The effect of hand pollination on the yield of African horned cucumber (*Cucumis metuliferus* E. May. Ex Naudin) fruit grown under protected environments

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Abstract

Pollination is the process by which pollen grains are exchanged in plant flowers to allow for fertilisation and production to take place. However, challenges occur when crops are grown under protected structures where there are minimal activities of natural pollination agents such as wind and animals which are responsible for transferring pollen grains from the anther to the stigma. Therefore, the study objective was to determine the effect on hand pollination on the yield of African horned cucumber grown under greenhouse and shade net environment. A factorial experiment with two factors (hand pollinated and non-hand pollinated/control) was conducted under two different growing environments (greenhouse and shade net). African horned cucumber plants were hand self-pollinated in the morning. Pollen were manually transferred with a hand using the new earbud from the male to the female flowers on the same plant (selfing). Results showed that hand pollinated African horned cucumber plants increased total biomass from 0.93 to 2.23 kg under greenhouse environment. Hand pollinated plants increased harvest index from 0.07 to 0.35 under shade net environment. It can thus, be deduced that hand pollination increases African horned cucumber yield in the greenhouse and shade net environments.

Keywords: Harvest index, total biomass, fruit number, fruit length

Introduction

Pollination is defined by [12] as the process by which pollen grains are exchanged in plant flowers to allow for fertilisation and production to take place. Pollen grains containing the male gametes are normally transferred to the female gamete in the flower part called the carpel. In angiosperm crops, it is transferred from the anther to the stigma [9]. The African horned cucumber plant is monoecious, meaning both male and female flowers are produced on the same plant [5]. The non-bitter African horned cucumber is one of that has the potential to become a viable agronomic crop and has been claimed to be rich in nutrients such as; (i) vitamins, (ii) crude proteins, (iii) total soluble sugars, (iv) macro and micro-nutrients [8]. The crop can be propagated through seeds in the same way as the well-known English cucumber and it requires warm temperature under open field or protected environment for optimal growth,

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development and yield [16]. However, pollination challenges occur when grown under protected environment due to minimal pollination activities normally carried out by agents such as bees and wind [2]. Authors such as [7] suggested that hand pollination be introduced when the crop is cultivated under protected environment such as greenhouse and shade net with aim to improve yield. Hand pollination is described by [12] as the mechanical method which growers use to transfer pollen grains from the anther to the stigma of the flower. The use of quality sterilised equipments is recommended for better results [3]. Researchers such as [10] stated that there should be good air circulation and adequate light for higher fruit production and reduce fruit abortion when growing the crop under protected structure. [9] remarked that trellising is recommended in order to obtain maximum production during the vegetative growth and fruiting stage. The balance is achieved by constant pruning of shoots, foliage, fruits and flowers. [3] indicated that if the canopy of the leaves is too dense, it will shade fruits from sunlight and that can result in pale or unevenly fruits colour, subsequently reduce yield. The study objective was therefore, to investigate the effect of hand pollination on the fruit yield of African horned cucumber grown under greenhouse and shade net environment.

Materials and methods

This study was conducted during [2019/20 and 2020/21] in a (greenhouse-controlled average temperature 16-28˚C and shade net environment-not controlled average (16-30˚C) at the Florida science campus of the University of South Africa (26º 10’ 30’’S, 27º 55’ 22.8’’ E). The relative humidity was measured and maintained between 60 and 75% using automated aerial sprinklers and (Anden Wall Mount Digital Humidistat). Certified seeds were sourced from commercial seed supplier (Seed for Africa, Cape Town). A factorial experiment with two factors (hand pollinated and non-hand pollinated/contol) was conducted under two different growing environments (greenhouse and shade net). The pot experiment was a completely randomised design with nine (9) replicates. The pots were spaced 1 m apart, and an up-rope vertical trellising was used to support the plants. Each site had plants used as guard plants, in order to separate the plants from the external effects outside the experimental plot. Well-established, uniform, and healthy African horned cucumber seedlings, germinated from peat substrate, that were 30 days old, were transplanted into 30 cm depth × 30 cm width. Briefly Area (depth × width) 30 cm × 30 cm = 900 cm^2, A $=\pi \left(\frac{d}{2}\right) \times 2$ d =286.5 cm^2 planting pots.

