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EXTENT OF LOSSES INFLICTED BY APHID COMPLEX AT DIFFERENT LEVELS OF INFESTATION ON WHEAT AND DETERMINATION OF EIL AND ETL

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ABSTRACT
Field experiments were conducted at Experimental Farm of Department of Entomology, CSK HPKV, Palampur, Himachal Pradesh during 2013-14 and 2014-15 to assess the losses caused by aphid complex in wheat. The aphid population at initial infestation levels of 5, 10, 20 and 40 aphids per plant released at CRI stage and peaked during 3rd week of March with the corresponding population of 26.7, 38.5, 38.9 and 38.5 aphids per plant and 25.2, 37.6, 38.1 and 39.0 aphids per plant during 2013-14 and 2014-15, respectively. The highest avoidable losses in grain yield were 28.64 and 26.67 per cent during 2013-14 and 2014-15, respectively. Tillering stage showed higher yield losses and thus proved to be the most susceptible stage. EIL determined for aphids for the infestation initiated at CRI was 32.61 CAD (Cumulative aphid days) and at tillering and panicle emergence stages the corresponding EIL values were 41.55 and 35.77 CAD per plant and the ETL values were 24.46, 31.16 and 26.83 CAD per plant, respectively. On the basis of initial aphid infestation levels, the EIL was 14.93, 7.19 and 6.78 aphids per plant and the ETL values were 11.20, 5.39 and 5.09 aphids per plant at CRI, tillering and panicle emergence.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important cereal in India after rice and it covers an area of 30 million hectares with the production of 93.50 million tonnes (Anonymous 2014). In Himachal Pradesh, during 2013-14, it was grown an area of 371.06 thousand hectares with the production of 538.52 thousand tonnes (Anonymous 2014a). Wheat being a premier winter cereal crop in India and is attacked by number of insect pests viz., termites, armyworm, shoot fly, brown wheat mite and cutworms (Dhadwal *et al.,* 2014). More than eleven aphid species infest wheat crop out of them four species viz., *Sitobion avenae* (Fabricius), *S. miscanthi* (Takahashi), *Rhopalosiphum padi* (Linnaeus) and *R. maidis* (Fitch) are reported to be the most predominant (Jarosik *et al.,* 2003). A complex of four species viz., *R. maidis*, *S. miscanthi*, *R. padi* and *S. avenae* was reported to infest wheat crop and losses were estimated to the tune of 3.53-21.05 per cent in Punjab (Deol *et al.,* 1987; Singh and Deol 2003). The aphids are emerging as important pests of wheat in Himachal Pradesh. During 2010-11 and 2011-12, aphid population ranging from 7.75-52.07 aphids per shoot was recorded in the month of March under Palampur conditions of Himachal Pradesh (Sharma *et al.,* 2013). Highest yield of wheat recorded by Meena *et al.* (2013) was 41.2 quintals per hectare. Populations exceeding 50 aphids per ear have been reported to inflict 6.13-27.82 per cent yield losses (Singh *et al.,* 2008). Keeping in view the fact that no systematic work on the extent of losses on wheat has been undertaken in Himachal Pradesh, the studies were undertaken on this aspect and working out ETL and EIL values for the successful management of the pest, the present studies were conducted to assess the losses caused by aphid complex in wheat.

MATERIALS AND METHODS

Stock culture of aphids was maintained in laboratory for the present studies and aphid population levels *i.e.* 5, 10, 20 and 40 were released on 10 marked plants at CRI (Crown Root Initiation), tillering and panicle emergence stages of wheat in separate plots of size of 9 m². Level 'zero' plants were maintained with the spray of dimethoate 30EC (Rogor). Observations on the number of aphids per 10 shoots were recorded at weekly intervals after the release of aphids at their respective levels in the different crop stages. The relationship between cumulative aphid days and yield was worked out for different population levels as per the method used by Jeon *et al*. (2008) and the losses at different infestation levels were worked out. The grain yield was recorded from all the marked plants in different levels of release during different crop growth stages. The per cent avoidable losses were calculated using formula outlined by Atwal and Singh (1990). Economic injury level (EIL) was calculated for three plant growth stages in crop by using following parameters:

EIL = C / (V x I x D x K)

where, C is the cost of management, V is the market value of crop, I is the unit injury per aphid, D is the damage per unit injury and K the control efficacy or proportional reduction in potential injury or damage by management practices as outlined by Pedigo *et al*. (1986) and Pedigo (2002).

