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EFFICIENCY OF EUROPEAN HONEY BEE (*APIS MELLIFERA* L.) OVER BEE ATTRACTANTS IN POLLINATION AND SEED YIELD OF CORIANDER, *CORIANDRUM SATIVUM* L.

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ABSTRACT

The efficiency of different pollination treatments was tested for yield parameters in coriander. Results revealed that, *A. mellifera* pollinated crop recorded highest number of seeds per umbel (23.31), seed size (58.15 mm^3), filled seeds (93.66%), 1000 seed weight (15.33 g), seed yield (634.47 g/ 20 m^2), seed germination (79.33%) and seedling vigour (1014.07) which was followed by Citral-E treated plots. The plots where 5% solutions of jaggery, sugar, sugarcane juice sprayed separately, and open pollination are not differ from each other for yield parameters but significantly differed from *A. mellifera* pollinated and Citral-E treated plots. Whereas minimum was found in treatments without pollinators (16.39, 43.39 mm^3, 74.08%, 9.53 g, 201.30 g/ 20 m^2, 59.33% and 485.69, respectively). The study found out that *A. mellifera* pollinated plots resulted in better yield parameters than others. This emphasizes more to conserve and utilize European bees which apart from being efficient pollinators act as productive insects and most importantly they maintain ecological balance in the agro-ecosystems.

Key words: Pollination, bee attractant, *Apis mellifera*, pollination, yield parameter, coriander, Tirupati, European honey bees, Citral-E, seed yield.

Pollination is one of the important ecosystem services to increase crop productivity, environment conservation and ecosystem balance. Among various insects rendering pollination service, honey bees contribute lion share and act as cost free bio-inputs in agriculture and forest systems. Bee pollination not only increases the yield by enhancing qualitative and quantitative parameters, also creates variation and maintains the gene flow in the ecosystem, thereby conserving the crop varietal diversity. Beekeeping is a fundamental agricultural activity in India and world-wide to harvest products like, honey, wax, pollen, bee venom and royal jelly apart from pollination of wide crop variety (Free, 1993). The efficient use of pollinators can significantly increase the yield level in a sustainable manner. *Apis* bees like *A. mellifera* followed by *A. cerena* are potential pollinator species and artificially reared worldwide. The former species is managed nearly in 100 countries whereas the later species in about 12 countries, majorly in India (Abrol, 1997).

India is known as "The Home of Spices" with diverse spices being cultivated and consumed. Coriander (*Coriandrum sativum* L.) is one of the prominent seed spices and constitutes about 25% of total seed spices export. Floral phenology and biology of coriander is quite interesting as inflorescence produces both hermaphrodite and staminate flowers. The hermaphrodite flowers are completely protandrous making this crop a completely cross-pollinated species (Nemeth and Szekely, 2000). Hence, pollination of coriander is largely dependent on various pollinating agents including insects especially honey bees. This crop is reportedly visited by several species of flower visitors namely, honeybees, solitary bees, butterflies, flies etc., but honeybees are the major pollinators (Ranjitha et. al., 2019) and reportedly increased yield to the extent of 49.86% (Annual report, All India Co-ordinated Project on Honey bee Research and Training, 2000).

Several problems like, decrease in habitats that preserves bees in and around crop fields due to anthropogenic activities, continuous hybridization of crops reducing rewards in flowers to attract bees and non-preference of small crop patches by bee colonies have driven a surge in research to identify substances which attracts honey bees to specific crop and these substances are considered as highly economical and practical to enhance the benefits of cross pollination. Commercial bee attractants viz., beeline, citral, beehere, beescent, beescent-plus, fruit boost and bee-Q and other indigenous attractants like sugar, jaggery and sugarcane

solution are being used to boost the yield of pear, peach, blueberries, watermelon and apple in United States, Spain and Canada (Ma et al., 2015). However, studies on the use of bee attractants in countries like India is very rare, though few studies have been made on pollination of coriander with least attempts for exploring the possible use of bee attractants to boost the crop productivity. The impact of bee pollination during blooming of the coriander and use of different bee attractants for seed production has not been well understood. Hence, this study aimed at identifying efficiency of *A. mellifera* pollination over other pollination method coupled with use of bee attractants in coriander crop.

