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Full Length Article

Inorganic Fertilization of Wheat in Relation to Aphid Infestation, Natural Enemies Population, Growth and Grain Yield

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Abstract

A field study was carried out to evaluate the impact of inorganic fertilization to wheat variety Sehar-2006 on aphid infestation, natural enemies' population, growth and grain yield according to randomized complete block design with three replications at Adaptive Research Farm, Vehari during 2009-2010 and 2010-2011. Five NPK doses of 170-0-0 (T_1), 170-114-0 (T_2), 170-0-62 (T_3), 170-114-62 (T_4) and 0-0-0 (T_5) (Control) kg ha^{-1} were tested in the experiment. Average results of the both years showed that NPK doses affected all the growth and yield parameters significantly. Application of 170-114-62 NPK kg ha^{-1} gave maximum plant height (110.1 cm), highest germination counts (240.2), increased No. of productive tillers (376.3), highest No. of grains spike^{-1} (42.33), heavier grain weight (41.57 g) and maximum grain yield (3732 kg ha^{-1}) as compared to data recorded with 170-0-62, 170-114-0, 170-0-0 and 0-0-0 (control) NPK kg ha^{-1}. Results also indicated that main effects of time of sampling, NPK doses, and their interaction significantly affected aphid and predator population. On 15.03.2010, maximum aphid population per tiller (12) was observed, where 170-0-0 NPK kg ha^{-1} was applied followed by (11.78) at 0-0-0 NPK kg ha^{-1} as against the minimum (6) with 170-114-62 NPK kg ha^{-1}. Maximum aphid population per tiller (7.445) was observed, where 170-0-0 NPK kg ha^{-1} was applied followed by (5.963) at 170-0-62 NPK kg ha^{-1} as against the minimum (2.852) with 170-114-62 NPK kg ha^{-1} recorded on 15.03.11. A highest population of predators per plant (1.259 and 1.562) was observed during 31.03.2010 and 31.03.2011, respectively followed by (1.018) on 22.03.10 and (0.424) on 22.03.2011. Significant negative relationships (R^2=-0.86 and -0.75) was depicted between NPK doses and No. of aphids during 2009-2010 and 2010-2011, respectively. Gradual decrease in aphid population was noted when balanced NPK was applied. Significant relationship (R^2=0.71 and 0.87) was found between maximum temperature and predators per plant during 2009-2010 and 2010-2011, respectively. Negative correlation (r=-0.82 and -0.57) was observed between aphid population and grain yield during 2009-2010 and 2010-2011, respectively with respect to inorganic fertilization on wheat crop.

Keywords: NPK doses; Aphid population; Predator population; Yield; *Triticum aestivum*; Pakistan

Introduction

Wheat (*Triticum aestivum* L.) ranks first among the cereal crops in Pakistan and occupies about 66% of the annual food crop area. It is grown on about 8.41 m ha, out of which about 6.27 m ha (74%) falls in Punjab province. Incidence of wheat aphid is emerging issue limiting wheat productivity. For the last few years it has started feeding on wheat at milky grain stage when it is not advisable to spray non selective pesticides on a large scale as a sole agent for its management. Wheat yield as well as production experienced substantial fluctuations during some years, only because natural population of predators and parasitoids failed to keep aphid population to acceptable limits. This natural balance seems to be disturbed largely in recent years due to extensive and indiscriminate use of non-selective pesticides of various crops. Therefore, it is imperative to think of ways and means to resolve the issue (Farooq *et al*., 2011). There is a general perception that unbalanced and excessive doses of nitrogenous fertilizers encourages heavy infestation of aphid on wheat crop and positive correlation between nitrogen doses and aphid population is found in some research trials. The maximum incidence of aphid was observed on maximum dose of nitrogen while minimum was recorded in untreated check (Tetarwal *et al*., 2012).

