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Influence of Pollinator Attractant Crops on Abundance of Honeybees and Yield Parameters of Onion

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ABSTRACT

The experiment was conducted during the *rabi* season (November, 2021 to May, 2022) at the Sidapur farm, University of Agricultural Sciences, Dharwad, Karnataka, India to comprehensively study the influence that various pollinator attractant crops can have on both the abundance of honeybees and the yield parameters associated with onion crop. To facilitate this study, two distinct rows of marginal crops composed of coriander, buckwheat, carrot, radish, fennel, and black cumin were intentionally grown all along the borders of the onion crop fields. The results of the study revealed that the highest level of activity among pollinators was observed in the plots of onion that included coriander as the marginal crop, which was closely followed by the onion fields that were bordered with buckwheat. Furthermore, the highest diversity indices for pollinators *i.*e., Shannon-Wiener and Simpson's diversity index (H and 1-D, respectively), were prominently recorded in the situation where onions were bordered with coriander. In addition, both the quantitative and the qualitative parameters were noted to be significantly higher in the treatment of onion with coriander as a border crop. It was also observed that the bees, which were attracted towards the flowering border crops, subsequently shifted their focus to the main onion crop, thereby providing essential pollination services right from the very first flower that opened. This phenomenon ultimately contributed to an overall enhancement in both the quantity and quality of seeds produced in the main crop, leading to improved agricultural outcomes.

KEYWORDS: Coriander, honey bees, marginal crop, onion

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1. INTRODUCTION

Honeybees are considered one of the efficient and eco-friendly approaches to maximise the yield of cross-pollinated crops (Kamala and Devanand, 2021). Onion is the world's third most important vegetable farmed all over the world (Rao, 2016), originated in Asia's Eastern area, which includes China, the Soviet Union, the United States, the Netherlands, Bulgaria, Egypt, Spain, the United Kingdom and Japan. In terms of area, the onion ranks next to the tomato, with production of 36 mt from an area of 2–5 mha. India occupies second place in onion output next to China (Gopal, 2015). In India, the production was above 22.82 million tonnes from a total area of 1.22 mha with productivity of 18,712 kg ha^{-1} (Anonymous, 2020). Being the most significant vegetable in India with high demand from consumers all around the year, it is possible to meet the consumer demand by increasing the yield of onion seeds (Patil et al., 2011). Pollination is essential for plant reproduction and seed production. Honeybees and other insects have traditionally aided this process. Pollinators are vital for plant fertility, ecosystem function and food production, but their populations are declining (Tanda, 2022). Bee decline forces artificial pollination which is laborious and uneconomical (Kamala and Devanand, 2021). As most vegetable crops are cross-pollinated, proper pollination is essential for any meaningful increase in seed yield (Divekar et al., 2024). In the absence of adequate pollinators, onions do not generate good-quality seeds and bulb yield might drop up to 28% after three generations of inbreeding (Chandel et al., 2004). Pollinators are attracted to flowers because of their shape, colour and scent (Zariman et al., 2022). Aside from morphological characteristics, the caloric reward supplied by flowers, such as nectar and pollen, is a source of diversity for genotype differentiation in attraction. It has been discovered that the nectar produced by flowers is a crucial feature that determines pollinator activity concerning their energetic needs (Abrol, 1990). Pollinating insects are in trouble due to climate change, pesticides and habitat loss. Ecological engineering can help them by providing food and restoring their habitat (Decourtye et al., 2019). Pollinator-friendly management techniques have been found to improve crop yield, quality, diversity and resilience in a variety of agroecosystems and ecologies (Egan et al., 2020). These techniques include: protecting wild habitat; designing cropping systems with flower-rich field margins, buffer zones and permanent hedgerows to ensure habitat and forage; planting shade trees; and managing bee nest sites by leaving standing dead trees as a place for bees to build their hives (Decourtye et al., 2010; Munyuli, 2011; Sardinas et al., 2022). In some situations, acceptable pollinator attractants such as fennel, dill and black cumin, fruit juice (mango, jackfruit), or dried fish can be distributed around the blossoming crop to increase pollinator vigilance. Losapio et al. (2019) recently discovered that facilitation by cushion plants (*Arenaria tetraquetra*) acting as ecosystem engineers increases pollinator diversity and synergistically supports ecological network structure. According to research conducted by Losapio et al. (2021), plant facilitation can strengthen the connections between biodiversity and ecosystem functioning. The most likely cause of this is plant complementarity, which draws more and a wider variety of floral visitors. One possible explanation is that engineers and related plants work in harmony and complementarity to make shared visits more appealing and to expand pollination niches. In summary, plant-to-plant facilitation can scale up to a complete network, supporting ecosystem functioning both directly through diversification impacts and indirectly through microhabitat amelioration. The study aimed to determine if marginal flowering crops increase pollinator services towards the main crop.

