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Differential response of intercrops to mitigate aphid (Homoptera: Aphididae) incidence on cruciferous crops

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Abstract
The field study was conducted to determine the impact of intercropping of cabbage, cauliflower and mustard in combinations of onion garlic and fennel on incidence of aphid species. The results revealed significantly the minimum population of *Myzus persicae*, in mustard+garlic (28.6±1.11aphids/plant) followed by mustard+onion (31.4±1.16 aphids/plant) and mustard+fennel (49.8±0.75 aphids/plant) over sole mustard (66.6 ±1.22 aphids/plant) after 30 days of sowing. The intercropping of cauliflower with garlic caused significant (f= 32.71, $p<0.05$) reduction (26.8±1.00 aphids/plant) of *Brevicoryne brassicae* over sole cauliflower (65.8±1.12 aphids/plant) after 30 and 90 days. However, cabbage+onion (131.0±0.56 aphids/plant) and cabbage and garlic (130.6±1.22 aphids/plant) combinations showed no differential response in population reduction of *Lipaphis erysimi*, but exhibited significant decrease (154.6±0.95 aphids/plant) over sole cabbage. The garlic blended with mustard, cauliflower and cabbage caused significant reduction of aphids over control. The study inferred minimized pest incidence if the main crops are cultivated in combination of intercrops.

Keywords: *Lipaphis erysimi*, *Myzus persicae*, *Brevicoryne brassicae*, mustard, cabbage, cauliflower, intercropping

Introduction
The challenging problem of pest outbreak and resistance have arisen the need of holistic approach rather than the reliance on one method of pest management. The pest control options ranges from conservation of natural enemies (predators and parasitoids), variation in planting dates (to create asynchrony between pest appearance and growth stage), raising two or more crops (intercropping) in one ecosystem (for habitat diversification) accounting low herbivore and amplification of natural enemies [1-3]. The maintenance of habitat diversity of natural enemies supports the "resource concentration hypothesis" and "enemies hypothesis" [4, 5]. The habitat manipulation, render the main crop unfavorable for pest incidence but favourable for natural enemies occurrence [6, 7]. The intercrops generate beneficial interactions between host and non-host crops by increasing yields, more efficiently use available resources, reduced weed, insect and disease pressures and induces greater biological and economic stability [8]
Brassica crops suffers the incidence of several pest causing heavy losses. Aphid constrains the crop production severely, degrading crop quality and declining yield on account of sap sucking behaviour and vectoring potency of several plant diseases [9]. The sap feeding cause around 83% loss to brassica crops [10]. Feeding results in leaf curling, stunting, drying of leaf tissues along with the development of sooty mold fungi, restricting photosynthesis, consequently [11,12]. Therefore, an investigation was carried out to assess the differential response of various intercropping combinations on incidence of aphid species *viz.*, *Myzus persicae* (Sulz.), *Lipaphis erysimi* (Kalt.) and *Brevicoryne brassicae* (Linn.) under field conditions.

Materials and Methods
To establish the influence of various combinations of intercropping on natural incidence of *M. persicae L. erysimi* and *B. brassicae* an experiment was conducted by raising onion, garlic and fennel as intercrops each with *Brassica oleracea* var. *capitata*, *Brassica oleracea* var. *botrytis*, and *Brassica campestris*. Mustard variety Krishna kranti was used as main crop with local varieties of onion (Nasik red), garlic (Yamuna safed 3) and fennel (RF 281) with 4:2 ratio, respectively. Cabbage (variety Golden acre) and cauliflower (variety Snow ball) was intercropped with onion, garlic and fennel in 6:2 ratio, respectively.

Experimental layout: The experiment was carried out during winter months of consecutive years of 2011-12 and 2012-13 at experimental field of Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University. The experiment was conducted in randomized block design and laid down in 3 × 8 m plot size. Mustard [(4:2) mustard+onion, mustard+garlic, mustard+fennel], cabbage [(6:2) cabbage+onion, cabbage+garlic, cabbage+fennel] and cauliflower [(6:2) cauliflower+onion, cauliflower+garlic, cauliflower+fennel] were intercropped with onion, garlic and fennel and each combination was replicated five times. The experiment was maintained in rows, raised at 30 cm line to line and 20 cm plant to plant spacing.