RESULTS AND DISCUSSION

Population buildup of aphids in wheat crop during 2013-14

Infestation initiated at CRI stage

In order to study the effect of differential infestation levels of aphids at 5, 10, 20 and 40 aphids per plant on population buildup, released artificially on wheat plants at CRI crop growth stage, and thereafter weekly observations recorded on population buildup of aphids are presented in table 1.At CRI stage, the plants were infested artificially on January 18, 2014 by releasing 5, 10, 20 and 40 aphids per plant. A perusal of data contained in table 1 revealed that one week after initiation of infestation, the population of aphids was 9.50, 15.60, 15.70 and 16.80 aphids/ plant at the corresponding infestation levels of 5, 10, 20 and 40. The number of aphids in plants which were infested with 20 and 40 aphids/ plant decreased because of the crowding at higher levels of infestation and also due to small size of plants, they were not able to hold that much of pest population released at higher levels. Thereafter, the population increased significantly and reached the peak in 3rd week on March, 2014 with a population of 26.70, 38.50, 38.90 and 38.50 aphids per plant at infestation levels of 5, 10, 20 and 40 aphids per plant, respectively. Further, a decline in population was set in and aphid count was zero during first week of May, 2014. The mean population varied significantly at all the initial infestation levels 23.70, 22.40, 21.50 and 14.50 aphids per plant in descending order at 40, 20, 10 and 5 aphids level of infestation.

Infestation initiated at tillering stage

At tillering stage, the plants were infested artificially on Feb 22,

Table 1: Population buildup of aphids released at varying infestation levels at different stages of wheat during 2013-14

Sampling date	Aphids (number/ plant) at indicated levels of initial infestation				
	5	10	20	40	Mean
1. CRI Stage					
18-01-2014	5.00	10.00	20.00	40.00	18.80
25-01-2014	9.50	15.60	15.70	16.50	14.30
01-02-2014	12.50	19.70	18.60	18.60	17.40
08-02-2014	15.10	21.40	20.70	19.20	19.10
15-02-2014	16.20	25.20	24.90	25.00	22.80
22-02-2014	17.50	29.40	28.90	29.70	26.40
01-03-2014	18.90	31.20	33.40	34.60	29.50
08-03-2014	20.20	35.10	36.20	36.40	32.00
15-03-2014	26.70	38.50	38.90	38.50	35.70
22-03-2014	23.40	35.20	36.40	36.70	32.90
29-03-2014	22.10	27.60	28.10	28.40	26.60
05-04-2014	20.50	25.40	26.30	26.20	24.60
12-04-2014	15.20	17.80	18.40	18.50	17.50
19-04-2014	8.60	9.10	9.40	9.50	9.20
26-04-2014	1.20	2.00	2.00	2.10	1.80
03-05-2014	0.00	0.00	0.00	0.00	0.00
Mean	14.50	21.50	22.40	23.70	
CD (p=0.05): A = 0.65, B = 0.32, AB = 1.30					
2. Tillering stage					
22-02-2014	5.00	10.00	20.00	40.00	18.80
01-03-2014	12.60	19.70	28.90	49.20	27.60
08-03-2014	18.90	24.80	32.70	51.60	32.00
15-03-2014	29.60	32.60	39.90	54.90	39.30
22-03-2014	28.20	30.40	37.50	53.10	37.30
29-03-2014	26.40	29.10	35.10	52.20	35.70
05-04-2014	25.20	27.50	31.20	45.70	32.40
12-04-2014	17.20	20.10	22.10	31.60	22.80
19-04-2014	10.80	11.20	12.10	14.20	12.10
26-04-2014	5.40	5.80	6.60	7.10	6.20
03-05-2014	0.00	0.00	0.00	0.00	0.00
Mean	16.30	19.20	24.20	36.30	
CD (p=0.05): A = 0.74, B = 0.44, AB = 1.48					
3. Panicle emergence stage					
05-04-2014	5.00	10.00	20.00	40.00	18.80
12-04-2014	13.70	19.50	27.60	49.90	27.70
19-04-2014	18.50	22.20	30.10	50.50	30.33
26-04-2014	10.20	13.10	17.60	20.10	15.30
03-05-2014	2.10	2.50	3.20	7.10	3.73
Mean	9.90	13.50	19.70	33.52	
CD (p=0.05): A = 0.64, B = 0.58, AB = 1.29					