2. MATERIALS AND METHODS

The experiment was conducted during *rabi* (November, 2021 to May, 2022), at Saidapur farm, University of Agricultural Sciences, Dharwad, Karnataka, India. Onion being a highly cross-pollinated crop, efficient seed setting is not possible unless and until these flowers are pollinated by insects. Therefore, an attempt was made to attract bees to the main crop (onion) by growing the border crops. The bees that are attracted to the flowers of border crops were then shifted onto the main crop and helped in the pollination of onion flowers. The planting of border crops was adjusted in such a way that their flowering should be initiated before the flowering of the onion crop. Due to this, the bee population attracted towards border crops was utilised for onion pollination. Attractant crops were planted all along the border of the main crop (Table 1). The onion crop was raised as per the recommended package of practices except for plant protection measures during the flowering period. Three rows of marginal crops were raised all around the onion plot of 4×3 m^2 size following the recommended package of practices except for plant protection measures (Anonymous, 2013).

2.1. Abundance and diversity of pollinators on onion with different marginal crops

The visual count was made on the number of pollinators visiting onion flowers in different treatments by selecting five spots of one square meter area for 2 minutes at peak visiting hours of the pollinators. Such observations were recorded at 50, 75 and 90% flowering of onion. Data collected on different species was used to quantify, Simpson's index of diversity (1-D) and Shannon-Wiener diversity index (H).

2.1.1. Shannon-wiener diversity index (H)

The Shannon-Wiener diversity index is calculated by using the following equation:

$H=-\Sigma$ pi ln pi

Where,

pi=Proportion of the i^{th} species of pollinator

ln=Natural log with base exp = 2.718

2.1.2. Simpson's index of diversity (1-D)

$D=1-\Sigma pi$

2.2. Yield parameters of onion

2.2.1. No. of seeds umbel^{-1}

After maturity, harvesting of the crop was done separately as per the treatments. The seeds were dried and cleaned. From each treatment, at the time of harvest randomly twenty umbels were selected separately and the number of seeds per umbel was counted manually and expressed as a mean number of seeds umbel^{-1}.

2.2.2. Seed yield (kg ha^{-1})

Seeds harvested from each treatment were separately dried and cleaned. The seed yield obtained per plot was weighed using a single pan digital electronic balance and was later converted into kg ha^{-1}.

2.2.3. Test weight (1000 seeds)

From each treatment 1000 dried seeds were counted using the seed counter instrument and the observation was made by 1000 dried seeds sampled randomly from all the treatments using a single pan digital electronic balance. The seed weight was expressed in grams.

2.2.4. Germination (%)

Randomly selected 100 seeds from each treatment were taken and placed in moistened germination paper, then kept in a germination chamber. The germination count was taken at 10 days after incubation. The % germination was worked out using the formula mentioned below:

$$\text{Germination (\%)} = \frac{\text{No. of seed germinated}}{\text{Total no. of seeds kept for germination}} \times 100$$

2.2.5. Seedling vigour

From each treatment, 20 rooted seedlings were selected randomly after germination and the length of the shoot and root were measured 10 days after germination and expressed in centimetres. The data was then averaged per treatment and noted.

2.3. Statistical analysis

Results of the abundance of pollinators recorded from each treatment were analyzed statistically by applying a paired sample t-test (Table 1).

Table 1: Treatment details

Treatment No.	Treatments with border crop
1.	Onion (*Allim cepa* L.)+Coriander (*Coriandrum sativum*)
2.	Onion+Buckwheat (*Fagopyrum esculentum*)
3.	Onion+Radish (*Raphanus sativus*)
4.	Onion+Fennel (*Foeniculum vulgare*)
5.	Onion+Black cumin (*Nigella sativa*)
6.	Onion+Carrot (*Daucus carota*)
7.	Sole onion

3. RESULTS AND DISCUSSION

3.1. Activity of pollinators in different treatments of onion during different flowering stages

At 50, 75 and 90% flowering, the activity of pollinators on onion with distinct marginal crops showed that the treatment of onion with coriander as a border crop had the highest mean activity of pollinators on onion, followed by the buckwheat. While in sole onion the least activity was recorded. Among the different insect pollinators documented, the highest activity was found in the case of *A. florea*, followed by *Tetragonula* sp., while the least activity was found in the case of *A. cerana indica*. Furthermore, the maximum activity of *A. florea* was seen in the case of onion with coriander, followed by onion with buckwheat. While the least activity of *A. florea* was found in the case of sole onion (Table 2).