Hand pollination

African horned cucumber plants were hand self-pollinated in the morning. According to [1], fruit set occurs best in flowers pollinated between 6 am and 8 am. The pistillate and staminate flower buds which were close to anthesis were identified a day before and covered to prevent possible insect visit by enclosing the corolla with paper bags. Pollen were manually transferred with a hand using the new earbud from the male to the female flowers on the same plant (selfing). The staminate flower were taken out and pollen applied on the receptive stigma of pistillate flowers identified. This were achieved by rubbing the pollen contained earbud against the stigma.

Light intensity

The light intensity (lux) was evaluated using a (three-way meter, made in China). The hand-handle device has a built-in light sensor (0-2000) and has been utilized by authors such as [13]. The device enables researchers to test if plants are receiving adequate light right though their canopy.

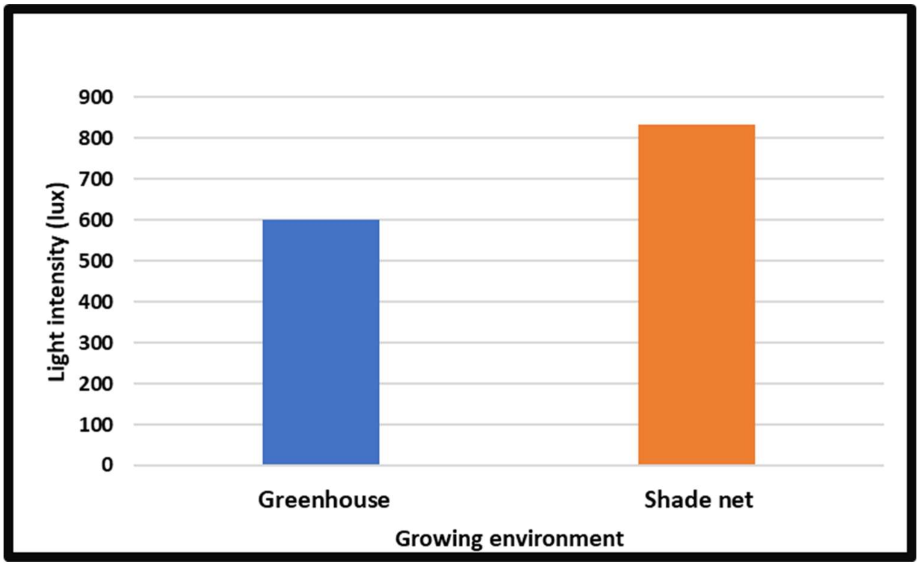

Figure 1: Total light intensity for African horned cucumber grown under two different environments (greenhouse and shade).

Figure 1 illustrate the total light intensity received by plants across different growing environments. The observed trend revealed that light intensity was higher under shade net (833 lux) environment compared to the greenhouse environment (600 lux), showing that light intensity is unequally, depending on the cladding material use for a specific growing structure/environment.

Plant growth parameters

Chlorophyll

Chlorophyll content was measured at different growth stages during the experimental period. The leaf chlorophyll content (μmol/m^2) was measured in the morning using a leaf chlorophyll meter (OPTI-SCIENCES-CCM 200 PLUS, USA). The instrument records four (4) replicate readings of the adaxial or upper leaf surface, since chlorophyll activities are more dominant on the upper leaf surface when compared to the lower surface [15], and gives the average value.

Stomatal conductance

Stomatal conductance (mmol m^{-2} s^{-1}) was measured at different growth stages during the experimental period. The abaxial or lower leaf surface was measured, since stomatal opening and conductance activities are more dominant on the lower leaf surface when compared to the upper surface [14, 8]. The porometer (Delta-T Device, AP4 Leaf Porometer, United Kingdom) was used for the measurement of stomatal conductance.

