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MB Zala
Assistant Research Scientist, Agricultural Research Station, Anand Agricultural University, Sansoli, Gujarat, India

TM Bharpoda
Retd. Professor, Department of Agricultural Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
MB Zala
Assistant Research Scientist, Agricultural Research Station, Anand Agricultural University, Sansoli, Gujarat, India

Resistance/susceptibility of mango varieties against gall midge, *Procontarinia matteiana* Kieffer & Cecconi

MB Zala and TM Bharpoda

Abstract
The field experiments were conducted at Horticulture farm, B. A. College of Agriculture, Anand Agricultural University, Anand during 2014 (March-April & September-October) and 2015 (March-April & September-October) to study the resistance/susceptibility of mango varieties against gall midge, *Procontarinia matteiana* Kieffer & Cecconi. During the period of investigations, 10 mango cultivars (Langra, Kesar, Rajapuri, Alphonso, Amrapali, Mallika, Totapuri, Dasheri, Sonpari and Vanraj) were evaluated based on the leaf damage (galling) index (0-5). Among all the mango varieties evaluated, Totapuri, Rajapuri, Vanraj, Langra as well as Amrapali were registered in resistant (R) category as the incidence of *P. matteiana* ranged between 0.60 to 1.54 leaf damage index. Dasheri as well as Alphonso exhibited the incidence in the range of 2.29 to 2.53 leaf damage index and were grouped as moderately susceptible (MS) cultivars during summer seasons of two consecutive years (2014 and 2015). Mango varieties Totapuri, Rajapuri, Vanraj, Langra as well as Mallika recorded the incidence in the range of 0.60 to 1.38 leaf damage index and grouped as resistant varieties and Dasheri as well as Alphanso recorded greater than 2.06 leaf damage index but less than 2.62 leaf damage index and categorized as moderately susceptible varieties during *kharif* seasons of two consecutive years (2014 and 2015). Morphological characters *viz*., thickness (mm), length (cm), width (cm) and area (cm^2) of compound leaf of different mango varieties has shown no any significant role on the activity of *P. matteiana*.

Keywords: Mango, varieties, resistance, susceptible, gall midge, *Procontarinia matteiana*

Introduction
Mango (*Mangifera indica* Linnaeus) is national fruit of India and known as "King of fruits" due to its wide adaptability, excellent taste, exotic flavour, exemplary nutritive value, richness in variety, attractive colour, appearance and popularity among the masses. The major mango producing countries in the world are India, China, Pakistan, Mexico, Thailand, Indonesia, Brazil, Philippines, Nigeria and Viet Nam. India ranks first in production of mango in the world. Uttar Pradesh, Andhra Pradesh, Bihar, Karnataka, Himachal Pradesh, Maharashtra, Orissa, Tamil Nadu, Gujarat and West Bengal are the major mango producing states. In Gujarat, Valsad, Kheda, Junagadh, Surat and Banaskantha are the known districts for cultivation of mango crop. The popular varieties grown in Gujarat are Kesar, Rajapuri, Langra and Alphonso. The mango tree suffers regularly a colossal loss due to ravages of pests, a serious threat to mango industry. The crop is attacked by about 492 species of insects, 17 species of mites and 26 species of nematodes at the world level. Of these, 188 species of insects have been reported from India (Tandon and Verghese, 1985) [14]. The infestation of mango gall midge, *Procontarinia matteiana* Kieffer & Cecconi (Cecidomyiidae: Diptera) has steadily increased year after years in mango orchards due to changes in environment, cropping system, cultivation of susceptible varieties etc. About 26 species of insects produces galls on various plant parts of mango tree. Most of the mango gall inducing species belong to genus *Procontarinia* (Cecidomyiidae: Diptera) (Boucek, 1986) [3]. Mango gall midge is a common gall midge on mango found in India (Askari and Radjabi, 2003) [1]. In India, the infestation of gall midge found on mango throughout the year, prominently during vegetative and fruit maturity period *i.e.* September and April (Kaushik *et al.*, 2012) [7]. Jadhav *et al.*, (2013_b) [5] observed that the early instar maggot burrows the leaf tissues and forms reddish spot on the leaf tissues and it becomes swollen and soft. The maggot remains inside the leaf tissues and fully developed maggot produce a gall due to continuous feeding on the leaf tissue with the help of cephalopharangeal apparatus. A serious outbreak might be resulted in reduction of fruit yield (Augustyn *et al*., 2013) [2].

