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Bionomics of whitefly on soybean cultivars under laboratory conditions

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Abstract
Biology of *Bemisia tabaci* was carried out on eight soybean cultivars, in controlled laboratory conditions (25± 2 ^{0}C, 70±10% RH, 13 photophase). Plants at the trifoliate stage were placed in plastic cages and a pair of whitefly/cage was released for 72 hrs. The development was observed until adult emergence. Adult emergence percentage was highest on cultivar JS 335 (96.30%) followed by RVS- 2001-4, JS 97-52, JS 20-69, JS 20-98, NRC 86, JS 20-29 and RVS- 24 (95.83%, 94.44%, 91.67%, 86.67%, 75.56%, 75.00% and 63.89%) while the total developmental period from egg to adult on the soybean cultivars varied and it was lowest (16.59 days) on JS-335, followed by JS-97-52 (17.94 days), RVS- 2001-4 (18.76 days), JS 20-69 (21.83 days), JS 20-98 (23.14 days), RVS- 24 (23.18 days), JS 20-29 (23.36 days) and highest (23.99 days) on NRC 86, respectively.

Keywords: *Bemisia tabaci,* soybean, bionomics, development

Introduction

Soybean (*Glycine max* L.) is considered as "Miracle Crop" or "Wonder Crop" owing to its good quality vegetable protein and edible oil. There is a gradual reduction in the soybean yield because of various problems in the field, such as interference from plant intruder organisms (pests and diseases). Whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is one of the most serious, cosmopolitan sucking pest that causes severe yield losses in soybean. This insect causes both direct and indirect damage to plants. Direct damage occurs due to the nymphs and adults feeding on the phloem sap, which compromises the plant's vegetative and reproductive development. While, the indirect damage is due to the insects' excretion of honeydew during the feeding process, which serves as a substrate for the growth of sooty mold. Sooty mold darkens foliage, affecting the plants' ability to photosynthesize [1, 2]. Furthermore, whiteflies are also considered one of the most important virus vectors for several economically important crops [3]. To improve the ecologically based management of the pest, the behaviour of the pest such as the host preference and oviposition should be known [4]. It prefers the leaves having thick trichomes for egg-laying and it lays stalked eggs [5]. In resistant cultivars very few number of eggs hatch into nymphs [6] and period of the developmental stages is also affected [7]. The number of adults developing from nymphs also decreases due to antibiosis [8]. Considering the damage caused by whiteflies and the fact that controlling them mainly involves massive spraying of synthetic insecticides, it is important to search for new tools that can be used to manage this pest. In this sense, the adoption of resistant genotypes may represent an important avenue of investigation. Therefore, the present studies were designed to evaluate some biological aspects of *B. tabaci* on eight cultivars of soybean.

Materials and Methods

Studies on the biology of *B. tabaci* were carried out on eight soybean cultivars (*viz.*, JS 335, JS 20-29, JS 20-69, JS 20-98, JS 97-52, RVS- 24, RVS- 2001-4 and NRC 86) in the Biocontrol Research and Production Centre, Department of Entomology, JNKVV, Jabalpur (M.P.) during the year 2017-2018. During the study period the average temperature and relative humidity were maintained at 25±2 ºC and 70±10%, respectively with 13 hours of photophase period as suggested by (Oriani *et al*., 2011) [9]. The culture of *B. tabaci* was multiplied and maintained on the potted plants of soybean variety JS 335. Initially whitefly adults were collected from the field using an aspirator and were released on the soybean plants which were kept inside the screen house. The second generation of the non-virulent *B. tabaci* adults were used for the study of their biology (Gopaldas *et al*., 2018) [10].

Different immature stages and adults of whitefly were obtained from the culture for the experiment. Soybean cultivars were raised in small pots (50x40 cm) under caged condition (80 mesh) in the walk-in BOD chamber. Each variety was maintained with 3 plants /cage and replicated 3 times. The males and females of *B. tabaci* were identified based on the abdominal tips, size, and compound eyes. The females are bigger in size, have prominent dark brown colored compound eyes with smoky white wings and pale yellow broader abdomen, blunt abdominal tips, with an ovipositor, while the males are smaller in size and have narrow abdominal tips with a pair of claspers [11]. Moreover, fore and hind wings and antennae of females were larger than those of males [12, 13]. Further during mating, the males raise pair of wings on females [14]. After 72 hours of release, the adults were removed from the cages. However, the numbers of eggs laid on the seedlings of each cage were examined after 24, 48, and 72 hours of release. To study the incubation period of the eggs which were laid on the leaves of the seedlings were marked with marker for easy recognition. Daily observations were made to note the changes in the eggs. The length and breadth of the eggs were measured by using an ocular micrometer. The incubation period, hatching (%) and survival from egg to adult, duration, and measurement of various immature stages and adult emergence were recorded. The length of the immature stages was recorded by placing the ocular meter on the body in vertical position and breadth was recorded by placing it on the widest portion of the body.

