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# Integration of Planting Time and Insecticide to Manage Aphid Infestations in Wheat for Better Crop Productivity

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## ABSTRACT

Wheat (*Triticum aestivum* L.) is an important cereal crop in Pakistan. An aphid complex feeds and signifcantly decrease the grain yield in wheat crop. Field experiment was conducted at NIAB, Faisalabad to evaluate the use of the planting time and the insecticide sprays for managing aphids to avoid losses to grain yield. During the crop season in year 2015-16, wheat variety (Millat 2011) was sown on three planting dates: mid Nov (crop 1), end Nov (crop 2), and mid Dec (crop 3). Trial was laid out in split plot design having three replications. Planting dates were kept in main plots while, insecticide treatments were kept in sub plots. Incidence of aphid population was found in mid January. Three species of aphids: *Rhopalosiphum padi* (L.), *Schizaphis graminum* (R.) and *Sitobion avenae* (F.) were found infesting the wheat crop. At the time of aphid invasion crops were at different growth stages such as 1st node (crop 1), at stem elongation (crop 2) and at end of tiller (crop 3). Maximum aphid infestation was recorded in all crops in the 3rd week of February when crops were at booting stage (crop 1), at flag leaf stage (crop 2) and at 2nd node stage (crop 3). Decline of aphid population was observed in mid March. The highest aphid population was recorded in mid-Dec sown crop followed by end-Nov and mid-Nov sown crops. Two applications of insecticide were used to control aphids during the season. Aphid infestations were higher in untreated plots of mid-Dec sown crop followed by end-Nov and mid-Nov sown crops. Heavy infestation of aphids in untreated plot caused for reduction in plant photosynthetic rate and chlorophyll content. Untreated plots had significantly less grain yield as compared to treated plot in all three crops. Cost benefit ratios were significantly different among three crops as 1:7.3, 1:5.7 and 1:4.8 in mid-Nov, end-Nov and mid-Dec crop, respectively. It is concluded that aphids infestation during the season cause for a decrease of grain yield in untreated plots compared to the treated plots. Early planting gave the highest cost benefit ratio when protected against aphids.

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**FJ did the experiments and data observations; NAS conceived, designed and drafted the field study and analyzed the data statistical; SN and MH had expert opinions and critically edit and revised the manuscript.**

**Key words**
**Wheat crop, Planting dates, Aphid infestations, Yield loss, Cost and benefit ratios.**

## INTRODUCTION

Wheat (*Triticum aestivum* L.), is a major cereal crop, cultivated over larger area in Pakistan; therefore, it plays a vital role in economic stability of the country (Anwar *et al*., 2009). Low yield of wheat per hectare in Pakistan, compared to the other wheat growing countries, is due to several abiotic and biotic factors, such as use of traditional methods in cultivation, use of poor performing varieties, lack of irrigation facilities, dependence on rain fed areas, poor soil fertility and incidence of insect pests and diseases. Among the insect pests, a severe damage is caused by aphids. Aphids cause for yield losses either directly (35-40%) by sucking the sap of the plants or indirectly (20-80%) by transmitting viral diseases (Aslam *et al*., 2005).

Aphids infest the plant at different growth stages of the crop and both the adults and nymphs suck cell sap, reducing the vitality of the plants. Some aphid species have toxins in their saliva and dense infestation may kill young shoots. Honey dew excretion is often prolific and sooty moulds usually accompany aphid's infestation which eventually affects the rate of photosynthesis in plants. Aphids multiply very rapidly under favorable conditions on leaves, stems and inflorescence. The infestation causes for distortion of leaves and inflorescence, and can significantly decrease the yield through direct feeding (Khan *et al*., 2012)

Dominant species of aphids in wheat crop are the greenbug, *Schizaphis graminum* R., bird cherry oat aphid, *Rhopalosiphum padi* L., English grain aphid, *Sitobion avenae* F., and corn leaf aphid, *Rhopalosiphum maidis* F. (Mushtaq *et al*., 2013). *Schizaphis graminum* is found to be the most dangerous because it affects the spikes which are direct bearer of the grains. *Rhopalosiphum padi* is usually found on wheat leaves and stems (Wains *et al*., 2014). The leaves infested with *R. padi* turn pale, wilt and wear a silky appearance (Khan *et al*., 2012) whereas, *S. avenae* was dominant on ears but also occurred on leaves (Jarosik *et al*., 2003).

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Aphid population generally appears in January, and remains at low population level due to low temperature and increases towards February. Population reaches the peak in March and drops sharply at the beginning of April (Wains *et al*., 2008; Zeb *et al*., 2011). It was also reported that aphid peak was present at milky stage while its population declined during dough stage (Aheer *et al*., 2006). Aphid population remains high in late sown crop and it is very low in timely sown crop, even lower than that of early sown crop (Aslam *et al*., 2005).