MATERIALS AND METHODS

To study the efficiency of European bees (*A. mellifera* L.) over bee attractants in pollination and seed yield of coriander, the experiment was conducted in randomized block design during rabi 2018-19 at the insectary, department of Entomology, Sri Venkateswara Agricultural College, Tirupati. The study location was situated at an altitude of 189.2 m above MSL, 13^0N latitude and 79^0E longitude, geographically and receiving 905 mm rainfall annually.

Coriander (variety-Suguna) crop was sown in 21 plots (for 7 treatments, 3 replications) and each plot measured 5×4 m. There were seven treatments viz. (T_1) bee pollination *(A. mellifera)*, (T_2) pollinator exclusion, (T_3) open pollination, (T_4) crop sprayed with sugar solution (5 %), (T_5) crop sprayed with jaggery solution (5 %), (T_6) crop sprayed with sugarcane juice solution (5%) and (T_7) crop sprayed with Citral E @ 1%. In bee pollination and pollinator exclusion experiments, the insect proof nylon net cages were erected on standing crops once crop attained bud stage and a colony of European bees having five frames with sufficient honey storage was confined inside the cage of bee pollination treatment. Colony was occasionally supplied with 10% sugar solution to balance the energy source for bees until complete flowering of the crop. While in open pollination treatments, the natural pollinating insects had free access to the flowers visitation. In case of bee attractant treatments, first spray was given when crop attained 10% flowering specifically during morning hours, whereas the second and third spraying was given for every 10 days interval. The cultural operations and irrigation were given as and when required following recommended agronomic practices. No insecticides spray was undertaken during the entire crop growing period.

To study the effect of bee pollination on the seed set and yield of coriander, five sampling patches of 1×1 m^2 each were selected randomly within each plot following methods reported by Revanasidda and Belavadi (2019). In each sampling patch, twenty-five random plants were selected and the observations were recorded on number of seeds per umbel, filled seeds per umbel (%) and seed yield. The data collected from 25 plants was further converted to the whole plot data based on total plants count per plot. Seed size (n= 50 seeds per plot) was taken by measuring seed length in three angles using digital Vernier's caliper and expressed in mm^3. 1000 seeds were weighed for test weight. Germination (%) of seeds (n= 50) were recorded by conducting the germination test using moistened germination paper. The germination count was taken after seven days of incubation and seedling vigour was calculated using the formula (Abdul-Baki and Anderson, 1973).

Seedling vigour = shoot length + root length × germination %

The data collected on various aspects were interpreted with appropriate statistical tools before arriving at conclusion.

RESULTS AND DISCUSSION

Coriander flowers were visited by insects belonging to five families representing four insect orders. The major pollinators were *Apis cerana indica* F. (45%), *A. florea* F. (25%), *Tetragonula iridipennis* Smith (20%), *Stomorhina* sp. (5%) and *A. mellifera* L. (3%). Whereas *Braunsapis* sp., *Coccinella transversalis*, *Micraspis discolor*, *Polyommatus icarus* and *Catopsilia pomona* were less abundant. The diversity, abundance, dominance and foraging behavior of the mentioned flower visitors has been discussed in detail in Ranjitha et al. (2019). The results of yield parameters such as number of seeds per umbel, filled seeds (%), seed yield, seed size, 1000 seed weight, seed germination (%) and seedling vigour differed significantly among different treatments in coriander are described in detail and discussed below (Table 1).

The maximum number of seeds per umbel was recorded significantly higher in *A. mellifera* (23.31± 0.12) followed by the plot sprayed with 1% citral (19.87± 1.06). Whereas crop sprayed with 5% sugarcane juice solution recorded 18.27± 0.23 seeds per umbel which was on par with other treatments like, 5% jaggery solution (18.08± 0.68), open pollination (18.04± 1.04) and 5% sugar solution (17.93± 1.44). However, the

Table 1. Effect of different pollination treatments on different yield parameters in coriander