Statistical Analysis

The whitefly, *B. tabaci,* biology, mortality, length, and width were studied by using mean and standard deviation.

Results and Discussion

The *B. tabaci* females laid eggs singly on the lower surface of the leaves. The eggs are very small with a tube-like structure called stalk or pedicel, which helps the eggs to get attached to the leaf surface and transports the water from the tissues to the eggs. The present findings confirm the findings of Diez (2007) [15], Kumarasinghe *et al*. (2009) [16], Kedar *et al.* (2014) [11] and Gopaldas (2018) [10], as they also reported that the eggs of *B. tabaci* are whitish-yellow in colour and spindle shape. Highest egg laying was observed in cultivar JS-335 (34eggs) and JS 97-52 (28eggs) followed by RVS-2001-4, NRC 86, JS 20-29, JS 20-69 (27,23,22,20eggs) and lowest on JS 20-98 and RVS-24 (19eggs) (Table 1). The preference and variation in the oviposition might be attributed to the presence of trichomes and their density on the leaves. Presence of dense trichomes on soybean rendered it vulnerable for egg-laying (Mansaray and Sundufu 2009 [17]; Khan *et al*. 2010 [4]; Vieira *et al*. 2011[6]; Baldin *et al*. 2012 [18]; Taggar and Gill 2012 [19]; Valle *et al*. 2012 [20] and Hasanuzzaman *et al*. 2016 [21]). The mean incubation period on the eight soybean cultivars varied and it was lowest on JS-335 (5.42 days) followed by JS 97-52 and RVS 2001-4 (5.91days) while it was highest in cultivar RVS- 24, NRC 86, JS 20-69, JS 20-98 and JS 20-29 (6.72,6.96,7.14,7.69 and 7.94). The highest hatching percentage was recorded on the susceptible cultivar, JS-335 (94.59%) and least hatching percentage was recorded on JS 20-29 (81.55%) (Table 1)

Table 1: Impact of soybean cultivars on oviposition and egg development of *Bemisia tabaci*

Soybean cultivars	Mean no. of eggs			Incubation period (days)
	Laid	Hatched	Hatching %	
JS 335	34	32	94.59	5.42
JS 20-29	22	18	81.55	7.94
JS 20-69	20	17	86.31	7.14
JS 20-98	19	16	83.33	7.69
JS 97-52	28	23	82.37	5.91
RVS-24	19	16	84.13	6.72
RVS-2001-4	27	25	92.59	5.91
NRC 86	23	19	82.14	6.96
Mean ± SD	24.00 ± 5.29	20.75± 5.60	71.11± 4.99	6.71 ± 0.89
SEm±	-	-	7.93	0.26
CD at 5%	-	-	NS	0.79

Newly emerged first instar nymphs are known as crawlers. The mean developmental period of the crawlers on the soybean cultivars was significant. It was highest on resistant cultivars *viz.* NRC 86, JS 20-98, JS 20-29, RVS- 24 and JS 20-69 (3.68, 3.66, 3.61, 3.53 and 3.49 days), followed by tolerant cultivar, RVS- 2001-4 and JS 97-52 (3.65 and 3.51 days), while it was lowest on susceptible cultivar JS 335 (2.54 days) (Table 2). Thus the developmental period of crawlers was minimum on the susceptible cultivar followed by tolerant and resistant cultivar, respectively. The present findings confirm with the findings of Salas and Mendoza (1995) [22]; Kedar *et al*. (2014) [11], Silva *et al*. (2012) [23] and Gopaldas (2018) [10]. They also reported that the mean developmental period of the first instar nymphs was 4.01±1.0 days on tomato and 3 to 5 days on cotton while on resistant soybean genotype it was 1.61±0.10 days and lowest (1.00±0.00 days) in susceptible cultivar, respectively. This indicates that resistant cultivar extends the developmental period of the crawlers, which may be attributed to the presence of some degree of antibiosis factor. Silva *et al*. (2012) [23] and Sulistyo and Inayati (2016) [8].