Table 2: Population buildup of aphids released at varying infestation levels at different stages of wheat during 2014-15

Sampling date	Aphids (number/ plant) at indicated levels of initial infestation				
	5	10	20	40	Mean
1. CRI stage					
10-01-2015	5.00	10.00	20.00	40.00	18.80
17-01-2015	7.20	13.20	13.50	14.60	12.10
24-01-2015	10.60	17.20	17.50	18.10	15.90
31-01-2015	13.70	19.60	20.10	20.50	18.50
07-02-2015	14.80	23.10	23.20	24.10	21.30
14-02-2015	16.90	27.70	27.80	28.20	25.20
21-02-2015	17.80	30.10	30.50	31.10	27.40
28-02-2015	19.90	32.60	32.90	33.20	29.70
07-03-2015	21.20	34.70	35.80	36.30	32.00
14-03-2015	25.20	37.60	38.10	39.00	35.00
21-03-2015	22.10	33.10	34.20	35.30	31.20
28-03-2015	20.20	24.60	25.70	26.60	24.30
04-04-2015	18.40	19.00	20.10	21.20	19.70
11-04-2015	12.50	14.10	14.50	15.00	14.00
18-04-2015	5.20	5.50	5.50	5.70	5.50
25-04-2015	0.90	1.40	1.40	1.50	1.30
02-05-2015	0.00	0.00	0.00	0.00	0.00
Mean	13.60	20.20	21.20	23.00	
CD (p=0.05): A = 0.63, B = 0.30, AB = 1.25					
2. Tillering stage					
14-02-2015	5.00	10.00	20.00	40.00	18.80
21-02-2015	10.60	17.60	26.60	47.50	25.60
28-02-2015	17.80	20.40	30.70	50.10	29.80
07-03-2015	28.70	29.90	35.60	52.70	36.70
14-03-2015	31.20	34.50	37.80	55.50	39.80
21-03-2015	27.10	28.90	31.20	47.60	33.70
28-03-2015	25.20	27.40	29.70	44.50	31.70
04-04-2015	18.90	20.10	23.40	40.10	25.60
11-04-2015	17.20	18.20	20.50	33.50	22.40
18-04-2015	11.50	12.10	12.50	15.70	13.00
25-04-2015	5.10	5.20	5.60	6.10	5.60
02-05-2015	0.00	0.00	0.00	1.20	0.30
Mean	16.53	18.69	22.80	36.21	
CD (p=0.05): A = 0.65, B = 0.37, AB = 1.29					
3. Panicle emergence stage					
11-04-2015	5.00	10.00	20.00	40.00	18.80
18-04-2015	12.80	17.20	25.20	48.20	25.85
25-04-2015	17.20	20.10	28.10	50.00	28.90
02-05-201509-05-2015	6.401.30	6.601.50	8.202.40	20.007.00	10.303.05
Mean	8.54	11.08	16.78	33.04	
CD (p=0.05): A = 0.57, B = 0.51, AB = 1.14					