3.2. Pollinator abundance in different treatments of onion at different % flowering

Pollinator activity in different treatments of onion at different flowering stages was subjected to statistical analysis (Paired t-test), where each treatment was compared with sole onion. The results from the statistical analysis revealed that a significant increase in pollinator activity was seen in the treatments of onion plots border cropped with coriander and buckwheat. Whereas onion surrounded by fennel, carrot, radish and black cumin was found to be on par with sole onion (Table 3).

Very limited studies have been conducted on the influence of marginal crops on the activity of pollinators to make meaning full discussion of the present study. In Finland, patches of farmland with dicotyledonous flowers had higher bumblebee species richness and total density compared to grassy margins (1.5–2.5 m wide) (Backman and Tiainen, 2002). However, Ghazoul (2006) stated more pollinators visited *Raphanus raphanistrum*, a self-incompatible herbaceous plant when grown along with *Cirsium arvense*, *Hypericum*

Table 2: Activity of pollinators in different treatments of onion during different flowering stages

Species	Number of visitors/m²/2 min. on onion						
	Onion with coriander	Onion with buckwheat	Onion with fennel	Onion with carrot	Onion with radish	Onion with black cumin	Sole onion
50% flowering							
A. florea	10.40	9.00	8.00	7.80	6.40	6.20	6.00
Tetragonula sp.	9.20	8.40	5.00	5.20	4.80	5.00	5.40
A. dorsata	5.60	4.00	2.60	2.40	2.60	2.80	2.20
A. cerana indica	2.80	2.20	1.20	1.60	1.60	1.80	1.40
Total	28.00	23.60	16.80	17.00	15.40	15.80	15.00
Mean	7.00	5.90	4.20	4.25	3.85	3.95	3.75
75% flowering							
A. florea	16.40	14.00	13.00	13.60	10.80	10.60	10.20
Tetragonula sp.	13.20	11.40	10.80	10.40	10.00	9.00	9.60
A. dorsata	6.40	6.00	3.40	4.00	3.20	3.00	3.80
A. cerana indica	5.40	4.40	2.80	2.20	3.00	2.20	2.40
Total	41.40	35.80	30.00	30.20	27.00	24.80	26.00
Mean	10.35	7.52	7.50	7.55	6.75	6.20	6.50
90% flowering							
A. florea	20.20	17.40	13.80	14.00	15.00	14.40	14.60
Tetragonula sp.	17.60	15.80	13.60	13.80	14.20	14.60	14.00
A. dorsata	8.60	7.40	4.80	5.20	5.40	4.40	5.00
A. cerana indica	6.80	6.20	4.20	3.20	3.80	4.00	3.60
Total	53.20	46.80	36.40	36.20	38.40	37.40	37.20
Mean	13.30	11.70	9.10	9.05	9.60	9.35	9.30

Table 3: Pollinator abundance in different treatments of onion at different % flowering

% flowering	Mean number of pollinators/m²/2 min. in different treatments of onion						
	Onion with coriander	Onion with buckwheat	Onion with fennel	Onion with carrot	Onion with radish	Onion with black cumin	Sole onion
50	7.00	5.90	4.20	4.25	3.85	3.95	3.75
75	10.35	7.52	7.50	7.55	6.75	6.20	6.50
90	13.30	11.70	9.10	9.05	9.60	9.35	9.30
Mean	10.15	8.37	6.93	6.95	6.73	6.50	6.51
T statistic	16.14	4.37	1.20	1.15	1.32	0.11	-