The freshly moulted second instar nymphs were oval, flat, and whitish-yellow in colour. The mean developmental period was highest on cultivar RVS- 24 (3.67 days) and lowest on JS 97-52 (2.52 days). The third instar nymphs were also oval and flat, initially, it appeared pale yellow and gradually turned dark yellow after feeding and mycetomes continued to be visible. The highest developmental period was observed on resistant cultivar NRC 86 (4.67days), followed while it was lowest on tolerant and susceptible cultivars RVS- 2001-4, JS 335, and JS 97-52 (2.62, 2.55 and 2.48 days) (Table 2). The present findings conform to the findings of Salas and Mendoza (1995) [22] and Silva *et al*. (2012) [23]. They also reported that the mean developmental period of third instar nymphs on tomato was 2.5±0.7 days while it was 3.26±0.35 and 2.10±0.10 days on resistant and susceptible tomato cultivars, respectively. The fourth instar nymphs or pseudopupa was oval shape and yellowish in colour. Well developed reddish-brown coloured compound eyes were distinctly visible. The mean developmental period was highest on cultivar RVS- 24 (5.61days) and lowest on cultivar JS 97-52 (3.52 days) (Table 2)

Table 2: Impact of soybean cultivars on the total developmental period of *Bemisia tabaci*

Soybean cultivars	Mean incubation period (days)	Mean developmental period of immature stages (days)					Total period (egg to adult) (days)
		Crawler (I^{st} instar)	II^{nd} instar nymphs	III^{rd} instar nymphs	IV^{th} instar nymphs/ Pseudo pupa	Total	
JS 335	5.42	2.54	2.55	2.55	3.53	11.17	16.59
JS 20-29	7.94	3.61	3.59	3.57	4.65	15.42	23.36
JS 20-69	7.14	3.49	3.42	3.39	4.39	14.69	21.83
JS 20-98	7.69	3.66	3.55	3.61	4.63	15.45	23.14
JS 97-52	5.91	3.51	2.52	2.48	3.52	12.03	17.94
RVS-24	6.72	3.53	3.67	3.65	5.61	16.46	23.18
RVS-2001-4	5.91	3.65	2.65	2.62	3.93	12.85	18.76
NRC 86	6.96	3.68	3.50	4.67	5.18	17.03	23.99
Mean ± SD	6.71 ±0.89	3.45 ±0.37	3.18 ±0.51	3.32 ±0.74	4.43 ± 0.75	-	-
Sem ±	0.26	0.09	0.11	0.12	0.23	-	-
CD at 5%	0.79	0.28	0.32	0.37	0.70	-	-

In the present study length and width of eggs measured 0.149 and 0.131 mm on susceptible cultivars, while it was 0.144 and 0.126 mm on tolerant cultivars and 0.136 and 0.121mm on resistant cultivars, respectively. The results indicate that bigger size eggs were found to be more abundant on the susceptible cultivar, followed by tolerant and smaller size eggs on the resistant cultivar. On the contrary, Gopaldas 2018 [10], reported length and width of 0.129±0.046mm and 0.113±0.022mm on susceptible cultivar (JS-335), 0.126± 0.045 mm and 0.113±0.022mm on tolerant cultivar (JS-97-52) and 0.124±0.044mm and 0.112±0.022 mm on resistant cultivar (JS-20-98), respectively.

Differences in the crawler length were found to be significant. The length of the crawler was maximum on cultivar JS 335 (0.269 mm) however minimum length was observed on the cultivar RVS- 24 (0.230mm) (Table 3). The differences in the crawler width was also significant. Cultivar JS 335 recorded maximum width (0.197mm), while minimum crawler width was observed on cultivar RVS- 24 and NRC 86 (0.158 and 0.150mm) with no significant difference among them.

The maximum length of II^{nd} instar nymphs was observed on JS 335 (0.356 mm), while it was minimum on NRC 86 (0.334mm) (Table 3). The maximum width of II^{nd} instar nymphs was observed on cultivar JS 335 (0.250 mm) and minimum on JS 20-69 (0.215mm).

