

Article

Yield Responses of Red Chili (*Capsicum Annuum* L.) Cultivars to Nutrient Solution Volumes and Agricultural Building Types

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Abstract. This study aimed to evaluate the yield responses of red chili to three agricultural buildings (greenhouse, screenhouse, open field), four nutrient solution volumes (100%, 75%, 50%, 25% ETc) and two cultivars (Pilar and Osaka). This is the first study to assess the combined effects of agricultural building type, nutrient volume based on ETc, and two red chili cultivars (Pilar and Osaka) using a split-split plot design under tropical-dry season conditions. The experiment was conducted from August 2024 to February 2025 at Padjadjaran University, Indonesia, using a split-split plot design with 24 treatment combinations and three replications. Data were analyzed using ANOVA and DMRT at the 5% level. The results showed no interaction among three factors but each had a significant individual effect. Greenhouse conditions significantly increase the number of fruits per plant, fruit weight per plant, individual fruit weight and fruit length. Nutrient volume of 75% ETc and 100% ETc produced comparable result for fruit number and fruit weight per plant. The Pilar cultivar outperformed Osaka in fruit weight and diameter. These findings suggest that greenhouse cultivation with 75% ETc and Pilar cultivar enhance yield and supporting sustainable chili production in tropical regions.

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1. Introduction

Red chili (*Capsicum annum* L.) is a horticultural plant from the Solanaceae family with high economic value due to its distinctive flavor, color, and aroma. In addition to its culinary use, capsaicin contributes health-promoting properties, functioning as an antioxidant, antimicrobial and anti-inflammatory [1]. Cultivar development has been widely conducted to enhance adaptation to diverse agroclimatic conditions and to improve crop productivity. The Pilar cultivar, developed in Indonesia, has demonstrated strong adaptation to hot and humid tropical environments, whereas the Osaka cultivar, introduced from Japan, performs well in both tropical and subtropical climates and is characterized by high pungency. These cultivars differ in physiological and morphological traits that may influence yield potential and fruit quality. This condition requires strategies increase chili productivity by improving the cultivation system.

Extreme climate variability present a major challenge in chili cultivation, particularly due to uneven rainfall distribution leading to both drought and excessive water condition [2]. Water limitation directly affects plant productivity because water is a critical factor for optimal chili growth. Therefore, efficient water management strategies are required to minimize water use while maintaining optimal yield performance [3]. One promising approach is irrigation management based on crop evapotranspiration (ETc), which aligns water supply with plant demand. Previous studies reported that applying 75–100% of ETc in chili cultivation could sustain high yields and fruit quality without causing significant water stress. In contrast, insufficient irrigation disrupts plant water balance, reduces nutrient uptake, impairs photosynthesis, and accelerates leaf senescence, ultimately limiting plant growth and fruit development. Conventional open-fields cultivation also poses the uncontrolled climate conditions. Fluctuations in temperature, rainfall, and air humidity have a direct impact on plant growth and development [4]. Extreme weather can drastically reduce yields and increase plant stress, thus affecting the quality and quantity of production [5].

The use of agricultural buildings offers a potential solution to overcome the limitations of open fields cultivation while improving water-use efficiency. Agricultural buildings are able to regulate microclimate conditions including temperature, humidity, and light intensity that creating favorable condition for optimal growth and water efficiency [6]. Common types of agricultural buildings include greenhouses (closed buildings with UV plastic or polycarbonate) and screenhouses (constructed with insect screen nets). The water requirements of chili plants vary according to the microclimate conditions within these structures as well as the characteristic of the cultivar. Environmental factors, particularly temperature and humidity affect evapotranspiration which in turn determines irrigation needs. In addition, morphological differences among cultivars such as plant size and leaf area affect transpiration and overall water demand. Previous studies indicate that irrigation management based on ETc can optimize both yield and fruit quality in chili production [7].