Yield component

Total biomass and above-ground plant biomass

Above-ground fresh biomass (stem, leaves and fruits) was weighed at the end of the experiment using an electronic scale (Uni-Bioc, China). The plant materials that had already been counted were weighed, placed in paper bags and in an oven for 72 hours at 80˚C before re-weighing to determine dry weight. Total biomass was determined using the formula below:

Total biomass= above-ground biomass (dry) + fruit biomass (dry) **Equation 1**

Fruit number and length

Number of fruits were visually counted, and fruit length were measured at the end of the experiment (12 weeks) after transplanting.

Fruit ripening rate

The fruit colour chart developed by [11] was used to determine the ripeness of the fruit.

Fruit weight

The fruit that had already been counted were weighed, placed in paper bags and in an oven for 90 hours at 80˚C before re-weighing to determine dry weight. Dry Fruit weight was weighed using an electronic scale (Uni-Bioc, China).

Fruit water content

The African horned cucumber fruit water content was determined following the method used by [4]. Briefly, calculating entails (subtracting dry weight from fresh weight).

Harvest index

The *African horned cucumber* harvest index was determined by adopting the formula used by El-mageed & Semida, (2015) below:

$$HI = \frac{\text{fruit dry biomass (dry)}}{\text{total biomass (dry)}}$$ **Equation 2**

Data analysis

Generalised linear mixed model procedures for GenStat (version 14, VSN, UK) were used for data analysis. The model was used to assess the fixed effects of two treatments (hand-pollinated and non-hand pollinated) under greenhouse and shade on the studied variables. In cases where there were no significant interactions between all three studied factors, significant differences for one or two factors were considered

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and reported under results section to determine the effects of all studied variables (chlorophyll content, stomatal conductance, fruit length, fruit number, water content, above-ground biomass, total biomass, harvest index, and fruit number. Shapiro Wilk's and Bartlett's test were used to check the normality and homogeneity of variance. All statistical analysis was done using GenStat (version 14, VSN, UK).

