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ECOLOGICAL IMPORTANCE OF WEED AND INSECT DIVERSITY IN WHEAT FIELDS UNDER DIFFERENT CHEMICAL INTENSIFICATION

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ABSTRACT

The study was focused to collect, identify and compare the species richness and abundance of weeds and insects with respect to their ecological importance in wheat fields with low (organic) and high (conventional) inputs (LIP and HIP, respectively) in the four major zones of Punjab (Pakistan). The pesticidal effect was significant in all the four wheat crop zones in terms of their floral and faunal diversity. The LIP fields of all these systems except that of CWZ were highly diversified with respect to weeds and insects number and species richness. The weed species ranged from 5-10 in HIP fields while the number ranged from 11-18 in LIP fields. Some of the weeds such as C. iberica and C. didymus seemed to be indicated or of higher nutrient quantities of P or K in the soil. Out of 29 species of insects belonging to reportedly phytophagous families, 14 were reported to be the major (8) and minor (6) pest of wheat crop. The rest 15 species have not yet been reported as the major or minor pests of wheat crop. This meant that at least 15 or more than 50% phytophagous invertebrates are used to feed on weed plants. An aphid, Microsiphum miscanthi infested the pair fields in all zones but surprisingly their number was almost double in HIP fields but predator species were abundant in LIP fields.

Key words: chemical, pest, phytophagous insects, weeds diversity, wheat.

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INTRODUCTION

Diversity stabilizes natural ecosystems (McCann, 2000), but in agro-ecosystems plant diversity is deliberately reduced to maximize

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crop production. The plants other than crop plants, called weeds, are considered redundant and refrain crop production. The chemical eradication of the weeds has caused environmental problems leading to loss of biodiversity in adjacent ecosystems as well as loss of sustainability in agro-ecosystems (Sigg, 1999).

Most of the weeds are crop associated plants (Ashiq *et al*., 2003) in the crop system playing a vital role for providing food to many of the pests as alternate host, preys of many invertebrates and vertebrates and predators of pests (Marshall *et al*., 2003). The performance of the organic (low-input) farming systems indicated that herbicide use could be reduced by 50% or more in corn with little or no yield reduction (Clark *et al.*, 1998). The herbicides in conventional (high-input) farming system decrease weed abundances, which may have subsequent deleterious effects on insects and birds depending on these plants for their living (Chiverton and Sotherton, 1991). Moreover, medicinal value of various weeds by cultivating them in crops (as polyculture practice) may add to the total out-put in terms of economic benefits (Aslam, 2002).

Weeds can act by providing a 'sink' that attracts pests away from crops, or by serving as a 'source' that increases abundance of natural enemies, or by acting to visually or olfactorally confuse pests by increasing diversity of habitat within fields, or by modifying microclimate variables so that these are less favorable to herbivorous pests (Bugg, 1992). Of course, such beneficial effects must be balanced against harm caused by weeds by other mechanisms. A thorough review of interactions between weeds, arthropod pests and their natural enemies (Norris and Kogan, 2000) reveal that weeds could contribute to ecological control in some circumstances by providing alternative food resources or refuges for pests (Jervis *et al*., 1993).

Weeds are weeds because they are able to grow and proliferate in soils with varying fertility. They are able to survive in very harsh environmental conditions. Furthermore, weeds can decompose very rapidly as a result of low C: N ratios, thereby providing an important form of available organic matter and N to the soil (Wardle, 1995). Therefore, certain weeds may be valuable components of cover-cropping, especially if the aim is a multi-species cover-crop "polyculture" that can provide multiple ecological benefits.

In the upcoming scenario of chemical free food production the intensive agricultural practices should be oriented to ecological handling of the crop systems. So, that in-farm resources may be depended upon and thus reducing the reliance on off-farm inputs such as synthetic fertilizers and pesticides. The hypothesis in the present study advocates for ecological benefits of weed diversity by comparing wheat farms receiving two different agrochemical in-puts in four agro-ecosystems of different cropping patterns in the province of Punjab.

MATERIALS AND METHODS

Based on different cropping patterns and agroclimatic conditions wheat cultivation in Punjab is classified into four major zones (Fig. 1). The exact localities selected for the sampling were Ayub Agriculture Research Faisalabad, Bokhari Farms,Nia shahar Multan, 174G.B.MuhammadPura Sheikhupura, and Wonhar Chakwal. These represented Mixed crop zone, Cotton-wheat zone, Rice-wheat zone and Rain-fed zone hereafter called MCZ, CWZ, RWZ and RFZ respectively.

At each locality two blocks each of more than 10 acres of the wheat fields, one under reduced input farming system hereafter called LIP was taken as control whereas the other under conventional high input farming system hereafter called HIP was taken as treated. The two blocks were at least 3-5 km apart from each other. At each block, two acres were selected randomly. Numbers of weed plants and wheat tillers - were collected and counted within three randomly placed quadrats (100 cm x 100 cm) across the two acre area of wheat crop. Two sampling attempts, one (S1) at about 20-30 cm high tillering stage and the second (S2) at mature earing stage of wheat plant, were made. Sampling was employed for two wheat seasons. On each wheat season two localities were sampled. To determine the suspected weed and wheat forager insects pitfall traps (for ground runners), light traps (especially for flying insects) and sweep nets were used to collect insects from the vegetation of the wheat fields.

The richness, diversity and evenness indices were computed by using Shannon's diversity index and SPDIVERS.BAS Programme.

RESULTS AND DISCUSSION

Weed diversity

Plants are the converters of Sun's energy into bio-energy for the functioning of entire ecosystem. In agroecosystems, many of these plants named as "weeds" are now known to be beneficial with respect to their role as alternate food of many pests and non-pests and harbourages of many predators of different pests. Two components of the diversity of the agroecosystem i.e., species richness (the number of species) and species evenness (the abundance of each species) were studied for the pair wheat fields of each of the four zones. The abundance of weed plants was 2.75 times higher in LIP fields (in combined data for four zones) while the weed species richness was 1.2 times greater in LIP fields than those of HIP fields (Table-1). A total of 19 species was found in all wheat fields of Punjab under study. *C.*

album, C. murale, C. iberica, M. indica, M. polymorpha and *P. plebejem* were common broad-leaved weeds of wheat in the four zones whereas the common grassy weeds were *P. minor* and *A. fatua*. The other broad-leaved weed species viz., *C. intybus, C. arvense, C. oxyacantha, C. arvensis, F. indica, L. aphaca, R. dentatus, A. arvensis* and *G. aparine* varied in their distributions among the four zones. It was interesting to note that frequency of weed plants decreased in each of the second (S2) sample whether collected from HIP or LIP wheat field. This suggested that dominance of crop plants had some inhibiting effect on weed plants, which might also be due to the potential vigour of the seed of the crop plants.