The length and width of third instar nymphs was maximum (0.448 and 0.347 mm, respectively) which developed on susceptible cultivar (JS 335), followed by tolerant cultivars, JS 97-52, RVS- 2001-4 (0.430 and 0.322mm, respectively), whereas it was minimum (0.428 and 0.311mm, respectively) on resistant cultivar (JS 20-29, JS 20-69, JS 20-98, RVS- 24 and NRC 86) (Table 3). The results indicate that the third instar nymphs attained luxuriant growth on susceptible cultivar while tolerant and resistant cultivars had a negative influence on its development. Similar findings have been reported by Gopaldas (2018) [10].

The length and width of fourth instar nymphs / pseudo pupae which developed on cultivar JS 335 was maximum (0.549 and 0.450mm), followed by tolerant cultivars JS 97-52 and RVS-2001-4 (0.532mm and 0.439mm) and minimum (0.529 and 0.420mm) on resistant cultivars (JS 20-29, JS 20-69, JS 20-98, RVS- 24 and NRC 86). The present findings contradict the findings of Auslane and Smith (2000) [24], as they reported that the average length of fourth instar nymphs on tomato cultivars was 0.662mm. The results indicate that bigger size fourth instar nymphs were found to be more abundant on the susceptible cultivar followed by tolerant and resistant cultivar, respectively.

Differences in the length of an adult male were nonsignificant. Maximum length was observed on cultivars JS 335 and minimum on NRC 86 (0.812 mm) (Table 3). Similarly, differences in the wingspan of an adult male were nonsignificant. The maximum width of the wingspan of an adult male was observed on JS 335 (1.815mm) and minimum on NRC 86 (1.732mm) (Table 3).

Differences in the adult female length were found to be nonsignificant. JS 335 recorded maximum length of 0.865mm, followed by JS 20-29 and JS 97-52 (both registered 0.863 mm), RVS- 2001-4 (0.856mm), JS 20-29 (0.854 mm), RVS- 24 and NRC 86 (both recorded 0.845mm) and JS 20-98 (0.843mm), respectively (Table 3). Similarly, differences in the wingspan of adult females were nonsignificant. Maximum wingspan was observed on cultivar JS 97-52 (2.172 mm) and minimum on RVS- 24 (2.129mm) (Table 3).

Table 3: Impact of soybean cultivars on size of immature and adults of *Bemisia tabaci*

Soybean cultivars	Mean size of immature stages of whitefly (mm)													
	Egg		Crawler		Nymph				Pseudo nymph / Pre pupa		Adults			
					2^{nd} instar		3^{rd} instar				Male		Female	
	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Wing span	Length	Wing span
JS 335	0.149	0.131	0.269	0.197	0.356	0.250	0.448	0.347	0.549	0.450	0.834	1.815	0.865	2.170
JS 20-29	0.143	0.126	0.249	0.169	0.343	0.236	0.438	0.335	0.540	0.441	0.830	1.767	0.854	2.145
JS 20-69	0.139	0.126	0.247	0.159	0.342	0.215	0.433	0.297	0.531	0.408	0.826	1.747	0.863	2.138
JS 20-98	0.139	0.102	0.238	0.160	0.345	0.219	0.429	0.319	0.536	0.429	0.816	1.737	0.843	2.130
JS 97-52	0.144	0.126	0.255	0.188	0.346	0.222	0.429	0.323	0.534	0.439	0.834	1.809	0.863	2.172
RVS-24	0.129	0.113	0.230	0.158	0.352	0.231	0.407	0.296	0.521	0.411	0.817	1.733	0.845	2.129

RVS-2001-4	0.145	0.126	0.247	0.186	0.355	0.236	0.431	0.321	0.529	0.440	0.828	1.795	0.856	2.147
NRC 86	0.133	0.112	0.231	0.150	0.334	0.220	0.434	0.309	0.521	0.411	0.812	1.732	0.845	2.139
Mean ± SD	0.140± 0.007	0.120± 0.010	0.246± 0.013	0.171± 0.017	0.347± 0.007	0.229± 0.012	0.431± 0.012	0.318± 0.018	0.533± 0.009	0.429± 0.016	0.824± 0.009	1.767 ±0.035	0.854 ±0.009	2.146 ±0.017
SEm±	0.005	0.005	0.006	0.003	0.010	0.011	0.006	0.007	0.006	0.006	0.137	0.292	0.174	0.436
CD at 5%	NS	0.014	0.018	0.010	NS	NS	0.019	0.020	NS	0.020	NS	NS	NS	NS

