

# Engineering And Agronomic Evaluation of a Detachable Mini Hoop House for Muskmelon Cultivation Adapted to Climate Change in Central Vietnam

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**ABSTRACT:** Protected cultivation is increasingly required in humid tropical regions where rainfall variability, high humidity, pest pressure, and storm-related risks reduce the reliability of open-field production. In central Vietnam, muskmelon cultivation is constrained by unstable weather conditions, while conventional greenhouses and permanent net houses remain costly and vulnerable to structural damage during the storm season. This study developed and evaluated a low-cost detachable mini hoop house for muskmelon production. The structure consisted of a steel arch frame designed to fit raised beds and to permit rapid assembly and removal before severe weather events. Four cultivation treatments were compared: mini hoop house covered with a 19-mesh insect net, a 25-mesh insect net, transparent nylon film, and open-field cultivation as the control. Covering material significantly affected the crop microclimate, vegetative growth, crop protection, yield, and fruit quality. Mean air temperature was highest under transparent nylon film ( $36.8 \pm 2.1$  °C) and lowest in the open field ( $31.9 \pm 0.9$  °C), whereas the 19-mesh insect net provided a more moderate thermal environment ( $33.4 \pm 1.2$  °C) with relatively high humidity ( $74.2 \pm 4.1\%$ ). The 19-mesh treatment produced the best agronomic performance, including plant growth, higher female flower production, and the highest fruit quality. The detachable mini hoop house therefore represents a practical climate-adaptive protected-cultivation option for smallholder muskmelon production in central Vietnam and comparable tropical coastal environments.

**KEYWORDS:** Climate adaptation; low tunnel; mini hoop house; muskmelon; protected cultivation; tropical horticulture

## I. INTRODUCTION

Protected cultivation has become an important strategy for stabilizing horticultural production under increasingly variable climatic conditions. In humid tropical and subtropical environments, intense rainfall, high relative humidity, and high pest pressure frequently reduce

crop productivity and fruit quality under open-field conditions. For high-value fruit vegetables, crop protection systems are therefore expected not only to protect plants from rainfall and insects, but also to regulate temperature, ventilation, and canopy humidity while remaining economically accessible to smallholder farmers (Singh et al., 2024).

Melon (*Cucumis melo* L.) is a high-value horticultural crop widely appreciated for its sweetness, appearance, and market potential (Drost & Hefelbower, 2010). However, successful muskmelon production requires relatively warm and dry conditions, while excessive rainfall and humidity can increase disease incidence, reduce fruit quality, and lower marketable yield (Phong, 2016). In central Vietnam, weather variability, seasonal storms, and prolonged wet periods create serious constraints for open-field muskmelon production. Under such conditions, farmers need a cultivation system that provides protection but remains affordable and adaptable to local small-scale production.

Conventional greenhouses and permanent net houses can improve crop protection, but their wider adoption by smallholders is restricted by high investment cost, maintenance requirements, and vulnerability to structural damage in storm-prone regions. For this reason, simpler low-tunnel or mini hoop house systems deserve greater attention as climate-adaptive technologies for tropical horticulture. Such systems offer lower construction cost, easier field installation, and the possibility of seasonal disassembly, which is particularly relevant in areas exposed to typhoons and strong winds (Arancibia, 2018, Baudoin and von Zabeltitz, 2002).

Despite the practical promise of small protected structures, the performance of a mini hoop house depends strongly on covering material. A cover that is too closed may trap excessive sensible heat and depress crop performance, whereas a cover that is too permeable may provide insufficient protection from rain, insects, and wind-driven disturbance. The key design challenge is therefore to integrate engineering considerations, including structural simplicity, detachability, and ventilation

capacity, with agronomic requirements such as canopy development, reproductive success, and fruit quality (Rault, 1988).

The present study addressed this gap by designing and evaluating a detachable mini hoop house for muskmelon production under the climate conditions of central Vietnam. The specific objectives were to: (i) develop a low-cost mini hoop house adapted to raised-bed muskmelon cultivation and seasonal storm risk; (ii) compare the effects of three covering materials on microclimate, crop growth, crop protection, yield, and fruit quality; and (iii) identify the most suitable cover type for small-scale protected muskmelon production in Hue and comparable tropical environments. The novelty of the study lies in the integration of structural design and agronomic performance assessment for a detachable mini hoop house intended for low-cost use in storm-prone tropical conditions.

## II. MATERIALS AND METHODS

### A. Study site and materials

The experiment was conducted at the experimental field of the University of Agriculture and Forestry, Hue University, Hue, Vietnam. The muskmelon cultivar used in the study was Yuki 109, selected for its fruit quality and production potential under local conditions. Seeds were sown in seedling trays and transplanted at the two-true-leaf stage.

