Indian Journal of Agricultural Sciences **84** (10): 1274–7, October 2014/Short Communication
https://doi.org/10.56093/ijas.v84i10.44218

Detection of durable resistant sources for sugarcane aphids, *Melanaphis sacchari* and their mechanisms of resistance in post rainy sorghum

V R BHAGWAT[1], G SHYAM PRASAD[2], PRABHAKAR[3], D B PAWAR[4], A P BIRADAR[5], K SRINIVASA BABU[6], A KALAISEKAR[7], B SUBBARAYUDU[8] and J V PATIL[9]

Directorate of Sorghum Research, Rajendranagar, Hyderabad, Andhra Pradesh 500 030

Received: 6 July 2013; Revised accepted: 26 May 2014

Key words: Antibiosis, Mechanism of resistance, Non-preference, Sugarcane aphid, Tolerance

Sorghum [*Sorghum bicolor* (L.) Moench] is the staple food for more than 300 million people and feed for cattle in Asia, Africa, the Americas and Australia. It is attacked by about 150 insects (Sharma 1993). In India, nearly 26% of sorghum crop is lost due to insect pests during the post rainy season (Daware *et al.* 2012). Sugarcane aphid (*Melanaphis sacchari* Zehntner) is one of the most important pests in Asia, Africa, Australia, and the USA and is known as a serious pest in the post rainy season in India (Sharma *et al.* 1997). The aphid infestation was noticed quite high during the flowering and grain filling stages when long moisture stress and suitable environmental conditions are available (Raetano and Nakano 1994). Sugarcane aphid is also known as a vector of sugarcane yellow leaf virus (Smith *et al.* 2000). Several efforts have been made in the past to identify sources of resistance to the pest. Moderate levels of resistance to *M. sacchari* have been reported (Sarath Babu *et al.* 2000, Balikai and Biradar 2004, Sharma and Dhillon 2005 and Sharma *et al*. 2013). Application of chemical insecticides for aphid control under marginal farming conditions may not be feasible, and create environmental and operational hazards. Because of increasing economic importance of *M. sacchari* in post-rainy sorghum production and considering availability of limited moderate level of resistance sources, a diverse array of sorghum genotypes were evaluated to identify cultivars with improved and durable resistance to this pest under natural infestation.

[1] Principal Scientist (Entomology) (e mail: bhagwat@sorghum.res.in), [2] Principal Scientist (Entomology) (e mail: shyam@sorghum.res.in), [3] Principal Scientist (Breeding), (e mail: prabhakar@sorghum.res.in), CRS, DSR, Solapur; [4] Associate Professor (Entomology) (e mail: pawardattaji@yahoo.co.in), AICSIP, MPKV, Rahuri; [5] Associate Professor (Entomology) (e mail: apbiradar123@rediffmail.com), AICSIP, RARS, UAS, Bijapur; [6] Senior Scientist (Entomology) (e mail: sbabu@sorghum.res.in), [7] Senior Scientist (Entomology) (e mail: kalai@sorghum.res.in), [8] Senior Scientist (Entomology) (e mail: subba@sorghum.res.in), [9] Director (e mail: jvp@sorghum.res.in)

Field studies were conducted during three consecutive post-rainy seasons (2007-08, 2008-09, 2009-10) at three hot spot locations, viz. Centre for Rabi Sorghum (CRS), Directorate of Sorghum Research (DSR), Solapur, Maharashtra, India, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, and Regional Agricultural Research Station, University of Agricultural Sciences, Bijapur, Karnataka. Twenty four diversified B and R lines developed at CRS, Solapur along with resistant check (TAM 428), susceptible check (Hathi kuntha) and a local check (M-35-1) were evaluated for aphid resistance. The plot size consisted of 2 rows of 2 m 45 cm apart with 12 cm spacing between the plants. The experiment was conducted in RCBD with three replications. Observations were recorded on aphid colonization (no/cm^2 leaf), plant damage ratings (1- least damage, 9- severe damage) at physiological maturity as suggested by Sharma *et al.* (2013). The data on days to 50% flowering, plant height (cm), SPAD chlorophyll meter readings (SCMR) and grain yield (g/plant) were also recorded. The three years data on above parameters were subjected to analysis of variance and means were compared by LSD at P = 0.05. The data were also subjected to principle component analysis and genotypes classified (SPSS 1999). Studies on the progeny production and non preference were also conducted under ambient conditions to determine mechanisms of resistance as suggested by Mote and Kadam (1984) and Sharma and Nwanze (1997).

