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Susceptibility of Rose Varieties Against Pests in Relation to Plant Morphological Characters Under Open Field Condition

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Abstract: Rose is attacked by thrips, *Frankliniella schultzei* (Pergande), *Scirtothrips dorsalis* Hood; aphid, *Macrosiphum rosae* (Linnaeus); whitefly, *Trialeurodes vaporariorum* (Westwood); mealybug, *Planococcus citri* (Risso); foliage feeders and bud borers, *Helicoverpa armigera* (Hubner); *Spodoptera litura* (Fabricius) and mite, *Tetranychus urticae* Koch. As great deal of variation of pest attack to rose varieties exists, role of plant morphological characters in inducing plant resistance need investigation. Rose varieties Barbone rose, cabbage rose, Chinese rose and Gladiator were screened against major pests at Navsari Agricultural University (NAU), Navsari, Gujarat, India. Relationship of each character to pest incidence was established on the basis of correlation. Gladiator was considered as tolerant variety against thrips, blister beetle, castor semilooper, tussock moth and bud borer. Chinese rose was tolerant against aphid while, it was moderately susceptible against thrips (*R. syriacus*) and blister beetle. Barbone rose was moderately susceptible against castor semilooper and tussock moth. Overall, Gladiator was considered tolerant against majority of pests (except aphid). Plant growth habit exhibited significant positive correlation with aphid. Plant height had significant positive correlation with all the pests except aphid. Higher number of primary branches showed increased susceptibility to thrips, blister beetle, semilooper and tussock moth while, aphid was indirectly related to primary branches. Increased prickle density indicated increased thrips on leaves, larval populations of semilooper and tussock moth. Leaf colour exhibited negative relationship with semilooper, tussock moth and bud. Leaf area also influenced abundance of bud borer significantly. Increased leaf thickness showed decreased defoliator pests. Increased leaf glossiness showed decreased plant susceptibility to thrips, semilooper and tussock moth. Flower colour had negative relationship with semilooper, tussock moth and bud borer. Increased flower compactness indicated increased aphids and decreased thrips and blister beetle. Number of flower petals exhibited significant positive relationship with aphid and negative relationship with thrips and blister beetle. Lastly, number of flowers exhibited significant positive relationship with thrips, blister beetle, semilooper, tussock moth and bud borer while, it exhibited indirect relationship with aphid. Overall, most important biophysical traits of rose varieties grown under open field condition were plant height, number of primary branches, flower (compactness, number of petals and number of flowers/plant) which directly or indirectly influenced plant tolerance or susceptibility against major pests.

Keywords: Rose, Biophysical Traits, Rose Varieties

1. Introduction

Major flowers of commercial importance in India are rose, gladiolus, tuberose, carnation, chrysanthemum, gerbera, lily and marigold. Amongst them, Rose is universally acclaimed as “Queen of Flowers” and is one of the most important ornamental flower species used in landscape and cut flowers the world over. In Gujarat, the commercial cultivation of rose

is confined to Ahmedabad, Anand, Vadodara, Surat, Navsari and Valsad districts [10]. In South Gujarat during 2018-20, total area under rose cultivation was about 1161 hectares with production of 10814 MT [1]. Rose is attacked by several pests causing considerable damage to the crop. The most commonly associated pests with rose are thrips, *Frankliniella schultzei* (Pergande); aphid, *Macrosiphum rosae* (Linnaeus); whitefly, *Trialeurodes vaporariorum* (Westwood); mealybug, *Planococcus citri* (Risso); foliage feeders and bud borers, *Helicoverpa armigera* (Hubner); *Spodoptera litura* (Fabricius) and mite, *Tetranychus urticae* Koch [2, 19].

The commercial cultivation of rose under open field and protected structure is gaining importance. In this regard, it is also important to know the biodiversity of pests under both the conditions. There exists a great deal of variation or reaction of pests to various varieties of rose grown under open field conditions in particular. It could be also due to variations in plant growth, vegetative and floral characters which need thorough investigation. So, it is imperative to evaluate the rose varieties and their reaction to the pests on the basis of morphological characters particularly under open field condition. In this regard, no comprehensive studies has been carried out under South Gujarat conditions in the past. So, the present experiment was designed and proposed to investigate the resistant/susceptible source so that it could be utilized in the crop management:

2. Method

2.1. Experimental Details

Location	Navsari Agricultural University (NAU), Navsari, Gujarat, India
Design	RBD
Repetition/Replication	5
Varieties	Barbone rose, Cabbage rose, Chinese rose, Gladiator
Period of experiments	16-14 SMW: 2018-19, 16-14 SMW: 2019-20

2.2. Observations

Five plants of each variety were selected and observations were taken during two years period (2018-2020).

2.3. Method of Recording Observation

Thrips: Thrips population per flower on randomly selected plants by tapping flowers on black paper [3].

Aphid: Nymph and adult aphids on three tender shoots of 10 cm length on each selected plant [7]. Thus, pest population for one shoot per plant was computed.

Foliage feeders and bud borers: Absolute population of larvae on selected plants at standard week wise interval [16]. The pest population per plant was computed.

2.4. Categorization

For this purpose, mean value of individual variety ($\overline{X_i}$) was compared with mean value of all varieties ($\overline{X}$) and standard deviation (SD) [17].

Category of Resistance	Scale for Resistance
Tolerant	$X_i < \overline{X}$
Less Susceptible (LS)	$X_i > \overline{X} < (\overline{X} + 1\ SD)$
Moderately Susceptible (MS)	$X_i > (\overline{X} + 1\ SD) < (\overline{X} + 2SD)$
Highly Susceptible (HS)	$X_i > (\overline{X} + 2SD)$

2.5. Role of Major Morphological Characters on Susceptibility of Rose Varieties to Pests

Vegetative attributes

Plant growth habit (upright-1, semi upright-3, intermediate-5, moderately spreading-7 and strongly spreading-9), plant height (ground level to top of the plant using measuring tape in cm at second flush of flowering), number of primary branches (per plant during entire duration of the experiment) and prickle density (prickles/5 cm shoots).

Leaf characters

Leaf colour (light-3, medium-5 and dark colour-7), leaf area (using digital leaf area meter in cm^2), leaf thickness (selected leaves plucked from the plant, kept in a paper bag, brought to the laboratory and measured using digital Vernier calliper in millimeter) and leaf glossiness on dorsal surface (absence-0 or presence-1).

Floral attributes

Flower colour (white- 1, creamy pink- 2, yellow- 3, whitish pink- 4, pink- 5, dark pink- 6, red- 7 and dark red- 8) and flower compactness [14].

$$\text{Flower compactness (g/ml)} = \frac{\text{Weight of flower}}{\text{Water displacement}}$$

Flower shape (round-1, irregularly round-2 and star shaped -3), flower diameter (average from N-S and E-W directions in cm), number of petals per flower and number of flowers per plant.

2.6. Statistical Analysis

The morphological traits of test varieties of rose were statistically analyzed using ANOVA. Correlation of morphological parameters with pest population was assessed in different varieties.