### B. Mini hoop house design

The mini hoop house was developed as a detachable, low-cost protected-cultivation structure suitable for smallholder conditions in central Vietnam. The design was based on practical field requirements and on protected-cultivation principles emphasizing crop space, structural simplicity, ventilation, and resilience under tropical weather constraints. Instead of using a permanent greenhouse configuration, the structure was conceived as a seasonal unit that could be dismantled before the peak storm period, thereby reducing the risk of structural damage and minimizing farmer losses.

The arch was fabricated from steel pipe with a diameter of 21 mm, wall thickness of 1.2 mm, and

## III. RESULTS AND DISCUSSION

### A. Structural suitability of the detachable mini hoop house

The proposed mini hoop house was designed specifically for the climatic and socioeconomic context of central Vietnam. Its engineering rationale was not to replicate a permanent greenhouse at smaller scale, but to provide

length of 4.0 m to provide sufficient structural strength, preserve the curved hoop configuration, and permit repeated use over multiple cropping seasons. The resulting structure measured approximately 1.4 m in width, 1.7 m in height, and with frame spacing of 1.2–1.4 m. These dimensions were selected to fit the raised-bed cultivation system while allowing farmers to stand comfortably and conduct manual crop management operations inside the structure. In addition, the internal height provided adequate air volume above the crop canopy, which improved passive ventilation and helped reduce heat accumulation under tropical growing conditions.

### C. Experiment treatments and measurement

Four treatments were compared in the article framework, T1: mini hoop house covered with 19-mesh insect net, T2: mini hoop house covered with 25-mesh insect net, T3: mini hoop house covered with transparent nylon film, T4: open-field cultivation.

Plants were grown on raised beds approximately 20 cm high and 1.0–1.2 m wide. Plant spacing was 40 cm within rows and 140 cm between rows. Fertilizer was applied at the equivalent rate of 130 kg N, 100 kg P<sub>2</sub>O<sub>5</sub>, and 100 kg K<sub>2</sub>O ha<sup>-1</sup> according to the local muskmelon production protocol. Irrigation, pruning, hand pollination, fruit thinning, and fruit-support practices were performed according to standard local management procedures used for protected muskmelon cultivation.

Environmental variables monitored during the cultivation cycle included air temperature and relative humidity within each production system. Crop observations included growth duration, plant height, leaf number, node number, female flower number, pest incidence, and fruit-quality attributes. Fruit-quality assessment included fruit length, fruit width, average fruit weight, flesh thickness, and soluble solids concentration, expressed as °Brix.

### D. Statistical analysis

Treatment means are presented as mean ± standard deviation. Mean separation was conducted using Tukey's honestly significant difference test at the 5% probability level using R software.

a structurally simple, low-cost, and detachable system compatible with raised-bed muskmelon cultivation and seasonal storm risk. This distinction is important for tropical coastal regions, where the economic viability of protected cultivation depends not only on crop response but also on whether farmers can remove or secure the structure before damaging weather events.

The width and height of the structure were

also agronomically justified. A width of 1.4 m matched the bed configuration, while the 1.7 m height provided sufficient working space for manual crop operations and maintained an air volume above the canopy to support passive thermal buffering. In

practical terms, this design created a compromise between affordability, ease of assembly, and environmental control, thereby strengthening the link between agricultural engineering and crop management. (Fig 1.)

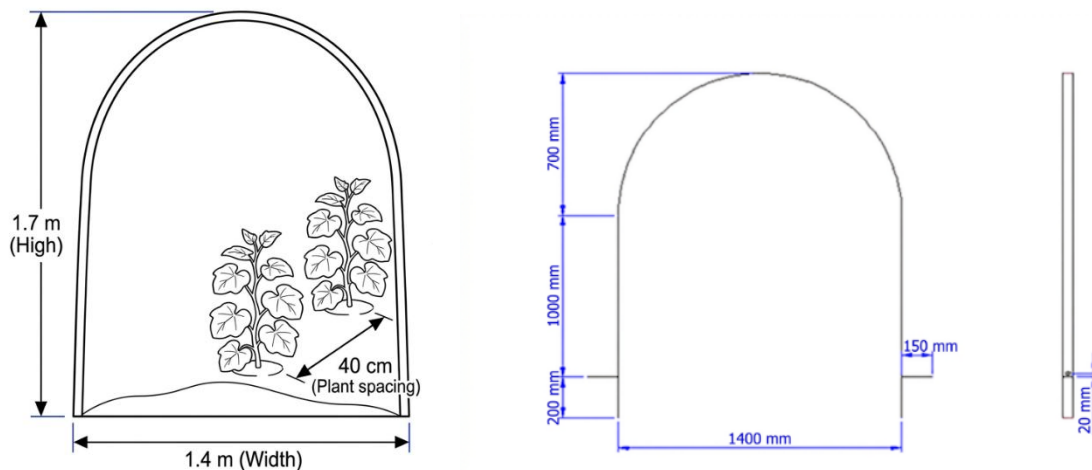


Fig 1. Detachable mini hoop house used for muskmelon cultivation in central Vietnam

