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Effect of Insecticides on the Population of Aphids, Natural Enemies and Yield Components of Wheat

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QZ and MN conceived and designed the study. QZ executed the experimental work and wrote the article. QZ, SAK and SA analyzed the data.

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A B S T R A C T

Field experiment was conducted at Agricultural Research Institute-Tarnab Peshawar, KPK to determine the effect of different insecticides on the population of wheat aphids, its natural enemies and yield, yield components of wheat. Two wheat varieties, one susceptible and one "partially resistant" against aphids, were sown in a randomized complete block design in split plot arrangement, in three replicates. Varieties were kept in the main plots, while subplots received four insecticides, Thiamethoxam 25 GW at the rate of 24 g acre,$^{-1}$ Imidaclopride 20% EC at the rate of 70 ml acre,$^{-1}$ Acetamiprid 20 SP at the rate of 150 g acre,$^{-1}$ Orange peel extract at the rate of 2500 ml acre $^{-1}$. In main plot one plot was kept as control. In the sprayed plots the aphids infestation was reduced compared to control. The synthetic insecticides had sharply decreased aphids population, compared to orange peel extract plots where less aphid reduction was noticed. Wheat grain yield and yield parameters like thousand grain weight and number of grains per spike were improved in Imidaclopride treated plots compared to other treatments. If a cultivar is "partially resistant" the damage suffered by aphids should be lower than the damage suffered by a "susceptible". However, when both were treated with selective insecticides; Saleem-2000, suffered less damage compared to Pirsabak-2004. Host plant defense and natural enemies should be a good IPM package against wheat aphids. But in case of aphids population build up and to avoid economic losses selective insecticides should be applied to control wheat aphids.

INTRODUCTION

Numerous factors are responsible for the low production/yield of wheat. Arthropod pests are one of these factors and are known to attack wheat worldwide (Hatchett *et al*., 1987). Wheat is attached by number of insect, pests such as termites (Isoptera: Termitidae), cutworm and armyworm (Lepidoptera: Noctuidae), wheat beetles and weevils (Coleoptera: Chrysomelidae, Carabidae, Curculionidae), aphids (Hemiptera: Aphididae), thrips (Thysanoptera: Thripidae Phlaeothripidae,), Chinchbug (Hemiptera: Lygaeidae, Miridae, Pentatomidae), Sunn pest (Hemiptera: Scutelleridae), leafhopper (Hemiptera: Cicadellidae) and hessian fly (Diptera: Cecidomyiidae) (Miller and Pike, 2002; El-Wakeil and Volkmar, 2013). Wheat aphids are common pest of wheat which affect the yield adversely (Carter *et al.*, 1980; Hamid, 1983; Steffey and Gray, 2009). Aphids are soft bodied insect that suck the cell sap of their host plant. Worldwide, several aphids species have been reported on cereal crops including, bird cherry-oat aphid, *Rhopalosiphum padi* (L.), wheat grain aphid, *Sitobion avenae* (Fabricius), grain aphid, *Sitobion miscanthi* (Takahashi), corn leaf aphid, *Rhopalosiphum maidis* (Fitch), Greenbug, *Schizaphis graminum* (Rondani), Russian wheat aphid, *Diuraphis noxia* (Mordvilko), yellow sugarcane aphid, *Sipha maydis* (Passerini), rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki) and rusty plum aphid, *Hysteroneura setariae* (Thomas) (Hashmi *et al.*, 1983; Morrill, 1995; Buriro *et al.*, 1996; Blackman and Eastop, 2000).

Aphids attack is becoming very common in Pakistan and farmers have started to spray pesticides on their wheat crop and the sprayed area is widening yearly (Anonymous, 2011). Heavy aphids infestation in early growth stage can kill the young wheat plants, but normally aphids feeding resulting in poor root growth and ultimately reduction in tiller number and grain yield (Russell, 2013). The abundance of wheat aphids adversely affect the nitrogen and protein contents, weight of 1000 grains, number of grains per ear (Ciepiela, 1993) decreasing carbon assimilation rate, transpiration and total chlorophyll as well as reduction in plant biomass (Holmes *et al.*, 1991). Aphids may reduce wheat production by causing 35-40% yield losses directly through sucking injury and 20-80% yield losses indirectly by transmitting viral and fungal diseases (Trdan and Milevoj, 1999; Kieckhefer and Gellner, 1992; Girma *et al.*, 1993). Various environment friendly control measures are available to keep the aphids below economic injury level (EIL). These control measures included cultural, biological, chemical and host plant

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resistance (Hatchett *et al.*, 1987). Host plant resistance is more important, which can keep aphids population well below economic threshold level and reduce the chance of biotypes development. Combination of non-chemical *i.e.* host plat resistance and natural enemies can keep aphids population below economic injury level. But in case of aphid's population build up selective insecticide should be applied to control aphids on wheat and decrease the chance of economic losses due to wheat aphids (Newsom, 1980; Lowe, 1987).