Insecticide application provides a control of aphid population up to 98% (Royer *et al*., 2005). Increase in yield was recorded to be 2.06% after the application of insecticides (Iqbal *et al*., 2008). It was illustrated that the use of imidacloprid (Gaucho® 70%WS @ 0.7-1.05 g a.i. per kg wheat seed) as a seed treatment, efficiently suppress the green bug (*Schizaphis graminum*) for 6-8 weeks after sowing (Ahmed *et al*., 2001). Another study showed that population of aphids has been reduced with the use of Hombre® 186.25FS (imidacloprid + tebuconazole @ 4 ml per kg wheat seed) when used as seed treatment (Suhail *et al*., 2013). It was also reported that imidacloprid (Confidor® 20%SL @ 400 ml per ha) has been most effective when applied as a foliar spray against wheat aphids (Joshi and Sharma, 2009). No local data is available on managing aphid population in wheat crop through integration of planting date, together with insecticide spray, therefore, this study was conducted to evaluate the effect of planting dates and use of insecticide on aphid infestations to avoid reported losses to grain yield in wheat crop.

## MATERIALS AND METHODS

Field experiment was carried out at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad during crop season 2015-16. Crop was sown during mid November, end Novemebr and mid December of the year 2015. Experiment was laid out as a split plot design. Main plots had crops in three planting dates: mid Nov. (crop 1), end Nov. (crop 2) and mid Dec. (crop 3). Main plots were further divided into two subplots. The aphids in one of the subplots in main plot (treated plot) were controlled by insecticide applications. Two foliar applications of Confidor® 200SL (Imidacloprid) were used at the rate of 625 ml per hectare on February 8 and February 22, 2016 against aphid infestations in all three crops established at different planting dates. The other subplot of the main plot was unsprayed and considered as untreated plot.

At each planting date, a pre-sowing irrigation was applied and when soil moisture reached at field capacity level, field preparation was done by using tractor mounted cultivator followed by planking (Hussain *et al*., 2015). The field was prepared in such a way as to destroy weeds etc. The stubbles of the previous crop were incorporated into the soil to have organic matter (Anwar *et al*., 2011). At each planting date, wheat seeds were sown by hand drill method, using recommended seed rates (100 – 125 – 150 kg per hectare for mid-Nov, end- Nov and mid-Dec planting dates, respectively). Seeds of wheat variety, Millat-2011, were planted in rows consisting of 6 rows per plot, with a row length of 4.9 m separated apart by 30.5 cm. Distance between main plots was 122 cm. Standard agronomic practices were applied uniformly for wheat crop sown on each planting date. Diammonium phosphate (DAP: 46% P and 18% N) was used as a source of phosphorus. Urea (46%) was applied as a source of nitrogen. All the dose of phosphorus (125 kg per hectare of DAP) and two fifth portion of the nitrogen (50 kg per hectare of urea) were used as basal at the time of sowing while, rest of nitrogen was applied in three equal splits (25 kg per hectare). A total of three irrigations were done to crop up to maturity.

### *Data collection on aphid infestation*

The aphid population was recorded at 10 days interval starting from January (25.01.2016) to March (18.03.2016). There were six recordings of aphid populations on Jan. 25, Feb. 05, Feb. 15, Feb. 25, Mar. 07 and Mar. 18 of crop season 2015/2016. Among these observations, intial two observations were pre-spray while, remaining four observations were post spray counts of two insecticide sprays. During each sampling, six wheat plants from each plot were randomly selected. The number of aphids per tiller of each plant was recorded as aphid density (Khan *et al*., 2012; Muhammad *et al*., 2013). The growth stage of all three crops was also recorded (Laycock, 2004), to observe the onset and progress of aphids in relation to wheat phenology.

### *Measurement of chlorophyll content*

Relative chlorophyll content, in plants of both the treated and untreated plots of all crops, was recorded by using a hand-held device, atLEAF+ chlorophyll meter. Three dry, clean and fresh leaves were randomly selected from each subplot and placed on the sensors of the machine to measure the relative chlorophyll content till the appearance of reading. Chlorophyll was measured at mid-day (between 10 am to 4 pm) during all observations.

### *Measurement of photosynthetic rate*

Photosynthetic rate of plants in each subplot was measured using LiCor Porometer as per Ashraf *et al*. (1992). Three dry, clean leaves were randomly selected from each sub-plot. Fresh green leaves were taken and their upper surfaces were placed on the sensor of the machine.

Quantum, diffusional resistance and transpiration rate were recorded.