Farmers are facing problem to manage this pest in sustainable ways hence they are using a range of management tactics including host plant resistance, insecticide applications and biological control etc. Considering sustainable agriculture, host plant resistance is an important component of integrated pest management, thus finding any varieties that are resistant could be a key aspect for developing sustainable strategies to control emerging insect pests and minimize yield losses. Mango gall midge, *P. matteiana* was reported as an economic pest during 1980_s in Gujarat as it caused 25.80 to 47.70% leaf damage on three mango varieties *viz*., Alphonso, Kesar and Rajapuri (Jhala *et al.*, 1987) [6]. Nature of damage and biology of this pest makes it very difficult to control by conventional insecticides and biological control agents. Thus, there is a need to develop alternative management strategies. Keeping in view the above facts, the study was conducted on 10 varieties of mango with an objective to find out resistant variety(s) against mango gall midge, *P. matteiana*.

Materials and Methods

The field experiments were carried out at Horticulture farm, B. A. College of Agriculture, Anand Agricultural University, Anand during 2014 (March-April & September-October) and 2015 (March-April & September-October) to study the resistance/susceptibility of mango varieties against gall midge, *Procontarinia matteiana* Kieffer & Cecconi. During the period of investigations, 10 mango cultivars (Langra, Kesar, Rajapuri, Alphonso, Amrapali, Mallika, Totapuri, Dasheri, Sonpari and Vanraj) were evaluated based on the leaf damage (galling) index (0-5) in Completely Randomized Design with three repetitions (one tree as one repetition). Each of mango varieties had the sown distance of 10 x 10 m. All the standard agronomical practices except plant protection have been followed. The experiment was laid out by selecting more or less equal age (15 years) trees having similar size and canopy. For recording observations of mango gall midge on each selected and tagged trees, four leaves from terminal twig were selected randomly from each direction at weekly interval during its main activity period (March-April and September-October). On visual observations, leaf (galling) damage index (0-5) was given. To standardize the scale, 100 leaves were randomly selected and brought to the laboratory. Collected leaves were categorized into the following index looking to the per cent leaf area covered based on number of galls counted (Zala and Bharpoda, 2022) [15].

Galling Index

Index	Leaf area covered (%)	Average number of gall (s)	Standard deviation (±)
0	No galls (completely free)	0	0
1	20% leaf area covered	6.9	2.02
2	40% leaf area covered	16.6	1.17
3	60% leaf area covered	26.8	3.19
4	80% leaf area covered	47.9	4.38
5	More than 80% leaf area covered	129.6	5.58

The mango varieties were grouped into four categories of resistance/ susceptibility to gall midge, *P. matteiana viz*., resistant (R), less susceptible (LS), moderately susceptible (MS) and highly susceptible (HS). For the purpose, mean value of individual cultivar ($\overline{X}_i$) was compared with mean value of all cultivars ($\overline{X}$) and standard deviation (SD) following the standard scale given as under (Patel *et al*., 2002) [11].

Category of resistance	Scale
Resistant (R)	$\overline{X}_i < \overline{X}$
Less susceptible (LS)	$\overline{X}_i > \overline{X} < (\overline{X} + 1\ SD)$
Moderately susceptible (MS)	$\overline{X}_i > (\overline{X} + 1\ SD) < (\overline{X} + 2\ SD)$
Highly Susceptible (HS)	$\overline{X}_i > (\overline{X} + 2\ SD)$

Morphological characters *viz*., thickness (mm), length (cm), width (cm) and area (cm^2) of compound leaf of different mango varieties under study were recorded from ten leaves of randomly selected trees during March-April, 2014. Leaf area of the compound leaf was measured by using Leaf Area Meter (LICOR-3100). Similarly, length and width of leaf was also measured. Thickness of the leaf in mm was also measured by using Vernier Caliper and Micrometer Screw. The correlation between the morphological characters *viz*., thickness (mm), length (cm), width (cm) and area (cm^2) of compound leaf of mango varieties under study and infestation of *P. matteiana* was also worked out to see the mechanism of resistance.