Table 3: Yield obtained at various infestation levels during 2013-15

Crop growth stages	Yield at varying infestation levels					Mean grain yield (g/ plant)	Mean grain yield (q/ ha)
A. 2013-14	0	5	10	20	40		
CRI	2.74	2.60	2.41	2.37	2.36	2.50	21.66
Tillering	2.55	2.20	2.10	1.93	1.82	2.12	18.37
Panicle emergence	2.95	2.83	2.70	2.42	2.22	2.62	22.71
Mean	2.75	2.54	2.40	2.24	2.13		
B. 2014-15							
CRI	2.86	2.72	2.55	2.54	2.52	2.64	22.88
Tillering	2.70	2.44	2.29	2.08	1.98	2.30	19.93
Panicle emergence	3.00	2.89	2.78	2.54	2.31	2.70	23.40
Mean	2.85	2.68	2.54	2.39	2.27		

CRI = Crown Root Initiation

2014 by releasing 5, 10, 20 and 40 aphids per plant and resulted in population of 18.0, 19.70, 28.90 and 49.20 at infestation level of 5, 10, 20 and 40 aphids on March 1, 2014 (Table 1). The population of aphids resulted in peak population

Table 4: Avoidable losses (%) at indicated levels of infestation and at selected crop growth stages

2013-14	Avoidable losses (%) at indicated levels of infestation and at selected crop growth stages				Mean
	5	10	20	40	
CRI	5.11	12.04	13.50	13.87	11.13
Tillering	13.71	17.65	24.30	28.64	21.08
Panicle emergence	4.03	8.45	17.96	24.73	13.79
Mean	7.62	12.71	18.59	22.41	
2014-15					
CRI	4.92	10.85	11.21	11.90	9.72
Tillering	9.62	15.17	22.95	26.67	18.60
Panicle emergence	3.67	7.33	15.33	23.00	12.33
Mean	6.07	11.12	16.50	20.52	

