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Performance of Garlic (*Allium sativum* L.) Varieties as Affected by Different Shading Materials

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ABSTRACT

This study examined the effects of different shading materials on garlic varieties at the Organic Agriculture Training and Demonstration Farm in Brgy. Baroro, Bacnotan, La Union, from October 6, 2022, to February 29, 2023. Using a Split Plot in a Randomized Complete Block Design with three replications, the treatments were: S_0 - No Shade, S_1 - Feed Sack White, S_2 - Feed Sack Plastic, and S_3 - Black Mesh Net, while the garlic varieties included V_1 - Mexican, V_2 - Miracle, and V_3 - Ilocos Pink. The findings revealed that garlic grown under feed sack shade exhibited the highest plant height (59.48 cm), number of leaves (11.79), bulb weight (14.67 g), fresh weight (22.6 kg), and dry bulb yield (0.50 kg). The Ilocos Pink variety achieved the highest leaf length (45.17 cm), bulb weight (14.94 g), bulb diameter (3.44 cm), fresh bulb yield (0.71 kg), and dry bulb yield (0.45 kg). These results suggest that using shading materials, particularly feed sack shades, can significantly enhance the growth and yield of garlic, with the Ilocos Pink variety showing superior performance across several parameters.

Keywords: Garlic cultivation, Shading materials, Growth and Yield

INTRODUCTION

Garlic (*Allium sativum* L.), commonly known as "bawang," is one of the most widely cultivated members of the Allium family. It ranks as the second most widely distributed species within the Allium genus worldwide (Tesfaye, 2021). Garlic is native to central Asia but grows wild in Italy and southern France and is a classic ingredient in many national cuisines. Garlic is among the most essential food seasonings globally. It is primarily used as a condiment to enhance the flavor of meats, fish, and salads, whether fresh or dried. Additionally, garlic has been shown to lower blood sugar and cholesterol levels. Its numerous health benefits have led to the creation of therapeutic tablets, beverages, and powders made from garlic extracts (Ansary et al., 2020). Due to its various applications, the demand for this crop continues to rise (Jiku et al., 2020) The garlic plant produces a bulb encased in sheaths, composed of thin-shelled bulblets, cloves, or sets, all capable of developing into new plants. The most active components in fresh garlic are an amino acid called alliin and an enzyme named alliinase. When a garlic clove is chewed, chopped, bruised, or cut, these substances combine to produce allicin, which is responsible for garlic's distinctive strong odor. The bulbs have a powerful onion-like aroma and pungent taste and are not usually eaten raw. These plants can grow about 60 cm (2 feet) tall, depending on the variety. The long leaves typically arise from a short hard stem above the bulb or a softer pseudo-stem of overlapping leaf sheaths. The bulb is covered with membranous skin and encloses up to 20 edible bulblets called cloves. The spherical flower cluster is initially enclosed in a pair of papery tapered bracts; the bracts split open when the green-white or pinkish flowers bloom. Flower stalks sometimes arise, bearing tiny bulbils (secondary bulbs forming in place of flowers) and sterile blossoms. Garlic is usually grown as an annual crop and is propagated by planting cloves or top bulbils, though seeds can also be used (Britannica, 2023). Garlic is widely grown in the Philippines, and the Philippines Statistics Authority (2022) states that the Ilocos region is the leading producer of the seven producing regions. The two regions that generate the most garlic are ILocos Sur and Ilocos Norte. The Philippines has several popular garlic varieties, including Batanes Red, Ilocos White, Ilocos Pink, Tan Volters, Romblon, Mindoro, Mexican, and Miracle. Ilocos White is the most commonly planted variety for commercial production. It features purple to white scales and is moderately resistant to insect pests and diseases. It matures within 90 to 110 days after planting, yielding up to 3.5 tons per hectare, with a prolonged shelf life. Department of Agriculture recognizes a deficit of 63,000 metric tons in the country's garlic supply Cariaso (2022). In 2021, garlic production in the Ilocos Region was estimated at 4,571.08 metric tons, reflecting a 1.18 percent decrease from the 2020 output of 4,625.73 metric tons. The Ilocos Region contributed 77.61 percent to the total national output of 5,890.14 metric tons in 2021, as indicated by the Philippine Statistics Authority (2022). Despite La Union’s excellent agricultural potential, characterized by its favorable soil, climate, and market conditions, the province currently lacks any commercial garlic production, unlike its counterparts in the region. Ilocos Norte, has designated 1,880 hectares for garlic cultivation, Ilocos Sur 130 hectares, and Pangasinan four hectares (Micua, 2022). This disparity highlights a significant economic opportunity that local farmers in La Union are missing out on. Arcalas (2024) states that the Department of Agriculture (DA) advocates garlic as a high-value crop owing to rising demand. Garlic is more readily to produce locally than onions, which necessitates imported seeds. Arcalas additionally stated that The DA is formulating a financial strategy to bolster the local garlic sector. However, the garlic industry faces significant challenges, such as declining production and reduced planting areas, primarily due to the low yield of existing garlic varieties, inadequate quality of planting materials, and substantial postharvest losses (Adorada et al., 2023). Additionally, garlic farmers contend with complex environmental, agronomic, economic, and political hurdles. In addressing these issues, passive microclimate control techniques, such as shading and insect-proof screens, have proven effective in enhancing crop production under adverse environmental conditions (Wen et al., 2022). Light intensity, a critical external factor influencing plant growth and photosynthesis rates, can be managed through shading, affecting chlorophyll content and overall plant health (Hadid & Febriana, 2022). Employing shading nets has become a prevalent practice in agronomy to create optimal environments for plant acclimation and growth (Reis et al., 2022). For instance, Nguyen et al. (2022) reported that the use shading nets to improve greenhouse micro-climatic conditions, promoting healthier crop production and safer working environments. This study investigated the effects of various shading materials on the performance of garlic varieties, to improve productivity and sustainability in the garlic sector. Therefore, the study aimed to determine the performance of garlic varieties as affected by different shading materials. Specifically, it sought to determine the growth and yield of three garlic varieties, assess the effect of different shading materials on the growth and yield of garlic, and to analyze the interaction effect of garlic varieties and shading materials in terms of growth and yield.

