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Effect of dates of sowing and insecticidal spary on arthropods diversity in direct seeded rice ecosystem

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Abstract
The present studies were conducted at Punjab Agricultural University Ludhiana and PAU Regional Research Station Gurdaspur during *Kharif* 2017-18 to determine arthropods diversity under paired row direct seeded rice with different dates of sowing and sprayed & unsprayed condition. The total 94 species of arthropods were recorded in direct seeded rice ecosystem. Among three dates of sowing, the highest arthropods diversity index was observed in the second date of sowing (first fortnight of June) due to higher evenness index and it was followed by third (second fortnight of June) and first (second fortnight of May) date of sowing. Higher diversity was recorded at Gurdaspur as compared to Ludhiana. The highest leaffolder& stem borer incidence and planthoppers population was also observed in third date (second fortnight of June) of sowing. The leaffolder incidence and planthoppers population was higher at Gurdaspur whereas stem borer incidence was higher at Ludhiana.

Keywords: Arthropods, conditions, diversity, fortnight, investigation, paired rows

Introduction
Rice (*Oryza sativa*) is the second-most important cereal crop after maize in the world. It is a crop that ensures food security in many of the developing countries for East Asia and Southeast Asia regions. Therefore, rice being the most consumed cereal grain globally, the growth of the rice market is expected to increase. About 40% of the world population consumes rice as the major staple food (Dunna and Roy, 2013) [1]. The global rice (grain) production during 2018-19 was about 495.87 million tons (mt) and global consumption was recorded nearly 490.27 mt (Anonymous, 2019) [2]. In Punjab it occupied an area of 30.46 lakh ha, which was nearly 50 per cent of total cultivated area of the state with production of 199.72 lakh tones averaging 65.16 quintal yield per hectare (Anonymous, 2020) [3]. In rice fields due to high humidity various physical, chemical and biological processes occur rapidly and these fields become rich sources of arthropod biodiversity (Fritz *et al.*, 2011) [4]. Ecosystems in rice fields change rapidly, because in short period of time rice fields have to pass through various agronomic practices and series of growth stages that make rice fields heaven for wide range of pests. To these pest, rice fields provide food, shelter and breeding grounds (Edirisinghe and Bambaradeniya, 2006) [5]. Arthropod community of rice fields consists of rice insect-pests, non-rice insect-pests and their natural enemies that reside or just visit rice crop (Heong *et al.*, 1991) [6].

The study on biodiversity in contrast with agro ecosystems has attained importance in the fields of ecology and conservation, because the maintenance of biodiversity is pre-requisite for ecologically sustainable productivity in agriculture (Pimentel *et al.* 1992 and Scherr & McNeely 2008) [7, 8]. Biodiversity productivity hypothesis infers that biodiversity is principal element for sustaining ecological balance and for maintaining agricultural productivity. Non-judicious use of pesticides and worst farming practices like monoculture are major threats to biodiversity associated with paddy cropping (Asghar *et al.*, 2013) [9].

For developing a sound crop ecosystem, it is necessary to study diversity of arthropod community in rice crop systems. It is also mandatory to check high rate of insect pest population in rice to get higher production (Savary *et al.*, 2012) [10]. Natural enemies are widely used in tropical Asian conditions to check insect pest problems in rice (Matteson, 2000) [11]. The clear demarcation of insect species is necessary for pest management. For determining the use of pesticides, it is important to understand the role of insect species whether it is a natural

enemy or pest (Emden and Williams, 1974) [12].

During process of domestication, human has disturbed cropping patterns and distribution of crops due to selection process, which adversely modified insect diversity, their inter and intra specific behavior (Evans 1993) [13]. While shifting from natural ecosystem to non-sustainable agriculture system, loss of biodiversity can force arthropod community to distribute in abnormal way, which can reduce ecological functions such as herbivore regulation. The changes in diversity and abundance of other arthropod guilds can also destabilize arthropod food webs (Chen and Bernal 2011) [14]. Decline in arthropod diversity is also associated with pest emergence and agricultural intensification (Wilby *et al.*, 2006) [15]. Monoculture is key feature of modern agriculture, which decreased species diversity of agro-ecosystems, particularly in rice fields and has led to instability (Roger *et al.*, 1991) [16].

