International Journal of Sustainable Agricultural Research
2022 Vol. 9, No. 2, pp. 76-86
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/ijsar.v9i2.2975

IMPACT OF NATURAL AND HAND-ASSISTED POLLINATION ON CUCUMBER FRUIT AND SEED YIELD

David T. Agbor[1,3+]
Derick A. Acha[1]
Kizito S. Eboh[1,4]
Calvin N. Morara[1]
John D. Dohnji[1]
Lony M. Teche[1]
Raymond N. Nkongho[1,2]

[1]*Department of Agronomic and Applied Molecular Sciences, Faculty of Agriculture and Veterinary Medicine, University of Buea, Buea, South West Region, Cameroon.*
[2]*Department of Food Science and Technology, Faculty of Agriculture and Veterinary Medicine, University of Buea, Buea, South West Region, Cameroon.*
[3]*Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey.*
[4]*Department of Agricultural and Resource Economics, Kangwon National University, Chuncheon, South Korea.*

(+ Corresponding author)

[1,3]*Email: agbordavid@gmail.com Tel: +237650422023*
[1]*Email: derickatemacha@gmail.com Tel: +237679614934*
[1,4]*Email: kizitosone2@gmail.com Tel: +237681271962*
[1]*Email: moraracalvin5@gmail.com Tel: +237651996667*
[1]*Email: dohbilajohn@gmail.com*
[1]*Email: techelony2016@gmail.com Tel: +237678465890*
[1,2]*Email: nrndip@yahoo.com Tel: +237671098637*

Article History
Received: 7 February 2022
Revised: 30 March 2022
Accepted: 14 April 2022
Published: 25 April 2022

Keywords
Artificial
Flowers
Foraging-insects
Fruits
Honeybees
Pollination
Seeds.

ABSTRACT

Pollination is an important agro-ecological service, necessary for fruits and seed production in 60-70% plant species. The purpose of this study was to demonstrate the importance of artificial pollination on the fruit and seed yield of cucumber in the wake of natural pollination decline. This research was conducted at Faculty of Agriculture and Veterinary Medicine, University of Buea, Cameroon. The experimental design was a randomized complete block design with four treatments and three replicates. The treatments were; open for foraging insects, assisted-hand pollination, hand emasculation, and caged with insect-proof net. Parameters such as number of bees and ants, vegetative and reproductive growth, weight of fruits, number of misshaped fruits, and weight of seeds were recorded. Data collected were subjected to ANOVA, $P< 0.05$ in SPSS package. Cucumber vegetative and reproductive parameters differed significantly ($P<0.05$) with highest in Caged with insect-proof net, assisted-hand pollination, and Caged with insect-proof net respectively. The highest number of honey bees were observed in Open for foraging insects 13 and differed significantly ($P<0.05$) across treatments. The highest weight of fruits and seeds yield was recorded in assisted-hand pollination 31.93 t/ha and 13.23 kg/ha respectively and differed significantly ($P<0.05$) across treatments. The number of misshaped fruits was highest in hand emasculation 9 and differed significantly ($P<0.05$) across treatments. Fruit yield correlated positively with number of honeybees (R^2 = 0.65). The study demonstrates the significance of artificial pollination in increasing fruits and seed yield of cucumber and the role of honey bees in open pollination.

Contribution/Originality: This works enables farmers to assist natural pollination due to honeybees' decline by using artificial methods like hands to pollinate cucumber plants, enhance pollination and increase yield. It alerts farmers to protect honeybees whose role in pollination cannot be over emphasized. It is a new idea for open field cultivation.

1. INTRODUCTION

Cucumber is a climbing annual herbaceous vine that yields cylindrical fruits that are picked and consumed as they develop as fresh vegetables (Abbey, Nwachoko, & Ikiroma, 2017; Tuo, Coulibaly, Kone, Kone, & Koua, 2019). Cucumber originated in Northern India, in the Himalayan foothills, from which it was transported to secondary centres in China and the Near East, before being widely dispersed around the world (Jiménez-Ballesta et al., 2018). According to Atlas Big (2020), China is the world's top producer, producing 53,596.6 kg/ha, while Cameroon ranks sixteenth, producing 942.7 kg/ha. Cucumber yields in Cameroon are quite low, with a potential yield of 15,000-22,000kg/ha (Singh, Brar, & Dhall, 2016). Cucumber cultivation improves the livelihoods of those involved in the production and distribution while providing health benefits to consumers as a rich source of vitamin C, thiamine, niacin, iron, phosphorus (Abbey et al., 2017; Kaushik, Aeri, & Mir, 2015; Saboo, Thorat, Tapadiya, & Khadabadi, 2013). One of the causes of low cucumber yield is pollination. The pollination service provided by the cucumber's ecological interaction with foraging insects is one of the most important factors in its fruit and seed production (Abrol, 2012 ; Atibita, Djieto-Lordon, & Fohouo, 2020; Tuo et al., 2019). Pollination is essential for fertilization and the generation of high-quality fruits and seeds in the life cycle of Cucurbits (Hossain, Yeasmin, Rahman, Akhtar, & Hasnat, 2018; Inam, Shah, Khan, & Usman, 2015). Cucumber, like most cucurbit plants, produces male and female inflorescence on the same plant, which is known as monoecious in botanical terms (Nicodemo, Malheiros, De Jong, & Couto, 2012). Due to the flower's nature, pollination by wind, water, birds, and bats is not ideal for cucumber. Male blooms are found lower on the vine, while female blossoms are found higher up. Coevolution with insects has resulted in flower characteristics such as vivid yellow colour, fragrance, nectar, and sticky pollen grains (Agbagwa, Ndukwu, & Mensah, 2007; Bomfim, Bezerra, Nunes, Freitas, & Aragão, 2015). As a result, foraging insects are the primary pollinators, flying from male to female flowers at random in quest of pollen and nectar stimulates pollination leading to fruits and seeds production (Azo'o et al., 2010; Hossain et al., 2018).

