Ethiop. J. Agric. Sci. 28(2) 85-98 (2018)

Field Resistance in Bread Wheat to Russian Wheat Aphid, *Diuraphis noxia* Under Flood Irrigation

Tebkew Damte and Geteneh Mitiku
Ethiopian Institute of Agricultural Research, Debre Zeit Center, P. O. Box 32, Debre Zeit, Ethiopia

አህፅሮት

የሩሲያ ክሽክሽ (Diuraphis noxia) በዓለም ላይ በሰፊው የተሰራጨ ተባይ ሲሆን የስንዴ ምርትን እስከ 93 በመቶ ሊያወድም ይችላል። እንዲሁም ይህ ክሽክሽ ቅዉም ሰባሪዎች ስላለው ክሽክሹን የሚቋቋሙ ዝርያዎች የሚያገለግሉት ለተወሰነ አካባቢ ብቻ ነው። ይህም በመሆኑ ከኢትዮጵያ ውጭ ባሉ ስንዴ አብቃይ አገሮች ክሽክሹን የሚቋቋሙ 49 ብዝሀ-ዘሮችን በማስገባት ደብረ ዘይት ላይ ለሁለት ዓመት (2007 እና 2008 ዓም) መስኖ እና የተፈጥሮ ወረራ በመጠቀም ተፈትሿል። ሙከራው የተካሄደው 7 በ 7 በሆነ የላቲስ ንድፍ ላይ ብዝሀ-ዘሮችን በመዝራት ነው። ሙከራ ከተደረገባቸው 49 ብዝሀ-ዘሮች መካከል ከሩሲያ ክሽክሽ ወረራ ነፃ የሆነ ብዝሀዘር ባይኖርም በክሽክሽ አህዛብ ብዛት ግን ሰፊ ተለያይነት ነበር። በሁለቱም ዓመት ከፍተኛ ቁጥር ባለው ክሽክሽ የተወረሩና ከፍተኛ ጥቃት የደረሰባቸው ብዝሀ-ዘሮች ትንሽ ቁጥር ባለው ክሽክሽ የተወረሩ እና ከፍተኛ ቅውሞሽ ያሳዩ ብዝሀ-ዘሮች ነበሩ። ቀሪዎች ብዝሀ-ዘሮች ግን መካከለኛ የቅውሞሽ ደረጃ ነበራቸው። ስለሆነም የሩሲያ ክሽክሽ አህዛብ ዕድገት በተለያዩ ብዝሀ-ዘሮች የተለያየ ነበር። በተጨማሪም በተወረሩ ቀዘባዎች (መቶኛ) እና በአንድ ቀዘባ ላይ የነበረው የክሽክሽ ብዛት መካከል ቀጥተኛ ግንኙነት አልነበረም።

Abstract

The Russian wheat aphid (RWA) (Diuraphis noxia) is cosmopolitan pest and yield losses of up to 93% have been reported in different wheat growing countries. It also has a high degree of biotypic diversity that necessitates the development and utilization of location specific resistant wheat varieties. Thus, 49 wheat genotypes known to be resistant to RWA in other countries were evaluated using natural infestation in 7x7 Simple Lattice for two seasons under flood irrigation at Debre Zeit, Ethiopia. In both seasons none of the tested genotypes were free of RWA infestations. However, in the 2015 season, there was statistically significant difference among genotypes in RWA intensity in all sampling dates, whereas in the 2016 season there was the statistically significant difference among genotypes in RWA intensity in the first three sampling dates but not in the later three sampling dates. The genotypes CIMMYT 109, CMYRWA-7, CMY RWA 36, CMY RWA 103, Correll, SH01-Correll, IG41560, IG 41556, IG 107166, KRWA-9, KRWA 152, SHK01-A26-15, SHK01-B32-59, SHK01-C96-149 and SHK01-D12-167 were highly susceptible to RWA, while CMY RWA 101, PI 625140-1, R-765-RWA-152, SHK01-A36-22, SHK01-B10-46, SHK01-B30-58, SHK01-B35-60, SHK01-B84-89 and SHK01-D37-184 were highly resistant. The remaining genotypes were moderately resistant/ susceptible. As a result the pattern of population increase on the different genotypes was variable across sampling dates. There was no apparent relationship between percent infested tillers and number of aphids per tiller.

Introduction

The Russian wheat aphid (RWA), *Diuraphis noxia* (Hemiptera: Aphididae), is pest of wheat (*Triticum spp.)* in many parts of the world (Smith *et al.* 1991; Botha *et al.*

2005; Ennahli *et al*. 2009). During feeding this aphid injects toxins, which leads to leaf rolling or twisted heads when the flag leaf is attacked (Smith *et al.* 1991). Consequently, yield losses in wheat attributable to RWA damage are very huge.