Various spp. of wheat aphids have worldwide distribution and wide range of host plants e.g. *Schizaphis graminum* (Rond.) recorded from many parts of the world including South and Southeast Asia feeding on many host plants as. *Cynodon dactylon* (Linn.) Pers., *Hordeum vulgare* L., *Oryza sativa* L., *Pennisetum glaucum* R. Br., *Triticum aestivum* L., *Zea mays* L., *Eleusine coracana* (Linn.) Gaertn. It causes substantial yield loss by direct feeding and as a vector of many viral diseases. Bird cherry oat aphid

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(*Ropalosiphum padi* L.) and green bug (*Schizaphis graminum* (Rond) and *Sitobion avenae* (F.) are causing damage to wheat every years in different wheat growing areas (Radchenco, 1994; Khan and Ullah, (2005). Several studies (Aheer *et al.,* 1994, 2006, 2007) reported that aphid population reached to peak during March (Aslam *et al.,* 2004) under ecological conditions of Mandi Baha-ud-Din and Faisalabad districts in Pakistan. They further found significant and positive effect of maximum temperature of 28.3^{o}C, low temperature (9.57^{o}C) and 65% relative humidity on aphid population. Correlation between wheat grain yield and number of aphids causing yield loss was significant and negative (Aheer *et al.*, 1993a and d). Late wheat sowing effect on grain yield and number of grains per tiller due to aphid infestation was reported by Aheer *et al.* (1993b and c). Significant relationship of aphids and predators on different genotypes of wheat was reported by Hassan *et al.* (2004) and Aheer *et al.* (2007).

Fertilizers are a major input for increased agricultural productivity. The form of these inputs can influence pest population depending on the kind of fertilizer used, the crop grown and insect species present. Increasing level of nitrogen (N) fertilizer application promotes the occurrence of herbivorous insects and crop damage from these insects by reducing plant resistance (Douglas, 1993; Bi *et al*., 2001; Ge *et al*., 2003). Plant nutritional status and defense systems that directly act on herbivores are altered by N fertilization (Prudic *et al*., 2005; Chen and Ruberson, 2008). Wang (2001) in a field trial with wheat concluded that N significantly stimulated honey production in two aphid species (*Sitobion avenae* and *Rhopalosiphum padi*) and balanced application of the three major nutrients is important for mediating the aphid population density. Several studies have established that balanced application of fertilizers is an integral component of crop management for realizing good crop yields and increased net returns in spite of higher fertilizer costs (Shukla *et al.,* 1998).

Present studies were planned and executed under field conditions at Vehari to evaluate the effects of nitrogen, phosphorus, and potassium fertilizers applied either alone or in combinations on incidence of aphids, predators and the growth and yield performance of wheat. An effort was made to make a recommendation for aphid management through an effective fertilizer application strategy.