The effects of irrigation levels and protective structures on chili (*Capsicum annum* L.) growth and yield have been widely studied. However, most studies were conducted under varying seasonal conditions or focused on a single cultivar, limiting the broader applicability of their results. In addition, the interactions among agricultural building, irrigation volume, and cultivar performance under tropical conditions remain largely unexplored, particularly when comparing locally developed and introduced cultivars. Addressing these gaps, this study evaluates the responses of two chili cultivars, Pilar and Osaka, to different irrigation volumes across multiple types of agricultural building during the dry season. By integrating building type, irrigation volume, and cultivar performance, the study aims to identify optimal strategies for maximizing yield, enhancing fruit quality, and improving water-use efficiency, thereby supporting more sustainable chili production.

2. Experimental Section

2.1. Materials

The experiment was conducted from August 2024 to February 2025 at Bale Tatanen, Faculty of Agriculture, Universitas Padjadjaran University, Indonesia. The experimental site is located at an elevation of ± 781 meters above sea level (asl) with coordinates 6.55°S, 107.46°E and has a C3 rainfall type according to Oldeman classification.

The plant materials consisted of two red chilli pepper cultivars such as Pilar and Osaka. Pilar as a local cultivar adapts well at 900-1100 m asl, while Osaka as a Japanese cultivar performs optimally at 0-600 m asl. Other materials are cocopeat, rice husk charcoal, 40x40 cm polybags, raffia string, plant stakes, AB mix nutrient solution, and 100 L water tanks. The tools used consisted of plastic measuring cups, seedling trays, measuring tape, digital caliper, weighing scale, digital analytic scale, thermo recorder (TR-72U, Japan), digital lux meter (Mother Tool LX-1108, Taiwan), and digital anemometers (Lutron LM-8000A, Taiwan).

2.2. Method

A split-split plot randomized block design design was applied to analyze the effect of agricultural building type, nutrient solution volume, and chilli cultivar. The main plot included three building types, such as greenhouse, screenhouse, and open field (Figure 1). The subplot included four nutrient solution volumes based on crop evapotranspiration (ET_c), which were 100% ET_c, 75% ET_c, 50% ET_c, and 25% ET_c. The sub-subplot involved two chilli cultivars, Pilar and Osaka. A total of 24 treatment combinations were tested. Each combinations was replicated three times, resulting 72 experimental units. Each experimental unit contained three plants, leading to total of 216 plants. This means that each treatment combination had a sample size of three experimental units, with each unit containing three plants, for a total of nine plants per treatment.



Figure 1. Agricultural Building Types A) Greenhouse, B) Screenhouse, and C) Open field.

Chili plants were cultivated at three locations: a greenhouse ($24 \times 17 \times 6$ m) with a 200-micron UV plastic roof and 50-mesh screen net walls, a screenhouse ($15 \times 3.5 \times 2.8$ m) entirely covered with 50-mesh screen netting, and an open field (15×5 m). Before planting, all locations were cleared of plant residues, weeds, and debris. In the greenhouse, plastic mulch was installed as a base for the plant polybags, while in the screenhouse and open field, the soil was leveled and covered with weedmat to suppress weed growth and maintain a clean experimental area.

Chilli pepper seeds were pre-treated by soaking in warm water for one hour to select viable seeds, with only seeds that sank being used for sowing. Seedlings were raised in seedling trays containing a 2:1 mixture of rice husk charcoal and cocopeat. One seed was sown per hole, and trays were maintained under shaded conditions and irrigated daily until seedlings reached four weeks of age, with 4–6 fully expanded true leaves.

Transplanting was conducted when chili seedlings were four weeks old after sowing. The seedlings were placed into polybags filled with a 2:1 mixture of husk charcoal and cocopeat. Polybags were arranged at 50 x 50 cm spacing in each agricultural building. Crop management practices included routine pruning of lateral shoots and staking plants with bamboo stakes to maintain upright growth. Pest control carried out using methyl eugenol traps and a systemic insecticide containing spinoteram (120 g L^{-1}) that applied weekly. Weed growth around the polybags was managed manually throughout the experiment to minimize competition for nutrients and water, ensuring optimal plant growth. Fruit were harvest daily in the morning by handpicking when fully red.

