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Habitat manipulation strategies for sustainable management of mustard aphid

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Abstract

A field experiment was conducted at Tokowbari Farm, AAU-ZRS, Shillongani, during 2020–21 to 2022–23 to evaluate the effect of habitat manipulation on the management of mustard aphid (*Lipaphis erysimi*). The pooled data over three years revealed that the lowest mustard aphid population (25.08 and 15.98 aphids/plant) was recorded in the mustard + coriander intercrop, followed by mustard + fennel (38.84 and 25.77 aphids/plant) and mustard + chickpea (41.87 and 29.68 aphids/plant) during flowering and siliquae formation stages, respectively. Similarly, the highest population of coccinellids (2.22 beetles/plant) was observed in mustard + coriander, followed by mustard + fennel (2.01 beetles/plant) and mustard + chickpea (2.00 beetles/plant). Mustard-fennel intercrop recorded a significantly higher yield (677.44 kg/ha mustard + 172.89 kg/ha fennel) compared to sole mustard (586.89 kg/ha) and intercrops with chickpea (660.44 kg/ha mustard + 156.00 kg/ha chickpea) and coriander (702.11 kg/ha mustard + 171.78 kg/ha coriander). The yield of sole mustard and its intercrops with chickpea and coriander were statistically at par. The highest benefit-cost ratio (BCR) of 2.43 was observed in mustard-fennel intercrop, followed by mustard-coriander (2.10), mustard-chickpea (1.75), and sole mustard (1.69). These findings suggest that intercropping mustard with fennel or coriander can effectively manage mustard aphids while enhancing natural enemy populations and economic returns.

Keywords: *Benefit-cost ratio, habitat manipulation, intercrop, mustard aphid, yield*

Introduction

Amongst various Brassica species, *B. juncea, B. napus, and B. rapa* are the most important oilseed crops cultivated across the world, including India, together accounting for about 11.3% of global rapeseed–mustard production (Chattopadhyay *et al*., 2005). Mustard, *Brassica juncea* L. (Czern. and Coss) a member of the family Brassicaceae, originated in China and was later introduced into North Eastern India (Sahito *et al*., 2016) and from India, it spread to Afghanistan via Punjab. In the Indian subcontinent, mustard is widely cultivated in Uttar Pradesh, Rajasthan, Madhya Pradesh, Assam, Bihar, Odisha, Haryana, Punjab, Gujarat, and West Bengal (Kumar and Chauhan, 2005), and has recently expanded to non-traditional states such as Maharashtra, Andhra Pradesh, Tamil Nadu, and Karnataka. India is a major contributor to global rapeseed–mustard production, accounting for 14.8% of the world's output (Singh, 2014). Rapeseed–mustard ranks third among the world's oilseed crops and contributes 28.6% to India's total oilseed production. It is the second most important edible oilseed in the country after groundnut, representing 27.8% of the oilseed economy. Mustard seeds yield edible oil rich in energy and essential fatty acids, making them a key component of the human diet. However, per capita edible oil consumption in India averages only 5 kg annually compared to 26 kg in developing countries (Bakhetia and Brar, 1982), emphasizing the need to increase oilseed productivity.

Despite its economic importance, mustard yields are often reduced by insect pests. Rai (1976) reported 24 key insect pests of mustard and rapeseed in India, whereas Bakhetia and Sekhon (1989) identified 38 species, and Purwar *et al*. (2004) recorded over 43 species, with about a dozen considered major pests. The most damaging among them are the mustard aphid (*Lipaphis erysimi*), mustard sawfly (*Athalia lugens proxima*), painted bug (*Bagrada hilaris*), and leaf miner (*Phytomyza horticola*). The mustard aphid, *L. erysimi*, is the most destructive pest, infesting the crop from seedling to maturity and causing yield losses up to 96% (Singh and Sachan, 1994; Sharma and Kashyap, 1998; Singh and Sharma, 2002). Aphids feed on plant sap from inflorescences, shoots, pods, and leaves, resulting in stunted growth, flower abortion, and reduced pod set. Losses vary from 35–90% (Biswas and Das, 2000; Rohilla *et al*., 2004) and may include a 15% reduction in oil content (Verma and Singh, 1987). In severe cases, unprotected crops have recorded yield losses of up to 97.6% (Patel *et al*., 2014). Management of mustard aphid often relies heavily on chemical insecticides. However, indiscriminate use disrupts natural enemies such as parasitoids and predators, and may cause environmental and health hazards. Sustainable pest management therefore requires integrated approaches, including cultural methods, resistant varieties, optimized sowing time, trap cropping, nutrient and irrigation management, and the use of biological control agents. The objective of the study was to evaluate the effect of habitat manipulation through crop diversification on the management of mustard aphid (*Lipaphis erysimi* Kalt.), its associated natural enemies, and crop yield.