*Table t-value: 4.30; * Treatments with T statistic value > Table t-value are significantly different from the sole onion

perforatum and *Solidago canadensis*. Fields surrounded by tilled cropland had fewer bumblebees than fields with semi-natural pastureland within 800m of field edges, according to a study on Canadian canola fields (Morandin et al., 2007). Allowing weeds in sunflower fields helps pollinators to thrive, thereby enhancing crop productivity in remaining natural habitats (Carvalheiro et al., 2011). Urmila (2018) reported the highest bee visitation in plots bordered with mustard followed by sunflower, carrot with onion, coriander with onion, radish, fenugreek and marigold which were at par with each other. From observations of the current study, it was noticed that coriander and buckwheat have attracted all four species of bees, which were later shifted onto onion flowers. This might be the reason for more pollinator activity in these treatments compared to other treatments. Linalool which is a monoterpene alcohol is the main component (19.80–91.77%) in coriander essential oils (Kassahun, 2020) and the linalool is present in the floral fragrance of various plant families and is attractive to a broad spectrum of pollinators (Raguso and Pichersky, 1999). It is possible to enhance pollinator insects both native and wild bees through ecological engineering. Turnera, Cosmos, Helianthus and Antigonon were the plants that pollinator insects visited more frequently (Amrulloh et al., 2023).

3.3. Diversity indices of pollinators in onion with different marginal crops

The diversity indices of insect pollinators were calculated for onions with different marginal crops (Table 4). The highest values of Shannon-Wiener index (H) and Simpson diversity index (1-D) were registered in the case of onion plot border cropped with coriander (1.29 and 0.703, respectively) followed by onion with buckwheat (1.28 and 0.701). With fennel, carrot, radish, black cumin and sole onion there was no notable difference in the indices which ranged from 0.67–0.68 (1-D) and 1.21-1.24 (H). The highest values of the Shannon-Wiener index (H) and Simpson's index of diversity (1-D) were seen in the case of onion with coriander followed by onion with buckwheat. In the case of onion with fennel, carrot, radish, black cumin and sole onion there was no notable difference in the indices. The diversity indices did not vary much since the species remained the same throughout the season within the crop. The Shannon-Wiener index (H) describes the diversity of a species in a given community. It rises with an increased number of species and the evenness of their abundance. The higher the index, the more diverse the species are in the habitat. If the index is equal to 0, only one species is present in the community (No diversity). The Simpson's index of diversity (1-D) is also a simple measure that can be used to measure diversity. The value of 1-D ranges from 0–1, where with an increase in index value diversity increases. In the case of onion with coriander and buckwheat as marginal crops, different bee species were attracted and maintained throughout the cropping season because of the attractiveness towards coriander and buckwheat when they were flowering. The same species were restored on onion during its flowering period. This may be the reason for higher diversity in these treatments. Species diversity is determined by both species richness and the evenness of individuals among them (Rahman et al., 2017). In a study conducted by Hossain et al. (2021), the species diversity was high in mustard with 15 species while it was low in linseed (5 species).

Table 4: Diversity indices of pollinators in onion with different marginal crops

Treatment	Simpsons diversity index (1-D)	Shannon-Wiener index (H)
Onion with coriander	0.70	1.29
Onion with buckwheat	0.70	1.28
Onion with fennel	0.67	1.22
Onion with carrot	0.67	1.21
Onion with radish	0.68	1.24
Onion with black cumin	0.67	1.22
Sole onion	0.67	1.23