The RWA was first reported as pest of barley in 1972 around Atsbi in the northern region of Ethiopia (Adugna and Tesema 1987) and then it spread southward to the different wheat and barley growing areas. Research on RWA management on wheat began first at Debre Zeit in 1980 (DZARC 1984). But it was soon discontinued because the bread (*Triticum aestivum*)- and the durum (*T. durum*)- wheat is mainly produced as rainfed crop and under such production system the RWA assumes pest status only if the wheat crop is sohwn later in the season or if the season is dry. Because of the low productivity of rainfed wheat on one hand and the rapidly growing demand for wheat on the other hand, recent initiatives have been taken to produce wheat under irrigated conditions. Thus, in the 2015/16 season nearly 35,000 households produced wheat using irrigation on an area of more than 7,000 ha (CSA 2016). The RWA severely attacks these irrigated wheat and depending up on the variety grown, locations and season it causes 15 to 93%, 9 to 47% and 52% losses in grain yield, thousand seed weight and biomass yield, respectively (Damte 2015; Tesfaye and Alemu 2015).

In Ethiopia, although there is no insecticide labeled for use in irrigated wheat for RWA management, farmers are encouraged to use insecticides approved for managing other insect pests on other crops (Tesfaye and Alemu 2015). However, since wheat is producers by subsistent farmers, the use of insecticides for RWA control might not be economical (Adugna and Tesema 1987; Webster et al. 1991). Moreover, the durum- and the bread- wheat varieties released in Ethiopia are highly susceptible to RWA as they were evaluated for yield either in the absence the aphid or insecticide protected condition in the presence of the insect (Tebkew 2012).

Host plant resistance is the most effective and preferred method of RWA controls (Webster *et al.* 1991; Collins et al. 2005; El Bouhssini *et al.* 2011a). Consequently, in many countries, where RWA is a major pest of wheat, germplasms resistant to RWA have been identified and used in breeding programs (Du Toit 1990; Collins *et al.* 2005; El Bouhssini *et al.* 2011b**).** However**,** evaluation of RWA collections from different parts of the world has revealed the existence of a high degree of biotypic diversity, which necessitates the development and utilization of location specific resistant wheat varieties (Puterka *et al.* 1992). The objective of this study was to evaluate wheat genotypes known to be resistant to RWA in other countries under flood irrigation in Ethiopia.

Materials and Methods

The experiment was conducted at Debre Zeit Agricultural Research Center between January and May of 2015 and 2016 under flood irrigated and natural infestation conditions. A total of 49 wheat genotypes known to be resistant to the RWA outside Ethiopia was obtained from Mekelle Agricultural Research Center. The genotypes were tested in 7x7 simple Lattice design on Andosol in 2015 and Vertisols in 2016 (to get more infestation). In each year, every genotype was shown in two rows of one meter long and seeds were hand drilled at the rate of 10 to 15 seeds per row. Rows were spaced 20cm apart, while the spacing between plots within blocks, between blocks and replications was 50cm, 50cm and 2m, respectively. Nitrogen, in the form of urea (46%N), was applied in split form at the time of planting and four weeks after germination at the rate of 150 kg/ha on Andosol and 100kg/ha on the Vertisols. The phosphorus, in the form of DAP, was applied at the time of planting at the rate of 100 kg/ha on both soil types. Irrigation water was applied in the form of sprinkler three days before planting and until the seedlings establish. However, irrigation was given as flood after seedling establishment. The experimental plots were weeded as required.

Data on RWA number were counted *in situ* on randomly selected 10 shoots per plot beginning from two weeks after the initial appearance of the aphid. When the RWA reached peak intensity on the majority of the test entries, degree of leaf chlorosis was visually scored following 1 to 9 scale of Webster et al. (1991). Since some of the genotypes were winter types, grain yield, which was recorded only in 2015 (in 2016 season all genotypes were hit by rust), was not considered.

Statistical Analysis

In both seasons, preliminary analysis of RWA count data using Proc lattice of SAS revealed that the relative efficiency of lattice design over the randomized complete block design was less than 105% and the intrablock variance was greater than the variance of blocks within replications. Therefore, the data were analyzed using Proc ANOVA as if the experiment was laid in randomized complete block design with two replications. Before analysis, the aphid count and the percentage infestation data were transformed to square roost and arcsine, respectively. However, actual data were used for comparison and reporting. When the overall f-test was significant, means were separated using the Tukey's studentized range test.

Results and Discussion

On both soil types and seasons, none of the tested genotypes were free of RWA infestation. In the 2015 season, there was statistically significant ($p < 0.05$) differences among genotypes in RWA intensity in all sampling dates (Table 1).

Moreover, except on 16 March and 27 March samplings, where there was no statistically significant difference in percentage infestation, genotypes differed significantly in percentage of infested tillers in the remaining sampling dates. On 3 March 2015, genotypes CIMMYT 109, CMYRWA-7, IG 107166, KRWA 152 and SHK01-C96-149 not only had an average of one or more RWA per tiller but also had more number of infested tillers than the other genotypes. Genotypes CMY RWA 101, CMY RWA 103, SHK01-A27-16, SHK01-B84-89, and SHK01-D12-167 were free of infestation, while on the remaining genotypes the RWA intensity, on the average, was less than one per tiller.

