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Influence of reared honey bees on the yield of *Brassica juncea* (L.) Czern. 1859: A case study from South Dinajpur District, West Bengal, India

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Abstract

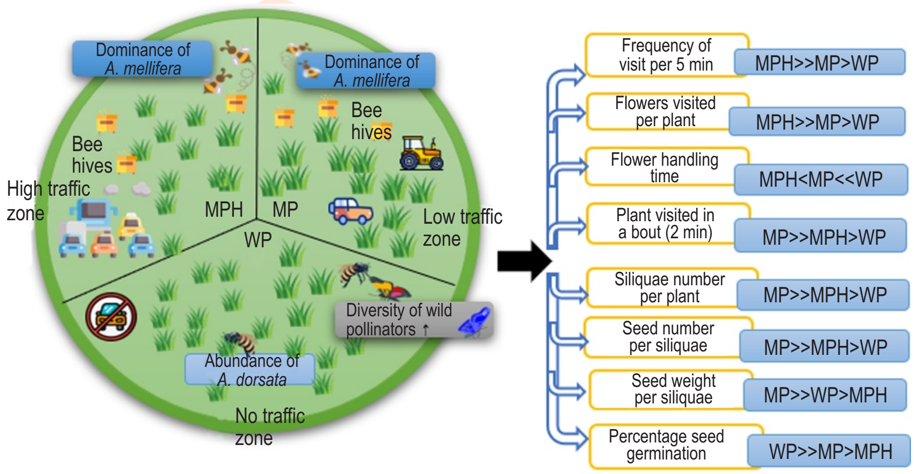
Aim: This study investigated the role of honey bees in promoting agricultural sustainability through pollination, enhancing global crop productivity and food security.

Methodology: Research was conducted across three agricultural sites: site with reared bees near MPH (within 200 m) highway; site with reared bees MP 3 km away from highway and site with wild, native bees (WP, 5 km away from highway). Observations focused on floral visitors, their foraging behaviour, plant fitness, and impact on fruit set.

Results: *Apis mellifera* was found to be the most frequent visitor at MPH and MP site. However, *A. dorsata* was the most frequent visitor at WP site. Fields with reared bee hives (MPH and MP) had a higher count of floral visitors (5.42 at MPH; 4.5 at MP) compared to natural field (1.12 WP) without reared bee hives. The number of flowers visited per plant and plants visited in a bout was higher at MPH and MP as compared to WP. MPH and MP sites exhibited reduced flower handling time as compared to WP site. Siliqua (pod) per plant (83.05), seed number per siliqua (26.8) and seed weight (0.094 gm) were found highest at MP site (55.23 %, 44.47%, 17.5% higher compared to the WP site and 24.85%, 7.2%, 62.06% higher compared to MPH).

Interpretation: Findings confirmed that reared bee pollination surpasses reliance on wild honey bees alone for effective pollination. The management of reared bees (*A. mellifera*) in agricultural practices would be an essential requirement for pollination services in mustard crops when the availability of wild, native bees is limited.

Key words: *Brassica juncea*, Crop production, Reared honey bees, Wild pollinators



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Introduction

Pollination, a critical ecological process facilitated by various organisms, underpins the maintenance and enhancement of Earth's biodiversity. Pollinators play a crucial role in shaping floral diversity, specialization, evolution, genetic variation within plant communities, conservation efforts, and ecological relationships (Negi *et al.,* 2020). Approximately, 90% of wild flowering plants and 75% of food crops rely on insect pollination to varying degrees (Klein *et al.,* 2007; Goswami and Khan, 2014). Honey bee pollination, primarily by *A. mellifera*, has been reported to have a substantial positive impact on oilseed production. Research indicates that honey bees are the most frequent visitors to rapeseed flowers among Hymenopteran insects. This high visitation rate ensures more uniform crop maturation, earlier ripening, significant improvements in fruit-set (pod), and enhanced yield (Ali *et al.*, 2011; Shakeel and Inayatullah, 2013). Consequently, honey bee pollination provides notable benefits to farmers and consumers alike.