Nutrient solution irrigation was applied daily in the morning using an AB mix solution mixed with water and applied along with irrigation. The solution was applied directly to the polybag media along with routine irrigation. The irrigation volume was adjusted according to crop evapotranspiration and calculated every week using the following formula:

$$ETc = P + I - D - R - (W_n - W_{n+1})$$

Description:

ETc	: Crop evapotranspiration (mm)
P	: Precipitation (mm)
I	: Irrigation (volume of nutrient solution irrigation applied) (mm)
D	: Drainage (percolation of irrigation and rain) (mm)
R	: Run off (surface flow) (mm)
W_n	: Media weight on day n after irrigation applied till field capacity (g)
W_{n+1}	: Media weight on day n+1 (on following day) (g)

Each plant sample was equipped with a water storage container under the polybag to calculate the amount of percolation (D) resulting from irrigation (I). The weight of the planting medium (W) was calculated by weighing the weight of the planting medium and the plants. The difference recorded will be considered the evapotranspiration from that plant media and will be assigned as 100% ETc. For 75% ETc the evapotranspiration of 100% will be multiply by 0.75, for 50% multiply by 0.50 and for 25% by 0.25.

Yield parameters were recorded for each plant throughout the experimental period. The parameters were measure included number of fruits per plant, fruit weight per plant (g), fruit weight (g), fruit length (cm) and fruit diameter (cm). Fruit length was measured from the pedicel to the apex using a measuring tape, while fruit diameter was measured at the base, middle, and apex using a digital caliper and averaged. All measurements were conducted at each harvest, and data from three plants per experimental unit were averaged to represent the unit. Microclimate conditions included air temperature ($^{\circ}\text{C}$), air humidity (%), wind speed (m/s), and light intensity (w/m^2). Data were analyzed using analysis of variance (ANOVA) at a 5% significance level after verifying normality (Shapiro–Wilk test) and homogeneity of variance (Levene's test). When significant differences were detected, Duncan's Multiple Range Test (DMRT) at the 5% level was used for mean separation.