CRI = Crown Root Initiation

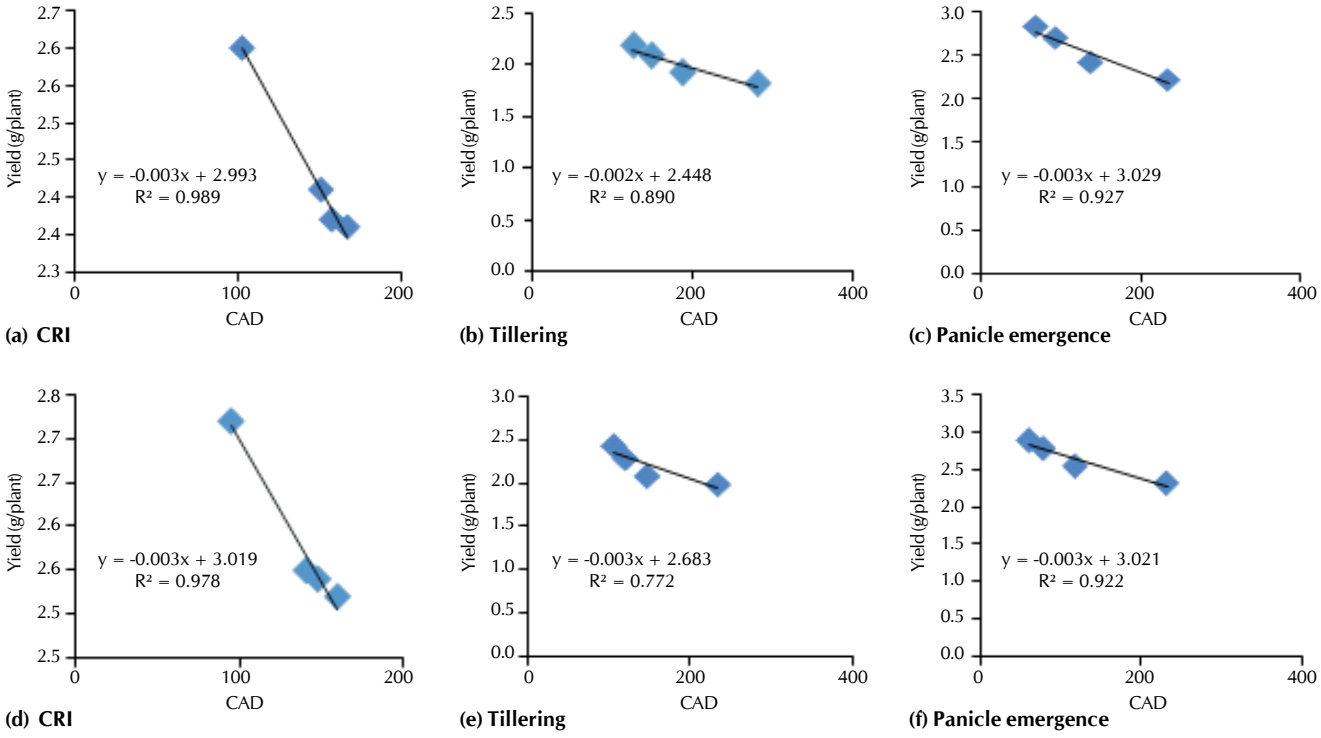

Figure: 1 Relationship between yield and cumulative aphid days (CAD) of levels released at different crop growth stages during 2013-14 (a-c) and 2014-15 (d-f)

of 29.60, 32.60, 39.90 and 54.90 at infestation levels of 5, 10, 20 and 40 aphids during March, 2014. It was evident that the mean population increased steadily upto3rd week of March, 2014 and mean peak activity was during the same period. Thereafter, aphid population experienced a steady decline till the last observation recorded on May, 2014.

Infestation initiated at panicle emergence stage

The plants with 5, 10, 20 and 40 aphids per plant were infested artificially on April 5, 2014 (Table 1) at panicle emergence stage of wheat and the mean aphid population was maximum on April 19, 2014 with 30.33 aphids and being lowest on May 3, 2014 with 3.73 aphids per plant. As evident from the mean aphid population at 5, 10, 20 and 40 the highest population was at level 40 followed by 20, 10 and 5 *i.e.*, 33.52, 19.70, 13.50 and 9.90 aphids per plant, respectively.

Infestation initiated at CRI stage 2014-15

During 2014-15 at CRI stage, the plants were infested artificially on January 10, 2015 by releasing 5, 10, 20 and 40 aphids per plant. A perusal of data contained in table 2 revealed that one week after initiation of infestation, the aphid population reached the level of 7.20, 13.20, 13.50 and 14.60 aphids/ plant at infestation levels of 5, 10, 20 and 40 on Jan 17, 2014 *i.e.*, 7 days after infestation. The number of aphids during 2014-15 also showed similar trend as during 2013-14 in population levels released at 20 and 40 aphids per plant. Whereas the population of aphids decreased after release because the population was crowded at high levels and due to small size of plants they were not able to hold that much of pest population released at 20 and 40 aphids/ plant. As evident from the data (Table 2) the population increased significantly and reached the peak in 2nd week on March, 2015 with the population of 25.20, 37.60, 38.10 and 39.00 aphids per plant