MATERIALS & METHODS

Research Design

The study was conducted employing the Split Plot in Randomized Complete Block Design, replicated three times. The different treatments are as follows:

Materials and Procedures

Source and Preparation of Planting Material

Factor A: Shading Materials	Factor B: Garlic Varieties
S_0 – No shade	V_1 – Mexican
S_1 – Feed sack white	V_2 – miracle
S_2 – Feed sack plastic	V_3 – Ilocos pink
S_3 – Black mesh net	

The garlic bulbs used in the study were procured from Pasuquin, Ilocos Norte. High-quality planting materials were selected, ensuring they were disease-free, well-developed, and fully matured. Cloves from the outer parts of the bulbs were chosen for planting.

Land Preparation

The study was conducted at the Organic Agriculture Training and Demonstration Farm in Baroro, Bacnotan, La Union, from October 6, 2022, to February 29, 2023. A two hundred square meter area was cleaned and rotavated twice using a four-wheeled tractor. A shovel was used to construct plots with dimensions of 1 meter in width by 3 meters in length.

Mulching

Mulching materials were applied a day before planting. Rice straw was laid on each plot with a thickness of 4 cm to aid in minimizing soil moisture evaporation and regulating favorable soil temperature, as well as controlling the growth of weeds.

Planting

Garlic cloves were soaked in 800g/kg of Mancozeb, based on the product recommendation, before planting. The planting was conducted with a spacing of 20cm x 20cm and at a depth of 2cm.

Preparation and Installation of Shading Materials

Ten days after planting, a low tunnel structure was installed. A bamboo frame was set up in a semi-arc shape with dimensions of 1m in width, 3m in length, and 0.75m in height. Feed sack white (S_1), feed sack plastic (S_2), and black mesh net (S_3) were used as shading materials.

Air Temperature Measurement

Air temperature was recorded weekly using an infrared thermometer gun, placed at the middle surface of the shading tunnel at 8:00 am, at 12:00 noon, and again at 3:00 pm.

Irrigation and Fertilization

Irrigation was scheduled twice a week or as needed, using overhead sprinklers after planting and flash irrigation 50 days post-planting. Fertilizers were applied in split applications. Complete fertilizer (14-14-14) was applied after planting through drench application, while urea was applied by broadcasting during early bulb formation. Crop Giant 15-15-30 + M.E was used as a foliar fertilizer.

Integrated Pest Management

150g/L of gamma-cyhalothrin insecticide was sprayed based on product recommendations to control sucking and chewing insect pests. Thiophanate methyl 700g/kg WP and 800g/kg mancozeb fungicide were used to control diseases such as purple blotch, bulb rot, and leaf blight. Weeding was conducted to remove alternate hosts or refuges for insect pests and diseases, performed manually by pulling the weeds.

Harvesting

Garlic was harvested when its maturity indices became visible, indicated by the yellowing of 75% of the leaves. The garlic was harvested by manually pulling individual plants, and the harvested bulbs were sun-dried for 5 days post-harvest.