Shannon diversity indices of weed flora in HIP and LIP wheat fields of the four zones confirmed that LIP fields of all the zones harboured highly significant diversity of weeds as compared to HIP fields. However, the total diversity of both HIP and LIP fields of the four zones could also be correlated with some climatic factors such as mean rainfall and relative humidity (see Table-1).

Correspondence analysis (CA) is a method used commonly in studies of modern ecology and vegetational succession (Gauch, 1982; Ter-Braak, 1992). With CA, two-dimensional plots (one set for taxa and the other for localities) are produced showing variance within data sets on a series of axes. Taxa that frequently co-occur plot closest together, whilst those that rarely co-occur are farthest apart. The greatest variation is shown on the first axis, with other axes accounting for progressively less. The same applies to the localities plot; those which share many taxa plot closest to one another, whilst those with little in common plot farthest apart. Proximity of a species to the study site in the ordination space indicate not only how strong were they associated with a given site but it did also give an idea of influence of other sites. Fig. 2 depicts the ordination of eight study sites and 19 species of weeds recorded from high and low input wheat fields of the four zones of Punjab. The axes one, two and three of this analysis extracted 30.70%, 25.03% and 14.42% of the proportions respectively. Accordingly, on the first and reliable axis MCZ and RWZ (LIP) and RWZ and RFZ (HIP) were more closely related with respect to *Chenopodium murale, Cirsium arvense, Convolvulus arvensis, Medicago polymorpha, Phalaris minor, Avena fatua, Anagallis arvensis* and *Galium aparine*. Site preference of weeds could be seen as subgroups on the plot farther from centroids, i.e., *Centaurea iberica* preferred CWZ (HIP) and *Coronopus didymus* and *Polygonum plebejum* preferred HIP of MCZ. For low input fields, *G. aparine, P. plebejum, C. arvensis* and *A. arvensis* preferred MCZ; *L. aphaca, C. iberica* and *C. arvensis* preferred CWZ; *P. monspeliensis, R. dentatus, C. intybus, C. murale* and *C. arvense* preferred RWZ whereas *C.*

oxyacantha, F. indica, C. intybus and *P. monospeliensis* showed a predilection for RFZ. The species showed more preference to the LIP fields than those of HIP fields as shown in Figure 2.

The abundance and richness of weeds significantly reduced in HIP fields. Nontheless, most of the broad-leaved weeds occurred in fairly good numbers in HIP fields of one, two or three wheat zones. *C. iberica* and *C. didymus* were present only in HIP fields of RWZ and MCZ respectively. However, the former weed also showed vigour in both types of fields in CWZ. It was noted that probably these species especially *C. iberica* needed excess (above 185 mg kg^{-1} K and above 14 mg kg^{-1} P) quantities of Potassium or Phosphorous respectively in the soil for its growth which were available ranging from 185-230 mg kg^{-1} K and 14-26 mg kg^{-1} P in the upper 15 cm of soil of HIP fields of MCZ, RWZ and pair fields of CWZ in the upper layer 30 cm of soil (Table-2). The individual species have different tolerances, responses and optimal needs (Poole, 1974). For example, in the present study *C. iberica* seemed to grow in higher quantities of Potassium or Phosphorous probably due to the accumulation of these ingredients of the intensively used synthetic fertilizers (ammonium nitrate, super phosphate and potassium sulphate in the soil), thus may be called as indicator weed of excess quantities of K or P in the soil. The amounts and types of nutrients in soils and plants may be changed by different distintegrated ingredients of pesticides, thereby altering the dynamics of the animal community in the agroecosystem (Ries and Wert, 1972). Thus, management of soil nutrients, out-competing abundance and vigour of the crop seed in the crop system could contain the growth of other plant species in the field, as reduced abundance of weeds with the growth of wheat crop was evidenced in crop fields of all zones.

Medicago polymorpha occurred frequently in all zones except CWZ. Interestingly, it was considerably of higher frequencies in HIP fields of these three zones. The possible reasons could be that (1) this weed was least sensitive to agrochemicals, (2) the weed showed a compromising increase or resilient growth in HIP fields, prior to its elimination due to pesticidal stress, because CWZ having a longer history of receiving more consistent and extensive usage of agrochemicals, did not harbour this weed, (3) the weed had been eliminated from CWZ due to magnified quantities of chemical ingredients fatal to this weed. The LIP fields of this zone were also supposed to be affected by the residual or off-site effects of intensively used pesticides or inorganic fertilizers on cotton fields prior to wheat plantation, (4) some unknown edaphic factors may also be responsible for its elimination such as excessive quantities of P or K in the soil which favoured the growth of *C. iberica* in this zone. Wheat, *Triticum aestivum* cereal of temperate climates and proposed as to be the C_3

plant of this region (Bowen and Hollinger, 2002), is the important winter crop in the area. Almost all of the weeds associated with this crop were C_3 plants and supposedly had originated in the cool climates of temperate region because most of the species associations were related with exploitation of common resources in the same habitat (Webb and Peart, 2000). C_3 weed associations with wheat crop could be due to the same morphology of photosynthetic apparatus of these plants as well as soil nutrients and physical factors such as temperature and light (Furbank and Taylor, 1995) as has been evidenced by the changed weed flora one or two of wheat farm zones.

Shift of some weed species was evidenced in MCZ. *Asphodelus tenuifolius* and *Carthamus oxyacantha,* the characteristic weeds of sandy soil have been replaced by *C. album, C. arvensis, M. indica, R. dentatus* of heavy soils and *A. fatua* and *P. minor* of loam soil. *Vicia sativa* of sandy soils once common in wheat fields of this region was also not present in the samples of pair fields. *A. tenuifolius* mainly shifted from irrigated cultivations of the central Punjab to the sandy loam soil of *Thall* (gram belt) and some rainfed areas (Ashiq *et al.*, 2003).