On 16 March 2015, about 43% of the genotypes had an average of less than one RWA per tiller. Moreover, out of these genotypes 16 genotypes had only 10 to 30% infested tillers, while five genotypes namely CMYRWA 76, CMY RWA 103, SHK01-B48-68, SHK01-B56-71, and SHK01-D12-167 had 35 to 40% infested tillers. On the other hand, PASA, SHK01-A28-17, SHK01-A38-23, SHK01-B3-41, SHK01-B32-59, and SHK01-C102-155 even if they had low percentage (25-30%) of infested tillers, they had an average of one to two aphids per tiller. IG 107166 had the highest RWA intensity, while R-765-RWA-152 had the highest percentage of infested tillers. On SHK01-C99-152 the infestation reached peak of 3 aphids per tiller and then declined thereafter.

On 27 March 2015, the RWA intensity was greater than one aphid per tiller on all genotypes except on SHK01-B11-47, which had less than one aphid per tiller. On about 37% of the genotypes the maximum RWA intensity was recorded on this date. The increase in RWA intensity was accompanied by increased numbers of infested tillers in all genotypes. Similarly, on the fourth (8/4/15) sampling occasion the RWA intensity peaked on 39% of the remaining genotypes. At this date the degree of leaf chlorosis on Correll, SH01-Correll, CIMMYT 109, IG41560, IG 107166, and KRWA 152 was very severe (scale 8) and some plants began to die. About 41% of the genotypes exhibited moderately susceptible reaction (scale 3 to 5) and the remaining 47% fall in the resistant category (1 to 2 scales).

On the fifth sampling (17/4/ 15) the RWA intensity and percentage of infested tillers decreased on those genotypes that were at booting and heading stage, but it increased on 22% of the genotypes, which were late maturing types.

In the 2016 season, there was significant ($P < 0.05$) different among genotypes in RWA intensity in the first three sampling dates, but not in the later three sampling dates (Table 2). Moreover, except on 1 March and 19 April sampling dates in which there was significant ($p < 0.05$) difference in percent infested tillers, genotypes were not statistically different ($P > 0.05$) in percentage of infested tillers. On 1 March 2016, CIMMYT 109, Correll, IG 107166, PI 625140-1, SHK01-A38-23, SHK01-B32-59, and SHK01-C102-155 had on the average more than six RWA per tiller, whereas SHK01-B10-46, SHK01-B30-58, SHK01-B35-60 and SHK01-D19-172 had less than three aphids per tiller. However, in terms of percent infested tillers, except SHK01-B30-58 which had only 40% infested tillers, on the remaining genotypes more than half of the sampled tillers were infested by RWA.

On 11 March 2016, the reaction of genotypes was highly variable in terms of RWA intensity and percentage infested tillers. Thus, on about 57% the genotypes both RWA intensity and percentage of infested tillers increased, whereas about 8% of the genotypes both RWA intensity and percentage infested tillers decreased. On 12% of the genotypes RWA intensity decreased and percentage of infested tillers increased; in 14% of the genotypes RWA intensity increased and percentage of infested tillers decreased. Similarly, on 6% of the genotypes RWA intensity increased, but the percentage of infested tillers remained unchanged. On one genotype (2%) RWA intensity remained unchanged but the percentage infestation increased.

On the third sampling (28/3/2016), except on SHK01-A36-22, SHK01-B32-59, and SHK01-C97-150 in which the RWA intensity was less than the preceding sampling date RWA intensity, the RWA intensity increased considerably and nearly on all genotypes 90% or more of the tillers were infested. At this date the RWA intensity reached peak and then continued to decline on genotypes SHK01-A27-16, SHK01-B35-60, and SHK01-D8-164.

RWA intensity reached maximum level and began to fall on 61% of the genotypes on March 28, 2016, but it continued to increase on 33% of the genotypes. On the other hand, the percentage infested tiller remained unchanged at 44%, increased on 27% and decreased on 29% of the genotypes. At this sampling date, genotypes CIMMYT 109, CMYRWA-7, CMY RWA 36, CMY RWA 103, Correll, SH01-Correll, IG41560, IG 41556, IG 107166, KRWA-9, KRWA 152, SHK01-A26-15, SHK01-B32-59, SHK01-C96-149, and SHK01-D12-167 exhibited extensive chlorosis and necrosis (scale 8) and plants began to die. On the other hand, chlorotic spots became only noticeable (scale 2) on CMY RWA 101, PI 625140-1, R-765-RWA-152, SHK01-A36-22, SHK01-B10-46, SHK01-B30-58, SHK01-B35-60, SHK01-B84-89, and SHK01-D37-184.