An insight of literature in India indicated that there is dearth of information on abundance of arthropods diversity in paired rows under direct seeded rice (DSR). Therefore the present study was carried out to determine the biodiversity of arthropods under direct seeded rice sown at different dates.

Materials and Methods

Experiment on arthropods diversity in paired row under direct seeded rice (DSR) with sprayed and unsprayed conditions during different sowing dates was conducted during in *Kharif Season* at Punjab Agricultural University, Ludhiana and PAU, Regional Research Station, Gurdaspur. The species were got identified from division of Entomology IARI, New Delhi. The details regarding materials used and methodology followed are discussed given below.

Crop establishment method: The rice variety PR121 was sown as direct seeded rice in paired rows (15x25x15cm), with three different dates, at two locations viz. Ludhiana and Gurdaspur. The first, second, and third date of sowing was 24th May, 8th and 23rd June, respectively at Ludhiana whereas, 26th May, 9th and 26th June, respectively at Gurdaspur. The crop was raised by following all the recommendations for direct seeded rice of PAU except plant protection measures.

Experimental layout: The experiment was laid out in a factorial randomized block design with two factors i.e. dates of sowing and sprayed & unsprayed conditions and three replication. The plot size of each treatment was kept as 100 m^2 and buffers were maintained with two and one meter between replication and treatment plots.

Plant protection measures against major pests: The crop was raised by following all recommended agronomic practices of PAU except plant protection measures. But, recommended insecticides (Fame and Ekalux @ 20 and 800 ml/acre, respectively) were applied against insect-pests at economic threshold level under sprayed condition. At Ludhiana, one spray of Fame 480 SC (flubendiamide) was given to first and second date of sowing plots against leaffolder at 80 days after sowing (DAS) whereas third date of sowing was sprayed at 70 DAS. Similarly, at Gurdaspur one spray of Fame 480 SC was given to first and second date of sowing against leaffolder at 70 DAS whereas third date of sowing was sprayed at 60 DAS. At 80 DAS in the third date of sowing plots, one spray of Ekalux 25 EC (quinalphos) was also given against planthoppers at Gurdaspur.

Collection, preservation and identification of arthropods: The crop monitoring was started and terminated at 30 and 110 DAS, respectively. Sampling was done at three random spots (1.0 m^2) in each treatment. Different sampling methods were used to collect arthropods i.e. pitfall traps & sweep net for soil dwelling & aerial arthropods respectively and visual observations were also made. Three pitfall traps were placed in each plot and 10 strokes of sweep net were made at three spots in each plot. The samples were collected under sprayed conditions at 3, 7 and 10 days after spray and further at successive 10 days interval. The collected arthropods were preserved according to their body size and firmness. For dry preservation, hard bodied & large and small sized arthropods were pinned and double mounted, respectively. For wet preservation soft bodied arthropods were preserved in 70% ethyl alcohol. The different arthropods were identified from Division of Entomology IARI New Delhi. Spiders were identified from Department of Zoology PAU Ludhiana. On the basis of respective orders of the arthropods, they were grouped into different sub-communities. The arthropods were also grouped into three categories: major and minor pests, beneficial arthropods and neutral/casual visitors.

Data analysis: The data were analyzed after applying factorial randomized block design to calculate effect of different dates of sowing and sprayed & unsprayed conditions on arthropods diversity. The arthropods diversity was worked out using various indices of diversity.

i) Index of Species Diversity (Shannon and Weaver 1963) [17]

Shannon Weaver's index (H') = $-\Sigma\, p_i \log_e p_i$

Where, p_i = importance probability of each species (n_i/N)

n_i = importance value for each species

N = total of importance value

ii) Evenness index (Pielou 1966) [18]

Evenness index (J) = H'/ $\log_e$ S

Where, H = Shannon-Weaver's index and S = number of species

iii) Index of Dominance (Southwood 1978) [19]