Weed user insects

Irrespective of the competition for nutrients with crop plants, the weed flora relieves to certain extent the primary consumption burden on wheat plants by offering alternate producers / hosts to the phytophagous insects. Table-3 shows the abundance and species richness of various insects sampled from the pair wheat fields of four zones. Accordingly, all the HIP fields showed significantly reduced diversity (H') of insects. The CA on first axis (Figure 3) indicating highest variation (63.63%) showed that LIP fields of CWZ, RWZ and RFZ were close to each other with respect to the co-occurrence of insect taxa, whereas these fields of MCZ differed to some extent. The comparison of high input (HIP) and low input (LIP) wheat farms of all the four zones of the Punjab province has shown that agrochemicals reduced significantly the weed and insect abundance and species richness. These results were truly the same as those demonstrated by Moreby and Southway (1999), who compared herbicide treated and untreated plots in the headlands of winter cereal fields in southern England.

HIP fields of four zones lying farthest significantly differed from those of LIP fields with respect to the co-occurrence of insect species. The highly treated fields of MCZ and RWZ showed wide distance with respect to the occurrence of springtail (collembolan) taxa which differed from those of CWZ and RFZ (probably) due to generally an arid climate of these zones The treated fields of these zones harboured abundant *Onychiurus armatus* belonging to zoophagous-saprophagous springtails of family Onychiuridae while the former zones had greater abundance of *Isotomus* sp. belonging to saprophagous family Isotomidae.

The HIP fields of MCZ and RWZ (of intensive irrigation) also harboured phytophagous springtail, *Sminthrus viridis* in good number. The higher densities of pests such as *M. miscanthi, A. maidis, Pechnephorus* sp. and *C. partellus* in HIP fields of some zones suggested that pest problem could increase or resurge even after the use of chemicals probably due to the reduced number of chemical sensitive predators or competitor species within the same trophic guild. Elimination of natural enemies disrupts the natural balance of the insect-plant system by allowing pests to multiply uncontrollably, sometimes resulting in new pest problems (Debach and Rose, 1977; Debach and Rosen, 1991; Gerson and Cohen, 1989; Huffaker *et al*., 1969, 1970; McMurtry *et al*., 1970).

Weed foragers (phytophagous insects)

Out of a total of 68 species of insects captured from all four zones 29 insect species were found to belong to phytophagous families (Table-4). All of these insects were known as major or minor pests of different crops including wheat crop. From the literature on line it was determined that out of 29 only 14 species were reported as major (8) and minor (6) pests on wheat crop. The rest 15 species were not yet reported as major or minor pests of wheat. It meant that at least 15 out of 29 or more than 50% phytophagous insects used to feed on weed plants.

Table-5 gives information on relatively abundant species of weeds and insects. The table was based on the general understanding that abundant phytomorphic autotrophs helped multiplication of related insect consumer populations. Accordingly, the weed and insect communities considerably differed between the pair fields and among the four zones. All the HIP fields showed reduced species richness with respect to their abundance. In HIP field the abundant weed populations ranged from 1 (CWZ) to 3 (MCZ) whereas in LIP fields these populations ranged from 3 (CWZ) to 7 (RWZ). The related insect consumers also reduced considerably in species richness in all HIP fields.

Interspecific competition depends upon availability and diversity of resources (Purves *et al*., 1998). Feeding delineation reduces competition (Gauld and Mound, 1982). Phytomorphic diversity helps feeding delineation in phytophagous species (Mizell, 2005). Conversely, resource / food scarcity increases the demand / competition among utilitarians. From the Table-5 it was possible to assess the strength of competition by calculating the resource (weed) demand and availability ratio (considering single insect species gets sustenance from single weed species). Accordingly, the resource demand (No. of phytophagous insects) and availability (No. of weed species) ratio was considerably higher in HIP fields of all zones; CWZ>RFZ>MCZ>RWZ, rendering the consumers in stronger competition whereas in LIP fields it was found to be low or loose to some extent. The D/A ratio were low in CWZ>MCZ and inverse in favour of weed heterogeneity and abundance in LIP fields of RWZ and RFZ. Thus from the above data it could be inferred that stenophagous herbivores/specialist feeders/users of specific weed plants could face defendant antiherbivore behaviour of other weeds or wheat and go extinct lacking or in the absence of their preferred (specialized) food in the system. Similarly a good number of moderately euryphagous herbivores facing reduced feeding niche might be compelled to shift to crop plants due to weed eradication by agrochemicals. Marshall *et al.* (2003) have recorded 52 weed specific insects in UK. According to them, 12 insect species have been declared as endangered in the Red List of IUCN.

Pests

The agroecosystems do offer a biosystem which is deliberately made simple to alleviate nutritional competition of the crop plants with non crop plants. Thus in the absence of the preferred site (some weeds) of a predator the prey's recovery to ad infinitum assumes pest status on the crop. In this context some major and minor pests of wheat were looked at (see Table-4).

Major pests

Those species of insects were taken as pests which fed on wheat plants, and suspected pests who subsisted on weeds as alternate hosts. Among aphids *Microsiphum miscanthi* was known to infest wheat crop in all zones indiscriminately whether sprayed by agrochemicals or not, but surprisingly their number was almost double in all HIP fields. *Aphis maidis* was found only in HIP fields of MCZ. One reported major pest species viz., *Pechnephorus* sp. was found to occur in the pair fields of MCZ and CWZ, whereas *C. partellus* (Pyrallidae) was common in the pair fields of RWZ and RFZ and were least affected by agrochemicals. *Anaphothrips sudanensis* (Thripidae) was present in LIP fields of all zones, while it was absent in HIP fields. These herbicides might have differential effects on animal pests rather than plants. Brown *et al.* (1987) reported that when corn-growing areas were treated with 2, 4-D at the recommended dosage of I kg ha^{-1}, the number of corn leaf aphids increased three fold; corn borers were 26% more abundant, and were 33% larger than those insects present on untreated corn. These larger corn borers produced one third more eggs, and thus contributed to the build-up of corn borers on corn.

The total number of recorded major pests was 12 in all the four types of agroecosystem. Out of these, four major pest species of family Scarabaeidae viz., *S. brahminus, G. miliaris, A. villosella* and *P. dionysis* had not been recorded as pests of wheat. Thus, these species could be suspected to consume weeds as major food items or use weeds for other needs like sheltering or egg laying etc.

Minor pests

LIP fields harboured greater diversity of minor pests than those of HIP fields. *G. bimaculatus*, *S. lituralis* and *E. insulana* were present in the pair fields of all zones except *E. insulana* which was absent in HIP fields of CWZ. All LIP fields harboured two more species of minor pests viz., *A. proxima* and *G. orientalis. T. indicus* occurred in HIP fields of MCZ and CWZ only.

