review study indicates that biochar treatment is highly effective in increasing yields in less fertile soils, such as sandy soils (Bekchanova et al., 2024). No specific literature reports the effects of seaweed biochar on the growth and yield of tomato plants. However, it is generally stated that biochar plays a significant role in enhancing the yield and quality of tomato fruits (Lei et al., 2024).

The application of seaweed biochar and chicken manure did not significantly affect the parameters of the percentage of flowers turning into fruits (fruit set), total chlorophyll, total microbes, organic C, and soil CEC. It is generally reported that applying soil amendments such as biochar and chicken manure can improve the soil's physical, chemical, and biological properties (Sandhu et al., 2019), thereby increasing tomato yields (Lei et al., 2024). However, the short-term effects of these soil amendments do not always result in significant impacts, and sometimes, there are no significant differences (Sandhu et al., 2019). Similarly, the effects of soil amendment treatments on sandy soils on specific soil chemical properties tend to be less optimal due to the high potential for leaching (Hays et al., 2023).

Conclusion

The research concluded that agronomic management, both within the soil (using chicken manure and seaweed biochar soil amendments) and above the soil (using UV plastic shading), can affect the growth and yield of tomato plants. An interaction between soil amendments and shading influences yield, yield components, and soil pH. The best results (fruit weight per plant and plot) were obtained from the seaweed biochar soil amendment combined with UV plastic shading. Meanwhile, single factors, shading, and soil amendments influenced growth variables and yield components.

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Author Contributions

First concept and methodology of the study, I Komang Damar Jaya and Laila Safta; field establishment and coordinating for data collection, Laila Safta, Sudirman and Herman Suheri; data analysis and interpretation Sudirman. Preparation of the draft, I Komang Damar Jaya and Laila Safta; writing-review, Herman Suheri and editing, Laila Safta.

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Conflicts of Interest
The authors declare no conflict of interest.

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