Results and Discussion

Based on screening of mango varieties against *P. matteiana*

The results on leaf damage (galling index: 0-5) by *P. matteiana* on different mango varieties during March-April, 2014 are presented in Table 1. Significantly the lowest gall midge incidence was recorded in mango variety Totapuri (0.67 leaf damage index). Rajapuri recorded 1.01 leaf damage index and was at par with Vanraj (1.16) followed by Langra (1.30). Mallika and Amrapali recorded 1.52 and 1.72 leaf damage index, respectively and found at par with each other followed by Sonpari (1.78). Among the different varieties evaluated, Alphonso recorded significantly maximum leaf damage (2.42) followed by Dasheri (2.22) and Kesar (1.93).

Table 1: Incidence of gall midge, *P. matteiana* on different mango varieties during March-April, 2014 & 2015

Varieties		Gall midge incidence (0-5 leaf damage index)		
		2014	**2015**	**Pooled**
Langra		1.34^{cd} (1.30)	1.36^{c} (1.35)	1.35^{cd} (1.32)
Kesar		1.56^{fg} (1.93)	1.53^{de} (1.84)	1.55^{efg} (1.90)
Rajapuri		1.23^{b} (1.01)	1.14^{b} (0.80)	1.19^{b} (0.92)
Alphonso		1.71^{h} (2.42)	1.78^{g} (2.67)	1.74^{h} (2.53)
Amrapali		1.49^{ef} (1.72)	1.37^{c} (1.38)	1.43^{de} (1.54)
Mallika		1.42^{de} (1.52)	1.48^{d} (1.69)	1.45^{def} (1.60)
Totapuri		1.08^{a} (0.67)	1.02^{a} (0.54)	1.05^{a} (0.60)
Dasheri		1.65^{gh} (2.22)	1.68^{fg} (2.32)	1.67^{gh} (2.29)
Sonpari		1.51^{f} (1.78)	1.62^{ef} (2.12)	1.57^{fg} (1.96)
Vanraj		1.29^{bc} (1.16)	1.24^{b} (1.04)	1.26^{bc} (1.09)
S. Em. ±	Treatment (T)	0.03	0.03	0.04
	Period (P)	0.03	0.03	0.02
	Year (Y)	-	-	0.01
	T × P	0.09	0.10	0.06
	T × Y	-	-	0.03
	P × Y	-	-	0.03
	T × P × Y	-	-	0.09
C. V.%		10.63	11.62	11.14
Note:				
1. Figures in parentheses are retransformed values; those outside are $\sqrt{X+0.5}$ transformed values.				
2. Figures in letter(s) in common are statistically at par as per DNMRT.				

The results on leaf damage (galling index: 0-5) by *P. matteiana* on different mango varieties during March-April, 2015 are presented in Table 1. The mango variety Totapuri recorded the lowest (0.54 leaf damage index) gall midge incidence. Rajapuri (0.80) and Vanraj (1.04) were at par with each other. Langra and Amrapali recorded 1.35 and 1.38 leaf damage index followed by Mallika (1.69) which was found at par with Kesar (1.84). Significantly the highest (2.67) gall midge incidence was registered in Alphonso followed by Dasheri (2.32) and Sonpari (2.12).

The pooled over years (September-October, 2014 & 2015) results on mean gall midge incidence (0-5 leaf damage index) of *P. matteiana* (Table 1) revealed that the mango variety Totapuri registered significantly the lowest (0.60 leaf damage index) gall midge incidence than the rest of the varieties under study. Rajapuri (0.92) and Vanraj (1.09) were at par with each other followed by Langra (1.32). Amrapali and Mallika were found at par with each other. Kesar and Sonpari registered 1.90 and 1.96 leaf damage index, respectively. Significantly the highest (2.53) gall midge incidence was recorded in Alphonso followed by Dasheri (2.29).

The results on leaf damage (galling index: 0-5) by *P. matteiana* on different mango varieties during September-October, 2014 are presented in Table 2. It is evident from the results that the mango variety Totapuri recorded significantly the lowest (0.54 leaf damage index) gall midge incidence than the rest of the varieties under study. Rajapuri (0.82) and Vanraj (0.99) were at par with each other followed by Mallika (1.27). Mallika was also at par with Langra (1.35) and Amrapali (1.54) followed by Kesar (1.66). Sonpari (1.90) and Dasheri (2.00) did not show any significant difference with each other. The highest (2.29) incidence of *P. matteiana* was noted in Alphonso than the rest of the varieties.