Pollinator decline is globally a decline in the abundance of insects and other pollinators in various ecosystems that began at the end of the twentieth century, and recent research shows that it is increasingly becoming a threat to agricultural productivity due to improper farm maintenance operations, with uncontrolled use of synthetic pesticides, which harms natural cucumber pollinators (Huang & Giray, 2012; Kluser & Peduzzi, 2007; Okolle, Ngosong, Nanganoa, & Dopgima, 2020). For successful pollination of many cucurbits, around twenty bees must visit each female flower (Inam et al., 2015). There will be no fruit set if no pollen is placed on the gynoecium. Fruit that is malformed and tiny in size is produced when pollination is insufficient (Tuo et al., 2019). Insufficient pollination in any cucumber crop would result in a reduction in the potential production per unit area of seeds sowed (Bauer & Wing, 2010; Okolle et al., 2020; Reyes, Gergely, & Paul, 2013). As a result, artificial pollination is crucial to supplement natural pollination to increase cucumber fruit and seed output (Atibita et al., 2020; Motzke, Tscharntke, Wanger, & Klein, 2015). The usage of seeds is the cornerstone of agricultural output. Cucumber seeds include important genetic information that allows the crop to adapt to a variety of growth environments and yield preferences (Singh et al., 2016). As a result, the volume of the crop, economic returns, and possibility for continuity will be determined to a considerable measure by the quality and quantity of seed that is readily available to farmers at a reasonable cost. This research was done to demonstrate the role of artificial pollination and to generate more seeds locally to increase cumber output and lower production costs by reducing seed purchases and pollinator losses. Assisted pollination was thought to boost cucumber pollination and yield more fruits and seeds.

2. MATERIALS AND METHODS

2.1. Experimental Site

The research was carried out at the University of Buea's Faculty of Agriculture and Veterinary Medicine's teaching and research farm. The location lies at the foot of Mount Cameroon in the Southwest Region, between the equator's latitudes of 4°3'N and 4°12'N, and longitudes of 9°12'E and 9°20'E. Buea has a mono-modal rainfall pattern with a less apparent dry season, 86 % relative humidity, and 900 to 12000 hours of sunlight each year. The dry season lasts from October to March, whereas the wet season lasts from March to September, with an average annual rainfall of 2800 mm. With an increasing elevation from 200 m to 2200 m above sea level, the mean monthly air temperature ranges from 19 °C to 30 °C, and the soil temperature at 10 cm depth decreases from 25 °C to 15 °C. Weathered volcanic rocks dominate the soil, which is dominated by silt and clay (Fraser, Hall, & Healing, 1998; John, Edwards, Payton, & Nagy, 2007; Manga, Agyingi, & Suh, 2014).

2.2. Experimental Design and Application of Treatments

The experimental field was measured with meter tape across a surface area of 143 m^2. The area was cleared and treated with GLYCOT (Glyphosate 42 % SL), a systemic herbicide. The experimental design was a randomized complete block design with four treatments, replicated three times. With the use of hoes, twelve plots of 2 m x 2 m were delineated and elevated 20 cm high. Plots within a replicate are separated by 1 m and one replicate is separated from the other by 1.5 m. Figure 1, shows the field representation of the experimental design. The planting distance was 50 cm x 75 cm. A digger was used to dig a hole at the centre of each plot, and a 2.2 m long central pole was installed for tying ropes and allowing cucumbers to climb on it. Each plot featured three inter-row plants and four intra-row plants, all of which were pecked to make climbing to the centre pole easier. The treatments were;

T_1: Open for foraging insects.

T_2: Assisted-Hand Pollination

T_3: Here, hand emasculation was done, where the male flowers are detached before anthesis.

T_4: Caged with insect-proof net.

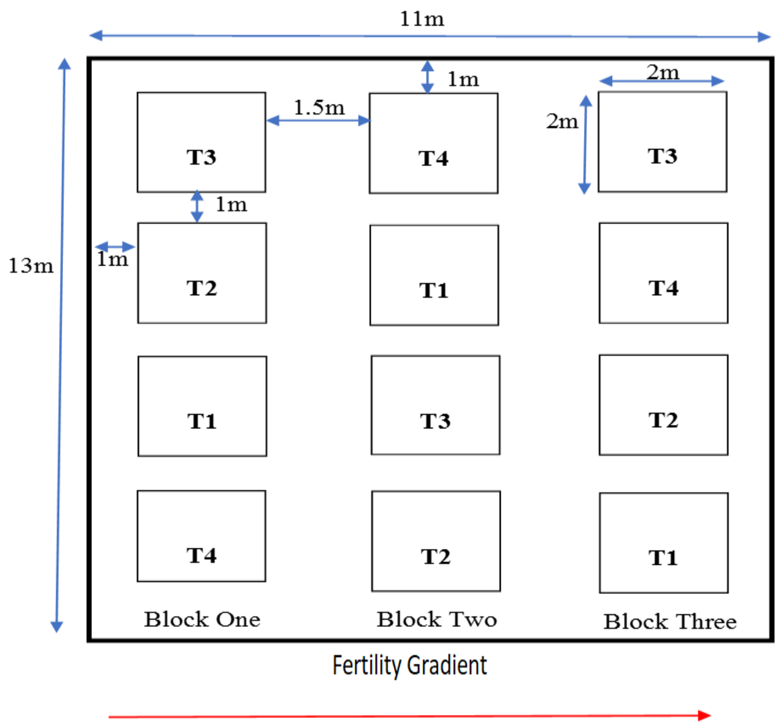

Figure 1. Field layout of the experiment.

