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VARIETAL SUSCEPTIBILITY OF POTATO TO THE BLACK CUTWORM, *AGROTIS IPSILON* (HFN) (LEPIDOPTERA: NOCTUIDAE)

Faiza E. E. SALAH[1], Abdien M. Zein ELABDIEN[2], Salah EL –TOM[2], Adam K. AZRAG[3], Hayder ABDELGADER[4]

[1]Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan
[2]Faculty of Agriculture, University of Khartoum, Khartoum, Sudan
[3]Ministry of Agriculture, Department of Plant Protection, Eldamazin, Sudan
[4]Agricultural Research Corporation, Sudan
(Corresponding author: faizaruba@yahoo.com)

Abstract

The black cut worm (BCW), *Agrotis ipsilon* (HFN) (Lepidoptera: Noctuidae), is a highly polyphagous pest of several winter crops and became a major potato pest in lighter soils of Khartoum state. BCW inflicts serious damage on the tubers, resulting in drastic yield losses annually. Despite its economic importance, little attention has been directed to this pest in the Sudan.

Field experiments were conducted for two seasons at Karari, Khartoum state, central Sudan, to evaluate 10 potato varieties (lines/accessions) for resistance to BCW damage. The percentage damaged tubers numbers (%DTN) and weight (% DTW) as parameters were used for evaluation. Differences in both parameters were very highly significant, due to varieties and seasons ($P < 0.001$ for both parameters). The interaction between the varieties and seasons was also very highly significant ($P < 0.001$). Two parameters were found to correlate strongly and significantly ($r = 0.83$). The 10 potato varieties (lines/accessions) were also subjected to a series of no – choice tests in the laboratory for two seasons. The tests included testing the larval and pupal developmental rates on potato tubers. Significant differences were noted in larval weight gains (LWGs), due to differences in potato varieties across the various feeding tests. Alpha, Lesita and Bright varieties showed higher levels of resistance both in the field and in the laboratory, while Desiree and Spunta showed the highest level of susceptibility. Factors governing the causes for resistance were discussed.

Keywords: *Sudan, Varietal Susceptibility, Potato, Black Cutworm, Agrotis ipsilon*

Introduction

Potato, *Solanum tuberosum* L., is one of the main food crops in the world.

In the Sudan, the crop was initially introduced in 1935, since then the area has increased steadily to meet the increasing domestic demand.

The black cut worm (BCW), *Agrotis ipsilon* (Hfn) (Lepidoptera: Noctuidae), is recognized as one of the most damaging insect pests of potato in the Sudan (Schmutterer, 1969, Salih, 1985) causing a loss as high as 50% in tubers of some fields (Siddig, 1987).

The objective of this study was to evaluate ten potato varieties for resistance to the BCW damage, both at field and Lab. levels in search for feasible control measures of the pest.

Materials and methods

A/ Field potato variety screening for resistance to the BCW:

Two field experiments were conducted for 2 seasons using 10 potato varieties, viz. Alpha, Ajax, Bright, lesita, Mondial, Draga, Spunta, Desiree, Escort and Famosa.

The tubers were planted on 27 and 16 November for season 1&2, respectively in a randomized complete blocked (RCB) design. Four replicates of plot measuring 8.0 m x 1.5 m at 20 cm distances between plants were used, but no chemical treatments.

At harvest, the following parameters were assessed:

1/ No. and weights (kg) of sound and damaged tubers.

2/ Percentages of damaged tubers (calculated).

The data were analyzed by ANOVA after arc-sin transformation, DMRT was used to separate means with significant differences.

The combined analysis was carried out using the method of Gomez & Gomez (1984).

B/ Lab. tests:

a) Effects of potato varieties leaves on the BCW development:

Three-day-old larvae were fed on excited leaves from the 10 potato varieties; one larva / 4.0 x 1.8 cm cup, 15 cups, replicated 4 times under laboratory conditions of 28±1°C, 25-40%R.H. and 12:12 L: D photoperiod till the pupal stage.

The following parameters were observed and recorded**:**

1- Mean larval weight (mg) after 25 days of feeding on their corresponding diet.
2- Mean larval duration (days).
3- Mean fresh pupal weight (mg).
4- Mean pupal duration (days).

For season (2) the mean larval weight (mg) after 18 days of feeding was the only parameter recorded.