The RWA intensity peaked on 20% of the genotypes on April 19, 2016 but continued to decline on the remaining genotypes. At this date percentage infested tillers generally began to fall on the majority of the genotypes.

Table 1. Russian wheat aphid intensity and associated level of tiller infestation in 2015 season on Andosol

	Sampling date									
	6/3/2015		16/3/15		27/3/15		8/4/2015		17/4/15	
Genotype	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*
CIMMYT 109	3.4	50	2.9	55	8.4	95	7.6	100	21.9	100
CMY RWA-7	1.2	15	0.6	30	3.3	65	1.2	50	1.0	45
CMY RWA- 20	0.2	5	0.4	20	4.3	80	2.4	80	2.1	55
CMY RWA- 36	0.3	15	0.7	20	5.9	80	6.5	90	5.9	100
CMY RWA- 76	0.6	40	0.8	35	13.3	90	14.3	85	11.0	80
CMY RWA- 101	0.0	0	3.1	50	5.4	90	4.4	80	3.7	75
CMY RWA- 103	0.0	0	0.8	35	6.8	85	10.9	100	7.4	80
Correll	0.3	15	2.9	35	10.9	100	17.4	100	21.0	100
IG- 41556	0.1	5	0.6	20	2.3	75	4.7	65	4.5	80
IG-41560	0.3	20	3.1	35	8.4	90	14.5	100	11.4	95
IG- 107166	2.5	50	7.1	55	15.6	100	30.4	100	13.2	90
IG-158374	0.4	25	0.8	30	2.9	75	5.7	80	7.3	85
KRWA-9	0.2	5	1.5	55	4.3	85	5.3	80	3.4	70
KRWA- 152	4.6	60	5.5	60	11.2	95	11.9	95	23.7	100
PASA	0.7	10	1.4	30	5.7	80	12.1	85	13.2	95
PI 625140-1	0.2	5	0.7	25	2.2	65	2.4	65	5.5	80
PI 624151-1	0.3	20	2.0	45	3.3	75	1.2	40	1.6	45
R-765-RWA-152	0.3	15	2.4	65	2.7	75	1.0	40	2.3	70
SHK01-A26-15	0.4	25	0.2	15	3.8	75	3.0	55	1.0	40
SHK01-A27-16	0.0	0	1.9	45	1.3	55	0.6	30	0.3	25
SHK01-A28-17	0.1	5	1.0	30	1.4	55	1.4	45	0.4	25
SHK01-A36-22	0.2	5	0.7	30	1.8	65	2.2	60	0.9	30
SHK01-A38-23	0.4	20	1.4	30	1.6	60	3.9	70	0.6	35
SHK01-A45-29	0.1	10	1.1	25	1.8	60	2.1	60	0.6	40
SHK01-B1-39	0.1	5	1.3	45	2.5	70	3.6	85	1.2	50
SHK01-B3-41	0.1	5	1.0	30	1.2	50	2.7	55	0.8	40
SHK01-B9-45	0.1	5	4.4	60	6.4	85	5.1	95	9.8	80
SHK01-B10-46	0.1	10	1.2	45	2.0	55	2.3	70	2.3	65

SHK01-B11-47	0.2	10	0.6	30	1.0	50	2.3	65	1.2	45
SHK01-B30-58	0.3	15	0.5	20	4.3	85	2.7	65	0.3	25
SHK01-B32-59	0.1	5	2.0	30	4.0	65	11.2	80	10.6	75
SHK01-B35-60	0.2	5	0.7	25	5.1	75	2.6	70	1.4	45
SHK01-B48-68	0.9	25	0.9	40	2.8	75	2.1	50	2.5	70
SHK01-B56-71	0.2	10	0.9	40	1.8	65	1.9	70	0.6	35
SHK01-B72-83	0.3	15	0.2	10	1.8	55	1.9	50	0.5	30
SHK01-B84-89	0.0	0	1.5	40	1.2	45	1.6	60	1.0	45
SHK01-C28-111	0.1	10	0.4	20	3.4	65	1.4	50	0.6	40
SHK01-C96-149	1.2	30	2.3	60	6.0	85	11.4	85	29.8	100
SHK01-C97-150	0.4	20	1.9	65	5.7	90	1.4	50	1.1	40
SHK01-C99-152	0.9	25	3.1	55	2.7	75	1.9	50	0.5	30
SHK01-C102-155	0.1	5	1.2	30	2.3	65	1.9	65	1.1	50
SHK01-C104-157	0.1	10	1.7	55	3.5	80	2.4	60	0.2	15
SH01-CORRELL	0.4	10	2.3	35	8.0	75	9.0	80	15.2	80
SHK01-D8-164	0.2	10	2.6	65	5.1	90	1.6	55	0.8	40
SHK01-D12-167	0.0	0	0.9	35	4.4	85	3.2	70	1.0	35
SHK01-D18-171	0.3	20	0.5	25	2.8	70	4.2	70	1.3	45
SHK01-D19-172	0.1	5	0.4	25	3.2	85	2.0	50	0.4	20
SHK01-D27-177	0.2	15	0.8	25	2.9	80	5.0	75	1.2	45
SHK01-D37-184	0.5	15	1.6	60	2.0	65	0.9	50	3.3	50
CV(%)	21.9	69.3	29.3	40.2	30.9	24.8	27.4	19.0	42.3	24.9
MSD(5%)	2.0	48.8	5.4	NS	13.7	NS	13.1	65.3	20.7	68.7