*Crop harvesting and cost benefit analysis*

The crop was harvested manually at physiological maturity, when the green color from the glumes and kernels was disappeared completely (Naseer-ud-Din *et al*., 2011). At maturity thirty tillers were randomly selected from each subplot for getting yield per sample. From each suplot, data were collected on grain yield per plant (Anwar *et al*., 2009). At harvest, the yields of both sprayed and unsprayed plots were compared to assess yield losses (Khan *et al*., 2012). After crop harvesting followed by recording of the grain yield, cost benefit analysis was done to assess the cost spent on the treated plot and the benefit received.

*Statistical analysis*

Data were computed and analysed by using Statistix 8.1(Analytical software, Statistix; Tallahassee, Florida, USA, 1985-2005) following Split Plot Design (Steel *et al*., 1997). A repeated-measures ANOVA was also done considering the number of observations as a factor. Means were compared by using Tukey HSD test (P = 0.05).

## RESULTS

*Planting time and crop growth stages*

Crop phenologies (plant growth stage) of each crop

**Table I.- Effect of planting time on wheat crop phenology during year 2015/16 at NIAB Faisalabad.**

| Planting dates | Crop | Observation dates with months | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 15 N | 25 N | 05 D | 15 D | 25 D | 05 J | 15 J | 25 J | 05 F | 15 F | 25 F | 05 M | 15 M | 25 M | 05 A | 15 A | 25 A |
| mid Nov | 1 | S | 11 | 13 | 21 | 25 | 29 | 30 | 31 | 32 | 37 | 39 | 49 | 55 | 59 | 69 | 89 | 89 |
| end Nov | 2 | - | S | 11 | 13 | 21 | 25 | 29 | 30 | 31 | 32 | 37 | 39 | 49 | 55 | 59 | 69 | 89 |
| mid Dec | 3 | - | - | S | 11 | 13 | 21 | 25 | 29 | 30 | 31 | 32 | 37 | 39 | 49 | 55 | 59 | 89 |

S, Seeding; 11, first leaf; 13, three leaves; 21, start of tillering; 25, five tillers; 29, end of tillering; 30, start of stem elongation; 31, first node visible; 32, second node visible; 37, flag leaf just visible; 39, flag leaf fully emerged; 49, booting; 55, ear 50% emerged; 59, ears fully emerged; 69, end of flowering; 89, fully ripe; N, November; D, December; J, January; F, February; M, March; A, April.

**Table II.- Effect of planting time on occurrence of wheat aphids during year 2015/16 at NIAB Faisalabad.**

| Status of Aphid population | | Plant growth stages of three crops | | |
|---|---|---|---|---|
| | | Crop 1 | Crop 2 | Crop 3 |
| All aphids | Incidence | 1st node visible | Stem elongation | End of tillering |
| | Peak | Booting stage | Flag leaf just visible | 2nd node visible |
| | Decline | Ear fully emerged | Flag leaf fully emerged | Ear 50% emerged |
| | Elimination | End of flowering | Ear fully emerged | Ear fully emerged |
| *R. padi* | Incidence | 1st node visible | 1st node visible | End of tillering |
| | Peak | Booting stage | Booting stage | Stem elongation |
| | Decline | Fully ripe | Ear fully emerged | Ear fully emerged |
| *S. graminum* | Incidence | 1st node visible | 1st node visible | End of tillering |
| | Peak | Flag leaf just visible | Flag leaf just visible | 1st node visible |
| | Decline | Ear fully emerged | Flag leaf fully emerged | 2nd node visible |
| *S. avenae* | Incidence | Ear fully emerged | Ear 50% emerged | End of flowering |
| | Peak | End of flowering | Ear fully emerged | End of flowering |
| | Decline | End of flowering | Ear fully emerged | Fully ripe |

Crop 1, mid Nov; Crop 2, end Nov; Crop 3, mid Dec sown crop.

**Table III.- Effect of planting time and insecticide use on aphid infestations (no./tiller ± S.E) during the whole crop season (ANOVA of split plot design).**

| Main plots / Crops | Observation dates | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25-01-2016 | 05-02-2016 | 15-02-2016 | 25-02-2016 | 07-03-2016 | 18-03-2016 | Seasonal Mean |
| Crop 1 | 0.6±0.1*B* | 1.2±0.2 *B* | 2.8±1.1 *B* | 3.7±0.6 | 5.31±2.3 *B* | 0.0±0.0 *C* | 2.3±0.7 *B* |
| Crop 2 | 0.3±0.1 *B* | 1.5±0.7 *B* | 5.7±2.5 *B* | 14.3±1.4 | 11.4±1.8 *B* | 1.1±0.2 *B* | 5.7±1.2 *B* |
| Crop 3 | 1.6±0.6 *A* | 3.4±0.9 *A* | 24.7±1.4 *A* | 13.0±3.2 | 20.1±4.6 *A* | 2.5±1.1 *A* | 10.9±2.1 *A* |
| Fvalue | 8.29 | 9.58 | 9.38 | 2.98 | 27.90 | 8.20 | 7.19 |
| P value | (0.0378)* | (0.0298)* | (0.0309)* | (0.1612)n.s | (0.0045)* | (0.0385)* | (0.0473)* |
| Tukey HSD | 1.2 | 1.6 | 14.3 | - | 5.9 | 1.2 | 3.6 |

