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Biophysical basis of resistance in soybean genotypes against defoliators

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Abstract
The field trial was conducted at Research Farm of Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *kharif* season 2015-16. In the study twenty genotypes were evaluated for resistance against defoliators. The results revealed that the genotypes viz; AMS 9933, AMS 115, AMS MS 5-18, RVS 2001-18, MACS 1370, SL 979, AMS 104 and JS 2029 proved effective to combat the menace of defoliators, resulted into minimum per cent leaf damage. The correlation studies revealed that a biophysical character like leaf succulency was positively and significantly associated with per cent leaf damage by defoliators at 25 DAS (r = 0.877) and at 40 DAS (r = 0.743). The leaf area recorded at 25 DAS also has positive correlation with the per cent leaf damage (r = 0.451). While leaf thickness (r = -0.793, -0.789) and trichome density on the leaf surface (r = -0.821, -0.835) were significantly and negatively associated with leaf damage percentage at 25 and 40 DAS. Moreover, trichome density has significantly negative correlation with incidence of *Spodoptera* larvae (r = -0.459, -0.463) at 25 and 40DAS. Thus, these soybean genotypes could be used in resistance breeding programme.

Keywords: Biophysical characters, correlation, defoliators and soybean

1. Introduction

Soybean [*Glycine max* (L.) Merril], has become second most important *Kharif* crop in Vidarbha after cotton playing a key role in synergizing the economy of the region. In early seventies, when soybean was introduced to India only about a dozen minor insect pests were recorded, but in recent years this number has swelled to an alarming figure. Soybean growers witnessed instability in its production due to outbreaks of insect pests particularly, defoliators like tobacco leaf eating caterpillar (*Spodoptera litura*), soybean semilooper *(Crysodexis acuta)* are cause of concern. These pests not only cause direct losses to the crop but also increase the cost of crop protection by increasing number of sprays. The management of pests using chemical insecticides leads to mounting up of the cost of cultivation, environmental pollution, development of insecticide-resistant pest strains, menace to natural enemies and other non-target organisms and biomagnifications of pesticide residues in food and feed [1]. Accordingly, an alternative source of management of insect pests using non chemical methods is becoming more acceptable.

Each plant species has a unique defense mechanism involving various morphological traits which have profound influence on the reproduction and survival of herbivores on a plant species. Exploration for sources of resistance and mechanism of resistance in it forms a basic requirement for developing potential resistant cultivars. Taking in to consideration the importance of resistance cultivars as an important component of IPM and for exploitation of defoliator resistance soybean genotypes, it was felt necessary to plan the present investigation to study the response of different soybean genotypes and exploring the biophysical basis of host plant resistance in different genotypes against the defoliators of soybean.

2. Material and Methods

The present investigation was carried out at Research farm, Department of Agricultural Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *kharif* 2015-16. In screening programs twenty soybean genotypes were replicated thrice under Randomized Block Design were evaluated for resistance against defoliators. All the genotypes were kept unsprayed and allowed to build up the pest population and field screening technique was followed. The data were recorded on population of major defoliator pest like leaf eating caterpillar (*Spodoptera litura*), soybean semilooper (*Crysodexis acuta)*) and leaf damage caused by defoliators at weekly interval. Similarly, the data were also collected at 25 and 40 Days after sowing (DAS) on biophysical traits using following method to determine resistance/susceptibility of soybean genotypes against defoliators.

2.1 Collection of experimental data on biophysical parameters

Observation on different biophysical parameters of soybean genotypes were recorded on five randomly selected plants from each net plot at 25 and 40 Days after sowing (DAS).

2.1.1 Leaf succulence

Leaf succulence is expressed as relative water content (RWC). A composite sample of the leaf was taken and the fresh weight is determined, followed by flotation on water for up to 4 hrs. The turgid weight is then recorded and the leaf tissue is subsequently oven-dried to a constant weight and dry weight was taken as described by [2].

$$\text{RWC \%} = \frac{\text{(Fresh weight – dry weight)}}{\text{(Turgid weight – dry weight)}} \times 100$$

2.1.2 Leaf thickness

Leaf thickness is expressed as specific leaf weight (SLW).It was estimated as per the formula given by [3].

$$\text{Specific leaf weight (SLW)} = \frac{\text{Dry leaf weight (gm)}}{\text{Leaf area (cm}^2\text{)}} \times 100$$

2.1.3 Leaf area and Trichomes

Leaf area was measured by Portable leaf area meter instrument. Whereas, the observations on trichomes were recorded under microscope on abaxial leaf as per [4]. The leaf was collected at 25 and 40 DAS, kept overnight in to acetic acid: alcohol (2:1). After removal of chlorophyll, leaf was transferred into 90 per cent lactic acid in small vials for recording the observations. For microscopic examination, the leaf was mounted on a slide in a drop of lactic acid and observed under a microscope at 10X magnification. The trichomes on abaxial leaf surface were counted from randomly selected microscopic fields and expressed as trichomes density (no. /cm^2).