### B. Microclimate modification under different cover treatments

Covering material markedly altered the internal microclimate of the mini hoop house (Table 1). The transparent nylon film treatment produced the highest mean air temperature ( $36.8 \pm 2.1$  °C), followed by the 25-mesh insect net ( $34.1 \pm 1.5$  °C), the 19-mesh insect net ( $33.4 \pm 1.2$  °C), and the open-field control ( $31.9 \pm 0.9$  °C). Relative humidity was highest under the 19-mesh net ( $74.2 \pm 4.1\%$ ) and lowest under transparent nylon film ( $68.5 \pm 5.8\%$ ). Relative humidity differences were less pronounced, but the covered treatments still changed the crop environment, with recorded humidity values ranging from 64-82% in the 19-mesh treatment, 64-79% in the 25-mesh treatment, 61.5-75% in the nylon treatment, and 64-80% in the open field.

These differences can be explained by the interaction between radiation transmission, convective heat exchange, and aerodynamic resistance. Transparent nylon film allows incoming shortwave radiation to enter the structure while restricting longwave heat loss and strongly limiting air exchange with the external atmosphere; as a result, sensible heat accumulates rapidly during sunny periods. In contrast, insect-net covers permit continuous passive ventilation, but the degree of

airflow restriction depends on mesh size. The finer 25-mesh net likely imposed greater resistance to air movement than the 19-mesh net, which helps explain its slightly higher internal temperature.

Humidity behavior also reflected the balance between canopy transpiration and ventilation. Under transparent film, the very high air temperature would increase saturation vapor pressure and enlarge vapor pressure deficit, thereby lowering relative humidity even when evapotranspiration remained substantial. Under netted treatments, reduced wind speed around the canopy can retain a localized humid boundary layer, but the 19-mesh net appears to have preserved a more favorable balance than the 25-mesh net by combining moderate humidity retention with better heat dissipation. From a protected-cultivation perspective, this result is important because muskmelon requires both thermal adequacy and sufficient ventilation to sustain photosynthesis, floral development, and fruit filling.

The nylon structure (T3) recorded the lowest mean relative humidity, dropping to a minimum of 31.0% during peak radiation hours (13:00 - 15:00).

Table 1. Microclimatic parameters within different mini hoop house cover and open-field control during the experimental cultivation cycle in Central Vietnam

<i>Treatment</i>	<i>Protective Cover Specification</i>	<i>Mean temperature (°C)</i>	<i>Mean humidity (%)</i>
T1	Mini hoop house + 19-mesh insect net	33.4 ± 1.2 <sup>b</sup>	74.2 ± 4.1 <sup>a</sup>
T2	Mini hoop house + 25-mesh insect net	34.1 ± 1.5 <sup>b</sup>	72.8 ± 4.5 <sup>a</sup>
T3	Mini hoop house + Transparent nylon film	36.8 ± 2.1 <sup>a</sup>	68.5 ± 5.8 <sup>c</sup>
T4	Open-field cultivation (Control)	31.9 ± 0.9 <sup>c</sup>	70.1 ± 3.9 <sup>b</sup>

Note: Values represent the treatment mean ± standard deviation. Means within a column followed by different lowercase superscript letters (a, b, c) indicate statistically significant differences determined by Tukey's Honestly Significant Difference (HSD) post-hoc test at  $\alpha = 0.05$ .

### C. Vegetative growth and reproductive response

Protected cultivation improved vegetative growth relative to the open field, and the 19-mesh treatment produced the strongest overall plant development. At 35 days after transplanting, plants under the 19-mesh cover reached 176.90 cm in height, 30.80 leaves per plant, and 30.20 nodes per plant, whereas the open-field control reached only 84.50 cm, 25.00 leaves, and 24.00 nodes, respectively. The same treatment also produced the highest number of female flowers, with 8.50 flowers per plant compared with 7.10 under the 25-mesh net, 6.60 under transparent film, and 3.60 in the open field.

These responses indicate that the 19-mesh cover produced a microenvironment closer to the physiological optimum for muskmelon. Moderate warming can accelerate leaf expansion and node development, but excessive temperature reduces pollen viability, disrupts assimilate partitioning, and increases respiratory cost. The superior reproductive performance observed under the 19-mesh net therefore supports the view that this cover improved the balance between thermal protection and ventilation, allowing improved vegetative growth without the heat stress likely induced by the nylon-film treatment.