3. Results and Discussion

3.1. Screening of Rose Varieties Against Major Pests Thrips, S. dorsalis

None of the rose variety remained free from the attack of thrips on leaves wherein the varieties Gladiator (0.88 thrips/leaf) and Cabbage rose (1.00 thrips/leaf) were categorized as tolerant. Likewise, with respect to thrips incidence on flowers, Gladiator (1.43 thrips/flower) and Cabbage rose (2.22 thrips/flower) were categorized as tolerant entries (Table 1).

Local red remained most susceptible to *S. dorsalis* which

attained peak during 16th SMW [4]. The Local white and Local yellow cultivars were highly resistant to thrips wherein the incidence occurred during March - May indicating peak incidence of 6.14 and 4.29 thrips per flower, respectively. Kanara and Acharya (2014) [9] categorized Lemon sarbat as resistant variety and Eiffel tower, Summer Holiday and Devine as susceptible. Similarly, Arjun, Shanti and Taj Mahal showed moderate resistance and Australian Gold, Raktima and Glory, the low resistance to thrips. The cultivars with moderate susceptibility to thrips were Dr. B. P. Pal, Naveen, Black beauty and Jaya while, low susceptible cultivars were Rose Local, Sonika, First Red, Pusa Mohit, Angelica, Girija, Sugandha, Pusa Muskan, Super Star and Golden showers [21].

Earlier findings revealed slightly different results than that of the current investigation as the earlier workers used different set of varieties but proved variability of rose varieties towards thrips. In the current investigation, Gladiator and Cabbage rose were categorized as tolerant entries.

Thrips, R. syriacus

Gladiator (0.01 thrips/leaf) and Cabbage rose (0.11) were categorized as tolerant varieties while, Barbone rose (0.52) and Chinese rose (0.66) as less and moderately susceptible entries (Table 1).

Aphid

Chinese rose (0.33 aphid/bud) and Barbone rose (1.81) were considered as tolerant while, Gladiator (4.33) and Cabbage rose (4.98) as less susceptible (Table 1). Majhi (2007) [11] reported Jyoti and Edweard rose least susceptible to aphid as they harboured considerably lower aphids (1.41 and 3.18 aphids/flower/plant). Munib *et al*. (2015) [12] revealed that Grand Gala and Nobless varieties harboured highest aphid *M. rosae* (1.33 and 1.10) and were considered highly susceptible cultivars, while cv. Golden Gate and Naranga indicated moderate aphid infestation (0.99 and 0.88) and Konifittii, the minimum infestation (0.55) indicating moderate susceptibility. Norboo *et al*. (2017c) [15] revealed that Superstar was found highly resistant to aphids and Shanti was found moderately resistant against aphid. As earlier workers screened different set of varieties in their respective trials yet degree of variability of aphid occurrence was also evident in the varieties screened under the current investigation.

Table 1. *Susceptibility of rose varieties against important sucking pests under open field condition.*

Pests / Varieties	*S. dorsalis*				*R. syriacus*		Aphid /bud	Category
	Thrips/leaf	Category	Thrips/flower	Category	Thrips/leaf	Category		
Barbone rose	1.30 (1.19)	LS	1.84 (2.89)	LS	0.98 (0.52)	LS	1.52 (1.81)	T
Cabbage rose	1.22 (1.00)	T	1.65 (2.22)	T	0.78 (0.11)	T	2.34 (4.98)	LS
Chinese rose	1.29 (1.17)	LS	1.90 (3.09)	LS	1.08 (0.66)	MS	0.91 (0.33)	T
Gladiator	1.17 (0.88)	T	1.39 (1.43)	T	0.71 (0.01)	T	2.20 (4.33)	LS
Mean	1.06		2.41		0.33		2.86	
SD	0.15		0.755		0.31		2.17	

Blister beetle, M. pustulata

Gladiator (0 beetle/flower) and Cabbage rose (0.12) were considered as tolerant varieties while, Barbone rose (0.34) and Chinese rose (0.40) as less and moderately susceptible entries, respectively (Table 2). Close scrutiny of literature revealed no evidence of published work on this aspect and hence the present findings could not be compared.

Castor semilooper, A. janata

Gladiator (0.02 larva/plant) and Chinese rose (0.09) were considered as tolerant varieties (Table 2). Since no published information on this aspect is available hence, the present findings could not be compared with others.

Tussock moth, Orgyia sp.

Gladiator (0.01 larva/plant) and Chinese rose (0.08) were grouped as tolerant varieties (Table 2). The perusal of the literature revealed no published information on tussock moth.

Table 2. *Susceptibility of rose varieties against important defoliator pests under open field condition.*

Pests / Varieties	Blister beetles/flower	Category	Semilooper		Tussock moth		Bud borer	
			Larva/plant	Category	Larva/plant	Category	Larva/plant	Category
Barbone rose	0.92 (0.34)	LS	0.82 (0.19)	MS	0.80 (0.14)	MS	0.83 (0.20)	T
Cabbage rose	0.79 (0.12)	T	0.80 (0.14)	LS	0.78 (0.11)	LS	0.89 (0.29)	LS
Chinese rose	0.95 (0.40)	MS	0.76 (0.09)	T	0.76 (0.08)	T	0.88 (0.28)	LS
Gladiator	0.71 (0.00)	T	0.72 (0.02)	T	0.71 (0.01)	T	0.77 (0.10)	T
Mean	0.22		0.11		0.09		0.22	
SD	0.19		0.07		0.06		0.09	

Bud borer, H. armigera

Gladiator rose and Barbone rose were found tolerant against bud borer indicating 0.10 and 0.20 larva/plant, respectively. On the other hand, Chinese rose (0.28) and Cabbage rose (0.29) were found less susceptible. Patel *et al.* (2012) [18] reported that White moster piece and Montreal had minimum number of larvae (0.82 and 0.90 larva/plant) while, Gladiator and Sophiya coren had higher number of larvae (1.81 and 1.43 larvae/plant).

Overall, it can be concluded that rose varieties grown under open field condition indicated tolerant reaction in Gladiator and Cabbage rose against thrips. Chinese rose and Barbone rose were found tolerant against aphid. Gladiator and Cabbage rose were categorized as tolerant varieties

against blister beetle. Gladiator and Chinese rose were categorized as tolerant varieties against castor semilooper and tussock moth Lastly, Gladiator and Barbone rose were categorized as tolerant against bud borer (*H. armigera*). Overall, Rose variety Gladiator grown was found tolerant against all the pests (except aphid) considered in this investigation.

3.2. Abundance of Major Pests in Relation to Morphological Characters of Rose Varieties

3.2.1. Plant Growth Habit

Thrips, S. dorsalis

Thrips tolerant varieties Gladiator and Cabbage rose possessed intermediate to upright growth habits. Correlation between Thrips, S. dorsalis population on leaves and flowers v/s plant growth habit was non-significant but negative (r=-0.268) and (r=-0.304) (Table 3).