Similarly, correlation coefficient analysis was also worked out to explore the relationship between different biophysical parameters of soybean genotypes with defoliator infestation. At harvest the weight of seed from each net plot was recorded. The yield per hectare was worked out and was expressed in quintal per hectare.

3. Results and Discussion

3.1 Larval population of green semilooper on different soybean genotypes

The data (Table 1) showed statistically significant differences in population of green semilooper at 4, 5, 6 and 7 weeks after sowing (WAS). However, initially at3 WAS and later at 8, 9 and 10

Table 1: Larval population of semilooper on different soybean genotypes

Sr no		Number of larvae per plant							
	Genotype	3 WAS	4 WAS	5 WAS	6 WAS	7 WAS	8 WAS	9 WAS	10 WAS
1	AMS 99 33	0.00 (0.71)	0.20 (0.84)	0.80 (1.14)	0.87 (1.17)	0.97 (1.21)	0.90 (1.18)	0.80 (1.14)	0.53 (1.02)
2	DS 2705	0.10 (0.77)	0.67 (1.08)	0.90 (1.18)	1.13 (1.28)	1.13 (1.28)	1.03 (1.24)	0.83 (1.15)	0.63 (1.06)
3	AMS MS- 5-18	0.13 (0.79)	0.37 (0.93)	0.60 (1.04)	0.83 (1.14)	1.03 (1.24)	0.93 (1.20)	0.93 (1.20)	0.87 (1.17)
4	MACS 1370	0.00 (0.71)	0.63 (1.06)	0.90 (1.18)	0.97 (1.21)	0.93 (1.20)	0.87 (1.17)	0.83 (1.15)	0.57 (1.03)
5	DSB 23-2	0.20 (0.84)	0.97 (1.21)	1.20 (1.30)	1.23 (1.31)	1.40 (1.38)	1.43 (1.39)	1.07 (1.25)	0.77 (1.13)
6	AMS 1002	0.07 (0.75)	0.80 (1.14)	0.80 (1.14)	1.03 (1.24)	1.17 (1.27)	1.03 (1.23)	0.73 (1.11)	0.57 (1.03)
7	DSB 25	0.07 (0.75)	0.63 (1.06)	0.80 (1.14)	0.90 (1.18)	1.07 (1.25)	1.03 (1.24)	0.87 (1.17)	0.57 (1.03)
8	NRC 94	0.10 (0.77)	0.63 (1.06)	0.80 (1.14)	0.90 (1.18)	1.20 (1.30)	0.90 (1.18)	0.83 (1.15)	0.60 (1.05)
9	SL 979	0.00 (0.71)	0.50 (1.00)	0.73 (1.11)	0.87 (1.17)	1.17 (1.29)	1.03 (1.24)	0.97 (1.21)	0.93 (1.20)
10	NRC 93	0.03 (0.73)	0.90 (1.18)	1.13 (1.28)	1.23 (1.32)	1.43 (1.39)	1.07 (1.25)	0.90 (1.18)	0.70 (1.09)
11	AMS 115	0.10 (0.77)	0.53 (1.01)	0.67 (1.08)	0.73 (1.11)	1.00 (1.22)	0.90 (1.18)	0.83 (1.15)	0.83 (1.15)
12	KDS 743	0.17 (0.81)	1.07 (1.25)	1.23 (1.32)	1.27 (1.33)	1.63 (1.46)	1.13 (1.28)	1.03 (1.21)	1.07 (1.25)
13	RVS 2001-18	0.00 (0.71)	0.57 (1.03)	0.87 (1.17)	0.90 (1.18)	1.13 (1.24)	1.03 (1.24)	1.07 (1.25)	0.97 (1.21)
14	MACS 1410	0.10 (0.77)	0.83 (1.15)	0.80 (1.11)	1.03 (1.24)	1.20 (1.30)	1.07 (1.25)	0.97 (1.21)	0.60 (1.03)
15	BAUS 96	0.13 (0.79)	0.63 (1.06)	0.80 (1.14)	1.50 (1.40)	0.93 (1.20)	0.87 (1.17)	0.93 (1.20)	0.20 (0.84)
16	SL 955	0.13 (0.79)	0.40 (0.94)	0.97 (1.20)	1.00 (1.22)	1.07 (1.25)	0.97 (1.21)	1.00 (1.22)	0.90 (1.14)
17	KDS 726	0.17 (0.81)	1.07 (1.25)	1.20 (1.30)	1.33 (1.34)	1.70 (1.48)	0.90 (1.14)	0.97 (1.18)	0.77 (1.13)
18	AMS 104	0.10 (0.77)	0.63 (1.06)	0.80 (1.14)	0.97 (1.21)	1.10 (1.26)	1.03 (1.24)	0.87 (1.17)	0.63 (1.06)
19	JS 335 (S)	0.17 (0.82)	1.10 (1.26)	1.27 (1.32)	1.37 (1.36)	1.67 (1.47)	1.43 (1.39)	1.10 (1.26)	0.97 (1.21)
20	JS 2029 (R)	0.03 (0.73)	0.40 (0.95)	0.63 (1.06)	0.83 (1.15)	0.93 (1.20)	0.97 (1.21)	0.87 (1.17)	0.83 (1.15)
	F' test	NS	Sig	Sig	Sig	Sig	NS	NS	NS
	SE(m) ±	0.03	0.05	0.06	0.06	0.07	0.06	0.06	0.07
	CD at5%	-	0.13	0.17	0.16	0.19	-	-	-
	CV %	7.16	7.35	9.07	8.14	9.24	8.60	8.53	10.56

Figures in parentheses indicate $\sqrt{x + 0.5}$ transformed values. WAS – Weeks After Sowing

WAS there was non-significant difference in respect of green semilooper population on different genotypes.

