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Research Article

Evaluation of Potential Insectary Plants for Conservation Biological Control of Cabbage Insect Pests

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Abstract

Habitat manipulation is an important pest management strategy in sustainable agriculture. Deployment of floral resources in and off-farm, trap cropping, cover cropping, intercropping etc are the major pest management options in habitat manipulation. The current agricultural pest management approaches are mostly relied on synthetic fossil-fuel based compounds such as insecticides, fungicides, herbicides etc. These anthropogenic practices are directly linked to human health, biodiversity loss and environment. The rapid decline of pollinators and beneficial arthropods such as predators and parasitoids are the most potent impact of pesticides in agricultural fields. Hence, a study was proposed to increase the fitness of natural enemies such as predators and parasitoids by the provision of floral resources to them and promote conservation biological control of cabbage pests. Insectary plants or floral resources supply shelter, nectar, alternative food and pollen (SNAP) to pest's natural enemies and supply these resources to them at adverse conditions. Buckwheat (*Fagopyrum esculentum*), coriander (*Coriandrum sativum*), marigold (*Tagetes* spp), mustard (*Brassica* spp.) had deployed in cabbage fields as potential insectary plants of cabbage pests. All of these insectary plants were compared with the cabbage (*Brassica oleraceae*) strips. The results confirmed that coriander, buckwheat and marigold significantly increase the population of syrphid fly and ladybird beetle (*Coccinella septempunctata*) and reduce the population pressure of aphids (*Brevicoryne brassicae*) and diamondback moth (*Plutella xylostella*) in cabbage fields. It is also suggested that the population of beneficial arthropods were higher in floral strips and declined their numbers with distance. The lower aphid population in the proximity of flower strip suggested that conservation biological control has the potential to reduce pest population in cabbage fields. This information's are important to develop an integrated pest management protocol of cabbage pests in cabbage fields.

Keywords: insectary plants; conservation biological control; cabbage aphids; diamondback moth; syrphid fly

Introduction

Cabbage (*Brassica oleraceae* L.) is an important vegetable crop of Brassicaceae group. Cabbage, cauliflower, radish, mustard, broccoli are the major vegetable crops in that group. These crops are primarily used for raw salad and as cooked vegetables. In Nepal, these crops have been grown almost all parts and seasons. Insect pests, diseases and weeds are the major crops limiting factors in cabbage production (Ghimire, Lamsal, Paudel, Khatri, & Bhusal, 2018). Among them, insect pest's loss has been recorded up to 20% in cabbage fields. The major insect pests commonly encountered in cabbage fields are the cabbage butterflies, *Pieris brassicae* L. (Lepidoptera: Pieridae), the diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), the cabbage aphid, *Brevicoryne brassicae* L. (Homoptera: Aphididae), the cabbage butterfly, *Pieris brassicae nepalensis* Doubleday (Lepidoptera: Pieridae), the flea beetle, *Phyllotreta crucifera* Goeze (Coleoptera: Chrysomelidae), the mustard sawfly, *Athalia lugens* Klug (Hymenoptera: Tenthredinidae) (Kunjwal & Srivastava,

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2018). Pesticides is one of the important parts of pest management culture in Nepal. Chlorpyrifos, synthetic pyretrhodis and permethrin are the common pesticides have been used for insect pest's management in cabbage fields. These pesticides are hazardous to human health and the environment (Atreya, 2007) and also impact on pollinators and many beneficial arthropods such as predators and parasitoids (Fauser, Sandrock, Neumann, & Sadd, 2017; Kessler et al., 2015). Ladybird beetles, syrphids flies, spiders, rove beetles, ichneumonids, braconids are important biocontrol agents of aphids and diamondback moth (Beltrà, Wäckers, Nedvěd, & Pekas, 2018; Garzón, Medina, Amor, Viñuela, & Budia, 2015). However, such biocontrol agents are declining over time because of overdose and frequent use of pesticides in agricultural fields (Smith & Krischik, 2000; Van Driesche & Hoddle, 2016). The destruction of non-crop habitats such as hedges, floral borders, riparian vegetation's, native plants is also other important reasons of their population decline in agricultural fields (Barbosa, 1998; Bascompte & Solé, 1998; Kruess & Tscharntke, 1994). Because these non-crop habitats such as floral strips can supply floral resources such as nectar, pollen, alternative food, and shelter to the pest natural enemies and impact on conservation biological control (Barratt, Moran, Bigler, & Van Lenteren, 2018; Fiedler, Landis, & Wratten, 2008; Landis, Wratten, & Gurr, 2000) and improve the provision of multiple ecosystem services (Gurr, Wratten, Landis, & You, 2017; Westphal et al., 2015). Conservation biological control (CBC) practices reduce pest pressure in farming systems and manage agriculture pest (Gurr et al., 2017; Landis, 2017), and also decrease the dependency on chemical pesticides, thereby increase the income of farmers (Gurr et al., 2017).