Results

Plant growth parameters

Physiological parameters

Chlorophyll content and stomatal conductance

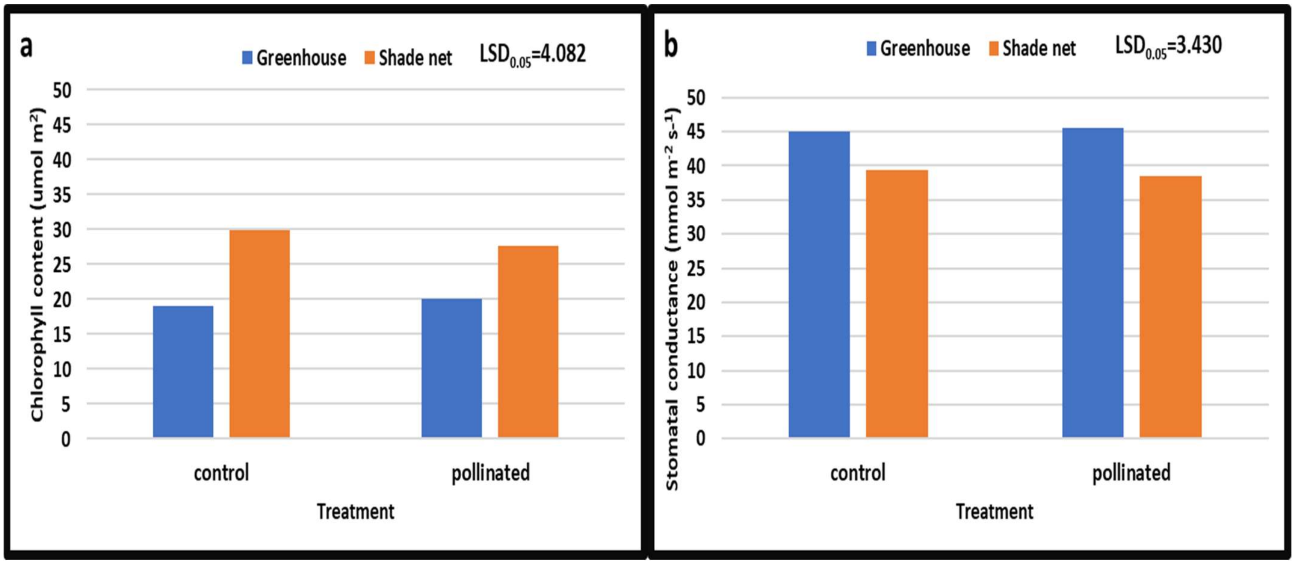

Figure 2: Physiological parameters of African horned cucumber grown under different environments (greenhouse and shade net). **(a)** means the chlorophyll content of African horned cucumber grown under greenhouse and shade net environment; and **(b)** means the stomatal conductance of Africa horned cucumber grown under greenhouse and shade net environment. **$LSD_{0.05}$** is the least significant difference of means.

Figure 2 present the chlorophyll content and stomatal conductance of African horned cucumber grown under the greenhouse and shade net environment. Results evinced that there was no significant ($P>0.05$) difference for both chlorophyll content and stomatal conductance under greenhouse and shade net environments (Figure 2a and b). Chlorophyll content ranged from 19.04 to 30.0 μmol.m^{-2}. The study showed revealed that non-pollinated (control) under greenhouse environment reduced chlorophyll content from 30.0 to 19.04 μmol.m^{-2}, whereas non-pollinated (control) under shade net environment increased chlorophyll content from 19.04 to 30.0 μmol.m^{-2} (Figure 2a).

In addition, results in Figure 4b delineated that stomatal conductance ranged from 38.5 to 45.6 mmol.m^{-2}. The study results illustrated that pollinated plants grown under shade net environment reduced stomatal conductance from 45.6 to 38.5 $mmol.m^{-2}$, whereas greenhouse pollinated plants increased it from 38.5 to 45.6 $mmol.m^{-2}$.