Table-4 showed that seventeen minor pest species occurred in the pair wheat fields of four zones. Out of 17 minor pest species, 11 pest species had not been reported on wheat plants. Thus these minor pest species were suspected to feed on weed plants or as alternate hosts. These were *C. trachypterus, E. moli, A. fabricii, A. domesticus, H. armigera, A. ipsilan, E. vittella, A. nigrisigna, T. orichalcea, M. brassicae* and *N. pronuba.*

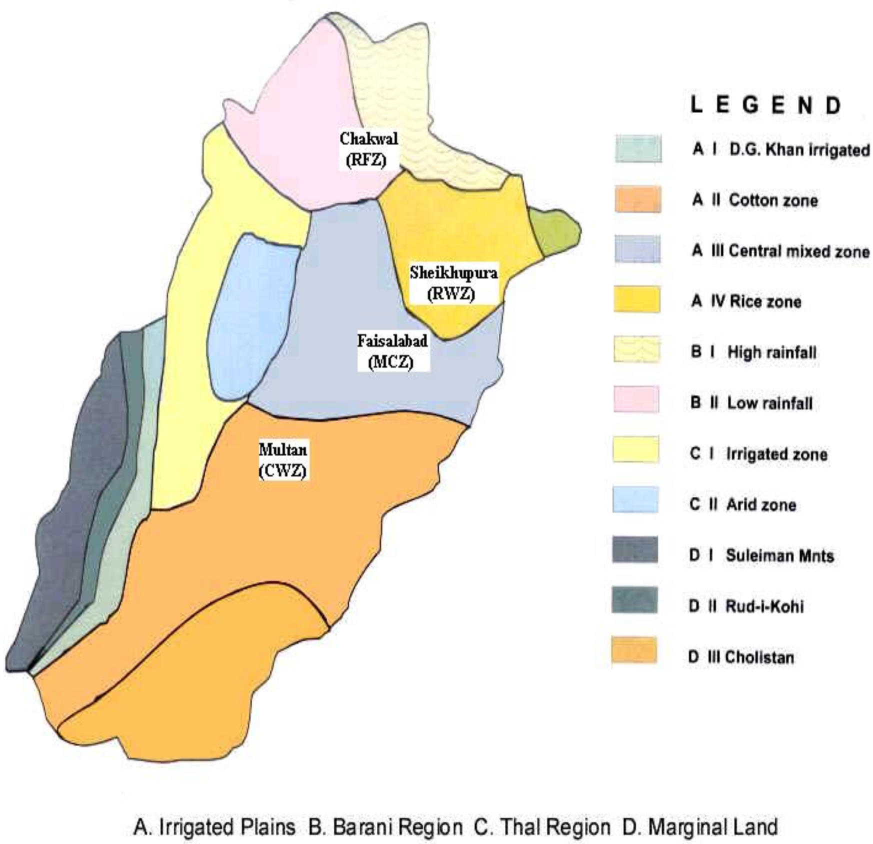
Predators

Occupying the higher trophic levels as secondary or tertiary consumers, predators help controlling the populations of primary consumers or phytophagous organisms. While looking at the Table-5 it revealed that insects belonging to predator/scavengers/detrivore families were considerably higher in all LIP fields ranging from 27 in RFZ, 29 each in RWZ and CWZ, and 32 in MCZ wheat farms. In almost all HIP wheat farms species richness of predators at secondary or tertiary consumer's trophic level of the above ground was considerably reduced food web. At this distant trophic level, the predator species were expected to be lesser in abundance, yet their relative abundance in pair fields of different zones could provide an index of their relationship with their suspected prey abundance. In all LIP fields the insect communities of relatively abundant populations included at least 3 frequently occurring predator species each but CWZ showed comparatively greater number (5) of predator species. The potential aphid pests (*S. avenae, S. gramium* and *D. noxia*) are held in check or at below economic injury levels by a combination of factors but especially by natural enemies and native predators (Zuniga, 1990; Stary *et al*., 1993).

The detrivore or scavenger insects where present in abundance indicated presence of increased undecomposed organic matter. Higher diversity of abundant weed plants in LIP wheat fields of MCZ and RWZ could be a possible explanation for this increase but detrivore's abundance in HIP fields of CWZ seemed to signal the deposition of organic matter in the field due to slow process of decomposition. This probably happened due to decreased decomposer microflora such as bacteria and fungi in the soil.