Two pest management mechanisms have been suggested by habitat manipulation for sustainable pest management. They are the top-down approach 'natural enemies' hypothesis and the bottom-up approach or 'resource concentration' hypothesis (Root, 1973). Deployment of floral resources or insectary plants in farming system act on pest by the top-down approach by the action of natural enemies. The abundance, diversity and efficiency of natural enemies such as ladybird beetle, spiders, syrphid fly and other parasitoids increased by the regular provision of floral resources that increase the fitness of these biocontrol agents and improve conservation biological control (Gurr et al., 2017; Landis, 2017). The common insectary plants have been used for insect pest management in agricultural fields are buckwheat (*Fagopyrum esculentum* Moench), coriander (*Coriandrum sativum* L.), marigold (*Tagetes* spp L.), mustard (*Brassica* spp L.), phacelia (*Phacelia tanacetifolia* Benth), alyssum (*Lobularia maritima* L. Desv.) etc.(Badenes-Pérez, 2018; Brennan, 2016; Jado, Araj, Abu-Irmaileh, Shields, & Wratten, 2018; Ribeiro & Gontijo, 2017). Flower nectar is an important source of carbohydrates for the arthropods which are used to maintain their activity and metabolism (Jonsson, Wratten, Landis, & Gurr, 2008). For example, some spiders (non-web-building) such as jumping spiders (Saliticidae), crab spiders (Thomisidae), and other fast-moving spiders such as Miturgidae, Anyphaenidae and Corinnidae, use flower nectar as their food source (Taylor & Pfannenstiel, 2008). Pollen supply protein, minerals and vitamins to the beneficial arthropods. For example, in a laboratory study, *Coleomegilla maculata lengi* Timberlake (Coleoptera: Coccinellidae) exhibited a better performance when feeding on alfalfa and maize pollen than control (no-pollen) (Ostrom, Colunga-Garcia, & Gage, 1996).

Hence, the current study hypothesized flowering plants could increase the abundance of generalist beneficial arthropods such as ladybird beetles, syrphid fly, spiders, and parasitoids, thereby reducing aphid and diamondback moth populations in cabbage fields. This work could contribute to reducing pest pressure on radish crops and reducing pesticide consumption in vegetables through conservation biological control. This pest management practices can help IPM farmers, researchers, extension workers and policymakers to revise their integrated pest management protocol and can be exploited in sustainable intensification and organic farming.

Materials and Methods

The study was conducted at Mangalpur, Chitwan, Nepal (27°40′N 84°21′E) from January to April 2018. The research field was prepared by the tractor on 3 January 2018; 2.5 kg of chicken manure plus 1 kg compost per m^2 was thoroughly incorporated into the soil. The size of each plot was 10 m x 5 m, with 2 m gaps between them. There were 5 plots in each block (35 m x 10 m). The experiment was a randomized complete block design with five replicates. All flowering vegetation on all sides of the plots was thoroughly removed to minimize the cross effect of flowering vegetation's. Seeds of buckwheat, coriander, mustard, and marigold were broadcasted at the edges strip of each insectary plot. The size of the edge strip was 1 m x 5 m. These treatment plots were compared with the control plots (1m x 5 m wide cabbage strips). Cabbage seedlings were transplanted in main plots (9 m x 5 m) adjoining to the edge strips (1 m x 5 m).