Storage

Garlic was stored under ambient conditions by hanging the bundles in rows with bamboo sticks or lumber in a well-ventilated place.

Data Gathered

The data for this study were collected by employing various measurement techniques on garlic across different plots. The following parameters were measured:

Plant Height (cm). The height of 10 randomized sample plants per plot was measured from the soil surface level to the tip of the plant using a meter stick or ruler at 90 days after transplanting (DAT).

Number of Leaves. The healthy leaves of the 10 sample plants per plot were counted at both 60 DAT and 90 DAT.

Leaf Length (cm). The average length of the longest leaf was determined by measuring ten random sample plants per plot at 60 days after planting (DAP) and 90 DAP.

Days to Maturity. This was recorded when 75% of the leaves of the plants in each plot had turned yellow and/or shown signs of senescence. The days to maturity were counted from the day of planting.

Fresh Bulb Weight (g). The individual weight of ten freshly harvested garlic bulbs was measured.

Dry Bulb Weight (g). The individual weight of ten sample plants was taken after five days of drying.

Fresh Bulb Yield Per Plot (kg). This was measured by weighing the freshly harvested garlic from each plot using a weighing scale.

Dry Bulb Yield Per Plot (kg). The dried harvested garlic was weighed five days after drying per plot.

SPAD Index. The chlorophyll content of the leaves of five sample garlic plants per plot was measured using a SPAD meter.

Number of Cloves. The number of cloves produced by the 10 garlic bulb samples was counted.

Bulb diameter (cm). The center bulb diameter of the 10 garlic samples was measured using a vernier caliper after five days of sun drying.

Percentage of Garlic with Bulbil. This percentage was calculated by counting the plants that produced bulbils per plot, divided by the total number of garlic plants, and then multiplied by 100.

Survival percentage. The survival percentage was calculated by counting the total harvested plants, divided by the number of seeds planted, and then multiplied by 100.

Air Temperature (°C). The air temperature was recorded by placing an infrared thermometer gun in the middle surface of the tunnel shading. This measurement was conducted weekly at 8:00 am, 12:00 noon, and 3:00 pm.

STATISTICAL ANALYSIS

The collected data were analyzed using a Two-way ANOVA (Analysis of Variance) in a Split-Plot Design. The LSD (Least Significant Difference) test was employed to determine the difference between and among treatment means, using the Statistical Tool for Agricultural Research (STAR) version 2.0.1, 2014.

RESULTS AND DISCUSSION

Plant Height, Number of Leaves, Leaf length, and Days to Maturity

Interaction effect

The analysis of variance (ANOVA) results indicates that there were no significant interactions observed in terms of mean plant height, number of leaves, leaf length, and days to maturity. Specifically, for plant height, the interaction effect between variety and shading materials was not significant, with an F value of 0.15 and a p-value of 0.9869. Similarly, for the number of leaves at 60 and 90 days after planting (DAP), interactions were also non-significant, with F values of 0.18 (p = 0.9786) and 0.41 (p = 0.8650), respectively. The leaf length at 60 DAP and 90 DAP showed no significant interaction effects, with F values of 0.46 and 0.35 and p-values of 0.8310 and 0.9001, respectively. Lastly, the days to maturity revealed no significant interaction, with an F value of 0.90 and a p-value of 0.5191. These findings suggest that the different shading materials did not significantly alter the growth parameters of the garlic varieties studied, indicating that other factors may play a more crucial role in influencing these growth parameters.

Effect of Variety

Table 1 presents the analysis of three garlic varieties—Mexican, Miracle, and Ilocos Pink — reveals no significant differences in plant height, number of leaves, or leaf length at 60 days after planting (DAP), as well as in days to maturity. The mean plant heights ranged from 45.83 cm to 53.43 cm, with the number of leaves varying between 6.75 and 7.14 at 60 DAP, and between 11.10 and 11.41 at 90 DAP. Leaf lengths at 60 DAP ranged from 36.82 cm to 39.65 cm, while days to maturity spanned from 117.83 to 119.25 days. Notably, at 90 DAP, the Ilocos Pink variety (V_3) exhibited significantly longer leaves (45.17 cm) compared to the Mexican (V_1) (40.39 cm) and Miracle (V_2) (41.77 cm) varieties. The observed superior vegetative growth characteristics of the Ilocos Pink variety can be substantiated by recent research in garlic cultivation. According to Moustafa et al. (2023), variations in leaf morphology significantly affect the photosynthetic efficiency and overall growth of garlic plants. Atif et al. (2020) further elaborates that longer leaf lengths, as seen in the Ilocos Pink variety, correlate with increased light absorption, which can enhance growth and yield.