Index of Dominance (D) = 1- J Where, J= Evenness index

Results and Discussion

Arthropod Diversity

The data revealed that 94 species of arthropods were found to be associated with rice crop at both experimental locations. These 94 species belonged to 11 orders and 60 families. These arthropod species included 21 of pests (P) constituting major, minor and sporadic pests (herbivorous arthropods), 45 of beneficial insects (B) [predator & parasitoid] and 28 of casual visitors/neutral species (N). Among total arthropod fauna, maximum number of species belonged to Coleoptera (20) constituting 11 families, followed by Hymenoptera, Hemiptera (14 species each) and Lepidoptera (13), Araneae (12), Orthoptera (9), Diptera (6), Odonata (3), Mantodea, Neuroptera, Dermaptera (one species each) constituting 7, 9, 10, 8, 5, 5, 2 and 1 families, respectively. Among 11 arthropod orders which were found to be associated with rice crop (Fig. 1), Coleoptera occupied 21.28% followed by Hymenoptera and Hemiptera (14.89% each) and Lepidoptera (13.83%). Order Araneae occupied 12.77% followed by Orthoptera (9.57%), Diptera (6.38%) and Odonata (3.19%). Order Mantodea, Neuroptera and Dermaptera occupied 1.06% each.

Likewise, Earlier in China, Zhang *et al.*, (2013) [20] collected 114 arthropod species in rice, comprising 58, 16, 25 and 15 species of spiders, predatory, phytophagous and neutral/other insects respectively in early season crop. Subsequently they collected 109 arthropods species, constituting 50, 19, 24 and 16 species of spiders, predatory, phytophagous and neutral/other insects in the late season crop. Bambaradeniya and Edirisinghe, (2008) [21] documented 342 arthropod species in Sri Lanka, comprising 282 insects and 60 arachnids species. Majority of insect species belonged to Hymenoptera (mostly ant and bees). On the basis of feeding habits, 149 species of predators were recorded which were dominated by spiders.

Arthropods Diversity at Ludhiana

The Shannon-Weaver index showing (Table 1) that the effect of different dates of sowing on the arthropod's diversity varied significantly from each other in all the treatments. After spray at 70 DAS in third date of sowing the significant effect of spray on arthropods diversity was observed only at 73 DAS because species again recolonizes at 77 DAS. Similarly, after spray at 80 DAS in first and second dates of sowing the significant effect of spray on arthropods diversity was observed only at 83 and 87 DAS. The interaction between different dates of sowing and sprayed & unsprayed conditions was significant at 73, 83 and 87 DAS whereas no interaction was observed in other dates. The overall diversity index revealed that highest arthropod diversity (1.594) was observed in second date and followed by third (1.570) and first (1.563) date of sowing. The Shannon-Weaver index varied significantly among different dates of observations. The species were evenly distributed throughout the season with high evenness index and low dominance (Table 2 and 3).

In first date of sowing, the diversity index ranged from 0.929 to 1.302 with highest diversity in September (100 DAS) and lowest in June (30 DAS). The arthropod diversity started increasing from July and reached its peak during September. The natural enemies like Spiders, *Xanthopimpla punctata*, *Xanthopimpla flavolineata*, *Charops brachypterum*, *Paederus fusiceps* etc. were more prevalent in the month of September. The species were evenly distributed throughout the crop season with higher evenness index and low dominance index. The diversity index slightly decreased after spray at 83 DAS but species remained evenly distributed. The evenness index showed that arthropod community recorded in rice crop at Ludhiana is diverse with all the species distributed evenly. Evenness index denotes the even distribution of all the species in rice crop without dominance of any particular species and low dominance index also proved that no species was dominant in rice crop during first date of sowing. After spray of Fame 480 SC at 80 DAS, significant effect of spray on arthropods diversity (Table 1) was observed only at 83 and 87 DAS.

In second date of sowing diversity index ranged from 1.031 to 1.361 with highest diversity at 100 DAS and lowest at 30 DAS. In unsprayed plots the diversity decreased after 80 DAS due to increase in dominance of leaffolder population but diversity again increased during September (90 DAS) due to increase in population of natural enemies. In sprayed plots the species remained diverse due to high evenness index and low dominance index. Insecticide Fame 480 SC was sprayed at 80 DAS and significant effect of spray on arthropods diversity (Table 1) was observed only at 83 and 87 DAS.

In third date of sowing the Shannon-Weaver index varied from 1.096 to 1.359 with highest diversity at 90 DAS and lowest at 30 DAS. In unsprayed plots, the arthropod diversity started increasing from 30 DAS (July) and reached its peak at 90 DAS. The gradual decline in diversity after 90 DAS was observed due to increase in planthoppers and spiders' population and decrease in evenness index. After spray of Fame 480 SC at 70 DAS, significant effect on arthropods diversity (Table 1) was observed only at 73 DAS.