Aphid counting: The aphid incidence on various intercropping combinations was recorded on randomly selected five plants per plot and marked with metal tags. During field monitoring, the aphid species were distinguished by close view of aphids on leaf with the help of LED MICROSCOPE having 45 X magnifying power and the population each of *B. brassicae*, *M. persicae* and *L. erysimi* was counted weekly on three marked leaves per plant. The data collected on aphid count was analyzed statistically by using one way analysis of variance (ANOVA). When the significant difference was obtained within the means of various aphid species, it was subjected to Duncan multiple range test using SPSS version 16.

Results and Discussion

Effect of intercropping on aphid incidence on mustard: The surveillance on population dynamics of aphid species revealed the significant reduction of *B. brassicae* (30.6 ±2.12 aphids/plant) over control (62.6 ±0.98 aphids/ plant) after one month of sowing, on mustard intercropped with garlic. Similarly, the minimum population of *M. persicae*, was observed in mustard + garlic (28.6 ±1.11aphids/plant) followed by mustard + onion (31.4 ±1.16 aphids/plant) and mustard+ fennel (49.8 ±0.75 aphids/plant) combinations as compared to sole mustard (66.6 ±1.22 aphids/plant) after 30 days of sowing. The population incidence of *L. erysimi* was however greatly declined (121.4 ± 0.08 aphids/plant) in mustard + garlic combination as compared to sole crop (160.8 ±1.05 aphids/plant), after 90 days of sowing (Table 1). Akin to 2011-12 population scenario, it followed recessing trend on intercrops in succeding year (2012-13). The density of *B. brassicae* and *M. persicae* on mustard+garlic combination (32.6 ±0.06 aphids/plant) was reduced to half over sole mustard (78.6±01.12 aphids/plant) after 30 days of sowing, however, after 90 days, a significant (f= 110.37, $p<0.05$) reduction in population of *B. brassicae* was noticed with mustard+ onion (90.6 ±0.05 aphids/plant) intercropping over control (147.6 ± 1.21 aphids/ plant). The population of *L. erysimi* however, significantly (f=82.98, $p<0.05$) recessed to 137.2±1.07 aphids/plant on mustard and garlic combination over sole mustard (163.8 ±1.45 aphids/plant). The observations on *B. brassicae* and *M. persicae* on mustard with all intercrops revealed a pronounced decrease in rate of occurrence at 30 and 90 DAS. The aphid population reduction might be due to strong pungency of *Alium* species [10, 11], which might have as repellent and antifeeding agent [12].

Effect of intercropping on aphid incidence on cauliflower: The intercropping of cauliflower with garlic caused significant (f= 32.71, $p<0.05$) reduction (26.8±1.00 aphids/plant) of *B. brassicae* over sole cauliflower (65.8 ± 1.12 aphids/plant) after 30 and 90 days of sowing. Whereas, intercropping of cauliflower with fennel harbored more aphids (50.6 ±2.11 aphids/plant) and found comparatively less effective in reducing *B. brassicae* population. As far as the population of *M. persicae* was concerned, no significant (f= 89.01, $p<0.05$) variation in population count was witnessed with cauliflower+onion (22.8±1.09 aphids/plant) and cauliflower+garlic (20.2±1.09 aphids/plant) intercropping, yet the least population was noticed with regard to cauliflower and garlic combination after 30 days of sowing. The cauliflower intercropped with fennel was however next in order against sole cauliflower and this combination didn't produce significant reduction in population (48.6±0.78 aphids/plant). The population of *L. erysimi* was found greatly reduced in cauliflower+garlic combination (87.8±1.12 aphids/plant) as compared to sole cauliflower (112.6 ±1.3 aphids/plant) after 90 days of sowing (Table 2). During subsequent cropping season (2012-2013), at 30 DAS, *B. brassicae* dynamics followed a definite pattern: cauliflower+ garlic < cauliflower+ onion< cauliflower+fennel<sole cauliflower. Of these, cauliflower and garlic intercrop significantly (f=258.8, $p<0.05$) reduced *B. brassicae* population (59.2±1.76 aphids/plant) after 90 days of sowing, in contrast to control (92.6±2.09 aphids/plant). On the other hand, the least population of *M. persicae*, (21.8±0.93 aphids/plant) was noticed with regard to cauliflower+garlic combination vis-a-vis sole cauliflower (51.6±1.22 aphids/plant). The trend of population dynamics remained static till 60 days of standing crop. Interestingly, after 90 days of sowing, cauliflower intermixed with fennel impacted well in reducing *M. persicae* population (50.8±1.54 aphids/plant) over sole cauliflower (72.6± 1.12 aphids/plant). The population of *L. erysimi*, after 30 days of sowing was found significantly low when cauliflower was intercropped with garlic (58.6±1.67 aphids/plant). Whereas, after 60 as well as 90 days, the prevalence of population was found similar as it was recorded with cauliflower+ onion (92.8±1.45 aphids/plant) combination. Whereas, cauliflower intercropped with fennel (95.8±2.31 aphids/plant) did not produce any significant (f= 104.29, $p<0.05$) impact on *L. erysimi* population as compared to control (115.8±1.38 aphids/plant). Of all the intercrops, *B. brassicae* population was reduced to minimum level when it was intermixed with fennel. Similar findings have also been reported [13-14]. The effect of intercropping was found highly significant on population dynamics of *M. persicae.* Interestingly, the population on garlic and fennel intercrops was found identical and both crops were considered as suitable combination which could be used in association with cauliflower to reduce the pest attack. As compared to other combinations, cauliflower with onion was found less effective for suppression of *M. persicae.* The population reduction in different crop combinations was possibly due to the disruption in host finding by aphids resulting in low number. [15-18]