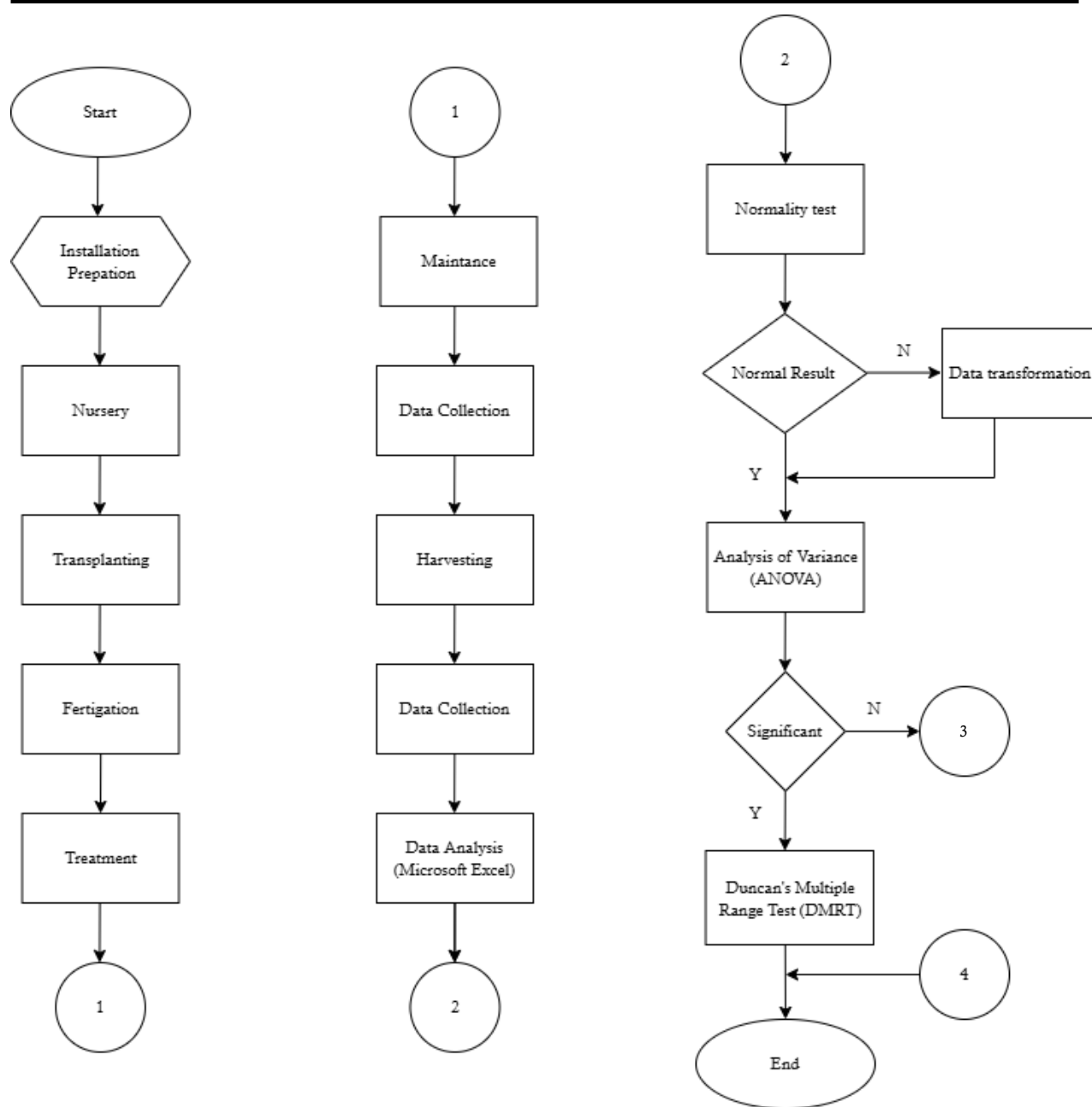


Figure 2. Schematic/flowchart of research

(1) Proceed to maintenance stage. (2) proceed to data analysis. (3) is a non-significant result in the analysis of variance. (4) result interpretation of DMRT. Y is a sign of a normal or significant result; N is a sign of an abnormal or non-significant result from the test.

3. Results and Discussion

3.1 Microclimate Conditions

The microclimate observed during the study consisted of temperature, humidity, wind speed, and light intensity in each agricultural building.

Table 1. Average microclimate conditions in each agricultural building

Nutrient Solution Volume	Temperature (°C)	Humidity (%)	wind speed (m/s)	light intensity (w/m ²)
Greenhouse	27.24	66.76	0.03	280.00
Screenhouse	26.86	70.53	0.39	205.56
Open field	26.13	73.00	1.03	521.67

The average air temperature at the four locations ranged from 26°C-27°C, which is generally still within the optimal temperature range for chili cultivation (Table 1). The optimal temperature for growing red chilies ranges from 24°C-28°C [8]. The highest temperature was found in greenhouse with 27.24°C and the lowest temperature was found in open field with 26.13°C. Greenhouse has a higher average temperature than other buildings due to the completely closed building structure, allowing heat accumulation and increased temperature. Higher temperatures increase evapotranspiration leading to higher water demand [9]. The lowest temperature was recorded in the open field due to its open design that enhance air circulation and stabilizing internal temperatures. However, the open design also increases risk of pest incidence. This supported by previous study that reported higher pest incidence in open field compared to greenhouses and screenhouses [10].