Sample Observations

Yellow pan traps (12 cm diameter and 8 cm deep) were used to take the samples of syrphid flies and ladybird beetles. These samples were then averaged of two yellow pan traps placed in each insectary plot. Total 50 yellow pan trap, 2 yellow trap in each plot, was used at a time. Traps were two-thirds filled with water and 5 ml dish-soap was added. Samples were collected at 15 days interval dated on January 15, January 30, February 15, February 30 and March 15 in 2018. Samples were taken after 24 h of trap establishment.

The syrphid fly and ladybird beetles collected in each yellow trap were strained with the help of muslin cloth and enumerated. The other collected arthropods in yellow pan traps were discarded. Yellow sticky traps (15 cm x 15 cm) and diamondback moth funnel traps (5 cm diameter x 5 cm depth) were established to count the winged aphids and diamondback moth, respectively, in each insectary plot and control plot. These samples were also taken five times (see above) and averaged by the trapezoid rule by the area under the curve (AUC) method (Hanley & McNeil, 1983).

Similarly, yellow water traps (see above) were placed at 1m, 2 m, and 5m distance to the top half of each plot on February 3, February 15 and February 27, 2018. Only syrphid flies' samples were collected in each yellow pot and other insects were discarded. The yellow sticky traps (see above) and diamondback moth funnel traps were established in each distance at 1m, 2 m, and 5m to the top half of each plot and samples were counted in each sampling date (February 3, February 15 and February 27, 2018). Each sample was taken after 24 h of trap establishment.

Data Analysis

Samples collected in each yellow pan trap over five samplings were averaged by AUC method for syrphid flies and ladybird beetles. Similarly, the number of winged aphids and diamondback moths have counted accordingly in five samplings and averaged by AUC method (Hanley & McNeil, 1983). These counts data were transformed to square root for normality check and homogeneity of variance. Two-way ANOVA (Block and treatment) were performed for data analysis and means were compared using unprotected LSD at $p < 0.05$ (Saville, 2015).

The syrphid fly and winged aphid populations collected in three different dates were also averaged by AUC method and square root transformed for normality checking and homogeneity of variance. Two-way ANOVA followed by unprotected LSD at $p < 0.05$ were used for data analysis and means comparisons.

Results and Discussions

Syrphid Fly and Ladybird Beetles Number

Syrphid fly population (Syrphidae: Diptera) were significantly different in various insectary plants ($p < 0.001$) (Fig. 1). The more numbers of syrphid fly were observed in coriander and buckwheat plots which were significantly higher than marigold, mustard and control plots. The highest population of syrphid flies in coriander, buckwheat and marigold could be the effect of potential floral resources such as nectar and pollen in these plants. These floral nectars and pollens increase the fitness of syrphid fly (Sarkar, Wang, Wu, & Lei, 2018) and increase abundance (Badenes-Pérez, 2018). The higher population density of syrphid fly in buckwheat insectary plant also confirmed by Araj and Wratten (2015), Laubertie et al. (2012) and Jado et al. (2018). The syrphid fly numbers collected in marigold is significantly higher than in mustard and control but lower than in coriander and buckwheat insectary plants The lower numbers of syrphid fly population in control plots could be less opportunity of fitness of the natural enemies (Landis et al., 2000). The numbers were not significantly different in between coriander and buckwheat and between mustard and control plots (Fig. 1).