3.4. Influence of marginal crops on qualitative and quantitative yield parameters in onion

The number of umbels per plant of onion was highest in the treatment of onion with radish as a border (4.80) followed by black cumin (4.40). Whereas the least number of umbels per plant of onion was recorded in the treatment of onion with buckwheat (3.80). Further, the number of flowers per umbel of onion was maximum in the treatment of onion with carrot (374.20) followed by fennel (344.40). The least number of flowers per umbel of onion was recorded in the treatment of onion with black cumin (288.40). The number of seeds per umbel of onion was highest when it was surrounded by coriander (742.30), with a 21.45% increase over sole onion, followed by buckwheat (712.50) with a 16.57% increase. The number of seeds per umbel of onion was lowest in the case of sole onion (611.20). The highest seed yield of onion (113.50 kg ha^{-1}) was recorded in the case of onion border cropped with coriander with a 16.65% increase followed by buckwheat (110.20 kg ha^{-1}) with a 13.26% increase over sole onion. The lowest onion seed yield of 97.30 kg ha^{-1} was realized in the case of sole onion. The highest test weight of onion seeds was also recorded in the treatment of onion border cropped with coriander (3.50 g) with a 25.00% increase over sole onion followed by buckwheat (17.85% increase). Whereas the lowest test weight was recorded in the case of sole onion (2.80 g). The highest germination % of onion seeds was recorded in the treatment of onion border cropped with coriander (85.00) with the maximum % increase over sole onion (10.40), followed by buckwheat (82.00). The lowest germination % was registered in the sole onion. Data on the effect of different marginal crops on the shoot length of onion exhibited that the average seedling length was highest (8.82 cm) in the treatment of onion with coriander as a marginal crop having a maximum % increase of 18.80 over sole onion, followed by buckwheat (8.64 cm) with 16.40% increase. Similarly, the highest root length was recorded in the case of onion with coriander as a border crop (5.48 cm), showing a maximum of 18.30% increase over sole onion followed by buckwheat (5.40 cm) with a 16.60% increase. Whereas the root length was lowest in the case of sole onion (4.63 cm) (Table 5). The number of umbels per plant and flowers per umbel are genetic characteristics of a plant variety, so there was little difference between the treatments for these characters. Other parameters like the number of seeds per umbel, seed yield, test weight, germination %, shoot and root length were higher in the treatment of onion with coriander. The influence of pollinators was more evident in the treatment of onion with coriander than in other treatments as indicated by increased % over control of yield parameters. Uddin et al. (2015), reported that the highest seed setting and seed yield was recorded in onion+fennel which was statistically identical to onion+coriander. %, seed setting and seed yield were lowest in sole onion. Further, Moghaddam et al. (2020) concluded that planting three rows of onions alongside chamomile and ajwain improves the attraction of insects, enhances the pollination of onion flowers, and increases the yield of all three plants. Van Reeth et al. (2019) stated that at the local level, having more of the same type of plant improved seed production by making it easier for honeybees to pollinate and also found a strong positive correlation between honeybee abundance and seed set. Tanda (2019) and Pushpalatha et al. (2023) also stated that onion is a highly cross-pollinated crop, even a slight increase in pollinators will lead to an increase in yield. The bees that are attracted towards flowering border crops were then shifted to the main crop and provided pollination service from the first opened flower itself, thereby enhancing seed quantity and quality in the main crop.

Table 5: Influence of marginal crops on qualitative and quantitative yield parameters of onion

Sl. No.	Character	Treatments						
		Onion with coriander	POC	Onion with buckwheat	POC	Onion with fennel	POC	Onion with carrot
1.	No. of umbels $plant^{-1}$	4.00	-	3.80	-	4.20	-	4.00
2.	No. of flowers $umbel^{-1}$	325.30	-	298.30	-	334.60	-	374.20
3.	No. of seeds $umbel^{-1}$	742.30	21.45	712.50	16.57	700.40	14.59	657.00
4.	Seed yield (kg ha^{-1})	113.50	16.65	110.20	13.26	104.30	7.19	100.20
5.	1000 seed weight (g)	3.50	25.00	3.30	17.85	3.20	14.28	3.00
6.	Germination (%)	85.00	10.40	82.00	6.50	80.00	3.90	79.00
7.	Shoot length (cm)	8.82	18.80	8.68	16.40	8.46	14.00	8.44
8.	Root length (cm)	5.48	18.30	5.40	16.60	5.01	8.20	4.96

Table 5: Continue...

Sl. No.	Character	Treatments					
		POC	Onion with radish	POC	Onion with black cumin	POC	Sole onion
1.	No. of umbels $plant^{-1}$	-	4.80	-	4.40	-	4.20
2.	No. of flowers $umbel^{-1}$	-	318.60	-	288.40	-	334.40
3.	No. of seeds $umbel^{-1}$	7.49	642.20	5.07	623.80	2.06	611.20
4.	Seed yield (kg ha^{-1})	2.98	101.20	4.01	98.20	0.92	97.30
5.	1000 seed weight (g)	7.14	2.70	3.50	2.70	3.50	2.80
6.	Germination (%)	2.60	78.00	1.30	76.00	0.00	76.00
7.	Shoot length (cm)	13.74	7.88	6.20	7.52	1.30	7.42
8.	Root length (cm)	7.10	4.72	1.90	4.64	0.20	4.63

*POC: % increase over control

4. CONCLUSION

Data showed that plots with different crops attracted honeybees, with the highest visitor count in onion with coriander treatment, followed by onion with buckwheat. The highest diversity index occurred with onion with coriander. Pollinator activity significantly increased in these treatments. Onion with coriander also yielded better quantitative (e.g., seeds per umbel, seed yield, test weight) and qualitative (e.g., germination %, shoot and root length) results. The impact of pollinators was most pronounced in onion with coriander, enhancing yield parameters of onion.

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