2.3. Crop Management

i. Characteristics of Seeds Used

MURANO F1' is a tropical slicing cultivar for outdoor and indoor cultivation. It produces high-quality fruits that are dark green in colour, cylindrical in shape, and consistent in size. After seeding, the fruit matures 40-45 days later. It's mostly disease-resistant and may be cultivated all year.

ii. Prenursery

With the use of hoe, black polybags measuring 15 cm x 10 cm were filled with top 15 cm soil. Stones were removed, soil lumps were broken, and polybags were placed in a nursery made of palm fronds for 14 days. Transparent nylon was used to shade the nursery area 50 cm around and above the polybags. The seedlings benefited from the shade since it protected them from sunburn and direct rainfall. Before seeding, the polybags were watered to field capacity, and two seeds per polybag were sowed at a depth of 3 cm and covered with 1-2 cm soil above. The seedlings were transplanted two per stand in the field after 14 days in the nursery.

2.3.1. Maintenance of Main Plot after Transplanting

i. Cultural Control

Watering was done once every two days in the nursery. The field was irrigated to field capacity before transplanting. Seedlings with soil attached were taken from polybags and transplanted into 10 cm × 10 cm excavated holes, which were subsequently filled. Watering was done every morning for 8 days after transplanting, and every 3 days thereafter until harvest.

Trellising and Trailing; Within the third week following seeding, trailing began. To make an equilateral triangle, garden ropes were strung to short hard sticks of 30 cm and hammered in front of each stand, then hauled over the 2.2 m central trellis frame to the opposite side of the plot. This was done for all of the field's plants and plots. Tendrils gripped the ropes once they were placed, and vines climbed upwards.

Weeding and Earthing Up; After transplanting, weeding was done once a week with the aid of a hoe, earthing up was done after the second fertilizer application by pulling nearby topsoil to the root zone of the plants.

Caging; All three replicates of the treatment T4 were individually caged two weeks following transplanting using mosquito-proof nets measuring 2 x 2 x 2.5 m. The net had a hole width of 5 mm, which prevented bees and other pollinators from entering.

Hand Pollination and Tagging; Daily, male flowers from the third treatment (T3) were emasculated and used for assisted-hand pollination every morning. The pollen area of each emasculated male flower was carefully removed and rubbed on the stigma surface of the female bloom. Each female flower was pollinated with one male bloom, and each fertilized flower was labelled with a paper ribbon that included the pollination date.

ii. Chemical Control

For outdoor cucumber production, blanket fertilization comprising nitrogen, phosphorous, and potassium in the ratio 0.85kg N:0.65kg P_2O_5:1.35kg K_2O was applied in line with the prescribed fertilizer rates of 170kg N/ha, 130kg P_2O_5/ha, and 270kg K_2O/ha. At transplanting, 1 kg of NPK was applied for the first time. The second of 1.85kg NPK at blooming and fruiting when the plants were 28 days old. This was accomplished by wrapping a band around each stand at a distance of 10 cm and covering the fertilizer with soil.

Integrated Pest and Disease Management; Crushed eggshells were scattered against molluscs, certain insects were picked and destroyed, and diseased leaves were pruned. 5 days after transplanting, a contact insecticide cypercal with active ingredient cypermethrin at the rate of 26 ml and the fungicide cotzeb with active ingredient mancozebe at the rate of 80 g were mixed in 15 l water, sprayed on plants at 2 weeks' interval and stopped at flowering.

iii. Harvesting and Seed Extraction

The first harvest was done 42 days after transplanting, with subsequent harvests taking place every three days. Harvesting was accomplished by delicately removing matured fruits from the vine by hand. Picking the ripe fruits that had been labelled as the fifth harvesting step. This was completed 70 days after the seedlings were transplanted. Fruits were gently opened after harvesting to expose the seeds. Internal contents were scooped out with a tablespoon and deposited in separate dishes for each treatment, along with a litre of cool water. The seeds were removed from the pulp and unhealthy seeds in suspension were discarded and while healthy seeds were stored in a cool, shaded spot for two days. The seeds were then air-dried indoor to avoid damage from direct sunshine.

2.4. Data Collection

2.4.1. Growth Data

Beginning at 28 days old, growth parameters such as the number of leaves and the length of the main vine were recorded weekly for three weeks from five tagged plants.

2.4.2. Reproductive Data

From the time the plants were 28 days until 56 days old, reproductive data was recorded weekly. The number of honey bees, as well as the number of ants, were counted three times during the day (8:00-9:00 am, 12:00-1:00 pm, and 4:00-5:00 pm). The number of open male flowers collected. Number of aborted female flowers were recognised from pollinated ones by the premise that an aborted flower begins to dry as soon as the bloom closes and the bright yellow petals fade away, but a pollinated flower remains fresh and elongates.

2.4.3. Yield Data

The fruit yield data was collected during the first, second, third, and fourth harvests, with the following parameters: number of cucumbers per tagged plant, total harvest weight assessed using a weighing balance per treatment, and number of misshaped/stunted fruits per treatment. Seed data was also collected for the weight of seeds per treatment at fifth harvest for the ripe fruits.