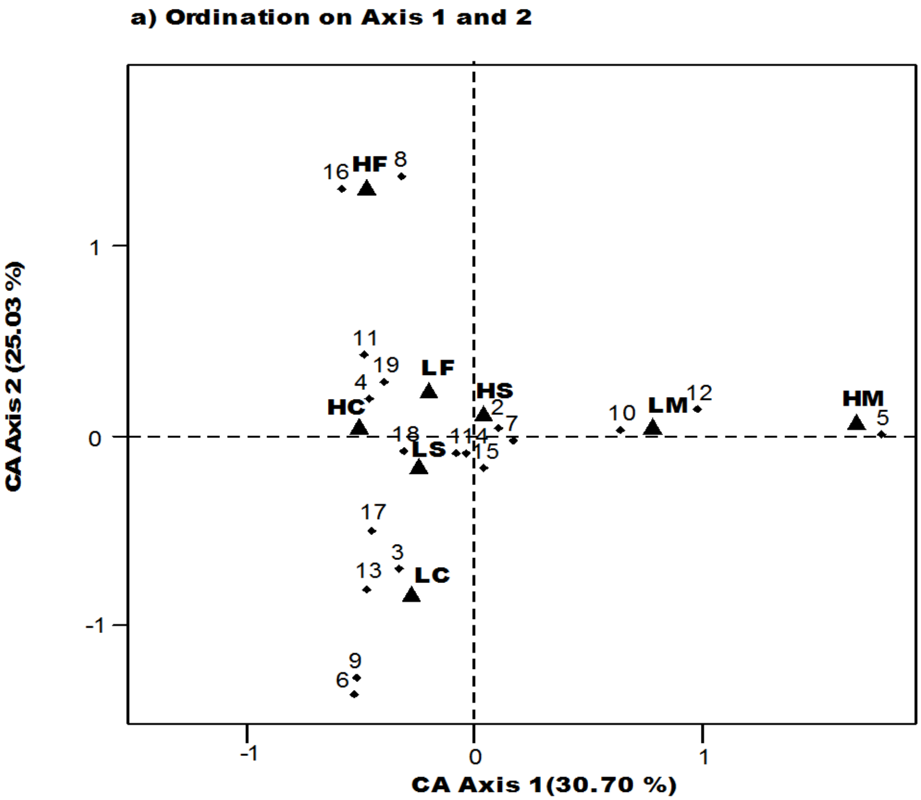
CONCLUSION

It is concluded from the research that almost all the winter weeds occurring in wheat fields had C_3 plant associations with the C_3 wheat plant. (*It was also recognized from literature that C_4 weeds were associated with C_4 plant of sugarcane crop*). All the weed species reduced in density and insects fluctuated with the growth of the wheat crop in all the eight (four HIP and four LIP) fields. *C. iberia* and *C. didymus* were suspected to associate with higher quantities of potassium and phosphorous in the soil. In this respect these could be suspected as bioindicator weeds. It was interesting to correlate the abundance of *T. indicus* with the exclusively P or K rich soils of CWZ which harboured an additional weed *C. iberica.* The *C. didymus* might be the harbourage of *T. indicus* in MCZ. However, *C. iberica* was also evidenced in HIP fields of RWZ, but without any indication of *T. indicus*. The present study suggests the potential for natural pest control in reduced chemical input fields as the known pest populations were low in abundance in all LIP fields. The seemingly redundant flora within the agro-ecosystem is not recommended to be eliminated altogether from the system but should be segregated with respect to their detrimental effects and then taken back to the system as necessary primary cover producers or green manure.



Study Areas: A-II (Multan), A-III (Faisalabad), A-IV (Sheikhupura), B-I (Chakwal). Source: www.punjab.gov.pk

Figure 1. The Map showing the locations of different districts of Punjab (Pakistan) from which high and low input samples were taken

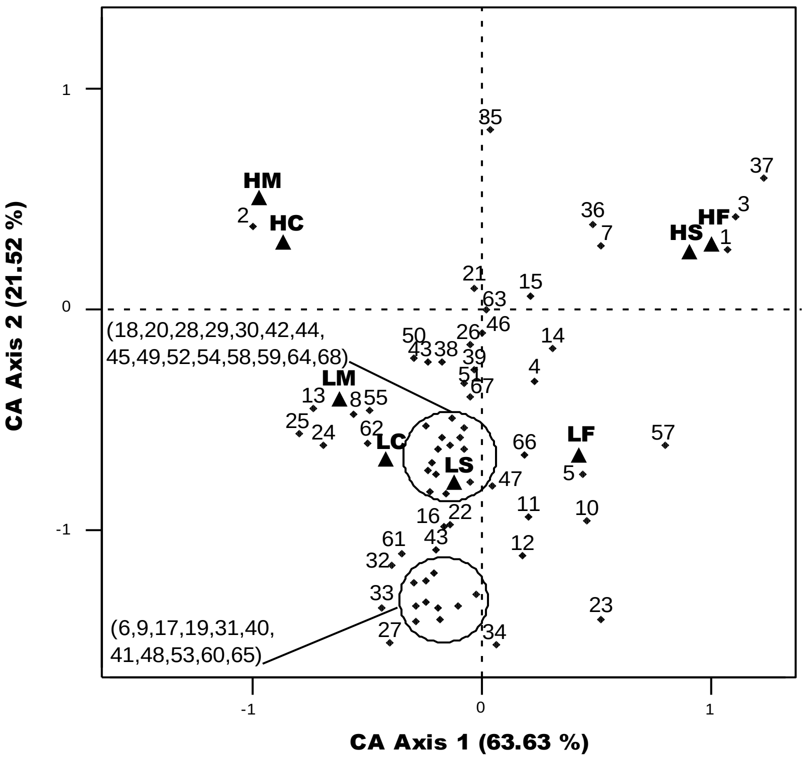


*HF = HIP-MCZ, LF = LIP-MCZ, HM = HIP-CWZ, LM = LIP-CWZ, HS = HIP-RWZ, LS = LIP-RWZ, HC= HIP-RFZ, LC = LIP-RFZ

Species Identity: 1*. C. album*, 2. *C. murale,* 3. *C. intybus,* 4. *C. arvense,* 5. *C. iberica,* 6. *C. oxyacantha,* 7. *C. arvensis*, 8*. C. didymus*, 9. *F. indica,* 10*. L. aphaca*, 11. *M. polymorpha*, 12. *M. indica,* 13. *P. monspeliensis,* 14. *P. minor,* 15. *A. fatua,* 16. *P. plebejum,* 17. *R. dentatus,* 18*. A. arvensis,* 19. *G. aparine*

Figure 2. Ordination on axis 1 and 2 of eight study sites* and 19 species of weeds recorded from high and low input wheat fields in the four zones of Punjab.

a) Ordination on Axis 1 and 2



* HF = HIP-MCZ, LF = LIP-MCZ, HM = HIP-CWZ, LM = LIP-CWZ
HS = HIP-RWZ, LS = LIP-RWZ, HC= HIP-RFZ, LC = LIP-RFZ

Species Identity: 1. *Isotomas* sp., 2. *O. armatus,* 3. *S. viridis,* 4. *G. bimaculatus,* 5. *A. domesticus,* 6. *G. orientalis,* 7. *C. trachypterus,* 8. *H. priesnerianus,* 9. *A. sudanensis,* 10. *O. obesus,* 11. *M. obesi,* 12. *Labidura* sp*.,* 13. *A. janus,* 14. *E. moli,* 15. *M. miscanthi,* 16. *A. maidis,* 17. *C. carnia,* 18. *C. maderae,* 19. *C. hamifer,* 20. *C. pictus,* 21. *P. fuscipes,* 22. *O. olens,* 23. *S. brahminus,* 24. *G. miliaris,* 25. *A. villosella,* 26. *P. Dionysius,* 27. *A. mancus,* 28. *C. septempunctata,* 29. *M. sexmaculata,* 30. *C. undecimpunctata,* 31. *C. sexmaculata,* 32. *B. suturalis,* 33. *B. muronota,* 34. *M. indicus,* 35. *T. indicus,* 36. *A. fabricii,* 37. *S. multistriatus,* 38. *Pechnephorus* sp*.,* 39. *P. brassica,* 40. *A. styx,* 41. *A. convolvuli,* 42. *E. complana,* 43. *U. pulchella,* 44. *H. armigera,* 45. *S. lituralis,* 46. *A. ipsilan,* 47. *E. insulana,* 48. *E. vittella,* 49. *A. nigrisigna,* 50. *T. orichalcea,* 51. *M. brassicae,* 52. *N. pronuba,*

53. *D. chrysippus,* 54. *C. partellus,* 55. *A. quadrimaculatus,* 56. *Culex* sp., 57. *A. caliginosa,* 58. *E. balteatus,* 59. *E. tenax,* 60. *S. scripta,* 61. *S. Indiana,* 62. *M. domestica,* 63. *A. soccata,* 64. *C. cinctus,* 65. *A. proxima,* 66. *Formica* spp., 67. *A. florae,* 68. *A. dorsata*

Figure 3. Ordination on axis 1 and 2 of eight study sites* and 68 species of insects recorded from high and low input wheat fields in the four zones of Punjab.