Thrips, R. syriacus

Thrips, R. syriacus tolerant varieties were Gladiator and Cabbage rose which possessed intermediate to upright growth habits Correlation between thrips, R. syriacus population and growth habit was negative and non-significant (r=-0.441) (Table 3).

Aphid

Tolerant Chinese rose and Barbone rose varieties recorded aphid population of 0.33 and 1.81/bud, respectively which in turn possessed upright growth habit. Pest abundance in relation to plant growth was highly significant and positive (r=0.620) (Table 3).

Blister beetle, M. pustulata

Blister beetle tolerant Gladiator (0.0 beetle/flower) and Cabbage rose (0.12 beetle/flower) possessed intermediate and upright plant growth habits. Correlation between blister beetle population and growth habit was non-significant but negative (r=-0.301) (Table 3).

Castor semilooper, A. janata

Tolerant Gladiator and Chinese rose possessed upright growth habit which in turn recorded lower population of semilooper larva (0.02 and 0.09 larva/plant). Correlation between castor semilooper and plant habit was non-significant and positive (r=0.245) (Table 3).

Tussock moth, Orgyia sp.

Tolerant Gladiator and Chinese rose possessed upright growth habit which in turn recorded lower population of tussock moth larva (0.01 and 0.08 larva/plant), respectively. Correlation between tussock moth larva and plant habit was non-significant and positive (r=0.300) (Table 3).

Bud borer, H. armigera

Gladiator rose and Barbone rose recorded larval population of 0.10 and 0.20 larva per plant which in turn possessed upright growth habit. Relationship of bud borer to plant growth was non-significant and positive (r=0.442) (Table 3).

3.2.2. Plant Height

Thrips, S. dorsalis

Tolerant varieties Gladiator and Cabbage rose had plant heights of 63.14 and 73.92 cm, respectively which in turn recorded thrips, *S. dorsalis* populations to the tune of 0.88 and 1.00 thrips/leaf, respectively. Correlation between thrips population on leaves and plant height was highly significant and positive (r=0.851). Similar trend was observed in case of thrips population on rose flowers wherein correlation was highly significant and positive (r=0.788) (Table 3).

Thrips, R. syriacus

Tolerant rose variety Gladiator variety recorded 0.01 thrips (R. syriacus) per leaf which in turn had 63.14 cm height whereas, another tolerant variety Cabbage rose had slightly higher plant height (73.92 cm) which in turn recorded thrips, R. syriacus population of 0.11 per leaf. Correlation between thrips population and plant height was significant and positive (r=0.778) (Table 3).

Aphid

Tolerant varieties to aphid were Chinese rose and Barbone rose which in turn possessed higher plant heights (92.60 and 120.62 cm) while, less susceptible Gladiator and Cabbage rose had comparatively lower plant heights (63.14 and 73.92 cm) which in turn indicated comparatively higher aphid (4.33 and 4.98 /bud). So, plant height had significant negative relationship (r=-0.655) with aphid incidence (Table 3).

Blister beetle, M. pustulata

Population of blister beetle was not observed in Gladiator which had comparatively lower plant height (63.14 cm) and was categorized as tolerant entry. Another tolerant variety Cabbage rose possessed 73.92 cm plant height had blister population of 0.12 beetles per flower. Relationship between plant height and pest population was positive (r=0.734) and highly significant (Table 3).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had plant height of 63.14 and 92.60 cm, respectively whereas, Barbone rose which had the highest plant height (120.62 cm) and highest semilooper population (0.19 larva/plant). Correlation between semilooper and plant height was positive and highly significant (r=0.588) (Table 3).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator recorded very low larval population of tussock moth (0.01 larva/plant) which in turn had comparatively lower plant height (63.14 cm) while another tolerant variety Chinese rose (0.08 larva/plant) possessed 92.60 cm plant height. The tussock moth population had highly significant and positive correlation with plant height (r=0.652) (Table 3).

Bud borer, H. armigera

The tolerant varieties Gladiator and Barbone rose recorded 63.14 and 120.62 cm plant height, respectively which in turn recorded 0.10 and 0.20 larva/plant, respectively. The bud borer exhibited positive and non-significant correlation with plant height (r=0.252) (Table 3).

3.2.3. Number of Primary Branches

Thrips, S. dorsalis

Number of primary branches was lowest (2.98) in tolerant

Gladiator rose which in turn had lowest thrips (0.88/leaf) thrips population. The correlation between thrips population on rose leaf and number of primary branches was highly significant and positive (r=0.798). Similar trend was observed in thrips population on rose flowers. Correlation between thrips population and primary branches was highly significant and positive (r=0.690) (Table 3).

Thrips, R. syriacus

The Gladiator variety had very low population of thrips (R. syriacus) (0.01 thrips/leaf) which in turn had the lowest primary branches (2.98/plant) and categorized as tolerant. Another tolerant variety Cabbage rose had comparatively lower primary branches (3.26) which in turn had comparatively lower thrips, R. syriacus populations (0.11/leaf). Correlation between thrips population on leaf and primary branches was positive and highly significant (r=0.718) (Table 3).

Aphid

Chinese rose (0.33 aphids/plant) and Barbone rose (1.81) remained tolerant to aphid which possessed 3.56 and 4.06 primary branches, respectively. The aphid population exhibited significant and negative correlation with primary branches (r=-0.555) (Table 3).

Blister beetle, M. pustulata

The Gladiator variety did not host any blister beetle had comparatively fewer primary branches (2.98). The blister beetle population exhibited significant and positive (r=0.674) correlation with primary branches (Table 3).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had 2.98 and 3.56 primary branches which in turn harbored lower population of castor semilooper (0.02 and 0.09 larva/plant). Correlation between larval population of semilooper and number of primary branches was positive (r=0.677) and highly significant (Table 3).

Tussock moth, Orgyia sp.

Tolerant variety Gladiator had low population (0.01 larva/plant) of tussock moth which in turn had lowest number of primary branches (2.98) along with another tolerant Chinese rose (0.08 larva/plant) which possessed 3.56 primary branches. The tussock moth population had positive and highly significant correlation with primary branches (r=0.622). (Table 3).

Bud borer, H. armigera

Tolerant varieties Gladiator and Barbone rose recorded 2.98 and 4.06 primary branches, respectively which turn in had larval population of 0.10 and 0.20 per plant, respectively. The bud borer infestation had positive but non-significant correlation with primary branches (r=0.325) (Table 3).

3.2.4. Prickle Density

Thrips, S. dorsalis

Tolerant varieties Gladiator and Cabbage rose had prickle density of 3.94 and 4.52, respectively which in turn recorded 0.88 and 1.00 thrips (S. dorsalis) per leaf, respectively Correlation between thrips population and prickle density was positive (r=0.531) and significant. Correlation between thrips population on rose flowers and prickle density was positive (r=0.380) but non-significant (Table 3).

