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Evaluation of Some Promising Soybean Genotypes to Infestation with Cotton Leafworm (*Spodoptera littoralis*) under Field Conditions

Eman Ibrahim Abdel-Wahab[1*], Magda Hanna Naroz[2]

[1]Food Legumes Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt
[2]Economic Entomology and Pesticides, Faculty of Agriculture, Cairo University, Giza, Egypt
Email: *eman00eman70@yahoo.com

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Abstract

A two-year study was carried out in Giza Agricultural Experiments and Research Station, Agricultural Research Center (ARC), Giza, Egypt in the 2020 and 2021 summer seasons to evaluate the relative tolerance of ten soybean genotypes for cotton leafworm infestation under field conditions. Soybean genotypes $H_{11}L_{145}$, H_{155}, H_{113}, H_4L_4, $H_{15}L_{17}$, H_{129}, H_{30}, $H_{19}L_{96}$, Giza 111, and Crawford were distributed in randomized complete blocks design with three replications. Soybean genotypes differed significantly for cotton leafworm at the 6th, 7th, and 8th week from sowing. Low values of cotton leafworm assemblages were recorded for H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129}. Low percentages of the larval survival number and weight, as well as the number of the survival of pupa were recorded by feeding on leaves of genotypes H_4F_4, $H_{15}L_{17}$, and Giza 111 under laboratory conditions. There were significant differences among the studied genotypes in most yield attributes in both seasons. Soybean genotypes $H_{15}L_{17}$, Giza 111, H_{113}, H_{129}, $H_{19}L_{96}$, and H_4L_4 gave higher seed yield per ha, meanwhile soybean genotypes H_{155}, $H_{19}L_{96}$, H_{30}, Giza 111, and $H_{15}L_{17}$ had higher seed oil content than the other genotypes in both seasons. The number and weight of larvae surviving, as well as the number of pupa survival, were negatively correlated with leaf total phenols and seed oil content. It can be concluded that soybean genotypes $H_{15}L_{17}$, H_4L_4, and Giza 111 are promising genotypes with desirable seed oil content for tolerating cotton leafworm infestation in breeding programs.

Keywords

Soybean Genotypes, Cotton Leafworm, Seed Yield, Seed Oil Content, Phenotypic Correlation

1. Introduction

Recently, the Egyptian government, represented by the Ministries of Agriculture, Trade, Industry, and Supply, began to face a deficiency of oils corn, canola, sunflower, cotton seeds, and soybeans. Thus, in light of the Egyptian government's tendency to try to reduce the gap between oil consumption and production, specialists breed plant varieties characterized by high levels of edible oil [1]. The soybean (*Glycine max* (L.)) crop is a very important economic crop due to that it is accounting for 58% of the world's oil seed production [2]. However, the soybean crop is attacked by cotton leafworm (*Spodoptera littoralis* (Boisd.)) which is considered the major pest throughout its growing season [3]. This insect represents a serious problem due to its ability to attack more than 112 host plants [4]. This insect is spread in the Middle East, Africa, and Europe [5]. Some colleagues identified the cotton leafworm and they controlled it by spraying the field with different insecticides which can be contained organophosphate, carbamate, or a pyrethroid. Unfortunately, some individuals (whether merchants or farmers) used these insecticides in an unsuitable technique at higher concentrations than recommended. Consequently, excessive use of cotton leafworm insecticides led to adverse effects on the agricultural environment such as pest tolerance and resurgence, as well as the appearance of other pests. Due to the appearance of high tolerance for many insecticides [6], there is an urgent interest to use soybean genotypes that can tolerate insect infestation.

According to Hanley *et al.* [7], the defensive compounds are either produced as a response to soybean leaves damage or constitutively to affect the feeding, growth, and survival of cotton leafworm. Direct (mechanical) and indirect (physiological and chemical) defense mechanisms can be present constitutively or induced after cotton leafworm infestation. Soybean genotypes can differ in some morphological characteristics due to their genetic variations [8]. Pubescence that is one of the morphological characteristics can play a considerable role in plant growth and development by protecting from herbivore attacks [9]. Additionally, cotton leafworm infestation can alter soybean physiology and chemistry. In this concern, Abdel-Wahab *et al.* [10] reported that reduced total phenols of some soybean cultivars played an important role in herbivores' attack. Particularly, Serag *et al.* [11] showed that soybean cultivars Giza 111, Giza 22, Giza 83, Giza 21, and Giza 35 can tolerate cotton leafworm infestation with an acceptable level. Moreover, they added that Celest, Forrest, and MBB-80-133 have previously identified as sources of resistance for cotton leafworm through National Legume Research Program a few years ago. To make an effective evaluation of cotton leafworm with soybean seed yield and its oil contents is necessary through studying phenotypic simple correlation coefficients. Seed yield was positively associated with leaf pubescence density, but oil percentage was insignificant and negatively associated with pubescence density [12]. So, the objective of this study was to evaluate the relative tolerance of ten soybean genotypes for cotton leafworm infestation under field conditions.

2. Materials and Methods

The experiments of the present study were carried out at Giza Agricultural Research Station (Lat. 30˚00'30''N, Long. 31˚12'43''E, 26 m a.s.l), Agricultural Research Center (ARC) during 2020 and 2021 summer seasons to evaluate the relative tolerance of ten soybean genotypes for cotton leafworm infestation under field conditions. Soybean genotypes $H_{11}L_{145}$, H_{155}, H_{113}, H_4L_4, $H_{15}L_{17}$, H_{129}, H_{30}, $H_{19}L_{96}$, Giza 111, and Crawford have been tested for infestation of the cotton leafworm. The common names, pedigree, and origin of these genotypes are presented in Table 1. Table 2 shows the meteorological data of solar radiation, maximum and minimum temperatures, and relative humidity during the two summer seasons according to POWER Docs [13].

Table 1. The common names, pedigree, and origin of the studied soybean genotypes.

Soybean genotypes	Pedigree	Origin
$H_{11}L_{145}$	Giza 111 × HC83-123-9	Egypt
H_{155}	Giza 111 × L86-k73	Egypt
H_{113}	Giza 21 × Major	Egypt
H_4L_4	Dr101 × Lamar	Egypt
$H_{15}L_{17}$	Bershing × Giza 111	Egypt
H_{129}	Giza 35 × D76-8070	Egypt
H_{30}	Crawford × L62-1686	Egypt
$H_{19}L_{96}$	H_2F_{20} × PI-416-937	Egypt
Giza 111	Crawford × Celest	Egypt
Crawford	Williams × Columbus	U.S.A.

Table 2. The metrological data of solar radiation, maximum and minimum temperatures, and relative humidity during the 2020 and 2021 seasons.

Item	First season (2020)				Second season (2021)			
	Solar radiation (MJ/m²/day)	Max. Temp. (˚C)	Min. Temp. (˚C)	RH (%)	Solar radiation (MJ/m²/day)	Max. Temp. (˚C)	Min. Temp. (˚C)	RH (%)
June	28.98	36.53	19.11	41.50	29.24	36.89	19.48	41.40
July	27.94	38.81	21.58	42.90	28.02	39.27	22.48	41.15
August	26.42	38.89	22.00	45.33	25.98	39.73	22.90	42.80
September	24.59	38.54	21.93	47.88	22.67	35.92	20.83	50.99
October	18.74	33.30	19.13	57.28	18.48	31.52	17.72	55.18
Average	**25.33**	**37.21**	**20.75**	**46.97**	**24.87**	**36.66**	**20.68**	**46.30**

Furrow irrigation was the prevalent system in the region. Representative soil samples were taken from each site in the top 0 - 30 cm arable soil layer. The procedure of soil analysis followed the methods of Black [14]. The soil analysis indicated that the experimental soil is clay loamy (3.45% coarse sand, 30.64% fine sand, 28.33% silt and 37.58% clay in the 1st season, and 3.69% coarse sand, 31.02% fine sand, 29.46% silt and 35.83% clay in the 2nd season), the pH (paste extract) is 7.85 in the 1st season, and 7.93 in the 2nd season, the available nutrients in mg/kg are nitrogen (33.63 in the 1st season and 34.50 in the 2nd season), phosphorous (10.82 in the 1st season, and 11.13 in the 2nd season), and potassium (238 in the 1st season, and 265 in the 2nd season).

Wheat was the preceding winter crop in both seasons. Calcium super phosphate (15.5% P_2O_5) at the rate of 357 kg per ha was applied during soil preparation in the two summer seasons. Soybean seeds were inoculated with *Rhizobium japonicum* and gum Arabic was used as a sticking agent.