| Suplots | Observation dates | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25-01-2016 | | 05-02-2016 | | 15-02-2016 | | 25-02-2016 | | 07-03-2016 | | 18-03-2016 | | Seasonal Mean | |
| Crop | Unt | Trt | Unt | Trt | Unt | Trt | Unt | Trt | Unt | Trt | Unt | Trt | Unt | Trt |
| Crop 1 | 0.8±0.2b | 0.4±0.1b | 0.8±0.1b | 1.7±0.1b | 5.3±0.4c | 0.5±0.1c | 5±0.3 | 2.5±0.3 | 30.5±0.3 | 9.8±0.2 | 0.0±0.0 | 0.0±0.0 | 7.2±0.1 | 2.7±0.1 |
| Crop 2 | 0.8±0.1b | 0.0±0.0b | 3.2±0.2a | 0.0±0.0b | 11.3±0.4b | 0.1±0.1c | 17.4±0.3 | 11.2±0.2 | 10.4±0.4 | 0.2±0.1 | 0.8±0.2 | 1.5±0.3 | 8.0±0.1 | 1.9±0.1 |
| Crop 3 | 2.9±0.2a | 0.3±0.3b | 5.4±0.2a | 1.5±0.5b | 27.9±0.7a | 21.6±0.6a | 20.5±0.3 | 5.7±0.3 | 15.6±0.3 | 7.3±0.2 | 5.1±0.2 | 0.0±0.0 | 11.0±0.1 | 7.1±0.1 |
| Mean | 1.5±0.4A | 0.2±0.1B | 3.1±0.7A | 1.0±0.2B | 14.8±3.4A | 7.3±3.5B | 14.3±2.4 | 6.4±1.2 | 18.8±3.0A | 5.7±1.4B | 1.9±0.7 | 0.5±0.2 | 9.1±0.8A | 3.6±0.6B |
| F value | 23.6 | | 26.74 | | 3.72 | | 4.25 | | 30.40 | | 3.93 | | 20.77 | |
| P value | (0.0028)* | | (0.0021)* | | (0.0119)* | | (0.0850)n.s | | (0.0015)* | | (0.0948)n.s | | (0.0039)* | |
| Tukey HSD | 0.6 | | 1.1 | | 5.9 | | - | | 4.4 | | - | | 2.6 | |

| Interaction = Crop × Treatment | Observation dates | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25-01-2016 | 05-02-2016 | 15-02-2016 | 25-02-2016 | 07-03-2016 | 18-03-2016 | Seasonal Mean |
| F value | 8.02 | 6.19 | 0.85 | 2.25 | 2.95 | 3.56 | 0.09 |
| P value | (0.0202)* | (0.0348)* | (0.0439)* | (0.1865)n.s | (0.1283)n.s | (0.0957)n.s | (0.0.9164)n.s |
| Tukey HSD | 1.9 | 3.1 | 6.2 | - | - | - | - |
| **Repeated measure ANOVA$^{\$}$ (Sample dates as additional factor)** | | | | | | | |
| Sample dates | 25-01-2016 | 05-02-2016 | 15-02-2016 | 25-02-2016 | 07-03-2016 | 18-03-2016 | |
| Mean±S.E | 0.8±0.3 B | 2.0±0.6 B | 11.1±3.6 A | 10.3±2.3 A | 12.3±3.2 A | 1.2±0.6 B | |

Crop 1, mid Nov; Crop 2, end Nov; Crop 3, mid Dec sown crop; Unt, no insecticide; Trt, two applications of imidacloprid insecticides; *, significant (P = 0.05); n.s., non significant; Means (for Crop) sharing similar letter (Capital & Italic) in column are not significantly different; Means (for Treatment) sharing similar letters (Capital) in rows are not significantly different; Means (for interaction Crop × Treatment) sharing similar letters (Small) in rows and columns are not significantly different; Means (for interaction Sampling dates × Crop × Treatment) sharing similar letters (Capital) in rows and columns are not significantly different; $^{\$}$Repeated measure ANOVA: Sampling dates (df = 5, F = 18.50, P = 0.0000, Tukey HSD = 4.9); Crop (df = 2, F = 7.19, P = 0.0473, Tukey HSD = 3.6); Sampling dates × Crop (df = 10, F = 5.56, P = 0.0000); Treatment (df = 1, F = 20.77, P = 0.0039, Tukey HSD = 2.7); Sampling dates × Treatment (df = 5, F = 2.76, P = 0.0261); Crop × Treatments (df = 2, F = 0.09, P = 0.9164); Sampling dates × Crop × Treatment (df = 10, F = 1.75, P = 0.0902).