Thrips, R. syriacus

The Gladiator variety of rose recorded low population of thrips (R. syriacus) (0.01 thrips/leaf) which had the lowest prickles (3.94/5 cm shoot) and was categorized as tolerant followed by another tolerant Cabbage rose which had prickle density of 4.52 which in turn hosted thrips population of 0.11 per leaf. Correlation between thrips population and prickle density was non-significant and positive (r=0.324) (Table 3).

Aphid

Tolerant varieties Chinese rose (0.33 aphids/plant) and Barbone rose (1.81) possessed 4.06 and 5.90 prickles. The aphid population exhibited negative and non-significant correlation with prickle density (r=-0.203) (Table 3).

Blister beetle, M. pustulata

The tolerant variety Gladiator did not record any blister beetle population (0.00) had comparatively lower prickle density (3.94) and another tolerant Cabbage rose possessed 4.52 prickles which in turn had blister beetle population of 0.12 beetle per plant. The blister beetle population had positive but non-significant correlation with prickle density (r=0.422) (Table 3).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had 3.94 and 4.06 prickles. Correlation between larval population of semilooper and prickle density was highly significant and positive (r=0.674) (Table 3).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator had the lowest population of tussock moth (0.01 larva/plant) which in turn had comparatively lower prickle density (3.94) along with another tolerant Chinese rose (0.08 larva/plant) which possessed 4.06 prickles. The tussock moth larval population exhibited positive and highly significant correlation with prickle density (r=0.647) (Table 3).

Bud borer, H. armigera

The tolerant varieties Gladiator and Barbone rose recorded 3.94 and 5.90 prickles, respectively which in turn harboured 0.10 and 0.20 larva/plant, respectively. The bud borer larval population had positive and non-significant correlation with prickle density (r=0.131) (Table 3).

Table 3. *Abundance of major insect-pests in relation to plant growth habit, height, number of primary branches and prickle density of rose varieties.*

Varieties	*S. dorsalis*		*R. syriacus*	Aphids/bud	Blister beetles/flower
	Thrips/leaf	Thrips/flower	Thrips/leaf		
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.268	-0.304	-0.441	0.620**	-0.301

Varieties	*S. dorsalis*		*R. syriacus*	Aphids/bud	Blister beetles/flower
	Thrips/leaf	Thrips/flower	Thrips/leaf		
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	0.851**	0.788**	0.778**	-0.655**	0.734**
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	0.798**	0.690**	0.718**	-0.555*	0.674**
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	0.531*	0.380	0.324	-0.203	0.422

Table 3. *Continued.*

Varieties	Semilooper larva/plant	Tussock moth larva/plant	Bud borer larva/plant	Plant growth habit (scale)
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	1 (upright)
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	5 (Intermediate)
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	1 (upright)
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	1 (upright)
Correlation 'r'	0.245	0.300	0.442	
Plant height (cm)				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	120.62
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	73.92
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	92.60
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	63.14
Correlation 'r'	0.588**	0.652**	0.252	
No of primary branches				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	4.06
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	3.26
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	3.56
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	2.98
Correlation 'r'	0.677**	0.622**	0.325	
Prickle density/ 5 cm shoot				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	5.90
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	4.52
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	4.06
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	3.94
Correlation 'r'	0.674**	0.647**	0.131	

3.2.5. Leaf Colour

Thrips, S. dorsalis

The tolerant variety Gladiator possessed dark green leaves which in turn had the lowest thrips population (0.88/leaf). Correlation between thrips population and leaf colour was non-significant and negative (r=-0.323) (Table 4). Similar trend was observed in thrips population on rose flowers. Correlation between thrips population on flowers and leaf colour was non-significant and negative (r=-0.286). (Table 4). Previous finding revealed that correlation between leaf colour and thrip population in rose was found positive and significant. With increase in intensity of green colour of rose leaves, thrips population also increased [8]; however in the present findings decrease in leaf colour intensity led to higher plant susceptibility has been observed. This variation might be due to selection of different set of varieties at different locations.

Thrips, R. syriacus

Tolerant Gladiator which recorded very low population of thrips (R. syriacus) (0.01 thrips/leaf) had dark green coloured leaves. Another tolerant variety, Cabbage rose possessed light green colour which in turn recorded thrips, R. syriacus population of 0.11 thrips per leaf Correlation between thrips population and leaf colour was negative (r=-0.140) and non-significant (Table 4).

Aphid

The varieties which were tolerant to aphid were Chinese rose and Barbone rose which in turn possessed green coloured leaves. The aphid population had negative and non-significant correlation with leaf colour (r=-0.099) (Table 4).

Blister beetle, M. pustulata

Tolerant variety Gladiator which did not record any blister beetle population (0.00) possessed dark green leaves followed by another tolerant variety cabbage rose (0.12 beetle/flower) possessing light green leaves. The blister beetle population exhibited non-significant and negative correlation with leaf colour (r=-0.225) (Table 4).

Castor semilooper, A. janata

Tolerant varieties Gladiator and Chinese rose had dark green and green leaves, respectively. Correlation between larval population of semilooper and leaf colour was highly significant and negative (r=-0.563) (Table 4).

Tussock moth, Orgyia sp.

The rose variety Gladiator observed as tolerant variety against tussock moth recorded very low population of tussock moth larva (0.01 larva/plant) which in turn possessed dark green leaves and another tolerant Chinese rose (0.08 larva/plant) possessed green coloured leaves. The tussock moth larval population exhibited significant and negative correlation with leaf colour (r=-0.645) (Table 4).

Bud borer, H. armigera

The tolerant varieties viz., Gladiator and Barbone rose possessed dark green and green leaves, respectively which in turn recorded 0.10 and 0.20 larva/plant, respectively. The bud borer larval population had significant and negative correlation with leaf colour (r=-0.707) (Table 4).

3.2.6. Leaf Area

Thrips, S. dorsalis

Tolerant varieties Gladiator (0.88 thrips/leaf) and Cabbage rose (1.00) had leaf area of 7.18 and 9.40 cm^2, respectively. Correlation between thrips population and leaf area was negative (r=-0.091) and non-significant. Similar trend was observed in case of thrips population infesting flowers. Correlation between thrips population and leaf area was non-significant and negative (r=-0.119) (Table 4).

Thrips, R. syriacus

The tolerant variety which recorded very low population of thrips (0.01 thrips/leaf) was Gladiator having leaf area of 9.40 cm^2. Another tolerant variety Cabbage rose had leaf area of 7.18 cm^2 which in turn recorded thrips, R. syriacus population of 0.11 per leaf. Correlation between thrips population and leaf area was positive (r=0.015) and non-significant (Table 4).

Aphid

The varieties which were tolerant to aphid were Chinese rose and Barbone rose which in turn possessed 8.15 and 9.20 cm^2 leaf area. The aphid population had negative (r=-0.133) and non-significant correlation with leaf area (Table 4).