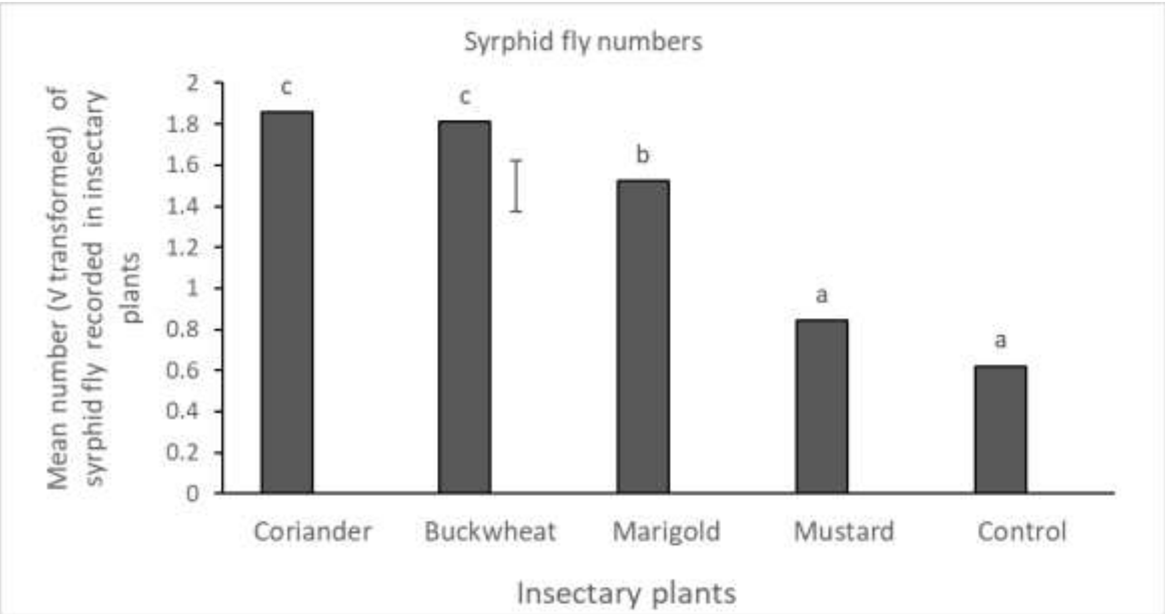

Fig. 1: Mean numbers (√ transformed) of syrphid fly over five samplings recorded in each of five insectary plant species. The vertical bar is the least significant difference, LSD (5%). Means with no letters in common are significantly different (Unprotected LSD; $p < 0.05$) (n = 5).

Similarly, the highest number of ladybird beetles were collected in marigold plots which were significantly higher than coriander, mustard and control plots but significantly similar to buckwheat ($p < 0.001$). The ladybird beetles collected in coriander, mustard and buckwheat were significantly similar. However, the lowest numbers were collected in control plots (Fig. 2). Higher population of ladybird beetles could correlate the availability of floral resources that increase the abundance of predators such as ladybird beetles (Martínez-Uña, Martín, Fernández-Quintanilla, & Dorado, 2013). Similarly, other potential insectary plants such as coriander, mustard and buckwheat also supply the floral resources to predators (Colley & Luna, 2000; Laubertie, Wratten, & Hemptinne, 2012) and promote conservation biocontrol and multiple ecosystem services in agricultural fields (Gurr et al., 2017; Landis et al., 2000).

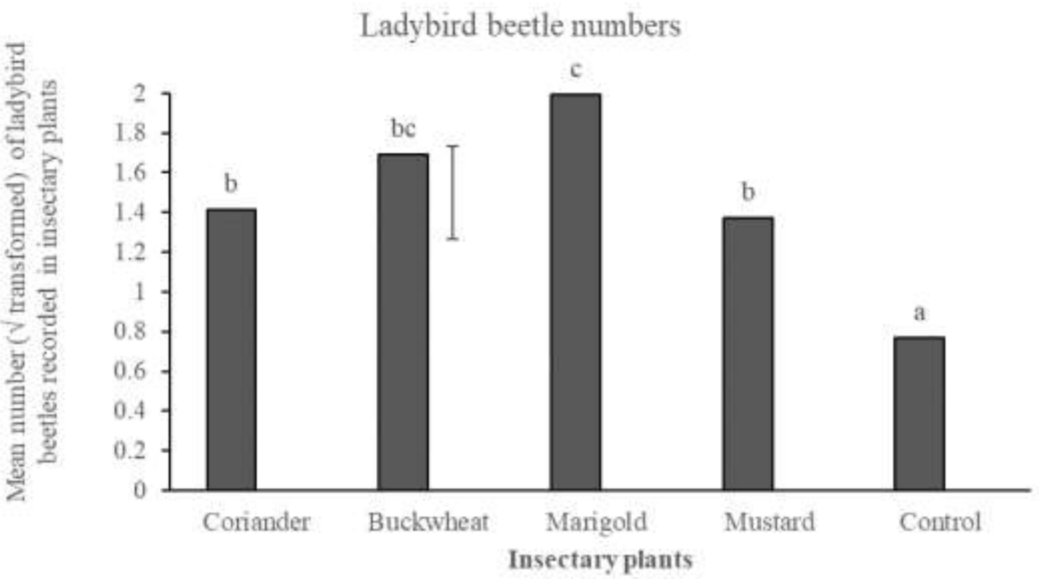

Fig. 2: Mean numbers (√ transformed) of ladybird beetle over five samplings recorded in each of five insectary plant species. The vertical bar is the least significant difference, LSD (5%). Means with no letters in common are significantly different (Unprotected LSD; $p < 0.05$) (n = 5).

