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Identifying Resistance to Ethiopian Russian Wheat Aphid (*Diuraphis noxia* (Mordvilko)) Populations in Introduced Bread Wheat Genetic Resources

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Abstract **– Russian wheat aphid (R.W.A.), *Diuraphis noxia* (Mordvilko), is a major insect pest of wheat and barley in Ethiopia. Yield losses of 67.7% have been reported on irrigated wheat. Bread wheat genetic resources (125) with promise of resistance to R.W.A. in other parts of the world were screened to northern Ethiopian R.W.A. populations in field experiment for two years. Twenty five wheat lines were resistant while 22 had moderate resistance to northern Ethiopian R.W.A. populations. R.W.A. resistant germplasm in other parts of world became susceptible to Ethiopian R.W.A. population. This might indicate biotypic diversity in the R.W.A. populations and might require full-fledged investigation using R.W.A. differentials. The resistant bread wheat germplasm identified from this study can be further tested for agronomic traits or can be used in breeding programs aimed at developing R.W.A. resistant cultivars for irrigated agriculture.**

Keywords **– Russian Wheat Aphid, Bread Wheat, Ethiopia, Biotypic Diversity.**

I. INTRODUCTION

The Russian wheat aphid (R.W.A.), *Diuraphis noxia* Mordvilko (Hemiptera: Aphididae), first reported in Atsbi and Adigrat areas in 1972 [30], is still a serios insect pest of wheat and barley in northern Ethiopia. R.W.A. is one of the major insect pests of wheat and barley with a worldwide distribution as it can be found in Russia, East and Western Europe, Middle East, North Africa, East Africa, South Africa, China, Canada, USA, Mexico, and Chile [23]. It was also recorded in Pakistan [20]. R.W.A. feeding on the thin-walled sieve tubes and xylem [33] resulted in leaf chlorosis, leaf folding and rolling [32].

In the US R.W.A. has caused a total loss of $ 1 billion for a period of eight years [35]. In South Africa, yield losses of 35-60% were reported [11] while in Kenya yield loss of 25-90% was recorded [25]. In Canada it caused yield loss of 25-37% [28]. In Pakistan the yield loss due to RWA ranged from 7.9 to 34.3% [20]. A study conducted on irrigated wheat in Debrezeit (Central Ethiopia) revealed grain yield loss of 69-93% [9]. Similarly, recent studies in northern Ethiopia showed grain and biomass yield losses amounting to 67-68% and 44-55%, respectively, on irrigated wheat [6]. A 22% reduction in seed weight per thousand seeds and delayed heading and maturity of wheat due to R.W.A. was also reported [6]. With the expected expansion of irrigated agriculture to meet increasing wheat demands, R.W.A. is likely to become a threat and it becomes imperative to work on a sustainable management. Seed dressing and foliar insectcides have been identified for R.W.A. management on barley [21]. They were however expensive and farmers are not using them. In Atsbi area of northern Ethiopia, where it was first reported on barley, farmers are reluctant to spray insectcides against RWA because of its impact on bees. Host-plant resistance thus remains the most important control method because of its low cost to the farmer and environment, combined with the ease of putting it into practice [17]. In USA and South Africa, where R.W.A. is a key pest of wheat and barley, they have identified and deployed resistant varieties to control the pest [34]-[2]. In Australia they have started a pre-emptive breeding program aimed at identifying and deploying R.W.A. resistant wheat and barley before the advent of the insect to their country. Because Australia, using a climate computer model, was identified as potential R.W.A. region [29]. The only problem with host-plant resistance is the emergence of biotypes or populations that can injure or kill plants with resistance genes [19].

In Ethiopia information on the R.W.A. wheat resistance was scanty while you can find limited work on barley [21]. Recently the reaction of the released bread and durum wheat varieties in Ethiopia to R.W.A. infestation under irrigated conditions were phenotyped and found out that none were resistant [9]. Susceptible reaction of an American RWA resistant wheat variety (containing *Dn4* gene) to an Ethiopian R.W.A. population was also reported [8]-[7]. Screening of wheat germplasm aimed at identifying resistant sources should therefore be given a priority besides to evaluating R.W.A. resistant cultivars in production elsewhere. In the study reported here, we evalauted bread wheat germplasm against RWA in field experiments conducted in the offseason for the last two consecutive years.