Table-1. Comparison of Species richness and abundance of weeds (m^{-2}) (S_1+S_2= each zone consists of 2 samples by taking mean of 3 quadrates) in high and low input wheat fields of four zones of Punjab.

Table-1. Comparison of Species richness and abundance of weeds (m^{-2}) (S_1+S_2= each zone consists of 2 samples by taking mean of 3 quadrates) in high and low input wheat fields of four zones of Punjab.

Families	Inputs / Species		HIP (S_1+S_2) MCZ	CWZ	RWZ	RFZ	Total	LIP (S_1+S_2) MCZ	CWZ	RWZ	RFZ	Total
Chenopodiaceae	*Chenopodium album*		3.5	0	8	0	**11.5**	17	12	19.5	11.5	**60**
	Chenopodium murale		2.5	3.5	4.5	0	**10.5**	10	5	13	4	**32**
Compositae	Cichorium intybus		0	0	0	1.5	**1.5**	0	1	2.5	3	**6.5**
	Cirsium arvense		2	0	1	0	**3**	3	0	3.5	2	**8.5**
	Centaurea iberica		0	9	3.5	0	**12.5**	0	7.5	0	1	**8.5**
	Carthamus oxyacantha		0	0	0	0	**0**	0	0	2	7.5	**9.5**
Convolvulaceae	*Convolvulus arvensis*		0	0	1	2	**3**	12	10	1	4.5	**27.5**
Cruciferae	*Coronopus didymus*		4.5	0	0	0	**4.5**	0	1.5	2	0	**3.5**
Fumariaceae	*Fumaria indica*		0	0	0	0	**0**	0	0	4.5	11.5	**16**
Papilionaceae	*Lathyrus aphaca*		0	0	2	0	**2**	2	9	3.5	0	**14.5**
	Medicago polymorpha		9	0	9.5	9	**27.5**	8	0	7	4	**19**
	Melilotus indica		3.5	9	0	0	**12.5**	3	10	5	3.5	**21.5**
Poaceae	*Polypogon monspeliensis*		0	0	0	0	**0**	0	0	4.5	2.5	**7**
	Phalaris minor		0	3	2	6.5	**11.5**	13	4	6	6	**29**
	Avena fatua		0	2	8.5	0	**10.5**	9	3	8.5	5.5	**26**
Polygonaceae	*Polygonum plebejum*		9.5	0	0	0	**9.5**	9	0	3	0	**12**
	Rumex dentatus		0	0	2.5	2.5	**5**	1	0	8	4.5	**13.5**
Primulaceae	*Anagallis arvensis*		0	0	0	3.5	**3.5**	6	2	5.5	2	**15.5**
Rubiaceae	Galium aparine		1	0	0	0	**1**	10	0	5	1	**16**
	Number of Weeds		**35.5**	**26.5**	**42.5**	**25**	**129.5**	**103**	**65**	**104**	**74**	**346**
	Number of Species (N0)		8	5	10	6	**16**	13	11	18	16	**19**
Shahnnon diversity indices		H'	1.87	1.44	*2.04*	1.59	**2.48**	2.38	2.18	2.63	2.56	**2.73**
		N1	6.48	4.23	7.73	4.93	**11.91**	10.80	8.84	13.86	12.98	**15.31**
		N2	6.39	4.20	7.58	4.88	**10.42**	10.68	8.78	12.32	12.77	**13.07**
		E5	0.98	0.99	0.98	0.99	**0.86**	0.99	0.99	0.88	0.98	**0.84**

		HIP Vs LIP MCZ	CWZ	RWZ	RFZ	Total
Shahnnon diversity indices	-					
	t-test	4.793	6.224	5.201	7.475	**3.681**
	df	54	52	83	44	**218**
	P-Value	0.000***	0.000***	0.000***	0.000***	**0.000*** **
	-	Climatic Factors				
Mean Temperature (°C)		18.8	19.2	18.8	14.6	**17.8**
Mean Rel. Humidity (mm)		61.4	57.9	80.1	72.9	**68.1**
Mean Rainfall (mm)		3.1	1.4	20.5	34.2	**14.8**

Table-2. Analysis of the soil from high and low input areas of four wheat zones in Punjab.

Area	Locality	Sample depth (cm)	EC (dsm^{-1})	T.S.S ($mg\ kg^{-1}$)	Soil pH	O.M. (%)	Available P ($mg\ kg^{-1}$)	Available K ($mg\ kg^{-1}$)
High Input	MCZ	0-15	0.18	18.0	8.0	0.94	19.6	230
	(Faisalabad)	15-30	0.13	13.0	8.2	0.90	12.7	140
	CWZ	0-15	0.25	25.0	8.1	0.78	26.2	230
	(Multan)	15-30	0.27	27.0	8.2	0.68	24.8	220
	RWZ	0-15	0.15	15.0	8.3	1.00	15.0	215
	(Sheikhupura)	15-30	0.10	10.0	8.4	0.72	8.5	155
	RFZ	0-15	0.26	26.0	8.0	0.70	12.5	150
	(Chakwal)	15-30	0.20	20.0	8.2	0.62	5.2	70
Low Input	MCZ	0-15	0.16	16.0	8.2	0.98	15.8	180
	(Faisalabad)	15-30	0.12	12.0	8.3	0.93	10.8	140
	CWZ	0-15	0.20	20.0	8.2	1.00	16.3	215
	(Multan)	15-30	0.22	22.0	8.4	0.90	14.0	185
	RWZ	0-15	0.14	14.0	8.3	1.03	12.0	155
	(Sheikhupura)	15-30	0.09	9.0	8.6	0.72	3.3	100
	RFZ	0-15	0.25	25.0	8.0	0.72	10.0	130
	(Chakwal)	15-30	0.20	20.0	8.2	0.62	2.9	40

Table-3. Comparison of species richness and abundance of insects (S_1+S_2= Summation of 2 samples) in high and low input wheat fields of four zones of Punjab.