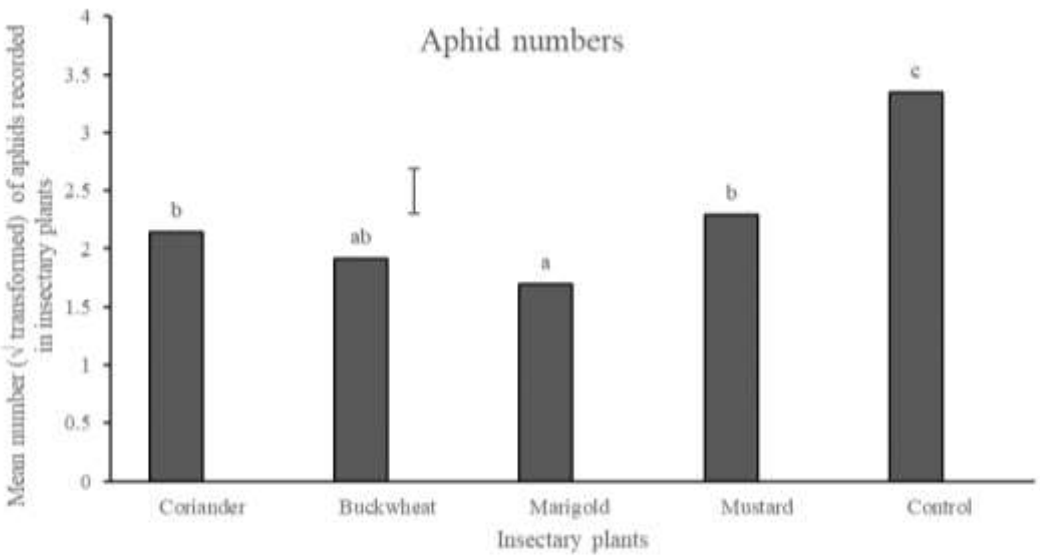

Fig. 3: Mean numbers (√ transformed) of aphids over five samplings recorded in each of five insectary plant species. The vertical bar is the least significant difference, LSD (5%). Means with no letters in common are significantly different (Unprotected LSD; $p < 0.05$) (n = 5).

Cabbage Aphids and Diamondback Moth Numbers

The two important pests of cabbage, cabbage aphids and diamondback moth numbers were significantly different in all insectary plots ($p < 0.05$). Maximum numbers of aphids and diamondback moths were collected in control plots (Fig. 1 & 2). Cabbage aphid populations were lowest in the marigold which was significantly lower than in coriander, mustard and buckwheat. The lowest aphid population in these plants could be the action of potential aphid predators such as ladybird beetle and syrphid fly (Ambrosino, Luna, Jepson, & Wratten, 2006; Jado et al., 2018). These flowering plant species supply the floral rewards to the natural enemies (Amorós-Jiménez, Pineda, Fereres, & Marcos-García, 2014; Barbir, Badenes-Pérez, Fernández-Quintanilla, & Dorado, 2015) and increase their predation and parasitism rate and promote conservation biological control (Ambrosino et al., 2006). However, the aphid population in coriander, buckwheat and mustards were not significantly different (Fig. 3).

The DBM population was not significantly different in between coriander and marigold, and between mustard and control plots. However, the lowest population was recorded in buckwheat insectary plots. These numbers were significantly lower than all other insectary plants including control plots (Fig. 4). The lowest population of diamondback moth could be the action of parasitoids which increase parasitism rate (Ambrosino et al., 2006; Wratten et al., 2003)

The preference of syrphid flies in various stages of insectary plants was significantly different ($p < 0.05$). Flowering stage of coriander, buckwheat, marigold was the most prefered stage than vegetative stage. Syrphid fly including other predators such as ladybird beetles, spiders can get sufficient floral resources in flowers that attracts in flowers (Ambrosino et al., 2006; Amorós-Jiménez et al., 2014). The numbers collected were not significantly different in between vegetative and senescence stage in buckwheat, marigold, mustard and control plots. However, the population of the syrphid fly was higher in senescence stage than in vegetative stage in coriander. The preference on various stage by syrphid fly was not significantly different in mustard.