Materials and Methods

The investigations pertaining to the effect of inorganic fertilization on aphid infestation, natural enemies population (predators), and yield of wheat crop were carried out under field conditions in randomized complete block design with three replications at Adaptive Research Farm, Vehari (latitude 30^{o} 1 ^{o} N, longitude: 42^{o} 21^{o}) during 2009-2010 and 2010-2011. Five NPK doses of 170-0-0 (T_1), 170-114-0 (T_2), 170-0-62 (T_3), 170-114-62 (T_4) and 0-0-0 (T_5) (Control) kg ha^{-1} were tested in the experiment. Soil was analyzed before sowing and after harvesting (Table 1). Wheat variety Sehar-2006 was sown on November 30, in 2010 and 2011. Band placement of full doses of phosphorous and potassium in the form of single super phosphate and sulphate of potash with half nitrogen as urea were applied at seed bed preparation and remaining half dose of nitrogen was top dressed with first irrigation. Meteorological data regarding temperature, rainfall and relative humidity were recorded during crop growth period and are presented in Fig. 1 and Fig. 2. Each experimental plot measured 9 x 18 m. Irrigation water was applied through the furrows according to lay out plan. All agronomic practices were kept normal and uniform and weeds were controlled by Isoproturon and Bromoxynal+MCPA applied @ 2000 g ha^{-1} and 1250 mL ha^{-1}, respectively after first irrigation. Data of aphid infestation was recorded weekly from February 22 to March 31 from nine different sites as per treatment and replication by taking one tiller, where as predator population was recorded from same nine sites by taking one plant as per treatment and replication. Whole plant sample was carefully clipped from the selected location, put in the sample bag, and secured in ice chest box before transporting. All samples were thoroughly examined to record aphid and predator population data. Crop was harvested during 3rd week of April of the respective year. Three sites of one square meter were randomly selected from each experimental plot. Plant height (cm) was measured for 10 randomly selected plants from each plot. Productive tillers were determined from an area of one square meter marked randomly at three different locations in each plot. Wheat yield data were also taken from a quadrat of one square meter (1 m × 1 m) from each site of three replications. At each site, spikes of wheat plants were harvested, put into bags and brought to station. Number of grains per spike was counted by threshing from spikes of each site after drying and 1000-grain weight was measured through electronic weighing balance. The data collected were analyzed statistically using ANOVA technique and the significant means were separated by the least significant difference test (Steel *et al*., 1997).

Results and Discussion

Aphid Population per Tiller

Aphid population per tiller was affected significantly ($p<0.01$) due to main effects of time of sampling, NPK doses, and their interaction. The population density of aphid was higher in 2009-2010 than that in 2010-2011. During 2009-2010 and 2010-2011 maximum number of aphids per tiller (9.422 and 5.133) were recorded on March 15 followed by (6.978 and 3.288) observed on March 7 as against the minimum (0.299 and 0.778) on March 31, respectively (Table 2, 3). Aslam *et al.* (2004) also reported such peaks in population of aphid (*Schizaphis graminum* R.)

Table 1: Soil characteristics of experimental site

Sample No.	Sampling time	Depth (cm)	Ec_e (dS m^{-1})	pH	Saturation%	Texture	Type of soil
1	Pre-sowing	0-15	2.40	8.70	36	Clay Loam	sodic
2		15-30	1.98	8.70	38	Clay Loam	
1	After harvesting	0-15	1.89	8.65	38	Clay Loam	sodic
2		15-30	1.80	8.70	37	Clay Loam	

Table 2: Aphid population per tiller as affected by various NPK doses in 2009-10 (Mean ±SE)

Time of sampling	T_1	T_2	T_3	T_4	T_5	Mean
	NPK (kg ha^{-1}))					
	170-0-0	170-114-0	170-0-62	170-114-62	0-0-0	
	No of aphids per tiller					
22.02.10	4.741±0.417	0.741±0.243	1.333±0.339	1.111±0.169	2.000±0.064	1.985D
28.02.10	8.556±0.401	3.778±0.357	3.111±0.279	2.333±0.357	7.148±1.331	4.985C
7.03.10	10.00±0.421	6.556±0.509	5.333±0.222	3.222±0.449	9.778±0.484	6.978B
15.03.10	12.00±0.651	9.111±0.294	8.222±1.118	6.000±0.192	11.78±0.780	9.422A
22.03.10	1.111±0.064	0.407±0.037	0.333±0.111	0.259±0.098	0.444±0.064	0.511E
31.03.10	0.911±0.005	0.188±0.001	0.088±0.001	0.031±0.003	0.278±0.001	0.299E
Mean	6.2198A	3.4635C	3.0701C	2.1593D	5.2380B	

Table 3: Aphid population per tiller as affected by various NPK doses in 2010-11 (Mean ±SE)