The data were statistically analyzed and the means were separated by DMRT.

b) The effects of variety tubers on BCW development:

Similarly, 2 experiments were carried out in the Lab. simultaneously with the leaf feeding experiments except that the larvae were fed on the tubers of the 10 potato varieties. The experiments were designed in the RCB of 4 replicates and 20 cups /treatment.

The following parameters were observed & recorded:

1- Mean larval weight (mg) after 25 days of feeding.
2- Mean larval duration (days).
3- Mean fresh pupal weight (mg).
4- Mean pupal duration (days).

The data were statistically analyzed and the means were separated by DMRT.

C/ Biochemical factors for resistance:

Sliced tubers of the following six varieties: Alpha, Lesita, Desiree, Mondial, Escort and Draga were biochemically analyzed in the lab. for percentage dry matter content, starch, protien, tannins, glycoalkaloids(solanine ng/100g) to test for some nutrients and/or allelochemicals of the tuber of potato that might influence the potato susceptibility to injury caused by the BCW**.**

Results and discussion

A/ Field potato varieties screening for resistance to the BCW:

The field performance of the 10 potato varieties to the natural infestation of the BCW for seasons (1) and (2) is shown in tables (1) and (2), respectively where highly significant

differences ($P < 0.001$) in % DTN were evident due to varietal susceptibility (table 1). For season (2) the differences between the means % DTN were significant ($P < 0.05$) but were highly significant ($P < 0.01$) for % DTW

Table 1. Ranked variety mean % DTN of 10 potato varieties screened naturally for cut worm resistance (season 1).

Variety	**Mean % DTN**[*1]
Escort	37.83 (37.94)[*2] a
Desiree	25.33 (29.60) ab
Spunta	21.20 (27.42) bc
Mondial	20.18 (26.49) bc[*3]
Ajax	18.34 (24.73) bcd
Draga	18.29 (24.50) bcd
Famosa	16.39 (21.86) bcde
Bright	9.04 (17.28) cde
Alpha	7.32 (15.60) de
Lesita	5.34 (12.88) e
G Mean	22.81
SE ±	3.059

[*1]Means of 4 replicate
[*2]Figures in parentheses were the angular transformed values
[*3]Means followed by the same letters(s) were not significantly different.

Table 2. Variety mean % DTN and % DTW of 10 potato varieties screened for resistance to the BCW (season 2)

Variety	Means[*1]	
	% DTN	% DTW
Desiree	47.90 a (43.80)[*2]	57.87 a (49.54)
Spunta	46.76a[*3] (43.14)	44.61 ab (41.90)
Ajax	34.95 ab (35.09)	37.82 abc (37.94)
Fomosa	32.03ab (34.41)	34.32 abcd (35.85)
Draga	29.63 ab (32.31)	32.36 abcd (34.70)
Alpha	23.68 ab (29.13)	15.63 cd (23.26)
Lesita	17.01 b (23.30)	22.07 bcd (28.04)
Bright	14.96 b (22.56) b	13.20 d (21.30)
Escort	19.00 b (22.31)	30.24 abcd (35.79)
Mondial	14.60 b (21.97)	15.28 cd (23.03)
G.M	30.802	33.133
SE ±	4.7265	4.888

[*1]Means of 3 replicates
[*2]Figures in parentheses are the arc – sin percent transformation.
[*3]Means followed by the same letters(s) were not significantly different.
($P > 0.05$) in Duncan's MRT.

Further statistical analysis showed that the measured parameters viz. % DTN and % DTW correlated strongly and significantly (r = 0.83) (table 3), and that the varieties which have % DTN < Grand mean were found to have % DTW < Grand mean (table 2).

The combined analysis of variance on the percentage DTN of the to potato varieties screened for resistance to the BCW for season (1) gave very highly significant interaction between season and variety (P < 0.001) as well as highly significant differences (P < 0.001) in cut worm incidence (Table 4).

Table 3. Correlation matrix between the 2 susceptibility indices (% DTN and % DTW) of 10 potato varieties screened for cut worm damage.

Parameter	Correlation coefficient DF = 8	
	1	2
1% DTN	1.000	
3% DTW	0.832 **	1.000

**Significant at P = 0.01 (r ± 0.552)
%DTN = Percent damaged tuber numbers.
%DTW = Percent damaged tuber weight.

Table 4. Combined analysis of variance on the % DTN of 10 potato varieties screened for resistance to the BCW (season 1).