** PI = Percentage infestation; MSD = minimum significant difference; NS= statistically non-significant*

On R-765-RWA-152, SHK01-A26-15, SHK01-A28-17, SHK01-B11-47, SHK01-C28-111, and SHK01-D19-172 the RWA intensity peaked on 6 April 2016 and began to fall thereafter. On the other hand, percentage of infested tillers increased on about 16% of the genotypes but it remained unchanged and decreased on 41 and 43%, respectively, of the genotypes.

Table 2. Russian wheat aphid intensity and associated level of tiller infestation in 2016 season on Vertisols

Genotype	Sampling date											
	1/3/2016		11/3/2016		18/3/2016		28/3/2016		6/4/2015		19/4/2016	
	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*	Mean No. of aphid per tiller	PI*
CIMMYT 109	9.5	90	9.1	95	37.6	100	104.7	100	72.1	100	43.1	100
CMY RWA-7	4.5	75	9.3	90	30.9	95	64.8	100	57.3	100	49.0	100
CMY RWA- 20	4.8	90	6.5	85	10.6	95	22.9	100	19.9	90	19.3	100
CMY RWA- 36	4.2	85	9.1	95	14.5	90	60.7	100	42.3	100	19.8	95
CMY RWA-76	3.8	80	6.7	95	25.8	100	46.0	100	36.8	100	25.8	90
CMY RWA- 101	4.5	70	6.4	85	7.7	95	14.6	95	12.6	95	8.6	95
CMY RWA- 103	5.6	100	7.3	85	15.3	100	46.8	100	36.2	100	28.3	95
Correll	8.1	90	15.1	100	19.8	100	25.9	90	23.0	100	31.2	100
IG- 41556	3.3	85	5.7	75	8.0	100	18.8	100	25.9	85	26.4	100
IG-41560	5.1	95	9.9	90	11.6	100	53.8	100	33.9	100	22.9	100
IG- 107166	8.2	90	17.7	95	40.8	100	99.6	100	59.4	100	20.6	100
IG-158374	5.7	90	7.6	90	10.5	100	30.6	100	27.5	90	13.5	100
KRWA-9	4.8	85	4.4	90	14.4	95	19.9	95	15.5	100	20.4	80
KRWA- 152	5.9	90	10.2	95	50.7	100	99.4	100	43.2	100	30.5	100
PASA	5.0	85	8.2	85	16.8	100	48.0	85	34.6	80	33.5	100
PI 625140-1	6.2	90	3.4	85	6.8	90	12.4	80	12.4	80	19.6	95
PI 624151-1	5.5	80	5.5	90	14.8	100	19.8	100	14.0	80	28.7	90
R-765-RWA-152	3.7	75	4.8	90	5.2	90	8.7	90	9.7	80	5.1	70
SHK01-A26-15	5.3	100	6.0	90	15.9	90	41.9	95	48.3	100	20.5	100
SHK01-A27-16	4.6	90	4.4	80	13.9	95	12.5	85	6.9	80	3.6	85
SHK01-A28-17	4.9	85	6.6	95	13.8	100	26.5	100	28.2	100	4.0	65
SHK01-A36-22	4.4	80	6.2	95	6.0	95	10.8	80	8.6	80	22.0	80
SHK01-A38-23	6.9	95	13.5	90	28.0	100	63.4	100	63.0	100	46.8	100
SHK01-A45-29	4.4	75	5.1	90	7.9	100	13.3	100	6.7	85	5.3	80
SHK01-B1-39	3.4	80	7.6	95	15.2	95	8.4	80	10.1	95	14.4	90
SHK01-B3-41	4.3	75	5.1	85	12.2	95	16.4	95	9.1	90	11.6	85
SHK01-B9-45	3.15	65	7.5	85	12.2	95	28.6	95	27.6	100	15.4	100
SHK01-B10-46	2.1	60	3.2	75	5.7	90	13.6	90	9.6	85	29.75	90