Indian mustard (*Brassica juncea*), an essential oilseed of family Brassicaceae, originated in China and subsequently cultivated in India. Mustard is considered as a vital component of the country's oilseed production, contributing 12-15% of the global oilseed area (Shekhawat *et al.,* 2012; Dutta *et al.,* 2017). With the increase in human population, the projected demand for oil seed is estimated about 20 million tons by 2030 (Sharma *et al.,* 2022). In West Bengal, mustard cultivation spans 4.58 lakh hectares, producing 4.99 lakh tons of oilseeds, with an average productivity of 1090 kg ha^{-1} (Kumar *et al.,* 2019). Rich in essential nutrients such as proteins, dietary fibers and antioxidants, mustard seeds also offer significant health benefits, making them an indispensable part of agricultural and nutritional systems in India (Negi *et al.,* 2020). Additionally, mustard production plays a substantial role in rural livelihoods, bolstering the economic stability of small holder farmers in West Bengal. Moreover, apiculture is widely recognized as one of the most efficient, economical, and sustainable methods for improving both the quality and quantity of crop production.

Apiculture has emerged as a critical component of modern agriculture, driven by the dual pressures of a growing global population and escalating food demand. This study analyzed the interplay between apiculture and mustard production, exploring strategies to optimize crop yields, enhance ecological resilience, and address challenges posed by urbanization and environmental degradation. The relative contribution of reared and wild native bees in food crop production has sparked considerable debate (Thapa, 2006; Allsopp *et al.,* 2008; Rader *et al.,* 2009; Plutino *et al.,* 2022). While farmers often introduce large numbers of honey bees into their fields to secure adequate pollination (Greenleaf and Kremen, 2006), the complementary roles of wild pollinators in sustaining ecosystem functions must also be critically evaluated. Studies suggest that a diverse pollinator population can provide greater stability and resilience against environmental stressors, underscoring the need for integrated pollinator management strategies (Rader *et al.,* 2009; Plutino *et al.,* 2022).

Mustard being a predominant self-incompatible species, it depends on pollinators for a successful fruit set (Roy *et al.,* 2014). While honey bees are widely regarded as primary pollinators (Singh *et al.,* 2004; Pudasaini and Thapa, 2014; Bijarniya *et al.,* 2024), the potential contributions of other insect species if any, such as butterflies, beetles, and solitary bees, warrant further empirical investigation to fully understand their ecological significance. Research into the foraging preferences and seasonal dynamics of these pollinators can shed light on their roles in enhancing agricultural productivity. In addition to the inherent challenges posed by self-incompatibility, mustard cultivation is increasingly threatened by pollution and pesticides. At present, extensive use of pesticides has become a major concern of biodiversity loss, especially of pollinator population (Singh *et al.,* 2024). Moreover, rising levels of traffic pollution in India, characterized by dust particles and heavy metals, present significant risk to pollinators health and crop productivity (Ewen *et al.,* 2009; Janta and Chantara, 2017; Waser *et al.,* 2017). Studies have linked these disruptions with decline in both pollinator populations and crop yields, highlighting the urgent need for traffic pollution mitigation strategies in agricultural landscapes (Waser *et al.,* 2017; Janta and Chantara, 2017). This research focused on investigating the impact of pollination by honey bees (reared honey bees vs. native/wild bees) on the yield of *B. juncea* along different agricultural lands based on anthropogenic disturbances.

Materials and Methods

Study sites: The present study was carried out at two blocks, Gangarampur Block and Kumarganj Block in South Dinajpur district of West Bengal, India. Three different agricultural lands were selected as study sites: MPH (site with reared bees within 200 m from highway); MP (site with reared bees 3 km away from highway and 3.7 km away from MPH site); WP (site with wild bees 5 km, 23 km and 21 km away from highway, MPH and MP sites), respectively. During investigation, the reared bee hive boxes (*A. mellifera*) were present at MPH and MP sites, which were located at Gangarampur Block. On the other hand, at WP site (Kumarganj Block), no reared bee hive boxes were maintained.

Foraging activity and plant fitness: Twenty plants were randomly selected to observe the foraging activity of floral visitors at three sites, each with a 5 m^2 observation area. Observations were made on alternate days during the peak blooming period of *B. juncea* (mid-January to 1^{st} week of February) in 2023 at each site, using Nikon SZM 800 binoculars, between 10:00-16:00 hrs. Photographs of floral visitors were captured with a Canon D70 DSLR camera for identification from available literatures (Awasthi, 2019). The following parameters of floral visitors were recorded: frequency of visits (number of floral visitors observed within 5 m^2 area in 5 min duration), the number of flowers visited per plant by a floral visitor, flower handling time [time spent (sec) on a single flower], and number of plants visited per bout (in 2 min duration). During March (harvesting time), parameters of plant fitness were assessed, including the number of siliquae per plant, siliqua length (cm), seed number per siliqua and seed weight per siliqua. These metrics facilitated a comprehensive evaluation of the impact of foraging activity on plant reproductive success.