The data on green semilooper at 4 WAS revealed that minimum larval population was noticed on genotype AMS 9933, AMS MS 5-18, SL 955 and JS 2029 (resistance check) with 0.20, 0.37, 0.40 and 0.40 larvae per plant, respectively and found statistically at par among themselves. Maximum larval population was recorded on susceptible check JS 335 (1.10 larvae per plant). At 5 WAS, the lowest population of green semilooper was noticed in genotype AMS MS 5-18

(0.60 larvae per plant) which was followed by JS 2029 (0.63), AMS 115 (0.67), SL 979 (0.73),MACS 1410 (0.80), AMS 104 (0.80), BAUS 96 (0.80), NRC 94 (0.80), AMS 1002 (0.80), AMS 9933 (0.80), RVS 2001-18 (0.87), MACS 13710 (0.90), DS 2705 (0.90) and SL 955 (0.97) all these treatments were found at par with each other. Whereas, susceptible check JS 335 recorded maximum of 1.27 larvae per plant. At 6 WAS the genotype AMS 115 recorded significantly minimum of 0.73 larvae per plant. It was found at par with entries AMS MS 5-18 (0.83), JS 2029 (0.83), SL 979 (0.87), AMS 9933 (0.87), RVS 2001-18 (0.90), NRC 94 (0.90), DSB 25 (0.90), AMS 104 (0.97), MACS 1370 (0.97), SL 955 (1.00), AMS 1002 (1.03) and MACS 1410 (1.03). At 7 WAS minimum semilooper larvae were observed in entry BAUS 96 (0.93 larvae per plant). This entry was found at par with resistance check JS 2029 (0.93), MACS 1370 (0.93), AMS 9933 (0.97), AMS 115 (1.00), AMS MS 5-18 (1.03), RVS 2001-18 (1.13), DSB 25 (1.07), SL 955 (1.07), AMS 104 (1.10), DS 2705 (1.13), AMS 1002 (1.17), SL 979 (1.17), NRC 94 (1.20), MACS 1410 (1.20), DSB 23-2 (1.40) and NRC 93 (1.43). Whereas, maximum larval population was recorded in KDS 726 with 1.70 larvae per plant.

3.2 Larval population of *Spodoptera litura* on different soybean genotypes

The data (Table 2) revealed statistically significant differences in population of *S. litura* recorded at 5, 6 and 7 WAS. However initially at 3 and 4 WAS and latter on at 8 to 10 WAS non-significant differences in respect of *S. litura* larval population on different soybean genotypes were noticed.

The data on *S. litura* larval population recorded at 5 WAS indicated least feeding preference on genotypes AMS 1002, NRC 93, AMS 115, SL 979, MACS 1410 and AMS 104. The *S. litura* larva was not noticed on these genotypes. However, these were found statistically at par with AMS 9933, DS 2705, MACS 1370, SL 955, JS 2029, NRC 94, RVS 2001-18, BAUS 96