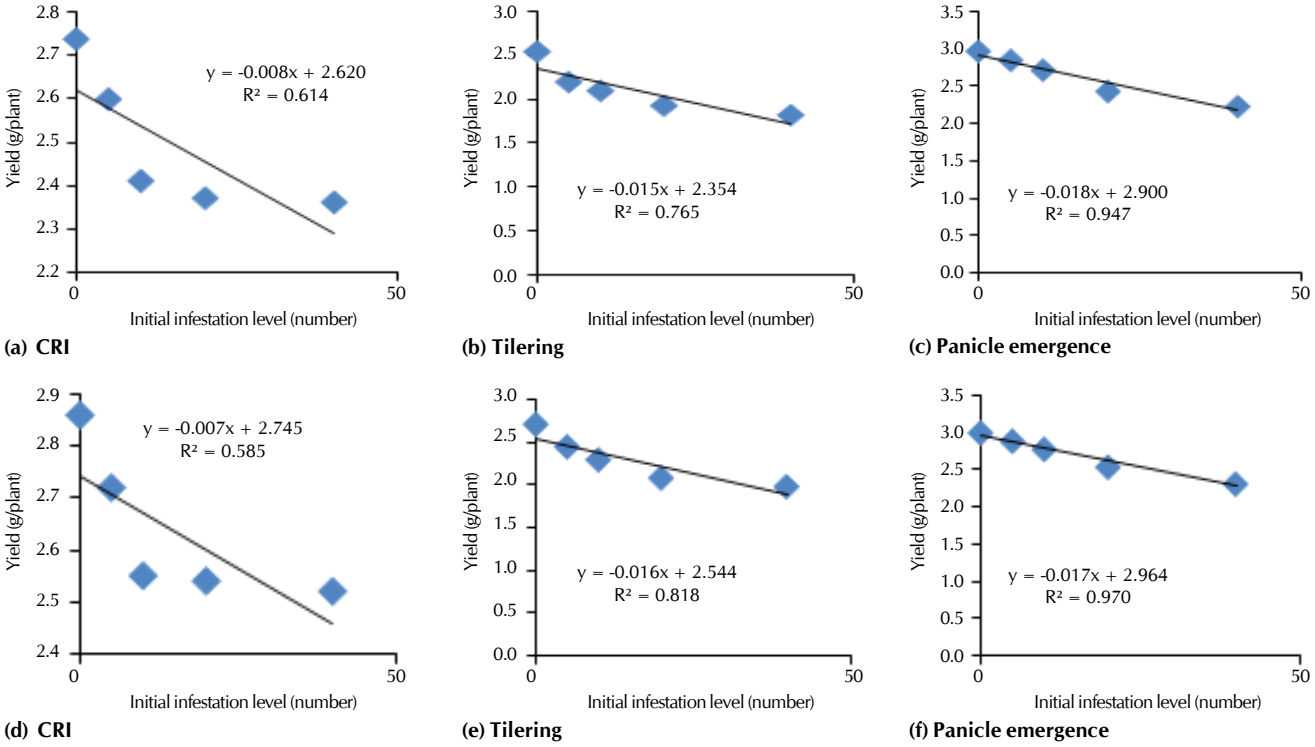

Figure: 2 Relationship between yield and indicated levels of infestation released at different crop growth stages during 2013-14 (a-c) and 2014-15 (d-f)

at corresponding infestation levels of. Thereafter, a decline in population was started and aphid count became zero on May 2, 2015. It was also evident that the mean population varied significantly at all the infestation levels being lowest at 5 aphid level with 13.60 aphids per plant and maximum corresponding to 40 aphids level i.e., 23.00 aphids per plant and mean aphid population at level 10 and 20 was 20.20 and 21.20 aphids per plant, respectively.

Infestation initiated at tillering stage

At tillering stage, the plants were infested artificially on Feb 14, 2015 by releasing 5, 10, 20 and 40 aphids per plant and resulted in population of 10.60, 17.60, 26.60 and 47.50 at infestation level of 5, 10, 20 and 40 aphids on March 8, 2014 (Table 2). The population of aphids resulted in peak population of 31.20, 34.50, 37.80 and 55.50 at infestation levels of 5, 10, 20 and 40 aphids, respectively. It was evident that the peak activity was observed on March 14, 2015. Thereafter, aphid population experienced a steady decline and was zero on May 9, 2015.Similar trend of aphid population was also observed by Sharma *et al*. (2013),they reported that the maximum or the peak population of aphids was recorded during the 3rd week of March under Palampur conditions of Himachal Pradesh. These findings are in close conformity with the findings of present studies. Similar observations on the peak period of aphid population have also been reported from Argentina by Rios and Conde (1986).