starting from seeding to harvest is shown in Table I. On 25th December, crop 1 (mid-Nov) was at five tiller stage while crop 2 (end-Nov) was at start of tiller whereas, crop 3 (mid-Dec) was at 3 leaf stage. Similarly, on 25th January (time of aphid incidence), crop 1 was at first node visible stage while crop 2 was at start of stem elongation when crop 3 was just at end of tillering. This difference continued, for example on 25th March (end of aphid infestation), crop 1 was at stage with ears fully emerged when crop 2 was at ½ ear stage while, crop 3 was just at booting stage. The crop 1 got longer growing period while, crop 3 got shorter growing period, and therefore, had immature crop termination. For example on 15th April, crop 1 was fully ripe when crop 2 was at end of flowering stage, while, crop 3 was just at fully emerged ear stage. Crops were harvested during the last week of April.

*Crop phenology and aphid infestation*

Crops were attacked by three species of aphids *i.e.*, Bird cherry oat aphid, *Rhopalosiphum padi*; the greenbug aphid, *Schizaphis graminum* and English grain aphid, *Sitobion avenae.* Occurance of three aphid species is described (Table II) with respect to the crop phenology during the period of aphid activity from initiatiation to decline of population.

Data on aphid population recorded during January to March 2016, showed that incidence of aphid was started in mid January in all crops at different plant growth stages (Table II). *R. padi* was the first to observe on all three crops followed by *S. graminum* during the mid January and it remained high till mid March. *S. avenae* appeared late during the first week of March. Aphid population reached its peak during booting stage (crop 1), flag leaf stage (crop 2) and 2nd node stage (crop 3). Aphid decline was observed at ear fully emerged (crop 1), flag leaf fully emerged (crop 2) and ear 50% emerged stage (crop 3). Decline and elimination of aphids were observed after mid March in all three crops.

*Planting time, insecticide sprays and aphid infestation*

Table III shows the records of aphid population on six different observation dates from mid of Januray to mid of March on all crops. Significant differnce was found among all three crops in all observations except on 25.02.2016. Maximum aphid population was recorded in crop 3 (mid-Dec) followed by crop 2 (end-Nov) and crop 1 (mid-Nov). Aphid poulations were significantly different between treated and untreated plots. Aphid infestations were higher in untreated plots of crop 3 followed by crop 2 and crop 1 as compared to respective treated plots. Our results showed that higher population of aphids was due to tender plant growth in crop 3, which was prefered by aphid species to feed. Seasonal population of aphid showed significant difference among six observation dates by using repeated measure ANOVA considering observation date as additional factor (Table III). Significantly higher aphid densities were recorded on sample dates during mid February to mid March.

*Chlorophyll content*

Plant leaf chlorophyll content was recorded on three observations of both treated and untreated plot in all crops established on three planting dates (Table IV). Chlorophyll content of plants was significantly different among all crops in all observation dates. Chlorophyll contents in plants, treated with insecticide and untreated plants were significantly different. Maximum chlorophyll content was recorded in crop 1 followed by crop 2 and crop 3.

*Photosynthetic rate*

Photosynthetic rate of plants was recorded in both the treated and untreated plots in all crops established in three planting dates (Table V) on three observations. Photosynthetic rate was significantly different among all crops on 25.03.2016. Plants in treated plot showed higher photosynthetic rate as compared to plants in untreated plot. Maximum photosynthetic rate was recorded in crop 1 followed by crop 2 and crop 3. Results showed that higher chlorophyl contents of the plant may lead for higher photosynthetic rate.

*Grain yield of experiment*

Grain yield of plots was significantly different among crops established in three planting dates (Table VI). Insecticide treated and untreated plots were also significantly different from each other in terms of grain yield. The maximum grain yield was recorded in mid-Nov sown crop followed by end-Nov and mid-Dec sown crops. Yield of treated plot was higher than the yield of untreated plot.

*Cost benefit analysis of planting time and insecticides use*

After yield analysis, cost benefit ratio was calculated for all three crops considering insecticide applications (Table VII). Cost benefit ratio, of insecticide treated plot, was higher, moderate and the least in mid-Nov, end-Nov and mid-Dec sown crops, respectively. Impact of insecticide usage in early sown crops was higher because of better growth and crop stage which escaped the aphid infestation.