Thereafter, the soybean genotypes were seeded at density 20 plants per m in one row of the ridge. Soybean seeds were sown on 2nd June and 9th June in 2020 and 2021 seasons, respectively. Mineral N fertilizer was added at a rate of 35.7 kg N per ha as ammonium nitrate (33.5% N) before the first irrigation. Normal recommended cultural practices for growing soybean genotypes were used. A randomized complete block design with three replications was used. The experimental plots received all regular agricultural practices and chemical control was entirely avoided. The area of the plot was 10.8 m^2 with each plot consisting of six ridges and each ridge was 3.0 m in length and 0.6 m in width.

2.1. Data Recorded

2.1.1. Antibiosis Traits

1) Insect assemblages under field conditions

The susceptibility of soybean genotypes to the infestation with cotton leafworm was investigated at 45, 52, and 60 days (6th, 7th, and 8th week) from sowing in the both seasons. Ten soybean plants, represented the sample, were randomly collected from of each plot and examined to record the population density of cotton leafworm.

2) Plant responses to insect attack

Five plants from each replication and nine leaves (upper, middle and lower) from each plant [15] were selected from Giza Agricultural Experiments Research Station to at 45 days from sowing to estimate rating levels of % consumed leaf area by feeding larvae of cotton leafworm under field and aboratory conditions according to Mengel *et al.* [16]. **Table 3** shows percentages of rating levels of leaf area consumed by leaf-feeding larvae of cotton leafworm.

2.1.2. Soybean Genotypes Performance at 45 Days from Sowing

1) The photosynthetic potential: it is proportional to leaf dry weight during early leaf growth. Leaves of five soybean genotypes were taken randomly to estimate the leaf fresh weight (g) and leaf dry weight (g). The fresh leaves of each

Table 3. Percentages of rating levels of leaf area consumed by leaf feeding larvae of cotton leafworm

Scale	Rating levels of leaf area consumed (%)			Relative susceptibility
	Value	Phenotype		
1	1% - 10%			Tolerant
2	11% - 30%			Intermediate
3	>30%			Susceptible

sample were weighed and record as Wf, then dried at 72 h at 80˚C [17]. The dry matter weighed was record as Wd. This analysis was done by the General Organization for Agricultural Equalization Fund, Agricultural Research Center, Giza, Egypt.

2) Direct defense mechanism: observations on leaf pubescence density were taken on the studied soybean genotypes exhibiting a range of insect infestation levels and pubescence ratings. Leaf pubescence density was divided into three phenotypes: dense, normal and sparse [18]. Leaf pubescence density was recorded by counting number of hairs on the lower surface of the leaflet per 500 µm under electronic microscope. Leaf pubescence density was estimated as an indication of direct defense for insect infestation by using SEM Model Quanta 250 FEG (Field Emission Gun) in the Egyptian Mineral Resources Authority Central Laboratories Sector.

3) Indirect defense mechanisms: leaf water content was calculated as according to Jin *et al.* [17]: Leaf water content (%) = (Wf − Wd)/Wf × 100. Meanwhile, leaves of five soybean plants were taken randomly to estimate the leaf total phenols (g/100 g dry weight). Leaf total phenols were analyzed by Cairo University Research Park, Faculty of Agriculture, Cairo University, Giza, Egypt.

4) Artificial feeding: Egg-masses of cotton leafworm were collected from Giza Agricultural Experiments and Research Station and separately confined in sterilized jars, tapped with muslin covers. Upon larval hatching, fresh and clean soybean leaves were taken from five soybean genotypes at 45 days from sowing for feeding larvae. Third-instar larvae Egg-masses of cotton leafworm were collected from Giza Agricultural Experiments and Research Station reared on artificial diet under controlled conditions at 25˚C ± 2˚C, 70% ± 5% RH and a 16 h light photoperiod [19]. Daily clean jars were substituted for the used ones. At pupation, the pupae were sexed and then confined, 12 in each jar, at a sex-ratio of two females to one male, for moth emergence. Deposited egg-masses were daily collected for further experimentation. Whenever it was necessary field-collecting egg-masses were picked up from the previously mentioned station, reared under

the laboratory conditions, for only one generation, after which time egg-masses for the present work were taken. Insects were kept at a constant temperature of 25˚C ± 1˚C, in 75% ± 10% relative humidity under an artificial photoperiod of 16 h of light and 8 h of dark. This method was carried out at to Laboratory of Economic Entomology and Pesticides Department, Faculty of Agriculture, Cairo University, Giza, Egypt to estimate the following traits:

a) Survival of larval number of cotton leafworm after 10 days from feeding on soybean leaflets (%).

b) Survival of larval weight of cotton leafworm after 10 days from feeding on soybean leaflets (g).

c) Number of the pupa survival after 20 days from larvae feeding on soybean leaflets (%).

2.1.3. Soybean Genotypes Performance at Harvest

At harvest, ten plants were chosen randomly from each plot to estimate the following traits: plant height (cm), number of branches per plant, pod weight per plant (g), seed yield per plant (g) and 100-seed weight (g). Biological, straw and seed yields per plot (kg) were recorded on the basis of the experimental plot and converted to t/ha.. The yield data were utilized to work out harvest index "HI" (%) according to Donald [20]. Seed oil content: oil content in the seed was done through the Soils, Water and Environment Research Institute, ARC according to procedures described by A.O.A.C. [21].

2.1.4. Phenotypic Simple Correlation

Phenotypic simple correlation coefficients were calculated for the combined data of the two seasons of all the studied traits by MSTAT-C computer program [22].

2.2. Statistical Analysis

Analysis of variance of leaf pubescence density, leaf total phenols content, larval survival number and weight of cotton leafworm, number of the pupa survival of cotton leafworm, leaf fresh and dry weights, leaf water content, seed yield, and its attributes of each season was performed. Mean comparisons were performed using Duncan's multiple range test [23] and the least significant differences (L.S.D) test with a significance level of 5% [24]. The measured variables were analyzed by ANOVA [25].

3. Results and Discussion

3.1. Insect Assemblages under Field Conditions

The differences in the cotton leafworm assemblages between the first and second seasons could be due to the seasonal fluctuations (**Table 2**). These results reveal that cotton leafworm can spread under moderate temperatures with high relative humidity. Relative tolerance soybean genotypes to the infestation by cotton leafworm statistically varied in both seasons (**Table 4**). Higher cotton leafworm assemblages on soybean leaf in the 6th week from sowing were recorded for

Table 4. Insect assemblages on soybean leaf of the studied soybean genotypes in the 6th, 7th, and 8th week from sowing in both seasons.

Treatments	6th week	7th week	8th week
	First season		
$H_{11}L_{145}$	3.33ab	4.33b	7.66cd
H_{155}	3.66ab	6.33a	9.66ab
H_{113}	1.66cd	2.66c	6.33d
H_4L_4	1.33cd	1.66cd	6.33d
$H_{15}L_{17}$	1.00d	1.00d	4.33e
H_{129}	1.66cd	1.66cd	4.00e
H_{30}	2.66bc	5.33ab	8.33bc
$H_{19}L_{96}$	3.66ab	6.00a	8.33bc
Giza 111	1.66cd	1.33cd	4.66e
Crawford	4.33a	6.66a	10.33a
L.S.D. 0.05	1.47	1.56	1.60
	Second season		
$H_{11}L_{145}$	4.33bcd	6.66c	7.00cd
H_{155}	5.33ab	8.33abc	8.66bc
H_{113}	3.00de	3.66d	4.33e
H_4L_4	2.33e	3.66d	4.66e
$H_{15}L_{17}$	3.00de	4.00d	5.33de
H_{129}	2.66e	4.66d	5.00e
H_{30}	3.66cde	7.33bc	8.00bc
$H_{19}L_{96}$	5.00abc	8.66ab	9.66b
Giza 111	3.33de	4.66d	4.33e
Crawford	6.33a	9.66a	11.66a
L.S.D. 0.05	1.45	1.70	1.71

Different letters indicate a significant difference at $p \leq 0.05$ according to Duncan's multiple tests.

soybean genotypes Crawford, $H_{19}L_{96}$, and H_{155} than the other genotypes, meanwhile, the reverse was true for H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} in both seasons. It is worth noting that soybean genotypes $H_{11}L_{145}$ and H_{30} had the lowest cotton leafworm assemblages in the first season compared with the other genotypes.