Statistical analysis: Statistical analysis was applied to the experimental data with IBM SPSS 22 software (2013, Chicago, IL, USA). One-way ANOVA was employed to examine the differences in pollinator activity (frequency of visits, number of flowers visited per plant, flower handling time and number of plants visited in a bout) across three study sites. Variables such as number of siliquae per plant, siliqua length, number of seeds per siliqua and seed weight per siliqua in response to floral visitors were analyzed by One-way ANOVA to evaluate the reproductive success of *B. juncea.* This dual-layered approach enabled the identification of significant site-specific variations in plant reproductive success, likely attributable to the influence of floral visitors at each site.

Results and Discussion

Flowers of *B. juncea* were visited by a total number of seven insect species (Fig. 1, 2), which belonged to the members of family Hymenoptera (*A. mellifera, A. dorsata*), Lepidoptera (*Catopsilia florella*), Diptera (*Eristalinus sepulchralis, Stomorhina lunata*) and 2 unidentified species. *A. mellifera* was the dominant pollinator at MPH and MP sites (due to of the presence of bee hives), while frequency of *A. dorsata* and other insects were negligible (1 visit observed in 72 hrs) at these two sites. At WP site, *A. dorsata* demonstrated a higher prevalence (1.12 visits in 5 min), corroborating its affinity for open, less-disturbed natural settings, as documented by Rader *et al.* (2009). Furthermore, at WP site, a broader range of foragers, including *Catopsilia florella, Eristalinus sepulchralis* and *Stomorhina lunata* were observed (Fig. 2), however, their frequency of visits was negligible (1/2 visits observed in 72 hrs). The dominance of *A. mellifera* at sites having reared bee hives (MPH and MP) and *A. dorsata* at WP site aligns with previous findings (Roy *et al.,* 2014; Bijarniya *et al.,* 2024), which emphasize the major role of *A. mellifera* and *A. dorsata* in agricultural environments. This was particularly evident at sites with reared bee hives (*A. mellifera*) like MPH and MP, where reared bee hives enhanced the frequency of pollinator visits (Fig. 3), boosting crop pollination and potentially increased crop yield (Fig. 4). A noteworthy observation was the reduced presence of *A. dorsata* at MPH and MP sites. The significant variation in visit frequencies between *A. mellifera* at MPH and MP sites and *A. dorsata* at WP site may be attributed to preference species-specific habitat and presence of reared bee hives (Fig. 3).

The increased frequency of floral visits by *A. mellifera* at MPH and MP sites (4 to 5 times more than *A. dorsata* at WP site; Fig. 3) is attributable to the presence of bee hives, which ensured a reliable supply of *A. mellifera,* crucial for pollination in agricultural fields. This pattern supports findings with previous studies where reared bee hives provided a reliable population of pollinators and helped in maintaining the pollination requirements of crop plants (Bijarniya *et al.,* 2024). In contrast, the WP site presented a different pattern of visits by *A. dorsata* (Fig. 3). The predominance of *A. dorsata* at WP suggests that natural pollination in *B. juncea* is supported by *A. dorsata,* where reared bee hives were not available. The findings of this study highlight the role of reared bee hives (*A. mellifera*) and wild bees (*A. dorsata*) pollination in agricultural systems, especially for pollinator-dependent crops like *B. juncea.* While sites with reared bee hives exhibited greater pollination frequency, site without reared bee hives demonstrated a unique contribution by attracting the natural/wild pollinators. Future research should focus on the ecological balance between reared and wild pollination systems to optimize pollinator resources without compromising biodiversity.