Plant growth parameters

Fruit number and fruit length

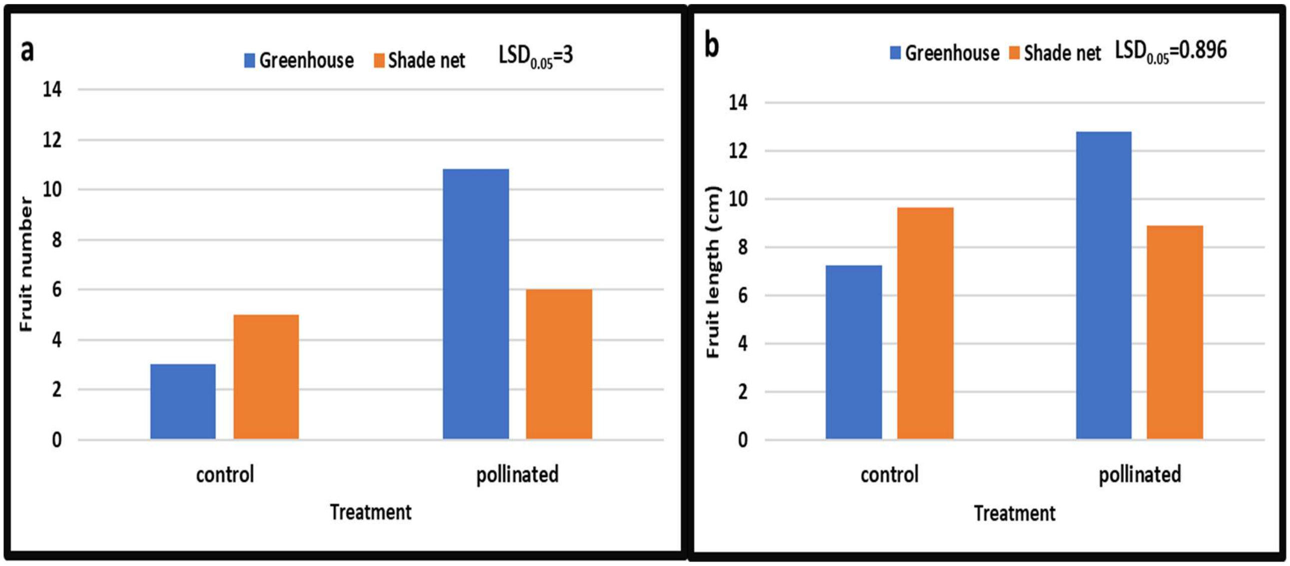

Figure 4: The effect of hand pollination and non-pollinated (control) on the fruit number and length of African horned cucumber fruit grown under different environments. **(a)** means the chlorophyll content of African horned cucumber grown under greenhouse and shade net environment; and **(b)** means the stomatal conductance of African horned cucumber grown under greenhouse and shade net environment. **$LSD_{0.05}$** is the least significant difference of means.

Figure 4 present the effect on hand pollination and non-pollinated (control) on the fruit number and length of African horned cucumber grown under greenhouse and shade net environment. Results outlined that there was a significant ($P \leq 0.05$) difference on fruit number and length between pollinated and non-pollinated (control) *of* African horned cucumber grown under varying environment (greenhouse and shade net).

Under greenhouse environment, fruit number ranged from 3 to 11, whereas shade net fruit number ranged from 5 to 6 (Figure 4a). Moreover, the study results showed that non-pollinated plants (control) under greenhouse environment reduced fruit number from 11 to 3. The highest fruit number of 11, was observed from pollinated plants grown under greenhouse environment. Regarding the fruit length, results evinced that fruit length under greenhouse environment ranged from 7.3 to 12.8 cm, whereas fruit length under shade net environment ranged from 8.8 to 10 cm (Figure 4b). Moreover, results showed that non-pollinated (control) reduced fruit length from 12.8 to 7.3 cm, whereas pollinated plants under greenhouse environment increased it from 7.3 to 12.8 cm (Figure 4b).

Ripening fruit rate

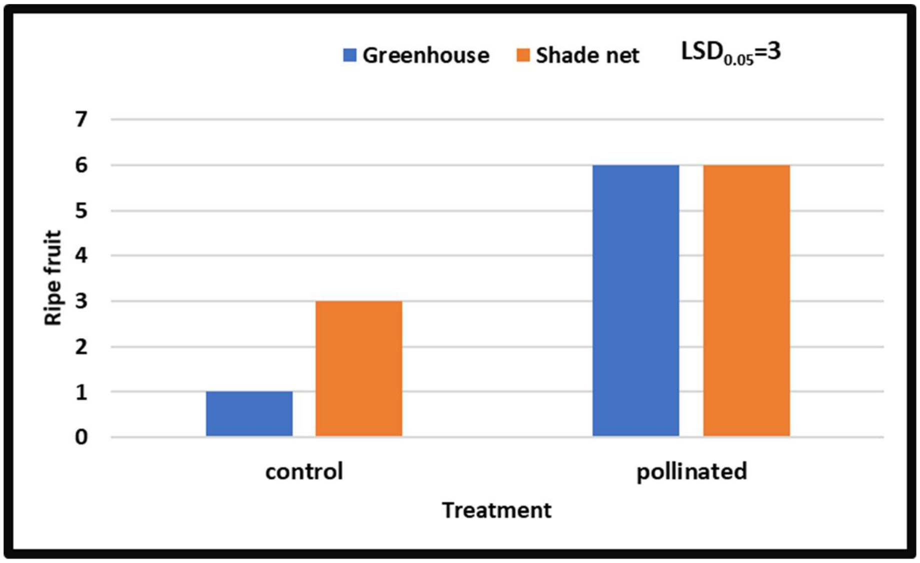

Figure 5: The effect of hand pollination and non-pollinated on the fruit ripening rate of African horned cucumber grown under different environment (greenhouse and shade net). $\mathbf{LSD_{0.05}}$ is the least significant difference of means.