Effect of intercropping on aphid incidence on cabbage: The cabbage blended with onion, garlic and fennel showed a significant reduction (f= 21.32, $p<0.05$) of *B. brassicae* at early stage (30 DAS) of growth. However, after 60 and 90 days of sowing, the population (43.2 ±2.06 aphids/plant) increased steadily and the maximum decline was recorded after 60 days of sowing on cabbage+ garlic combination (Table 3). With regard to *M. persicae*, no significant (f=

25.73, $p<0.05$) difference in population build up was noticed in cabbage+garlic (40.4±0.95 aphids/plant) and cabbage+fennel intercrops (41.4± 1.16 aphids/plant) at 60 DAS. However, significant (f=117.98, $p<0.05$) decrease in aphid population was recorded, while combining cabbage with garlic (74.2 ± 1.56 aphids/plant) at 90 DAS. Whereas, the cabbage + onion (131.0 ± 0.56 aphids/plant) and cabbage and garlic (130.6±1.22 aphids/plant) combinations showed no differential response in population reduction of *L. erysimi*, but exhibited significant decrease (154.6±0.95 aphids/plant) over sole cabbage after 90 days of sowing (Table 3).

During 2012-2013 cropping season, the combination of cabbage+garlic was found effective (41.8±1.55 aphids/plant) over control (67.2±1.50 aphids/plant) for *B. brassicae* at early stage of growth. The intercropping of cabbage+fennel (91.6±1.89 aphids/plant) was comparatively more effective to repel aphid population at late stage of crop growth. Nonetheless, at seedling stage, no significant (f= 51.29, $p<0.05$) difference in fluctuation of *M. persicae* population was noticed on cabbage+ onion (28.4±0.79 aphids/plant) as well as cabbage+garlic (28.2±1.17 aphids/plant) combination. At later stage (90 DAS), the minimum population was recorded in cabbage+garlic (80.2±2.13 aphids/plant) intercropping vis-a-vis sole cabbage (115.4±1.50 aphids/plant). Similarly, the population of *L. erysimi* got significantly (f= 90.64, $p<0.05$) reduced while combining cabbage and onion (139.4±2.25aphids/plant). These findings are in close agreement to those reported by other workers, [17, 19] while intercropping rape with garlic. Moreover, the low aphid density in cabbage+ fennel might be due to presence of relatively high population of natural enemies on this cropping system.

Conclusion

In monoculture agro-ecosystems, besides the heavy incidence of pest, the population of parasitoid and predators suffer from a lack of food, alternative prey or hosts and shelter against adverse conditions. The non-cropped habitat plays a crucial role in maintaining natural enemy abundance and diversity in agro ecosystems by providing floral resources to adults. Therefore, in brassica cultivation garlic can be used as intercrop to minimize the aphid infestation in mustard cabbage and cauliflower, simultaneously the intercropping with fennel can be opted to attract more number of natural enemies needed for their natural perpetuation.