Source	df	SS	MS	F - Ratio
Seasons	1	2191.16	2191.16	46.0869***
Varieties	9	6136.23	681.80	14.340 ***
Interaction (Season x Var)	9	3925.00	436.12	9.173 ***
Pooled Error	36	1711.584	47.544	
SE ±	= 4.8757			

***Highly significant (P < 0.001)

The varietal weighted means for the mean % DTN (table 5) showed that 4 varieties were found to sustain weighted mean DTN < G. mean in the 2 seasons. These varieties were: Mondial, Alpha, Bright and Lesita and thus considered to be least susceptible (table 6).

Table 5. Weighted mean* damage of the BCW on the harvested tuber numbers of 10 potato varieties screened in season (1) and (2).

Variety	**Mean percent damage of the harvested*1 tuber number (% DTN)**		
	Season (1)	Season (2)	Weighted mean DTN
Desiree	25.33(29.6)*2 ab	47.90(43.80) a	(36.68) a
Spunta	21.20(27.60) bc	46.76(43.14) a	(35.23) ab
Escort	37.83(39.92) a	19.00(22.31) b	(31.11) abc
Ajax	18.34(24.73) bcd	34.95(35.09) ab	(29.91) abc
Draga	18.29(24.50) bcd	29.63(32.31) ab	(28.41) abc
Famosa	16.39(21.86) bcde	32.03(34.41) ab	(28.14) abc
Mondial	20.18(26.49) bc	14.60(21.97) b	(24.23) abc
Alpha	07.32(15.60) dc	23.68(29.13) ab	(22.35) abc
Bright	09.04(17.28) cde	14.96(22.56) b	(19.92) bc
Lesita	05.34(12.88) e	17.01(23.30) b	(18.09) c
G. Mean	17.93(22.81)	28.05(30.80)	(27.41)
SE ±	3.059	4.727	4.785*3

*1Variety mean for the mean DTN of the two seasons.
*2Figures in parentheses are the arc. sin percent.
*3Calculated from the combined analysis of variance.
*Means followed by the same letter(s) were not significantly different (P > 0.05).

Table 6. Least susceptible (relatively resistant) potato varieties with both weighted mean DTN and DTW < G. mean compared to susceptible checks.

Variety	Weighted[*1] Mean % DTN	Mean[*2] DTW
Lesita	18.09 a[*3]	28.04 abc
Bright	19.92 ab	21.30 a
Alpha	22.35 ab *[4]	23.26 ab
Mondial	24.23 bc	23.26 ab
Mean	21.148	23.97
G. Mean	27.41	33.13
Desiree (S. check)	36.68	49.54
Spunta (S. check)	35.23	41.90

[*1]Means of 3 replicates in two screening trials.
[*2]Means of 3 replicates in one screening trial.
[*3]Figures presented in the table are the angular transformed values.
[*4]Means followed by the same letters were not significantly different according to Duncan's MRT.

B/ Laboratory tests:

a) Effects of potato varieties leaves on the BCW development**.**

From table 7 (Test 1) where the larvae were allowed to feed for 28 days, the 3 varieties: Spunta, Famosa and Desiree (described as susceptible varieties in the field screening trials) had the highest larval weight gain (LWG) > G. mean.

Table 7. Differential weight gains (mg) of the BCW larvae fed on excited leaves of 10 potato varieties for 28 and 18 days in tests (1) and (2), respectively.

Variety	Mean LWG (mg)	
	First test (1)	Second test (2)
Mondial	761.2 a	203.3 abcd
Spunta	741.1 ab	226.0 ab
Fomosa	634.2 abc	165.8 cd
Desiree	632.3 abc[*1]	157.8 d
Lesita	601.4 abc	234.8 a
Escort	595.0 abc	49.7 e
Draga	594.0 abc	177.9 bcd
Bright	588.0 bc	38.7 e
Ajax	575.2 bc	212.7 abc
Alpha	503.3 c	219.9 ab
G.M	622.57	168.66
SE ±	49.315	14.824

[*1]Mean of followed by the same letter(s) were not significantly different in Duncan's MRT.