SHK01-B11-47	3.9	75	3.4	65	5.9	70	14.0	95	23.8	80	3.2	65
SHK01-B30-58	1.1	40	3.4	70	10.2	90	16.4	100	12.5	80	12.2	90
SHK01-B32-59	6.3	90	20.1	100	13.5	100	96.0	100	54.5	100	89.5	100
SHK01-B35-60	2.2	65	2.2	80	7.3	80	6.3	80	4.3	75	0.6	40
SHK01-B48-68	3.8	80	6.4	85	8.6	90	32.0	95	29.7	95	13.3	90
SHK01-B56-71	3.7	80	4.7	90	12.4	95	23.1	100	15.0	90	7.6	90
SHK01-B72-83	4.2	75	7.4	95	12.1	90	39.2	100	22.1	85	13.1	90
SHK01-B84-89	5.9	80	5.5	85	8.6	95	20.3	95	21.7	85	23.9	85
SHK01-C28-111	4.1	85	5.1	75	10.5	100	19.3	90	19.9	95	5.9	85
SHK01-C96-149	5.3	90	7.8	90	15.4	95	51.3	90	38.6	80	41.8	90
SHK01-C97-150	2.9	75	6.9	90	6.6	95	37.4	95	30.4	85	43.2	85
SHK01-C99-152	4.5	80	8	85	13.6	95	60.8	100	52.8	100	11.5	95
SHK01-C102-155	6.7	90	5.2	80	10.9	90	29.9	95	29.4	85	11.4	95
SHK01-C104-157	6.0	90	5.8	95	10.4	95	7.0	80	4.4	70	14.5	100
SH01-CORRELL	4.1	75	5.8	90	24.5	80	52.5	100	27.4	100	41.6	95
SHK01-D8-164	3.9	70	2.4	75	12.1	95	9.1	70	7.7	75	6.4	85
SHK01-D12-167	5.1	80	6.5	85	30.4	100	61.7	95	55.4	95	4.7	90
SHK01-D18-171	3.1	80	5.8	85	12.3	95	30.5	100	13.4	85	9.6	95
SHK01-D19-172	2.4	65	3.7	85	9.0	95	9.1	70	9.2	70	5.2	75
SHK01-D27-177	4.1	80	4.6	85	10.8	95	12.9	90	12.2	90	2.2	70
SHK01-D37-184	3.6	65	5.1	85	7.75	100	40.2	80	27.8	85	11.7	85
CV(%)	18.9	15.5	24.5	18.4	32.2	16.5	39.8	14.5	38.4	16.0	47.3	14.5
MSD (5%)	6.0	53.9	14.3	NS	44.9	NS	NS	NS	NS	NS	NS	45.7

** PI = Percentage infestation, MSD = minimum significant difference; NS= statistically non-significant*

The overall RWA intensity and the percentage of infested tillers in 2016 season were greater than in 2015, which might be attributed to the difference in planting date that exposed the test genotypes to different temperature regime and/or the difference in soil type. At Debre Zeit, the RWA begins to infest irrigated wheat at two to three leaf stages. The wheat sown on 6 February 2015 reached two to three leaf stage between the last week of February and the first week of March, whereas those sown on 25 January 2016 reached same stage in the second week of February. The average minimum daily temperature in the first week of March 2015, i.e. the time at which the RWA establishes, was 8.7 °C, while in 2016; the average daily minimum temperature in the second week of February was 10.8°C. Therefore, the relatively cooler temperature in 2015 might have affected the performance of the alate aphids that begin the infestation or their first progenies. According to Aalbersberg and Du Toit (1987) and Girma et al. (1990) RWA has shorter nymphal development time and produces more progeny at high temperature (14°C) than at low (13°C) temperature. The 2016 experimental period was relatively wetter the than the 2015 experimental period. It is known that, RWA strives best in areas where the temperature is warmer and precipitation is low (< 400mm) (Hughes and Maywald 1990; Archer et al.1998). On the other hand, the occurrence and the establishment of RWA is affected by high rainfall because of the direct mortality effect of rain and the physiological changes that it cause in the host plant (Sotelo 2014). Therefore, the survival of RWA in 2016 despite the presence of rain might be attributed to the time at which it started to rain (it began to rain after the RWA established and feed within rolled wheat leaves), the low intensity and the distribution (it rained only in 19 days in three months) of rainfall. The other factor that might have brought a difference in intensity and percentage infestation is soil type. It is known that the rate of crop establishment and subsequent growth rate of the crop is influenced by soil type. Although empirical datum is not available, on Andisol the wheat establishes earlier and grows faster than on the Vertisol. According to Schotzko and Bosque-pe´rez (2000) the initial aphid density and the crop phenology have a profound effect on RWA establishment and further growth of the population. Moreover, soil types, with their associated differences in soil color and texture, affect soil moisture availability and temperature on a microclimatic scale, which in turn affect aphid dispersal and desiccation (Merrill *et al*. 2009).

Despite the large numerical differences ,both in RWA intensity and percentage of infested tillers, there were not statistically significant differences among genotypes in RWA intensity on 28 March, 6 April and 19 April 2016 samplings and in percentage of infested tillers except on 1 March and 19 April 2016. Therefore, the lack of statistically significant differences among genotypes on those sampling occasions might be attributed to the high inherent variability among genotypes in resistance to RWA and to the small number of replications.