Parameters / Treatments	No. of seeds per umbel	Filled seeds (%)	Yield (g)	Seed size in (mm^3)	Test weight (g)	Germination (%)	Seedling vigour
A. mellifera pollination	23.31± 0.12^{a}	93.66± 0.31^{a}	634.47± 76.63^{a}	58.15± 1.61^{a}	15.33± 1.07^{a}	79.33± 9.02^{a}	1014.07± 136.03^{a}
Pollinator exclusion	16.39± 0.02^{d}	74.08± 1.23^{e}	201.30± 86.33^{c}	43.39± 5.46^{b}	9.53± 0.69^{c}	59.33± 3.06^{c}	485.69± 146.44^{c}
Open pollination	18.04± 1.04^{c}	81.52± 1.07^{d}	448.79± 66.98^{b}	51.73± 7.01^{ab}	13.28± 0.68^{ab}	70.00± 6.00^{ab}	760.61± 31.96^{b}
Sugar solution (5%)	17.93± 1.44^{c}	84.82± 2.60^{c}	409.11± 47.03^{b}	55.95± 6.45^{a}	11.76± 1.03^{bc}	76.67± 3.06^{ab}	720.52± 175.81^{bc}
Jaggery solution (5%)	18.08± 0.68^{c}	87.26± 1.38^{b}	419.44± 71.90^{b}	54.63± 11.77^{ab}	11.58± 0.93^{bc}	63.33± 15.28^{ab}	737.10± 103.40^{b}
Sugarcane juice solution (5%)	18.27± 0.23^{c}	87.39± 0.63^{b}	412.39± 97.59^{b}	52.62± 3.34^{ab}	11.98± 0.81^{b}	70.00± 6.00^{ab}	620.60± 228.51^{bc}
Citral E (1%)	19.87± 1.06^{b}	88.08± 0.61^{b}	506.55± 69.58^{ab}	56.55± 7.16^{a}	14.84± 0.43^{a}	78.67± 16.29^{a}	1013.73± 120.84^{a}
SEM±	0.49	0.74	38.44	3.41	0.51	5.33	74.25
CD	1.51	2.29	118.46	10.53	1.59	16.43	228.81

Note: Means followed by same alphabet do not differ significantly at $p < 0.05$ (post-hoc tukey's HSD test following One way ANOVA)

minimum number of seeds per umbel (16.39± 0.02) was recorded in case of pollinator exclusion plot (Fig. 1).

The present findings were in conformity with Shelar and Suryanarayana (1989) wherein *A. cerana indica* pollinated coriander crop resulted higher yield followed by crop sprayed with citral and both were significantly different from crop sprayed with sugarcane juice solution and jaggery solution. In the present study, the number of seeds per umbel in case of crop sprayed with sugar solution was falling in between open pollinated and pollinator exclusion treatment but, it was on par with open pollination treatment and other bee attractants except citral and pollinator exclusion. This might be due to concentrated and specific active ingredient of citral which attracted more number of pollinators as reported by Valenta et al. (2016) who inferred that the plant attractants provide information regarding the presence, location, and quality of the reward to the pollinating insect species. Similar results regarding number of seeds per umbel from open pollinated treatment differing significantly from pollinator exclusion treatment was done in coriander (Basawana, 1982; Marvin et al., 1992; Patil and Pastagia, 2016), onion (Kumar et al., 1989) and radish (Verma and Poghat, 1994).

The highest filled seeds (93.66 ± 0.31%) was found in *A. mellifera* pollinated crop which was significantly higher than other treatments (Table 1, Fig. 1). The treatments such as crop sprayed with 1% citral (88.08± 0.61%), 5% sugarcane (87.39± 0.63%) and jaggery solution (87.26± 1.38%) were on par with each other. Whereas the crop sprayed with 5% sugar solution (84.82± 2.60%) was significantly differed from previous treatments and from open pollination (81.52± 1.07%). Significantly least filled seeds were recorded in pollinator exclusion treatment (74.08± 1.23%). Overall, there was a significant difference in filled seeds among the treatments indicating *A. mellifera* yielded higher filled seeds in the coriander crop. Whereas other treatments also contributed good seed fill but comparatively not as efficiently as the *A. mellifera* (Fig. 1). Patil and Pastagia (2016) mentioned that filled seeds were higher in bee pollination treatments followed by open pollination and least was in the pollinator exclusion treatment applied to coriander plot.

