**The link between pollinators' diversity and pollination services and possible mechanisms underlying this link in the pollination of seed watermelon (*Citrullus lanatus*)**

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**Abstract**

Biotic pollination is crucial for two- thirds of the world's leading crops and one third of the human diet. Agricultural pollination worldwide relies largely on the managed honeybee (*Apis mellifera*) as a major pollinator. This may risk agricultural production as in the past few decades, the number of honeybee hives has decreased in different parts of the world while the demand for crop pollination has increased globally. In addition, honeybees are not effective pollinators of some crops. About 20,000 species of bees globally are known, and they provide significant pollination service to many crops. However, wild bee populations worldwide are in decline, mainly because of intensive agricultural management, and there is an urgent need to conserve and enhance wild pollinators in agricultural landscapes. One of the main challenges in the study of crop pollination is whether there is a positive relationship between pollinators' diversity and the pollination service they provide, and if such positive relationship exist, how agricultural landscapes should be managed to support diverse pollinator communities. Specifically little is known about the mechanism underlying the functionality-diversity link in pollinators' communities. In this research, I examined the link between pollinators' species diversity in agricultural systems and the pollination services they provide as well as possible underlying mechanisms of this relationship.

I used watermelon (a 'Malali' cultivar grown for seed production) as the model plant, mainly because of its attractiveness to a diverse group of pollinators and the positive effect of pollinator visits on its fruit set. I conducted a field study and a set of controlled experiments in net cages. Field experiments were held in the beginning of summer 2013 and 2014, during the blooming period of watermelon, in seven watermelon fields located in the Judean foothill, Lachish and the north Negev. Two plots were located along the edges of each field; one plot adjacent to a patch of wild bloom, and the second plot adjacent to an agricultural field. In each plot, 'Malali' flowers were exposed to insect visits during the morning. I conducted visitation observations to characterize the functional group of the visiting insect and its relative size. All the visited flowers were monitored once a week to check for fruit development, and to measure their size. In the 2014 field study, only observation scans were conducted, using a similar protocol as in 2013. In addition, in summer 2013 and 2014, I conducted controlled experiments in net cages. In this study system I was able to closely monitor the visitation pattern and foraging behavior of different functional groups in one to three consecutive visits as well as the combination of two and three functional groups, and monitor fruit set, and stigmatic pollen deposition (amount and spread). Five net cages constructed in an open area in the campus were populated with bees of different body sizes: tiny, small, medium, large, extra large and honeybee. Some of these bees were collected from the fields. Foraging and nesting resources were provided to the bees during the season. Potted 'Malali' plants, grown in a nearby greenhouse, were exposed to different sets of pollinators and pollination treatments; one, two and three visits of bees from the same functional group as well as combinations of different groups. All the visitation activities were recorded with a high resolution video camera in order to extract behavioral parameters.

In the field experiment (2013 and 2014), honeybees were the most abundant visitor, but also wild bees, beetles and flies were observed. The functional diversity and visitation rate were positively affected by the proximity to wild bloom. In 2013 the activity of the honeybees as well was positively affected by the proximity to wild bloom. Nonetheless, fruit set was not affected by the type of field edge (wild bloom vs agriculture).

In the controlled experiments of 2013, the highest level of fruit set was achieved by the combination of small and medium bees and by two visits of medium bees. The effectiveness of honeybees was lower than medium bees but higher than small bees. The effectiveness of small bees was significantly higher in two visits compared to one visit. In 2014, I found significant variation in the pollination efficiency of different functional groups and also between different combinations of functional groups. Functional group body size was not a main factor in determining its efficiency (for one, two and three consecutive visits). Different functional groups showed variable patterns of pollination efficiency along consecutive visits (up to three). In addition, I found no clear advantage for the combination of two functional groups compared to a single one. Specifically, the combination of honeybees and wild bees provided relatively lower fruit set compared to the combination of two wild bee groups and two consecutive visits of the same wild bee group. Combination of honeybees and wild bees showed different trends on pollen deposition and distribution on the stigma, with relatively higher efficiency compared to two consecutive visits of the same group and to the combination of two wild bee groups.

In conclusion, the results of this study show that the availability of wild bloom along the edges of Mallali fields during its bloom enhance the diversity and visitation activity of wild pollinators on the Mallali flowers, and also the activity of honeybees (found only in 2013). It is possible that the wild bloom provides foraging and nesting resources for these pollinators, especially when the agricultural crops are not in bloom. The lack of effect of edge type on fruit set can be related to the relatively narrow extent of the wild bloom patches; it is possible that larger patches of wild bloom would support more diverse and abundant communities of wild pollinators, that would translate to increased pollination activity. On the other hand, the results of the controlled pollination experiments in the net cages show that fruit set is nearby at its maximum after two consecutive visits of some of the groups, and that the variation in fruit set between the different groups is large. In addition, I didn't find any direct advantage of functional diversity on the pollination services provided in this system (though this has to be qualified for the narrow range of functional diversity tested here – one vs two groups). The relatively high pollination efficiency of some of the wild pollinators points to the importance of their existence and activity in the watermelon fields. However, it seems that functional diversity has only limited significance in this system (qualified to the narrow range of functional groups tested). Therefore, enhancing wild pollinator activity in the Mallali fields can positively affect fruit set by increasing visitation rates, and by providing higher pollination efficiency compared to honeybees (some of the wild visitors). In addition, a diverse wild pollinator community can potentially provide combinations of different functional groups of higher efficiency compared to non-diverse communities (not tested in this study).