2.5. Data Analysis

Data were collected and entered into a Microsoft Excel spreadsheet 2016, after which it was uploaded to IBM SPSS Statistics for Windows (SPSS v26). To examine the influence of treatments (n 4) as categorical predictors, variables were submitted to univariate analysis of variance (ANOVA, P<0.05). Duncan Multiple Range Test (DMRT) $P < 0.05$ was used to differentiate significant data means.

3. RESULTS

3.1. Effect of Treatments on Vegetative and Reproductive Parameters of Cucumber

Table 1. Effect of treatments on cucumber vegetative and reproductive parameters.

Treatment	Number of leaves	Length of the vine (cm)	Number of open male flowers	Number of aborted female flowers
Open for foraging insects	24 ± 1.2^a	214.7 ± 5.8^b	20 ± 6.1^a	11 ± 1.2^b
Hand-assisted pollination	25 ± 0.6^a	217.1 ± 5.3^b	22 ± 5.1^a	3 ± 2.1^c
Hand emasculation of male flowers	25 ± 0.6^a	217.6 ± 11.2^b	4 ± 1.2^b	14 ± 1.5^b
Caged with an insect-proof net	27 ± 0.9^a	244.4 ± 5.0^a	20 ± 1.7^a	26 ± 3.0^a

Note: Values within the column with the same letters are not significantly different according to Duncan Multiple Range Test, $P < 0.05$.

From the result in Table 1, the number of leaves ranged from 24 to 27 and did not differ significantly ($F_{3, 8}$ = 2.75, P = 0.112) across treatments, with the highest in Caged with insect-proof net treatment 27 and lowest in Open for foraging insects 24. The vine length ranged from 214.7 to 244.4 cm and differed significantly ($F_{3, 8}$ = 7.21, P = 0.017) across treatments, with the highest in Caged with insect-proof net 244.4 cm and lowest in Open for foraging insects 214.7 cm. The number of open male flowers ranged from 4 to 20 and differed significantly ($F_{3, 8}$ = 12.76, P = 0.002) across treatments, with the highest in Open for foraging insects 20 and lowest in Hand emasculation of male flowers 4. The number of aborted female flowers ranged from 3 to 26 and differed significantly ($F_{3, 8}$ = 66.43, P = 0.000) across treatments, with the highest in Caged with insect-proof net 26.

3.2. Effect of Treatments on Honey Bees and Ants' Cucumber Pollinators.

The number of honey bees observed on cucumber flowers ranged from 0 to 14 and differed significantly ($F_{3, 8}$ = 17.05, P = 0.001) across treatments with the highest in Open for foraging insects 13 and the lowest in Caged with insect-proof net 0 (Figure 2). The number of ants observed on cucumber flowers did not differ significantly ($F_{3, 8}$ = 0.71, P = 0.573) across treatments with the highest in assisted-hand pollination 18 and the lowest in Hand emasculation of males flowers 13 (Figure 3).

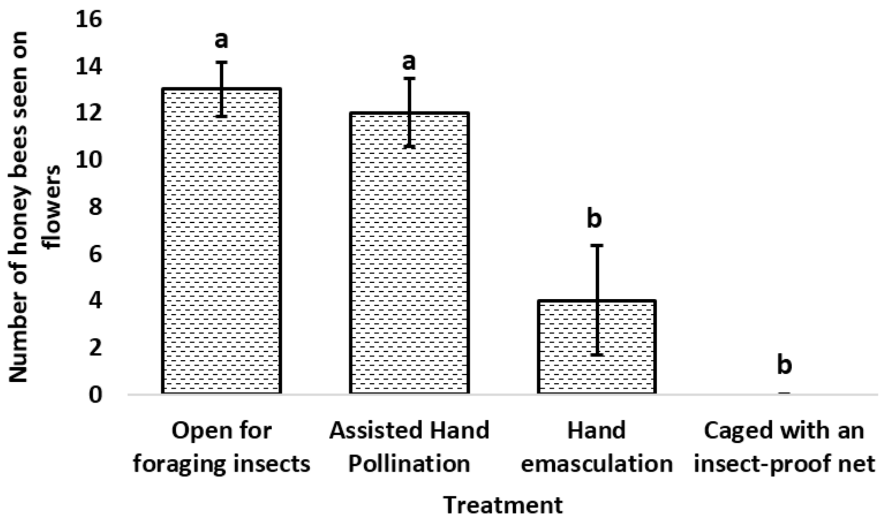

Figure 2. Effect of treatments on the number of honey bees observed. Different letter columns are significantly different ($P < 0.05$), Duncan multiple range test.

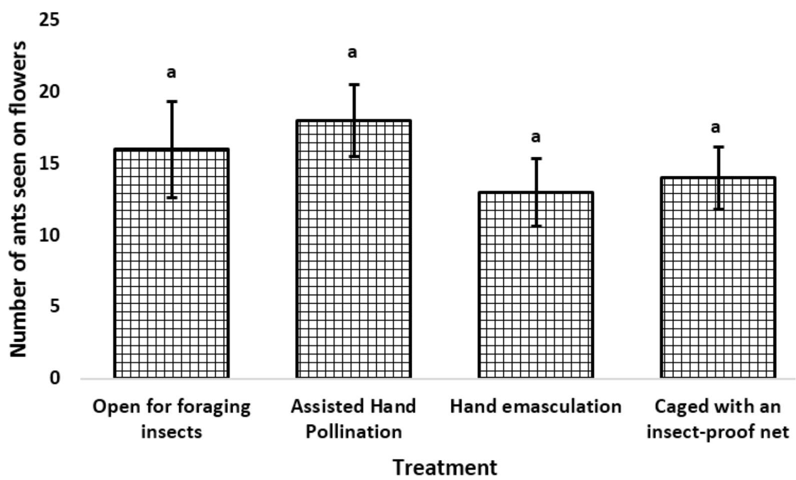

Figure 3. Effect of treatments on the number of ants observed. Different letter columns are significantly different ($P < 0.05$), Duncan multiple range test.