Time of sampling	T_1	T_2	T_3	T_4	T_5	Mean
	NPK (kg ha^{-1})					
	170-0-0	170-114-0	170-0-62	170-114-62	0-0-0	
	No of aphids per tiller					
22.02.11	2.148±0.703704	2.963±0.498282	2.518±0.9715	2.185±0.296296	2.741±0.522472	2.511C
28.02.11	2.741±0.743513	1.926±0.464073	1.334±0.2796	1.222±0.400617	3.296±0.498282	2.103C
7.03.11	4.185±0.225288	3.074±0.316445	3.889±0.3849	2.074±0.097991	3.222±0.400617	3.288B
15.03.11	7.445±0.968644	4.482±0.303161	5.963±0.8615	2.852±0.329192	4.926±1.039019	5.133A
22.03.11	3.778±0.1283	3.185±0.303161	3.630±0.4857	1.778±0.111111	3.482±0.596055	3.170B
31.03.11	0.815±0.074074	1.000±0.19245	0.926±0.2062	0.518±0.097991	0.629±0.097991	0.777D
Mean	3.5187A	2.7717B	3.0433B	1.7715C	3.0493B	

Table 4: Predator population per plant as affected by various NPK doses in 2009-10 (Mean ±SE)

Time of sampling	T_1	T_2	T_3	T_4	T_5	Mean
	NPK (kg ha^{-1})					
	170-0-0	170-114-0	170-0-62	170-114-62	0-0-0	
	No of predators per plant					
28.02.10	0.3827±0.0327	0.148±0.037	0.387±0.0321	0.222±0.064	0.123±0.0123	0.2526 D
7.03.10	0.6667±0.0642	0.593±0.037	0.679±0.0932	0.745±0.033	0.568±0.0123	0.6502 C
15.03.10	0.5185±0.0370	1.222±0.111	1.321±0.0123	0.852±0.098	1.148±0.0370	1.0122 B
22.03.10	0.8148±0.1959	1.593±0.161	1.519±0.2429	0.963±0.037	0.778±0.1111	1.0186 B
31.03.10	1.4070±0.09799	2.037±0.206	1.926±0.1614	1.333±0.111	1.037±0.1960	1.259A
Mean	0.7579BC	0.6542C	0.9764A	0.8229B	0.7308BC	

Any two means not sharing a letter in common differ significantly ($p \leq 0.05$); LSD sampling time= 0.5663; LSD fertilizer dose =0.5663; LSD sampling time × fertilizer dose=1.266

during the month of March. NPK fertilization significantly affected the population density of aphids during both the years. Maximum number of aphids per tiller (6.220 and 3.519) was recorded for NPK 170-0-0 kg ha^{-1} followed by (5.238 and 3.049), where no NPK was applied as against the minimum (2.159 and 1.771) with NPK 170-114-62 kg ha^{-1} during 2009-2010 and 2010-2011 respectively (Table 2, 3). It is evident that aphid population gradually increased from Feb. 22 to March 15 on weekly basis during both years of study and declined sharply till March 31. Such peak periods of occurrence of aphids in wheat at moderate temperature have also been reported earlier (Aheer *et al*., 1994, 2006). A negative relationship (R^2=-0.861 and R^2= -0.756) between NPK doses and aphid population per tiller was observed in this study (Fig. 3) for the both year. Balanced NPK application exhibited minimum aphid population as compared to sole application of N. Plant nutritional quality and plant defenses that directly act on herbivores are altered by N fertilization, and the herbivorous insects can distinguish such alterations in plants (Prudic *et al*., 2005; Chen and Ruberson, 2008). Balanced application of NPK mediated the aphid population density and higher nitrogen significantly stimulated higher population density and honey production in (*Sitobion avena and Rhopalosiphum padi* (Cisneros and Godfrey, 1998; Wang, 2001). A negative and significant correlation (r=-0.56, 2009-2010) was found