Out of 24 lines, three (SLB 80, ICSV 93046 and SLR 31) were moderately resistant as determined by the visual damage ratings (1-9) and held relatively minimum population at physiological maturity with an average of 46.9, 50.7 and 51.4 aphids/cm^2 of leaf area respectively, as compared to 35.2 aphids/cm^2 on TAM 428, a widely used source of resistance to *M. sacchari* across the locations and seasons. Hathi Kuntha and C 43 recorded up to 6.1 damage rating and above 70 aphids/cm^2 (Table 1). Balikai (2001) reported that SPV 570, RS 29 and C 49 were highly resistant to *M. sacchari.* The data on days to 50% flowering was significant at 5% level. SLB 19 was earliest (78.6 days),

Table 1 Reaction of sorghum genotypes to *Melanaphis sacchari* at three locations, India during 2008-2010 post rainy seasons

Sorghum lines	Pedigree	Aphid No/cm^2	Damage rating (1-9)	Days to flower (50%)	Plant height (cm)	SPAD meter reading	Grain yield (g/plant)
SLB-10	104B×SPV-1376-2	56.7	4.3	83.1	107.9	36.4	74.73
SLB-19	104B×Dhamngaon local-3	56.0	4.6	78.7	113.2	37.1	53.36
SLB-64	Selection from SLK-1	57.9	4.4	86.8	120.2	36.9	72.25
SLB-50	Selection from IS-4070-1	57.0	4.2	84.3	124.9	36.2	77.09
SLB-52	Selection IS-18466-1	60.2	4.4	81.8	116.3	38.9	63.42
SLB-77	Selection from IS-34003-B	59.4	4.6	86.4	121.7	38.8	70.87
SLB-78	Selection from EP-133B	61.9	4.7	87.3	129.5	39.4	69.38
SLB-79	Selection from EP-135B	56.5	4.2	87.8	149.9	38.9	96.69
SLB-80	Selection from SLK-30B	46.9	3.4	86.3	125.8	35.3	130.59
SLB-81	Selection from IS-3492B	64.4	5.1	84.7	136.8	37.2	121.07
SLB-83	Selection from PCE-10-1	53.4	4.6	88.3	116.4	39.6	104.97
SLR-30	SPV-1376×SPV-1155-3-11	53.3	4.8	85.7	141.1	35.8	72.34
SLR-31	CR-9×RSG-262-1-6-7	51.4	4.7	85.1	125.9	35.6	74.93
CRS 11	Chungi Maldandi×PEC-17	57.4	5.1	86.4	115.4	36.8	85.12
Y- 75	Not known	61.7	5.5	80.7	96.7	39.7	82.72
Hathi Kuntha (Sus check)	Landrace from Madhya Pradesh (India)	81.2	6.1	80.6	117.7	42.3	52.43
DJ 6514	(Jola 6514) landrace from Dharwad (India)	54.3	4.9	91.2	109.2	37.9	62.77
ICSV 93046	(ICSV 700×ICSV 708)-9-1-3-1-1-1	50.7	3.5	84.5	130.2	35.1	103.49
ICSV 745	(PM 11344×A 6250)-4-l-l-l)	51.8	4.3	87.8	105.9	36.7	97.67
ICSV 700	(IS 1082×SC 108-3)-1-1-1-1	57.2	4.5	86.9	127.7	35.6	66.90
TAM 428 (Res check)	SC 502, F_1; 9213161 (IS 40618)	35.2	3.1	84.2	92.1	34.9	94.12
IS 2205	(IC 6183-Jaglur) landrace from India	52.4	4.5	89.3	137.7	36.8	85.72
C-43 (Sus check)	CS 3541×IS23549	74.0	5.7	82.4	104.0	41.4	59.14
M 35-1 (Local check)	Selections from local in Maharashtra	55.3	4.1	86.3	152.5	37.4	105.12
Mean		56.9	4.6	85.3	121.6	37.5	82.37
LSD (P = 0.05)	16.99	1.04	6.19	9.67	3.79	10.12	
CV (%)		24.67	24.55	7.79	8.54	24.65	13.18

while DJ 6514 recorded delayed flowering (91.2 days). Plant height ranged from 92.1 to 149.9 cm with an average of 121.6 cm (Table 1).