### D. Yield and fruit quality

The best fruit performance was also obtained under the 19-mesh mini hoop house. This treatment produced fruit length of 15.20 cm, fruit width of 14.80 cm, average fruit weight of 1.48 kg, flesh thickness of 3.45 cm, and soluble solids

concentration of 13.82 °Brix. By comparison, the 25-mesh treatment produced 14.10 cm fruit length, 13.90 cm fruit width, 1.31 kg fruit weight, 3.12 cm flesh thickness, and 12.94 °Brix, whereas the transparent nylon-film treatment produced 13.20 cm, 12.80 cm, 1.21 kg, 2.88 cm, and 12.18 °Brix, respectively. The open field did not produce marketable fruit because of severe pest damage and unstable environmental conditions.

The same performance trend was reported across two cropping cycles in the supporting design-and-installation dataset, where the 19-mesh treatment again achieved the highest fruit weight and sweetness. This consistency strengthens the interpretation that the agronomic advantage of the 19-mesh cover was systematic rather than incidental. Better fruit size and sweetness under this treatment are physiologically plausible because muskmelon fruit development depends on stable photosynthetic activity, effective source-sink balance, and avoidance of heat or water stress during fruit enlargement and sugar accumulation.

### E. Crop protection

The protected structures also functioned as physical barriers against insect pests. Fruit-fly damage reached 100% in the open field but remained 0% under all covered treatments, demonstrating the essential role of physical exclusion in muskmelon production under local conditions. Whitefly incidence differed among covers, suggesting that pest exclusion alone did not determine crop performance. Instead, the most effective system was the one that combined sufficient insect protection with adequate

ventilation and thermal moderation. This engineering-agronomy interaction explains why the 19-mesh net outperformed both the finer net and the closed nylon film.

#### ***F. Implications for climate-adaptive protected cultivation***

The study has direct relevance for climate-change adaptation in smallholder horticulture. In central Vietnam, increasing weather variability is likely to intensify rainfall uncertainty, heat episodes, and storm-related production risks. A detachable mini hoop house offers a practical intermediate technology between open-field cultivation and expensive permanent structures: it protects the crop during the growing period, reduces pesticide dependence through pest exclusion, and can be removed before the most hazardous storm events.

From an engineering perspective, the key contribution of the present system is that structural simplicity was combined with functional environmental control. Low tunnels and similar temporary structures are advantageous because they are easy to assemble and disassemble, can reduce insect damage, and can improve vegetative growth and yield through microclimate modification. However, the performance of a protected structure depends strongly on cover permeability: overly closed covers restrict ventilation and may trap excessive heat, whereas more permeable net covers can preserve airflow while still excluding pests. This principle is consistent with tropical tunnel studies

#### **IV. CONCLUSION**

This study demonstrates that a detachable mini hoop house is a technically feasible and agronomically effective protected-cultivation system for muskmelon production in central Vietnam. The structure is low-cost, easy to assemble, and suitable for seasonal dismantling before the storm period. These characteristics make it particularly relevant for smallholder farmers in tropical coastal regions where permanent protected structures may be economically risky.

Among the tested covers, the 19-mesh insect net provided the best overall performance. It created a more favorable microclimate than the 25-mesh insect net and transparent nylon film, supported stronger vegetative growth and reproductive development, reduced effective pest damage, and produced the highest fruit weight and soluble solids content. The agronomic results indicate that successful protected muskmelon cultivation depends on achieving an appropriate balance between physical protection and passive ventilation.

showing that natural ventilation is essential for controlling internal temperature in humid lowland climates (Ben-Yakir et al., 2008).

From an agronomic standpoint, the present results indicate that the 19-mesh cover achieved the best balance between thermal regulation, humidity retention, and pest exclusion. Insect nets and row covers can reduce pest entry and virus transmission, thereby decreasing the need for insecticides and improving crop safety and marketable yield. At the same time, reduced wind speed under covered systems can lower evapotranspiration and moderate plant stress, which helps explain the stronger vegetative growth and improved fruit development observed under protected cultivation. For muskmelon, this balance is critical because excessive enclosure can reduce fruit quality, whereas moderate protection can enhance sugar accumulation and fruit enlargement under stable canopy conditions (Anusha et al., 2025).

These findings support a broader design principle for climate-adaptive horticulture in storm-prone tropical regions: the most effective protected structure is not the most enclosed one, but the one that best balances ventilation, heat dissipation, and pest exclusion for the target crop. The detachable mini hoop house therefore represents a practical and scalable option for smallholders in central Vietnam, where farmers need a low-cost technology that can improve productivity during the cropping season while reducing exposure to climatic hazards

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