Figure 5 present the ripening fruit rate of African horned cucumber grown under different environment (greenhouse and shade net). Results show that there was significant ($P \leq 0.05$) variation among pollinated and non-pollinated (control) of African horned cucumber grown under varying environment. Under greenhouse environment, African horned cucumber ripening rate ranged from 1 to 6, while shade net ripening rate ranged from 3 to 6. Furthermore, the results revealed that non-pollinated (control) from greenhouse environment reduced fruit ripening rate from 6 to 1. The observed trend showed that pollinated plants from both growing environments (greenhouse and shade net) indicated increase in fruit ripening rate from 1 to 6 (Figure 5).

Yield component

Total biomass

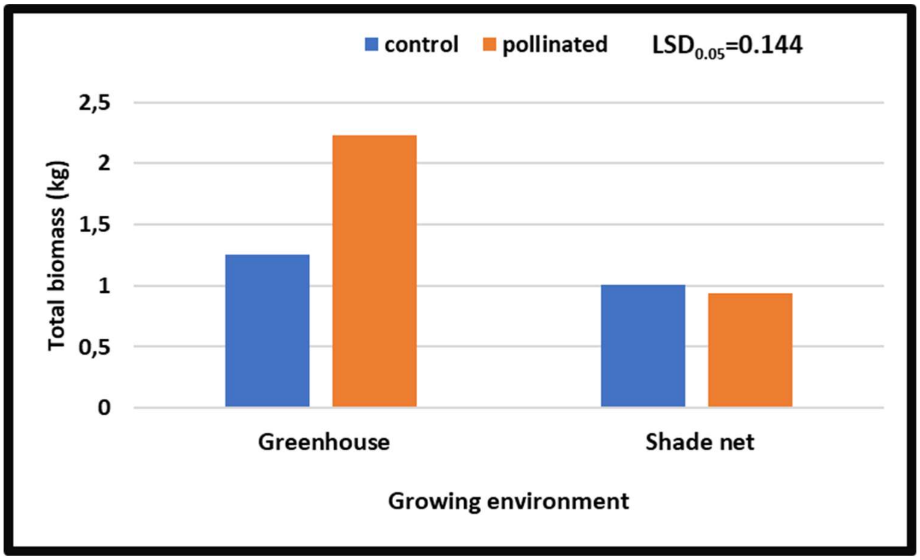

Figure 6: The effect of hand pollination and non-pollinated (control) on the total biomass of African horned cucumber grown under different environment (greenhouse and shade net).

Figure 6 present the effect of hand pollination and non-pollinated (control) on the total biomass of African horned cucumber grown under different environments (greenhouse and shade net). Results showed that there was significant ($P \leq 0.05$) different on the total biomass of African horned cucumber from pollinated and non-pollinated (control) plants grown under different environments (greenhouse and shade net). Under greenhouse, total biomass ranged from 1.23 to 2.23 kg, whereas shade net total biomass ranged from 0.94 to 1.01 kg. In addition, pollinated plants under shade net reduced total biomass from 2.23 to 0.94 kg, whereas an increase in total biomass from 0.93 to 2.23 kg, was observed from pollinated plants under greenhouse environment.

