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Research Article

Impact of Different Insect Pollinators Conservation Strategies on the Fruit and Yield Parameters of Round Gourd (*Praecitrullus fistulosus* L.)

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Authors' Contributions
MZM and SI conceived the idea and prepared research protocol. FN, MIS and MSK conducted experiments. FN and MIS wrote the first draft. MZM provided technical support and revised the manuscript. AS analyzed the data and prepared graphs and tables. SI and MZM proofread the manuscript.

Keywords
Cucurbits, Yield parameters, Insect pollinators, Conservation strategies, Beehive, Floral intercropping

Abstract | Cucurbit vegetable crops depend primarily on such insects as solitary bees, honeybees, bumblebees, stingless bees, wasps and hover flies for their pollination, seed setting and fruit production. Modern plant protection strategies predominantly based on synthetic pesticides have led to considerable decline in insect pollination services and sustainable production. The present study was aimed to compare the impact of different pollinator conservation techniques on fruit and yield parameters of round gourd (*Praecitrullus fistulosus* L.). The trial was conducted at College of Agriculture, University of Sargodha using randomized complete block design. Three treatments including installation of bee hotels, beehives and flowers intercropping were evaluated for their effect on the number of fruits, fruit weight, fruit diameter and average fruit yield. The results revealed that the presence of beehives improved pollination of round gourd and showed 1.32 to 1.95 fold increase in number of fruits per plant, 1.33 to 2.10 fold increase in average fruit yield per plant, 0.92 to 1.32 fold increase in fruit weight and 23.9% increase in fruit size. Moreover, treatment plots with bee hotels and flower intercropping also showed higher fruit yield as compared to the control. The correlation analyses further showed strongly positive association between fruit sizes, number of fruits and fruit yields.

Novelty Statement | This in-situ study has demonstrated that the presence of honeybees in cucurbit fields can significantly improve the yield and fruit parameters of round gourd.

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Introduction

The round gourd (*Praecitrullus fistulosus* L.) belongs to family Cucurbitaceae and is cultivated as a major summer vegetable in India, Pakistan, Afghanistan and East Africa (Ebert, 2014). Round gourd fruits have a high nutritional value, consisting of carbohydrates, lipids, digestible proteins, vitamins and important minerals such as Ca, P and Mg (Rahman *et al*., 2008). In India and Pakistan, the mature fruits of round gourd are cooked as vegetable and are used to produce pickles etc. (Raheel *et al*., 2019). Like

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most of cucurbit crops, round gourd is an entomophilous crop and depend primarily on insect pollinators for its pollination and fruit setting (Reddy *et al*., 2022).

The abundance and diversity of insect pollinators have been shown to enhance the yield of a variety of crops (Kremen *et al*., 2002; Ollerton, 2017). As per records, insects are efficient pollinators and their visits to flowers improve the fruit setting and yields of many entomophilous crops including cucurbitaceous plants (Reddy *et al*., 2022). Insects notably honeybees and bumble bees are the most common insects that provide pollination services to a variety of plants (Meena, 2012; Hung *et al*., 2018). It is reported that about 80 percent of wild plants and over 70 percent of agricultural crops rely entirely or partially on insects for pollination (Tilman *et al*., 2014; Ollerton, 2017; Coulibaly *et al*., 2022). The massive and monoecious flowers of round gourd plant produce a large amount of pollen and nectar, which in turn attract a large number of insects particularly bees (Unni *et al*., 2021). The fruit setting of the cucurbit crops including pumpkins, squashes and gourds is intrinsically tied to the common eastern bumblebees found in Northern America (Stoner, 2020).

Therefore, pollinators decline has a dramatic effect on ecosystem functions, agricultural production and food security (Garibaldi *et al*., 2020). The economic consequences of this drop are projected to be significant. Pollination services are worth roughly 153 billion euros per year worldwide and 22 billion euros per year in Europe (Gallai *et al*., 2009). Pollinators' loss has been linked to habitat destruction, fragmentation, pesticidal applications, degradation, as well as climate variability, introduction of invasive species and infections (Goulson *et al*., 2015; Janousek *et al*., 2023). The number of all bee species has been progressively dropping over the last several years as a result of human activities such as deforestation, the use of chemical fertilizers and pesticides (Abrol, 2012; Wakgari and Yigezu, 2021; Janousek *et al*., 2023).

Keeping in view the global importance of insect pollinators for crop production and contemporary decline in diversity and abundance of insect pollinators, the main objective of this study was to compare the impact of different pollinator conservation techniques on the quality and quantity of fruit yield of round gourd (*P. fistulosus*).

Materials and Methods

This research work was carried out in the vegetable research area and in the Laboratory of the Department of Horticulture, College of Agriculture, University of Sargodha.