In present study overall higher diversity index was observed under Fame 480 SC (flubendiamide) sprayed field conditions. Earlier, Bakar and Khan, (2016) [22] recorded highest species richness at early tillering stage under sprayed field conditions. They further concluded that by using non-chemical control methods and using fewer toxic insecticides for pest management a better environment for natural enemies' population would be created which are ultimately helpful in suppressing pest populations. Similarly, Kousika *et al.*, (2017) [23] recorded higher diversity index value in sprayed fields as compared to unsprayed field using Beta diversity indices. They also calculated diversity using Shannon – Weaver index and found no difference between tetraniliprole sprayed and unsprayed field's diversity. They also revealed that after application of tetraniliprole, natural enemies' diversity initially decreased but later on recolonize which means that nature of pesticide applied affected the diversity.

Arthropods Diversity at Gurdaspur

The Shannon-Weaver index (Table 4) reveled that arthropods diversity in all treatments varied significantly with different dates of sowing from each other except at 40 and 63 DAS. After spray of Fame 480 SC in third date of sowing at 60 DAS, no significant effect of spray was observed on arthropod's diversity. After spray of Fame 480 SC in first and second date of sowing at 70 DAS, significant difference was observed only at 73 DAS but diversity again increased and non-significant difference was observed at 77 DAS. Significant effect of spray was observed on arthropods diversity after spray of Ekalux 25 EC at 80 DAS in third date of sowing. The interaction between different dates of sowing and sprayed & unsprayed conditions was significant at 73, 83, 87, 90 and 100 DAS. The overall diversity depicted that highest arthropods diversity (Table 5 & 6) was observed (1.639) in second date followed by third (1.612) and first (1.576) date of sowing due to high evenness and low dominance index.

During first date of sowing, the Shannon-Weaver diversity index ranged from 1.049 to 1.391 with highest diversity at 90 DAS and lowest at 30 DAS. The arthropod diversity started increasing from July (30 DAS) and reached its peak during August (90 DAS). After spray at 70 DAS, significant effect of spray on arthropods diversity was observed only at 73 DAS (Table 4). Diversity in sprayed plots again increased after 73 DAS because Fame 480 SC did not adversely affect the arthropods diversity. The evenness index showed that arthropod community recorded at Gurdaspur was diverse with all the species distributed evenly. Evenness index denotes the even distribution of all species without dominance of any particular species (Table 5) and low dominance index also proved that no species was dominant during first date of sowing (Table 6).

In second date of sowing the diversity index varied from 1.083 to 1.426 with highest diversity at 90 DAS and lowest at 30 DAS. In unsprayed plots, the diversity decreased after 63 DAS due to increase in dominance of leaffolder population

but diversity again increased due to increase in population of natural enemies and reached its peak (1.426) at 90 DAS. After 90 DAS again diversity decreased due to increase in planthoppers and spider's population. After spray of Fame 480 SC at 70 DAS, effect of spray was significant only at 73 DAS but again diversity increased and effect of spray became non-significant at 77 DAS. The species were evenly distributed throughout the season with low dominance and high evenness index (Table 5 & 6).

In third date of sowing the Shannon-Weaver index ranged from 0.978 to 1.421 with highest diversity at 77 DAS and lowest in sprayed plots at 83 DAS. The arthropod diversity started increasing from 30 DAS (July) and reached its peak at 77 DAS (September). The gradual decline in diversity after 77 DAS was observed due to increase in dominance of planthoppers population and decrease in evenness index. No significant effect of spray was observed in arthropods diversity after spray of Fame 480 SC at 60 DAS while significant effect of Ekalux 25 EC on arthropods diversity was observed after spray at 80 DAS (Table 4). This reveals that Fame 480 SC was safer to arthropods while Ekalux 25 EC adversely affect arthropods diversity index. Earlier, Sekh *et al.*, (2007) [23] reported that Fame 480 SC @ 24 and 30 g a.i./ha was safe to egg parasitoids of stem borers and found almost equal parasitization in treated and untreated fields. Tohnishi *et al.*, (2005) [25] and Thilagam *et al.*, (2006) [26] have also reported similar results and found that insecticide flubendiamide was least toxic to beneficial arthropods species.