With respect to the 7th week, leaves of soybean genotypes Crawford, $H_{19}L_{96}$, and H_{155} recorded higher cotton leafworm assemblages, meanwhile; the reverse was true for H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} in both seasons. Also, soybean genotype H_{30} had the highest cotton leafworm assemblages in the second season, while soybean genotypes H_{113} and $H_{11}L_{145}$ had the lowest values in the first season only.

With respect to the 8th week, leaves of soybean genotypes Crawford, $H_{19}L_{96}$, $H_{11}L_{145}$, and H_{155} recorded higher cotton leafworm assemblages, meanwhile; the reverse was true for H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} in both seasons. Also, soybean genotype H_{30} had the highest cotton leafworm assemblages in the second season, while soybean genotype H_{113} had the lowest values in the first season only. The results indicate that the relative tolerance or susceptibility of soybean genotypes H_{30} and $H_{11}L_{145}$ to cotton leafworm infestation differed from one week to another and from the first season to the second one. These results are in agreement with El-Mezayyen [26] who indicated that the population of the cotton leafworm had seven peaks from the third week of May until the first week of September.

3.2. Soybean Genotypes Performance at 45 Days from Sowing

3.2.1. The Photosynthetic Potential

Leaf fresh weight at 45 days from sowing is shown in Table 5. Soybean genotypes H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} had higher leaf fresh weight the others in

Table 5. Leaf fresh and dry weights of the studied soybean genotypes at 45 days from sowing.

Treatments	Leaf fresh weight (g)		Leaf dry weight (g)	
	First season	Second season	First season	Second season
$H_{11}L_{145}$	22.27^{abcd}	18.97^{bcd}	11.02^{bc}	7.62^{b}
H_{155}	18.35^{bcd}	15.74^{cd}	6.97^{c}	4.11^{b}
H_{113}	25.20^{abc}	23.27^{abcd}	17.42^{ab}	14.27^{a}
H_4L_4	26.69^{ab}	25.63^{abc}	19.64^{a}	16.77^{a}
$H_{15}L_{17}$	28.11^{a}	27.47^{ab}	19.85^{a}	17.82^{a}
H_{129}	30.19^{a}	29.41^{a}	22.34^{a}	19.63^{a}
H_{30}	22.31^{abcd}	18.17^{bcd}	10.01^{bc}	6.76^{b}
$H_{19}L_{96}$	17.79^{cd}	15.78^{cd}	6.22^{c}	4.68^{b}
Giza 111	28.27^{a}	24.03^{abc}	19.63^{a}	14.91^{a}
Crawford	15.99^{d}	13.04^{d}	4.21^{c}	2.23^{b}
L.S.D. 0.05	8.55	10.41	7.45	6.33

Different letters indicate a significant difference at $p \le 0.05$ according to Duncan's multiple tests.

both seasons. These results can be due to these genotypes being characterized by high efficiency in the photosynthesis process, which relatively contributed to maintaining the amount of dry matter accumulation against the cotton leafworm attack. Leaf fresh weight was positively correlated with total dry weight/plant as mentioned by Noureldin *et al.* [27].

With respect to leaf dry weight, leaf dry weight at 45 days from sowing is shown in **Table 5**. Soybean genotypes H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} had higher leaf dry weights; meanwhile, the converse was true for Crawford, $H_{19}L_{96}$, H_{30}, $H_{11}L_{145}$, and H_{155} in both seasons. The results are probably due to that leaves of soybean genotypes H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} were thick that contributed to a tolerance of cotton leafworm infestation. The increased leaf dry weight can be due to the increased leaf thickness [28]. So, it may be possible that soybean genotypes H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} can tolerate cotton leafworm infestation by higher photosynthetic potential at early growth stages. These results are in harmony with Masud [29] who found that soybean genotypes have significantly differed for leaf dry weight.

3.2.2. Direct Defense Mechanism

Leaf pubescence density differed among soybean genotypes, as shown in **Figure 1**. The leaves of the soybean genotypes $H_{15}L_{17}$, H_{113}, H_{129}, $H_{11}L_{145}$, and H_4L_4 were characterized by dense pubescence density. Meanwhile, leaves of soybean genotypes H_{30}, Giza 111, and $H_{19}L_{96}$ were characterized by normal pubescence density. However, leaves of soybean genotypes Crawford and H_{155} were characterized by sparse pubescence density. These results may be due to the genetic makeup of the studied soybean genotypes that translated into differences in leaf morphology and structure. The pubescence leaf seems to be as jagged leaf hinders the feeding of the larvae compared to the smooth leaf. These results are in accordance

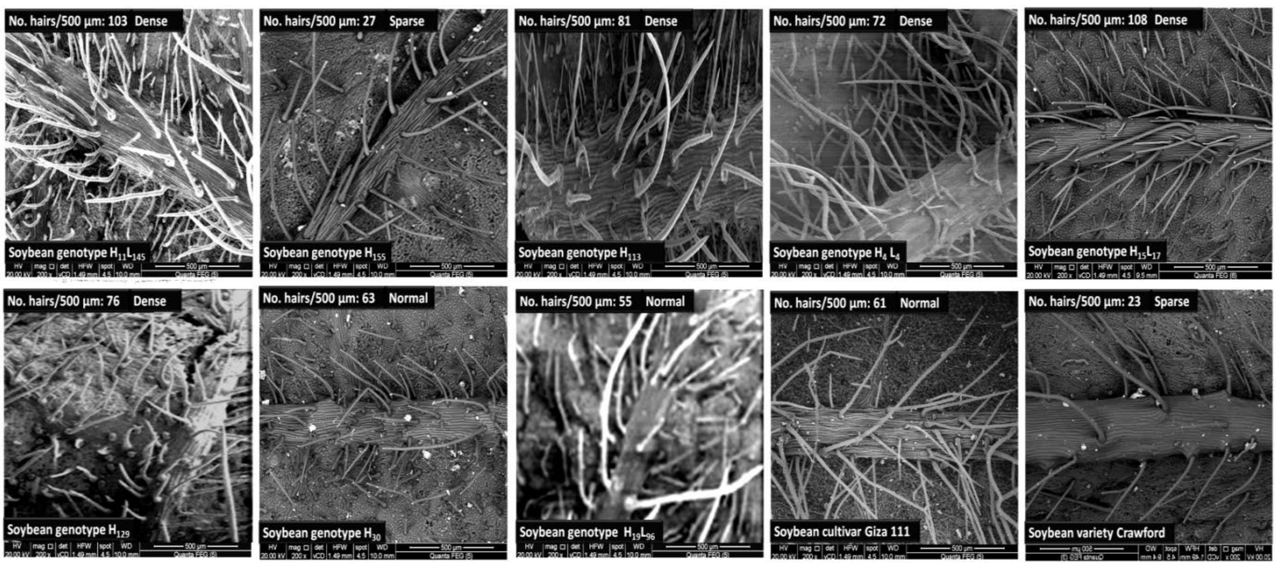

Figure 1. Leaf pubescence density of the studied soybean genotypes under electronic microscope.

with Abdel-Wahab *et al.* [10] who showed that there were significant differences among soybean genotypes for leaf pubescence density.

3.2.3. Indirect Defense Mechanism

With respect to leaf water content, it can be considered one of the physiological mechanisms that enhance the tolerance of soybean plants to cotton leafworm infestation. The leaf water content of studied soybean genotypes is presented in **Figure 2**. Soybean genotypes H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} had lower leaf water than the others in both seasons. Tolerance is an important defense strategy of plants that is influenced by water availability due to its close association with growth [30]. It is known that lower water availability increased the levels of constitutive and induced defensive proteins in leaves [31], which positively affected tolerance to cotton leafworm infestation.

These results show that these genotypes had a relative tolerance to infestation with cotton leafworm as compared with the others. Meanwhile, soybean genotypes $H_{11}L_{145}$, H_{155}, H_{30}, $H_{19}L_{96}$, and Crawford had higher leaf water contents than the others in both seasons. The high water content of soybean genotype leaves $H_{11}L_{145}$ may be reflected through a deeper root in different soil depths than the other genotypes. A greater root density and a deeper root extension produced densely pubescence lines as reported by Garay and Wilhelm [32].