II. MATERIALS AND METHODS

2.1. Description of study area

The field experiment was carried out at the Mekelle Agricultural Research Center, which is located at 13°5'0" N, 39°6'0" E and an altitude of 1970 meters. The area is situated in the semi-arid agro-ecological zone, which is characterized by low and erratic rainfall [36]. Annual rainfall ranges from 445 to 550 mm. The long-term average maximum and minimium temperature for the hottest month of June is 27.3 ^{0}C and 13.2 ^{0}C, respectively. The coldest month is December and has mean maximum and minimum temperatures of 22.3 and 8.4 ^{0}C, respectively [4]. The potential evapo-transpiration is in the range of 1100-1250mm [5]. The soil type is mainly clay loam with a pH of 7.47.

2.2. EXPERIMENTAL LAYOUT AND TREATMENTS

The experiment was conducted in the off season at Illala site of the Mekelle Agricultural Research Center for two consecutive years (2013-2014) using natural R.W.A. infestation. A total of 182 bread wheat germplasm were secured from the Pre-emptive Breeding program for Russian Wheat Aphid Resistance program of Murdoch University, Australia in June 2012. Some were Plant introductions and collections with resistance to R.W.A. that were phenotyped in the US, ICARDA (Syria) and Kenya and rest were crosses of commercial cultivars with resistant sources (Mehmet Cakir, Personal comm.). Out of the 182, only 125 were included in the experiment as the rest failed to set seeds in pre-experimental tests aimed to increase seed and test adaptation.

In January 2013, 20 seeds from each germplam were planted in 1 meter long single rows spaced 30 cms with no replications. While in January 2014, 54 lines identified as resistant in the 2013 screening plus a susceptible variety (Mekelle 1) were planted in 1 meter long single rows spaced 30 cms and replicated three times in randomized complete block design. Recommended fertilizer rate was applied at planting and rows were watered immediately and everyother day till emergence. Natural R.W.A infestation was used. After emeregnce water was applied in the furrow at 4-5 days interval so as not to dislodge the RWA from the leaves. The germplasm were then scored for leaf chlorosis and leaf rolling at Zadoks 12 growth stage [13]. Plants were randomly selected for damage scoring. Leaf chlorosis was measured using 1-9 score [15] with 1, healthy looking plant; 2, isolated chlorotic spots; 3, chlorosis ≥5% but <20%; 4, chlorosis ≥20% but <35%; 5, ≥35% but <50%; 6, ≥50% but <65%; 7, ≥65% but <80%; 8, ≥80%; and 9, plant death. Leaf rolling was also measured on a scale of 1-3 [15], where 1 is flat and 3 fully rolled leaf. Reaction of the germplasm were determined as resistant: if leaf chlorosis is 1-3 and leaf rolling 1, intermediate: if leaf chlorosis is 4-6 and leaf rolling 2 and susceptible: if leaf chlorosis is 7-9 and rolling is 3 [3].

The average leaf chlorosis and rolling scores were computed with descritpive analysis procedure of the IBM SPSS 20 statistics [14]. The number of entries under each category of resistance/susceptibility were presented in bar graphs using the chart builder procedure of the same software.

III. RESULTS AND DISCUSSION

The wheat lines under the three levels of resistance/susceptibility [3] from the 2013 experiment are presented in Fig. 1. Fifty four lines (43.2%) had mean leaf chlorosis score of 1-3 and leaf rolling score 1 and were considered resistant; thirty lines (24%) had mean leaf chlorosis 4-6 and leaf rolling 2 and were intermediate and forty one lines (38.2%) had mean leaf chlorosis 7-9 and leaf rolling 3 and were categorized as susceptible.

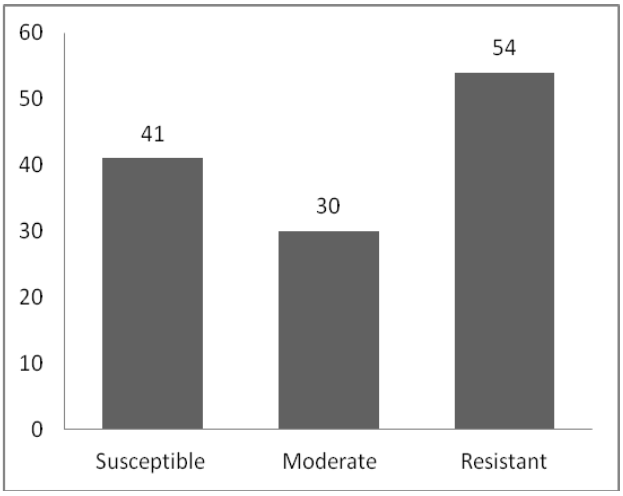

Fig.1. Wheat lines with susceptible, intermediate and resistant reaction to RWA in field screening, 2013 season

A large majority of the wheat lines turned out to be resistant to northern Ethiopian R.W.A. population and hence there was no need to consider lines with intermediate resistance for the time being. So only those lines with resistant reaction were included in the subsequent screening conducted in 2014 at Mekelle Agricultural Research Center.