Families	**Inputs**	**HIP (S_1+S_2)**					**LIP (S_1+S_2)**				
	Species	**MCZ**	**CWZ**	**RWZ**	**RFZ**	**Total**	**MCZ**	**CWZ**	**RWZ**	**RFZ**	**Total**
Isotomidae	*Isotomas* sp.	5649	0	2370	0	8019	1124	0	286	0	1410
Onychiuridae	*Onychiurus armatus*	53	5734	0	2815	8602	11	1502	637	740	2890
Sminthuridae	Sminthurus viridis	482	0	1022	0	1504	98	0	0	0	98
Gryllidae	*Gryllus bimaculatus*	51	13	30	13	107	21	16	39	19	95
	Acheta domesticus	0	0	26	0	26	21	4	22	0	47
Gryllotalpidae	*Gryllotalpa orientalis*	0	0	0	0	0	10	11	11	14	46
Acrididae	*Chrotogonus trachypterus*	13	8	27	7	55	11	0	0	0	11
Phlaeothripidae	*Haplothrips priesnerianus*	0	110	6	0	116	65	143	36	16	260
Thripidae	Anaphothrips sudanensis	0	0	0	0	0	11	7	17	9	44
Termitidae	*Odontotermus obesus*	7	0	4	0	11	20	0	11	2	33
	Microtermus obesi	2	0	0	1	3	5	0	2	2	9
Labiduridae	*Labidura* sp.	6	0	2	0	8	44	20	12	0	76

Pentatomidae	*Aspongopus janus*	0	11	0	4	15	3	13	2	10	28
Cicadellidae	*Empoasca moli*	37	30	124	18	209	17	19	93	0	129
Aphididae	*Macrosiphum miscanthi*	569	444	638	163	1814	265	220	207	117	809
	Aphis maidis	12	11	15	7	45	73	87	57	39	256
Chrysopidae	*Chrysoperla carnia*	0	0	1	1	2	23	30	22	11	86
Carabidae	*Calosoma maderae*	117	111	42	113	383	154	166	86	213	619
	Chlaenius hamifer	0	0	0	4	4	14	13	22	0	49
	Chlaenius pictus	0	0	0	6	6	11	6	0	0	17
Staphylinidae	*Paederas fuscipes*	70	78	81	57	286	30	40	32	22	124
	Ocypus olens	0	4	7	0	11	15	17	17	7	56
Scarabaeidae	*Scarabaeus brahminus*	0	0	0	0	0	4	0	0	0	4
	Gymnopleurus miliaris	0	2	0	0	2	0	2	2	1	5
	Apogona villosella	0	0	0	1	1	0	1	0	1	2
	Phyllognathus dionysius	1	1	0	0	2	1	1	0	0	2
Elateridae	*Agriotes mancus*	0	0	0	0	0	0	0	11	15	26
Coccinellidae	*Coccinella septempunctata*	86	104	107	72	369	147	169	222	130	668
	Menochiolus sexmaculata	40	31	27	25	123	98	60	141	82	381
	Coccinella undecimpunctata	44	44	33	24	145	80	99	90	86	355
	Cheilomenes sexmaculata	10	0	0	0	10	71	32	62	32	197
	Brumoides suturalis	0	0	0	0	0	0	21	35	15	71
Tenebrionidae	*Balps muronota*	0	0	0	0	0	1	2	0	1	4
	Mesomorphus indicus	0	0	0	0	0	5	0	9	0	14
Curculionidae	*Tanymecus indicus*	32	31	0	0	63	0	0	0	0	0
	Alcidodes fabricii	9	7	21	3	40	0	0	5	0	5
Scolytidae	*Scolytus multistriatus*	6	0	0	0	6	0	0	0	0	0
Chrysomelidae	*Pechnephorus* sp.	1	1	0	0	2	1	2	0	0	3
Pieridae	*Pieris brassica*	27	21	28	18	94	0	0	41	30	71
Sphingidae	*Acherontia styx*	0	0	0	0	0	2	1	2	5	10
	Agrius convolvuli	0	0	0	0	0	6	5	3	4	18
Arctiidae	*Eilema complana*	1	3	1	0	5	6	3	3	4	16
	Utetheisa pulchella	1	0	0	1	2	4	3	2	5	14
Noctuidae	*Helicoverpa armigera*	33	38	56	18	145	32	59	134	27	252
	Spodoptera lituralis	6	6	5	6	23	12	8	10	14	44
	Agrotis ipsilan	12	9	7	8	36	10	8	5	2	25
	Earias insulana	5	0	2	3	10	10	7	6	4	27
	Earias vittella	0	0	0	0	0	9	5	5	4	23
	Autographa nigrisigna	3	2	5	4	14	6	5	7	8	26
	Thysanoplusia orichalcea	3	4	3	5	15	3	3	3	4	13
	Mamestra brassicae	5	3	7	7	22	6	8	5	4	23
	Noctua pronuba	2	6	4	3	15	8	4	8	11	31
Danaidae	Danaus chrysippus	0	0	0	0	0	13	15	17	10	55
Pyralidae	*Chilo partellus*	0	0	3	3	6	3	2	2	8	15

Culicidae	*Anopheles quadrimaculatus*	21	71	13	138	243	34	107	36	182	359
	Culex sp.	100	86	113	91	390	124	106	117	97	444
Phoridae	*Aneurina caliginosa*	13	0	0	0	13	20	0	0	0	20
Syrphidae	*Episyrphus balteatus*	50	58	36	24	168	62	60	70	71	263
	Eristalis tenax	29	35	35	16	115	50	51	57	40	198
	Sphaerophoria scripta	0	0	0	0	0	10	9	13	5	37
	Sphaerophoria indiana	0	0	0	11	11	27	45	28	36	136
Muscidae	*Musca domestica*	6	17	0	0	23	7	26	7	18	58
	Atherigona soccata	70	66	82	57	275	41	37	36	29	143
Cephidae	*Cephus cinctus*	1	0	2	3	6	1	1	3	2	7
Tenthredinidae	*Athalia proxima*	0	0	0	0	0	74	139	89	23	325
Formicidae	*Formica* spp.	412	45	170	201	828	592	95	357	326	1370
Apidae	*Apis florea*	15	14	8	6	43	17	17	13	9	56
	Apis dorsata	22	24	25	13	84	36	37	37	23	133
	Number of Insects	**8134**	**7283**	**5188**	**3970**	**24575**	**3679**	**3569**	**3304**	**2589**	**13141**
	Number of Species	**44**	**37**	**39**	**39**	**55**	**60**	**55**	**57**	**52**	**66**
Shahnnon diversity indices	H'	1.41	1.11	1.93	1.41	1.98	2.80	2.58	3.11	2.79	3.06
	N1	4.10	3.02	6.88	4.09	7.27	16.37	13.21	22.49	16.23	21.36
	N2	2.02	1.60	3.76	1.96	4.15	7.49	5.15	13.34	8.36	11.59
	E5	0.33	0.30	0.47	0.31	0.50	0.42	0.34	0.57	0.48	0.52