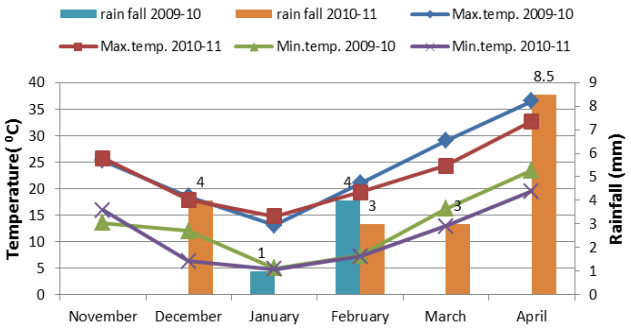

Fig. 1: Monthly mean maximum and minimum temperatures (°C) and rainfall (mm) during crop growth period in 2009-2010 and 2010-2011

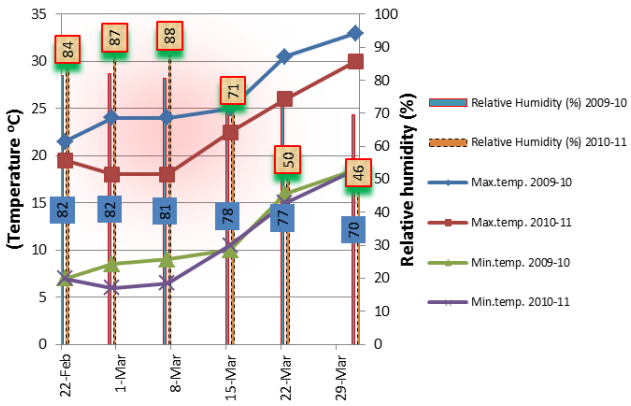

Fig. 2: Weekly mean maximum and minimum temperature (°C) and relative humidity (%) during crop growth period in 2009-2010 and 2010-2011

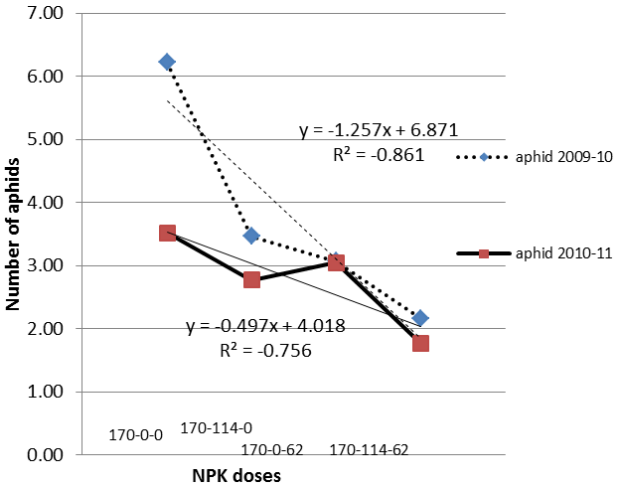

Fig. 3: Relationship between NPK doses and number of aphids per tiller

between maximum temperature and aphid population per tiller so that higher temperature (33°C and 30°C as observed in March 31) causing decline in the aphids (0.299 and 0.777) during both year of study (Fig. 4). Negative and significant correlation (r=-0.59, 2009-2010) was also evident between minimum temperature and aphid population (Fig. 4). Fig. 5 indicating that there was a negative correlation (r=-0.61) between aphids per tiller and predators population only during 2010-2011 because higher predator population in this year might have caused decline in aphids. Contrary to this, Hassan *et al.* (2004) and Aheer *et al.* (2007) reported highly significant but positive correlation between the population of predators and aphids.