A. mellifera pollinated plot yielded higher seed (634.47± 76.63 g/ 20 m^2) followed by crop sprayed with 1% citral (506.55± 69.58 g/ 20 m^2). Open pollination (448.79± 66.98 g/ 20 m^2), jaggery solution (419.44± 71.90 g/ 20 m^2), sugarcane juice (412.39± 97.59 g/ 20 m^2) and sugar solution (409.11± 47.03 g/

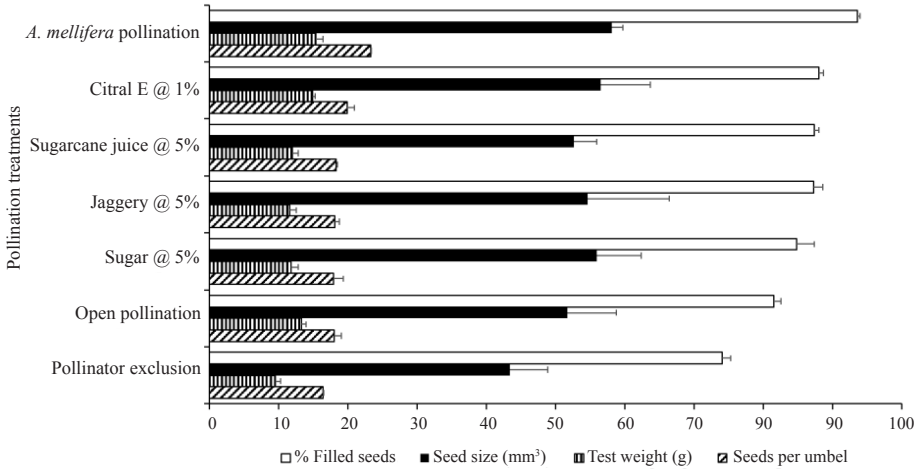

Fig. 1. Effect of different pollination treatments on seed set, seed filling, seed size and test weight in coriander

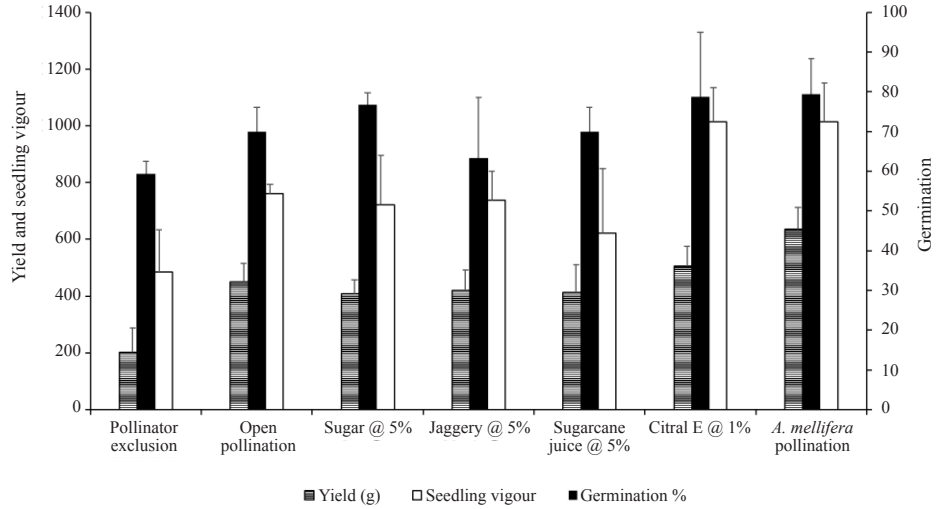

Fig. 2. Effect of different pollination treatments on seed yield, germination and seedling vigour

20 m^2) treatments were on par with citral treatment but significantly lesser than *A. mellifera* pollinated plot. Whereas pollinator exclusion treatment recorded significantly less yield (201.30± 86.33 g) than all the treatments (Table 1, Fig. 2). Hence, the results indicate that coriander depends on insect pollination for better yield quantity and quality. Importance of bees pollination in increasing yield was earlier established by Chaudhary and Singh (2006), Khalid (2008), Patil and Pastagia (2016) in coriander crop; and Ebadah El-Wahab (2011) in black cumin and Wankhede et al. (2018) in cucumber. Similar results were also reported by AICRP on Honey bee Research and Training (2000) in coriander crop and Vrushali et al. (2015) also reported that citral increased seed yield in sesamum, whereas Jogindar and Painkra (2018) reported that *A. cerana indica* was attracted to buckwheat sprayed with honey solution (10%) which increased yield significantly.