Thiamethoxam, Imidaclopride and Acetamiprid belong to neonicotinoid group of chemical which act as systemic insecticides against sucking pests. These chemicals have quick knock down effect on target pest by interfering with transmission of impulse in the nerve system. The quick and excellent systemic and traslaminar activity of these insecticides make them able to control sucking pests such as aphids, whiteflies and other insects of plant pathogenic viruses. Neonicotinoid application reduce infection rate and spread of many crop viruses. (Dewar, 1992; Knaust and Poehling, 1992; Mullins, 1993; Westwood *et al.*, 1998; Elbert *et al.*, 1998; Bethke *et al.*, 2001; Elzen, 2001). Although the neonicotinoid have adverse effects on beneficial insects and non target such as bees, wasps and other nectars and pollens feeders but they are much safer than older insecticides such as organophosphate and carbamate (Boyd and Boethel, 1998; Brunner *et al.*, 2001; Elzen, 2001). Any portion of an insecticides that is not intercepted by vegetation will eventually reach the soil surface and small amount may reach water bodies. The neonicotinoid are rapidly degradable in the sunlight, However, if it is not completely broken down is further subjected to chemical processes and thoroughly metabolized in carbon dioxide (Krohn, 2001).

The effectiveness of products of orange (*Citrus sinensis*) against different insects, pest have been reported by different researchers; like Iqbal *et al.* (2011) have reported the effective use of orange peel extract against wheat aphids, while in other study, Zewde and Jembere (2010) tested the effectiveness of sun dried orange peel and essential oil of citrus against store product beetle. Sundried powder and essential oil of orange killed 65 percent and 67 percent of the *Z. subfaciatus* (L.) respectively. Belmain and Stevenson (2001) also reported the efficacy of orange peel powder against legume pests. The effectiveness of orange peel extract is probably attributed to silica or silica like compound, which are abrasive and ability of the particle to adhere to the brain. Sharaby (1988) and Tripathi *et al.* (2003) have reported that the toxicity of the orange peel extract may be due to d. limonene.

The present study was aimed to determine (1) the role of some selective insecticides against wheat aphids and rate of aphids parasitism, (2) the yield losses to susceptible and partially resistant wheat varieties due to wheat aphids, one subplot was kept as control (without spray) in each main plot and (3) the effect on yield and yield components of wheat when aphids were control due to insecticides.

Table-I.- Insecticides with their trade name, active ingredient and respective concentration.

Insecticides	Active ingredient	Recommended dose	Spray calibrated
Actara 25 WG	Thiamethoxam	24 g acre^{-1}	0.24 g liter^{-1}
Confidor 20% SL	Imidaclopride	70 ml acre^{-1}	0.7 ml liter^{-1}
Mospilon 20 SP	Acetamiprid	150 g acre^{-1}	1.5 g liter^{-1}
Orange peel extract	D-limonene	2500 ml of extract acre^{-1}	25 ml extract liter^{-1}
Control	-	-	-

MATERIALS AND METHODS

To determine the effect of botanical extract and systemic insecticides (Table I) on aphids and yield components of wheat an experiment was conducted in the cropping season 2012-2013 at Agricultural Research Institute (ARI), Tarnab-Peshawar. Two wheat varieties, one susceptible (Saleem-2000 with parentage CHAM-6//KITE/PGO) and other partially resistant (Pirsabak-2004 with parentage KAUZ/STAR) selected after laboratory and field screening against wheat aphids, were sown in the main plots on 13/11/2012 in a Randomize Complete Block design (RCBD) in split plot arrangement with three replication. One replication consisted of two main plots where the wheat varieties were assigned at random. Each main plot was further divided into five sub-plots where insecticides were applied at random. The sub-plot size was 2.5x3.6 m^2, with 9 rows per plot and one meter buffer zone between sub-plots and replications. All other measurable agronomic practices *i.e*. 90 g seed per sub-plot at the rate of 100 kg ha^{-1} of each variety was weighed and kept separately in plastic bags. The seed was sown on 15th November, 2012 in straight line at a distance of 30 cm from other line with the help of hand hoe (manual single line seed drill), fertilizers at rate of 120 kg N and 90 kg P ha$^{-1,}$ from urea and DAP sources were used. Half of the nitrogen and full dose of phosphorous was applied at soil preparation, while the remaining half nitrogen was applied with first irrigation at three weeks after seed sowing (Inamullah *et al.*, 2011).