During the present studies, the overall diversity index in Ekalux 25 EC treated plots has less as compared to untreated field. The results corroborate with Park and Lee, (2009) [27] who found that arthropods density was reduced in treated fields by 48.4% as compared to untreated fields. The broad-spectrum insecticides used for control of insect-pests were toxic to predaceous and parasitic arthropods. Similarly, Wilby & Thomas (2002) [28] and Gangurde (2007) [28] concluded that in modern pest management system with higher utilization of agrochemicals, depletion in biodiversity of rice fields are observed.

Summary

Among the total arthropod fauna (94 species) constituting insects and spiders, maximum number of species belonged to Coleoptera (21.28%), followed by Hymenoptera and Hemiptera (14.89% each) and Lepidoptera (13.83%), Araneae (12.77%), Orthoptera (9.57%), Diptera (6.38%), Odonata (3.19%), Mantodea, Neuroptera and Dermaptera (1.06% each). There were 21 species of pests of rice constituting major, minor and sporadic pests (herbivorous arthropods), 45 species of natural enemies or beneficial arthropods (predator & parasitoid) and 28 species of neutral/casual visitors. Araneae comprised the maximum number of natural enemies' species (12 species).

The overall diversity depicted highest arthropod diversity (1.649) in second (9 June) date of sowing followed by third (27 June) (1.635) and first (27 May) (1.612) date of sowing. The diversity was more at Gurdaspur as compared to Ludhiana because of higher evenness index and more relative humidity at Gurdaspur as compared to Ludhiana.

Table 1: Effect of dates of sowing and sprayed & unsprayed conditions on the arthropod's diversity at Ludhiana

Date of sowing	Shannon-Weaver Index (H´) at different days after sowing																				
	30			40			50			60			70			73			77		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
24 May	0.951	0.929	0.94	1.065	1.072	1.068	1.149	1.151	1.15	1.103	1.143	1.123	1.148	1.175	1.161	1.189	1.207	1.198	1.188	1.24	1.214
8 June	1.031	1.039	1.035	1.147	1.145	1.146	1.19	1.197	1.193	1.232	1.21	1.221	1.26	1.269	1.264	1.291	1.296	1.293	1.285	1.328	1.306
23 June	1.090	1.096	1.093	1.194	1.170	1.182	1.21	1.267	1.238	1.216	1.223	1.219	1.219	1.233	1.226	1.248	1.073	1.160	1.262	1.179	1.220
Mean	1.024	1.021		1.135	1.129		1.183	1.205		1.184	1.192		1.209	1.226		1.243	1.192		1.245	1.249	
CD (p=0.05) A (Dates) B (Insecticide) A*B	0.039 NS NS			0.035 NS NS			0.035 NS NS			0.032 NS NS			0.042 NS NS			0.060 0.049 0.085			0.063 NS NS		
Date of sowing	Shannon-Weaver Index (H´) at different days after sowing																				
	80			83			87			90			100			110			Overall		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
24 May	1.244	1.241	1.242	1.293	1.127	1.210	1.256	1.214	1.235	1.288	1.295	1.292	1.298	1.302	1.300	1.269	1.278	1.274	1.549	1.563	1.556
8 June	1.333	1.345	1.339	1.321	1.222	1.272	1.293	1.267	1.280	1.327	1.31	1.319	1.359	1.361	1.360	1.312	1.322	1.317	1.578	1.594	1.586
23 June	1.311	1.287	1.299	1.278	1.331	1.305	1.328	1.346	1.337	1.301	1.359	1.330	1.311	1.326	1.319	1.203	1.122	1.163	1.561	1.57	1.566
Mean	1.296	1.291		1.297	1.227		1.292	1.276		1.305	1.321		1.323	1.330		1.261	1.241		1.563	1.576	
CD (p=0.05) A (Dates) B (Insecticide) A*B	0.041 NS NS			0.023 0.019 0.033			0.011 0.007 0.013			0.039 NS NS			0.011 NS NS			0.057 NS NS			0.011 0.008 NS		

US – Unsprayed; SP – Sprayed

Table 2: Effect of dates of sowing and sprayed/unsprayed conditions on the evenness index at Ludhiana