Predator Population per Plant

Predators population recorded on weekly basis varied significantly with respect to time of sampling, NPK doses and their interaction (Table 4 and 5). Highest number of predators (1.259 and 1.562) were recorded during March 31 of the respective years of the study followed by predator population of (1.018 and 0.424) recorded during March 22. Variable trend of predators was noted among the NPK doses during both the years. Maximum predator population (2.037 and 1.925) was recorded from the plots where 170-114-0 NPK kg ha^{-1} was applied followed by 1.926 and 1.851 with 170-0-62 NPK kg ha^{-1} as against the minimum (1.037 and 1.222) in the control during both the years when recorded on March 31. Predators appeared in low number in the samples collected early in crop season and increased gradually over time during both years of study. The data (Fig. 6) elucidated that as temperature increased the predator population enhanced accordingly. Data regarding predator population per plant recorded on 28.02.11, and 07.03.11 was found as nil due to lower temperature and higher relative humidity. There was negative and significant correlation (r=-0.61) between aphids and per plant population of predator during 2010-2011 (Fig. 5). There was also significant relationship (R^2= 0.71 and 0.87) between maximum temperature and predator population during 2009-2010 and 2010-2011, respectively (Fig. 6).

Growth and Grain Yield of Wheat

Highest growth attributes of wheat were recorded with the application of 170-114-62 NPK kg ha^{-1} as against the lowest recorded in control treatment. Wheat plots fertilized with balanced NPK ensured the highest germination count (240.2 m^{-2}), productive tillers, (376.3 m^{-2}), plant height (110.1 cm), number of grains per spike (42.3), 1000 grain weight (41.6 g), and relative increase in yield by 51.28% over control (Table 6). There was negative correlation (r=-0.82, 2009-2010 and r = -0.57, 2010-2011; Fig. 7) between aphid population and grain yield. Redchenco (1994) also concluded that bird cherry oat aphid (*Ropalosiphum padi* L.) and green bug (*Schizaphis graminum* (Rond.) cause damage to wheat every years in different wheat growing areas of the world.

Table 5: Predator population per plant as affected by various NPK doses in 2010-11 (Mean ±SE)

Time of sampling	T_1	T_2	T_3	T_4	T_5	Mean
	NPK (kg/ha)					
	170-0-0	170-114-0	170-0-62	170-114-62	0-0-0	
	No of predators per plant					
15.03.11	0.4074±0.037037	0.3703±0.037	0.2222±0.06415	0.2716±0.0494	0.2592±0.0979	0.3061 B
22.03.11	0.3703±0.074074	0.4198±0.025	0.5925±0.03704	0.4444±0.0642	0.2962±0.0741	0.4246 B
31.03.11	1.2222±0.293972	1.9259±0.185	1.8518±0.25926	1.5925±0.2429	1.2222±0.2566	1.562 A
Mean	0.6666C	0.9053A	0.8888A	0.7695B	0.5925D	

Any two means not sharing a letter in common differ significantly ($p \leq 0.05$); LSD sampling time =0.1565; LSD fertilizer dose =0.0954

Table 6: Pooled data regarding agronomic traits and yield attributes of wheat as affected by various NPK doses in 2009-10 and 2010-2011 (means of three replicates)

N-P-K (kg/ha)	Germination. counts (m^{-2})	No. of productive tillers m^{-2}	Plant height (cm)	Number of grains (spike^{-1})	1000-grain weight (g)	grain yield (kg ha^{-1})	Relative increase in yield (%)
170-0-0	215.8C	277.53D	97.83C	36.665C	36.775C	3034C	122.98
170-114-0	221.5BC	319.965C	105.23B	38.515BC	38.72B	3549B	143.86
170-0-62	228.3B	327.7B	107.58AB	39.425B	39.3B	3594B	145.68
170-114-62	240.2A	376.3A	110.1A	42.33A	41.575A	3732A	151.28
0-0-0	208.8C	248.23E	92.465D	32.8D	34.015D	2467D	100.00
LSD=0.05	7.45	4.561	2.912	2.016	1.069	114.7	

Any two means not sharing a letter in common differ significantly ($p \leq 0.05$)