The differences between the means LWG were significant ($P < 0.05$). However, in test (2) where the larvae were allowed to feed for 18 days only, the differences between the means LWGs were highly significant ($P < 0.001$, table 7).

Comparing the results of the 2 tests, the differences were much more prominent in the first than in the 2nd test and that resistance due to potato leaf feeding was more detectable in late than in early larval stages.

b) Effect of variety tubers on cut warm development:

Table (8) shows that the differences due to tuber varieties were highly significant ($P < 0.001$) for LWG, larval longevity ($P < 0.001$) and pupal weights ($P < 0.05$). It could be seen that 5 varieties sustained LWG > G mean, those were Desiree, Mondial, Escort, Spunta and Famosa. Those varieties (except Mondial), showed high susceptibility in the field screening trials and produced (including Monidal) higher larval weight gains in the leaf feeding tests.

Five varieties were found to have LWG < G. mean; of those Alpha and Bright produced the lowest LWG of 132.3 and 112.5 mg, respectively. Also, Alpha had the longest larval duration as well as the lowest pupal weight, while Desiree (susceptible) had the heaviest**.**

Table 8. Mean L. weight gain (mg), larval duration (days) and fresh pupal weight (mg) of the BCW larvae fed on sliced tubers of 10 potato varieties in a laboratory no-choice test.

Entry	**Variety Means***		
	Larval Weight (mg)	Larval longevity (day)	Pupal Weight (mg)
Desiree	342.4 a	40.7 d	319.2 a
Mondial	336.5 a	43.4 cd	281.6 abc
Escort	312.9 ab	50.3 ab	269.2 bc
Spunta	294.1 abc	51.7 ab	272.4 abc
Famosa	264.3 abc	47.7 bc	318.8 a
Draga	220.5 bcd	47.9 bc	313.4 ab
Lesita	199.4 cd	53.2 ab	250.2 c
Ajax	192.3 cd	51.0 ab	283.6 abc
Alpha	132.3 d	56.7 a	250.0 c
Bright	112.5 d	48.7 bc	264.0 c
G. Mean	240.72	49.13	279.24
SE ±	34.5	2.09	14.04

*Means followed by the same letter(s) were not significantly different (P > 0.05).

The correlation matrix (Table 9 and 10) showed that the % starch correlated positively and significantly with LWGs, % DTN and % DTW (test 1 and 2).

Dry matter was negatively correlated with LWGs in both tests. The % protein and tannins of the tubers were found to have no significant correlation with LWGs in the laboratory or with tuber damage in the field.

A negative correlation was found between the amount of solanine in the variety tubers and the LWGs due to feeding on them in both tests, and damage observed in the field in terms of % DTN and % DTW.

Table 9. Mean biochemical constituents of 6 potato varieties with their mean LWG (mg) in the laboratory and the resulting % DTN and DTW in the field

Variety	Means								
	% Starch	% dry Matter	% Protein	Solanine ng/100 g	% Tannin	Mean % L.W test 1	Mean % DTN	Mean % DTW	Mean L.W tests 2 tubers
Escort	52.0	26.0	9.8	0.00	0.115	82.3	25.84	35.97	82.33
Mondial	52.0	22.7	7.2	15.0	0.150	133.15	22.46	23.03	135.58
Desiree	64.5	22.45	8.58	0.00	0.190	288.8	43.8	49.54	337.66
Draga	40.1	24.6	10.87	18.0	0.115	68.7	33.0	34.7	67.33
Alpha	40.1	27.23	7.86	31.0	0.06	51.1	29.13	23.26	52.83
Lesita	35.8	25.33	8.269	0.00	0.086	33.83	24.35	28.04	33.83
G.M	47.41	24.70	8.76	10.66	0.12	109.65	29.76	32.42	118.26

Table (10): Correlation matrix between susceptibility parameters (% DTN. % DTW. LWG) in season (1), LWG in season (2) and the 5 biochemical components of 6 potato varieties differing in the susceptibility