Date of sowing	Evenness Index (J) at different days after sowing																				
	30			40			50			60			70			73			77		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
24 May	0.966	0.945	0.956	0.966	0.963	0.965	0.962	0.971	0.967	0.897	0.936	0.917	0.895	0.925	0.910	0.919	0.928	0.924	0.903	0.919	0.911
8 June	0.97	0.964	0.967	0.97	0.966	0.968	0.956	0.974	0.965	0.976	0.952	0.964	0.938	0.97	0.954	0.96	0.956	0.958	0.936	0.95	0.943
23 June	0.975	0.966	0.971	0.971	0.951	0.961	0.947	0.985	0.966	0.93	0.936	0.933	0.908	0.921	0.915	0.936	0.916	0.926	0.922	0.902	0.912
Mean	0.970	0.958		0.969	0.960		0.955	0.977		0.934	0.941		0.914	0.939		0.938	0.933		0.920	0.924	
CD (p=0.05) A (Dates) B (Insecticide) A*B	NS NS NS			NS NS NS			NS NS NS			NS NS NS			0.034 NS NS			NS NS NS			0.029 NS NS		
Date of sowing	Evenness Index (J) at different days after sowing																				
	80			83			87			90			100			110			Overall		

	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
24 May	0.909	0.915	0.912	0.911	0.895	0.903	0.908	0.884	0.896	0.876	0.897	0.887	0.869	0.86	0.865	0.867	0.848	0.858	0.849	0.857	0.853
8 June	0.949	0.936	0.943	0.923	0.965	0.944	0.936	0.919	0.928	0.956	0.944	0.950	0.911	0.931	0.921	0.872	0.895	0.884	0.858	0.873	0.866
23 June	0.916	0.895	0.906	0.943	0.965	0.954	0.967	0.972	0.970	0.915	0.931	0.923	0.888	0.903	0.896	0.876	0.863	0.870	0.843	0.853	0.848
Mean	0.925	0.915		0.926	0.942		0.937	0.925		0.916	0.924		0.889	0.898		0.872	0.869		0.850	0.861	
CD (p=0.05) A (Dates) B (Insecticide) A*B	0.024 NS NS			0.018 0.015 0.026			0.017 0.014 0.024			NS 0.021 NS			0.032 NS NS			NS NS NS			NS NS NS		

US – Unsprayed; SP – Sprayed

Table 3: Effect of dates of sowing and sprayed/unsprayed conditions on the dominance index at Ludhiana

Date of sowing	Dominance Index (D) at different days after sowing																				
	30			40			50			60			70			73			77		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
24 May	0.034	0.055	0.045	0.034	0.037	0.036	0.038	0.029	0.034	0.103	0.064	0.084	0.105	0.075	0.090	0.081	0.072	0.077	0.097	0.081	0.089
8 June	0.03	0.036	0.033	0.03	0.034	0.032	0.044	0.026	0.035	0.024	0.048	0.036	0.062	0.03	0.046	0.04	0.044	0.042	0.064	0.05	0.057
23 June	0.025	0.034	0.030	0.029	0.049	0.039	0.053	0.015	0.034	0.07	0.064	0.067	0.092	0.079	0.086	0.064	0.084	0.074	0.078	0.098	0.088
Mean	0.030	0.042		0.031	0.040		0.045	0.023		0.066	0.059		0.086	0.061		0.062	0.067		0.080	0.076	
CD (p=0.05) A (Dates) B (Insecticide) A*B	NS NS NS			NS NS NS			NS NS NS			NS NS NS			0.034 NS NS			NS NS NS			0.029 NS NS		
Date of sowing	Dominance Index (D) at different days after sowing																				
	80			83			87			90			100			110			Overall		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
24 May	0.091	0.085	0.088	0.089	0.105	0.097	0.092	0.116	0.104	0.124	0.103	0.114	0.131	0.14	0.136	0.133	0.152	0.143	0.151	0.143	0.147
8 June	0.051	0.064	0.058	0.077	0.035	0.056	0.064	0.081	0.073	0.044	0.056	0.050	0.089	0.069	0.079	0.128	0.105	0.117	0.142	0.127	0.135
23 June	0.084	0.105	0.095	0.057	0.035	0.046	0.033	0.028	0.031	0.085	0.069	0.077	0.112	0.097	0.105	0.124	0.137	0.131	0.157	0.147	0.152
Mean	0.075	0.085		0.074	0.058		0.063	0.075		0.084	0.076		0.111	0.102		0.128	0.131		0.150	0.139	
CD (p=0.05) A (Dates) B (Insecticide) A*B	0.024 NS NS			0.018 0.015 0.026			0.017 0.014 0.024			NS 0.021 NS			0.032 NS NS			NS NS NS			NS NS NS		