This study established that the frequency of visits by *A. mellifera* was significantly higher at MPH site (5.42) in comparison to the MP site (4.5) within a 5 min period whereas the frequency of visits by *A. dorsata* was lowest at WP site, which (1.12) may be due to high number of bee hives available at MPH compared to the MP site. The absence of bee hives at WP site may explain the low frequency of floral visitors. The number of flowers visited per plant was highest at MPH site as compared to other two sites. The number of flowers visited per plants were 3.2 at MPH, 2.65 at MP site by *A. mellifera,* 1.7 flowers at WP site by *A. dorsata.* Additionally, the findings of this study results revealed that the flower handling time by *A. mellifera* significantly decreased at MPH sites (2.02 sec) as compared to MP site (3.1 sec). While flower handling time by *A. dorsata* was significantly highest in WP site (3.35 sec), which may be due to the presence of ample amount of nectar and low disturbance. Again, the number of individual plants foraged in a bout of 2 min interval was higher at both the sites having reared bee hives, MPH (20.55 plants per 2 min interval) and MP (21.32 plants per 2 min interval) as compared to WP site (15.67 plants per 2 min interval). This may be correlated with external environmental factors (vehicular pollution/ turbulence) or the amount of presentable nectar (the frequency of floral visitors was high) at MPH site (presence of more bee hives as compared to MP), which showed a negative impact on the flower handling time (Dargas *et al.,* 2016; Phillips *et al.,* 2021). Additionally, as the MPH site was adjacent to traffic area, there were high chances of deposition of road dust on the flowers as documented previously that pollinators generally avoid foraging dusty flowers (Waser *et al.,* 2017). At WP site, due to less frequency of floral visitors, the amount of presentable nectar may be one of the factors for deciding the number of individuals to be visited in bout by a forager (Singh *et al.,* 2014).

The number of siliquae per plant was significantly higher at MP site (83.05) than at WP and MPH sites (53.5 and 66.8, respectively; Fig. 4). Low disturbance and presence of reared bee hives may have facilitated the bees to efficiently forage a greater number of flowers per plant at this site, which resulted in higher fruit set at MP site. The MP site had the longest siliqua length

Fig. 1: (A) Managed bee hives at MPH site; (B) Mustard field at MPH site; (C) A bee (*A. mellifera*) from managed hives foraging brassica flower at MPH site; (D) Managed bee hives at MP site; (E) Mustard field at MP site and (F) A bee (*A. mellifera*) foraging a brassica flower at MP site.

Fig. 2: Wild pollinators foraging flowers at WP site. (A) *Apis dorsata*; (B) *Catopsilia florella*; (C) *Eristalinus sepulchralis*; (D) Unidentified species 1; (E) *Stomorhina lunata* and (F) Unidentified species 2.

(4.27 cm) in comparison to the MPH (4.05 cm) and WP site (4.25 cm) (Fig. 4). The number of seeds per siliqua significantly varied at three different sites. The highest result was found at MP site (26.8) followed by MPH (25) and WP (18.55) sites (Fig. 4). This variation aligns with the higher foraging activity observed at MP site, highlighting the role of reared pollination systems in maximizing reproductive success without any external (traffic) disturbances. These findings suggest that reared honey bees were more efficient in fruit production in *B. juncea,* corroborates with previous studies (Takayama and Isogai, 2005; Roy *et al.,* 2014). *A. mellifera* might be more efficient at collecting pollens and transferring compatible pollens to other individuals of *B. juncea* as compared to *A. dorsata.* Dust deposition on stigmatic surface along with low pollen load near the highways might be one of the reasons for lower seed number per siliqua (although not established in this study) at MPH site as compared to MP stie. This may be correlated with the study carried out by Waser *et al.* (2017), who demonstrated that plants exposed to dust had an