Marini (1999) stated that if the responses are inherently highly variable, very large sample size is required to detect differences at the 5% level of significance.

Unlike the percentage infested tillers, the pattern of population increase on the different genotypes was variable, which might be ascribed to the difference in the level of RWA resistance in each genotype (Schotzko and Bosque-pe´rez 2000). On the other hand, on a given sampling date genotypes could have equal number of infested tillers, but they may differ in the average number of RWA per tiller. For instance, on 28 March 2016 sampling, all sampled tillers on CIMMYT 109, SHK01-A28-17, and SHK01-A45-29 were infested by RWA. However, the average number of RWA per tiller on CIMMYT 109 was four and eight times greater than on SHK01-A28-17 and SHK01-A45-29, respectively, and the average number of RWA per tiller on SHK01-A28-17 was twice greater than the intensity on SHK01-A45-29. This suggests that percentage of infested tiller is not a reliable indicator of wheat resistance to RWA. Du Toit (1990) and Puterka *et al*. (1992) have reported lack of correlation between percent infested tiller and population intensity and visual score and population intensity, respectively. Therefore, number of aphids, as recommended by Lykouressis (1984), should be used as measure of wheat resistance to RWA.

The fertilizer rate used in this experiment was adopted from rainfed wheat and on the Vertisol, the amount of nitrogen fertilizer (urea) used was less than the amount used on Andisol. It is not clear if the high aphid intensity and high percentage infested tiller in 2016 is associated with the rate of nitrogen fertilizer used. However, according to Archer *et al.* (1995) variation in nitrogen fertilizer rate has no effect on RWA density.

Since RWA is known to develop biotypes (Puterka *et al*. 1992; Haley *et al*. 2004; Botha *et al*. 2005), the tested genotypes performed differently under Ethiopian condition. For instance, the genotypes IG-41560 and IG-41556 are resistant and IG-107166 is moderately resistant to the Syrian RWA population (EL Bouhssini *et al.* 2011a). But under Ethiopian condition, IG-41560 and IG-107166 were susceptible and the genotype IG-41556 was moderately resistant. Moreover, genotypes CMYRWA-7, CMY RWA 36, CMY RWA 103, CIMMYT 109, Correll, SH01-Correll, IG-41560, IG-107166, KRWA-152, KRWA-9, SHK01-A26-15, SHK01-B32-59, SHK01-C96-149, and SHK01-D12-167 were highly susceptible to the Ethiopian RWA population, which suggests that the Ethiopian RWA population is different from some of the RWA population in other countries. On the other hand, genotypes CMY RWA 101, PI 625140-1, R-765-RWA-152, SHK01-A36-22, SHK01-B10-46, SHK01-B30-58, SHK01-B35-60, SHK01-B84-89, and SHK01-D37-184 are resistant to the Ethiopian RWA. This is in line with Smith et al. (1991) who found that wheat genotypes that were resistant to South African RWA population were also resistant to RWA in the USA.

Wheat resistance to RWA is conferred by different genes (El Bouhssini *et al*. 2011b; Fazel-Najafabadi *et al*. 2014). Therefore, determining the mechanism(s) of resistance along with the gene(s) responsible for the resistance requires future work.

References

Aalbersberg YK and F Du Toit. 1987. Development rate, fecundity and lifespan of apterae of the Russian wheat aphid, *Diuraphis noxia* (Mordvilko) (Hemiptera: Aphididae), under controlled conditions. Bull. Ent. Res. 77: 629-635.

Adugna Haile and Tessema Megenasa. 1987. Survey of aphids on barley in parts of Shewa, Weloand Tigrai, Ethiopia. Ethiop. J. Agric. Sci. 9: 39-53.

Archer TI, EO Bynum Jr, AB Onken, and CW Wendt.1995. Influence of water and nitrogen fertilizer on biology of the Russian wheat aphid (Homoptera: Aphididae) on wheat. Crop Prot. 14: 165-169.

Archer TL, GD Johnson, FB Peairs, KS Pike, and MK Kroening. 1998. Effect of plant phenology and climate on Russian Wheat Aphid (Homoptera: Aphididae) damage to winter wheat. Environ. Entomol. 27: 221-231.

Botha AM, Y Li, and NLV Lapitan. 2005. Cereal host interactions with Russian wheat aphid: A review. Journal of Plant Interactions. 1: 211-222.

Collins MB, SD Haley, FB Peairsand, JB Rudolph. 2005. Biotype 2 Russian Wheat Aphid resistance among wheat germplasm accessions. Crop Sci. 45: 1877–1880.

Central Statistical Agency. 2016. Agricultural Sample Survey: Report on Farm Management Practices. Statistical Bulletin No. 584. Addis Ababa, Ethiopia.