Table VII showed that heavy infestation of aphids in untreated plot causes for reduction in photosynthetic rate and chlorophyll content of the crop. Treated plots had significantly less population of aphid which causes for

**Table IV.- Effect of planting time and insecticide use on chlorophyll content (ANOVA of split plot design).**

| Main plots / Crop | Observation dates 18-02-2016 | | 25-03-2016 | | 01-04-2016 | | Seasonal Mean | |
|---|---|---|---|---|---|---|---|---|
| Crop 1 | 57.3±1.0 *A* | | 46.9±0.9 *A* | | 45.3±1.3 *A* | | 49.8±1.1 *A* | |
| Crop 2 | 54.1±1.2 *B* | | 46.3±0.6 *A* | | 39.1±0.6 *B* | | 46.5±0.8 *B* | |
| Crop 3 | 52.9±1.0 *B* | | 42.9±0.6 *B* | | 28.4±4.6 *C* | | 41.4±2.1 *C* | |
| Fvalue | 24.5 | | 53.20 | | 769.6 | | 212.7 | |
| P value | (0.0057)* | | (0.0013)* | | (0.0000)* | | (0.0001)* | |
| Tukey HSD | 2.35 | | 1.5 | | 1.5 | | 1.4 | |
| **Subplots** | **Observation dates** | | | | | | | |
| | **18-02-2016** | | **25-03-2016** | | **01-04-2016** | | **Seasonal Mean** | |
| **Crop** | **Unt** | **Trt** | **Unt** | **Trt** | **Unt** | **Trt** | **Unt** | **Trt** |
| Crop 1 | 55.3±1.0 | 59.4±0.4 | 44.9±0.3 | 49.0±0.2 | 42.6±0.3 b | 48.1±0.1 a | 47.6±0.5 b | 52.2±0.1 a |
| Crop 2 | 51.5±0.3 | 56.9±0.3 | 45.0±0.3 | 47.7±0.4 | 37.9±0.4 c | 40.4±0.3 b | 44.8±0.3 c | 48.3±0.1 b |
| Crop 3 | 50.8±0.3 | 55.1±0.3 | 41.7±0.4 | 44.3±0.2 | 17.8±0.4 d | 39.1±0.3 b | 36.7±0.2 2 | 46.1±0.1 c |
| Mean | 52.5±0.8 B | 57.1±0.6 A | 43.8±0.6 B | 47.0±0.7 A | 32.7±3.8 B | 42.5±1.4 A | 43.0±1.6 B | 48.8±0.9 A |
| F value | 903 | | 98.0 | | 1936.0 | | 817.8 | |
| P value | (0.0001)* | | (0.0001)* | | (0.0000)* | | (0.0000) | |
| Tukey HSD | 1.1 | | 0.7 | | 0.5 | | 0.5 | |
| **Interaction = Crop × Treatment** | **Observation dates 18-02-2016** | | **25-03-2016** | | **01-04-2016** | | **Seasonal** | |
| F value | 0.81 | | 2.0 | | 703.0 | | 82.17 | |
| P value | (0.4872)n.s | | (0.2160)n.s | | (0.0000)* | | (0.0000) | |
| Tukey HSD | - | | - | | 2.3 | | 1.2 | |

Crop 1, mid Nov; Crop 2, end Nov; Crop 3, mid Dec sown crop; Unt, no insecticide; Trt, two applications of imidacloprid insecticides; *, significant (P = 0.05); n.s., non significant; Means (for Crop) sharing similar letter (Capital & Italic) in column are not significantly different; Means (for Treatment) sharing similar letters (Capital) in rows are not significantly different; Means (for interaction Crop × Treatment) sharing similar letters (Small) in rows and columns are not significantly different.