Blister beetle, M. pustulata

Gladiator being the tolerant variety did not record any blister beetle population (0.0 beetle/flower) and had comparatively higher leaf area (9.40 cm^2). The pest exhibited positive but non-significant correlation with leaf area (r=0.018) (Table 4).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had leaf area of 9.40 and 8.15 cm^2 leaf. Correlation between larval population of semilooper and leaf area was negative (r=-0.090) and non-significant (Table 4).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator variety recorded very low population of tussock moth larva (0.01 larva/plant) had comparatively higher leaf area (9.40 cm^2) than another tolerant variety Chinese rose (0.08 larva/plant) possessing slightly lesser leaf area of 8.15 cm^2. The tussock moth larval population had negative and non-significant and correlation with leaf area (r=-0.218) (Table 4).

Bud borer, H. armigera

Tolerant varieties viz; Gladiator and Barbone rose recorded leaf area of 9.20 and 9.40 cm^2, respectively had larval population of 0.10 and 0.20 per plant, respectively. The bud borer population had negative and significant correlation with leaf area (r=-0.495) (Table 4).

3.2.7. Leaf Thickness

Thrips, S. dorsalis

There was no significant difference between leaf thicknesses of different varieties of rose. Tolerant varieties viz., Gladiator (0.88 thrips/leaf) and Cabbage rose (1.00 thrips/leaf) possessed leaf thickness of 0.30 and 0.24 mm, respectively. Correlation between thrips population on leaf and flower and leaf thickness was negative (r=-0.424 and -0.324) (Table 4).

Thrips, R. syriacus

The tolerant variety Gladiator had the lowest population of thrips (R. syriacus) which in turn had highest leaf thickness (0.30 mm). Similarly, another tolerant variety Cabbage rose had leaf thickness of 0.24 mm which in turn recorded slightly higher thrips, R. syriacus (0.11/leaf) Correlation between thrips population and leaf thickness was negative (r=-0.256) but non-significant (Table 4). Nirmala (2015) revealed that among the biophysical traits, the leaf thickness, leaf area, flower colour exhibited a significant positive correlation with thrips incidence however, the results vary from the present investigation which might be due to different set of varieties used by the earlier worker.

Aphid

The varieties which were tolerant to aphid population were Chinese rose and Barbone rose had leaf thickness of 0.27 and 0.24 mm. The aphid population had negative and non-significant correlation with leaf thickness (r=-0.011) Table 4).

Blister beetle, M. pustulata

The tolerant variety Gladiator did not record any blister beetle population (0.00 beetle/flower) had the highest leaf thickness (0.30 mm) indicating negative but non-significant correlation (r=-0.270) (Table 4).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had leaf thickness of 0.30 and 0.27 mm indicating negative (r=-0.650) and highly significant correlation (Table 4).

Tussock moth, Orgyia sp.

Tolerant variety Gladiator recorded lowest larval population of tussock moth (0.01 larva/plant) exhibiting negative and significant correlation with leaf thickness (r=-0.728) (Table 4).

Bud borer, H. armigera

The tolerant varieties Gladiator and Barbone rose recorded leaf thickness of 0.30 and 0.24 mm, respectively which in turn recorded bud borer population of 0.10 and 0.20 larva/plant, respectively indicating negative (r=-0.533) and significant correlation (Table 4).

3.2.8. Leaf Glossiness on Dorsal Side

Thrips, S. dorsalis

Tolerant varieties Gladiator (0.88 thrips/leaf) and Cabbage rose (1.00 thrips/leaf) had leaf glossiness. Correlation between thrips population on leaf and leaf glossiness was negative (r=-0.563) and highly significant. Similarly, correlation between thrips population on flowers and leaf glossiness was negative (r=-0.423) and non-significant (Table 4).

Thrips, R. syriacus

The most tolerant variety Gladiator which had lowest thrips (R. syriacus) (0.01 thrips/leaf) had glossy leaves while, less susceptible variety Barbone rose had absence of leaf glossiness. Correlation between thrips population and leaf glossiness was negative (r=-0.413) and non-significant (Table 4).

Aphid

The varieties which were tolerant to aphid were Chinese rose and Barbone rose wherein the Barbone rose leaves had absence of leaf glossiness. The aphid population exhibited positive and non-significant correlation with leaf glossiness (r=0.318) (Table 4).

Blister beetle, M. pustulata

The tolerant variety Gladiator which did not record any population of blister beetle (0.0 beetle/flower) indicated leaf glossiness while, less susceptible Barbone rose leaves had no leaf glossiness indicating negative (r=-0.398) but non-significant correlation (Table 4).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose possessed leaf glossiness indicating negative (r=-0.585) and significant correlation (Table 4).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator had a very low population of tussock moth (0.01 larva/plant) had leaf glossiness while, moderately susceptible Barbone rose (0.14) had no leaf glossiness indicating negative and significant correlation (r=-0.547) (Table 4).

Bud borer, H. armigera

The tolerant variety Gladiator possessed leaf glossiness and Barbone rose recorded absence of leaf glossiness, respectively which had 0.10 and 0.20 larva/plant, respectively. The bud borer population had positive but non-significant correlation with leaf glossiness (r=0.088) (Table 4).

3.2.9. Flower Colour

Thrips, S. dorsalis

Tolerant rose variety Gladiator possessed dark red flowers indicating lower thrips (0.88 thrips/leaf) followed by another tolerant Cabbage rose (1.00) which in turn had whitish pink colour. Correlation between thrips population on leaves and flowers v/s flower colour was non-significant and negative (r=-0.306 and -0.193) (Table 4).

Thrips, R. syriacus

The tolerant variety Gladiator which possessed dark red coloured flowers had very low population (0.01 thrips/leaf) of thrips species R. syriacus exhibiting negative and non-significant correlation (r=-0.048) (Table 4). Murugan and Jagadish (2006) [13] reported that local white and local yellow rose cultivars were highly resistant to thrips. These results might differ from the present findings due to different set of rose varieties used at different locations. The Earlier findings also revealed that thrips prefer to feed on red or orange coloured petals of flowers (5, 20). Hegde (2010) [6] reported that red, pink and orange flowers attracted more thrips indicating mean thrips population of 26.66, 24.53 and 20.25 per flower, respectively. Varieties having light colored flowers, harboured less thrips. Mean thrips per flower was 4.41 in white and 8.82 in rose. In the present investigation, red coloured Chinese rose had higher population of thrips than pink coloured Barbone rose which is somewhat similar to the earlier findings and conform the ongoing discussion.

Aphid

The varieties which were tolerant to aphid were Chinese rose and Barbone rose which possessed red and pink coloured flowers, respectively indicating negative but non-significant correlation (r=-0.210) (Table 4).

Blister beetle, M. pustulata

The variety which did not record any blister beetle infestation was Gladiator possessing dark red flowers and said to be tolerant while another tolerant Cabbage rose (0.12 beetle/flower) possessed whitish pink flowers. The blister beetle infestation had negative but non-significant correlation with flower colour (r=-0.154) (Table 4).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had dark red and red colour flowers, respectively. Correlation between larval population of semilooper and flower colour was negative (r=-0.706) and highly significant (Table 4).

Tussock moth, Orgyia sp.