The survival percentage of various immature stages on the soybean cultivars varied. It was maximum in susceptible cultivar, JS 335 (94.59% crawler, 96.30%, second instar nymph, 97.44% third instar nymph and pseudopupa, 89.72%, respectively). This was followed by tolerant cultivar, JS-97-52 (82.37% crawler, 92.59% second instar nymphs, 95.24% third instar nymphs and 84.92% pseudo pupa) and RVS-2001-4 (92.59% crawler, 96.30% second instar nymphs, 95.83% third instar nymphs and 91.67% pseudopupa). The survival percentage was minimum in all the resistant cultivar, JS 20-69 (86.31% crawler, 88.57% second instar nymphs, 87.78% third instar nymphs and 60.00% pseudopupa), JS 20-98 (83.33% crawler, 86.90% second instar nymphs, 88.89% third instar nymphs and 83.33% pseudopupa), RVS- 24 (84.13% crawler, 86.11% second instar nymphs, 94.44% third instar nymphs and 73.33% pseudopupa), JS 20-29 (81.55% crawler, 88.57% second instar nymphs, 94.44% third instar nymphs and 80.00% pseudo pupa) and NRC 86 (82.14% crawler, 86.11% second instar nymphs, 88.89% third instar nymphs and 85.00% pseudopupa). The present findings confirm with the findings of Fancelli and Vendramim (2002) [25], they reported that the total survival percentage of immature stages was 86.9% ± 2.1% and 42.3 ± 9.7% on *Lycopersicon* spp.cv. LA1739 and LA1609 respectively (Table 4). Maximum mortality of all the immature stages *viz.*, egg, crawler, second instar nymph, third instar nymph, pseudo pupa was observed on resistant cultivars, JS 20-29, JS 20-69, JS 20-98, RVS- 24, and NRC 86 (16.51, 12.75, 9.11, 23.67 and 21.44%, respectively) followed by tolerant cultivars JS 97-52 and RVS- 2001-4 (12.52, 5.56, 4.47, 11.71 and 4.87%, respectively) and minimum on the susceptible cultivar, JS 335 (5.41, 3.7, 2.56, 10.28 and 3.7%, respectively),

Table 4: Impact of soybean cultivars on egg hatching, emergence and mortality of different immature stages and adults of *Bemisia tabaci*

Soybean cultivars	Hatching (H) and mortality (M) (%) (Egg to Crawler)		Emergence (E) and mortality (M) (%)								Cumulative mortality (egg to adult) (%)
			Crawler to II^nd instar nymphs		II^nd to III^rd instar nymphs		III^rd to IV^th instar nymphs / Pseudo pupa		IV^th instar nymphs / Pseudo pupa to adult		
	H	M	E	M	E	M	E	M	E	M	
JS 335	94.59	5.41	96.30	3.70	97.44	2.56	89.72	10.28	96.30	3.70	27.77
JS 20-29	81.55	18.45	88.57	11.43	94.44	5.56	80.00	20.00	75.00	25.00	54.54
JS 20-69	86.31	13.69	88.57	11.43	87.78	12.22	60.00	40.00	91.67	8.33	65.00
JS 20-98	83.33	16.67	86.90	13.10	88.89	11.11	83.33	16.67	86.67	13.33	57.83
JS 97-52	82.37	17.63	92.59	7.41	95.24	4.76	84.92	15.08	94.44	5.56	42.85
RVS-24	84.13	15.87	86.11	13.89	94.44	5.56	73.33	26.67	63.89	36.11	68.42
RVS-2001-4	92.59	7.41	96.30	3.70	95.83	4.17	91.67	8.33	95.83	4.17	25.92
NRC 86	82.14	17.86	86.11	13.89	88.89	11.11	85.00	15.00	75.56	24.44	60.86

Conclusion

Among the eight soybean cultivars, JS 335 was found to be highly susceptible to whitefly and is evident by maximum oviposition and hatching coupled with short developmental period of various immature stages, least mortality, and high survival percentage. However, cultivars JS 97-52 and RVS-2001-4 were found to be tolerant and cultivars JS 20-29, JS 20-69, JS 20-98, RVS- 24, and NRC 86 were found to be resistant to whitefly having a detrimental effect on the biology of whitefly *i.e.* less oviposition and hatching, with a prolonged developmental period, high mortality coupled with less survival percentage.

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