Table 1. Mean Plant Height (cm), Number of Leaves, Leaf Length (cm), and Days to Maturity of Three Garlic Varieties.

Variety	Plant Height (cm)	Number of Leaves		Leaf Length (cm)		Days to Maturity
		60 DAP	90 DAP	60 DAP	90 DAP **	
V_1- Mexican	45.83	6.91	11.10	36.82	40.39b	117.83
V_2- Miracle	48.28	7.14	11.29	37.68	41.77b	118.25
V_3- Ilocos Pink	53.43	6.75	11.41	39.65	45.17a	119.25
CV (%)	16.55	8.42	5.44	7.88	7.54	1.39

****Means with the same letter are not significantly different at 0.01 level of significance LSD.**

Effect of Shading Materials

The data presented in Table 2 highlights the impact of different shading materials on garlic's mean plant height, number of leaves, leaf length, and days to maturity. At 60 days after planting (DAP), there were no significant differences in the number of leaves, with means ranging from 6.86 to 7.10. However, by 90 DAP, a significant increase in the number of leaves was observed in garlic plants grown under feed sacks white (S_1), with an average of 11.79 leaves. This was comparable to garlic grown under a black mesh net (S_3), which had a mean of 11.52 leaves. Conversely, garlic grown under feed sack plastic (S_2) produced the fewest leaves, similar to garlic grown without any shading (S_O), with means of 10.83 and 10.92 leaves, respectively. This observation aligns with the findings of Kabir et al. (2020), who emphasized that varying levels of net shading (0 (open field), 30, 47, 63, and 80%) can influence plant morphology, resulting in taller plants with larger but thinner leaves. Further supporting this, recent studies have indicated that shading nets not only affect plant height and leaf number but can also enhance other plant growth responses and water use efficiency (WUE). For instance, research conducted by Mohawesh et al. (2021) demonstrated that applying green and black shading nets to sweet pepper production systems in semi-arid environments significantly improved plant growth parameters and WUE, underscoring the potential benefits of strategic shading in agricultural practices.

The data on the mean plant height of garlic grown under different shading materials reveals significant differences among the treatments. At 60 days after planting (DAP), the tallest plants were observed under the S_1-Feed Sack (white) shading, with an average height of 59.48 cm, followed closely by the S_3-Black Mesh Net at 55.46 cm. In contrast, the S_0-No Shading treatment resulted in the shortest plants, with an average height of 38.32 cm, while the S_2-Feed Sack Plastic produced plants with an intermediate height of 43.46 cm.

Regarding plant height, significant variation was observed. Garlic grown under feed sack (S_1) achieved the tallest height, with a mean of 59.48 cm at 90 DAP, which was comparable to plants grown under a black mesh net (S_3) with a mean height of 55.46 cm. In contrast, garlic grown with feed sack plastic and without shading resulted in shorter plants, with average heights of 43.46 cm and 38.32 cm, respectively. According to Diaz-Perez and John (2019), plant height and stem diameter were reduced in unshaded treatments. Their findings also indicated that the use of different colored nets, such as black, red, silver, and white shade nets produced comparable results in terms of plant height and stem diameter. This suggests that shading can enhance plant height, aligning with the results observed in this study where shaded treatments led to taller garlic plants.

Leaf length also showed a significant difference at both 60 and 90 DAP. Garlic grown under feed sack white (S_1) produced the longest leaves, with means of 43.60 cm and 49.48 cm, respectively.

Additionally, the days to maturity varied significantly depending on the shading material used. Garlic grown without shading (S0) matured in the shortest time, taking only 108 days. This quicker maturity is likely due to uninterrupted exposure to sunlight, which accelerates photosynthesis, as noted by 1Atif et al. (2020). Garlic shaded with feed sack plastic (S2) matured in 114 days, while those treated with feed sack white (S1) and black mesh net (S3) took approximately 125 days to reach maturity.

The results in the study indicated that the use of feed sacks as shading material on garlic had possibly blocked sunlight which had indirectly affected the intensity of light received by plants during the growing season and caused it to consistently produce taller plants, a higher number of leaves, and longer leaves.