TAM 28 recorded low SPAD value (34.9) while Hathi Kuntha (42.3) and C 43 (41.4) recorded highest SPAD value (Table 1). The aphid colonization exhibited a significantly positive relationship (0.804**) with chlorophyll content implying that higher chlorophyll content supported aphid population (Table 2). Mote and Shahane (1994) observed that the development of aphid population and leaf sugary exudation (LSE) was more pronounced in varieties with higher nitrogen, sugar and total chlorophyll content of leaves which are in line with our observations. There was negative relationship between aphid colonization and earliness (–0.377) while positive relationship was observed between aphid colonization and plant height (0.024) (Table 2).

Table 2 Association between aphid density *M. sacchari* score, plant damage and morphological characters

	Aphid pop	Damage rating	Days to flower	Plant height	Grain yield	SPAD
Aphid pop	1.000					
Damage rating	0.857**	1.000				
Days to flower	–0.377^{NS}	–0.295^{NS}	1.000			
Plant height	0.024^{NS}	–0.138^{NS}	0.354^{NS}	1.000		
Grain yield	–0.464*	–0.535**	0.335^{NS}	0.302^{NS}	1.000	
SPAD	0.804**	0.738**	–0.242^{NS}	–0.150^{NS}	–0.484*	1.000

*P= * P = 0.05, ** P = 0.01

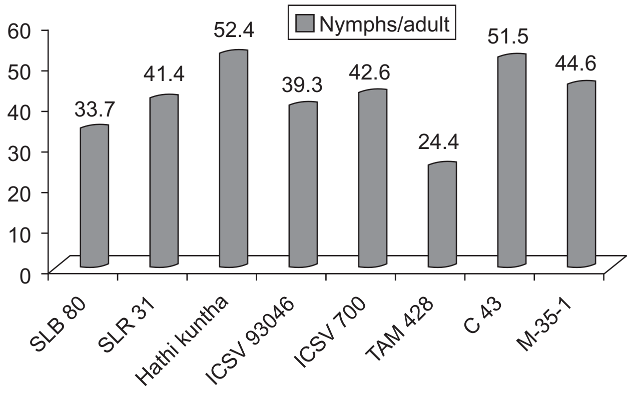

Fig 1 Mean progenies of *M. sacchari* on sorghum genotypes

The lowest grain yield (52.4 g/plant) was recorded in Hathi Kuntha and highest (130.6 g/plant) were recorded in SLB 80 with an average of 82.4 g/plant. The data was significant at 5% level (Table 1). The aphid population depicted a significantly negative relationship with grain yield (–0.464*) implying that higher aphid population led to yield loss due to depletion of plant sap by aphids (Sharma and Nwanze 1997). All three lines, SLB 80, ICSV 93046 and SLR 31 exhibited antibiosis, with an average progeny production of 33.7, 39.3, 41.4 nymphs per adult, respectively as compared to TAM 428 (24.4 nymphs/adult) (Fig 1). The

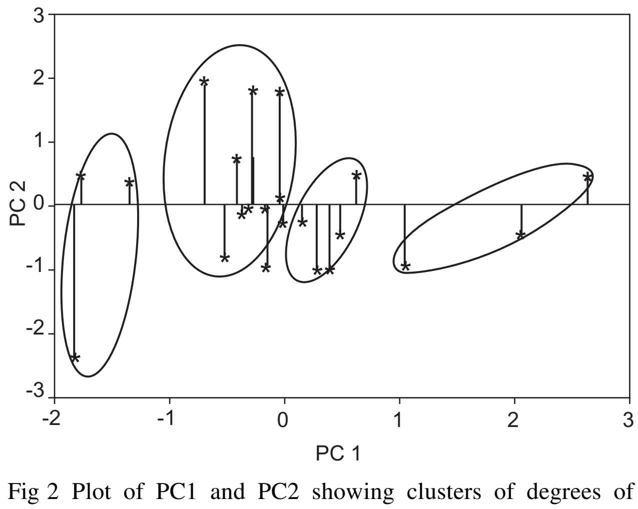

Fig 2 Plot of PC1 and PC2 showing clusters of degrees of resistance exhibited in *rabi* sorghum to *M. sacchari*