Preparation of orange peel extract

For preparation of botanical extract sour oranges were collected from the dropped fruits from sour orange trees in ARI-Tarnab, Peshawar. 200 gram of peel of sour oranges were grinded in one liter of distilled water. The extract was filtered in a pot passing through a filter paper and stored in dark brown glass bottle for 7 days before spray. Twenty five ml of filtered extract was mixed with one liter of water before spraying (Iqbal *et al.*, 2011).

Effect of spray application on wheat aphids population and on the rate of parasitism per tiller

After crop emergence five tiller^{-1} in each sub-plot were selected randomly and observed weekly for aphids and aphids mummies data. After pre-spray data which was recorded on 18th February, 2013 spray was done when aphid density reached to an average of 10 or more aphids tiller^{-1} (Aziz *et al.*, 2013). To determine the effect of different insecticides (Table I) on the aphid density (aphids tiller^{-1}) post-spray data were recorded after 24 h (19th February, 2013), 7 days, 15 days, 21 days and 30 days. For proper calibration spray machine was filled with water and sprayed on three different plots. The amount of water applied was subtracted from the water in the spray machine to determine the volume of water required to spray a plot uniformly. For spray the required amount of insecticides was mixed with calibrated amount of water. After application of an insecticide in the designated plots spray machine was washed and rinsed thoroughly with water for other insecticide application. After spraying the % mortality of aphids and the rate of parasitism was calculated according to Shah *et al*. (2007).

Grains per spike and spike length

At crop maturity five spikes were randomly selected from each plot and were individually measured from the base of the spike to the tip of spikelet with measuring tap to determine spike length. Grains were removed from each spike and counted separately for each plot for number of grains per spike in sprayed and control plots.

Grain yield kg ha^{-1}

To avoid lodging effect and bird damage on maturity the crop was sickle harvested (12th May, 2013) in 1 m^2 area in the center of each plot. The bundles were properly tagged and allowed to sun drying for seven days. After threshing separately grain yield of each plot was converted to kg ha^{-1} by the formula; yield (kg/ha) = [yield (kg plot^{-1})/area harvested (m^2)] x 10000 (Inamullah *et al.*, 2011) to compare the effect of non spray and spray on the grain yield for cultivars.

Thousand grains weight (g)

After harvesting a sample of grains were taken from each separately harvested plot and thousand grains were counted and weighted on microbalance. Thousand grains weight of sprayed and non sprayed plots were compared.

RESULTS

The effect of insecticides on wheat varieties and interaction of insecticides and varieties on the aphid density (aphids tiller^{-1}) at pre- and post-spray intervals are shown respectively in Tables II, III and IV. Pre-spray mean aphid density was statistically similar in subplots but it was significantly different (F=7278.23; df=1, 29; P=0.0001) in main plots. Interaction effect of sub plots and main plots was different statistically (F=13.42; df=4, 29; P=0.0001). It is evident that pre-spray aphids infestation was maximum on susceptible compared to resistant wheat variety.

The mean aphid density (13.80 tiller^{-1}) 24 h post-spray in control plots was significantly higher (F=3286.53; df=4,29; P=0.0000), followed by average aphid density in orange peel extract treated plots (6.37 aphids tiller^{-1}). Lowest aphid density was recorded in Acetamiprid-treated plots which was (0.12 aphids tiller^{-1}) with 99% mortality but at par with Imidaclopride. Main plots effect was not statistically different. It is evident from the interaction results of insecticides and varieties that post-spray (24 h) density of aphid was significantly (F=290.23; df=4,29; P=0.0000) controlled in each variety compared with untreated plots. Lowest aphid density and maximum rate of aphid mortality was recorded in Acetamiprid-treated plots on each wheat variety followed by Imidaclopride.