Table 2. Mean Plant Height (cm), Number of Leaves, Leaf Length (cm) and Days to Maturity of Garlic Grown Under Different Shading Materials

Shading Materials	Plant Height (cm)*	Number of Leaves		Leaf Length (cm)		Days to Maturity **
		60 DAP	90 DAP **	60 DAP **	90 DAP **	
S_0- No Shading	38.32b	7.10	10.92bc	34.04c	36.92c	108.67c
S_1-Feed Sack(white)	59.48a	6.86	11.79a	43.60a	49.48a	125.11a
S_2- Feed Sack Plastic	43.46b	6.90	10.83c	34.61c	40.43bc	114.22b
S_3- Black Mesh Net	55.46a	6.88	11.52ab	39.94b	42.94b	125.78a
CV (%)	14.22	8.21	5.04	5.81	15.15	1.32

****Means with the same letter are not significantly different at 0.01 level of significance LSD.**

Bulb Weight, Bulb Diameter and Number of Cloves

Interaction Effects

The analysis of variance (ANOVA) across the three garlic varieties with different shading materials revealed that the interaction effects were not significant for bulb weight, bulb diameter, and the number of cloves per bulb. Specifically, the F values for the interaction of treatment and variety were 0.26 (p = 0.9480) for bulb weight, 0.19 (p = 0.9756) for bulb diameter, and 1.90 (p = 0.1426) for the number of cloves. These p-values indicate that the interaction between the garlic varieties and shading materials does not significantly affect these traits. Thus, while shading materials may independently impact some aspects, they do not interact with the variety to significantly alter the bulb's physical characteristics.

Effect of Variety

Table 3 presents the mean values for bulb weight, bulb diameter, and the number of cloves across three garlic varieties. The results indicate no significant difference among the varieties in terms of the number of cloves per bulb, with means ranging from 21.83 to 22.68. However, significant variations were observed for bulb weight and bulb diameter. The Ilocos Pink variety (V_3) consistently produced the heaviest bulbs, with an average weight of 14.94 grams and a bulb diameter of 3.44 cm. This was followed by the Miracle variety (V_2), which had an average bulb weight of 12.82 g and a diameter of 3.21 cm, comparable to the Mexican variety (V_1) which had an average weight of 11.43 g and a diameter of 3.06 cm. The data suggest that among the varieties tested, Ilocos Pink holds the potential to produce the heaviest bulbs and the largest bulb diameters. Elias and Camalig (2023) noted that both the Ilocos Pink and Mexican varieties produced the highest bulb yields per hectare in Bacnotan, La Union. Additionally, Dixit (2021) highlighted that the significant variations in bulb weight, bulb diameter, and total bulb yield (kg/ha) can be attributed to the genotypic differences of each cultivar.

Table 3. Mean Bulb Weight (g), Bulb Diameter (cm), and Number of Cloves of Three Garlic Varieties

Variety	Bulb Weight(g) **	Bulb Diameter (cm) **	Number of cloves per bulb
V_1- Mexican	11.43b	3.06 c	22.50
V_2- Miracle	12.82b	3.21 b	21.83
V_3- Ilocos Pink	14.94a	3.44 a	22.68
CV (%)	14.16	4.54	8.19

****Means with the same letter are not significantly different at 0.01 level of significance LSD.**

Effect of Shading Materials

Table 4 presents data on the bulb weight, bulb diameter, and the number of cloves per bulb of garlic grown under different shading materials. The results indicate that the bulb diameter, ranging from an average of 3.13 cm to 3.37 cm, and the number of cloves per bulb, with an average ranging from 21.49 to 23.81, showed no significant differences across the different shading treatments.

However, when examining bulb weight, significant differences were observed among the shading materials tested. The mean bulb weight varied notably, ranging from 11.49 g to 14.67 g. This implies that the use of shade covers, such as feed sacks and black mesh netting, positively influences the growth and development of garlic bulbs, potentially due to improved microenvironmental conditions. According to Hadid and Febriana (2022), varying levels of shade (N0 = No Shade, N1 = 9% Shade, N2 = 18% Shade, N3 = 38% Shade, and N4 = 50% Shade) positively impact the fresh weight and overall yield of shallot tubers.

Table 4. Mean Bulb Weight (g), Bulb Diameter (cm), and Number of Cloves of Garlic Grown Under Different Shading Materials

Shading Materials	Bulb Weight (g) *	Bulb Diameter (cm)	Number of cloves per bulb
S_0- No Shading	11.49b	3.13	21.49
S_1- Feed Sack (White)	14.67a	3.37	23.81
S_2- Feed Sack Plastic	12.64ab	3.29	21.82
S_3- Black Mesh Net	13.46ab	3.16	22.22
CV (%)	13.79	6.43	14.52

*** Means with the same letter are not significantly different at 0.05 level of significance LSD.**

Percentage of Plants with Bulbil

Interaction Effects

The analysis of variance reveals no interaction between treatment and garlic variety with an F value of 1.41 and a p-value of 0.2746. This suggests that the interaction between garlic variety and shading materials did not significantly impact the percentage of plants with bulbils.