US – Unsprayed; SP – Spraye

Table 4: Effect of dates of sowing and sprayed/unsprayed conditions on the arthropod diversity Gurdaspur

Date of sowing	Shannon-Weaver Index (H´) at different days after sowing																							
	30			40			50			60			63			67			70			73		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
27 May	1.065	1.049	1.057	1.166	1.128	1.147	1.207	1.234	1.221	1.24	1.24	1.240	1.249	1.241	1.245	1.231	1.248	1.240	1.256	1.266	1.261	1.338	1.299	1.319
9 June	1.083	1.094	1.089	1.162	1.165	1.164	1.239	1.247	1.243	1.271	1.28	1.276	1.269	1.272	1.271	1.214	1.19	1.202	1.234	1.256	1.245	1.362	1.356	1.359
27 June	1.119	1.139	1.129	1.213	1.231	1.222	1.281	1.242	1.262	1.24	1.231	1.236	1.293	1.222	1.258	1.31	1.298	1.304	1.344	1.349	1.347	1.385	1.397	1.391
Mean	1.089	1.094		1.180	1.175		1.242	1.241		1.250	1.250		1.270	1.245		1.252	1.245		1.278	1.290		1.362	1.351	
CD (p=0.05) A (Dates) B (Insecticide) A*B	0.029 NS NS			NS NS NS			0.027 NS NS			0.021 NS NS			NS NS NS			0.034 NS NS			0.031 NS NS			0.012 0.010 0.177		
Date of sowing	Shannon-Weaver Index (H´) at different days after sowing																							
	77			80			83			87			90			100			110			Overall		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
27 May	1.345	1.326	1.336	1.355	1.359	1.357	1.366	1.372	1.369	1.325	1.336	1.331	1.391	1.382	1.387	1.358	1.366	1.362	1.27	1.281	1.276	1.576	1.564	1.570
9 June	1.381	1.377	1.379	1.384	1.398	1.391	1.316	1.322	1.319	1.385	1.374	1.380	1.419	1.426	1.423	1.396	1.387	1.392	1.301	1.298	1.300	1.626	1.639	1.633
27 June	1.4	1.421	1.411	1.299	1.302	1.301	1.31	0.978	1.144	1.308	1.05	1.179	1.336	1.179	1.258	1.316	1.255	1.286	1.271	1.262	1.267	1.612	1.587	1.600
Mean	1.375	1.375		1.346	1.353		1.331	1.224		1.339	1.253		1.382	1.329		1.357	1.336		1.281	1.280		1.605	1.597	
CD (p=0.05) A (Dates) B (Insecticide) A*B	0.013 NS 0.018			0.15 NS NS			0.064 0.052 0.090			0.082 0.067 0.116			0.034 0.028 0.048			0.014 0.011 0.019			0.023 NS NS			0.011 0.008 NS		

US – Unsprayed; SP – Sprayed

Table 5: Effect of dates of sowing and sprayed/unsprayed conditions on the evenness index at Gurdaspur

Date of sowing	Evenness index (J) at different days after sowing																							
	30			40			50			60			63			67			70			73		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
27 May	0.966	0.962	0.964	0.969	0.943	0.956	0.968	0.977	0.973	0.97	0.958	0.964	0.954	0.966	0.960	0.893	0.905	0.899	0.923	0.903	0.913	0.932	0.927	0.930
9 June	0.973	0.964	0.969	0.945	0.954	0.950	0.969	0.976	0.973	0.977	0.973	0.975	0.95	0.958	0.954	0.896	0.878	0.887	0.898	0.899	0.899	0.975	0.954	0.965
27 June	0.968	0.969	0.969	0.967	0.974	0.971	0.969	0.934	0.952	0.898	0.892	0.895	0.975	0.921	0.948	0.974	0.922	0.948	0.947	0.975	0.961	0.975	0.978	0.977
Mean	0.969	0.965		0.960	0.957		0.969	0.962		0.948	0.941		0.960	0.948		0.921	0.902		0.923	0.926		0.961	0.953	
CD (p=0.05) A (Dates) B (Insecticide) A*B	NS NS NS			NS NS NS			0.013 NS 0.019			0.012 NS NS			NS 0.018 0.031			0.023 0.018 NS			0.018 0.015 NS			0.023 NS NS		
Date of sowing	Evenness index (J) at different days after sowing																							
	77			80			83			87			90			100			110			Overall		