The average aphid density 7 day post-spray in control plots (24.07 aphids tiller^{-1}) was significantly higher (F=3411.62; df=4, 29; P=0.0000) compared to other insecticides. In orange peel extract aphid density was (10.80 aphids tiller^{-1}) with 55% aphids mortality, while the lowest aphid density of (0.47 aphids tiller^{-1}) and higher (98%) aphids mortality was recorded in Thiamethoxam-treated plots but it was statistically similar with Acetamiprid and Imidaclopride plots. Significantly (F=216.64; df=1, 29; P=0.0046) more aphids (8.91tiller^{-1}) was observed on susceptible variety compared to resistant variety. Interaction effect of insecticides and varieties were significantly different (F=251.45; df=4, 29; P=0.0000). Lowest aphid (0.4 tiller^{-1}) and maximum 99% aphid mortality was recorded for Imidaclopride on susceptible against (0.8 tiller^{-1}) and 95% aphids mortality on resistant wheat variety. Statistically similar mean aphid density and rate of aphids mortality was recorded for Thiamethoxam, Acetamiprid and Imidaclopride. Whereas in orange peel extract treated plots 45 and 61 percent aphids mortality was recorded in susceptible and resistant. In control plots aphid density

Table II.- Effect of insecticides on the aphid density (aphids tiller^{-1}), % mortality and rate of aphid parasitism tiller^{-1} during 2012-2013.

Insecticides	Pre spray	24 h	7 days	15 days	21 days	30 days
Aphid density (% mortality)						
Thiamethoxam	11.10 a	0.72 c (95)	0.47 c (98)	3.90 b (60)	3.11 c (70)	2.27 b (36)
Imidaclopride	11.23 a	0.33 d (98)	0.57 c (98)	2.73 b (70)	2.86 c (72)	1.63 b (54)
Acetamiprid	11.10 a	0.12 c (99)	0.83 c (97)	3.42 b (62)	2.98 c (71)	1.78 b (50)
Orange peel extract	11.58 a	6.37 b (21.7)	10.80 b(55)	3.65 b (60)	5.94 b (43)	2.47 b (47)
Control	12.07 a	13.80 a	24.07 a	9.03 a	10.34 a	3.57 a
LSD	0.76	0.31	0.53	0.63	2.01	0.98
Rate of aphid parasitism						
Thiamethoxam	1.17 a	11.17 c	17.62 b	4.18 b	7.33 c	18.00 b
Imidaclopride	1.50 a	22.83 a	21.00 a	1.92 c	6.43 c	16.00 d
Acetamiprid	1.17 a	18.33 b	21.76 a	4.00 b	9.67 b	26.67 a
Orange peel extract	1.50 a	1.67 d	21.67 a	18.50 a	11.08 a	17.25 bc
Control	1.50 a	1.17 d	5.17 c	18.60 a	10.84 a	16.83 cd
LSD	0.45	0.58	0.93	2.02	1.11	0.96

Mean followed by same letters within the columns are not significantly different at 5 % level of significance (LSD- test)

Table III.- Effect of wheat varieties on the aphid density (aphids tiller^{-1}), % mortality and rate of aphid parasitism tiller^{-1} during 2012-2013.

Insecticides	Pre spray	24 h	7 days	15 days	21 days	30 days
Aphid density (% mortality)						
Susceptible	13.00 a	4.21 a (68)	8.90 a (32)	5.13 a (60)	5.48 a (57)	2.86 a (78)
Resistant	9.833 b	4.32 a (56)	5.79 b (41)	3.97 b (75)	4.60 a (53)	1.59 b (83)
LSD	0.16	0.49	0.91	0.37	1.52	1.15
Rate of aphid parasitism						
Susceptible	1.13 b	13.20 a	18.90 a	10.79 a	8.67 b	16.93 b
Resistant	1.60 a	8.87 b	15.99 b	9.08 a	9.47 a	20.97 a
LSD	0.30	0.57	1.92	3.25	0.41	1.65

reached to (30.7 tiller^{-1}) and (17.6 tiller^{-1}) on susceptible and resistant variety respectively.

Fifteen days after spray the mean aphid density was 9.03 tiller^{-1} in control plots, which was significantly higher (F= 144.48; df= 4, 29; P= 0.0000) compared to other insecticides. This time aphid density was statistically similar in orange peel extract, Thiamethoxam, Acetamiprid and Imidaclopride treated plots. In main plots significantly more aphids (5.13 tiller^{-1}) were recorded on susceptible variety compared to resistant variety. Interaction effect of insecticides and varieties was significantly different (F=22.63; df=4, 29; P=0.0000). As evident from interaction table, higher (79%) aphids mortality was recorded from Imidaclopride-treated plots in susceptible which was statistically similar with resistant variety. On the other hand, orange peel extract treatment showed statistically similar results with systemic insecticides. In untreated plots aphid density was significantly maximum compared to treated plots.