With regard to leaf total phenols, there were significant differences among soybean genotypes in both seasons (**Figure 3**). Leaves of soybean genotypes H_{113}, H_{129}, H_4L_4, $H_{15}L_{17}$, and Giza 111 had the highest concentration of total phenols, without significant differences among them, as compared with the others. Conversely, leaves of soybean genotypes $H_{11}L_{145}$, $H_{19}L_{96}$, Crawford, H_{155}, and H_{30} had the lowest ones. These results could be due to increased leaf water content

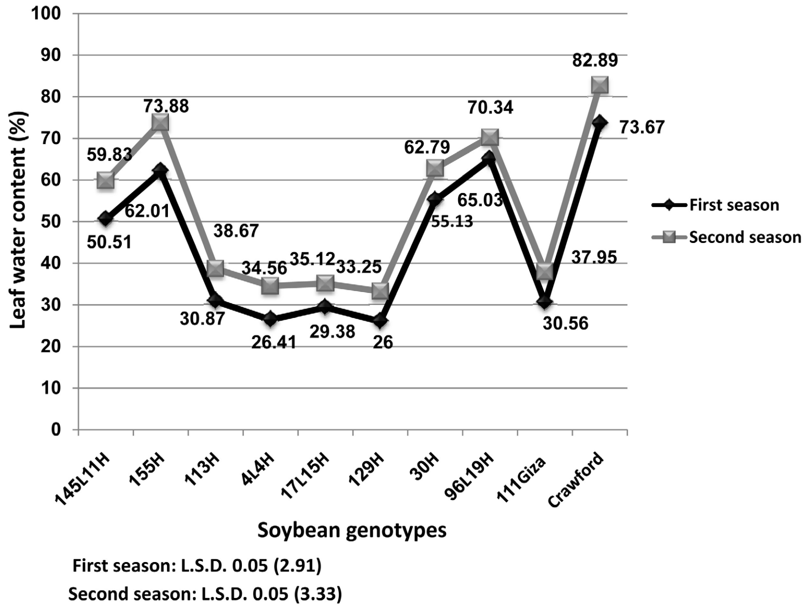

Figure 2. Leaf water content of the studied soybean genotypes at 45 days from sowing.

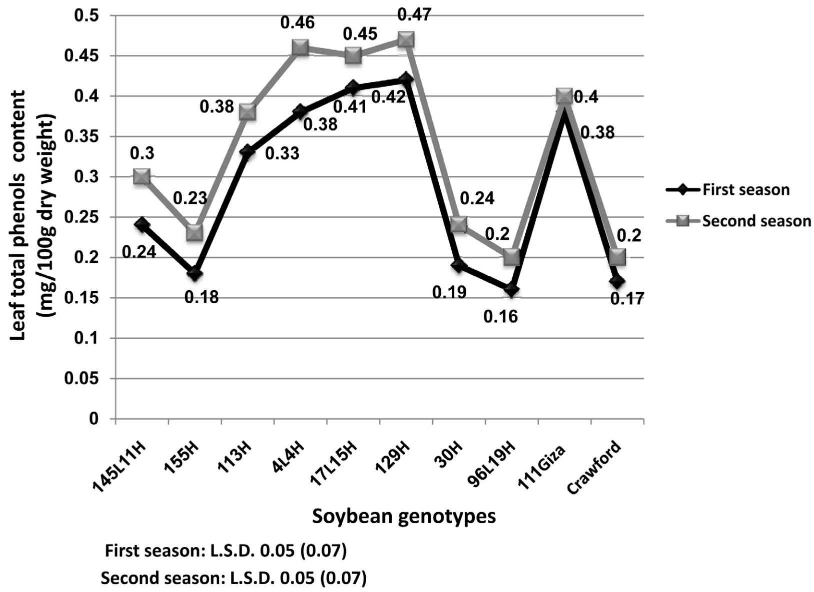

Figure 3. Leaf total phenols content of the studied soybean genotypes at 45 days from sowing.

positively affecting total phenols contents within genotypes that interacted with the surrounding environment. These results are in the same context with Abdallah *et al.* [33] and Abdel-Wahab *et al.* [10] whom found that soybean cultivars were significantly differed for leaf total phenols.

3.2.4. Artificial Feeding

The effects of infestation of cotton leafworm on leaves of the studied soybean genotypes under laboratory conditions are presented in Table 6. Leaves of soybean genotypes H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} caused lower cotton leafworm infestation (1 - 10%), while higher infestation (more than 30%) was observed for soybean variety Crawford. The other soybean genotypes $H_{14}L_{145}$, H_{155}, H_{30}, and $H_{19}L_{96}$ had moderate response. .

In general, soybean genotypes H_{113}, H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} were tolerant (R) to infestation with cotton leafworm. Meanwhile, soybean genotypes $H_{11}L_{145}$ and H_{30} were moderate tolerant (MR), and soybean genotypes H_{155} and $H_{19}L_{96}$ were moderately susceptible (MS) to infestation with cotton leafworm. Conversely, the soybean variety Crawford was susceptible (S) to infestation with cotton leafworm. These results are probably attributed to leaves of soybean genotypes H_4F_4, $H_{15}L_{17}$, H_{113}, and H_{129} that have been characterized by dense pubescence density (Figure 1), lower leaf water content (Figure 2) and, higher concentrations of total phenols (Figure 3) than the other genotypes. These results show that the relative tolerance of soybean genotypes H_4L_4, $H_{15}L_{17}$, H_{113}, and H_{129} had direct and indirect defense mechanisms against cotton leafworm attack. With respect to the soybean cultivar Giza 111, although it was characterized by normal leaf pubescence density, leaves of Giza 111 can be considered to have direct and indirect defense mechanisms.

Table 6. Rating levels of consumed leaflets area of the studied soybean genotypes and their categories for tolerance of cotton leaf worm under laboratory conditions at 45 days from sowing.

Treatments	Rating levels of consumed leaflets area (%)			
Season	First season	category	Second season	category
$H_{11}L_{145}$	20.66^{b}	MR	25.66^{b}	MR
H_{155}	22.66^{b}	MS	28.00^{b}	MS
H_{113}	7.33^{d}	R	9.33^{c}	R
$H_{4}L_{4}$	6.66^{d}	R	9.33^{c}	R
$H_{15}L_{17}$	5.33^{d}	R	7.00^{c}	R
H_{129}	8.66^{cd}	R	9.00^{c}	R
H_{30}	17.33^{bc}	MR	23.33^{b}	MR
$H_{19}L_{96}$	21.00^{b}	MS	27.33^{b}	MS
Giza 111	8.66^{cd}	R	9.00^{c}	R
Crawford	46.00^{a}	S	54.66^{a}	S
L.S.D. 0.05	9.75		9.15	

Different letters indicate a significant difference at $p \le 0.05$ according to Duncan's multiple tests.

On the other hand, soybean genotypes $H_{11}L_{145}$ and H_{30} were moderate tolerant (MR) to infestation with cotton leafworm. With respect to soybean genotype $H_{11}L_{145}$, it was characterized by dense leaf pubescence density (**Figure 1**), high leaf water content (**Figure 2**), and low concentration of leaf total phenols (**Figure 3**). With regard to soybean genotype H_{30}, it was characterized by normal leaf pubescence density (**Figure 1**), high leaf water content (**Figure 2**), and low concentration of leaf total phenols (**Figure 3**). So, it may possible that $H_{11}L_{145}$ and H_{30} had the direct defense mechanism only. Meanwhile, soybean genotypes $H_{19}L_{96}$ and H_{155} were moderately susceptible (MS) to infestation with cotton leafworm. With respect to soybean genotype $H_{19}L_{96}$, it was characterized by normal leaf pubescence density (**Figure 1**), high leaf water content (**Figure 2**), and low concentration of leaf total phenols (**Figure 3**). These results show that the relative susceptibility of soybean genotype $H_{19}L_{96}$ to cotton leafworm can be due to the absence of the indirect defense mechanism, despite the presence of the direct defense mechanism. With regard to soybean genotypes H_{155} and Crawford, they were characterized by sparse leaf pubescence density (**Figure 1**), high leaf water content (**Figure 2**), and low concentration of leaf total phenols (**Figure 3**). These results reveal that the relative susceptibility of soybean genotypes H_{155} and Crawford to cotton leafworm can be due to the absence of direct and indirect defense mechanisms. These results are in harmony with Hill *et al.* [34] who indicated that the higher pubescence density reduced leaf damage.

It is obvious that the larval survival number and weight of cotton leafworm, and development to pupa stage have statistically differed among the soybean genotypes under laboratory conditions (Table 7). Significant differences were found in the larval survival number of cotton leafworm by feeding on soybean

Table 7. The larval survival number and weight of cotton leafworm after 10 days and number of the pupa survival after 20 days from larvae feeding on soybean leaves.