The tolerant Gladiator which harboured very low larval population of tussock moth (0.01 larva/plant) possessed dark red flowers while, another tolerant variety Chinese rose (0.08 larva/plant) possessed red colour flowers. The tussock moth population had negative and significant correlation with flower colour (r=-0.752) (Table 4).

Bud borer, H. armigera

The tolerant varieties Gladiator and Barbone rose possessed dark red and pink coloured flowers, respectively had 0.10 and 0.20 larva per plant, respectively. The bud borer population exhibited significant and negative correlation with flower colour (r=-0.510) (Table 4).

Table 4. *Abundance of major insect-pests in relation to leaf colour, area, thickness and leaf glossiness of rose varieties.*

Varieties	*S. dorsalis*		*R. syriacus*	Aphids/bud	Blister beetles/flower
	Thrips/leaf	Thrips/flower	Thrips/leaf		
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)

Varieties	*S. dorsalis*		*R. syriacus*	Aphids/bud	Blister beetles/flower
	Thrips/leaf	Thrips/flower	Thrips/leaf		
Correlation 'r'	-0.323	-0.286	-0.140	-0.099	-0.225
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.091	-0.119	0.015	-0.133	0.018
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.424	-0.324	-0.256	-0.011	-0.270
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.563**	-0.423	-0.413	0.318	-0.398

Table 4. *Continued.*

Varieties	Semilooper larva/plant	Tussock moth larva/plant	Bud borer larva/plant	Leaf colour (Scale)
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	5 (medium)
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	3 (light)
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	5 (medium)
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	7 (dark colour)
Correlation 'r'	-0.563**	-0.645**	-0.707**	
Leaf area (cm^2)				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	9.20
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	7.18
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	8.15
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	9.40
Correlation 'r'	-0.090	-0.218	-0.495**	
Leaf thickness (mm)				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	0.24
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	0.24
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	0.27
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	0.30
Correlation 'r'	-0.650**	-0.728**	-0.533*	
Leaf glossiness (Scale)				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	0 (absence)
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	1 (presence)
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	1 (presence)
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	1 (presence)
Correlation 'r'	-0.585**	-0.547*	0.088	

3.2.10. Flower Compactness

Thrips, S. dorsalis

Both the tolerant varieties Gladiator (0.88 thrips/leaf) and Cabbage rose (1.00 thrips/leaf) indicated flower compactness of 0.35 g/ml. Correlation between thrips population and flower compactness was negative (r=-0.477) and significant. Correlation between thrips population on flower and flower compactness was negative (r=-0.652) and highly significant. Thus, higher flower compactness was observed in tolerant varieties (Gladiator and Cabbage rose) as compared to less susceptible varieties (Barbone rose and Chinese rose) conforming the negative relationship (Table 5).

Thrips, R. syriacus

The tolerant variety Gladiator recorded very low population of thrips (*R. syriacus*) (0.01 thrips/leaf) which in turn had flower compactness of 0.35 g/ml while, moderately susceptible Chinese rose (0.66 thrips/leaf) had lower flower compactness (0.26 g/ml) conforming negative (r=-0.684) and significant relationship (Table 5).

As there is no evidence of published information on this aspect, except that of Nirmala (2015) [14] who revealed that flower size and flower compactness showed a significant negative correlation with the thrips incidence which is also observed in the current investigation wherein tolerant varieties had higher floral compactness than moderately susceptible varieties. Thus, the investigation results are said to be in accordance with earlier reports.

Aphid

The varieties which were tolerant to aphid population were Chinese rose and Barbone rose having floral compactness of 0.26 and 0.33 g/ml. The aphid population exhibited positive and highly significant correlation with flower compactness (r=0.715) (Table 5).

Blister beetle, M. pustulata

The tolerant variety Gladiator did not record any blister beetle population (0.0 beetle/flower) had the highest flower

compactness (0.35 g/ml) followed by another tolerant variety Cabbage rose indicating the same flower compactness exhibiting negative (r=-0.673) and significant correlation (Table 5).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had flower compactness of 0.35 and 0.26 g/ml, respectively indicating positive (r=0.061) but non-significant relationship (Table 5).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator recorded very low population of tussock moth (0.01 larva/plant) which in turn had the highest flower compactness (0.35 g/ml. Larval population of tussock moth had negative (r=-0.130) but non-significant correlation with flower compactness (Table 5).

Bud borer, H. armigera

The tolerant varieties Gladiator and Barbone rose recorded flower compactness of 0.35 and 0.33 g/ml, respectively which in turn indicated bud borer population of 0.10 and 0.20 larva/plant, respectively. The bud borer had negative (r=-0.369) but non-significant correlation with flower compactness (Table 5).

3.2.11. Flower Shape

Thrips, S. dorsalis

Tolerant variety Gladiator possessed round flowers indicating lower thrips (0.88 thrips/leaf) followed by Cabbage rose (1.00 thrips/leaf) which in turn had star shaped flowers. Correlation between thrips population (on leaves) and flower shape was negative (r=-0.019) and non-significant. Tolerant Gladiator and Cabbage rose possessed 1.43 and 2.22 thrips/flower, respectively. Correlation between thrips population on flowers and flower shape was positive (r=0.023) and non-significant (Table 5).

Thrips, R. syriacus

Gladiator recorded lowest thrips (R. syriacus) (0.01 thrips/leaf) population which in turn had round shaped flowers. Similarly, tolerant variety Cabbage rose possessed star shaped flowers. Correlation between thrips population and flower shape was negative (r=-0.096) and non-significant (Table 5).

Aphid

The varieties which were tolerant to aphid were Chinese rose and Barbone rose which in turn had irregularly rounded and round shape flowers. Aphid population indicated positive but non-significant correlation with flower shape (r=0.251) (Table 5).

Blister beetle, M. pustulata

The tolerant Gladiator did not record any blister beetle population in turn possessed round flowers and another tolerant variety Cabbage rose (0.12 beetle/flower) possessed star shaped flowers. The blister beetle population exhibited negative and non-significant correlation with flower shape (r=-0.015) (Table 5).

Castor semilooper, A. janata

The tolerant varieties Gladiator and Chinese rose had round and irregularly rounded shape flowers, respectively. Correlation between larval population of semilooper and flower shape was positive (r=0.174) and non-significant (Table 5).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator recorded very low population of tussock moth (0.01 larva/plant) possessing round flowers followed by another tolerant Chinese rose (0.08 larva/plant) which possessed irregularly round shaped flowers. The tussock moth exhibited positive but non-significant correlation with flower shape (r=0.264) (Table 5).

Bud borer, H. armigera

Gladiator and Barbone rose designated as tolerant varieties possessed round shape flowers which in turn recorded 0.10 and 0.20 larva per plant, respectively. The bud borer population indicated positive and highly significant correlation with flower shape (r=0.649). (Table 5).

3.2.12. Flower Diameter

Thrips, S. dorsalis

Tolerant varieties Gladiator (0.88 thrips/leaf) and Cabbage rose (1.00 thrips/leaf) had floral diameter of 6.51 and 4.98 cm, respectively. Correlation between thrips population on leaves and flower v/s flower diameter was negative (r=-0.201 and -0.224) and non-significant (Table 5).