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Table 1: Effect of intercropping on incidence of aphid species on mustard

Brevicoryne brassicae				***Myzus persicae***				***Lipaphis erysimi***			
2011-2012											
Cropping system	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**
Mustard+ Onion	41.4±1.17c	63.8±1.12c	86.6±1.14d	Mustard+ Onion	31.4±1.16d	57.6±1.10d	71.6±1.15c	Mustard+ Onion	88.4±1.87c	104.2±1.02c	134.4±1.91c
Mustard + garlic	30.6±2.12d	40.8±2.13d	89.6±1.12c	Mustard + garlic	28.6±1.11c	54.4±1.19c	77.0±0.03d	Mustard + garlic	71.2±1.65d	92.4±0.98d	121.4±0.08d
Mustard+Fennel	50.6±0.05b	67.8±1.00b	114.2±1.18b	Mustard+Fennel	49.8±0.75b	75.0±1.21b	97.4±0.21b	Mustard+Fennel	99.8±1.98	118.2±1.13b	145.2±1.13b
Control (Mustard)	62.6±0.98a	74.8±1.25a	124.4±1.28a	Control (Mustard)	66.6±1.22a	85.6±2.10a	111.4±1.15a	Control (Mustard)	120.2±1.67a	137.8±2.05a	160.8±1.05a
F	33.45	38.52	81.16	*F*	46.36	23.6	46.16	*F*	94.35	115.93	105.06
LSD (p<0.05)	3.24	1.31	2.06	LSD (p<0.05)	1.01	2.34	3.35	LSD (p<0.05)	1.52	2.06	2.06
				2012-2013							
Cropping system	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**
Mustard+ Onion	45.6±1.10c	71.6±0.23c	90.6±0.05d	Mustard+ Onion	39.2±1.34c	65.4±0.09c	87.8±2.09c	Mustard+ Onion	91.8±0.87c	107.6±1.09c	142.8±1.17c
Mustard + garlic	32.6±0.06d	55.6±1.08d	97.0±103c	Mustard + garlic	33.8±2.10c	62.6±1.6c	92.2±0.95c	Mustard + garlic	73.41±0.98d	100.2±1.21d	137.2±1.07d
Mustard+Fennel	58±0.17b	83.2±0.89b	127.2±1.05b	Mustard+Fennel	58.6±1.09b	84.6±1.07b	117.0±0.64b	Mustard+Fennel	102.4±1.76b	119.6±2.14b	153.6±2.15b
Control (Mustard)	78.6±1.02a	109.4±1.04a	147.6±1.21a	Control (Mustard)	69.6±1.00a	97.4±2.12a	127.8±1.05a	Control (Mustard)	121.4±2.10a	144.2±1.31a	163.8±1.45a
F	53.97	71.29	110.37	*F*	70.09	72.33	126.73	*F*	115.13	23.02	82.98
LSD (p<0.05)	2.32	1.26	2.81	LSD (p<0.05)	2.14	2.97	3.51	LSD (p<0.05)	1.76	2.37	2.06

LSD= Least significant difference, Means followed by same letter in column are not significantly different ($p<0.05$) by Duncan multiple range test

Table 2: Effect of intercropping on incidence of aphid species on cauliflower

Brevicoryne brassicae				***Myzus persicae***				***Lipaphis erysimi***			
2011-12											
Cropping system	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**
Cauliflower+onion	36.6±1.08c	60.2±0.95c	71.2±0.65c	Cauliflower+onion	22.8±1.09c	40.4±0.87b	61.8±1.13b	Cauliflower+onion	67.8±1.09b	75.8±2.09c	90.8±0.23c
Cauliflower+garlic	26.8±1.0d	40.8±0.99d	57.8±1.45d	Cauliflower+garlic	20.2±1.09c	37.6±1.13c	49.6±0.12c	Cauliflower+garlic	57.2±1.04c	70.6±1.05d	87.8±1.12d
Cauliflower+Fennel	50.6±2.11b	67.8±1.87b	77.4±1.00b	Cauliflower+Fennel	29.2±1.99b	37.6±1.00c	49.6±0.96c	Cauliflower+Fennel	69.4±0.05b	81.8±1.21b	94.8±1.65b
Control (cauliflower)	65.8±1.12a	72.4±1.23a	90.6±2.11a	Control (cauliflower)	48.6±0.78a	59.6±1.21a	71.4±1.02a	Control (cauliflower)	70.4±2.13a	84.6±1.23a	112.6±1.34a
F	32.71	22.66	61.23	*F*	89.01	129.78	160.21	*F*	23.39	83.96	38.85
LSD (p<0.05)	2.15	3.02	3.37	LSD (p<0.05)	2.83	2.87	1.24	LSD (p<0.05)	2.88	1.15	2.49
2012-2013											
Cropping system	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**
Cauliflower+onion	40.8±1.78c	63.0±0.83c	71.2±1.32c	cauliflower +onion	24.4±2.10c	42.2±0.98c	63.6±1.13b	Cauliflower+onion	60.2±1.12b	76.6±0.45b	92.8±1.45c
Cauliflower+garlic	28.2±1.09d	42.2±1.67d	59.2±1.76d	Cauliflower+ garlic	21.8±0.93d	39.2±0.95d	52.6±1.95c	Cauliflower+garlic	58.6±1.67c	71.4±1.90c	59.4±1.50d
Cauliflower+Fennel	52.8±1.22b	70.0±1.00b	78.8±1.87b	Cauliflower + Fennel	30.2±2.10b	46.2±1.22b	50.8±1.54c	Cauliflower+Fennel	69.4±2.15a	83.8±1.98a	95.8±2.31b
Control (cauliflower)	70.4±1.56a	77.2±1.45a	92.6±2.09a	Control (cauliflower)	51.6±1.22a	60.2±2.78a	72.6±1.12a	Control (cauliflower)	71.2±1.32a	86.0±1.17a	115.8±1.38a
F	128.81	45.28	258.8	*F*	131.54	145.77	119.42	*F*	37.81	18.59	104.29
LSD (p<0.05)	3.87	2.91	2.67	LSD (p<0.05)	3.63	2.37	2.87	LSD (p<0.05)	3.04	4.78	3.57