Infestation initiated at panicle emergence stage

The plants with 5, 10, 20 and 40 aphids per plant infested artificially on April 11, 2015 (Table 2) at panicle emergence stage of wheat and the mean aphid population was highest on April 25, 2014 with 28.85 aphids and being lowest on May 9, 2014 with 3.05 aphids per plant. As evident from the mean aphid population at 5, 10, 20 and 40 the highest was at level 40 followed by 20, 10 and 5 i.e., 33.04, 16.78, 11.08 and 8.54 aphids per plant, respectively.

Yield obtained

The data of the mean yield at indicated levels of infestation at selected crop growth stages (Table 3) revealed that the mean yield of levels 40 and 20 was 2.13 g/ plant and 2.24 g/ plant, respectively which were at par with each other while the highest yield was obtained in 0 level with 2.75 g/ plant followed by levels 5 and 10 with 2.54 and 2.40 g/ plant, respectively. It was also evident that the mean yield at selected crop growth stages viz., CRI, tillering and panicle emergence was highest at panicle emergence (2.62 g/ plant) followed by CRI and tillering stage with 2.50 and 2.12 g/ plant, respectively. However, data presented in tables 7 and 8 also revealed that the tillering stage was found to be the most susceptible stage of wheat against aphids as population of aphids at this stage was maximum and resulted in reduced yields as compared to other stages of initial infestation levels.

Data presented on table 3 revealed that the mean yield of level 40 was 2.27 g/ plant followed by 20, 10 and 5 levels of infestation was 2.39, 2.54 and 2.68 g/ plant, respectively. Level 0 plants resulted in highest yield 2.85 g/ plant as these plants were free from infestation. It was also evident that the mean yield at selected crop growth stages was highest in panicle emergence *i.e.*, 2.70 while in CRI stage was 2.64 and lowest at

tillering stage with 2.30 g/ plant.

Avoidable per cent losses

The avoidable loss in grain yield during 2013-14 varied from 4.03 to 28.64 per cent in different infestation levels at different crop stages (Table 4). Amongst different crop stages, the mean losses inflicted were highest in tillering stage was (21.08%) followed by panicle emergence and CRI stage with 13.79 and 11.13 per cent, respectively. The mean losses were more at 40 aphid infestation level followed by 20, 10 and 5 aphids with 22.41, 18.59, 12.71 and 7.62 per cent, respectively. During 2014-15 (Table 4) the data revealed that the per cent losses in infestation levels at different crop stages varied between 3.67 and 26.67. The highest mean losses observed in tillering stage were 18.60 per cent and minimum was in CRI stage with 9.72 per cent losses. The infestation initiated at panicle emergence stage registered 12.33 per cent yield losses. However, the mean losses were maximum in 40 level of aphid infestation being 20.52 followed by 20, 10 and 5 levels with 16.50, 11.12 and 6.07 per cent avoidable losses, respectively. The avoidable losses during the present studies varied between 3.67 and 28.64 under different levels of infestation. The yield losses ranging from 7.9 and 34.2 per cent against average aphid population of 1.57 to 2.25 aphids per tiller have also been reported by Akhtar *et al*. (2010) from Pakistan. These variations in the yield losses may be attributed to the different varieties used in experiments. In the studies conducted by Singh *et al*. (2008), it was reported that population of aphids exceeding 50 aphids per ear caused losses ranging between 6.13 and 27.82 per cent whereas 6 to 10 aphids per ear resulted in 6.70 per cent losses and 11 to 25, 26 to 50 and 51 to 100 aphids per ear resulted in 9.28, 11.37 and 15.45 per cent yield losses, respectively which shows that their results were in agreement with our findings where 20 to 50 aphids per ear resulted in 16.50 to 18.59 per cent losses (Table 4). The variations in results of per cent losses may be due to different crop growth stages and various abiotic factors. Ali *et al*. (2011) reported 8.03 per cent loss in variety Sehar-06, minimum on FSD-08 (4.3%) and 5.55 and 6.73 per cent in varieties on Lasani-08 and Inqlab-91, respectively. The variations in per cent losses caused by aphids in comparison to our findings may be due to methods of estimation of losses and differences in response of the varieties to the aphids.