Effect of Variety

Table 5 presents the mean percentages of plants producing bulbils across three different garlic varieties. The data indicates significant differences among them. The Miracle variety (V_2) exhibited the highest percentage of plants with bulbils, with an average of 3.92. In contrast, the Ilocos Pink (V_3) and Mexican varieties (V_1) showed much lower percentages, with means of 0.85 and 1.00, respectively. According to [1]Atif et al. (2020), both plant characteristics and environmental factors play critical roles in determining bolting and the morphological characteristics associated with bulbil production.

Table 5. Mean Percentage of Plants with Bulbil of Three Garlic Varieties

Variety	Percentage of Plants with Bulbil *
V_1- Mexican	1.00 b
V_2- Miracle	3.92 a
V_3- Ilocos Pink	0.85 b
CV (%)	98.33

***Means with the same letter are not significantly different at 0.05 level of significance LSD.**

Effect of Shading Materials

Table 6 shows the mean percentages of plants with bulbils grown under different shading materials. The results indicate no significant differences between the shading materials including the control, with mean percentages ranging from 1.35 to 2.67. This suggests that the type of shading material used does not significantly impact the bulbil production in garlic plants.

Table 6. Mean Percentage of Plants with Bulbil Grown Under Different Shading Materials

Shading Materials	Percentage of Plants with Bulbil
S_1- No Shading	1.35
S_2- Feed Sack (White)	2.67
S_3- Feed Sack Plastic	1.44
S_4- Black Mesh Net	2.22
CV (%)	119.50

***Means with the same letter are not significantly different at 0.05 level of significance LSD.**

Fresh Bulb Weight, Fresh Bulb Yield per Plot, Dry Bulb Yield per Plot and Percentage Survival (%).

Interaction Effects

The analysis of variance (ANOVA) conducted on the three garlic varieties under different shading materials showed that the interaction effects between the treatment and variety were not significant on fresh bulb weight, fresh bulb yield per plot, and dry bulb weight. Specifically, the F values for these interactions were 0.63 ($p = 0.7025$) for fresh bulb weight, 0.61 ($p = 0.7185$) for fresh bulb yield per plot, and 1.40 ($p = 0.2742$) for dry bulb weight. These p-values suggest that while shading materials and garlic variety independently influence these parameters, their interaction did not significantly alter the outcomes. Consequently, variations in shading materials did not significantly interact with garlic varieties to impact the fresh or dry bulb weights or yield per plot.

Effect of Variety

Table 7 presents the mean of fresh bulb weight (g), fresh bulb yield per plot (kg), dry bulb yield per plot (kg), and percentage survival (%) of different garlic varieties. The Ilocos Pink variety (V_3) outperformed both the Mexican (V_1) and Miracle (V_2) varieties across all measured parameters, except for percentage survival, which did not vary significantly among the varieties.

Ilocos Pink achieved the highest fresh bulb weight of 25.58 g, a fresh bulb yield per plot of 0.7167 kg, and a dry bulb yield per plot of 0.4583 kg. In contrast, the Mexican variety recorded a lower fresh bulb weight of 17.63 g, with a fresh yield per plot of 0.4750 kg and a dry yield per plot of 0.3292 kg. The Miracle variety showed intermediate values, with a fresh bulb weight of 19.64 g, a yield per plot of 0.4917 kg for fresh bulbs, and 0.3458 kg for dry bulbs. Despite these differences, the percentage survival was relatively consistent across varieties, ranging from 59.89% to 64.03%. These findings emphasize the importance of selecting the right cultivar, as genetic differences play a critical role in determining the productivity and quality of garlic crops, consistent with the observations by Yebirzaf et al. (2018).

Table 7. Mean Fresh Bulb Weight, Weight of Fresh Bulb, Dry Weight Bulb, and Percentage Survival (%) of Three Garlic Varieties.

Variety	Fresh Bulb Weight (g) **	Fresh Bulb Yield per Plot (kg)**	Dry Bulb Yield per Plot (kg)**	Percentage Survival (%)
V_1- Mexican	17.63 b	0.4750 b	0.3292 b	59.89
V_2- Miracle	19.64 b	0.4917 b	0.3458 b	61.11
V_3- Ilocos Pink	25.58 a	0.7167 a	0.4583 a	64.03
CV	17.77%	27.22%	24.66%	19.97%