*The entry corresponding to number in scatter plot is detailed below

Reaction	Genotypes
Resistant (R)	9-SLB 80; 18- ICSV 93046; 21-TAM 428
Moderately resistant (MR)	1-SLB 10; 3-SLB 64; 4-SLB 50; 8-SLB 79; 10-SLB 81; 11- SLB 83; 12- SLR 30; 13-SLR-31; 19-ICSV 745; 20-ICSV 700; 22-IS 2205; 24-M-35-1
Susceptible (S)	2-SLB 19; 5-SLB 52; 6-SLB 77; 7-SLB 78; 14-CRS 11; 17-DJ 6514
Highly susceptible (HS)	15-Y 75; 16- Hathi kuntha; 23-C 43

grain yield depicted significantly negative relationship with aphid population (–0.464*) and damage rating (–0.535**) (Table 2). It indicates that these parameters are the key variables for the crop damage due to aphid in rabi sorghum (Mote and Shahane 1994 and Fitiwy *et al*. 2008).

In view of complexity of interactions between *M. sacchari* and sorghum, principal component analysis was applied for five parameters, viz. aphid population/cm^2, aphid damage rating, plant height, SPAD values and grain yield (g)/plant. The extraction communalities for all the variables tested at p = 0.5 indicated that the variables were well represented by the two extracted PCs which together explained a cumulative variation of 81.19%. PC_1 explained 59.17% of the variation while PC_2 explained 22.02% of the variation. PC_1 had the loadings for aphid population/cm^2 (0.92), aphid damage rating (0.92), grain yield/plant (0.67) and SPAD value (0.87), whereas plant height (0.91) was loaded in PC_2. The observations are comparable with Sharma *et al.* (2013) on the basis of principal coordinate analysis.

When compared to the PC_1, PC_2 explained lesser variation and the characters loaded in this component could be of less value in explaining the overall variability. Thus, PCA brought out four variables, viz. aphid population/cm^2, aphid damage rating, SPAD values and grain yield (g/plant), as the most important in explaining variability close to 50% of total variation in the genotypes tested. Therefore, these characters are indispensable in selecting the genotypes into different classes of aphid resistance or susceptibility. The plots of PC_1 and PC_2 depicted four discrete classes of genotypes which can be grouped into resistant (R), moderately resistant (MR) and susceptible (S) and highly susceptible (HS) (Fig 2).

The present study suggests that among the damage parameters, aphid population/cm^2, aphid damage rating, chlorophyll content and grain yield/plant were the most reliable parameters for characterization of resistance/susceptibility to *M. sacchari* in sorghum. The entries, SLB 80, SLR 31 and TAM 428 are resistant to aphid and could be utilized in rabi breeding program as aphid resistant sources to improve agronomically superior rabi lines.

SUMMARY

A set of 24 entries comprising B and R lines were evaluated under All India Coordinated Sorghum Improvement Project (AICSIP) at three hot spot locations, viz. Bijapur, Rahuri and Solapur during three consecutive post-rainy seasons 2008-2010 to identify durable and improved resistant sources for sugarcane aphid, *M. sacchari* under field conditions. Three lines (SLB 80, ICSV 93046 and SLR 31) were moderately resistant as determined by visual damage ratings and aphid population at physiological maturity. The mean aphid population was recorded as 46.9, 50.7, 51.4 aphids on SLB 80, ICSV 93046 and SLR 31 respectively, compared with 35.2 aphids/ cm^2 of leaf area on TAM 428, a widely used source of resistance for *M. sacchari* under natural conditions. All three lines exhibited antibiosis, with an average progeny of 33.7, 39.3, 41.4

nymphs per adult on SLB 80, ICSV 93046 and SLR 31, respectively, compared to 24.4 nymphs/adult on TAM 428. Principal component analysis suggested that the genotypes with aphid resistance are quite diverse and can be introgressed into adapted local varieties. The present investigation reveals that aphid population/cm^2, aphid damage rating, chlorophyll content and grain yield (g)/ plant appears to be the most reliable parameters for characterization of susceptibility or resistance to *M. sacchari.* The entries, SLB 80, SLR 31 and TAM 428 are resistant to aphid and could be utilized in *Rabi* breeding program as aphid resistant sources.

ACKNOWLEDGEMENT

The contribution made by Dr H C Sharma, Principal Entomologist, ICRISAT, Patancheru, in providing sorghum lines for evaluation is gratefully acknowledged.

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