Treatments	Larval Survival after 10 days from feeding on soybean leaf		Number of the pupa survival after 20 days from larvae feeding on soybean leaf (%)
	Number (%)	Weight (g)	
	First season		
$H_{11}L_{145}$	41.66^{c}	0.34^{cd}	33.33^{d}
H_{155}	62.33^{b}	0.67^{b}	58.33^{b}
H_{113}	33.00^{d}	0.26^{de}	24.33^{de}
$H_{4}L_{4}$	28.33^{de}	0.23^{e}	21.66^{e}
$H_{15}L_{17}$	21.66^{e}	0.21^{e}	17.66^{e}
H_{129}	23.33^{e}	0.24^{e}	24.33^{de}
H_{30}	41.66^{c}	0.36^{c}	43.33^{c}
$H_{19}L_{96}$	43.33^{c}	0.38^{c}	48.33^{c}
Giza 111	23.00^{e}	0.21^{e}	16.66^{e}
Crawford	73.33^{a}	0.94^{a}	78.33^{a}
L.S.D. 0.05	7.95	0.09	9.21
	Second season		
$H_{11}L_{145}$	45.66^{c}	0.53^{d}	44.33^{cd}
H_{155}	66.66^{b}	0.90^{b}	71.00^{b}
H_{113}	37.33^{d}	0.41^{e}	36.66^{d}
$H_{4}L_{4}$	32.66^{de}	0.33^{ef}	26.66^{e}
$H_{15}L_{17}$	23.33^{f}	0.28^{f}	21.66^{e}
H_{129}	28.33^{ef}	0.34^{ef}	40.66^{d}
H_{30}	48.33^{c}	0.58^{d}	53.33^{c}
$H_{19}L_{96}$	49.00^{c}	0.72^{c}	63.33^{b}
Giza 111	27.66^{ef}	0.31^{f}	22.33^{e}
Crawford	78.33^{a}	1.24^{a}	84.33^{a}
L.S.D. 0.05	7.92	0.09	9.09

Different letters indicate a significant difference at $p \leq 0.05$ according to Duncan's multiple tests.

leaves in both seasons. It was found that feeding the larvae on the leaves of soybean genotypes $H_{15}L_{17}$, Giza 111, and H_{129} recorded a lower percentage of the larval survival number of cotton leafworm without any significant differences between these genotypes than the other genotypes in both seasons. Meanwhile, feeding the larvae on the leaves of soybean genotype H_4L_4 had the same trend in the first season only.

Also, soybean genotypes H_4L_4, $H_{15}L_{17}$, Giza 111, and H_{129} had a lower percentage of the larval survival weight of cotton leafworm without significant differences between them in both seasons. Meanwhile, soybean genotype H_{113} had the same trend the first season only. Moreover, soybean genotypes H_4L_4, $H_{15}L_{17}$, and Giza 111 recorded the lowest number of survival of larval and pupa of cotton leafworm compared with the other genotypes in both seasons. Meanwhile, soybean genotypes H_{113} and H_{129} had the same trend in the first season only. These results are probably due to these genotypes having mechanical barriers, physiological and chemical mechanism defenses (**Figures 1-3**). These results show that these genotypes can be maintaining their growth performance under insect attack.

3.3. Soybean Genotypes Performance at Harvest

The mean performance of soybean genotypes for biological and straw yields/ha, plant height, number of branches per plant, pod weight/plant, seed yield per plant, 100–seed weight, seed yield/ha, and HI are presented in **Table 8**. Soybean cultivar Giza 111 was superior in this trait (13.02 and 12.14 t) compared with the others in the first and second seasons, respectively. Meanwhile, soybean genotype $H_{15}L_{17}$ came in the 2nd rank (12.56 and 11.77 t) followed by H_{129} (11.04 and 10.69 t), then $H_{19}L_{96}$ (10.87 and 10.17 t), and H_4L_4 (9.63 and 10.97 t), in the first and second seasons, respectively. Also, soybean genotypes Giza 111 and $H_{15}L_{17}$ had the highest straw yield per ha without significant differences between them in both seasons. This result can be due to maintaining the photosynthetic process of these soybean genotypes during growth and development. It seems that soybean genotypes Giza 111, $H_{15}L_{17}$, H_{129}, and H_4L_4 are tolerant to the cotton leafworm infestation due to direct and indirect defense mechanisms that control insect growth and development.

Meanwhile, soybean genotypes Crawford and H_{155} recorded the lowest values of biological yield/ha compared with the other genotypes in both seasons. Also, soybean genotypes H_{155} and Crawford had the same trend for straw yield/ha. These results can be due to soybean genotypes Crawford and H_{155} being susceptible and moderately susceptible, respectively, to cotton leafworm infestation. These results are in agreement with those obtained by Abdel-Wahab *et al.* [35] who showed that there were significant differences among soybean varieties for biological and straw yields/ha.

With respect to plant height, soybean genotypes H_4L_4 and $H_{15}L_{17}$ were the tallest genotypes (111.00 cm), which were statistically similar to H_{113} (109.00 cm),

Table 8. Seed yield and its attributes of the studied soybean genotypes at harvest.

Treatments	Biological yield/ha (t)	Straw yield/ha (t)	Plant height (cm)	Branches/ plant (no.)	Pod weight/ plant (g)
			First season		
$H_{11}L_{145}$	9.10^{e}	6.68^{c}	102.66^{bcde}	3.30^{def}	27.49^{d}
H_{155}	6.01^{h}	4.18^{d}	99.33^{cde}	4.43^{a}	20.25^{e}
H_{113}	8.93^{ef}	6.67^{c}	109.00^{ab}	3.20^{ef}	32.43^{bc}
$H_{4}L_{4}$	9.63^{d}	6.51^{c}	111.00^{a}	3.06^{ef}	33.65^{abc}
$H_{15}L_{17}$	12.56^{b}	8.84^{ab}	111.00^{a}	3.43^{cde}	36.43^{a}
H_{129}	11.04^{c}	7.89^{b}	106.33^{abc}	3.70^{cd}	35.72^{ab}
H_{30}	8.63^{f}	6.00^{c}	98.66^{de}	3.36^{cdef}	28.52^{d}
$H_{19}L_{96}$	10.87^{c}	7.89^{b}	108.00^{ab}	3.73^{bc}	30.38^{cd}
Giza 111	13.02^{a}	9.32^{a}	105.66^{abcd}	4.13^{ab}	36.26^{a}
Crawford	6.79^{g}	4.65^{d}	98.33^{e}	3.00^{f}	21.85^{e}
L.S.D. 0.05	0.35	1.00	7.16	0.42	3.29
			Second season		
$H_{11}L_{145}$	9.10^{e}	6.79^{e}	100.83^{de}	3.70^{bc}	26.30^{c}
H_{155}	5.60^{i}	3.90^{h}	96.66^{ef}	4.56^{a}	19.47^{d}
H_{113}	8.00^{g}	5.87^{f}	106.66^{abc}	3.33^{de}	29.32^{bc}
$H_{4}L_{4}$	10.97^{c}	7.93^{bc}	110.66^{a}	3.06^{e}	31.37^{ab}
$H_{15}L_{17}$	11.77^{b}	8.17^{ab}	109.00^{ab}	3.66^{bc}	34.40^{a}
H_{129}	10.69^{c}	7.66^{cd}	104.66^{bcd}	3.63^{cd}	31.47^{ab}
H_{30}	8.62^{f}	6.08^{f}	95.33^{f}	3.73^{bc}	26.40^{c}
$H_{19}L_{96}$	10.17^{d}	7.34^{d}	105.00^{bcd}	3.96^{b}	29.53^{b}
Giza 111	12.14^{a}	8.46^{a}	104.33^{cd}	4.33^{a}	33.80^{a}
Crawford	6.76^{h}	4.70^{g}	94.33^{f}	3.06^{e}	19.35^{d}
L.S.D. 0.05	0.36	0.33	4.53	0.33	3.06

Different letters indicate a significant difference at $p \leq 0.05$ according to Duncan's multiple tests.