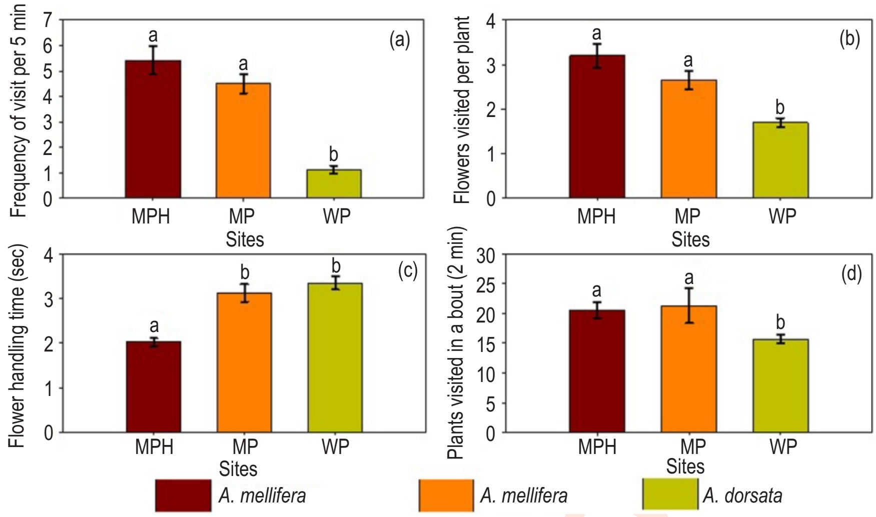

Fig. 3: Foraging behavior of bees at three sites (MPH, MP and WP) : (A) Frequency of visits (5min) (F= 31.29); (B) Number of flowers visited per plant (F= 13.34); (C) Flower handling time (sec) (F= 22.48); (D) Number of plants visited in a bout (2min) (F= 10.12). The values displayed are mean ± SE (n = 20). Using Duncan post-hoc analysis of variance (One-way ANOVA; $p < 0.05$), different letters indicate significant differences.

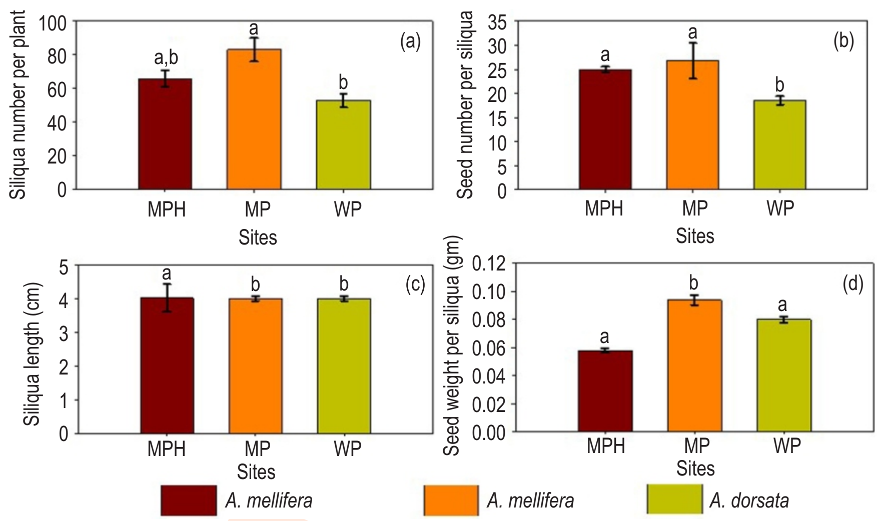

Fig. 4: Plant fitness in response to managed and wild bees at three sites (MPH, MP and WP): (A) Siliquae number per plant (F= 5.88); (B) Seed number per siliqua (F= 22.62); (C) Siliqua length (cm) (F=4.33) and (D) Seed weight per siliqua (g) (F= 67.66); The values displayed are mean ± SE (n = 20). Using Duncan post-hoc analysis of variance (One-way ANOVA; $p < 0.05$), different letters indicate significant differences.

overall decrease in pollen load (38%) on the stigmatic surface.

Furthermore, the seed weight per siliqua also differed significantly (Fig. 4), with MP having the highest weight (0.094 g), followed by WP (0.080 g) and MPH (0.058 g). The reduced seed weight at MPH may result from traffic-induced pollutants, which are known to affect plants reproductive success, physiological processes including photosynthesis and resource allocation (Aliyar *et al.,* 2020; Das *et al.,* 2024).

A detailed investigation is required to know the effect of abiotic factors responsible for such an outcome. Our study provides an insight on the importance of reared bees as pollinators in the yield of oilseeds. Enhanced pollination due to reared bees is a more efficient strategy than relying on wild native bees for successful pollination. However, wild pollinators in agricultural ecosystem are required to ensure continuous provision of pollination services to crop plants. Extensive use of pesticides, habitat loss and climate change, results into sudden decline of pollinators, especially bees. In such condition, reared bees can be an alternative for crops that rely on wild, native pollinators for successful seed set/yield. When economic benefits of agriculture pollination by honey bees is taken into account, a significant reduction in insect population can have a detrimental impact on crop yields.

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