The average aphid density in control plots (10.34 aphids tiller^{-1}) 21 days after spray was significantly higher (F=23.13; df=4, 29; P=0.0000), followed by orange peel extract (5.94 aphids tiller^{-1}). Lowest and statistically similar average aphid density was recorded in Imidaclopride (2.86 tiller^{-1}) followed by Acetamiprid (2.98 aphids tiller^{-1}) and Thiamethoxam (3.11 aphids tiller^{-1}) treated plots. Statistically similar aphid density was also recorded on both varieties. Interaction effect of insecticides and varieties although was not significantly different but minimum aphid density and maximum mortality (78%) was recorded for Imidaclopride which was statistically similar with other systemic insecticides in both varieties. For orange peel extract maximum aphids mortality (52%) was recorded on susceptible

Table IV.- Interaction effect of insecticides and varieties on the aphid density (aphids tiller^{-1}), % mortality and the rate of aphids parasitism tiller^{-1} in 2012-2013.

Insecticide	Pre spray		24 h		7 days		15 days		21 days		30 days	
	Susceptible	Resistant	Susceptible	Resistant	Susceptible	Resistant	Susceptible	Resistant	Susceptible	Resistant	Susceptible	Resistant
Aphids density (% mortality)												
Thiamethoxam	14.0 a	8.2 e	1.3 e (92)	0.1 f (99)	0.6 e (98)	0.4 e (97)	4.1 c (64)	3.7 cd (45)	3.2 cde (75)	3.1 e (62)	3.0 ab (21)	1.5 de (55)
Imidaclopride	12.5 b	9.9 d	0.4 f (97)	0.3 f (97)	0.4 e (99)	0.8 e (95)	2.7 e (79)	2.7 e (60)	2.8 e (78)	2.9 e (64)	1.93cde (49)	1.3 de (61)
Acetamiprid	11.4 c	10.8 cd	0.1 f (99)	0.1 f (99)	1.1 e (96)	0.6 e (97)	3.7 cd (70)	3.1 de (54)	2.9 e (77)	3.1 de (62)	2.9 abc (24)	0.67 e (80)
Orange peel extract	13.2 ab	10.0 d	3.5 d (78)	9.2 c (22)	11.9 c (61)	9.7 d (45)	3.7 cd (70)	3.6 cd (46)	6.0 bc (52)	6.0 bcd (26)	2.63bcd (31)	1.1 e (66)
Control	13.8 a	10.3 d	15.8 a	11.8 b	30.7 a	17.6 b	11.4 a	6.7 b	12.6 a	8.1 b	3.8 a	3.3 ab
LSD	0.97		0.59		1.07		0.87		2.87		1.36	
Rate of aphid parasitism tiller^{-1}												
Thiamethoxam	1.33 cd	1.00 de	14.00 d	8.33 e	20.73 b	14.50 c	3.67 c	4.70 c	5.00 d	9.67 b	9.67 g	26.33 b
Imidaclopride	0.67 e	2.33 a	26.00 a	19.67 c	26.83 a	15.17 c	4.33 c	3.83 c	5.27 d	7.60 c	13.00 f	19.00 c
Acetamiprid	0.00 f	2.33 a	22.67 b	14.00 d	20.72 b	22.80 b	5.67 c	2.33 cd	9.83 b	9.50 b	25.33 b	28.00 a
Orange peel extract	2.00 ab	1.00 de	2.00 f	1.33 fg	20.77 b	22.57 b	24.00 a	13.00 b	11.58 a	10.58 ab	13.67 f	20.83 d
Control	1.67 bc	1.33 cd	1.33 fg	1.00 g	5.42 d	4.93 d	15.67 b	21.53 a	11.68 a	10.00 b	23.00 c	10.67 g
LSD	0.62		0.89		2.12		3.88		1.45		1.93	

Mean followed by same letters are not significantly different at 5 % level of significance (LSD- test) with in pre spray, post spray (24h), (7days), (15 days), (21days) and (30 days) intervals.

Table V.- Effect of insecticides and wheat variety on grain yield, yield components of wheat during 2012-2013.

Insecticides / Wheat variety	Yield and yield components			
	Yield Kg/ha	Thousands grain weight (g) plot^{-1}	Spike length in (cm)	Number of grains per spike^{-1}
Insecticides				
Thiamethoxam	3660.0 a	60.28 b	10.51 a	67.50 b
Imidaclopride	3680.0 a	65.58 a	10.50 a	69.67 a
Acetamiprid	3676.0 a	59.63 b	10.49 a	63.67 c
Orange peel Extract	3496.7 b	60.28 b	10.29 a	62.52 d
Control	3415.0 b	56.38 c	10.21 a	60.83 e
LSD	89.07	1.31	0.90	0.53
Wheat variety				
Susceptible	3649.3 a	62.11 a	10.31 a	63.93 b
Resistant	3519.3 b	58.76 b	10.49 a	65.7 a
LSD	58.58	1.80	3.13	1.17

Mean followed by same letters within the columns are not significantly different at 5 % level of significance (LSD- test)

Table VI.- Interaction effect of insecticides and varieties on grain yield and yield components of wheat during 2012-2013.