-	**HIP Vs LIP**				
-	MCZ	CWZ	RWZ	RFZ	Total
t-test	43.986	43.093	40.408	35.488	72.679
df	>120	>120	>120	>120	>120
P-Value	0.000***	0.000***	0.000***	0.000***	0.000***
-	**Climatic Factors**				
Mean Temperature (^oC)	18.8	19.2	18.8	14.6	**17.8**
Mean Rel. Humidity (mm)	61.4	57.9	80.1	72.9	**68.1**
Mean Rainfall (mm)	3.1	1.4	20.5	34.2	**14.8**

Table-4. Determination of Trophic Guild (Producers for Primary Consumers) in high and low input wheat fields of four zones. (FR= Family Reported, SR= Species Reported)

Families	Phytophagous Species	Pests	Wheat Consumers FR	Wheat Consumers *SR*	Weeds
Acrididae	*Chrotogonus trachypterus*	Minor	+	-	+
Aphididae	*Macrosiphum miscanthi*	Major	+	+	-
	Aphis maidis	Major	+	+	-
Chrysomelidae	*Pechnephorus* sp.	Major	+	+	-
Cicadellidae	*Empoasca moli*	Minor	+	-	+
Curculionidae	*Tanymecus indicus*	Minor	+	+	-
	Alcidodes fabricii	Minor	+	-	+
Elateridae	*Agriotes mancus*	Major	+	+	-
Gryllidae	*Gryllus bimaculatus*	Minor	+	+	-
	Acheta domesticus	Minor	+	-	+
Gryllotalpidae	*Gryllotalpa orientalis.*	Minor	+	+	-
Noctuidae	*Helicoverpa armigera*	Minor	+	-	+
	Spodoptera lituralis	Minor	+	+	-
	Agrotis ipsilan	Minor	+	-	+
	Earias insulana	Minor	+	+	-
	Earias vittella	Minor	+	-	+
	Autographa nigrisigna	Minor	+	-	+
	Thysanoplusia orichalcea	Minor	+	-	+
	Mamestra brassicae	Minor	+	-	+
	Noctua pronuba	Minor	+	-	+
Pyrallidae	*Chilo partellus*	*Major*	+	+	-
Scarabaeidae	*Scarabaeus brahminus*	Major	+	-	+
	Gymnopleurus miliaris	Major	+	-	+
	Apogona villosella	Major	+	-	+
	Phyllognathus dionysius	Major	+	-	+
Tenthredinidae	*Athalia proxima*	Minor	+	+	-
Termitidae	*Odontotermus obesus*	Major	+	+	-
	Microtermus obesi	Major	+	+	-
Thripidae	*Anaphothrips sudanensis*	Major	+	+	-

Table-5. Relative abundance relationship of weeds and their foraging insects in four zones (SWF=Suspected weed feeders; DA= Demand (weed) Availability)

		Relatively abundant species						Not known as pest	
Zone	Input	Weed	Insects	Trophic guild	Total weed species	Total number of Insets	Reported wheat pest	DA-ratio (SWF)	Weed users as predators, Scavengers, Detrivores
MCZ	HIP	*Coronopus didymus* *Medicago polymorpha* *Polygonum plebejum*	*Isotomus* spp. *Sminthurus viridis* *Mesomorphus indicus* *Culex spp.*	S P S Z	8	44	9	1.87:1.00 (15)	20
	LIP	*Convolvulus arvensis* *M. polymorpha* *P. plebejum* *Anagallis arvensis* *Galium aparine*	*Odontotermes obesus* *Microtermus obesi* *Labidura spp.* *Aphis maidis* *Chrysoperla carnea* *Chlaenius hemifer* *C. pictus* *Balps muronota* *Acherontia styx* *Agrius convolvulus* *Earias insulana* *E. vitella* *Cules spp.* *Eristalis tenax* *Athelia proxima*	PS PS O P Z Z Z S P P P P Z PZ P	13	60	11	1.31:1.00 (17)	32

	HIP	*Centaurea iberica*	*Onychiurus armatus* *Haplothrips priesnerianus* *Aspongopus janus* *Gymnopleurus miliaris* *M. indicus*	ZS O PZ PS S	5	37	6	2.60:1.00 (13)	18
CWZ	LIP	*C.iberica* *C. arvensis* *Lathyrus aphaca*	*Haplothrips priesnerianus* *Chrysoperla carnea* *Ocypus olens* *C. pictus* *G. miliaris* *Cheilomenes sexmaculata* *Brumoides suturalis* *Scolytus multistriatus* *Acherontia styx* *Sphaerophoria scripta* *S. indiana* *Cephus cinctus*	O Z Z Z PS Z Z P P PZ PZ P	11	55	10	1.45:1.00 (16)	29
RWZ	HIP	*M. polymorpha*	*S. viridis* *Chrotogonus trachypterus* *Tanymecus indicus*	P P P	10	39	6	1.50:1.00 (15)	18

	LIP	*C. murale* *C. intybus* *c. arvensis* *Polypogon monospliensis* *Rumex dentatus* *A. arvensis* *G. aparine*	Anaphothrips sudanensis *C. hamifer* *O. olens* *G. miliaris* *Phyllognathus dionysius* *Cheilomenes sexmaculata* *Balps muronota* *Helicoverpa armigera* *Danaus chrysippus* *Eristalis tenax* *Cephus cinctus*	P Z Z PS PS Z S P P PZ P	18	57	11	0.94:1.00 (17)	29
	HIP	*M. polymorpha*	No insect with considerable Abundance	-	6	39	6	2.17:1.00 (13)	20
RFZ	LIP	*C. intybus* *Carthamus oxyacanthus* *Fumaria indica* *P. monospliensis* *R. dentatus*	*P. Dionysius* *Pieris brassica* *Eilema complana* *Chilo partellus*	PS P P P	16	52	11	0.87:1.00 (14)	27

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