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GROWTH AND DEVELOPMENT OF THE POTATO TUBER MOTH, *PHTHORIMAEA OPERCULELLA* (ZELLER), ON RESISTANT AND SUSCEPTIBLE POTATO GENOTYPES IN STORAGE[1]

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ABSTRACT

The growth and development of the potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera : Gelechiidae) were studied on 23 potato genotypes under laboratory conditions. The biological parameters such as entering larvae pupated, larval period,pupal weight, sex ratio, and fecundity per female differed from one genotype to another. The differences among genotypes indicated that antibiosis was in operation. Different growth indices have been computed and a comparison has been shown. The development of the total population (from equal initial infestation) of the PTM after three months of storing the potato tubers differed from one genotype to another. No correlation was found between the associations of the total glycoalkaloids, soluble protein, and total dietary fibre and total PTM population (larva + pupa + adult) development. A low but positive correlation (r = 0.483 [0.05]) was found between total protein in association with other constituents and the PTM population development while a negative correlation was found between digestible carbohydrates in combination with other constituents and the PTM population development. It was apparent that the individual chemical composition of potato tubers in association with other constituents showed a little effect on the PTM population development and ultimately the expression of resistance or susceptibility.

Key words: Resistance, potato, *Phthorimaea operculella* (Zeller), potato tuber moth, growth and development

INTRODUCTION

The growth and development of an insect greatly depend upon the nutritive value of the host. A host with adequate nutrient supports more population than one with less nutrients. It is a common observation that some percentages of the potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera : Gelechiidae) larvae upon entry into the tubers fail to complete their growth and development. Such figures differ from one genotype to

another. Some authors (Raman and Palacios, 1982; Ojero and Mueke, 1985; Estrada and Valencia, 1988) expressed views that the resistance of potato cultivars to the PTM may be due to the antibiosis. However, no serious attempt has been made to study antibiosis to explain the mechanism of resistance in potato cultivars against the PTM. The present study was undertaken (1) to determine the antibiotic effects of selected resistant potato genotypes and (2)to know whether the association of the chemical composition of potato tubers affects the total PTM population (larva pupa + adult) development and ultimately the expression of resistance or susceptibility.

MATERIALS AND METHODS

To study antibiosis ten tubers were randomly selected from each of the 23 genotypes (equally conditioned and free from any initial infestation). One replicate consisted of one tuber. The tubers were kept separately in plastic containers (0.06 m x 0.10 m). Ten newly hatched active larvae were carefully picked with a camel's hair brush (No. 0) and released in each container. Upon the release of the larvae the top of each container was covered with plastic lid(with very fine perforations for aeration) and kept undisturbed in the laboratory under room temperature (25°C - 27°C) for four days. After such period, dead larvae were counted from each replicate. The plastic lids were then replaced by cheese cloth secured with a rubber band for proper aeration in the container. Everyday starting 8:00 a.m., containers were checked to collect the newly formed pupae, if any. Pupae were sexed following the method of Chauhan and Verma (1982). The following data were collected : entering larvae (those that entered successfully the tubers) pupated, larval period, pupal weight (by Mettler balance), adult weight, sex ratio and fecundity per female.

The study was conducted in the laboratory (at the San Ramon station with latitude 11° 08'S and altitude 800 m of the International Potato Centre (CIP), Lima, Peru) under room temperature (26°C - 28°C) and 50 % - 55 % relative humidity following a completely randomized design. At the end of the experiment, all tubers were cut into pieces with a small knife to check for pupa, if any, in the tubers. From the data, individual growth indices (GI) and success indices (SI) as well as growth indices according to Pant and Dang (1969) and Howe (1971) were computed to find out the suitability of the genotypes. The cultivars Revolucion was taken as standard considering its low resistance and wide use for different studies by the Nematology and Entomology Department of CIP. Growth indices were determined according to the formulae:

Individual growth and success indices:

$$\text{Larval-pupal period index} = \frac{\text{Ave. larval period + Ave. pupal period on Revolucion}}{\text{Ave. larval period + Ave. pupal period on test genotype}}$$

$$\text{Pupal weight Index} = \frac{\text{Ave. pupal weight on test genotype}}{\text{Ave. pupal weight on Revolucion}}$$

$$\text{Adult longevity index} = \frac{\text{Ave. adult longevity on test genotype}}{\text{Ave. adult longevity on Revolucion}}$$

$$\text{Adult weight index} = \frac{\text{Ave. adult weight on genotype}}{\text{Ave. adult weight on Revolucion}}$$

$$\text{Oviposition index} = \frac{\text{Ave. number of eggs laid by adults emerging from larvae reared on test genotype}}{\text{Ave. number of eggs laid by the adults emerging from larvae reared on Revolucion}}$$

$$\text{Survival index} = \frac{\text{No. of adults emerging from the larvae reared on test genotype}}{\text{No. of adults emerging from the larvae reared on Revolucion}}$$

Success index = Ave. of all the above mentioned indices

$$\text{Growth index (Pant and Dang, 1969)} = \frac{\text{Percentage of larvae that became pupae}}{\text{Larval period (in days)}}$$

$$\text{Growth index (Howe, 1971)} = \frac{\text{Log (S)}}{\text{T}}$$

Where S = % Survival,
T = Developmental period (days)

Various growth indices were compared to show the differences among them which may guide future researchers in choosing the best in determining the suitability of a host to an insect.

To study the effects of the chemical components of potato tubers on total PTM population development potato tubers of 23 genotypes were used for the study. Tubers were kept in a cold storage for about a month prior to their use to ensure that there were no initial infestations. Twenty five medium size tubers were randomly selected for each genotype for this study. There were five replications each consisting of 20 tubers. Twenty tubers were initially placed in a brown paper bag (-0.21 m x 0.41 m x 0.38 m) and newly emerged (0-2 hours old) active larvae were carefully transferred with a camel's hair brush (No. 0) into each bag. To transfer larvae the head end of the brush moistened with clean water was used. Then the top open end of the bag was wrapped a little and carefully tied with a piece of masking tape. The bag was kept undisturbed for four days on the floor of the diffused light store (DLS) (widely used to store potato tubers) to limit larval movement and promote their entry into the tubers. After four days when the larvae had already penetrated, the tubers of each replicate were transferred into

a wooden crate covered with very fine double mesh (0.5 mm diameter). A piece of newspaper was placed at the bottom of each crate. All the crates were kept in a DLS following a completely randomized design and their positions were changed every 15 days to minimize the effect of diffused light, if any, on the lower and upper crates. The maximum temperature and maximum relative humidity in the DLS ranged between 27°C to 33°C and from 94% to 97%, respectively. Total number of adults, pupae, and larvae in each crate was obtained after three months of storage. Tubers from each crate were cut into pieces to check the presence of pupae and larvae. This test hoped to correlate population development with biochemical components of the respective tubers. Pupae and adults were also sexed. Sex ratios were computed. The remaining five tubers of each genotype were used for the analysis of biochemical components. Total glycoalkaloids (TGA), digestible carbohydrates, total dietary fibre, total protein and soluble protein were determined. TGA was determined according to the method developed by Fitzpatric and Osman (1974) while other constituents were determined by Kjeldahl method.