In the 2014, 26 (45.5%) wheat lines became resistant to R.W.A. (Fig. 2). Twenty two (40%) lines had intermediate (Table 2) reaction and 8 (14.5%) were susceptible (table 3). The R.W.A. resistant entries are presented in table 1. R.W.A. resistant Kenyan cultivars KRWA 9 and KRWA 16 [31] became susceptible to north Ethiopian RWA populations except R765/RWA 152. Similarly RWA resistant wheat lines IG138810 and IG41556 identified at ICARDA [10] succumbed to Ethiopian RWA populations while IG41560 and IG107166 had intermediate or moderate resistance and only IG138374 was resistant to the northern Ethiopian populations. The ICARDA wheat germplasm included in this study contained the *Dn4* resistance gene [27]. Earlier *Dn4* resistance gene containing wheat was susceptible to north Ethiopian R.W.A. populations [26]. Four plant introductions: PI624609-1 (Afghanistan), PI624151-1 (Turkmenistan), PI624656-3 (Kazakstan) and PI625140-1 (Afghanistan), proved resistant to R.W.A. in our study. These same germplasm were resistant to Syrian and South African R.W.A. populations [12]. Four other CIMMYT entries CMYRWA7, CMYRWA15, CMYRWA20, and CMYRWA101 proved resistant to Ethiopian R.W.A. population. Fifteen lines, obtained from crosses (PI626580-4 X Corell*)* of the pre-emptive breeding program of Murdoch University Australia, were resistant to northern Ethiopian RWA populations. The maturity class of most of the resistant bread wheat genotypes seems to fall within the acceptable range for northern Ethiopia but there is a need to study their agronomic traits.

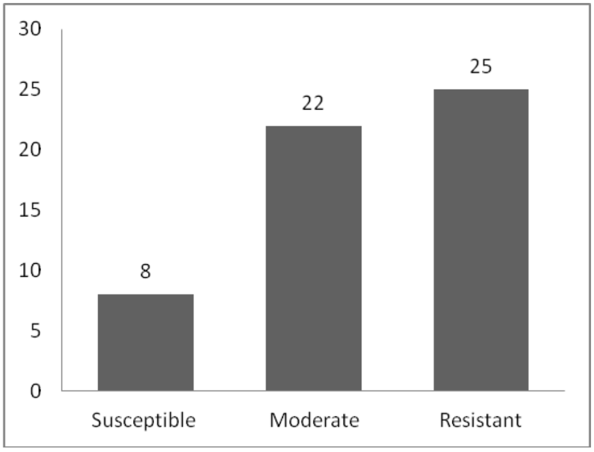

Fig. 2: Wheat lines with susceptible, moderate & resistant reaction to R.W.A. at Mekelle, 2014.

Over 70 wheat lines with potential R.W.A resistance genes and 99 Australian barley lines and found out that all the Australian barley lines and a number of exotic wheat lines were susceptible to US biotypes 1 and 2 [23]. In ICARDA 7746 bread and durum wheat accessions were evaluated for R.W.A. resistance and 33 wheat lines were identified resistant to Mideast R.W.A biotype [27]. Further, thousands of durum wheat lines and wild species were screened for resistance to RWA in ICARDA and found out eight lines of durum wheat and 19 accessions of wild species resistant to RWA and these sources were used in durum wheat breeding program to develop resistant varieties to RWA [24]. In the USA evaluated a collection of 761 germplasm accessions in standard seedling screening tests with Biotype 2 R.W.A. and identified 44 germplasm accessions with high to moderate level of resistance [26].

The tested entries showed differential response to R.W.A. The difference in the reaction of the wheat lines to R.W.A. in the countries tested might reflect likely biotypic differences in the R.W.A. populations of the countries. Similarly R.W.A. resistant wheat cultivars from South Africa (Caledon, SST 333, SST 972 and Halt) became susceptible to Hungarian R.W.A. populations indicating biotypic differences between the two countries [37]. A higher degree of biotypic diversity in a worldwide collection of Russian wheat aphid was reported [12] although genetic variation amongst reported biotypes was limited [19].

RWA resistant wheat cultivars containing *Dn4* and *Dny* genes became susceptible to north Ethiopian R.W.A. population[7]-[8]. Recently however R.W.A. resistant barley cultivars from the US, Burton and RWA-1758, had resistant reaction to the same northern Ethiopian populations [1]. The variable response of the wheat cultivars containing *Dn4* and *Dny* resistance genes and barley cultivars containing *Dnb1* and *Dnb2* resistance genes to northern Ethiopian RWA populations might indicate the existence of more than one biotype in the area. This might require a separate study on Ethiopian R.W.A. population using differentials, as the future success of Russian wheat aphid resistance is dependent on R.W.A. phenotypic and genetic diversity for virulence [15].