3.3. Effect of Treatments on Cucumber Fruits, Misshaped Fruits, and Seeds Yield

The weight of cucumber fruits collected differed significantly ($F_{3, 8}$ = 42.22, P = 0.000) across treatments with the highest in assisted-hand pollination 31.93 t/ha and the lowest in Caged with insect-proof net 1.5 t/ha (Figure 4). The number of cucumber misshaped fruits collected ranged from 0 to 9 and differed significantly ($F_{3, 8}$ = 8.36, P = 0.008) across treatments with the highest number of misshaped fruits in Hand emasculation 9 and the lowest in Caged with insect-proof net 0 (Figure 5). The weight of cucumber seeds collected differed significantly ($F_{3, 8}$ =

123.55, $P = 0.000$) across treatments with the highest in assisted-hand pollination 13.23 kg/ha and the lowest in Caged with insect-proof net 0.78 kg/ha (Figure 6).

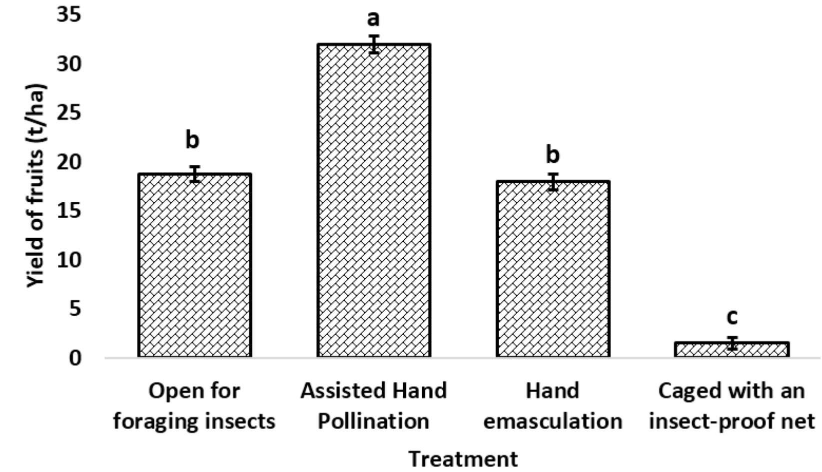

Figure 4. Effect of treatments on the yield of cucumber. Different letter columns are significantly different ($P < 0.05$), Duncan Multiple Range Test.

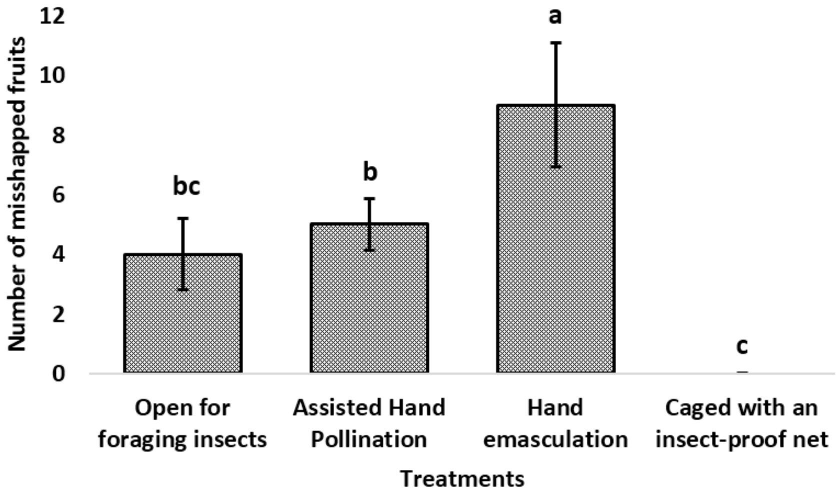

Figure 5. Effect of treatments on the number of misshaped fruits. Different letter columns are significantly different ($P < 0.05$), Duncan Multiple Range Test.

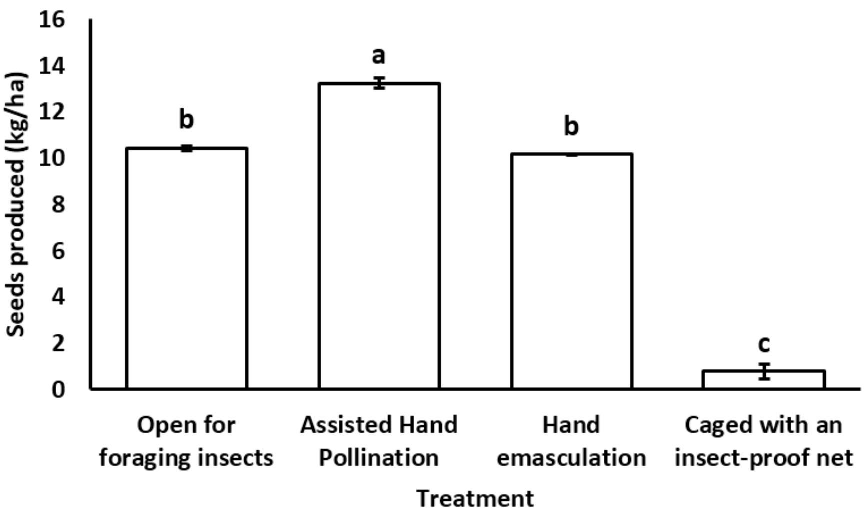

Figure 6. Effect of treatments on seeds produced. Different letter columns are significantly different ($P < 0.05$), Duncan Multiple Range Test.