The results on leaf damage (galling index: 0-5) by *P. matteiana* on different mango varieties during September-October, 2015 are presented in Table 2. The results indicated that the mango variety Totapuri exhibited significantly the lowest (0.67 leaf damage index) gall midge incidence. Rajapuri (0.99) and Vanraj (1.11) were at par with each other. Langra (1.40) and Mallika (1.49) recorded more or less equal gall midge incidence and were at par with each other followed by Kesar (1.90). The highest (2.60 leaf damage index) incidence was observed in Alphonso. Dasheri stood next to Alphonso in terms of higher infestation of *P. matteiana* with 2.19 leaf damage index.

The pooled over years (September-October, 2014 & 2015) results on mean gall midge incidence (0-5 leaf damage index) of *P. matteiana* (Table 2) revealed that significantly the lowest (0.60 leaf index) incidence of *P. matteiana* was registered in mango variety Totapuri. Rajapuri (0.89) and Vanraj (1.04) also recorded lower incidence and were at par with each other. Kesar (1.78) and Sonpari (1.78) did not show any significant difference between them as they were at par with each other. The higher incidence of *P. matteiana* was recorded in Dasheri (2.09). However, significantly the highest incidence of *P. matteiana* (2.42) was observed in Alphonso.

Table 2: Incidence of gall midge, *P. matteiana* on different mango varieties during September-October, 2014 & 2015

Varieties		Gall midge incidence (0-5 leaf damage index)		
		2014	**2015**	**Pooled**
Langra		1.36^{cd} (1.35)	1.38^{c} (1.40)	1.37^{c} (1.38)
Kesar		1.47^{de} (1.66)	1.55^{de} (1.90)	1.51^{d} (1.78)
Rajapuri		1.15^{b} (0.82)	1.22^{b} (0.99)	1.18^{b} (0.89)
Alphonso		1.67^{f} (2.29)	1.76^{f} (2.60)	1.71^{f} (2.42)
Amrapali		1.43^{cd} (1.54)	1.51^{cd} (1.78)	1.47^{d} (1.66)
Mallika		1.33^{c} (1.27)	1.41^{c} (1.49)	1.37^{c} (1.38)
Totapuri		1.02^{a} (0.54)	1.08^{a} (0.67)	1.05^{a} (0.60)
Dasheri		1.58^{ef} (2.00)	1.64^{ef} (2.19)	1.61^{e} (2.09)
Sonpari		1.55^{ef} (1.90)	1.48^{ef} (1.69)	1.51^{d} (1.78)
Vanraj		1.22^{b} (0.99)	1.27^{b} (1.11)	1.24^{b} (1.04)
S. Em. ±	Treatment (T)	0.04	0.04	0.03
	Period (P)	0.03	0.03	0.02
	Year (Y)	-	-	0.01
	T × P	0.10	0.10	0.07
	T × Y	-	-	0.04
	P × Y	-	-	0.03
	T × P × Y	-	-	0.10
C. V.%		12.79	12.65	12.72
Note:				
1. Figures in parentheses are retransformed values; those outside are $\sqrt{X+0.5}$ transformed values.				
2. Figures in letter(s) in common are statistically at par as per DNMRT.				

Jhala *et al*. (1987) [6] reported the damage caused by gall midge in Alphonso, Kesar and Rajapuri as 47.70, 27.21 and 25.80 galls/leaf with an average of 20.12, 17.64 and 12.46 galls/leaf, respectively. Patel *et al*. (2011) [10] screened fifteen mango cultivars against mango leaf gall midge and found the lowest (9.91%) leaf damage in Totapuri while, it was the highest (52.11%) in Alphonso. Jadhav *et al*. (2013$_a$) [4] reported that the gall midge infestation was recorded maximum (46.75%) in Kesar variety while, it was minimum (18.43%) in Totapuri. Muhammad *et al*. (2013) [9] recorded the highest numbers of galls on Sufaid Chaunsa (2.91 ± 0.2/leaf) followed by Dasehri (2.8 ± 0.2/leaf), Ratol (2.3 ± 0.2/leaf) and Kala Chaunsa (1.74 ± 0.2/leaf). Sideeg (2015) screened twelve mango cultivars against *P. matteiana* and found that that Alphonso and Tommy Atkins cultivars showed the highest mean of infested branches (%), infested leaves (%) and number of galls/leaf. The findings of the present investigations are more or less corroborative with the earlier reports.