Relationship between aphid population and damage inflicted

The damage inflicted to wheat crop was worked out on the basis of cumulative aphid days (CAD) and initial infestation population levels released at CRI, tillering and panicle emergence stages. The relationships worked out are being presented hereunder.

Cumulative aphid days based

The aphid infestation initiated at CRI stage during 2013-14 resulted in 106.21, 155.49, 157.69 and 158.62 cumulative aphid days (CAD) at initial infestation levels of 5, 10, 20 and 40 aphids, respectively 135.57, 156.49, 191.41 and 279.69 CAD at corresponding levels of aphid infestation when the infestation was initiated at tillering stage. The CAD values were 77.88, 100.28, 137.38 and 223.3 at corresponding levels of infestation when the infestation was initiated at panicle emergence stage. The relationship deduced between grain yield and CAD revealed that per unit increase in CAD resulted in reduction in grain yield to the tune of 0.003, 0.002 and 0.003 g/ plant when the infestation was initiated on CRI, tillering and panicle emergence stages, respectively, (Figure 1a,b,c). However, during 2014-15 the reduction in grain yield was to the tune of 0.003 g/ plant/ CAD at all the stages of initial infestation i.e. CRI, tillering and panicle emergence stages (Fig 1 d,e,f).

Aphid infestation levels based

The linear regression equations worked out between grain yield and aphid infestation levels presented in figure 2 (a,b,c) revealed that a unit aphid infestation initiated at CRI, tilllering and panicle emergence resulted in reduction in yield to the extent of 0.008, 0.015 and 0.018 g per plant, respectively. During 2014-15 the reduction in grain yield was 0.007, 0.016 and 0.017 g per plant at CRI, tillering and panicle emergence stages of wheat (Fig. 2 d,e,f).

Determination of economic injury level

The economic injury levels (EIL) were worked out based on the cumulative aphid days and aphid infestation levels. The parameters used for cost analysis of aphid management by foliar application of dimethoate (Rogor 30EC) on per hectare were application rate, insecticide required per hectare, rate of pesticide, cost of pesticide, cost of pesticide application and labour, total number of plant protection applications in cropping system, total cost of protection per ha (C) Rs 1300, market value of produce (V) Rs 13/ kg, and gain threshold (GT) where GT was comes out to be 100.

Cumulative aphid days based

A perusal of table 5 depicting the EIL determined for aphids in wheat crop for the infestation initiated at CRI stage was 32.61 CAD for dimethoate based aphid management programme. For the infestation initiated at tillering stage, the EIL value was comparatively higher (41.55 CAD) as compared to the infestation initiated at panicle emergence stage (35.77 CAD). The economic threshold level (ETL) at 75 per cent of EIL for the infestation starting CRI stage was established at 24.46 CAD. Whereas, it was 31.16 and 26.83 CAD, respectively for infestation starting at tillering and panicle emergence stages

Aphid infestation levels based

On the basis of initial aphid infestation levels, the EIL was found to be 14.93 for dimethoate based aphid management programme (Table 5), with corresponding ETL value 11.20 aphids per plant for CRI crop growth stage. The EIL values of 7.19 and 6.78 aphids per plant with corresponding ETL values of 5.39 and 5.09 aphids per plant were determined for the infestation initiated at tillering and panicle emergence stages, respectively.

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