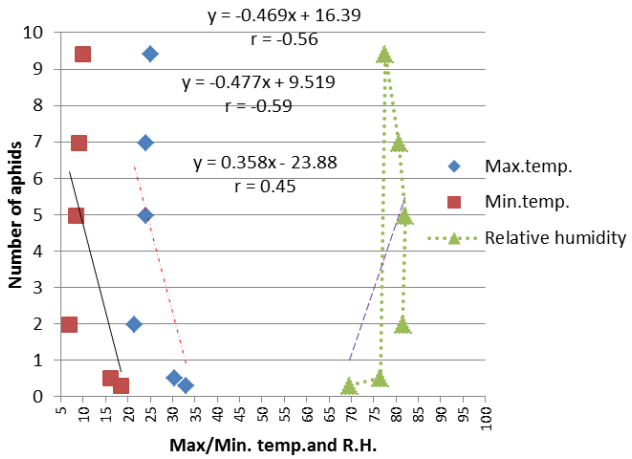

Fig. 4: Correlation between temperature, relative humidity and number of aphids per tiller at different times during 2009-2010

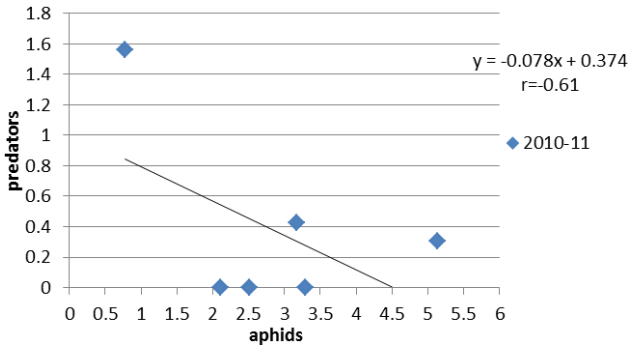

Fig. 5: Correlation between aphids and predators at different sampling time during 2010-2011

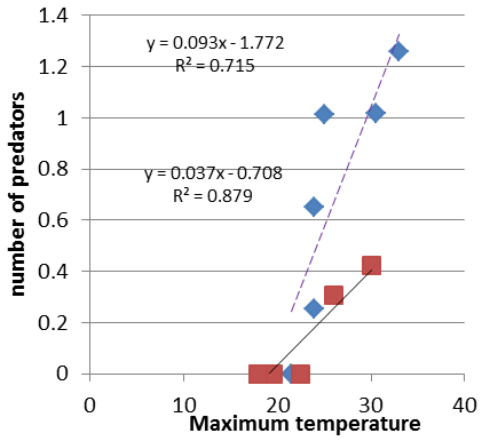

Fig. 6: Relationship between maximum temperature and number of predators with respect to time of sampling in 2009-2010 and 2010-2011

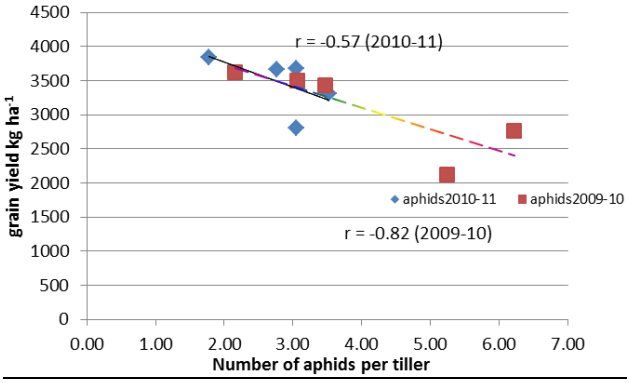

Fig. 7: Correlation between number of aphids and grain yield with respect to various NPK doses

Conclusion

Balanced NPK fertilizer decreased the aphid population density significantly. On the contrary, plants fertilized with higher rates of nitrogen either alone or in combinations with other fertilizers depicted higher infestation of aphid in both seasons of study. Gradual increase in temperature was conducive for enhancing predator population. Increase in aphid population in unbalanced nutrition treatments tended to decline wheat grain yield.

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