Materials and Methods

Experimental site and treatments details

A field experiment was conducted for three consecutive *rabi* seasons (2020–21, 2021–22, and 2022–23) at the Tokowbari Farm (Latitude: 26.356° N, Longitude: 92.6311° E) of the AAU- Zonal Research Station (Assam Agricultural University), Shillongani, Assam, India. The experiment was laid out in a Randomized Block Design (RBD) with four treatments, each replicated thrice. The plot size was 8 m × 3 m. Mustard variety *Brassica juncea* was sown during the second to third week of November in each year under uniform agronomic practices. The treatments were: T_1: Mustard alone (sole cropping), T_2: Mustard + chickpea, T_3: Mustard + coriander and T_4: Mustard + fennel.

Data collection and observations

Aphid population: Weekly observations on the number of mustard aphids (*L. erysimi*) were recorded from the initiation of infestation until the population declined. Data were collected from 10 randomly selected plants per plot, counting all visible aphids on the main shoot and branches.

Natural enemies: The number of mummified aphids parasitized by *Diaeretiella rapae* (McIntosh) was recorded weekly, along with the abundance of major generalist predators including ladybird beetles (*Coccinella* spp.), syrphid fly larvae, and green lacewings (*Chrysoperla* spp.), on the same plants sampled for aphid counts.

Yield: At harvest, the seed yield of mustard from each plot was recorded and converted to kg ha^{-1}. For intercrop treatments, the yield of intercrops (chickpea, coriander, or fennel) were also recorded separately.

Statistical analysis

The data on aphid and natural enemy populations were subjected to analysis of variance (ANOVA) using pooled means across the three years. Yield data were analyzed similarly, and the economics of each treatment were computed on a per-unit-area basis considering both mustard and intercrop yields.

Result and Discussion

Effect of plant diversity on mustard aphid abundance

The abundance of mustard aphid varied significantly among different treatments and crop growth stages during all three years of study (Table 1). Across seasons, the highest aphid populations were consistently recorded in mustard grown as a sole crop (T_1), with pooled mean populations of 68.72 aphids/plant at the flowering stage and 51.39 aphids/plant at the siliqua formation stage. Intercropping mustard with chickpea (T_2) substantially reduced aphid populations compared to the sole crop, with pooled means of 41.87 and 29.68 aphids/plant at flowering and siliqua stages, respectively. Even greater suppression of aphids was observed when mustard was intercropped with coriander (T_3), which recorded the lowest pooled mean populations of 25.08 (flowering stage) and 15.98 (siliqua formation stage) aphids/plant. Mustard–fennel intercropping (T_4) also reduced aphid numbers relative to the sole crop, but populations were higher than in mustard–coriander plots, with pooled

Table 1: Effect of plant diversity on abundance of mustard aphid {Mean aphid population (no/plant)}

Treatments	2020-21		2021-22		2022-23		Pooled mean	
	Flowering Stage	Siliqua formation	Flowering Stage	Siliqua formation	Flowering Stage	Siliqua formation	Flowering Stage	Siliqua formation
Mustard alone	63.30	47.90	71.2	53.4	71.67	52.87	68.72	51.39
Mustard + chickpea	47.30	33.60	39.4	27.6	38.90	27.83	41.87	29.68
Mustard + coriander	28.60	20.80	22.8	13.2	23.83	13.93	25.08	15.98
Mustard + fennel	31.20	21.70	42.5	28.5	42.83	27.10	38.84	25.77
SEm (±)	1.64	1.24	1.69	1.38	0.20	0.07	1.18	0.90
LSD (p=0.05)	3.29	2.47	3.36	2.68	0.68	0.26	2.44	1.80

means of 38.84 and 25.77 aphids/plant at the respective stages. The data revealed that all intercrop treatments significantly reduced aphid abundance compared to the sole mustard crop at both growth stages ($p<0.05$). Among intercrops, mustard–coriander proved to be the most effective in minimizing aphid infestation throughout the study period.