Relative humidity (RH) influences leaf transpiration and plant water balance. The highest RH was recorded in the open field (74.09%), which can reduce transpiration and nutrient uptake, inhibit chili growth, and increase the risk of disease and fungal infection [11-12]. In contrast, the greenhouse had the lowest RH (66.77%), which may enhance transpiration and water uptake but also increase water loss. If water supply is limited, stress can occur, leading to stomatal closure, reduced CO₂ intake, and decreased photosynthesis and yield [13].

The highest wind speed was recorded in the open field (1.03 m/s), due to the absence of structural barriers, while the lowest was observed in the greenhouse (0.03 m/s) due to its enclosed design. Greenhouse structures typically covered with UV plastic roofs and screennet walls, restrict airflow, resulting in reduced wind speed and heat accumulation that elevates internal temperatures. Increasing wind speed has been shown to significantly reduce greenhouse temperature [14]. Higher wind speed in open fields enhance transpiration by accelerating water vapor removal increasing water loss [15]. In contrast, low wind speed in greenhouse combined with high temperature can still raise transpiration. Therefore, optimal air circulation is crucial to maintain favorable conditions within protected cultivation systems.

Table 1 shows that the highest light intensity was in the open field (521.68 w/m²), while the lowest was in the screenhouse (205.56 w/m²), reflecting structural differences. Open fields allow full solar exposure, enhancing photosynthesis through increased stomatal opening [16]. However, excessive light can stress plants and raise transpiration, thereby increasing water demand. In contrast, screenhouse exhibited lowest light intensity among all structures, primarily due to the insect net roofing, which reduced light penetration into the growing area. Agricultural building effectively reduce light intensity received by plants. Crops grown under 25-80% shading can produced yields equal or higher than under full sunlight [14]. Chilli plants often benefit from partial shading to avoid stress caused by high light intensity. Meanwhile, low light intensity can reduce the rates of photosynthesis, transpiration, and stomatal conductance leads to decreasing plant dry matter accumulation [17].

3.2 Number of Fruits per Plant

The results of statistical analysis showed no interaction between agricultural buildings, nutrient solution volume and cultivars. The agricultural building and nutrient solution volume treatments independently had a significant effect on number of fruits per plant (Table 3).

Table 2. Interaction between agricultural buildings and chilli cultivars on number of fruits per plant

Factors	Treatment	Number of Fruits per Plant
Agricultural Buildings	b ₁ : Greenhouse	53.08 b
	b ₃ : Screenhouse	33.04 a
	b ₄ : Open field	20.88 a
Nutrient Solution Volume	w ₁ : 100% ETc	45.56 c
	w ₂ : 75% ETc	43.17 bc
	w ₃ : 50% ETc	31.39 ab
	w ₄ : 25% ETc	22.56 a
Cultivars	v ₁ : Pilar	36.17 a
	v ₂ : Osaka	35.17 a

Note: means followed by the same letter in the same column are not significantly different according to DMRT 5%; ETc=Evapotranspiration.

The absence of interaction indicates that the response patterns of the cultivars to nutrient solution volume and microclimatic modification through building type were parallel and independent. Both cultivars exhibited a similar response pattern across all building types and nutrient solution levels, with higher fruit numbers consistently observed in greenhouses and under higher nutrient volumes. This suggests that microclimate improvement through protected structures and sufficient nutrient supply benefit both cultivars in the same way, without cultivar-specific sensitivity. Consequently, the observed differences were attributable to the main effects of agricultural building type and nutrient solution volume rather than their combinations with cultivar.