Categorization of mango cultivars for their resistance/susceptibility: The different mango varieties were grouped into four categories of resistance/susceptibility *viz*., resistant (R), less susceptible (LS), moderately susceptible (MS) and highly susceptible (HS) based on incidence of *P. matteiana* by comparing the mean incidence of individual cultivar ($\overline{X}_i$) with mean incidence of all cultivars ($\overline{X}$) and standard deviation (SD).

The categorization of different mango cultivars for March-April, 2014 & 2015 is summarized in Table 3. The results revealed that none of the cultivar under study was found under the category of highly susceptible (HS) (Table 3). Totapuri, Rajapuri, Vanraj, Langra and Amrapali were registered in resistant (R) category as the incidence of *P. matteiana* ranged between 0.60 and 1.54 leaf damage index. Mallika, Kesar and Sonpari recorded incidence ranged from 1.60 to 1.96 leaf damage index and as such they were categorized as less susceptible (LS). Dasheri and Alphonso exhibited the incidence in the range of 2.29 to 2.53 damage index and were grouped as moderately susceptible (MS) varieties.

Table 3: Categorization of different mango cultivars for their resistance/susceptibility to gall midge, *P. matteiana* based on incidence (March-April, 2014 & 2015)

Category of resistance	Scale	Cultivars
Gall midge incidence (0-5 leaf damage index)	$\overline{X} = 1.58$	SD = 0.61
Resistant (R)	$\overline{X_i} \leq 1.58$	Totapuri (0.60), Rajapuri (0.92), Vanraj (1.09), Langra (1.32), Amrapali (1.54)
Less susceptible (LS)	$\overline{X_i} > 1.58 \leq 2.19$	Mallika (1.60), Kesar (1.90), Sonpari (1.96)
Moderately susceptible (MS)	$\overline{X_i} > 2.19 \leq 2.80$	Dasheri (2.29), Alphonso (2.53)
Highly susceptible (HS)	$\overline{X_i} > 2.80$	-

The categorization of different mango cultivars for September-October, 2014 & 2015 is summarized in Table 4. Considering the incidence of *P. matteiana* (0-5 leaf damage index), none of the cultivar found under highly susceptible (HS) group (Table 4). Totapuri, Rajapuri, Vanraj, Langra and Mallika recorded the incidence in the range of 0.60 and 1.38 leaf damage index and were emerged out as resistant cultivars. Amrapali, Kesar and Sonpari recorded greater than 1.50 and less than 2.06 damage index and proved to be less susceptible (LS) to *P. matteiana*. In the category of moderately susceptible, cultivars Dasheri and Alphonso recorded greater than 2.06 but less than 2.62 damage index.

Table 4: Categorization of different mango cultivars for their susceptibility to gall midge, *P. matteiana* based on incidence (September-October, 2014 & 2015)

Category of resistance	Scale	Cultivars
Gall midge incidence (0-5 leaf damage index)	$\overline{X} = 1.50$	SD = 0.56
Resistant (R)	$\overline{X_i} \leq 1.50$	Totapuri (0.60), Rajapuri (0.89) Vanraj (1.04), Langra (1.38), Mallika (1.38)
Less susceptible (LS)	$\overline{X_i} > 1.50 \leq 2.06$	Amrapali (1.66), Kesar (1.78), Sonpari (1.78)
Moderately susceptible (MS)	$\overline{X_i} > 2.06 \leq 2.62$	Dasheri (2.09), Alphonso (2.42)
Highly susceptible (HS)	$\overline{X_i} > 2.62$	-

Kumar *et al.* (2002) [8] tested twenty mango hybrids for multiple resistance to major insect pests and found that Amrapali, Arkapunit, HY-165, Mallika, Mehmood, Bahar, Neleshan, Neelgoa, Neeluddin, Prabhashankar, Sangareddy, Sonpari and Suvarnjahangir were highly susceptible to mango leaf gall midge. Patel *et al.* (2011) [10] categorized Totapuri and Alphonso cultivars as least and most susceptible cultivars, respectively. The findings of the present investigations are more or less in close conformity with the earlier reports.