Effect of plant diversity on abundance of coccinella spp.

The abundance of the predatory beetle *Coccinella* spp. (grub + adult) showed marginal variation among treatments during both flowering and siliqua formation stages across the three cropping seasons, but the differences were not statistically significant (Table 2). In 2020–21, the number of *Coccinella* individuals per plant ranged from 1.90 (flowering) and 2.00 (siliqua stage) in sole mustard (T_1) to 2.40 (flowering) and 1.80 (siliqua stage) in mustard–fennel (T_4). A similar trend was observed in 2021–22, with populations varying between 1.70 and 2.80 per plant across treatments. In 2022–23, the highest abundance was recorded in mustard–fennel (T_4) at the flowering stage (3.00/plant), while the lowest was in sole mustard (T_1) with 1.60/plant. Pooled mean data across the years indicated slightly higher predator populations in intercrop systems compared to the sole mustard crop. Mustard–fennel (T_4) supported the highest pooled mean abundance (2.73 at flowering, 2.01 at siliqua stage), followed by mustard–coriander (T_3) and mustard–chickpea (T_2). Sole mustard consistently recorded the lowest predator numbers (1.73 and 1.58 per plant at the respective stages). Although intercrops tended to harbor more *Coccinella* individuals than monocropped mustard, the differences were statistically non-significant ($p>0.05$), indicating that plant diversity did not markedly influence the abundance of this predator under the study conditions.

Table 2: Effect of plant diversity on abundance of the associated specialist and generalist natural enemies {Mean no. of cocinella (Grub+Adult)/plant}

Treatments	2020-21		2021-22		2022-23		Pooled mean	
	Flowering Stage	Siliqua formation	Flowering Stage	Siliqua formation	Flowering Stage	Siliqua formation	Flowering Stage	Siliqua formation
Mustard alone	1.90	2.00	1.7	1.2	1.60	1.53	1.73	1.58
Mustard + chickpea	2.00	1.80	2.3	1.9	2.33	2.30	2.21	2.00
Mustard + coriander	2.10	1.90	2.7	2.1	2.77	2.67	2.52	2.22
Mustard + fennel	2.40	1.80	2.8	1.7	3.00	2.53	2.73	2.01
SEm (±)								
LSD (p=0.05)			NS	NS	NS	NS	NS	NS

Effect of plant diversity on yield

The seed yield of mustard was significantly influenced by intercropping with chickpea, coriander, or fennel during all three crop seasons (Table 3). In 2020–21, sole mustard (T_1) recorded the lowest yield (578 kg/ha), whereas mustard + coriander (T_3) produced the highest mustard-equivalent yield (721 kg mustard + 179 kg coriander). Mustard + chickpea (T_2) and mustard + fennel (T_4) also outperformed sole mustard, yielding 654 kg mustard + 161 kg chickpea and 688 kg mustard + 172 kg fennel, respectively. A similar trend was observed in 2021–22, with mustard + coriander (T_3) recording maximum mustard yield (694 kg) along with 168 kg coriander,

Table 3: Effect of plant diversity on yield

Treatments	2020-21	2021-22	2022-23	Pooled mean
Mustard alone	578	591	591.67	586.89
Mustard + chickpea	654 + 161 (chickpea)	659+ (154 chickpea)	668.33 + (153.00 chickpea)	660.44+ (156.00 chickpea)
Mustard + coriander	721 + 179 (coriander)	694+ (168 coriander)	691.33 + (168.67 coriander)	702.11+ (171.7777 coriander)
Mustard + fennel	688 + 172 (fennel)	672+ (173 fennel)	672.33 + (173.67 fennel)	677.44+ (172.89 fennel)
SEm (±)	19.54	20.23	8.52	16.10
LSD (p=0.05)	38.62	41.53	29.48	36.54

followed by mustard + fennel (T_4) and mustard + chickpea (T_2). In 2022–23, the highest mustard yield was again obtained from mustard + coriander (T_3) at 691.33 kg mustard + 168.67 kg coriander, while the lowest was in sole mustard (T_1) at 591.67 kg/ha.