Insecticides	Yield kgha^{-1}		Thousands grain weight (g) plot^{-1}		Spike length (cm)		Number of grains spike^{-1}	
	Susceptible	Resistant	Susceptible	Resistant	Susceptible	Resistant	Susceptible	Resistant
Thiamethoxam	3760 a	3560 bc	61.7 b	58.8 de	10.9 a	10.8 a	67.0 c	68.0 bc
Imidaclopride	3780 a	3577 b	69.4 a	61.8 b	10.6 a	10.4 a	68.3 b	71.0 a
Acetamiprid	3770 a	3570 b	61.5 b	57.8 def	10.5 a	10.4 a	62.3 f	65.0 d
Orange peel Extract	3497 bcd	3497 bcd	61.4 bc	59.1 cd	10.2 a	10.1 a	61.3 g	63.7 e
Control	3437 cd	3393 d	56.6 ef	56.2 f	10.2 a	9.9 a	60.7g	61.0 g
LSD	23.7		2.31		3.20		17.90	

Mean followed by same letters are not significantly different at 5 % level of significance (LSD- test) within the adjacent Susceptible and resistant columns

variety followed by resistant.

Thirty days post-spray aphids density in all sub plots was significantly different (F=11.32; df=4,29; P=0.0001). In main plots the average density (2.86 aphids tiller^{-1}) was significantly higher (F=22.56; df=1, 29; P=0.0416) on susceptible variety compared to resistant. Interaction effect of insecticides and varieties was significant. Maximum rate of aphid mortality was noticed on resistant variety. In untreated plots natural decreased of aphid population was also noticed.

The effect of insecticides, wheat varieties and interaction of insecticides and varieties on the rate of aphids parasitism tiller^{-1} at pre- and post-spray intervals are shown in Tables II, III and IV, respectively. Pre-spray mean rate of aphids parasitism was statistically similar in sub-plots but it was significantly different (F=44.95; df=1, 29; P=0.0215) in main plots. Interaction effect of sub-plots and main plots was statistically different (F=23.7; df=4, 29; P=0.0000). Post-spray (24 h) mean rate of aphids parasitism (22.83 tiller^{-1}) in Imidaclopride-treated plots was significantly higher (F=2517.56; df=4,29; P=0.0000), followed by Acetamiprid (18.33 tiller^{-1}) and Thiamethoxam (11.17 tiller^{-1}). Lowest mean rate of parasitism was recorded in control plots and orange peel extract treatment which was (1.17 tiller^{-1}) and (1.67 tiller^{-1}), respectively. Main plots effect was significantly different (F=1056.25; df=1, 29; P=0.0009). Interaction effect was significantly different (F=90.00; df=4,29; P=0.0000). In sub-plots maximum (26%) parasitism was recorded in Imidaclopride plots. In orange peel extract treated plots rate of parasitism was not significantly different from control plots.

Seven days after spray, mean rate of aphids parasitism (21.76 tiller^{-1}) in Acetamiprid-treated plots was significantly higher (F=518.21; df=4,29; P=0.0000), followed by Imidaclopride (21.00 tiller^{-1}). On the other hand, lowest rate of aphids parasitism was recorded in control plots followed by Thiamethoxam which was 5.17

$tiller^{-1}$ and 17.62 $tiller^{-1}$ respectively. Main plots effect was significantly different and higher rate of aphids parasitism was recorded on susceptible variety. The interaction effect was significantly different (F=91.26; df=4,29; P=0.0000). Maximum rate of parasitism (26.83%) was recorded in Imidaclopride plots of susceptible variety. Rate of parasitism was also increased in orange peel extract treated plots. In untreated plots 5.42% and 4.93% parasitism was recorded in susceptible and resistant wheat varieties, respectively.

Fifteen days after spray, significantly (F=138.78; df=4, 29; P=0.0000) lowest rate of parasitism was recorded in Acetamiprid plots followed by statistically similar rate of aphids parasitism in Thiamethoxam and Imidaclopride plots. Higher rate of parasitism was observed in control plots which was statistically similar with orange peel extract treated plots. Significantly different parasitism was recorded in main plots, while interaction effect was significantly different (F=21.46; df=4, 29; P=0.0000). Non significantly different rate of aphid parasitism was recorded in sub-plots which was treated with systemic insecticides. Higher rate (24%) aphids parasitism was recorded in orange peel extract plots, however statistically it was similar with untreated plots.