Thrips, R. syriacus

The Gladiator hosted very low population of thrips (R. syriacus) (0.01 thrips/leaf) had the highest floral diameter (6.51 cm) which in turn exhibited negative (r=-0.137) and non-significant correlation (Table 5).

Aphid

The varieties which were tolerant to aphid were Chinese rose and Barbone rose had flower diameters of 5.66 and 5.84 cm. The aphid population exhibited negative and non-significant correlation with flower diameter (r=-0.085) (Table 5).

Blister beetle, M. pustulata

The variety which did not record any blister beetle population (0.00 beetle/flower) was Gladiator possessing 6.51 cm flower diameter and categorized as tolerant variety indicating negative (r=-0.285) but non-significant correlation (Table 5).

Castor semilooper, A. janata

The tolerant Gladiator and Chinese rose had flower diameter of 6.51 and 5.66 cm, respectively. Correlation between larval population of semilooper and flower diameter was negative (r=-0.401) and non-significant (Table 5).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator recorded very low larval population of tussock moth (0.01 larva/plant) possessed flower diameter of 6.51 cm. The tussock moth larval population exhibited negative and highly significant correlation with flower diameter (r=-0.592) (Table 5).

Bud borer, H. armigera

The tolerant varieties like Gladiator and Barbone rose recorded flower diameter of 6.51 and 5.84 cm, respectively which in turn recorded bud borer populations of 0.10 and 0.20 larva/plant, respectively. The bud borer population had negative and highly significant correlation with flower diameter (r=-0.677) (Table 5).

Table 5. *Abundance of major insect-pests in relation to flower colour, compactness, shape and flower diameter of rose varieties.*

Varieties	*S. dorsalis*		*R. syriacus*	Aphids/bud	Blister beetles/flower
	Thrips/leaf	Thrips/flower	Thrips/leaf		
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.306	-0.193	-0.048	-0.210	-0.154
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.477*	-0.652**	-0.684**	0.715**	-0.673**
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.019	0.023	-0.096	0.251	-0.015
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.201	-0.224	-0.137	-0.085	-0.285

Table 5. *Continued.*

Varieties	Semilooper larva/plant	Tussock moth larva/plant	Bud borer larva/plant	Flower colour
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	5 (pink)
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	4 (whitish pink)
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	7 (red)
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	8 (dark red)
Correlation 'r'	-0.706**	-0.752**	0.510*	
Flower compact (g/ml)				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	0.33
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	0.35
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	0.26
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	0.35
Correlation 'r'	0.061	-0.130	-0.369	
Flower shape				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	1 (round)
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	3 (star shaped)
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	2 (irregularly round)
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	1 (round)
Correlation 'r'	0.174	0.264	0.649**	
Flower diameter (cm)				
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	5.84
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	4.98
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	5.66
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	6.51
Correlation 'r'	-0.401	-0.592**	-0.677**	

3.2.13. Number of Petals

Thrips, S. dorsalis

Tolerant varieties Gladiator and Cabbage rose had 48.24 and 77.42 petals per flower, respectively which in turn had thrips, S. dorsalis populations of 0.88 and 1.00 per leaf, respectively Correlation between thrips population on leaf and number of petals was highly significant and negative (r=-0.623). Correlation between thrips population on flowers and petals on flowers was highly significant and negative (r=-0.664) (Table 6).

Thrips, R. syriacus

The tolerant Gladiator had a very low population of thrips (*R. syriacus*) (0.01 thrips/leaf) which in turn indicated comparatively higher petals (48.24/flower). Correlation between thrips population and petals was positive and highly significant (r=-0.758) (Table 6).

Aphid

The varieties which were tolerant to aphid were Chinese rose (0.33 aphid/bud) and Barbone rose (1.81 aphid/bud) which possessed 25.76 and 26.00 petals, respectively. The aphid population had a highly significant and positive correlation with petals (r=0.841) (Table 6).

Blister beetle, M. pustulata

The variety which did not record any blister beetle population was Gladiator (0.0) indicating 48.24 petals and was designated as tolerant. The blister beetle population had

a significant and negative correlation with number of petals (r=-0.619) (Table 6).

Castor semilooper, A. janata

The tolerant varieties Gladiator (0.02 larva/plant) and Chinese rose (0.09 larva/plant) had 48.24 and 25.76 petals per flower, respectively. Correlation between larval population of semilooper and petals was negative (r=-0.045) and non-significant (Table 6).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator had the lowest population of tussock moth larva (0.01 larva/plant) which in turn had the higher petals (48.24/flower). The tussock moth larval population had non-significant and negative correlation with petals (r=-0.037) (Table 6).

Bud borer, H. armigera

The tolerant varieties Gladiator and Barbone rose had 48.24 and 26.00 petals per flower, respectively which in turn harboured 0.10 and 0.20 larva per plant, respectively. The bud borer population had non-significant and positive correlation with petals (r=0.139) (Table 6).

3.2.14. Number of Flowers

Thrips, S. dorsalis

Tolerant varieties Gladiator and Cabbage rose had 2.40 and 5.62 flowers per plant, respectively which in turn recorded thrips, S. dorsalis populations of 0.88 and 1.00 per leaf, respectively. Correlation between thrips population on leaf and number of flowers was significant and positive (r=0.854). Correlation between thrips population and flowers was significant and positive (r=0.766) (Table 6).

Thrips, R. syriacus

The tolerant variety which recorded very low population of thrips (R. syriacus) (0.01 thrips/leaf) was Gladiator having 2.40 flowers. Correlation between thrips population and flowers was significant and positive (r=0.717) (Table 6).

Aphid

The varieties which were tolerant to aphid population were Chinese rose and Barbone rose which in turn possessed 6.24 and 7.36 flowers, respectively. The aphid population had negative but significant correlation with flowers (r=-0.519) (Table 6).

Blister beetle, M. pustulata

The tolerant variety which did not record any blister beetle population was Gladiator which in turn had comparatively fewer flowers (2.40). The blister beetle population exhibited significant and positive correlation with number of flowers (r=0.656) (Table 6).

Castor semilooper, A. janata

The tolerant varieties Gladiator (0.02 larva/plant) and Chinese rose (0.09 larva/plant) had 2.40 and 6.24 flowers, respectively. Correlation between semilooper and flowers was significant and positive (r=0.692) (Table 6).

Tussock moth, Orgyia sp.

The tolerant variety Gladiator recorded lowest larval population of tussock moth (0.01 larva/plant) in turn had comparatively fewer flowers (2.40/plant) indicating significant and positive correlation with flowers (r=0.624) (Table 6).

Bud borer, H. armigera

The tolerant varieties Gladiator and Barbone rose recorded 2.40 and 7.36 flowers per plant, respectively which in turn recorded 0.10 and 0.20 larva per plant, respectively. The bud borer population exhibited significant and positive correlation with number of flowers (r=0.553) (Table 6).