Table 2: Larval population of *Spodoptera litura* on different soybean genotypes

Sr.no		Number of larvae per plant							
	Genotype	**3WAS**	**4WAS**	**5WAS**	**6WAS**	**7WAS**	**8WAS**	**9 WAS**	**10 WAS**
1	AMS 99 33	0.03 (0.73)	0.07 (0.75)	0.03 (0.73)	0.13 (0.80)	0.00 (0.71)	0.00 (0.71)	0.03 (0.73)	0.00 (0.71)
2	DS 2705	0.03 (0.73)	0.10 (0.77)	0.03 (0.73)	0.23 (0.86)	0.00 (0.71)	0.03 (0.73)	0.07 (0.75)	0.00 (0.71)
3	AMS MS-5-18	0.07 (0.75)	0.17 (0.82)	0.20 (0.84)	0.40 (0.94)	0.10 (0.77)	0.10 (0.77)	0.10 (0.77)	0.03 (0.73)
4	MACS 1370	0.10 (0.77)	0.10 (0.77)	0.03 (0.73)	0.27 (0.88)	0.00 (0.71)	0.03 (0.73)	0.07 (0.75)	0.00 (0.71)
5	DSB 23-2	0.07 (0.75)	0.20 (0.84)	0.20 (0.84)	0.27 (0.88)	0.03 (0.73)	0.10 (0.77)	0.13 (0.80)	0.07 (0.75)
6	AMS 1002	0.03 (0.73)	0.10 (0.77)	0.00 (0.71)	0.43 (0.96)	0.10 (0.77)	0.07 (0.75)	0.07 (0.75)	0.00 (0.71)
7	DSB 25	0.07 (0.75)	0.17 (0.82)	0.13 (0.79)	0.40 (0.94)	0.03 (0.73)	0.07 (0.75)	0.10 (0.77)	0.03 (0.73)
8	NRC 94	0.03 (0.73)	0.10 (0.77)	0.07 (0.75)	0.17 (0.82)	0.00 (0.71)	0.03 (0.73)	0.07 (0.75)	0.00 (0.71)
9	SL 979	0.03 (0.73)	0.07 (0.75)	0.00 (0.71)	0.10 (0.77)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
10	NRC 93	0.07 (0.75)	0.07 (0.75)	0.00 (0.71)	0.13 (0.80)	0.00 (0.71)	0.03 (0.73)	0.03 (0.73)	0.00 (0.71)
11	AMS 115	0.00 (0.71)	0.07 (0.75)	0.00 (0.71)	0.10 (0.77)	0.00 (0.71)	0.00 (0.71)	0.03 (0.73)	0.00 (0.71)
12	KDS 743	0.13 (0.79)	0.11 (0.78)	0.20 (0.83)	0.20 (0.83)	0.17 (0.81)	0.13 (0.80)	0.17 (0.82)	0.17 (0.82)
13	RVS 2001-18	0.03 (0.73)	0.070 (0.75)	0.07 (0.75)	0.13 (0.80)	0.00 (0.71)	0.00 (0.71)	0.03 (0.73)	0.00 (0.71)
14	MACS 1410	0.03 (0.73)	0.07 (0.75)	0.00 (0.71)	0.13 (0.80)	0.00 (0.71)	0.03 (0.75)	0.03 (0.73)	0.00 (0.71)
15	BAUS 96	0.03 (0.73)	0.10 (0.77)	0.07 (0.75)	0.20 (0.84)	0.00 (0.71)	0.03 (0.75)	0.07 (0.75)	0.00 (0.71)
16	SL 955	0.03 (0.73)	0.13 (0.80)	0.03 (0.73)	0.30 (0.89)	0.00 (0.71)	0.07 (0.75)	0.07 (0.75)	0.00 (0.71)
17	KDS 726	0.03 (0.73)	0.17 (0.82)	0.17 (0.82)	0.30 (0.89)	0.03 (0.73)	0.07 (0.75)	0.07 (0.75)	0.03 (0.73)
18	AMS 104	0.03 (0.73)	0.10 (0.77)	0.00 (0.71)	0.13 (0.80)	0.0 (0.71)	0.03 (0.75)	0.07 (0.75)	0.00 (0.71)
19	JS 335 (S)	0.07 (0.75)	0.17 (0.82)	0.17 (0.81)	0.27 (0.87)	0.20 (0.83)	0.10 (0.77)	0.13 (0.80)	0.10 (0.77)
20	JS 2029 (R)	0.03 (0.73)	0.03 (0.73)	0.03 (0.73)	0.07 (0.75)	0.00 (0.71)	0.03 (0.71)	0.07 (0.75)	0.03 (0.71)
	F' test	NS	NS	Sig	Sig	Sig	NS	NS	NS
	SE(m) ±	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.02
	CD at5%	-	-	0.09	0.10	0.07	-	-	-
	CV %	7.3	6.12	7.48	7.8	6.05	6.23	7.7	6.0

Figures in parentheses indicate $\sqrt{x + 0.5}$ transformed values. WAS – Weeks After Sowing

and DSB 25 in which number of larvae ranged from 0.03 to 0.13 per plant. At 6 WAS, least number of *S. litura* larvae were recorded on resistant check JS 2029 (0.07 larvae per plant).It was found at par with entries viz, SL 979, AMS 115 (0.10 larvae each), AMS 9933, NRC 93, MACS 1410, AMS 104, RVS 2001-18 (0.13 larvae each) NRC 94 (0.17), KDS 743 and BAUS 96 (0.20 larvae each). At 7 WAS revealed that entries viz., AMS 9933, DS 2705, MACS 1370, JS 2029, NRC 94, SL 979, NRC 93, AMS 115, RVS 2001-18, MACS 1410, BAUS 96, SL 955, and AMS 104 showed least preference. However, these entries were found at par with DSB 25 (0.03), KDS 726 (0.03), DSB 23-2 (0.03), AMS 1002 (0.10) and AMS MS 5-18 (0.10).

3.3 Mean Per cent leaf damage due to defoliators in different Soybean genotypes

The data in Table 3 revealed that there were significant differences amongst soybean genotypes in respect of mean per cent leaf damage. Amongst the different genotypes, significantly minimum per cent leaf damage was noticed in resistance check JS 2029 i.e. 28.77 per cent which were at par with AMS MS 5-18 (30.05%), AMS 1002 (30.86%), AMS 115 (31.05%), AMS 104 (31.31%), SL 979 (31.68%), RVS 2001-18 (32.05%), AMS 9933 (32.27%) and DS 2705 (32.62%). Whereas maximum per cent leaf damaged was noticed in susceptible check JS 335 (37.48%).