Table 2 shows that greenhouse produced the highest number of fruits per plant compared to screenhouse and open field. This higher number of fruits reflects the more favorable microclimate in the greenhouse. As shown in the Table 1, greenhouse recorded the lowest wind speed (0.03 m/s), while higher wind speeds were observed in the screenhouse (0.39 m/s) and open field (1.03m/s). This indicates that lower wind speeds increase fruit yield and excessive wind speed reduce crop yield [18]. Previous study shows that wind velocity below 1 km/h in greenhouses is associated with avoidance of physical damage, flower and fruit abortion, and branch breakage, which are factors known to reduce fruit yield in open-field conditions [19]. Reduced wind exposure in protected structures likely contributes to higher fruit set and fruit weight through reduced mechanical and abiotic stress.

Conversely, excessive wind exposure in open environments can increase plant stress, impair pollination efficiency, and reduce fruit set, ultimately leading to lower fruit yield

The number of fruits per plant did not significantly differ between the nutrient solution volumes of 100% ETc and 75% ETc, but did significantly differ between the nutrient solution volumes of 50% ETc and 25% ETc. This finding aligns with previous studies reporting that applying 100% ETc irrigation volumes resulted in higher fruit numbers compared to lower irrigation volumes [10]. Also, Meanwhile 50% ETc and 25% ETc produced the lowest fruit indicates that 50% ETc is inadequate to meet the plant's water needs to produce higher fruit. Limited water availability leading plants to experience water stress, stomatal closure, reduced photosynthetic activity, which impaired fruit formation [20-21]. The 25% ETc likely triggered adaptive responses such as osmotic adjustment and antioxidant activity enabling continued fruit production under water deficit [22].

3.3. Fruit Weight per Plant

The results of statistical analysis showed no interaction between agricultural buildings, nutrient solution volume and chili cultivars. The agricultural building and nutrient solution volume treatments independently had a significant effect on fruit weight per plant (Table 3).

Table 3. Effect of agricultural buildings, nutrient solution volume, and chilli cultivars on fruit weight per plant

Factors	Treatment	Fruit weight per plant (g)
Agricultural Buildings	b ₁ : Greenhouse	582.83 c
	b ₃ : Screenhouse	305.10 b
	b ₄ : Open field	181.36 a
Nutrient Solution Volume	w ₁ : 100% ETc	465.13 c
	w ₂ : 75% ETc	420.03 bc
	w ₃ : 50% ETc	329.88 b
	w ₄ : 25% ETc	210.68 a
Cultivars	v ₁ : Pilar	384.66 a
	v ₂ : Osaka	328.20 a

Note: means followed by the same letter in the same column are not significantly different according to DMRT 5%; ETc=Evapotranspiration.

Table 3 shows that the greenhouses produced the highest fruit weight per plant compare to other agricultural building, in line with the number of fruits per plants. This consistency suggests that the greenhouse provide a favorable microclimate for fruit development. Microclimate stability plays a crucial role in plant physiological processes, including fruit formation and development, ensuring optimal growth [23]. Furthermore, greenhouses create a more stable environment than open fields, thus supporting chili plant growth [24]. Greenhouses also offer optimal light intensity compared to other structures (Table 2). Under these moderated light conditions, chili plants avoid photoinhibition that often occurs under excessive radiation in openfield. This allows plants to maintain high photosynthetic efficiency and improving assimilation with are essential for growth and fruit development. This consistent with previous findings that optimal light intensity enhances photosynthesis and ultimately supports greater fruit productivity [25].

Fruit weight per plant at 100% ETc nutrient solution volume was not significantly different with 75% ETc but was significantly higher than 50% ETc and 25% ETc volumes. This indicates that nutrient solution volumes at 50% ETc and 25% ETc are insufficient to meet optimal fruit production. Previous study reported that water belowe 50% ETc tend to result in reduced fruit weight per plant [20]. Limited water availability induced physiological water stress that triggers stomatal closure as a protective response to minimize transpiration. Stomatal closure leads to restricts CO₂ uptake which reduces photosynthetic activity and interferes with fruit development, thereby directly decreasing fruit weight per plant [21]. In addition, water deficit disrupts cell expansion and reproductive processes, ultimately resulting in smaller fruit size and lower overall yield.