Pooled mean analysis over three years indicated that mustard + coriander (T_3) consistently produced the highest mustard yield (702.11 kg) and intercrop yield (171.78 kg coriander), followed by mustard–fennel (T_4) and mustard–chickpea (T_2). Sole mustard recorded the lowest pooled mean yield (586.89 kg/ha). Statistical analysis revealed that the differences among treatments were significant at the 5% level in each year as well as in pooled data. These results indicate that intercropping mustard with coriander, fennel, or chickpea enhances overall productivity, with mustard + coriander being the most productive combination under the present agro-ecological conditions.

Discussion

The present study demonstrated that crop diversification through intercropping and habitat manipulation strategies significantly influenced the population dynamics of mustard aphid (*Lipaphis erysimi* Kalt.) and enhanced the abundance of associated natural enemies. Aphid infestation was consistently lower in diversified cropping systems as compared to sole mustard, indicating that intercropping and habitat modification can serve as sustainable pest management approaches. The reduced pest pressure in diversified systems could be attributed to the disruption of host-finding cues, altered microclimatic conditions, and the provision of alternative food resources for natural enemies, as reported earlier by Borkakati *et al*. (2019a, 2019b) and Pradhan *et al*. (2020a). Our observations are in agreement with Pradhan *et al*. (2020b), who reported that the seasonal incidence of *L. erysimi* was closely associated with meteorological factors, but was mitigated under cropping systems that provided a more heterogeneous habitat. Similar trends have been reported in cabbage and brinjal ecosystems, where crop habitat manipulation encouraged higher populations of predators and parasitoids, thereby suppressing pest outbreaks (Borkakati *et al*., 2019a; Borkakati *et al*., 2019b).

The increased activity of natural enemies such as coccinellids, syrphid flies, and parasitoids in diversified plots highlights the role of ecological engineering in pest suppression. Pradhan *et al*. (2020c) documented similar findings in mustard fields of Assam, where a diversified cropping pattern supported a more stable and abundant community of beneficial insects. Our results also align with the principles of conservation biological control, wherein habitat complexity enhances the effectiveness of naturally occurring enemies (Patel *et al*., 2004). Moreover, the incorporation of flowering intercrops such as coriander and fennel likely acted as nectar and pollen sources, supporting the longevity and fecundity of parasitoids, thereby contributing to aphid regulation. This observation is consistent with the findings of earlier workers who emphasized that the strategic inclusion of resource plants could be an effective part of an Integrated Pest Management (IPM) strategy (Pradhan *et al*., 2020a; 2020c).

Overall, the results indicate that habitat manipulation and crop diversification not only reduce reliance on chemical control measures but also contribute to sustainable mustard production systems by promoting ecological resilience. Considering the environmental and economic benefits, these strategies merit wider adoption among mustard-growing farmers, particularly in regions like Assam where climatic conditions favor rapid aphid multiplication.

Conclusion

The study demonstrated that plant diversity through intercropping significantly reduced mustard aphid populations and improved mustard yield, while exerting minimal influence on the abundance of *Coccinella* spp. predators. Among the tested combinations, mustard–coriander consistently recorded the lowest aphid infestations and the highest seed yields across all seasons, followed by mustard–fennel and mustard–chickpea systems. Sole mustard cultivation was most susceptible to aphid attack and produced the lowest yields. Although predator abundance showed a slight numerical increase in intercrops, differences were statistically non-significant. Overall, mustard + coriander intercropping emerged as the most effective and productive system under the prevailing agro-ecological conditions.

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