These findings on defoliators are on the line of research work carried out by earlier workers. The present results on defoliators finds support in earlier research work carried out by [5], who reported the maximum number of defoliator larvae on JS 335 during the fortnight of August. In the studies carried by [6] highest incidence of semilooper and tobacco leaf eating caterpillar was recorded in the JS-335 variety of soybean during the year of study. In present studies also peak activity of semilooper larvae was recorded during the month of August on JS- 335. Whereas, [7] reported that resistant genotypes showed the minimum number of green semilooper larvae (2.22 larvae/mrl) as compared to susceptible line (10.44 larvae/ mrl). Similarly, [8] evaluated different soybean germplasms against insect pest of soybean and reported maximum defoliator larval population on highly susceptible germplasms as against least susceptible germplasms at its peak activity. The results obtain by these workers are in close agreement with the present findings pertaining to record of maximum number of defoliator larvae on the susceptible genotypes.

Table 3: Per cent leaf damage due to defoliators in different soybean genotypes

Sr.no	Genotype	Per cent leaf damage								MEAN
		3 WAS	4 WAS	5 WAS	6 WAS	7 WAS	8 WAS	9 WAS	10 WAS	
1	AMS 99 33	24.02 (29.31)	24.49 (29.66)	26.59 (30.99)	34.29 (36.09)	38.98 (38.63)	38.64 (38.43)	35.34 (36.45)	27.58 (31.68)	32.27 (34.61)
2	DS 2705	27.65 (31.69)	27.65 (31.69)	32.68 (34.85)	37.13 (37.52)	40.09 (39.28)	40.40 (39.46)	36.29 (37.04)	21.26 (27.45)	32.62 (34.83)
3	AMS MS 5-18	19.31 (26.06)	22.18 (28.10)	25.16 (30.03)	29.34 (32.78)	36.39 (37.09)	34.20 (35.72)	37.03 (37.44)	21.39 (27.55)	30.05 (33.23)
4	MACS 1370	18.36 (25.36)	25.08 (29.98)	27.92 (31.89)	33.30 (35.23)	50.69 (45.40)	45.23 (42.26)	46.03 (42.72)	24.34 (29.56)	33.94 (35.63)
5	DSB 23-2	28.88 (32.41)	28.26 (32.11)	31.28 (33.99)	41.75 (40.25)	41.02 (39.83)	42.30 (40.53)	39.74 (39.05)	36.09 (36.85)	33.97 (35.65)
6	AMS 1002	23.78 (29.02)	23.31 (28.83)	28.93 (32.54)	32.33 (34.50)	48.15 (43.94)	49.81 (44.89)	41.01 (39.82)	20.74 (27.09)	30.86 (33.73)
7	DSB 25	25.42 (30.28)	29.85 (33.10)	30.15 (33.21)	26.63 (31.04)	51.79 (46.05)	43.73 (41.38)	44.86 (42.05)	22.87 (28.56)	34.37 (35.89)
8	NRC 94	25.58 (30.37)	30.07 (33.08)	30.13 (33.29)	33.05 (35.05)	45.17 (42.21)	42.98 (40.96)	47.72 (43.69)	24.46 (29.64)	35.08 (36.32)
9	SL 979	21.61 (27.65)	25.37 (30.24)	30.32 (33.36)	30.68 (33.58)	42.71 (40.80)	45.46 (42.40)	44.76 (41.99)	38.09 (37.65)	31.68 (34.25)
10	NRC 93	21.41 (27.26)	24.71 (29.78)	27.70 (31.74)	30.91 (33.77)	48.77 (44.30)	48.43 (44.10)	40.98 (39.77)	24.06 (29.37)	34.62 (36.02)
11	AMS 115	24.03 (29.01)	24.84 (29.89)	27.40 (31.55)	28.57 (32.31)	38.26 (38.20)	41.56 (40.14)	43.23 (41.11)	21.21 (27.41)	31.05 (33.87)
12	KDS 743	26.46 (30.96)	27.89 (31.86)	28.12 (31.97)	29.43 (32.83)	43.37 (41.18)	38.97 (38.62)	37.06 (37.49)	21.44 (27.58)	36.07 (36.89)
13	RVS 2001-18	24.46 (29.64)	28.45 (32.23)	29.95 (33.18)	31.08 (33.88)	45.83 (42.60)	39.20 (38.76)	40.87 (39.74)	24.60 (29.73)	32.05 (34.48)
14	MACS 1410	25.28 (30.15)	28.07 (31.99)	30.25 (33.32)	35.39 (36.48)	43.62 (41.32)	44.11 (41.61)	43.68 (41.36)	24.96 (29.96)	33.88 (35.58)
15	BAUS 96	24.31 (29.49)	26.89 (31.22)	31.25 (33.98)	29.86 (33.08)	45.74 (42.55)	47.01 (43.28)	47.98 (43.84)	23.75 (29.16)	34.59 (36.00)
16	SL 955	24.91 (29.93)	27.65 (31.62)	28.37 (32.07)	32.54 (34.78)	48.81 (44.32)	48.29 (44.02)	48.58 (44.19)	23.58 (29.04)	33.99 (35.66)
17	KDS 726	27.35 (31.38)	26.04 (30.66)	28.24 (32.07)	27.18 (31.40)	52.37 (46.37)	48.49 (44.13)	48.51 (44.14)	22.95 (28.58)	34.97 (36.25)
18	AMS 104	26.70 (31.08)	24.85 (29.87)	27.13 (31.39)	40.79 (39.69)	45.19 (42.24)	35.15 (36.34)	37.03 (37.44)	24.34 (29.56)	31.31 (34.02)
19	JS 335 (S)	26.04 (30.66)	32.68 (34.85)	31.53 (34.07)	35.33 (36.45)	52.30 (46.32)	43.17 (41.06)	46.97 (43.25)	39.72 (39.06)	37.48 (37.75)
20	JS 2029 (R)	21.35 (27.49)	22.67 (28.42)	26.85 (31.19)	23.94 (29.29)	32.48 (34.39)	33.98 (35.59)	37.78 (37.92)	22.98 (28.64)	28.77 (32.29)
	F' test	NS	Sig	NS	Sig	Sig	Sig	Sig	Sig	Sig
	SE(m) ±	1.70	1.28	1.23	1.37	1.89	1.42	1.42	2.25	0.99
	CD at5%	-	3.55	-	3.80	5.24	3.94	3.94	6.23	2.75
	CV %	9.97	7.46	6.55	6.87	7.83	6.06	6.07	12.89	5.61