Aboveground biomass

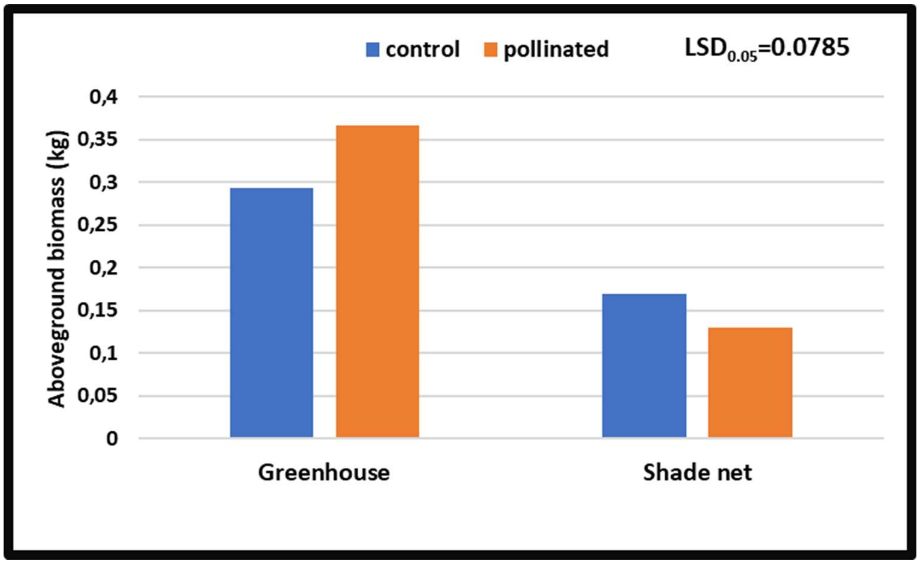

Figure 7: The effect of hand pollination and non-pollinated on the above ground biomass of African horned cucumber grown under different environment (greenhouse and shade net).

Figure 7 illustrate the effect on hand pollinated and non-pollinated on the above ground biomass of African horned cucumber grown under different environment (greenhouse and shade net). Results depicted that there was significant ($P \leq 0.05$) difference on the aboveground biomass of hand pollinated and non-pollinated plants of African horned cucumber grown under different environment (greenhouse and shade net). Under greenhouse environment, the aboveground biomass ranged from 0.29 to 0.37 kg, while aboveground biomass of shade net environment ranged from 0.13 to 0.17 kg. In addition, the study results demonstrated that pollinated plants under shade net reduced aboveground biomass from 0.37 to 0.13 kg, whereas pollinated plants under greenhouse environment increased it from 0.13 to 0.37 kg.

Harvest index

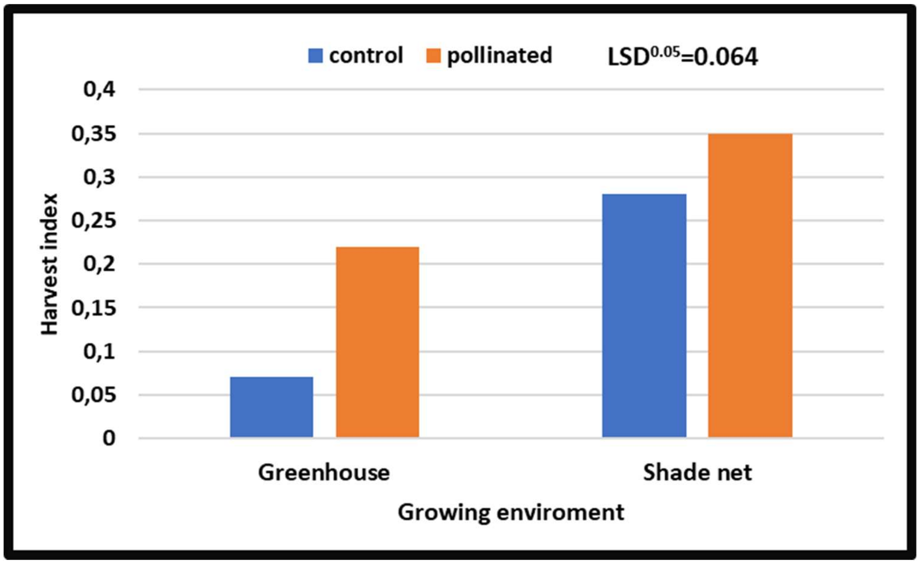

Figure 8: Effect of hand pollination and non-pollinated (control) on harvest index of African horned cucumber grown under different environment (greenhouse and shade net).