Treatments	Seed yield/plant (g)	100-seed weight (g)	Seed yield/ha (t)	HI (%)	Seed oil content (%)
			First season		
$H_{11}L_{145}$	25.37^{e}	14.68^{cde}	2.42^{cd}	26.58^{ef}	18.54^{cd}
H_{155}	17.80^{f}	19.40^{a}	1.83^{e}	30.44^{abc}	21.40^{a}
H_{113}	29.54^{bcd}	17.43^{abc}	2.26^{d}	25.29^{f}	18.76^{cd}

Continued

H_4L_4	31.39^{abc}	15.51^{bcd}	3.12^{b}	32.39^{a}	19.02^{bc}
$H_{15}L_{17}$	34.31^{a}	17.76^{abc}	3.72^{a}	29.62^{bcd}	19.05^{bc}
H_{129}	32.49^{ab}	19.25^{a}	3.15^{b}	28.52^{cde}	18.24^{d}
H_{30}	26.70^{de}	13.57^{de}	2.63^{c}	30.47^{abc}	21.00^{a}
$H_{19}L_{96}$	29.32^{cd}	18.51^{ab}	2.98^{b}	27.40^{def}	20.99^{a}
Giza 111	34.08^{a}	16.27^{abcd}	3.70^{a}	28.40^{cde}	19.56^{b}
Crawford	20.61^{f}	11.31^{e}	2.14^{de}	31.49^{ab}	18.96^{c}
L.S.D. 0.05	3.16	3.51	0.33	2.76	0.54
			Second season		
$H_{11}L_{145}$	24.21^{d}	12.65^{cd}	2.31^{de}	25.38^{e}	19.48^{ef}
H_{155}	16.32^{e}	17.25^{a}	1.70^{f}	30.35^{ab}	22.25^{a}
H_{113}	26.49^{cd}	15.02^{abc}	2.13^{e}	26.63^{de}	19.61^{def}
H_4L_4	29.62^{ab}	12.48^{cd}	3.04^{b}	27.72^{cde}	19.91^{cde}
$H_{15}L_{17}$	32.32^{a}	16.14^{ab}	3.60^{a}	30.58^{a}	20.24^{c}
H_{129}	29.62^{ab}	16.32^{ab}	3.03^{b}	28.35^{abcd}	19.11^{f}
H_{30}	24.23^{d}	12.30^{cd}	2.54^{cd}	29.45^{abc}	21.73^{ab}
$H_{19}L_{96}$	28.58^{bc}	16.41^{ab}	2.83^{bc}	27.81^{bcde}	21.66^{b}
Giza 111	32.13^{a}	14.16^{bc}	3.68^{a}	30.30^{abc}	20.31^{c}
Crawford	17.57^{e}	10.20^{d}	2.06^{e}	30.49^{a}	20.04^{cd}
L.S.D. 0.05	3.12	3.00	0.32	2.60	0.55

Different letters indicate a significant difference at $p \leq 0.05$ according to Duncan's multiple tests.

$H_{19}L_{96}$ (108.00 cm), H_{129} (106.33 cm), and Giza 111 (105.66 cm) in the first season. Also, soybean genotype H_4L_4 was the tallest genotype (110.66 cm), which was statistically similar to soybean genotypes $H_{15}L_{17}$ (109.00 cm), and H_{113} (106.66 cm) in the second season. Moreover, soybean genotypes $H_{19}L_{96}$ and H_{129} came in the 2^{nd} rank in plant height without significant differences between them in the second season. Conversely, soybean variety Crawford was the shortest variety (98.33 cm), which was statistically similar to H_{30} (98.66 cm), H_{155} (99.33 cm), and $H_{11}F_{145}$ (102.66 cm) in the first season. Also, the soybean variety Crawford was the shortest variety (94.33 cm), which was statistically similar to H_{30} (95.33 cm), and H_{155} (96.66 cm) in the second one. These results may be attributed to the genetic makeup of these genotypes that translated into differences in the growth of their internodes. Earlier studies found significant variation among soybean genotypes for plant height [27] [36] [37]. These results are in parallel with those observed by Serag *et al.* [11] who showed that soybean genotypes Giza 111, H_{105}, and Giza 21 were the tallest plants.

With respect to the number of branches/plant, soybean genotype H_{155} had the highest number of branches/plant (4.43 and 4.56), which was statistically similar to Giza 111 (4.13 and 4.33) in the first and second seasons, respectively. Soybean genotype $H_{19}L_{96}$ came in the 2nd rank for the number of branches/plant (3.73 and 3.96) in the first and second seasons, respectively. Conversely, soybean variety Crawford had the lowest number of branches/plant (3.00 and 3.06), which was statistically similar to soybean genotypes H_4L_4 (3.06 and 3.06), H_{113} (3.20 and 3.33) in the first and second seasons, respectively. These results may be attributed to the genetic makeup of these genotypes that translated into the alteration of branches' growth rate. These results are in accordance with those observed by Serag *et al.* [11] who showed that soybean genotype $H_{10}L_{10A}$ had higher number of branches per plant than soybean genotype $H_{15}L_{17}$.

With respect to pod weight/plant, soybean genotype $H_{15}L_{17}$ had the highest pod weight/plant (36.43 and 34.40 g), which was statistically similar to Giza 111 (36.26 and 33.80 g), H_{129} (35.72 and 31.47 g), and H_4L_4 (33.65 and 31.37 g) in the first and second seasons, respectively. Meanwhile, soybean genotype H_{113} came in the 2nd rank for pod weight/plant (32.43 g) in the first season. Soybean genotype $H_{19}L_{96}$ came in the 2nd rank for pod weight/plant (29.53 g), which was statistically similar to soybean genotype H_{113} (29.32 g) in the second one. These results can be due to soybean genotypes Giza 111, $H_{15}L_{17}$, H_{129}, H_{113}, and H_4L_4 being tolerant to the cotton leafworm infestation which had been positively reflected in their higher photosynthetic potentials. With respect to soybean genotype $H_{19}L_{96}$, this genotype had mechanical barriers in its leaves that negatively affected insect growth and development during feeding. Conversely, soybean genotype H_{155} had the lowest pod weight/plant (20.25 g), which was statistically similar to soybean cultivar Crawford (21.85 g) in the first season. Also, soybean variety Crawford had the lowest pod weight/plant (19.35 g), which was statistically similar to soybean genotype H_{155} (19.47 g) in the second one. These results can be due to soybean genotypes Crawford and H_{155} are susceptible and moderately susceptible, respectively, to the cotton leafworm infestation. These results are in agreement with those observed by Abdel-Wahab *et al.* [35] who showed that there were significant differences among soybean genotypes for pod weight per plant.

With respect to seed yield/plant, soybean genotype $H_{15}L_{17}$ had the highest seed yield/plant (34.31 and 32.32 g), which was statistically similar to soybean genotypes Giza 111 (34.08 and 32.13 g), H_{129} (32.49 and 29.62 g), and H_4L_4 (31.39 and 29.62 g) in the first and second seasons, respectively. Meanwhile, Soybean genotype H_{113} came in the 2nd rank for seed yield/plant (29.54 g) in the first season. Soybean genotype $H_{19}L_{96}$ came in the 2nd rank for seed yield/plant (28.58 g) in the second one. These results reveal that soybean genotypes Giza 111, $H_{15}L_{17}$, H_{129}, H_{113} and H_4L_4 are tolerant to cotton leafworm infestation due to direct and indirect defense mechanisms. Conversely, soybean genotype H_{155} had the lowest seed yield/plant (17.80 and 16.32 g), which was statistically similar to soybean variety Crawford (20.61 and 17.57 g) in the first and second seasons, respectively. These results may be attributed to the rapid degradation of cotton leafworm-infested leaves of Crawford and H_{155} during different growth and development stages. These results are in similar with Hassan *et al.* [36] [37], Noureldin *et al.* [27], Morsy *et al.* [38], El-Garhy *et al.* [39], Abdel-Wahab *et al.* [35], and Serag *et al.* [11] whom found significant variation among soybean genotypes for seed yield per plant.

With regard to 100-seed weight, soybean genotype H_{155} had the heaviest 100-seed weight (19.40 g), which was statistically similar to soybean genotypes H_{129} (19.25 g), $H_{19}L_{96}$ (18.51 g), $H_{15}L_{17}$ (17.76 g), H_{113} (17.43 g), and Giza 111 (16.27 g) in the first season. Also, soybean genotype H_{155} had the heaviest 100-seed weight (17.25 g), which was statistically similar to soybean genotypes $H_{19}L_{96}$ (16.41 g), H_{129} (16.32 g), $H_{15}L_{17}$ (16.14 g), and H_{113} (15.02 g) in the second season. Meanwhile, soybean cultivar Giza 111 came in the 2^{nd} rank for the 100-seed weight (14.16 g) in the second one. These results are probably due to these genotypes maintaining the translocation process of dry matter from their different organs to the seeds under natural conditions of the cotton leafworm infestation during the seed-filling stage. Conversely, soybean variety Crawford had the lowest 100-seed weight (11.31 and 10.20 g), which was statistically similar to soybean genotypes H_{30} (13.57 and 12.30 g), and $H_{11}L_{145}$ (14.68 and 12.65 g) in the first and second seasons, respectively. These results can be due to leaves of soybean genotypes Crawford, $H_{11}L_{145}$, and H_{30} had low total phenols with high leaf water contents which allowed cotton leafworm to attack these genotypes. These results are in similar with Hassan *et al.* [36] [37], Morsy *et al.* [38], Abdel-Wahab *et al.* [35], and Serag *et al.* [11] whom found significant variation among soybean genotypes for 100-seed weight.