Mechanism of resistance

The mango cultivars were further studied to know the role of morphological characters imparting resistance/susceptibility to *P. matteiana* during March-April, 2014. The data on mean values of morphological characters *viz*., thickness (mm), length (cm), width (cm) and area (cm^2) of compound leaf recorded from the different mango varieties are presented in Table 5. Further, the infestation of *P. matteiana* was also correlated with different morphological characters and the correlation co-efficient (r) was worked out (Table 5).

It was evident from the results that the thickness, length as well as width of compound leaf and leaf area were ranged from 0.15 to 0.27 mm, 17.10 to 20.80 cm, 5.10 to 6.30 cm and 94.0 to 130.30 cm^2, respectively (Table 5). More or less similar results have been reported by Rathod (2011) [12].

All the morphological parameters *viz*., thickness, length, width and area of compound leaf exhibited non-significant association with the *P. matteiana* (r = 0.041, 0.045, -0.105 and -0.046, respectively) [Table 5]. However, it has positive association with leaf thickness and length whereas negative association with leaf width and area. Hence, it is clearly seen that the incidence of mango gall midge was not directly and indirectly influenced by any of the morphological characters under study. The information on the relationship between incidence of mango gall midge and morphological characters of mango tree under study is meager in the past literatures and hence, present findings could not be compared and discussed.

Table 5: Morphological characters of mango cultivars and its correlation with gall midge, *P. matteiana*

Cultivars	Morphological characters of mango varieties				Gall midge incidence (0-5 leaf damage index) [March-April, 2014]
	Leaf thickness (mm)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	
Langra	0.18^{ab}	19.10^{abc}	5.80^{a}	122.70^{ef}	1.34^{cd} (1.30)
Kesar	0.20^{b}	21.70^{c}	6.10^{a}	125.70^{f}	1.56^{fg} (1.93)
Rajapuri	0.18^{ab}	18.10^{ab}	6.30^{a}	130.30^{f}	1.23^{b} (1.01)
Alphonso	0.20^{b}	20.10^{bc}	5.40^{a}	106.10^{bc}	1.71^{h} (2.42)
Amrapali	0.27^{c}	20.80^{c}	5.10^{a}	110.70^{cd}	1.49^{ef} (1.72)
Mallika	0.16^{ab}	18.10^{ab}	5.40^{a}	108.10^{bcd}	1.42^{de} (1.52)
Totapuri	0.15^{a}	17.10^{a}	5.10^{a}	115.10^{de}	1.08^{a} (0.67)
Dasheri	0.18^{ab}	18.10^{ab}	5.70^{a}	94.00^{a}	1.65^{gh} (2.22)

Sonpari	0.20[b]	18.50[ab]	5.30[a]	101.70[ab]	1.51[f] (1.78)
Vanraj	0.16[ab]	17.50[ab]	5.00[a]	102.50[b]	1.29[bc] (1.16)
S.Em.±	0.02	0.97	0.57	2.64	0.03
C. V. %	13.95	8.86	17.84	4.09	10.63
Correlation Coefficient (r)					
Gall midge incidence	0.041	0.045	-0.105	-0.046	-
Note: Letter(s) in common are statistically at par as per DNMRT.					

Conclusion

Based on the above findings, mango varieties *viz*., Totapuri, Rajapuri, Vanraj, Langra as well as Amrapali were categorized as resistant (R) against mango gall midge, *P. matteiana*. Dasheri as well as Alphonso were categorized as moderately susceptible (MS) varieties during March-April, 2014 & 2015. Mango varieties *viz*., Totapuri, Rajapuri, Vanraj, Langra as well as Mallika categorized as resistant cultivars and Dasheri and Alphanso categorized as moderately susceptible during September-October, 2014 & 2015. There was no any significant role of various morphological characters, *viz*., thickness, length, width and area of compound leaf on the activity of *P. matteiana*. Approaches like host plant resistance are not only easily disseminated and readily adopted by farmers due to their visible benefits but also requires fewer applications of insecticides than susceptible varieties. Hence, these varieties can be further used in breeding programmes for its advance researches on mango gall midge.

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