The rate of aphids parasitism 21 days after spray increased in systemic insecticides, but again it was maximum in orange peel and control plots. In main plots significantly (F=69.92; df=1, 29; P=0.0140) higher rate of parasitism was recorded on resistant variety. Interaction effect was also significantly different (F=12.7; df=4, 29; P=0.0001). Maximum rate of parasitism was recorded in orange peel extract plots and untreated plot compared to other subplots.

Significantly (F=184.89; df=4, 29; P=0.0000) maximum rate of parasitism (26.67 $tiller^{-1}$) was recorded in Acetamiprid plots followed by Thiamethoxam 30 days after spray. On the other hand, lower rate of aphids parasitism (16.00 $tiller^{-1}$) was recorded in Imidaclopride-treated plots. Main plot effect was significantly different (F=110.08; df=1, 29; P=0.0090) with mean maximum rate of parasitism (20.97 $tiller^{-1}$) on resistant variety. Interaction effect was also significantly different. Rate of parasitism was high in Acetamiprid-treated plots followed by Thiamethoxam-treated plots.

The interaction of insecticides and varieties on the grain yield and yield components is shown in Tables V and VI. Significant difference grain yield (Kg ha^{-1}) was observed in subplots. The maximum yield (3680 Kg ha^{-1}) was recorded in Imidaclopride spray plots followed by statistically similar yield in Acetamiprid (3670 Kg ha^{-1}) and Thiamethoxam treated plots, where average yield was (3660 Kg ha^{-1}). In the orange peel extract treated plots also showed increase in yield (3496.7 Kg ha^{-1}) compared to control plots (3415 Kg ha^{-1}). In main plot significantly more yield of grain (3649.3 kg ha^{-1}) for susceptible variety as against 3519.3 kg ha^{-1} for resistant variety was recorded. The interaction effect was significantly different (F=2.84; d=4, 29; P=0.0000). Significant increase in grain yield was recorded for systemic insecticides in susceptible wheat variety followed by resistant. For orange peel extract grain yield was increased but it was not significantly different from untreated plots.

Thousand grain weight was significantly greater in Imidaclopride treated plots, followed by Thiamethoxam, Acetamiprid and orange peel extract compared to control plots. While in main plot significantly maximum thousand grains were recorded for susceptible variety. Significantly different effect of insecticides and varieties was recorded for yield and thousands grain weight. The interaction effect was significantly different (F=18.13; d=4, 29; P=0.0000). In Imidaclopride treated plots thousand grain weight was maximum for both varieties compared to other insecticides and untreated plots.

Spike length was maximum in Thiamethoxam-treated plot, However, it was statistically similar with spike length in other plots. Similarly, it was not significantly different among the resistant and susceptible varieties. The maximum spike length was recorded for Thiamethoxam in susceptible wheat variety. However, interaction effect of insecticides and wheat varieties was not significantly different.

Significantly (F=425.98; df= 4, 29; P=0.0000) maximum number of grain $spike^{-1}$ were recorded in Imidaclopride plots followed by Thiamethoxam plots, while, minimum number of grain $spike^{-1}$ was recorded in control plots, followed by orange peel extract and Acetamiprid plots. Significantly (F=44.32; df= 1, 29; P=0.0218) more number of grain $spike^{-1}$ were observed in resistant varieties. Interaction of sub-plots and main plots in respect of number of grain $spike^{-1}$ was significantly different (F=9.24; df=4, 29; P=0.0000). The number of grains per spike were maximum in Imidaclopride plots of resistant wheat varieties followed by susceptible wheat variety.

DISCUSSION

Wheat aphids caused significant damage to wheat varieties under filed condition. It was noted that both varieties either susceptible or partially resistant showed reduction in yield kg ha^{-1}, thousands grain weight, number of grain $pike^{-1}$ and spike length. It was expected that susceptible variety should suffered more losses than the partially resistant, but contrary Saleem-2000 in spite of low yield potential of 4707 kg ha^{-1} (Subhan *et al.*, 2004) showed less damage as compared to Pirsabak-2004 of maximum yield potential of 5600 kg ha^{-1} (Khan *et al.*, 2006). It may be due to tolerance response of Saleem-2000, this variety suffered less damage against wheat aphids. (Akhtar *et al.*, 2009) in different study also recorded more yield for susceptible varieties also included Saleem-2000, this may be due to that susceptible varieties have sufficiently more food to supply for aphids feeding. On the contrary, Bakht *et al*. (2010) who studies the response of foliar vs soil application of nitrogen on grain yield (Kg ha^{-1}) and yield components (spike length, grains spike^{-1}, thousands grain weight) of different wheat varieties, recorded the significantly maximum grain of (3287.72 kg ha^{-1}) for Pirsabak-2004 followed by Saleem-2000 (3000.56 kg ha^{-1}).