Distance Effect of Floral Strips to Syrphid Fly

The aggregation of the syrphid fly was significantly higher close to the floral strips of buckwheat, coriander and marigold and their population were significantly higher than in 2 m and 5 m distances from floral strips ($p < 0.05$). Similar results were also proposed by many researchers and suggested that floral resources attract natural predators including pollinators and their abundance and aggregation could be higher in close to the floral resources and abundance decline with declining these floral resources. (Ambrosino et al., 2006; Barbir et al., 2015; Jado et al., 2018; Wratten et al., 2003). The population of syrphid fly in between 2 m and 5 m were not significantly different in each insectary plants including control ($p > 0.05$). The syrphid flies population were not significantly different in each distance in mustard and control plots, however, the population was higher in close to flowering strips compared with other distances (Barbosa, 1998; Ehler, 1998) but not significantly so (Fig. 6)

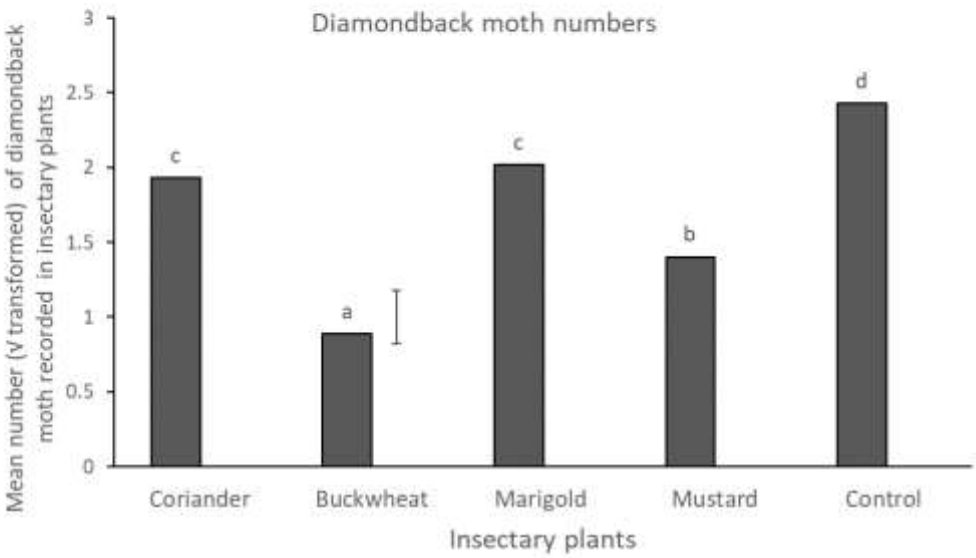

Fig. 4: Mean numbers (√ transformed) of diamondback moth over five samplings recorded in each of five insectary plant species. The vertical bar is the least significant difference, LSD (5%). Means with no letters in common are significantly different (Unprotected LSD; $p < 0.05$) (n = 5).