Figure parenthesis indicate Arc Sine transformed values WAS-Weeks after Sowing

In search of host plant resistance against leaf eating caterpillars, seven varieties of soybean were screened by [9], reported that among different varieties highest number of leaf eating caterpillars (3.97 l/mrl), maximum per cent defoliator (40.56 %) and maximum relative yield loss was recorded by JS 335 variety [10]. recorded lowest percentage of defoliators in KHSb-2 (14.33%) followed by DSb-1 and were categorized as highly resistant. Whereas, JS 335 and Monetta were classified as highly susceptible [11]. evaluated relative susceptibility of soybean genotypes against defoliators, reported that among the fifty genotypes AMS-9933, was categorized under moderately resistant. Thus these observations are in conformity with the present findings.

3.4 Biophysical bases of resistance in different soybean genotypes

3.4.1 Leaf succulency

Significant difference was observed in respect to leaf succulency expressed as relative water content (Table 4) in various soybean genotypes at 25 DAS. Among the different genotypes screened during the present study, lower leaf succulency was noticed in the genotypes AMS 115 and AMS 1002 with 76.40 per cent each. However genotype KDS 743 recorded higher leafsucculancy i.e. 91.09 per cent.

The data depicted Table 4 indicated that there were significant differences among the soybean genotypes in respect to leaf succulency at 40 DAS. Among the soybean genotypes, lower leaf succulency was recorded in AMS 1002 (41.11%), which at par with AMS 104, AMS 115, JS 2029, AMS MS 5-18, DS 2705, RVS 2001-18, SL 979, AMS 9933, MACS 1410, MACS 1370, NRC 93 and DSB 23-2 in which 41.87, 42.25, 42.30, 42.33, 43.22, 44.46, 44.46, 45.07, 45.17, 46.14, 47.24 and 47.57 per cent leaf succulency was noticed, respectively. The genotypes DSB 25 recorded higher leaf succulency of 59.64 per cent.

3.4.2 Leaf thickness
The data presented in Table 4 pertaining to leaf thickness expressed as specific leaf weight g/cm^2 recorded at 25 DAS revealed significant differences amongst the soybean genotypes. Maximum leaf thickness was noticed at resistance check JS 2029 (0.33 g/cm^2) that was on par with AMS 115 and RVS 2001-18 which recorded 0.29 g/cm^2 leaf thickness each. The genotype KDS 743 recorded lower leaf thickness (0.14g/cm^2).