3.4. Correlation of Fruit Yield with Number of Honey Bees.

From Figure 7, a strong positive correlation (R^2 = 0.65) exist between the fruit yield of cucumber and the number of honey bees observed on flowers which implies that the more the honey bees land on flowers, the more there is pollination and fruit production.

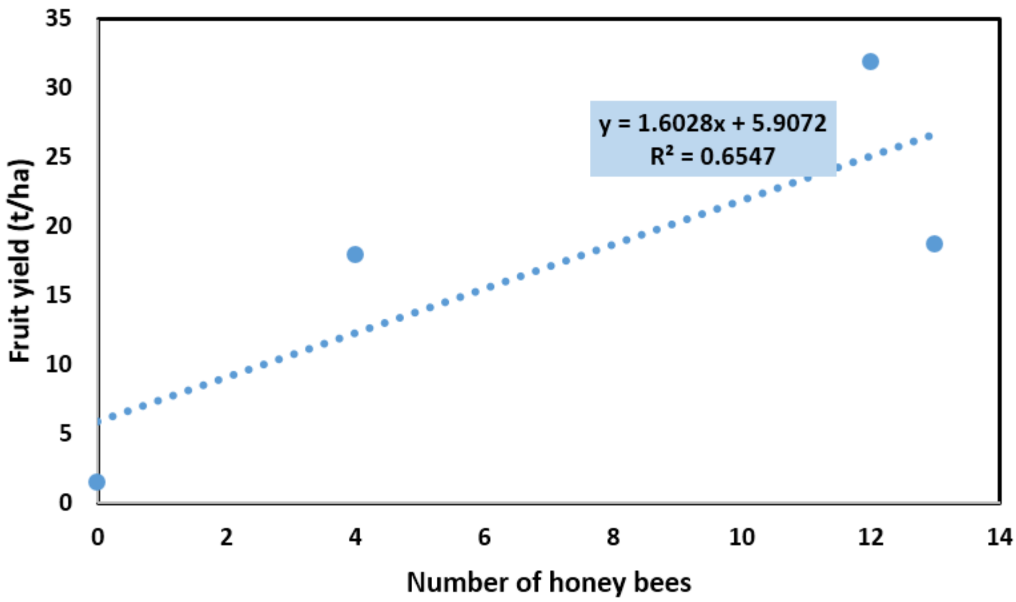

Figure 7. Correlation of fruit yield with the number of honey bees observed on flowers.

4. DISCUSSION

4.1. Effect of Treatments on Cucumber Vegetative Growth Parameters.

The number of cucumber leaves did not change across treatments, which might be explained by the fact that all treatments received blanket fertilization. The high vine length in Caged with insect-proof net treatment Table 1 is likely owing to no insect disturbance to cause infections that may slow development (Nicodemo, Malheiros, De Jong, & Couto, 2018; Tuo et al., 2019). Also, due to the insect-proof net, which limited pollination, the assimilate produced as a consequence of photosynthesis was primarily employed for the vigour with a bias towards reproductive development. The high number of open male flowers in the Open foraging insects' treatment Table 1 is consistent with no obstacles to inhibit insect interactions with flowers promoting higher flower development as compared to other treatments (Nicodemo et al., 2018; Tuo et al., 2019). The low frequency of aborted female flowers in cucumbers treated with manual pollination highlights the need for alternate pollination methods (Nicodemo, Malheiros, De Jong, & Nogueira Couto, 2013).

4.2. Effect of Treatments on Honey Bees and Ants' Cucumber Pollinators

The high number of honeybees observed on cucumber flowers in the Open for foraging insects' treatment (Figure 2) suggests that open pollination allows honeybees free access to pollinate, whereas no honeybees was found in the Caged with insect-proof net treatment, which is consistent with other studies (Inam et al., 2015; Nicodemo et al., 2018). As a result of no special control measures used for the different treatments, the number of ants observed on cucumber flowers was not significant (Figure 3), indicating that ants are more interested in feeding on the excreted sap generated by aphids. Therefore, it could be due to aphids excreting sap that attracts ants, and there was likely even aphids' distribution across the treatments. Though hand-aided pollination resulted in the maximum number of ants (Figure 3), which might be due to pollen being moved from male to female, allowing ants to thrive (Atibita et al., 2020; Motzke et al., 2015; Reyes et al., 2013). It's not a coincidence that there are honeybees on the blossoms. Indeed, according to Corbet and colleagues, the number of honeybees on flowers is determined by the strength of the aroma generated as pollinators search for nectar as a food source (Corbet, Williams, & Osborne, 1991). Delaplane and Mayer (2000) also discovered that nectar is the primary food source for bees visiting cucumbers. The concentration of chemicals released by flowers during their blossoming is a factor in pollinator attraction to inflorescences. Cucurbitaceae flowers have relatively high sugar content in nectar, which honeybees enjoy (Corbet et al., 1991).