LSD= Least significant difference, Means followed by same letter in column are not significantly different ($p<0.05$) by Duncan multiple range test

Table 3: Effect of intercropping on incidence of aphid species on cabbage

Brevicoryne brassicae				***Myzus persicae***				***Lipaphis erysimi***			
2011-2012											
Cropping system	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**
Cabbage+onion	41.2±0.96c	64.6±1.04b	91.2±1.24b	Cabbage+onion	26.2±1.04c	43.8±1.00b	80.6±0.89d	Cabbage+onion	60.4±1.11c	76.6±1.52c	131.0±0.56c
Cabbage+ Garlic	37.4±0.98d	43.2±2.06d	88.6±1.67c	Cabbage+ Garlic	22.8±1.23d	40.4±0.95c	74.2±1.56b	Cabbage+ Garlic	57.6±2.16d	71.8±1.17d	130.6±1.22c
Cabbage+Fennel	53.4±1.31b	60.0±1.09c	87.6±1.23c	Cabbage+Fennel	30.4±2.16b	41.4±1.16c	85.60±0.95c	Cabbage+Fennel	64.6±1.09b	82.8±2.22b	134.4±1.51b
Control (Cabbage)	59.8±1.78a	68.2±1.21a	94.8±2.17a	Control (Cabbage)	51.2±2.01a	57.4±1.54a	102.4±1.23a	Control (Cabbage)	69.6±1.09a	85.4±1.00a	154.6±0.95a
F	21.32	47.06	95.83	*F*	52.65	25.73	117.98	*F*	87.22	94.88	92.49
LSD (p<0.05)	2.96	2.47	3.41	LSD (p<0.05)	1.41	2.79	2.77	LSD (p<0.05)	1.04	1.74	2.33
212-2013											
Cropping system	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**	**Cropping system**	**30 DAS**	**60 DAS**	**90 DAS**
Cabbage+onion	48.6±0.55c	64.6±0.24b	100.6±2.01c	Cabbage+onion	28.4±0.79c	47.6±0.58b	89.6±1.54c	Cabbage+onion	63.8±1.25c	76.6±2.12c	139.4±2.25c
Cabbage+ Garlic	41.8±1.55d	47.6±1.67c	108.2±1.05b	Cabbage+ Garlic	28.2±1.17c	41.2±1.05d	80.2±2.13d	Cabbage+ Garlic	60.2±1.17d	71.4±1.67d	144.2±1.25b
Cabbage+Fennel	57.4±2.01b	72.8±1.25a	91.6±1.89d	Cabbage+Fennel	34.6±2.17b	44.2±1.15c	93.4±1.02b	Cabbage+Fennel	66.6±1.67b	83.8±2.25b	143.5±2.10b
Control (cabbage)	67.2±1.5a	73.8±2.11a	119.6±1.19a	Control (cabbage)	49.2±1.25a	58.8±1.25a	115.4±1.50a	Control (cabbage)	71.2±1.15a	86.12±1.05a	152.22±2.14a
F	65.5	51.32	684.32	*F*	51.29	21.72	111.77	*F*	59.05	18.59	90.64
LSD (p<0.05)	2.19	1.133	1.58	LSD (p<0.05)	1.24	2.08	2.31	LSD (p<0.05)	2.75	1.78	2.42

LSD= Least significant difference, Means followed by same letter in column are not significantly different ($p<0.05$) by Duncan multiple range test

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