Land preparation

For this experiment, land was prepared using rotavator in the first week of July, 2021 and the raised beds were prepared for the crop. The width and length of beds were 12 and 25 feet, respectively. Plant to plant distance was maintained as 2 feet and row to row distance was maintained as 12 feet.

Seed treatments

Seeds of round gourd (variety Dilpasand) were soaked in water for ten hours before sowing to break their dormancy and for uniform germination. After breaking dormancy, seeds were sown on beds out in the field. Choked method was used for seeding. Two seeds per hole were sown which were made on required distance. Seed depth was about 1.5 to 2.5 cm. After germination thinning was done to maintain population.

Experiment layout

Experiment was laid out using randomized complete block design (RCBD) and it consisted of four treatments and these were replicated in three blocks. T1: Control, T2: Honeybee hive, T3: Bee hotels and T4: Intercropping with seasonal flowers. A buffer zone was maintained around and in between the treatment plots. Moreover, sorghum plant stipes were sown in buffer zone to discourage the movement of insects among the blocks.

Treatment description

Woody handmade bee hotels were purchased from nearby market. Bloomed flowers of Chinese murwa, Jasmine, Hibiscus, Mexican Petunia, Marigold, Pluneria (Gul e Cheen) were procured from the nursery. Blooming period of round gourd flowers started after 8–10 weeks of the seedling germination. Male flowers appeared first then the female flowers. Female flowers appeared 10 days later then the male flowers. After blooming of round gourd flowers, the placement of active beehives, installation of wooden bee hotels and intercropping of different flowers were done in their respective treatment blocks.

Data collection

On each bed, five plants were selected on random basis for the observation and collection of data. Number of flowers were counted on these selected plants from each bed. Insect visitation was observed for 15 min on one flower of the selected plants of each bed. Insect movement was observed continuously during the blooming period. Observation was done twice a day at morning (9–11 am) and evening (3–5 pm) time when the insects were more active. Number and type of insects visiting the flowers in a day were noted. Finally crop yield was also recorded. After harvesting, the diameter of fruits was determined using digital Vernier caliper and the fruit weight was measured on digital electronic balance. During this experiment on round gourd, spray of different pesticides was done according to their need and requirement.

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Statistical analysis

The experiment was carried out on the basis of randomized complete block design (RCBD). The data were analyzed with the help of ANOVA and the least significant difference (LSD) test was employed to compare the treatment means at $P \leq 0.05$.

Results

Number of fruits per plant

Results showed the impact of different insect pollinator conservation strategies such as honeybee hives, bee hotels and flowers on the number of fruits per plant of round gourd (*P. fistulosus*). A significant (P<0.05) increase was observed in the number of fruits in all treatments as compared to control (Figure 1). However, the treatment (blocks) containing honeybee hives showed 1.32 to 1.95 fold increase in number of fruits per plant as compared to the control treatment. Bee hotel and flower intercropping treatments showed 1.6 and 1.3 increase in number of fruits per plant as compared to the control treatment, respectively. The data regarding number of fruits is presented in Figure 1.

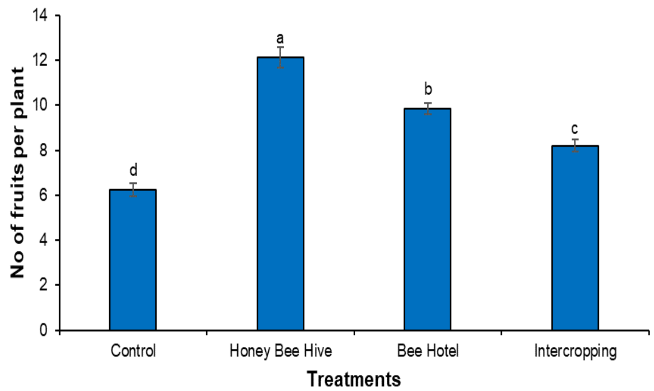

Figure 1: Impact of different insect pollinator conservation strategies on the number of fruits per plant of round gourd. Bars and columns represent standard error and mean, respectively, of triplicate values. Small letters at bar tops represent statistical difference among treatments (one-way ANOVA followed by LSD at α = 0.05).

Average fruit yield per plant

Results from the present study showed the impact of different insect pollinator conservation strategies such as honeybee hives, bee hotels and flowers on the average yield per plant of round gourd (*P. fistulosus*). A significant (P<0.05) increase was observed in average yield per plant of all treatments as compared to control as shown in Figure 2. However, the treatment (blocks) containing honeybee hives showed 1.33 to 2.10 fold increase in average fruit yield per plant as compared to the control treatment. Similarly, the other treatments, containing bee hotels and flowers showed 1.6 and 1.4 fold increase in average yield per plant as compared to the control treatment, respectively. The data regarding average fruit yield is presented in Figure 2.