**Table V.- Effect of planting time and insecticide use on photosynthetic rate (ANOVA of split plot design).**

| Main plots / Crop | Observation dates 18-02-2016 | | 25-03-2016 | | 01-04-2016 | | Seasonal Mean | |
|---|---|---|---|---|---|---|---|---|
| Crop 1 | 1.3±0.3 | | 1.0±0.3 *A* | | 0.6±0.1 | | 0.9±0.2 | |
| Crop 2 | 1.1±0.2 | | 0.6±0.1 *B* | | 0.2±0.1 | | 0.6±0.1 | |
| Crop 3 | 0.7±0.2 | | 1.0±0.4 *A* | | 0.1±0.0 | | 0.6±0.2 | |
| Fvalue | 1.0 | | 13.0 | | 1.0 | | 2.0 | |
| P value | (0.4444)n.s | | (0.0178)* | | (0.4444)n.s | | (0.2500)n.s | |
| Tukey HSD | - | | 0.4 | | - | | - | |
| **Subplots** | **Observation dates** | | | | | | | |
| | **18-02-2016** | | **25-03-2016** | | **01-04-2016** | | **Seasonal Mean** | |
| **Crop** | **Unt** | **Trt** | **Unt** | **Trt** | **Unt** | **Trt** | **Unt** | **Trt** |
| Crop 1 | 0.8±0.0 | 1.8±0.2 | 0.4±0.1 b | 1.6±0.1 a | 0.4±0.0 b | 0.9±0.1 a | 0.5±0.0 | 1.4±0.0 |
| Crop 2 | 0.7±0.2 | 1.6±0.2 | 0.5±0.1b | 0.7±0.1 b | 0.1±0.0 b | 0.3±0.1 b | 0.4±0.1 | 0.9±0.1 |
| Crop 3 | 0.4±0.1 | 1.1±0.1 | 0.2±0.0b | 1.8±0.3 a | 0.1±0.0 c | 0.2±0.0 bc | 0.2±0.0 | 1.1±0.1 |
| Mean | 0.6±0.1 B | 1.4±0.1 A | 0.3±0.1 B | 1.3±0.2 A | 0.1±0.0 | 0.4±0.1 | 0.3±0.0 B | 1.1±0.1 A |
| F value | 25.0 | | 49.0 | | 1.0 | | 18 | |
| P value | (0.0025)* | | (0.0004)* | | (0.0.3559)n.s | | (0.0054)* | |
| Tukey HSD | 0.5 | | 0.3 | | - | | 0.1 | |
| **Interaction = Crop × Treatment** | **Observation dates 18-02-2016** | | **25-03-2016** | | **01-04-2016** | | **Seasonal** | |
| F value | 0.25 | | 13.0 | | 1.0 | | 1.5 | |
| P value | (0.7865)n.s | | (0.0066)* | | (0.4219)n.s | | (0.2963)n.s | |
| Tukey HSD | - | | 0.8 | | - | | - | |

For abbreviations and statistical details, see Table IV.

**Table VI.- Grain yield (g)* of the experiment.**

| Crop | Main plot Crop yield (g) | Subplot Treatment yield (g) Unt | Interaction = Crop × Treatments Trt |
|---|---|---|---|
| Crop 1 | 32.6 *A* | 30.2 b | 35.0 a |
| Crop 2 | 24.5 *B* | 22.6 d | 26.4 c |
| Crop 3 | 19.1 *C* | 17.5 e | 20.7 d |
| Mean | | 23.4 B | 27.3 A |
| Fvalue | 610.5 | 74.0 | 1.1 |
| P value | (0.0000)* | (0.0001)* | (0.0372)* |
| Tukey HSD | 1.3 | 1.1 | 2.8 |

*Sample size, 30 tillers (0.6 sq. foot) = grain weight (g) per 0.6 sq. ft. For abbreviations and statistical details, see Table IV.

maximum rate of photosynthesis and higher chlorophyll content. The crop treated with insecticide had higher grain yield, giving maximum benefit. Of the three crops, the maximum yield and benefit were obtained from mid-Nov sown crop compared to end-Nov and mid-Dec sown crops.

## DISCUSSION

*Crop phenology and aphid infestation*

The infestation of aphid population started during the mid January which gradually increases with the vegetative stage of the plants in all crops established at different planting time. At that time crops sown on different dates had different growth stages. Planting time affected the plant growth pattern. In our results, change in planting time altered the growth stages of wheat plants. This change also affected the aphid occurrence on wheat plants. Incidence of aphid was recorded at 1st node stage (crop 1), at start of stem elongation (crop 2) and at end of tillering stage. Akhter *et al*. (2010) found aphids on wheat tillers, heads, leaves, and stems. They also observed that aphids kept rolling the flag leaf and trapping the emerging heads and awns. This phenomenon caused for reduction in pollination which results in low grain yield.

Third week of February was found to be the most suitable period for spread of aphids on wheat crop. At that time crop plants were at booting stage (crop 1), flag leaf stage (crop 2) and 2nd node stage (crop 3). Early sown crop plants had advanced growth stages than late sown crops and thus crop showed an escape from aphid infestation. Time of infestation and crop growth stage is as important and critical as the level of infestation on wheat crop for aphid susceptibility and its effect on grain yield.

Aphid infestations were reported to appear in the mid January (Aslam *et al*., 2004; Aheer *et al*., 2006; Zeb *et al*., 2011; Khan *et al*., 2012). Our results are similar to Manna (2002) and Khan *et al*. (2012), who describe peak of aphid population during mid February. It may be due to faster aphid breeding during the cold weather (Aslam *et al*., 2005). Our results are in contradiction to Akhter *et al*. (2010) and Muhammad *et al*. (2013) who reported aphid appearance in February. Our results are also inconsistant with Zeb *et al*. (2011), Muhammad *et al*. (2013) and Abbas *et al*. (2014), who recorded aphid peak during March.