Parameters	Correlation coefficients df = 4								
	1	2	3	4	5	6	7	8	9
1.Starch %	1.000								
2.Dry Matte %	-0.618	1.000							
3.Protein %	-0.119	-0.146	1.000						
4.Tannins %	+0.884	-0.498	-0.013	1.000					
5.Solanine	-0.419	-0.328	-0.156	-0.487	1.000				
6.LWG (1991)	-0.799*	-0.376	0.095	0.738*	-0.418	1.000			
7.LWG (1992)	0.801*	-0.360	0.059	0.743*	-0.414	0.999**	1.000		
8.% DTN	0.553	-0.387	0.282	0.550	-0.141	0.913**	0.908**	1.000	
9.DTW	0.682	-0.277	0.450	0.688	-0.593	0.912**	0.898**	0.850**	1.000

* Significant at p = 0.05 r = 0. 739 at p = 0.05

** Significant at p = 0.01 r = 0. 811 at p = 0.01

From the results, it was apparent that the pest population level was sufficient enough to allow for adequate evaluation of resistance. This has resulted in significant differences ($p<0.001$ and $p>0.005$) in the number of damaged tubers (%DTN) of the varieties tested in the first and second screening season, respectively. It was also noted that the overall mean % DTN was higher in the second than in the first screening trials; it was 30.8 %, and 22.87, respectively, an indication of a higher injurious level of the pest in the second than in the first screening trial.

The results indicated that there were clear differences in the degree of reaction of the potato varieties with the BCW. Some have reflected only slight tuber damage, others were deleteriously damaged and none was immune. The results were in conformity with the findings of Parihar and Singh (1988) in India who concluded that none of the 12 varieties they screened was immune to *A. ipsilon* but miner damage was recorded in the tuber of some varieties. From the results, the varieties Lesita, Bright, Alpha and Mondial were the least susceptible in the field over the 2 experiments, with weighted mean DTN of 18.09, 19.9, 22.25 and 24.23%, respectively, and weighted mean DTW of 38.04,21.3, 23.26 and 23.36%, respectively. On the other hand the varieties Desiree and Sponta were found to be the most susceptible in the field with weighted mean DTN of 36.6 and 35.23%, respectively, and weighted mean DTW of 49.54 and 41.9% respectively.

The variety Desiree being one of the most susceptible varieties was also reported by Anon, (1986) to be highly susceptible to the golden nematode. However, Spunta which proved to be susceptible to the BCW in the present work was found by Doss (1987) in Egypt to be the only resistant variety among 17 varieties, he tested to *P. operculella* (Zeller), *Gryllotalpa gryllotalpa* and *Euzophera ossentella*. This could be explained as stated by (Painter 1951) that the genes governing resistance to a certain pest could cause susceptibility to other pests.

The nearly perfect correlation (r = 0.9972) between the mean LWGs due to feeding on potato foliage and the LWGs due to feeding on the tubers strongly pointed out the presence of a shared antibiosis factor(s) in both the leaves and the tubers which confirmed the findings of Deahl et al. (1973) and Sanford et al. (1984) who showed that the toxic substance was found in both the leaves and the tubers.

The resistant varieties in the field i.e Lesita, Bright, Alpha except Mondial again showed higher tendency of resistance to the BCW larva, expressed as reduced LWG, prolonged larval duration, reduced pupal weight and higher mortality rates. However, duration of pupal stages did not differ significantly among the tested varieties. This result was

confirmed by the finding of Buching and Turpin (1977) who showed that pupal duration of the BCW did not differ significantly among the various plant species they tested.

On the other hand, the susceptible varieties in the field: Spunta and Ajax again were found to sustain consistently higher susceptibility levels across the various laboratory feeding tests. However, the resistance of Mondial which exhibited higher level of resistance in the field trails and revealed higher susceptibility level in the laboratory feeding tests, would be probably related to mechanisms other than antibiosis, e. g. non- preference or tolerance. Such mechanisms need further search.

In the present study, there appears to be a cause and effect relationship between the TGA (solanine) and resistance to BCW. Larval weights correlated negatively with solanine ($r = 0.418$, $r = 0.414$) in the 2 laboratory tests, respectively, and with tuber damage in the field ($r = -0.593$). Desiree with zero ng/100 g solanine was highly susceptible in the field and in the laboratory, while Alpha with 31 ng/100 g solanine was resistant.

Conclusion

The use of the resistant Alpha, Lesita and Bright should provide a foundation on which an IPM programme could be built. Resistant varieties are particularly valuable in the Sudan which often suffers from crop losses by insects in the presence of scarce resources. Resistant varieties are easily adopted by farmers at no extra cost.

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