***Means with the same letter are not significantly different at 0.01 level of significance LSD.**

Effect of Shading Materials

The study results, as outlined in Table 8, demonstrate the pronounced impact of different shading materials on bulb production parameters and survival, highlighting significant differences in fresh bulb yield per plot (kg), dry bulb yield per plot (kg), and percentage survival (%). Specifically, the use of Feed Sack White (S_1) yielded the highest fresh bulb yield per plot at 0.6944 kg and a dry bulb yield per plot at 0.5000 kg, with a notable survival percentage of 72.33%. This was closely followed by the Black Mesh Net (S_3), which resulted in a fresh bulb yield per plot at 0.6222 kg and a dry bulb yield per plot at 0.4386 kg, alongside a survival rate of 68.15%. Conversely, the absence of shading (S_0) resulted in the lowest fresh bulb yield per plot at 0.3667 kg and a lower survival rate of 51.70%, comparable to that of Feed Sack Plastic (S_2) (0.5611 kg fresh bulb yield and 54.52% survival). These findings align with the research by Ahmed et al. (2023), which underscores the role of light and shade in modulating crop yield and quality. Similarly, Nguyen et al. (2022) also observed enhanced growth and yield in shaded environments, as seen in eggplants. This suggests that the strategic use of shading materials can significantly improve yield outcomes in agricultural practices.

Table 8. Mean Fresh Bulb Weight, Fresh Bulb Yield per Plot, Dry Bulb Yield per Plot, Percentage Survival (%) of Garlic Grown Under Different Shading Materials

Shading Materials	Fresh bulb weight (g)	Fresh bulb yield per plot (kg) *	Dry bulb yield per plot (kg) **	Percentage Survival (%) *
S_0- No Shading	17.50	0.3667 b	0.2556 b	51.70 b
S_1- Feed Sack (White)	22.6	0.6944 a	0.5000 a	72.33 a
S_2- Feed Sack Plastic	21.98	0.5611 a	0.3167 b	54.52 b
S_3- Black Mesh Net	21.72	0.6222a	0.4386 a	68.15 a
CV	32.65%	27.93%	23.79%	18.15%

****Means with the same letter are not significantly different at 0.01 level of significance LSD.**

Temperature

Effect of Shading

The analysis of mean temperatures under different shading materials, as presented in Table 9, indicates significant variations. The results reveal that conditions without shading (S_0) consistently exhibited the highest temperatures, with means ranging from 27.67°C to 32.29°C. Following this, feed sack plastic (S_2) demonstrated intermediate temperature ranges between 27.33°C to 30.70°C. In contrast, feed sack white (S_1) and black mesh nets (S_3) recorded the lowest temperature ranges, with feed sack white showing means from 26.67°C to 29.14°C and black mesh nets from 26.88°C to 30.05°C. These findings are consistent with [2]Atif et al. (2020), who found that treatments at 30°C optimizes several growth and yield parameters in garlic, such as plant height, pseudostem diameter, bulb diameter, bulb weight, bulb height, and bulbing index. This suggests that temperature significantly influences the growth and yield of garlic. Therefore, it highlights the effectiveness of shading materials in regulating temperature fluctuations, potentially enhancing agricultural productivity.

Table 9. Mean Air Temperature as Affected by Different Shading Material

Shading Materials	Days After Planting													
	19**	26	33	40**	47*	54*	61**	68*	75**	82**	89**	96	103*	108*
S_0- No Shading	29.44 a	28.30	27.99	27.98 a	28.44 a	27.83 ab	27.67 ab	27.95 a	28.07 a	28.30 a	32.29 a	30.52	31.46 a	29.79 a
S_1- Feed Sack (White)	28.70 c	28.15	27.85	27.31 b	27.24 c	26.96 c	26.75 c	26.67 c	26.70 c	26.86 c	28.54 c	28.54	29.14 b	28.46 b
S_2- Feed Sack Plastic	28.94 b	28.43	28.30	27.77 a	28.01 b	28.12 a	27.76 a	27.33 b	27.50 b	27.58 b	30.70 b	29.54	29.76 b	29.19 ab
S_3- Black Mesh Net	28.97 b	28.16	28.2	27.29 b	27.35 c	26.88 c	27.21 bc	27.24 b	27.11 bc	27.24 bc	30.05 bc	30.3b	29.90 b	29.66 a
CV	1.87	1.78	2.03	2.03	2.79	3.01	1.81	1.60	1.16	1.15	3.31	2.68	1.86	1.27

****Means with the same letter are not significantly different at 0.01 level of significance LSD.**

SPAD index

Effect of Variety

The mean SPAD index values presented in Table 10 indicate that there were no significant differences in chlorophyll content among the varieties during the early stages of measurement, specifically at 68, 75, 82, and 89 days after planting. However, as the plants matured, significant differences emerged. The Ilocos Pink variety (V_3) consistently exhibited the highest chlorophyll content during 96, 103, and 110 days after planting, with mean values of 72.84, 69.06, and 60.88, respectively. In contrast, the Mexican (V_1) and Miracle varieties (V_2) showed lower chlorophyll content, with corresponding mean SPAD readings of 67.16, 62.72, and 56.17 for Mexican, and 69.28, 64.66, and 55.73 for Miracle. These findings align with the observations by Aswani et al. (2023), underscoring that chlorophyll content values are largely influenced by the genotype of the variety.