Damte T. 2015. Occurrence of, and yield response to, Russian wheat aphid, *Diuraphis noxia* (Hemiptera: Aphididae) in irrigated wheat in Ethiopia. International Journal of Tropical Insect Science. 35: 3-10.

Du Toit F. 1990. Field resistance in three bread wheat lines to the Russian wheat aphid, *Diuraphis noxia* (Hemiptera: Aphididae). Crop Prot. 9: 255-258.

Debre Zeit Agricultural Research Center. 1984. Crop protection annual report for the period 1977 to 1983. Addis Ababa University, Addis Ababa, Ethiopia.

EL Bouhssini M, K Street, A Amri, M Mackay, FC Ogbonnaya, A Omran, O Abdalla, M Baum, A Dabbous, and F Rihawi. 2011a. Sources of resistance in bread wheat to Russian wheat aphid (*Diuraphis noxia*) in Syria identified using the Focused Identification of Germplasm Strategy (FIGS). Plant Breeding. 130: 96-97.

El Bouhssini M, FC Ogbonnaya, H Ketata, MM Mosaad, K Street, A Amri, M Keser, S Rajaram, A Morgounov, F Rihawi, A Dabus, CM and Smith. 2011b. Progress in host plant resistance in wheat to Russian wheat aphid (Hemiptera: Aphididae) in North Africa and West Asia. Australian Journal of Crop Sciences. 5: 1108-1113.

Ennahli S, M El Bouhssini, S Grando, R Anathakrishnan, T Niide, L Starkus, S Starkey, and CM Smith. 2009. Comparison of categories of resistance in wheat and barley genotypes against biotype 2 of the Russian wheat aphid, *Diuraphis noxia* (Kurdjumov). Arthropod-Plant Interactions. 3: 45–53.

Fazel-Najafabadi M, J Peng, FB Peairs, H Simkova, A Kilian, and NLV Lapitan . 2014. Genetic mapping of resistance to *Diuraphis noxia* (Kurdjumov) biotype 2 in wheat (*Triticum aestivum* L.) accession CI2401. Euphytica, DOI 10.1007/s10681-014-1284-0.

Girma M, G Wilde, and JC Reese. 1990. Influence of temperature and plant growth stage on development, reproduction, life span, and intrinsic rate of increase of the Russian wheat aphid (Homoptera: Aphididae). Environ. Entomol. 19: 1438-1442

Haley SD, FB Peairs, CB Walker, JB Rudolph, and TL Randolph. 2004. Occurrence of a New Russian Wheat Aphid Biotype in Colorado. Crop Sci. 44: 1589–1592.

Hughes RD and GF Maywald. 1990. Forecasting the favorableness of the Australian environment for the Russian wheat aphid, *Diuraphis noxia* (Homoptera: Aphididae), and its potential impact on Australian wheat yields. Bull. Ent. Res. 80, 165-175.

Lykouressi D. 1984. A comparative study of different aphid population parameters in assessing resistance in cereals. Z. ang. Ent. 97: 77-84

Marini RP. 1999. Are nonsignificant differences really not significant? Hortscience. 34: 761-762.

Merrill SC, TO Holtzer, FB Peairs, and PJ Lester. 2009. Modeling spatial variation of Russian Wheat Aphid overwintering population densities in Colorado winter wheat. J. Econ. Entomol. 102: 533-541

Puterka GJ, JD Burd, and RL Burton. 1992. Biotypic variation in a worldwide collection of Russian wheat aphid (Homoptera: Aphididae). J. Econ. Entomol. 85: 1497-1506.

Schotzko DJ and NA Bosque-pe´rez. 2000. Seasonal dynamics of cereal aphids on Russian wheat aphid (Homoptera: Aphididae) susceptible and resistant wheats. J. Econ. Entomol. 93: 975-981.

Smith CM, D Schotzko, RS Zemetra, EJ Souza, and SS Teeter. 1991. Identification of Russian wheat aphid (Homoptera: Aphididae) resistance in wheat. J. Econ. Entomol. 84, 328-332.

Sotelo PA, GL Hein, FB Peairs, and CM Smith. 2014. Effects of planting date and barley variety on Russian wheat aphid (Hemiptera: Aphididae) populations in Colorado, Kansas, and Nebraska. J. Econ. Entomol. 107, 1969-1976; DOI: http://dx.doi.org/ 10.1603/EC14055

Tebkew Damte. 2012. Reaction of durum and bread wheat varieties to Russian Wheat Aphid, *Diuraphis noxia* attack under irrigated condition. Pest Mgt. J. Eth. 16: 49-56.

Tesfay Belay and Alemu Araya. 2015. Grain and biomass yield reduction due to Russian Wheat Aphid on bread wheat in northern Ethiopia. African Crop Science Journal. 23: 197 – 202.

Webster JA, CA Baker and DR Porter. 1991. Detection and mechanisms of Russian wheat aphid (Homoptera: Aphididae) resistance in barley. J. Econ. Entomol. 84: 669-673.