Table 4: Biophysical traits in different soybean genotypes

Genotypes	Leaf succulency (%) at 25 DAS	Leaf succulency (%) at 40 DAS	Leaf thickness (gm/cm^2) at 25 DAS	Leaf thickness (gm/cm^2) at 40 DAS	Leaf area (cm^2) at 25 DAS	Leaf area (cm^2) at 40 DAS	Leaf trichomes at 25 DAS	Leaf trichomes at 40 DAS	Yield in q /ha
AMS 9933	85.03	45.07	0.25	0.33	21.75	46.26	709	794	6.40
DS 2705	84.11	43.22	0.24	0.35	23.71	46.39	783	741	5.64
AMS MS 5-18	78.11	42.33	0.24	0.35	26.27	52.55	698	825	4.14
MACS 1370	84.83	46.14	0.24	0.31	27.11	40.53	698	698	4.98
DSB 23 2	85.25	47.57	0.21	0.30	28.10	41.61	571	540	3.94
AMS 1002	76.40	41.11	0.28	0.50	23.17	41.14	794	815	5.28
DSB 25	88.17	59.64	0.17	0.19	25.83	41.48	254	286	4.62
NRC 94	89.72	52.01	0.18	0.24	23.68	38.47	307	381	4.42
SL 979	84.08	44.46	0.24	0.33	20.45	33.40	698	730	4.02
NRC 93	85.27	47.24	0.22	0.31	23.83	40.97	571	603	5.64
AMS 115	76.40	42.25	0.29	0.48	24.46	30.95	836	857	6.71
KDS 743	91.09	53.37	0.14	0.24	23.92	37.98	212	212	4.21
RVS 2001-18	80.64	44.46	0.29	0.34	26.58	47.01	825	836	7.04
MACS 1410	84.11	45.17	0.23	0.31	32.11	45.10	635	698	3.37
BAUS 96	85.97	48.67	0.20	0.29	25.50	40.32	487	540	5.70
SL 955	86.07	49.25	0.19	0.27	25.62	41.14	413	476	4.53
KDS 726	85.60	48.71	0.19	0.29	28.50	46.38	444	540	5.91
AMS 104	76.99	41.87	0.25	0.49	24.09	38.95	751	783	4.90
JS 335 (S)	87.34	50.17	0.19	0.26	33.30	40.08	392	444	4.56
JS 2029 (R)	78.11	42.30	0.33	0.46	24.82	37.29	857	889	7.56
F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m) ±	3.28	2.72	0.16	0.03	1.94	2.28	30.72	23.03	0.36
CD at5%	9.09	7.53	0.43	0.07	5.38	6.33	85.13	63.82	0.94
CV	6.79	10.06	11.75	13.17	13.13	9.53	8.97	6.29	12

The results tabulated in Table 4 revealed that there were significant differences amongst the soybean genotypes in respect of leaf thickness at 40 DAS. The genotypes AMS 1002, AMS 104, AMS 115 and resistance check JS 2029 recorded significantly maximum leaf thickness of 0.50, 0.49, 0.48 and 0.46 g/cm^2, respectively. The genotype DSB 25 recorded lower leaf thickness of 0.19 g/cm^2.

3.4.3 Leaf area
The data in Table 4 indicated significant differences amongst the soybean genotypes in respect of leaf area at 25 DAS. Among the genotypes significantly lowest leaf area was observed in SL 979 (20.45 cm^2). It was found at par with AMS 9933, AMS 1002, NRC 94, DS 2705, NRC 93, KDS 743, AMS 104, AMS 115, JS 2029, BAUS 96, SL 955 and DSB 25 in which 21.75, 23.17, 23.68, 23.71, 23.83, 23.92, 24.09, 24.46, 24.82, 25.50, 25.62 and 25.83 cm^{2}leaf area was recorded, respectively. Whereas, the maximum leaf area was noticed in susceptible check JS 335 (33.30cm^2).
The leaf area indicated significant differences among the soybean genotype at 40 DAS (Table 4). Among the different genotypes screened during the present study AMS 115 recorded lowest leaf area of 30.95 cm^2 and found at par with SL 979 (33.40cm^2). However, the maximum leaf area was noticed in AMS MS 5-18 (52.55 cm^2).

3.4.4 Leaf trichome density
The data depicted in Table 4 revealed that there were significant differences amongst the soybean genotypes lines in respect to trichome density at 25 DAS recorded on abaxial surface of leaf. Significantly the maximum number of trichomes were recorded on the resistance check JS 2029 i.e. 857 trichomes / cm^2 was statistically at par with the genotype AMS 115 and RVS 2001-18 in which 836 and 825 trichomes per cm^2 were observed, respectively. Whereas, lowest number of trichome were observed on KDS 743 (212 trichomes/cm^2).
The data presented in Table 4 indicated significant differences in soybean genotypes pertaining to trichome density. The trichome density ranged between 889 to 212 trichomes/cm^2 in different genotypes at 40 DAS. Among the genotypes screened during the present study, the resistant check JS 2029 recorded significantly maximum numbers of trichomes on abaxial surface of leaf (889 trichomes/cm^2). It was closely followed by AMS 115, RVS 2001-18, AMS MS 5-18 and AMS 1002 with 857, 836, 825 and 815 trichomes/cm^2, respectively. All these entries were found to be at par with each other. Whereas, minimum number of trichomes were noticed in and KDS 743 (212 trichomes/cm^2).

3.5 Yield obtained from different soybean genotypes.

The data presented in Table 4 indicated significant differences among soybean genotypes in respect of yield. Among the genotypes highest yield was obtained from resistant check JS 2029 (7.56 q/ha) which was found at par with RVS 2001-18 (7.04 q/ha) and AMS 115 (6.71 q/ha).Whereas, MACS 1410 recorded minimum yield of 3.37 q/ha. In the present investigation, the results obtained are in agreement with the earlier workers who recorded lowest pest incidence and higher yield in less susceptible genotypes [10, 9]. Similarly [18] reported that the cultivars showing lowest defoliation by caterpillars has good yield and should be recommended for cultivation.