The largest average seed size of 58.15± 1.61 mm^3 was recorded in *A. mellifera* pollinated plot followed by crop sprayed with 1% citral (56.55± 7.16 mm^3) and 5% sugar solution (55.95± 6.45 mm^3) and both were on par with each other. Whereas crop sprayed with 5% jaggery (54.63± 11.77 mm^3) and sugarcane juice solution (52.62± 3.34 mm^3) and open pollination treatment (51.73± 7.01 mm^3) were falling between the previous two treatments and on par with pollinator exclusion treatment which has reported least seed size of 43.39± 5.46 mm^3, but significantly differed with previously described treatment where crop sprayed with 1% citral and 5% sugar solution (Table 1).

Present study reported the maximum seed size in case of *A. mellifera* pollinated treatment followed by crop sprayed with citral, jaggery, sugarcane juice and open pollinated treatment which were on par to each

other and with bee pollinated treatments (Fig. 1). This indicates the efficiency of *A. mellifera* as it visited more flowers with higher frequency which could ultimately gather and deposit sufficient pollen from one flower to others. Similar results were found by Gregory and Robert (1991) that cross pollination with *A. mellifera* increased fruit size by 14% over self-pollination. Similarly, Walters and Taylor (2006) found that there was an increase in pumpkin fruit size in *A. mellifera* pollinated crop.

The maximum test weight of 15.33± 1.07 g was recorded in *A. mellifera* pollinated plot followed by crop sprayed with 1% citral (14.84± 0.43 g) and open pollinated treatment (13.28± 0.68 g) and statistically all three were on par with each other. Crop sprayed with sugarcane juice (11.98± 0.81 g) was on par with open pollination, sugar (11.76± 1.03 g) and jaggery solution (11.58± 0.93 g) treatments but significantly differed from first three treatments. The least test weight was recorded in pollinator exclusion treatment (9.53± 0.69 g) which was on par with crop sprayed with sugar solution and jaggery solution but significantly differed from others (Table 1). The order of efficiency of different pollination treatments with respect to test weight was *A. mellifera* > citral > open pollinated crop > open pollination > sugarcane juice solution > sugar > jaggery solution > pollinator exclusion treatment (Fig. 1). Enhanced test weight of seeds due to honey bee pollination and through increased visitation using bee attractants was reported by AICRP on Honeybee Research and Training (2000) in coriander and the similar results were recorded by Verma and Poghat (1994) in radish.

The germination (%) did not differ significantly between treatments except in pollinator exclusion treatments which recorded significantly lower germination than other treatments. *A. mellifera* pollinated plot (79.33± 9.02%) recorded higher germination but not much differing with citral (78.67± 16.29%) treatment, whereas, open pollination, crop sprayed with 5% sugar, jaggery and sugarcane juice solution recorded 60-70% germination. Significantly low germination was recorded in pollinator exclusion treatment (59.33± 3.06%) (Table 1, Fig. 2). Kumar et al. (1989) and Patil and Pastagia (2016) reported significantly higher germination in seeds harvested from bee pollinated plots in onion crop and coriander crop, respectively.

Seedling vigour was maximum in seeds harvested from European bee pollinated plots (1014.07± 136.03) and 1% citral (1013.73± 120.84) sprayed plots. Treatment with open pollination (760.61± 31.96), crop sprayed with 5% of jaggery (737.10± 103.40), sugar (720.52± 175.81) and sugarcane juice solution (620.60± 228.51) were on par to each other and significantly differed from bee pollinated and citral sprayed treatments. Crop sprayed with sugar solution and sugarcane juice solution were on par to pollination exclusion (485.69± 146.44) treatment (Table 1, Fig. 2). Bee attractants attracted more number of pollinators and resulted in increased yield, enhanced germination and also seedling vigour of Niger (Guruprasad and Viraktamath, 2003).

The effect of pollination on yield parameters of coriander are summarized here under. The number of umbels per plant did not differ significantly since it was a varietal genetic character. The number of seeds per umbel, filled seeds, seed yield, seed size, 1000 seed weight, seed germination and seedling vigour were maximum in *A. mellifera* pollinated crop followed by crop sprayed with citral and the least results were found in pollinators exclusion treatment. This study reveals that in crops like coriander which depend completely on external pollinating agents, bee keeping and use of bee attractants can enhance both qualitative and quantitative yield parameters over other pollination methods.

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