RESULTS AND DISCUSSION

Huayro provided the highest pupation for larvae successfully entering the tuber (76.39%)while Capiro provided the least pupation (Table 1). It was apparent that there were some interactions between successful tuber penetration and biochemical components of tubers leading to the death of some larvae successfully penetrating the tubers. Fenemore (1980) concluded that differences in percentage of pupation may not actually reflect the establishment success of the first instar larvae as mortality after establishment may occur. The findings of this study agree with the observation of Fenemore. The duration of larval development is greatly influenced by the nutrient potential of the host under a particular environment. The larval duration in Amarilla was 13.50 days which was significantly different from Cica's 18.60 days. The female pupal weight was 0.01140 g for accession 701273 and 0.01831 g for Amarilla and the difference was also statistically significant. Corollary to this, Fenemore (1980) indicated significant differences in pupal weight of females depending on the cultivars on which the larvae were fed. Maximum male pupal weight was obtained from larvae fed with Ajanhuiri (0.01405g) while the least was from OCH - 10071 (0.00978g) which also differed significantly. The highest fecundity per female was obtained from larvae that fed on Amarilla (119.00) while the minimum was from larvae that fed on accession 701273 (84.20) which differed significantly. A positive correlation ($r = 0.047$ [0.01]) was found between female adult weight and fecundity (Fig. 1), although it was low as evident by the r value. In all but five genotypes (Yana -Imlila, Perricholi, OCH - 10071, Tahuaquena, and Capiro) the females outnumbered the males. It is apparent that genotypes had no effect on the expression of sex or subsequent male to female ratio.

These results showed that the tubers of different genotypes had significant effects on the various biological parameters of entering larvae, indicating that antibiosis is in operation.

The success indices differed from one genotype to the other (Table 2). As mentioned earlier, Revolucion was considered standard and assigned an index value of one in terms of growth and development of the insect. A genotype with a success index value of more than one was considered superior to Revolucion. In contrast, a genotype with a value of less than one was considered inferior. The values with parentheses under the success index values indictate ranking according to the suitability of the tubers. It is evident that Amarilla stand first followed by Huayro having very close index values. Therefore, these genotypes are highly suitable to the pest. In contrast, the least suitable genotype is Liberteña, followed by Capiro, OCH- 10071, and Cica. The success index values of these genotypes are very close to each other and may be considered almost equally suitable hosts to the PTM.

A comparison of three indices (success, Pant and Dang's, 1969 and Howe's, 1971) revealed not much variation among genotypes in terms of preference ranking (Table 3). In cases of success and Pant and Dang's indices, there were 23 rankings for 23 genotypes while for Howe's index 23 genotypes were grouped under 20 rankings. The Howe's index gave three genotypes the same ranking with another genotypes. It seems, therefore, that the Howe's index is more refined than those of the success and Pant and Dang's indices.

The total PTM population (larvae + pupae + adults) obtained after three months of tuber storage differed from one genotype to the other, even if the initial larval population was the same for all genotypes. Maximum population was observed in Huayro (1263.6) while the least was seen in Cica (365.2) and this difference was statistically significant (Table 4). Huamantanga and Amarilla populations were comparable with Huayro's. The differences in total population of different genotypes kept under similar environments obviously indicate variation in the suitability of tubers. Ojero and Mueke (1985) observed that the mean number of the larva which survived in ten tubers differed among the varieties. Similar to the previous study the sex ratio of the pupae and adult was 1:1 in some genotypes while in others the females outnumbered the males, indictating that genotypes had no apparent influence on sex expression.

No correlation was found between TGA levels in association with other constituents in the tubers and resistance to the PTM at 5% level (r = 0.026 [ns]) (Fig. 2). Resistance here corresponds to the population development as indicated in Table 4. Ojero and Mueke (1985) commented, without analysis of the chemical components of the potato tuber that TGA could play the role for the resistance to the PTM. But this experiment failed to validate the hypothesis of Ojero and Mueke. The highest amount of digestible carbohydrates was found in Sani-Imilla (78.20%)while the lowest in Alca-Compis (55.40%). There was a negative correlation between digestible carbohydrate in association with other constituents and resistance to the PTM (r = -0.43 (0.05)). It indicates that genotypes with more digestible carbohydrates in combination with other constituents appear to be more resistant to the PTM. With the increase in digestible carbohydrate in the tuber the total protein decreased. As protein is vital for the growth and development of the pest, a cultivar with less protein produces small population as compared to one with more protein. Therefore, a cultivar with more digestible carbohydrates in association with other constituents in potato tubers becomes more resistant to the PTM than one with less digestible carbohydrates.