Table 6. *Abundance of major insect-pests in relation to number of petals and number of flowers per plant of rose varieties.*

Varieties	*S. dorsalis*		*R. syriacus*	Aphids /bud	Blister beetles/flower
	Thrips/leaf	Thrips/flower	Thrips/leaf		
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	-0.623**	-0.664**	-0.758**	0.841**	-0.619**
Barbone rose	1.30 (1.19)	1.84 (2.89)	0.98 (0.52)	1.52 (1.81)	0.92 (0.34)
Cabbage rose	1.22 (1.00)	1.65 (2.22)	0.78 (0.11)	2.34 (4.98)	0.79 (0.12)
Chinese rose	1.29 (1.17)	1.90 (3.09)	1.08 (0.66)	0.91 (0.33)	0.95 (0.40)
Gladiator rose	1.17 (0.88)	1.39 (1.43)	0.71 (0.01)	2.20 (4.33)	0.71 (0.00)
Correlation 'r'	0.854**	0.766**	0.717**	-0.519*	0.656**

Table 6. *Continued.*

Varieties	Semilooper larva/plant	Tussock moth larva/plant	Bud borer larva/plant	No. of petals/flower
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	26.00
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	77.42
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	25.76
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	48.24
Correlation 'r'	-0.045	-0.037	0.139	
Barbone rose	0.82 (0.19)	0.80 (0.14)	0.83 (0.20)	7.36
Cabbage rose	0.80 (0.14)	0.78 (0.11)	0.89 (0.29)	5.62
Chinese rose	0.76 (0.09)	0.76 (0.08)	0.88 (0.28)	6.24
Gladiator rose	0.72 (0.02)	0.71 (0.01)	0.77 (0.10)	2.40
Correlation 'r'	0.692**	0.624**	0.553*	

Figures in parentheses are original values while those outside are $\sqrt{X+0.5}$ transformed values *Significant (p=0.05) **Significant (p=0.01)

So, it can be summarized that rose varieties *viz*; Barbone rose, Cabbage rose, Chinese rose and Gladiator screened against major sucking (thrips and aphids) and defoliating (castor semilooper, tussock moth and bud borer, *H. armigera*) pests in relation to biophysical traits *viz*; plant (growth habit and height), number of primary branches, prickle density, leaf (colour, area, thickness, glossiness), flower (colour, compactness, shape, diameter, number of petals and number of flowers/plant) under open field condition indicated Gladiator as the tolerant variety against thrips (*S. dorsalis* and *R. syriacus*), blister beetle, castor semilooper, tussock moth and bud borer. Chinese rose was found tolerant against aphid, semilooper and tussock moth.

Cabbage rose was found tolerant against thrips and blister beetle. Lastly, Barbone rose was tolerant against aphid and bud borer. Overall, it can be summarized that Gladiator was found tolerant against majority of pests (except aphid) considered in this investigation.

It was quite evident that plant growth habit of respective rose varieties exhibited significantly positive correlation (r=0.620) with abundance of aphid which implies that with increase in plant growth (horizontal and vertical growth) there was bound to increase in plant susceptibility (tolerance to susceptibility). Likewise, plant height exhibited significant positive correlation with respect to thrips, *S. dorsalis* (r=0.851 and 0.788), thrips, *R. syriacus* (r=0.778), blister beetle (r=0.734), semilooper (r=0.588) and tussock moth (r=0.652) indicating increase in population of these pests (increased plant susceptibility) in relation to increase in plant height. However, aphid abundance (r=-0.655) was indirectly related to plant height.

Increase in number of primary branches of rose varieties led to increased susceptibility to thrips (*S. dorsalis* and *R. syriacus*), blister beetle, semilooper and tussock moth (r=0.798, 0.690, 0.718, 0.674, 0.677 and 0.622, respectively) led to increased susceptibility towards these pests while, aphid abundance was indirectly (r=-0.555) related to primary branches.

Prickle density had a very limited role to play in inducing resistance or susceptibility of rose varieties wherein increased prickle density led to increased thrips (r- 0.531), semilooper (r=0.674) and tussock moth (r=0.647).

Leaf colour exhibited indirect relationship with abundance of semilooper (r=-0.563), tussock moth (r=-0.645) and bud borer (r=-0.707). Likewise, leaf area directly influenced abundance of bud borer (r=-0.495) significantly but it was indirect.

Increase in leaf thickness led to decreased abundance of defoliator pests (semilooper, tussock moth and bud borer) (r=-0.650, -0.728 and -0.533) and vice versa. Similarly, increase in leaf glossiness led to decreased plant susceptibility towards thrips (r=-0.563), semilooper (r=-0.585) and tussock moth (r=-0.547) and vice-versa.

Amongst the floral characters, flower colour had a negative relationship with semilooper (r=-0.706), tussock moth (r=-0.752) and bud borer (r=-510) whereas, increase in flower compactness led to increased aphid (r=0.715) and decreased thrips and blister beetle (r=-0.477, -0.652, -0.684 and -0.673).

Flower shape however could not influence the pest abundance significantly except bud borer (r=0.649). Flower diameter could indirectly influence abundance of tussock moth (r=-0.592) and bud borer (r=-0.677).

Number of flower petals exhibited significant positive relationship with aphid (r=0.841) and negative relationship with thrips (r=-0.623 and -0.664), thrips, *R. syriacus* (r=-0.758) and blister beetle (r=-0.619).

Lastly, number of flowers exhibited significant positive relationship with abundance of thrips (r=0.854, 0.766, 0.717), blister beetle (r=0.656), semilooper (r=0.692), tussock moth (r=0.624) and bud borer (r=0.553) while, it exhibited indirect relationship with aphid abundance (r=-0.519) and vice versa.

Overall, it can be summarized that most important biophysical traits of rose varieties grown under open field condition were plant height, number of primary branches, leaf (colour, thickness), flower (colour, compactness, number of petals and number of flowers per plant) which directly or indirectly influenced plant tolerance or susceptibility to the major pests considered in this investigation.

4. Conclusion

Rose varieties *viz*; Barbone rose, Cabbage rose, Chinese rose and Gladiator screened against major sucking (thrips and aphids) and defoliating (castor semilooper, tussock moth and bud borer, *H. armigera*) pests in relation to biophysical traits *viz*; plant growth (number of primary branches, prickle density, leaf (colour, area, thickness, glossiness), flower (colour, compactness, shape, diameter, number of petals and number of flowers/plant) under open field condition indicated Gladiator as the tolerant variety against thrips (*S. dorsalis* and *R. syriacus*), blister beetle, castor semilooper, tussock moth and bud borer. While, Chinese rose was found tolerant against aphid, semilooper and tussock moth. Most important biophysical traits of rose varieties grown under open field condition were plant height, number of primary branches, leaf (colour, thickness), flower (colour, compactness, number of petals and number of flowers per plant) which directly or indirectly influenced plant tolerance or susceptibility to the major pests considered in this investigation.

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