IV. CONCLUSION

Most of the bread wheat genotypes were earlier identified to possess resistance to R.W.A. and were used in breeding programs of the United States, South Africa, Kenya and Australia. They were screened against Ethiopian R.W.A. population for the first time and 25 of them proved resistant to Ethiopian R.W.A. population. Some had moderate resistance while few were susceptible. Biotypic diversity is documented for R.W.A. and it could account for the susceptible reaction of some of the bread wheat genotypes that were resistant to R.W.A. populations in other countries.

Amongst those identified to possess resistance, significant proportion of the genotypes could be suitable to the drylands of northern Ethiopia and there is a need to check for agronomic traits. They can also be valuable sources for a breeding program aimed at developing R.W.A. resistant cultivars. It might also be worth re-considering the moderately resistant wheat lines in future research as they might fit to integrated pest management programs with limited insecticide spray.

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Table 1: Response of resistant wheat lines to R.W.A. lines infestations at Mekelle, 2014.

S N	Wheat entries	Mean leaf chlorosis	Mean leaf rolling
1	*CMYRWA15*	*1*	*1*
2	*CMYRWA20*	*2*	*1*
3	*CMYRWA7*	*1*	*1*
4	*CMYRWA101*	*2*	*1*
5	*IG138374*	*3*	*1*
6	*PI624609-1*	*1*	*1*
7	*PI624151*	*1*	*1*
8	*PI624656-3*	*1*	*1*
9	*PI625140*	*2*	*1*
10	*R765-RWA152*	*2*	*1*
11	*SHK01-A45-29*	*2*	*1*
12	*SHK01-B10-46*	*2*	*1*
13	*SHK01-B11-47*	*2*	*1*
14	*SHK01-B3-41*	*2*	*1*
15	*SHK01-B30-58*	*2*	*1*
16	*SHK01-B35-60*	*2*	*1*
17	*SHK01-B9-45*	*2*	*2*
18	*SHK01-A26-15*	*2*	*1*
19	*SHK01-A27-16*	*2*	*1*
20	*SHK01-A28-17*	*1*	*1*
21	*SHKO1-B84-89*	*2*	*1*
22	*SHKO1-C102-155*	*2*	*1*
23	*SHKO1-C99-152*	*2*	*2*
24	*SHKO1-D18-171*	*2*	*1*
25	*SHKO1-D19-172*	*2*	*1*
26	*PI626580-4*	*2*	*1*

Table 2: Response of the moderately resistant wheat to R.W.A. infestations at Mekelle, 2014

SN	Wheat_lines	Mean chlorosis	Mean leaf rolling
1	*CMYRWA 103*	*5*	*2*
2	*CMYRWA 36*	*4*	*2*
3	*CMYRWA-76*	*4*	*2*
4	*IG107166*	*3*	*2*
5	*IG41560*	*4*	*2*
6	*PI625123*	*3*	*1*
7	*Correll*	*6*	*2*
8	*SHK01-B1-39*	*3*	*2*
9	*SHK01-B32-59*	*3*	*2*
10	*SHK01-B56-71*	*3*	*1*
11	*SHK01-C28-111*	*3*	*1*
12	*SHK01-A15-9*	*3*	*1*
13	*SHK01-A36-22*	*4*	*2*
14	*SHK01-A38-23*	*4*	*2*
15	*SHK01-A41-25*	*3*	*2*
16	*SHKO1-B72-83*	*4*	*2*
17	*SHKO1-C104-157*	*3*	*1*
18	*SHKO1-C97-150*	*3*	*1*
19	*SHKO1-D12-167*	*4*	*2*
20	*SHKO1-D27-177*	*3*	*1*
21	*SHKO1-D37-184*	*3*	*1*
22	*SHKO1-D8-164*	*3*	*1*

Table 3. Response of susceptible wheat lines to R.W.A. infestation at Mekelle, 2014.

SN	Wheat lines	Mean chlorosis	Mean leaf rolling
1	*CIMMYT 109*	*7*	*3*
2	*IG41556*	*6*	*3*
3	*KRWA 152*	*7*	*3*
4	*KRWA 9*	*6*	*2*
5	*Mekelle 01*	*8*	*3*
6	*PASA*	*7*	*3*
7	*SHK01-B48-68*	*5*	*3*
8	*SHKO1-C96-149*	*6*	*3*