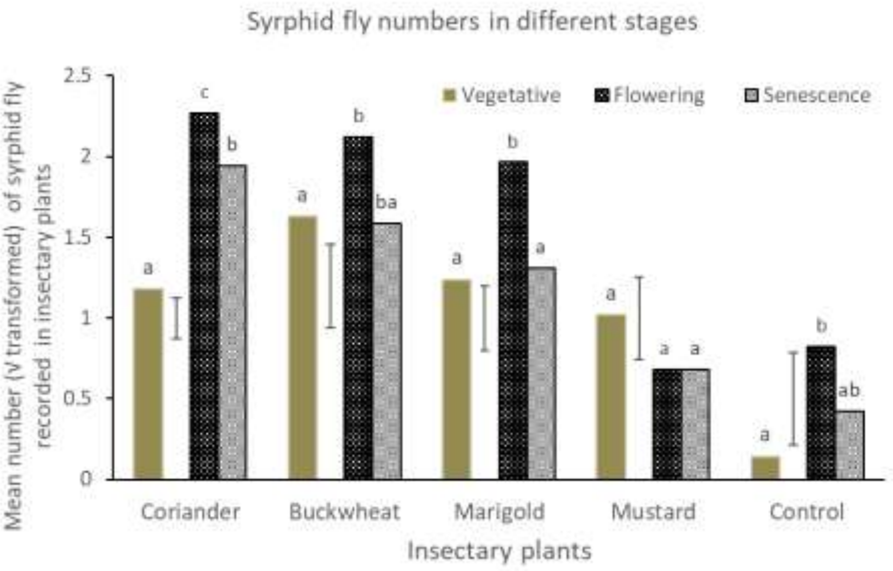

Fig. 5: Mean numbers (√ transformed) of syrphid fly in various growth stages of insectary plant species. The vertical bar is the least significant difference, LSD (5%). Means with no letters in common are significantly different (Unprotected LSD; $p < 0.05$) (n = 5).

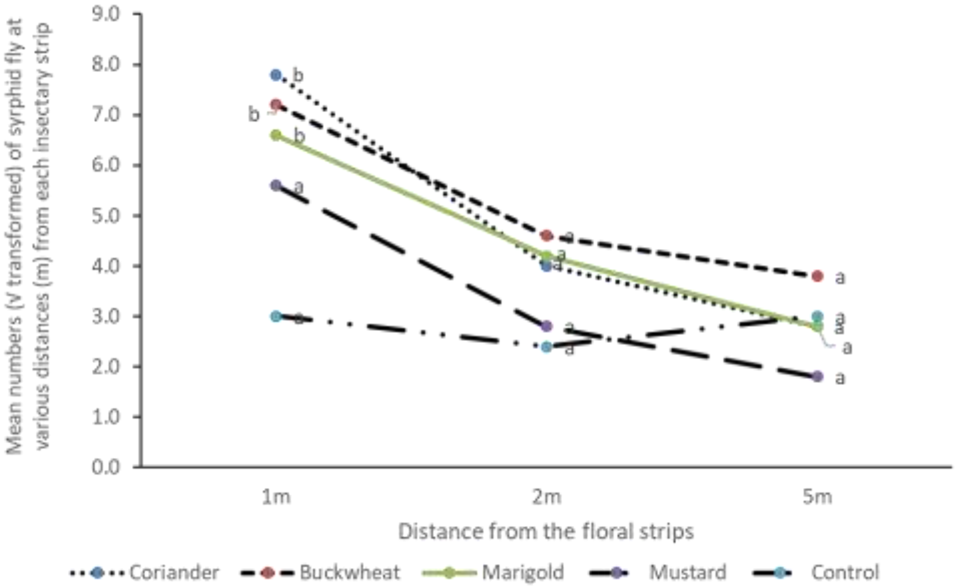

Fig. 6: Mean numbers (√ transformed) of syrphid fly at various distances (m) from each insectary strip. Samples were collected at 1 m from each insectary strips and at 2 m, and 5 m distances from each insectary strip to the cabbage fields. Within each trap strip, treatment means with no letters in common are significantly different (Unprotected LSD; $p < 0.05$) (n = 5).

Distance effect of floral strips to cabbage aphids

The cabbage aphid numbers were significantly lower in all insectary plants at the edges compared to 2 m and 5 m distance of each insectary plant ($p < 0.05$). These populations were the lowest at the edges and numbers were declined with distance. The aphid numbers in control plots were not significantly different in each distance. This could be the action of biological control agents such as syrphids and ladybird beetles that can increase predation and parasitism rate and improve conservation biological control (Brown & Mathews, 2007; Ramsden, Menéndez, Leather, & Wäckers, 2015; Santos et al., 2018). However, a few aphid numbers were recorded at the edge of control strips (Gillespie, Gurr, & Wratten, 2016; Yang et al., 2018). The aphid numbers in between 2 m and 5 m were not significantly different in each insectary plants including control ($p > 0.05$) (Fig. 7).