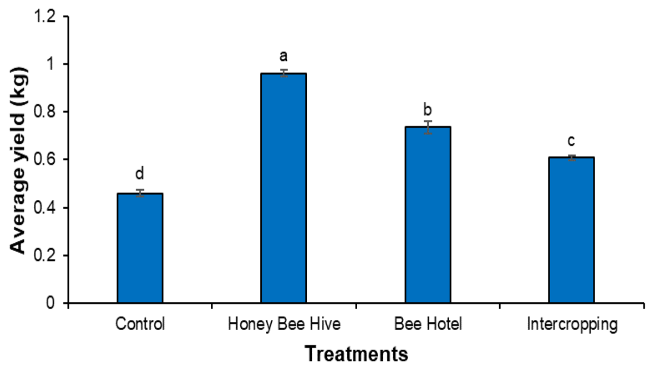

Figure 2: Impact of different insect pollinator conservation strategies on the average yield per plant of round gourd. Bars and columns represent standard error and mean, respectively, of triplicate values. Small letters at bar tops represent statistical difference among treatments (one-way ANOVA followed by LSD at α = 0.05).

Fruit weight per plant

There was also a significant impact was observed of different insect pollinator conservation strategies such as honeybee hives, bee hotels and flowers on the average fruit weight per plant of round gourd (*P. fistulosus*). A significant (P<0.05) increase was observed in fruit weight per plant of all treatments as compared to control as it shown in Figure 3. However, the treatment (blocks) containing honeybee hives showed 0.92 to 1.32 fold increase in fruit weight as compared to the control treatment. Similarly, bee hotels and flowers showed 1.2 and 0.8 fold increase in average fruit weight per plant as compared to the control treatment, respectively. The data regarding average fruit weight is presented in Figure 3.

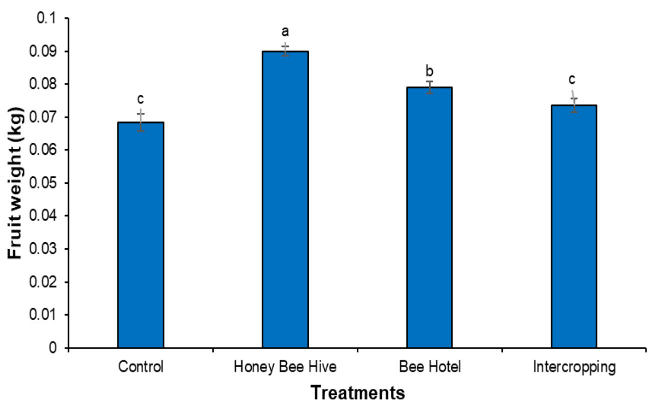

Figure 3: Impact of different insect pollinator conservation strategies on the average fruit weight per plant of round gourd. Bars and columns represent standard error and mean, respectively, of triplicate values. Small letters at bar tops represent statistical difference among treatments (one-way ANOVA followed by LSD at α = 0.05).

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Fruit size

In case of average fruit size, out of three different insect pollinator conservation strategies *i.e.,* honeybee hives, bee hotels and flower intercropping, only honeybee hive installation exerted a significant impact on the average fruit size in millimeters (mm) per plant of round gourd (*P. fistulous* L.). Honeybee hives treatment showed a significant increase (1.2 fold) in average fruit size as compared to the control treatment, while other two treatments had no significant difference from the control treatment. The data regarding average fruit size is presented in Figure 4.

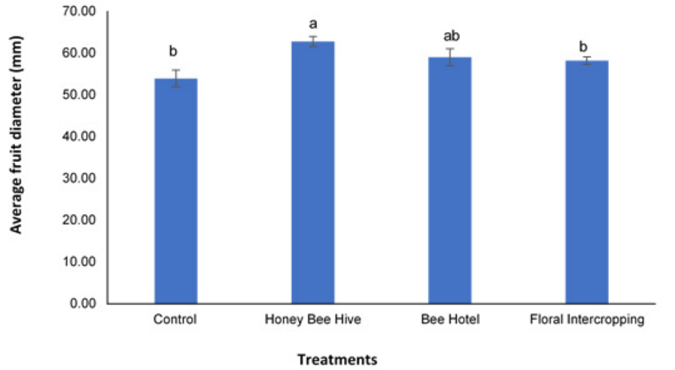

Figure 4: Impact of different insect pollinators conservation on the average fruit size (diameters in mm) of round gourd. Small letters at bar tops represent statistical difference among treatments (one-way ANOVA followed by LSD at α = 0.05).