Figure 8 presents the effect of hand pollinated and non-pollinated (control) on the harvest index of African horned cucumber grown under different environment (greenhouse and shade net). Results demonstrated that there was significant ($P \leq 0.05$) difference between hand pollinated and non-pollinated (control) on the harvest index of African horned cucumber grown under different environment (greenhouse and shade net environment). Under greenhouse environment, harvest index ranged from 0.07 to 0.22, whereas shade net harvest index ranged from 0.28 to 0.35. Moreover, the study results revealed that non-pollinated plants under greenhouse environment reduced harvest index from 0.35 to 0.07, whereas pollinated plants from shade net increased it from 0.07 to 0.35.

Discussion

This study assessed the effect of hand pollination and non-pollinated (control) on the yield of African horned cucumber under two growing environments (greenhouse and shade net). Previous studies evaluated the effect of honeybees and stingless bees on the pollination, fruit setting and yield of English cucumber. To the best of our knowledge, there is scanty work done to assess the effect of hand pollination versus non-pollinated on the on the yield of African horned cucumber, therefore, the findings of this study serve as a benchmark.

Aboveground and total biomass

The mean variation between the highest (2.23 kg) and lowest (0.94 kg) total biomass was (1.29 kg) on pollinated plants under greenhouse and shade net environment. The differences between means under growing environments were substantial. These observations suggest that the hand pollination treatment imposed on the African

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horned cucumber plants affected yield components. This fact was fully established in this research because the variation in total biomass was clearly difference in most cases. The plants subjected to hand pollination were not only higher in total biomass, but also exhibited higher abundance of aboveground biomass, particularly under greenhouse environment. It can be deduced that hand pollination increase productivity in terms of yield compared to no pollinated plants, regardless of the growing environment. These findings agree with those of [10], who concluded that visitation by bees to cucumber flowers play a pivotal role in increasing both quantity and quality of fruits.

Harvest index, fruit number and length

The harvest index varied from (0.07) non pollinated under greenhouse to (0.35) pollinated under shade net. The variation between means was (0.28). These observations between means demonstrate that harvest index was significantly affected by imposition of hand pollination on African horned cucumber plants grown under varying environments. The differences among the means were once more substantial, hence resulted in immense variation. The harvest index therefore increased when plants are pollinated but declined when plants are not pollinated.

Evidence obtained from the current study revealed that the mean differences between the lower (3) and higher (11) fruit number was (8). These variation between means was essential, hence resulted in noticeable difference. Perhaps the automated climate control in the greenhouse could have positively affected the pollinated plants to have higher fruit set, subsequently increased the fruit number and length. The same could not be said about the shade net pollinated plants. Nonetheless, the present study is in harmony with the previous findings by [6, 1], who reported that hand-pollinated plants produced heavier and longer fruits compared to those that are without hand pollination. The mean values of this study shown that hand pollination increase yield of African horned cucumber grown under protected environment, even in the absence of natural pollination agents such as wind and bees.

Conclusion

The study illustrated that hand pollination contribute to the yield increase of African horned cucumber grown under protected environment and might minimize the risk cause by bees imported in the greenhouse and shade net. Therefore, it is evidence present in this study suggest that hand-pollination should be considered when growing African horned cucumber under protected environment such as greenhouse and shade net. Moreover, quality parameters such as fruit number and length are important findings, particularly in the fresh market and juice industry. This is important for the juice-manufacturing industry and for fresh markets, where many fruits are required to meet the demand. In addition, modern day market is geared towards organoleptic quality-inexpensive market, for example, it may be best to grow this crop in both greenhouse and shade net environments and impose hand pollination. The other advantages are that the crop is protected from rainfall and extreme heat in summer. This is useful information to farmers, as quality has become more significant to most consumers worldwide.

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