But after spray a significant improvement in yield and yield components for both varieties was recorded, but at average susceptible showed more increase compared to resistant. This increase in the yield may be due to improvement in thousands grain weight of susceptible as compared to resistant variety. Shahzad *et al.* (2013) and Ali *et al.* (2011) also reported similar results that after spray yield and thousands grain weight significantly increased. Among the tested insecticides the systemic insecticides have provided quick control of wheat aphids, but overall Imidaclopride was very effective.

Joshi and Sharma (2009) conducted field experiment to study the effectiveness of different treatment concentration of Imidaclopride against wheat aphids at 24 h, 2 days, 7 days and 14 days post spray interval. Imidaclopride treatment at the rate of 400 ml ha^{-1} was found most effective against wheat aphids. Anikwe *et al.* (2009) tested various concentration of Thiamethoxam against cocoa mirid, *Sahlbergella singularis* Hagl. (Hemiptera: Miridae) at different post spray intervals. Post spray (24 h) caused 93.3-100 percent mortality of cocoa mirid. Das (2013) tested Imidaclopride insecticides in different concentration against chilli aphid, *Myzus persicae* (Hemiptera: Aphidsidae), spray effect was monitored after 24 h to 10 days. Good knock down effect was achieved after 24 h of spray. But highest percent mortality was observed after 3 days of spray.

In our experiment in orange peel extract treated plots aphids mortality was (21.7, 55, 60, 43 and 47) percent at 24 h, 7 days, 15 days, 21 days and 30 days respectively, Iqbal *et al.* (2011) reported 20.65-65.69 percent mortality of wheat aphids due to orange peel extract at 48 h, 72 h and 144 h post spray application intervals. We recorded 10.06 percent more yield increased for Saleem-2000 (susceptible variety) and 5.42 percent yield increased for Pirsabak-2004 (resistant variety in Imidaclopride treated plots or in other words this was a maximum decreased in yield due to wheat aphids in untreated plots. But, Girma *et al.* (1993) have reported up to 35-40% yield losses and Kieckhefer and Gellner (1992) observed that wheat aphids can caused 20-80% decrease in yield. Sundell (1977) estimated 10 % yield losses due to wheat aphids feeding and suggested wheat aphids resistance cultivars should be develop to reduce loss. Liu *et al*. (1986) reported 14% yield losses due to wheat aphids injury in case of infestation between ear emergence and flower stage. El-Heneidy *et al.* (2003) estimated economic injury level and threshold level for the key cereal aphids species; *R. padi* and *S. graminum* in different wheat locations in Egypt**.** Tested parameters were wheat plant growth stage, density and species of aphids and location. these values fluctuated significantly according to different seasons, sites, growth stages, and aphids species. However the highest economic injury level (6.23 to 10.47 aphids plant^{-1}) was recorded for *R. padi* during stem elongation growth stage. Economic injury levels for *S. graminum* were almost equal in all locations, where they ranged between 5.7-5.9 aphids plant^{-1}. In all growth stages, the impact of the stress of cumulated aphids infestation (reduction in grain yields) caused by *R. padi* alone was always the lowest, it ranged 21.2-75% compared to 21.3-80.8% by *S. graminum* alone and/or to 22.2 -84.2% by the two species together.

Our finding are in conformity with Liu *et al.* (2000) that the rate of parasitization of aphids increased in sprayed plots with insecticides. But the increase in the aphids parasitization rate was not due to the actual increased in the number of mummified aphids but due to rapid declined in aphid density after pray. Rate of parasitization of aphids was least affected in orange peel extract plots and was continued with its natural momentum in control plots.

CONCLUSIONS

The tested insecticides were effective in controlling wheat aphids. Both varieties showed increase in grain yield and also increase in yield components in sprayed plots. In control plots the susceptible in spite of less yield potential suffered less compared to resistant variety with more yield potential. This shows that susceptible variety (Saleem-2000) has some tolerance against wheat aphids. After treatment the response of susceptible was more compared to partially resistant variety. Host plant resistance character *i.e.* tolerance, antixenosis and antibiosis or combination of these characters and natural enemies should be a good IPM package against wheat aphids in field condition. But in case of heavy infestation selective insecticide should be applied against wheat aphids to avoid economic losses. Although the botanical extract have least effect on aphids natural enemies but systemic insecticides should be applied where quick knock down of wheat aphids is required.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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