Decline in aphid population was recorded after mid March in all crops established in three planting dates. After mid March, crop 1 was at end of flowering stage, whereas, crop 2 and 3 were at fully emerged ear stage. Aphid population was totally eliminated from the field by mid of March on all crops. After mid March, rise in temperature and humidity causes flora reduction or elimination of aphid infestation (Tabassum *et al*., 2012). Our results are similar to Khan *et al*. (2012) and Muhammad *et al*. (2013) who reported decline in aphid population after mid March due to the increase in temperature, ripening of crop and the attack of coccinellid beetles.

Our results are slightly different to Aslam et al. (2004) who reported the aphids elimination from the wheat crop during 1st week of April.

**Table VII.- Aphid population, chlorophyll content, photosynthetic rate, yield and cost benefit ratio.**

| Main Plots | Insecticide | Mean aphid/ tiller | Chlorophyll Contents | Photo-synthetic rate | Yield/ Acre (40 Kg) | Yield Difference (40 Kg/acre) | Yield Difference (40 Kg/hectare) | Benefit (Rs.) | Cost (Rs) | C:B |
|---|---|---|---|---|---|---|---|---|---|---|
| Crop 1 | Unt | 7.2±0.1 | 47.6±0.5 | 0.5±0.0 | 54.9 | | | | | |
| | Trt | 2.7±0.1 | 52.2±0.1 | 1.4±0.0 | 63.6 | 8.7 | 21.5 | 27904 | 3828.5 | 1:7.3 |
| Crop 2 | Unt | 8.0±0.0 | 44.8±0.3 | 0.4±0.1 | 41.2 | | | | | |
| | Trt | 1.9±0.0 | 48.3±0.1 | 0.9±0.1 | 47.9 | 6.8 | 16.7 | 21725 | 3828.5 | 1:5.7 |
| Crop 3 | Unt | 11.0±0.1 | 36.7±0.2 | 0.2±0.0 | 31.8 | | | | | |
| | Trt | 7.1±0.1 | 46.1±0.1 | 1.1±0.1 | 37.5 | 5.7 | 14.0 | 18231 | 3828.5 | 1:4.8 |

Cost of insecticide use, 3282.50; cost of product + labour cost= 575/A +200=775/- . Cost of product Confidor 575Rs./250ml/acre= 1914.25/ha= single application. For abbreviations, see Table IV.

*Planting time and aphid infestation*

In our findings, higher infestation of aphid was observed on untreated plot of the third crop (mid-Dec). These findings are at par with the study of Helmi and Rashwan (2013) who reported that crop sown in December becomes more suceptible for aphid species. Aslam *et al.* (2005) reported that aphid infestation can be reduced by sowing of wheat early in the season. Also, Shahzad *et al.* (2013) reported that delayed sowing of wheat crop get witnessed with increased aphid number. Significantly lower numbers of aphids (*S. graminum*) were reported in early November sown wheat crop. Timely sown wheat crop is not only important for better crop growth but also have less intensity of aphid infesation. Early sown crops synchronize with better environmental conditions and low aphid infestation and thus result in higher grain yield.

*Chlorophyll content and photosynthetic rate*

Observations showed the decrease of the photosynthetic rate and the chlorophyll content with the gradual increase of planting dates. It was also observed that the wheat plants in treated plots had higher photosynthetic rate and chlorophyll content than the plants in untreated plots. Our findings are consistant with Ahmad *et al.* (2015) who reported that higher chlorophyll contents in wheat plant was observed in early sown crop as compared to late sown crops.

*Impact of insecticides on crop yield*

Insecticide treated plots had higher grain yield as compared to untreated plots. Mid Nov sown crop gave the higest yield as compared to end Nov and mid Dec sown crops. Our results are in conformity to Akhter *et al.* (2010), Zeb *et al.* (2011), Ali *et al.* (2011) and Khan *et al.* (2012) who reported the higher yield under insecticide treated plots.

## CONCLUSION

Change in planting dates (early November to mid December) affects the plant growth in wheat crops. This change in plant growth affects the intensity of aphid infesation on wheat plants. Crops sown during November have less aphid intensities and have the ability to tolerate aphid feeding injury for their advanced plant growth resulting higher grain yield as compared to crop sown during mid December. Early wheat planting, together with insecticide use result into significantly higher grain yield, better chlorophyll content and photosynthetic rate due to check on aphid infesations as compared to untreated late sown crops.

*Statement of conflict of interest*

Authors have declared no conflict of interest.

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