Correlation analyses

A correlation analysis was performed to check the association of different yield parameters of round gourd such as number of fruits, average yield, fruit weight and fruit diameter per plant. The results from these analyses showed that all the parameters were highly and positively correlated with each other. Number of fruits per plant were strongly correlated to the average yield of round gourd per plant. Similarly, the fruit weight was also strongly correlated with average yield of the plant. Additionally, the fruit diameter was also strongly associated with the number of fruits and average yield of round gourd per plant.

Table 1: Correlation analyses regarding the impact of different insect pollination strategies from the different insect pollinators on yield parameters of round gourd.

	Fruit number	Fruit yield	Fruit weight	Fruit diameter
Fruit number	1			
Fruit yield	**0.997503	1		
Fruit weight	**0.989011	**0.996845	1	
Fruit diameter	**0.9962	**0.995696	**0.987376	1

**, shows the highly positive correlation between the existing parameters.

Discussion

Insect pollinators are one of the wonderful creatures on Earth upon which relies the production of many agricultural and horticultural crops including cucurbits (Garibaldi *et al.*, 2009; Dorjay *et al.*, 2017). Extensive and irrational use of broad-spectrum synthetic insecticides have played havoc with these important natural pollinators (Goulson *et al.*, 2020). This situation necessitates to look for practices which can enhance and sustain abundance and diversity of insect pollinators in agroecosystems (Merle et al., 2022). This research work evaluated three insect pollinator conservation strategies for their impact on fruit and yield parameters of round gourd (*P. fistulosus*) under field conditions.

Results of the study showed a significant effect of these strategies on the average number, weight, size and yield of round gourd fruits as compared to control treatment. Higher number of fruits per plant were recorded in all treatments particularly in plots provided with honeybee hives. These findings are consistent with the results of Pfister *et al.* (2017) who reported that presence of honeybees in near vicinity of the farm cause more pollination than other insect pollinators. This might be due to the presence of a specific group of pollinators who are present in the near vicinity of the farm blocks. The accessibility of flowers is easier because specific pollinators (such as in the case of beehives) were placed in the middle of the treatment plot. While in case of bee hotels, a larger variety of insect pollinators are available (but fewer are relevant) for the production of higher fruit numbers on plants. But these numbers are lesser as compared to the treatment with beehives followed by plots intercropped with seasonal flowers. This might be due to the presence of non-specific and random visitors. Bee hives are usually inhabited by solitary bees and other wild bees, and flowers are visited by other insect pollinators including hover flies, bumble bees and syrphid flies (Hamroud *et al.*, 2023).

When plants are intercropped with other flowering plants, they also attract random visits of non-specific pollinators, and this might be due to the absence of native pollinator species because of the higher use of pesticides such as insecticides and weedicides that damage the targeted as well as non-targeted (insect pollinators) species (Barbosa *et al.*, 2015). However, some other pollinator species that are observed in this study made less excursions to pistillate flowers, which may be connected to their lesser demands on pollen for larval development and adult maintenance, which might be substantial in proper pollination of flowers (Delgado- Carrillo *et al.*, 2018; Bezerra *et al.*, 2020).

Similarly, higher average fruit yield and fruit weight per plant and to some extent average fruit size were recorded in the blocks (treatment) provided with beehives as compared to bee hotels, intercropping and control treatments. Our results are in accordance with the findings of Pereira *et al.* (2015) and Brar *et al.* (2020) who also reported higher

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fruit yield parameters of different crops when subjected to higher population of honeybees. The reason behind this significant increase in fruit yield, weight and size would be the timely and successful pollination of maximum flowers by specific pollinators, higher contact time and presence of more blooming flowers. Although the presence of bee hotels also attract a variety of pollinators, but their visits are fewer (Nicodemo *et al*., 2009; Travis and Kohn, 2023).

It is important to mention that our findings need to be taken with caution due to the fact that the way we managed the bees throughout the scheduled visits may have had an effect on the pollen deposition measurements (Lowenstein *et al*., 2015; Cecala *et al*., 2020).

Conclusions and Recommendations

We conclude that maximum number of fruits, average fruits, fruit yield and fruit size per plant were observed in the treatment (plots) where beehives were placed as compared to those provided with wooden bee hotels and intercropped with flowers. While bee hotels also showed higher results as compared to the floral intercropping and control treatment.

Declarations

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IRB approval

The research work was ethically approved by Internal Review Board (IRB) of the University of Sargodha.

Ethical statement

Authors declare that this study did not require ethical committee's approval or any other ethical considerations.

Conflict of interest

The authors have declared no conflict of interest.

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