	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
27 May	0.922	0.929	0.926	0.948	0.969	0.959	0.948	0.957	0.953	0.896	0.924	0.910	0.949	0.888	0.919	0.874	0.896	0.885	0.88	0.87	0.875	0.889	0.872	0.881
9 June	0.971	0.959	0.965	0.967	0.959	0.963	0.913	0.881	0.897	0.966	0.933	0.950	0.949	0.965	0.957	0.905	0.842	0.874	0.878	0.918	0.898	0.897	0.907	0.902
27 June	0.972	0.977	0.975	0.849	0.882	0.866	0.972	0.974	0.973	0.878	0.95	0.914	0.879	0.901	0.890	0.872	0.869	0.871	0.862	0.906	0.884	0.851	0.86	0.856
Mean	0.955	0.955		0.921	0.937		0.944	0.937		0.913	0.936		0.926	0.918		0.884	0.869		0.873	0.898		0.879	0.880	
CD (p=0.05)																								
A (Dates)	0.026			0.022			0.015			0.016			0.010			0.039			0.035			0.011		
B (Insecticide)	NS			0.018			0.012			0.013			0.008			NS			0.029			0.008		
A*B	NS			NS			0.022			0.022			NS			NS			NS			NS		

US – Unsprayed; SP – Sprayed

Table 6: Effect of dates of sowing and sprayed/unsprayed conditions on the dominance index at Gurdaspur

Date of sowing	Dominance index (D) at different days after sowing																							
	30			40			50			60			63			67			70			73		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
27 May	0.034	0.038	0.036	0.031	0.057	0.044	0.032	0.023	0.028	0.03	0.042	0.036	0.046	0.034	0.040	0.107	0.095	0.101	0.077	0.097	0.087	0.068	0.073	0.071
9 June	0.027	0.036	0.032	0.055	0.046	0.051	0.031	0.024	0.028	0.023	0.027	0.025	0.05	0.042	0.046	0.104	0.122	0.113	0.102	0.101	0.102	0.025	0.046	0.036
27 June	0.032	0.031	0.032	0.033	0.026	0.030	0.031	0.066	0.049	0.102	0.108	0.105	0.025	0.079	0.052	0.026	0.078	0.052	0.053	0.025	0.039	0.025	0.022	0.024
Mean	0.031	0.035		0.040	0.043		0.031	0.038		0.052	0.059		0.040	0.052		0.079	0.098		0.077	0.074		0.039	0.047	
CD (p=0.05)																								
A (Dates)	NS			NS			0.013			0.012			NS			0.023			0.018			0.023		
B (Insecticide)	NS			NS			NS			NS			0.018			0.018			0.015			NS		
A*B	NS			NS			0.019			NS			0.031			NS			NS			NS		
Date of sowing	Dominance index (D) at different days after sowing																							
	77			80			83			87			90			100			110			Overall		
	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean	US	SP	Mean
27 May	0.078	0.071	0.075	0.052	0.031	0.042	0.052	0.043	0.048	0.104	0.076	0.090	0.051	0.112	0.082	0.126	0.104	0.115	0.12	0.13	0.125	0.111	0.128	0.120
9 June	0.029	0.041	0.035	0.033	0.041	0.037	0.087	0.119	0.103	0.034	0.067	0.051	0.051	0.035	0.043	0.095	0.158	0.127	0.122	0.082	0.102	0.121	0.093	0.107
27 June	0.028	0.023	0.026	0.151	0.118	0.135	0.028	0.026	0.027	0.122	0.05	0.086	0.121	0.099	0.110	0.128	0.131	0.130	0.138	0.094	0.116	0.149	0.14	0.145
Mean	0.045	0.045		0.079	0.063		0.056	0.063		0.087	0.064		0.074	0.082		0.116	0.131		0.127	0.102		0.127	0.120	
CD (p=0.05)																								
A (Dates)	0.026			0.022			0.015			0.016			0.010			0.039			0.035			0.011		
B (Insecticide)	NS			0.018			0.012			0.013			0.008			NS			0.029			0.008		
A*B	NS			NS			0.022			0.022			NS			NS			NS			NS		

US – Unsprayed; SP – Sprayed

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