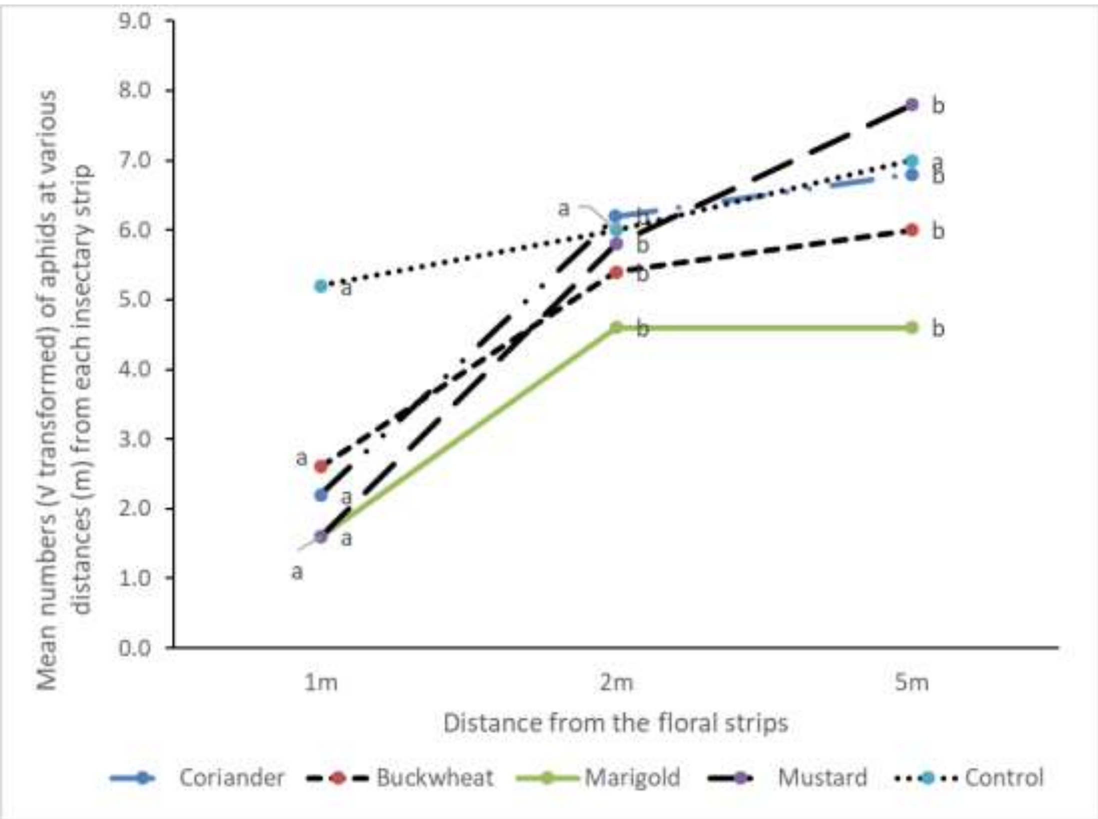

Fig. 7: Mean numbers (√ transformed) of aphids at various distances (m) from each insectary strips. Samples were collected at 1 m from each insectary strip and at 2 m, and 5 m distances from each insectary strip to the cabbage fields. Within each trap strip, treatment means with no letters in common are significantly different (Unprotected LSD; $p < 0.05$) (n = 5).

Conclusions

Cascading floral resources in farming systems promote the conservation biological control by increasing the abundance, diversity and fitness of natural enemies. In recent days, pesticide use in agricultural sectors and habitat destruction, as well as fragmentation of land, exacerbates the loss of these biocontrol agents by reduction of floral habitats. Floral habitats potentially provide the life-supporting resources to the pest natural enemies. These rewards are shelter, nectar, alternative foods and pollen. Nectar and pollen used by the natural enemies to increase their body metabolism and fecundity. The shelter could use by natural enemies during adverse weather conditions and at winter hibernations. Hence, this study envisages evaluating the potential floral resources and their uses in conservation biocontrol of cabbage pest. Conservation biological control with the deployment of potential floral crops reduces the damage from aphids and diamondback moth in cabbage crops. Before the deployment of these flowering plants in commercial crop fields, they need to be access, rank, manipulate, evaluate and multiply. The selected flowering insectary plant species are easily available in local environments and can be utilized in future pest management strategy and organic farming. This pest management protocol could also be integrated into current IPM curriculum designed for farmers and formal education programs for future sustainable farming's.

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