With respect to seed yield/ha, soybean genotype $H_{15}L_{17}$ had the highest value (3.72 t), which was statistically similar to Giza 111 (3.70 t) in the first season. Meanwhile, soybean genotype H_{129} came in the 2^{nd} rank for seed yield/ha (3.15 t), which was statistically similar to H_4L_4 (3.12 t), and $H_{19}L_{96}$ (2.98 t) in the first season. Also, soybean cultivar Giza 111 had the highest seed yield/ha (3.68 t), which was statistically similar to $H_{15}L_{17}$ (3.60 t) in the second season. Soybean genotype H_4L_4 came in the 2^{nd} rank for seed yield/ha (3.04 t), which was statistically similar to H_{129} (3.03 t), and $H_{19}L_{96}$ (2.83 t) in the second one. Conversely, soybean genotype H_{155} had the lowest seed yield/ha (1.83 and 1.70 t), which was statistically similar to Crawford (2.14 and 2.06 t) in the first and second seasons, respectively. These results can be due to the integration of the seed yield of the soybean plant with its density under natural conditions of the cotton leafworm infestation. Similar results were obtained by Hassan *et al.* [36] [37], Noureldin *et al.* [27], Morsy *et al.* [38], Abdel-Wahab *et al.* [35], and Serag *et al.* [11] whom found significant variation among soybean genotypes for seed yield per unit area. On the other hand, soybean genotype H_4L_4 had the highest HI (32.39%), which was statistically similar to Crawford (31.49%), H_{30} (30.47%), and H_{155} (30.44%) in the first season. Meanwhile, soybean genotype $H_{15}L_{17}$ had the highest HI (30.58%), which was statistically similar to Crawford (30.49%), H_{155} (30.35%), Giza 111 (30.30%), H_{30} (29.45%), and H_{129} (28.35%) in the second season. Conversely, soybean genotype H_{113} had the lowest HI (25.29%), which was statistically similar to $H_{11}L_{145}$ (26.58%), and $H_{19}L_{96}$ (27.40%) in the first season. Also, soybean genotype $H_{11}L_{145}$ had the lowest HI (25.38%), which was statistically similar to soybean genotype H_{113} (26.63%) in the second one. These results can be attributed to higher partitioning assimilated photosynthate to the seeds of soybean genotypes H_4L_4, Crawford, H_{30}, H_{155}, $H_{15}L_{17}$, Giza 111, and H_{129} than the other genotypes under natural conditions of the cotton leafworm infestation.

With regard to seed oil content, soybean genotype H_{155} had the highest seed oil content (21.40%), which was statistically similar to $H_{19}L_{96}$ (18.51 g), H_{30} (21.00%), and $H_{19}L_{96}$ (20.99%) in the first season. Soybean genotypes Giza 111 and $H_{15}L_{17}$ came in the 2nd rank for seed oil content (18.56 and 19.05%, respectively) in the first season. Also, soybean genotype H_{155} had the highest seed oil content (22.25%), which was statistically similar to H_{30} (21.73%) in the second one. Soybean genotypes $H_{19}L_{96}$ came in the 2nd rank for seed oil content (21.66%), followed by $H_{15}L_{17}$ (20.24%) and Giza 111 (20.31%) in the second one. These results can be due to that soybean genotypes Giza 111, $H_{15}L_{17}$, H_{155}, H_{30}, and $H_{19}L_{96}$ are tolerant, tolerant, moderately tolerant, moderately tolerant, and moderately susceptible, respectively, to the cotton leafworm infestation.

3.4. Phenotypic Simple Correlation

The results in **Table 9** reveal that number of larvae survival was positively correlated (highly significant) with each of the weight of larvae survival (r = 0.997**), number of pupa survival (r = 0.993**), leaf fresh weight (r = 0.892**), and leaf water content (r = 0.954**). Meanwhile, the number of larvae was negatively correlated (highly significant) with leaf pubescence density (r = −0.862**). Moreover, the number of larvae survival was negatively correlated (significantly) with leaf total phenols (r = −0.728*), and seed oil content (r = −0.721*). Finally, no significant correlation was detected between the number of larvae survival and each of leaf dry weight (r = 0.334), biological yield/ha (r = −0.123), straw yield/ha (r = 0.144), plant height (r = 0.182), number of branches/plant (r = 0.104), pod weight/plant (r = −0.455), seed yield/plant (r = −0.264), 100-seed weight (r = −0.287), seed yield/ha (r = −0.272), and HI (r = −0.139). On the other hand, the weight of larvae survival was positively correlated (highly significant) with each of the number of pupa survival (r = 0.877**), leaf fresh weight (r = 0.837**), and leaf water content (r = 0.883**). Meanwhile, the weight of larvae survival was negatively correlated (significantly) with each of leaf pubescence density (r = −0.752*), leaf total phenols (r = −0.713*), and seed oil content (r = −0.863*). Finally, no significant correlation was detected between the weight of larvae survival and each of leaf dry weight (r = 0.253), biological yield/ha (r = −0.166), straw yield/ha (r = 0.197), plant height (r = 0.223), number of branches/plant(r = 0.279), pod weight/plant (r = −0.344), seed yield/plant (r = −0.311), 100-seed weight (r = −0.153), seed yield/ha (r = −0.189), and HI (r = −0.168).

Table 9. Phenotypic simple correlation coefficients between cotton leafworm infestation and the soybean traits, combined data across the two seasons.

Traits	No. Survival Larvae	Wt. Survival Larvae	No. Survival pupa	Pubescence density	Total phenols	Leaf fresh wt	Leaf dry wt	Leaf water content
Wt. Survival Larvae	0.997**							
No. Survival pupa	0.993**	0.877**						
Pubescence density	−0.862**	−0.752*	−0.838**					
Total phenols	−0.728*	−0.713*	−0.773*	0.780*				
Leaf fresh wt	0.892**	0.837**	0.722*	0.747*	0.724*			
Leaf dry wt	0.334	0.253	0.569	0.809*	0.703*	0.943**		
Leaf water content	0.954**	0.883**	0.933**	0.786*	0.725*	0.966**	0.763*	
Biological yield/ha	−0.123	−0.166	−0.237	0.247	0.404	0.899**	0.914**	0.567
Straw yield/ha	0.144	0.197	0.112	0.505	0.542	0.578	−0.323	−0.431
Plant height	0.182	0.223	0.262	0.455	0.204	0.211	0.266	0.404
Branches/plant (no)	0.104	0.279	0.101	0.231	0.168	0.869**	0.978**	0.247
Pod wt/plant	−0.455	−0.344	−0.402	0.587	0.451	0.737*	0.782*	0.799*
Seed yield/plant	−0.264	−0.311	−0.191	0.725*	0.587	0.889**	0.968**	0.767*
100-seed wt	−0.287	−0.153	−0.111	0.707*	0.719*	0.755*	0.979**	0.721*
Seed yield/ha	−0.272	−0.189	−0.347	0.718*	0.555	0.904**	0.929**	0.739*
HI	−0.139	−0.168	−0.177	0.574	0.432	0.727*	0.744*	0.211
Seed oil content	−0.712*	−0.863*	−0.744*	−0.148	−0.317	−0.431	−0.784*	−0.267

**Significance at a 1% level of probability ($p < 0.01$); *Significance at a 5% level of probability ($0.01 =< p < 0.05$); NS non-significant ($p \geq 0.05$).