Chili pepper cultivar did not significantly affect fruit weight per plant. This indicates that both Pilar and Osaka cultivars exhibited consistence performance due to their adaptive capacity. Previous studies have demonstrated that cultivar identity has less impact than irrigation or microclimatic structure on yield and growth performance under diverse irrigation volume and environment conditions [26]. This consistency may be due to the similar physiological responses in utilizing light, nutrients, and water to support fruit development. Although Pilar and Osaka originate from different

environmental backgrounds, these results suggest both are capable of maintaining fruit productivity across various types of agricultural structures and nutrient solution volumes.

3.4. Fruit Weight

The results of statistical analysis showed no interaction between agricultural buildings, nutrient solution volume and chili cultivars. The agricultural building and cultivar treatments independently had a significant effect on fruit weight per plant (Table 4).

Table 4. Effect of agricultural buildings, nutrient solution volume, and chilli cultivars on fruit weight

Factors	Treatment	Fruit Weight (g)
Agricultural Buildings	b ₁ : Greenhouse	10.43 b
	b ₃ : Screenhouse	9.33 ab
	b ₄ : Open field	8.52 a
Nutrient Solution Volume	w ₁ : 100% ETc	9.17 a
	w ₂ : 75% ETc	9.68 a
	w ₃ : 50% ETc	9.03 a
	w ₄ : 25% ETc	8.99 a
Cultivars	v ₁ : Pilar	10.57 b
	v ₂ : Osaka	7.87 a

Note: means followed by the same letter in the same column are not significantly different according to DMRT 5%; ETc=Evapotranspiration.

The greenhouse agricultural structure showed no significant difference in fruit weight compared to the screenhouse (Table 4). Both structures have been reported to enhance fruit weight and yield through improved environmental conditions [27-28]. This consistency supported by microclimate condition (Table 1) which show that greenhouse and screenhouse condition maintain moderate temperatures and reduced wind speed compared to openfield. Stability microclimate promotes efficient gas exchange and reduces excessive evapotranspiration, thereby sustaining water balance and photosynthetic activity. Furthermore both structures reduced light intensity compared to open field, preventing photoinhibition while maintaining sufficient light for photosynthesis. The use of screen net materials used in greenhouse and screenhouse also help reduces pest and disease incidence and excessive sunlight intensity helping to minimize plant stress [29]. By lowering stress factors and stabilizing assimilate production, both building create favorable conditions for optimal fruit development, thereby increasing fruit weight.

The volume of the nutrient solution did not significantly affect the average weight per chili fruit. This finding is consistent with previous study reporting that irrigation volume had no significant effect on chili fruit weigh [30]. The insignificant difference in fruit weight suggest that chili plants possess physiological mechanisms that enable efficient regulation of water use under suboptimal conditions. Adaptive responses such as increased root length and enhanced nutrient uptake contribute to maintaining assimilate production and allocation to the fruit sink [31]. These adjustments help sustain the balance between photosynthesis as source activity and fruit growth as sink demand, thereby stabilizing individual fruit weight. However, under severe water limitation, these adaptive mechanisms may become insufficient, leading to reduced CO₂ assimilation, restricted carbohydrate partitioning, and disrupted cell expansion during fruit development, which collectively lead to a reduction in fruit weight.

Regarding varietal difference, Pilar cultivar exhibited a higher average fruit weight (10.57 g) compared to Osaka (7.87 g), consistent with its varietal characterization of producing larger fruits. This finding highlights the role of genetic factors in determining fruit weight and size. In addition to

genetics, environmental suitability also plays a role in plant performance. Genotype and environment interactions often determine the extent to which genotypes express their yield potential, and locally adapted cultivars frequently display greater stability under domestic growing conditions compared with introduced genotypes [32]. Pilar as a local cultivar likely benefits from better environmental compatibility than Osaka, leading to more optimal fruit development.