4.3. Effect of Treatments on Cucumber Fruits and Seeds Yield

The high weight of cucumber fruits reported in the Hand aided pollination treatment (Figure 4) suggests the need for artificial pollination in cucumber pollination leading to high production. Huang and Giray (2012) and Hossain et al. (2018), demonstrate similar results. The low weight of cucumber fruits in Caged with insect-proof net treatment indicates how plants denied access to natural pollinators or artificial pollination may drastically lower cucumber output. The variations in the amount of cucumber misshaped fruits found between treatments, with the highest numbers reported in Hand emasculation (Figure 5) compared to other treatments, demonstrate the relevance of male flowers in pollination and fruit development. Thus no or insufficient male flower pollen to pollinate female flowers means no or misshaped fruits, drastically reducing productivity (Tuo et al., 2019). This translates to the high weight of cucumber seeds observed in assisted-hand pollination treatment which is consistent with the potential ability of artificial pollination in increasing fruit yield as well as seed yield (Hossain et al., 2018; Singh et al., 2016). Also, poor seed yield was observed in Caged with insect-proof net treatment which is a reflection of little or no pollination occurrence due to the net barrier hindering natural or artificial pollination (Abrol, 2012 ; Motzke et al., 2015; Umeh & Ojiako, 2018). The increased weight of fruits produced by artificial pollination might be explained by the fact that, just as honeybees' activity on flowers transporting pollen is critical for fruit set, so is artificial pollination in the wake of natural pollination decline. It is clear that output is higher on plots with artificial pollination, as indicated by Ndola et al. (2017), who found that introducing honeybee colonies into crops, in this instance aided pollination, boosted the weight of fruits and seeds extracted (Ndola et al., 2017). Have also shown similar improvements on colza and other Cucurbits.

5. CONCLUSION

The value of artificial or aided pollination in enhancing cucumber fruit and seed output, the involvement of honeybees in open pollination, and the importance of male flowers in cucumber pollination were all proven in this study. As a result, artificial pollination and open pollination, devoid of synthetic pesticides that may harm natural pollinators, are the greatest ways to improve pollination and increase cucumber fruit and seed output. As a result, the findings of this study support the premise that aided pollination will boost cucumber pollination and generate more fruits and seeds.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.
Acknowledgement: Authors extend gratitude to the Ministry of Higher Education of Cameroon, and the Faculty of Agriculture and Veterinary Medicine (FAVM) of the University of Buea, Cameroon.

REFERENCES

Abbey, B., Nwachoko, N., & Ikiroma, G. (2017). Nutritional value of cucumber cultivated in three selected states of Nigeria. *Biochemistry and Analytical Biochemistry*, *6*(3), 1-3.Available at: https://doi.org/10.4172/2161-1009.1000328.

Abrol, D. P. (2012). Pollination biology: Biodiversity conservation and agricultural production (pp. 792). New York: Springer.

Agbagwa, I. O., Ndukwu, B. C., & Mensah, S. I. (2007). Floral biology, breeding system, and pollination ecology of Cucurbita moschata (Duch. ex Lam) Duch. ex Poir. varieties (Cucurbitaceae) from parts of the Niger Delta, Nigeria. *Turkish Journal of Botany*, *31*(5), 451-458.

Atibita, E. N. O., Djieto-Lordon, C., & Fohouo, F.-N. T. (2020). Insects associated with cucumbers (Cucumis SativusL.) At Bamunka-Ndop(North West Region, Cameroon). *Journal of Advances in Agriculture, 11*, 145–159.Available at: https://doi.org/10.24297/jaa.v11i.8840.

Atlas Big. (2020). Atlas Big. Retrieved from. https://www.atlasbig.com/en-us/countries-cucumber-production.

Azo'o, M. E., Messi, J., Fernand-Nestor, F. T., Joseph, T. L., Kekeunou, S., & Joseph, P. B. (2010). Foraging behavior of Apis mellifera adansonii and its impact on pollination, fruit, and seed yields of Citrullus lanatus at Nkolbisson (Yaoundé, Cameroon)", Camr. *The Journal of Experimental Biology, 6*(1), 41-48.Available at: https://doi.org/10.4314/cajeb.v6i1.56879.

Bauer, D. M., & Wing, I. S. (2010). Economic consequences of pollinator declines: A synthesis. *Agricultural and Resource Economics Review, 39*(3), 368-383.Available at: https://doi.org/10.1017/s1068280500007371.

Bomfim, I. G. A., Bezerra, A. D. d. M., Nunes, A. C., Freitas, B. M., & Aragão, F. A. S. d. (2015). Pollination requirements of seeded and seedless mini watermelon varieties cultivated under protected environment. *Brazilian Agricultural Research, 50*(1), 44-53.Available at: https://doi.org/10.1590/s0100-204x2015000100005.

Corbet, S. A., Williams, I. H., & Osborne, J. L. (1991). Bees and the pollination of crops and wild flowers in the European community. *Bee World, 72*(2), 47-59.Available at: https://doi.org/10.1080/0005772x.1991.11099079.

Delaplane, S. K., & Mayer, F. D. (2000). Crop pollination by bees (pp. 352). Wallingford, UK and New York: CABI Publishing.

Fraser, P. J., Hall, J. B., & Healing, J. R. (1998). Climate of the Mount Cameroon region, long and medium term rainfall, temperature and sunshine data (pp. 56). Limbe: SAFS, University of Wales Bangor, MCP–LBG.