3.6 Correlation between defoliator resistances contributing biophysical parameter

The data tabulated in Table 5 revealed a positive significant correlation between leaf succulacy and per cent leaf damage at 25 DAS (r = 0.877) and at 40 DAS (r = 0.743). Whereas, the relationship between leaf succulency and semilooper larval population at 25 DAS was positive but non-significant (r = 0.004) and negative but non-significant (r = -0.078) at 40 DAS. The data further revealed a positive but non-significant relationship between leaf succulancy and *Spodoptera* larvae (r = 0.186, 0.360) at 25 and 40 DAS, respectively. Similarly, correlation studies revealed the negative relationship between per cent leaf damage with a thickness (r = -0.793, -0.789) at 25 and 40 DAS. Further, the simple correlation studies revealed a negative non-significant correlation between semilooper and *Spodoptera* larval population with leaf thickness (r = -0.159, -0.002 and r = -0.344, -0.198) at 25 and 40 DAS, respectively.

The simple correlation studies confirmed that there was a significant positive relationship between per cent leaf damage and leaf area at 25 DAS (r = 0.451) but negative and non significant at 40 DAS(r = -0.017). The correlation studies revealed positive but non-significant relationship between semilooper larvae and leaf area at 25 DAS(r = 0.283) and negative non-significant at 40 DAS (r = -0.044). Further, the relationship between *Spodoptera* larval population and leaf area was positive but non-significant at 25 and 40 DAS (r = 0.167, 0.127). The result of leaf trichome density on abaxial surface at 25 and 40 DAS recorded negative and significant association with larval population of *Spodoptera* (r = -0.459, -0.463) and per cent leaf damage (r = -0.821, -0.835). Further, the relationship between larval population of semilooper and trichome density on abaxial leaf surface at 25 and 40 DAS showed negative but non-significant relationship (r = -0.079, -0.042).

The biophysical traits in plants may interfere with the mechanism of host selection, feeding, ingestion, digestion, mating, ovipositon and use by insect pest. The results of the present findings pertaining to the biophysical parameters such as leaf succulency, leaf thickness, leaf area and trichome density recorded on 25 and 40 DAS in order determine the role of morpho-physiological plant factors, which contribute towards resistance against defoliators finds support in the work carried out by the earlier workers. [12] suggested that genotypes of *Arachis hypogoea* with profuse hairiness of leaves were less preferred by *S. litura* larvae than other morphological types. However, [13] reported that leaf area and moisture contents showed positive correlation with soybean looper in festation (0.426, 0.821, respectively). The leaf hair density on abaxial surface of leaf has significantly negative correlation (-0.926, respectively) with this insect pest. Whereas, [14] concluded from their studies that the pubescence density on adaxial leaf surface of soybean were found to be important in determining resistance to *Spilosoma obliqua.* Similarly, [15] studied the morphological features in five soybean cultivars, revealed that leaf area and trichome density on abaxial leaf surface were positively associated with the resistance. In resistant varieties, leaf petioles were with lower moisture content as compared to susceptible varieties.

The present results on the bio-physical traits are also similar to the findings of [16] who reported that relationship between leaf succulency and larval population of defoliators, *S. litura* and *T. orichalcea* were positive, but non-significant at 45 DAS (r= 0.278, 0.333), whereas, per cent leaf damage (r=0.778) recorded significant positive relationship. Further, they reported that similar relationship existed between leaf area both with larval population and per cent foliar damage. While, it was observed that there was a negative non-significant relationship between leaf thickness with *S. litura* and *T. orichalcea* at 45 DAS. Whereas, a negative significant correlation was noticed between leaf thickness and per cent leaf damage (r= -0.632). [17] reported a highly significant negative correlation between leaf hair density and per cent infestation for *S.obliqua*, *S. litura and T. orichalcea*. Thus, confirms the present findings.

Table 5: Correlation between defoliator resistance contributing biophysical parameter

Traits	% leaf Damage		Semiooper larval population		*Spodoptera litura* larval population	
	25DAS	40DAS	25DAS	40DAS	25DAS	40DAS
Leaf Succulency	0.877*	0.743*	0.004	-0.078	0.186	0.360
Leaf thickness	-0.793*	-0.789*	-0.159	-0.002	-0.344	-0.198
Leaf area	0.451*	-0.017	0.283	-0.044	0.167	0.127
Trichomes density	-0.821*	-0.835*	-0.079	-0.042	-0.459*	-0.463*

* Correlation coefficients significant at $P = 0.05$ (r = 0.444).

4. Conclusion

It may be concluded from the present study that comparative resistance against defoliators measured in terms of increase reflection of their population in soybean varied with their genotypes tested. These variations were found to be mainly associated with the changes in various biophysical traits viz., leaf succulancy, leaf thickness, leaf area and trichome density. Leaf succulency was positively and significantly associated with per cent leaf damage by defoliators. The leaf area recorded at 25 DAS also has positive correlation with the per cent leaf damage. While, leaf thickness and trichome density on the leaf surface were significantly and negatively associated with leaf damage percentage. Moreover, trichome density has significantly negative correlation with incidence of *Spodoptera* larvae.

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