3.5. Fruit Length and Diameter

The results of statistical analysis showed no interaction between agricultural buildings, nutrient solution volume and chili cultivars. Agricultural building type and chili cultivar had significant independent effect on fruit length, whereas fruit diameter was significantly influenced by nutrient solution volume and cultivar (Table 5).

Table 5. Effect of agricultural buildings, nutrient solution volume, and chilli cultivars on fruit length and diameter

Factors	Treatment	Fruit Length (cm)	Fruit Diameter (cm)
Agricultural Buildings	b ₁ : Greenhouse	17.44 b	1.18 a
	b ₃ : Screenhouse	16.98 b	1.16 a
	b ₄ : Open field	15.27 a	1.19 a
	w ₁ : 100% ETc	17.07 a	1.21 b
Nutrient Solution Volume	w ₂ : 75% ETc	16.15 a	1.21 b
	w ₃ : 50% ETc	16.62 a	1.17 ab
	w ₄ : 25% ETc	16.43 a	1.12 a
Cultivars	v ₁ : Pilar	16.69 a	1.31 b
	v ₂ : Osaka	16.44 a	1.04 a

Note: means followed by the same letter in the same column are not significantly different according to DMRT 5%; ETc=Evapotranspiration.

Table 5 shows that the shortest fruit length was recorded in the open field (15.27 cm), significantly lower than all other agricultural buildings. This finding aligns with previous studies reporting that crops cultivated under protective structures generally produced longer fruits compare to those grown in open fields [25]. The advantage of protected environments lies in their ability to regulate microclimatic conditions, supporting more favorable physiological process during fruit development. As shown in tabel 1, both greenhouse and screenhouse exhibited lower light intensity compare to the open field. Moderated light intensity in such environments supports optimal photosynthesis without causing stress from excessive radiation [24]. Moderated light intensity optimized photosynthesis by preventing photoinhibition under excessive radiation, thus maintaining higher assimilate production [33]. In addition, relatively stable temperature and humidity within protective structures minimize abiotic stress, reduce excessive evapotranspiration, and support sustained cell division and elongation during fruit growth.

The nutrient solution volume had no significant effect on fruit length but showed a significant effect on fruit diameter. Consistently, previous studies has shown that irrigation volume does not significantly influence fruit length [24]. However, fruit diameter tended to decrease with lower nutrient volumes. Differences in fruit diameter may be attributed to the volume of nutrient solution applied. Fruit size is primarily influenced by cell division and expansion processes that are highly dependent on the availability of carbohydrates and water [34]. Therefore, limited water availability may interfere with these physiological processes, ultimately limiting fruit development.

The cultivar treatment had no significant effect on fruit length but showed a significant effect on fruit diameter. This may be attributed to genetic differences between cultivars that influence fruit development, particularly in traits associated with cell expansion and pericarp thickening. Previous studies have shown that fruit diameter exhibits high heritability and genetic advance, indicating that genetic factors contribute to differences among cultivars [35]. Furthermore, physiological processes such as enhanced cell division and expansion in the fruit wall contribute to larger diameters, reflecting the strong genetic control over this morphological characteristic.

4. Conclusion

There was no interaction between agricultural building types, nutrient solution volumes, and chili cultivars on red chili yield. However, each factor exhibited a significant independent effect. Greenhouse significantly enhanced number of fruits, fruit weight per plant, individual fruit weight and fruit length. Nutrient volume of 75% ETc and 100% ETc resulted comparable outcomes for fruit number and fruit weight per plant. The Pilar cultivar outperformed Osaka in terms of fruit weight and fruit diameter highlighting the role of genetic traits and local adaptability. These findings suggest that the combination of greenhouse conditions with 75% ETc nutrient solution volume and the use of the Pilar cultivar is recommended for efficient and sustainable chili cultivation. The result emphasizes the importance of integrating cultivar selection, irrigation management, and structural design to enhance chili productivity under tropical conditions.

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