Hossain, M., Yeasmin, F., Rahman, M., Akhtar, S., & Hasnat, M. (2018). Role of insect visits on cucumber (Cucumis sativus L.) yield. *Journal of Biodiversity Conservation and Bioresource Management, 4*(2), 81-88.Available at: https://doi.org/10.3329/jbcbm.v4i2.39854.

Huang, Z. Y., & Giray, T. (2012). Factors affecting pollinators and pollination. *Psyche: A Journal of Entomology*, 1-3.Available at: https://doi.org/10.1155/2012/302409.

Inam, S., Shah, M., Khan, A., & Usman, A. (2015). Response of insect pollinators to different cucumber, Cucumis sativus L.(Cucurbitales: Cucurbitaceae) varieties and their impact on yield. *Journal of Entomology and Zoology Studies, 3*(5), 374-378.

Jiménez-Ballesta, R., García-Navarro, F., García-Giménez, R., Trujillo-González, J., Iñigo, V., & Asensio, C. (2018). Agroecological analysis of cucumber (Cucumis Sativus L.) crops in orchards in a Mediterranean environment. *Journal of Agriculture and Crops, 4*(3), 16-28.

John, P., Edwards, I. D., Payton, R. W., & Nagy, L. (2007). Zonation of forest vegetation and soils of Mount Cameroon, West Africa. *Plant Ecology, 192*(2), 251-269.Available at: https://doi.org/10.1007/s11258-007-9326-5.

Kaushik, U., Aeri, V., & Mir, S. (2015). Cucurbitacins–an insight into medicinal leads from nature. *Pharmacognosy Reviews, 9*, 12–18.Available at: https://doi.org/10.4103/0973-7847.156314.

Kluser, S., & Peduzzi, P. (2007). Global pollinator decline: A literature review. UNEP/GRIDEurope. © UNEP.

Manga, V. E., Agyingi, C. M., & Suh, C. E. (2014). Trace element soil quality status of Mt. Cameroon soils. *Advances in Geology, 8*(8), 94-103.

Motzke, I., Tscharntke, T., Wanger, T. C., & Klein, A.-M. (2015). Pollination mitigates cucumber yield gaps more than pesticide and fertilizer use in tropical smallholder gardens. *Journal of Applied Ecology, 52*(1), 261-269.Available at: https://doi.org/10.1111/1365-2664.12357.

Ndola, B. P., Brostaux, Y., Le Goff, G., Susini, M.-L., Haubruge, E., Francis, F., & Nguyen, B. K. (2017). Effects of Apis mellifera adansonii, L. 1758 (Apidae: Hymenoptera) pollination on yields of Cucumeropsis mannii (Naudin) in Kisangani, Democratic Republic of Congo. *International Journal of Biological and Chemical Sciences, 11*(2), 640-650.Available at: https://doi.org/10.4314/ijbcs.v11i2.9.

Nicodemo, D., Malheiros, E. B., De Jong, D., & Couto, R. H. N. (2012). Floral biology of cucumber (Cucumis sativus L.) type Aodai cultivated in greenhouse. *Científica, 40*(1), 41-46.

Nicodemo, D., Malheiros, E. B., De Jong, D., & Nogueira Couto, R. H. (2013). Enhanced production of parthenocarpic cucumbers pollinated with stingless bees and Africanized honey bees in greenhouses. *Seminar: Agricultural Sciences*, *34*(6Supl1), 3625-3633.Available at: https://doi.org/10.5433/1679-0359.2013v34n6supl1p3625.

Nicodemo, D., Malheiros, E. B., De Jong, D., & Couto, R. H. N. (2018). Improved pollination efficiency and reduced honey bee colony decline in greenhouses by allowing access to the outside during part of the day. *Sociobiology*, *65*(4), 714-721.Available at: https://doi.org/10.13102/sociobiology.v65i4.3455.

Okolle, N., Ngosong, C., Nanganoa, L., & Dopgima, L. (2020). Alternatives to synthetic pesticides for the management of the banana borer weevil (Cosmopolites sordidus)(Coleoptera: Curculioniidae). *CAB Reviews*, *15*(026), 1-24.Available at: https://doi.org/10.1079/pavsnnr202015026.

Reyes, T., Gergely, S., & Paul, J. (2013). Bees in decline: A review of factors that put pollinators and agriculture in Europe at risk (pp. 48). UK. Amsterdam: University of Exeter, Greenpeace International.

Saboo, S. S., Thorat, P. K., Tapadiya, G. G., & Khadabadi, S. S. (2013). Ancient and recent medicinal uses of the Cucurbitaceae family. *International Journal of Therapeutic Applications*, *9*, 11-19.

Singh, G., Brar, P., & Dhall, R. (2016). Exploiting yield potential in cucumber (Cucumis sativus L.) through heterosis breeding. *Plant Gene and Trait*, *7*, 1-5.Available at: https://doi.org/10.5376/pgt.2016.07.0016.

Tuo, Y., Coulibaly, D., Kone, M., Kone, K., & Koua, H. K. (2019). Impact of a beehive on cucumber production parameters (Number and Weight of Fruits) in Korhogo, Northern Côte d'Ivoire. *International Journal of Advanced Science and Research and Engineering*, *5*(10), 42-48.Available at: https://doi.org/10.31695/IJASRE.2019.33536.

Umeh, O., & Ojiako, F. (2018). Limitations of cucumber (Cucumis sativus L.) production for nutrition security in Southeast Nigeria. *International Journal of Agriculture and Rural Development*, *21*(1), 3437-3443.