Traits	Biological Yield/ha	Straw yield/ha	Plant height	Branches/plant (no)	Pod wt/plant	Seed yield/plant	100-seed wt	Seed yield/ha	HI
Wt. Survival Larvae									
No. Survival pupa									
Pubescence density									
Total phenols									
Leaf fresh wt									
Leaf dry wt									
Leaf water content									
Biological yield/ha									
Straw yield/ha	0.903**								
Plant height	0.157	0.602							
Branches/plant (no)	0.221	0.574	0.773*						

Continued

Pod wt/plant	0.423	0.343	0.739*	0.725*					
Seed yield/plant	0.502	0.301	0.752*	0.854**	0.936**				
100-seed wt	0.448	0.468	0.727*	0.242	0.788*	0.882**			
Seed yield/ha	0.825**	0.773*	0.794*	0.743*	0.759*	0.996**	0.848**		
HI	−0.762*	−0.728*	0.239	0.544	−0.274	0.844**	0.746*	0.889**	
Seed oil content	−0.358	0.126	0.173	0.293	−0.336	−0.743*	−0.724*	−0.711*	−0.477

**Significance at a 1% level of probability ($p < 0.01$); *Significance at a 5% level of probability ($0.01 \le p < 0.05$); NS non-significant ($p \ge 0.05$).

The number of pupa survival was positively correlated (highly significant) with leaf water content (r = 0.933**). Also, it was positively correlated (significantly) with leaf fresh weight (r = 0.722*). Moreover, it was negatively correlated (significantly) with the leaf total phenols (r = −0.773*) and seed oil content (r = −0.744*). Meanwhile, there was no significant correlation between the number of pupa survival and each of leaf dry weight (0.569), biological yield/ha (r = −0.237), straw yield/ha (r = 0.112), plant height (r = 0.262), number of branches/plant (r = 0.101), pod weight/plant (r = −0.402), seed yield/plant (r = −0.191), 100-seed weight (r = −0.111), seed yield/ha (r = −0.347), and HI (r = −0.177). With respect to leaf pubescence density, it was positively correlated (significantly) with each of the leaf total phenols (r = 0.780*), leaf fresh weight (r = 0.747*), leaf dry weight (r = 0.809*), leaf water content (r = 0.786*), seed yield/plant (r = 0.725*), 100-seed weight (r = 0.707*), and seed yield/ha (r = 0.718*). Meanwhile, there was no significant correlation between leaf pubescence density and each of biological yield/ha (r = 0.247), straw yield/ha (r = 0.505), plant height (r = 0.455), number of branches/plant (r = 0.231), pod weight/plant (r = 0.587), an HI (r = 0.574), and seed oil content (r = −0.148).

With regard to leaf total phenols, they were positively correlated (significantly) with each of leaf fresh weight (r = 0.724*), leaf dry weight (r = 0.703*), leaf water content (r = 0.725*), and 100-seed weight (r = 0.719*).

Meanwhile, leaf total phenols were not correlated with each of biological yield/ha (r = 0.404), straw yield/ha (r = 0.542), plant height (r = 0.204), number of branches/plant (r = 0.168), pod weight/plant (r = 0.451), seed yield/plant (r = 0.587), seed yield/ha (r = 0.555), HI (r = 0.432), and seed oil content (r = −0.317). With respect to leaf fresh weight, it was positively correlated (highly significant) with each of leaf dry weight (r = 0.943**), leaf water content (r = 0.966**), biological yield/ha (r = 0.899**), number of branches/plant (r = 0.869**), seed yield/plant (r = 0.889**), and seed yield/ha (r = 0.904**). Also, it was positively correlated (significantly) with each of pod weight/plant (r = 0.737*), 100-seed weight (r = 0.755), and HI (r = 0.727*). Moreover, no significant correlation was detected between leaf fresh weight and each of straw yield/ha (r = 0.578), plant height (r = 0.211), and seed oil content (r = −0.431).

On the other hand, leaf dry weight was positively correlated (highly significant) with each of biological yield/ha (r = 0.914**), number of branches/plant (r = 0.978**), seed yield/plant (r = 0.968**), 100-seed weight (r = 0.979**), and seed yield/ha (r = 0.929**). Also, it was positively correlated (significantly) with each of leaf water content (r = 0.763*), pod weight/plant (r = 0.782*), and HI (r = 0.744*). Meanwhile, it was negatively correlated (significantly) with seed oil content (r = −0.784*). Moreover, no significant correlation was detected between leaf dry weight with each of straw yield/ha (r = −0.323) and plant height (r = 0.266). With respect to leaf water content, it was positively correlated (significantly) with each of pod weight/plant (r = 0.799*), seed yield/plant (r = 0.767*), 100-seed weight (r = 0.721*), and seed yield/ha (r = 0.739*). Meanwhile, it was not correlated with each of biological yield/ha (r = 0.567), straw yield/ha (r = −0.431), plant height (r = 0.404), number of branches/plant (r = 0.247), HI (r = 0.211), and seed oil content (r = −0.267).

With regard to biological yield/ha, it was positively correlated (highly significant) with each of straw yield/ha (r = 0.930**) and seed yield/ha (r = 0.825**). Meanwhile, it was negatively correlated (significantly) with HI (r = −0.762). Moreover, it was not correlated with each of plant height (r = 0.157), number of branches/plant (r = 0.221), pod weight/plant (r = 0.423), seed yield/plant (r = 0.502), 100-seed weight (r = 0.448), and seed oil content (r = −0.358). With respect to straw yield/ha, it was positively correlated (significantly) with seed yield/ha (r = 0.773*). Meanwhile, it was negatively correlated (significantly) with HI (r = −0.728*). However, straw yield/ha was not correlated with each of plant height (r = 0.602), number of branches/plant (r = 0.574), pod weight/plant (r = 0.343), seed yield/plant (r = 0.301), 100-seed weight (r = 0.468), and seed oil content (r = 0.126). On the other hand, plant height was positively correlated (significantly) with each of number of branches/plant (r = 0.773*), pod weight/plant (r = 0.739*), seed yield/plant (r = 0.752*), 100-seed weight (r = 0.727*), and seed yield/ha (r = 0.794*). Meanwhile, plant height was not correlated with each of HI (r = 0.239) and seed oil content (r = 0.173). With respect to number of branches/plant, it was positively correlated (highly significant) with seed yield/plant (r = 0.854**). Also, it was positively correlated (significantly) with each of pod weight/plant (r = 0.725*) and seed yield/ha (r = 0.743*). Meanwhile, no correlation was detected between number of branches/plant and each of 100-seed weight (r = 0.242), HI (r = 0.544), and seed oil content (r = 0.293).

With regard to pod weight/plant, it was positively correlated (highly significant) with seed yield/plant (r = 0.936**). Also, it was positively correlated (significantly) with each of 100-seed weight (r = 0.788*) and seed yield/ha (r = 0.759*). Meanwhile, pod weight/plant was not correlated with each of HI (r = −0.274) and seed oil content (r = −0.336). With respect to seed yield/plant, it was positively correlated (highly significant) with each of 100-seed weight (r = 0.882**), seed yield/ha (r = 0.996**), HI (r = 0.844**). Also, it was negatively correlated (significantly) with seed oil content (r = −0.743*). With regard to 100-seed weight, it was positively correlated (highly significant) with seed yield/ha (r = 0.848**). Also, it was positively correlated (significantly) with HI (r = 0.746*). Meanwhile, it was negatively correlated (significantly) with seed oil content (r = −0.724*). With respect to seed yield/ha, it was positively correlated (highly significant) with HI (r = 0.889**). Meanwhile, it was negatively correlated (significantly) with seed oil content (r = −0.711*). On the other hand, HI was not correlated with seed oil content (r = −0.477).

These results are in accordance with those obtained by Noureldin *et al.* [27] and Babka *et al.* [40] whom found the seed oil content was negatively correlated with seed yield. Moreover, Sridhar and Siddiqui [41] showed that leaf petioles of tolerant varieties were lower moisture content than susceptible ones. However, Moradi and Salimi [42] observed significant variations in all the studied traits and showed a significantly positive correlation between plant height, pods per plant, dry matter, and branches per plant with seed yield. Meanwhile, a highly significant negative correlation between leaf hair density and percent infestation for *S. oblique* was observed by Nautiyal *et al.* [43]. In the same trend, Sasane *et al.* [44] reported that pubescence density had a significantly negative correlation with the incidence of *S. larvae*.

4. Conclusion

It can be concluded that the defense mechanisms of the soybean genotypes are direct (leaf pubescence density) and indirect (leaf water content and leaf total phenols) played a major role in cotton leafworm tolerance. All studied soybean traits were negatively correlated with seed oil content except biological and straw yields/ha, as well as plant height. Soybean genotypes Giza 111, $H_{15}L_{17}$, and H_4L_4 which have desirable oil content in their seeds can tolerate infestation of the cotton leafworm under field conditions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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