Table 10. Mean SPAD Index of Three Garlic Varieties.

Variety	SPAD Index Days After Planting						
	68	75	82	89	96 *	103 *	110 *
V_1- Mexican	67.18	61.92	66.82	67.32	67.16 b	62.72 b	56.17 b
V_2- Miracle	67.62	62.70	64.35	71.19	69.28 ab	64.66 b	55.73 b
V_3- Ilocos Pink	62.37	63.66	60.45	66.55	72.84 a	69.06 a	60.88 a
CV	16.92%	8.71%	13.36%	15.75%	7.02%	7.51%	8.82%

***Means with the same letter are not significantly different at 0.05 level of significance LSD.**

Effect of Shading

The mean SPAD index values presented in Table 11 revealed no significant differences across the shading treatments on days 68, 75, 82, 89, 96, and 110 after planting. However, a notable variation was observed on day 103, where the garlic plants without shading (S_0) exhibited the highest SPAD index, with a mean value of 71.25. In contrast, the SPAD indices under different shading treatments namely feed sack white (S_1), feeds sack plastic S_2), and black mesh-net (S_3), were significantly lower, with mean values of 62.47, 64.08, and 64.12, respectively. These findings suggest that shading can affect the chlorophyll content of garlic, as the reduced light absorption under shaded conditions may lead to decreased photosynthetic activity, as supported by Sukasni et al. (2022). The results indicate that while shading may not significantly impact chlorophyll content in the early stages, it becomes a critical factor affecting plant physiology as the garlic matures, particularly around the 103rd day after planting.

Table 11. Mean SPAD Index of Garlic Grown Under Different Shading Materials

Shading Materials	SPAD Index Days After Planting						
	68	**75**	**82**	**89**	**96**	**103 ***	**110**
S_0- No Shading	67.18	68.68	66.06	71.73	71.39	71.25 a	57.07
S_1- Feeds Sacks (white)	56.33	60.90	61.35	66.43	67.75	62.47 b	57.46
S_2- Feeds Sack Plastic	67.52	59.67	61.71	68.98	62.21	64.08 b	57.58
S_3- Black-Mesh Net	61.86	61.78	66.32	66.27	70.68	64.12 b	58.26
CV	10.31%	12.69%	10.67%	11.16%	7.95%	7.51 %	12.04%

***Means with the same letter are not significantly different at 0.05 level of significance LSD.**

CONCLUSIONS

Based on the results of the study, the following conclusions were derived:

1. The evaluation of three garlic varieties namely, Mexican, Miracle, and Ilocos Pink, revealed that while initial growth parameters such as plant height, number of leaves, and leaf length were similar at 60 days, significant differences emerged at later stages. Notably, Ilocos Pink demonstrated superior performance with longer leaves at 90 days and the highest bulb weight and diameter. This suggests that Ilocos Pink holds the potential for higher yield and better quality, as evidenced by its elevated chlorophyll content during the later growth stages.
2. Shading materials like feed sack white (S_1) and black mesh net (S_3) enhanced plant height, leaf number, and leaf length, leading to increased bulb yield and survival rates compared to non-shaded plants. These materials effectively moderated temperature fluctuations and created favorable microenvironments, thereby supporting enhanced growth and development.
3. There was no significant interaction effect between the type of shading material used and the garlic variety concerning their growth and yield characteristics. Each variety responded similarly to the shading treatments, indicating that the main effects of shading materials and garlic varieties are independent of each other.

RECOMMENDATIONS

The following recommendations are made based on the conclusion of the study:

1. It is recommended to prioritize the cultivation of Ilocos Pink for improved garlic production in La Union. This variety's enhanced chlorophyll content suggests it can achieve better quality bulbs, making it a suitable choice for farmers aiming for higher market value.
2. To improve garlic growth and yield, it is advisable to utilize shading materials such as feed sack white (S_1) and black mesh net (S_3). These materials help

create favorable microclimates, promoting plant height, leaf number, and leaf length, which are crucial for increased bulb yield and plant survival rates.

3. Since there is no significant interaction between shading materials and garlic varieties, farmers can independently select the best shading material based on availability and cost without worrying about its compatibility with specific garlic varieties. Future studies could investigate other environmental or management factors that might interact with these variables to further refine garlic production strategies.

Declaration by Authors

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