The amount of soluble protein ranged from 0.46% (Tahuaquena) to 1.42% (Ñata). No correlation was found between levels of soluble protein in combination with other constituents and resistance levels at 5% level (r = 0.036 (ns)). It appears that the small amount of soluble protein itself had no significant effect on resistance levels among genotypes. On the other hand, maximum total protein was observed in Alca-Compis (18.44%), the least in Tahuaqueña (4.47%), and a low but positive correlation was found between total protein content in association with other constituents and resistance levels (r = 0.483 (0.05)) (Fig. 3). It is apparent that a genotype with more total protein in association with other conconstituents supports more PTM population, making it more in susceptible to others with less protein.

Total dietary fiber ranged from 8.77% (OCH - 10071) to 12.55% (Huayro). No correlation was found between total dietary fiber in association with other constituents in tubers and resistance phenomena at the 5% levels (r = 0.252 (ns)). The dietary fiber is mainly present in the periderm (skin) of the potato tubers. The PTM feeds under the skin (not the skin itself) and therefore, the amount of dietary fiber does not affect the expression of resistance or susceptibility to the PTM. The possible reason is that dietary fiber is not as essential as some amino acids and other components to show resistance or susceptibility.

From the above results it was observed that the individual chemical composition of potato tubers in association with the other constituents shows a little effect on the PTM population development and ultimately the expression of resistance or susceptibility to the PTM.

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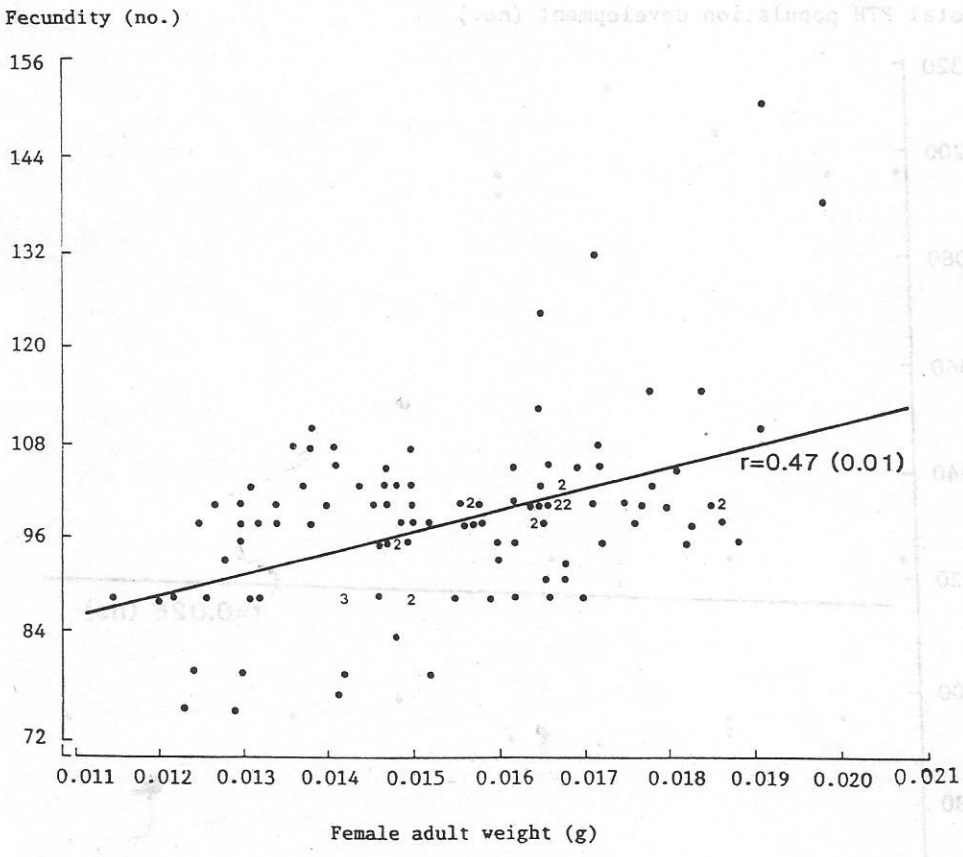

Figure 1. Relationship between the potato tuber moth female adult weight and fecundity.

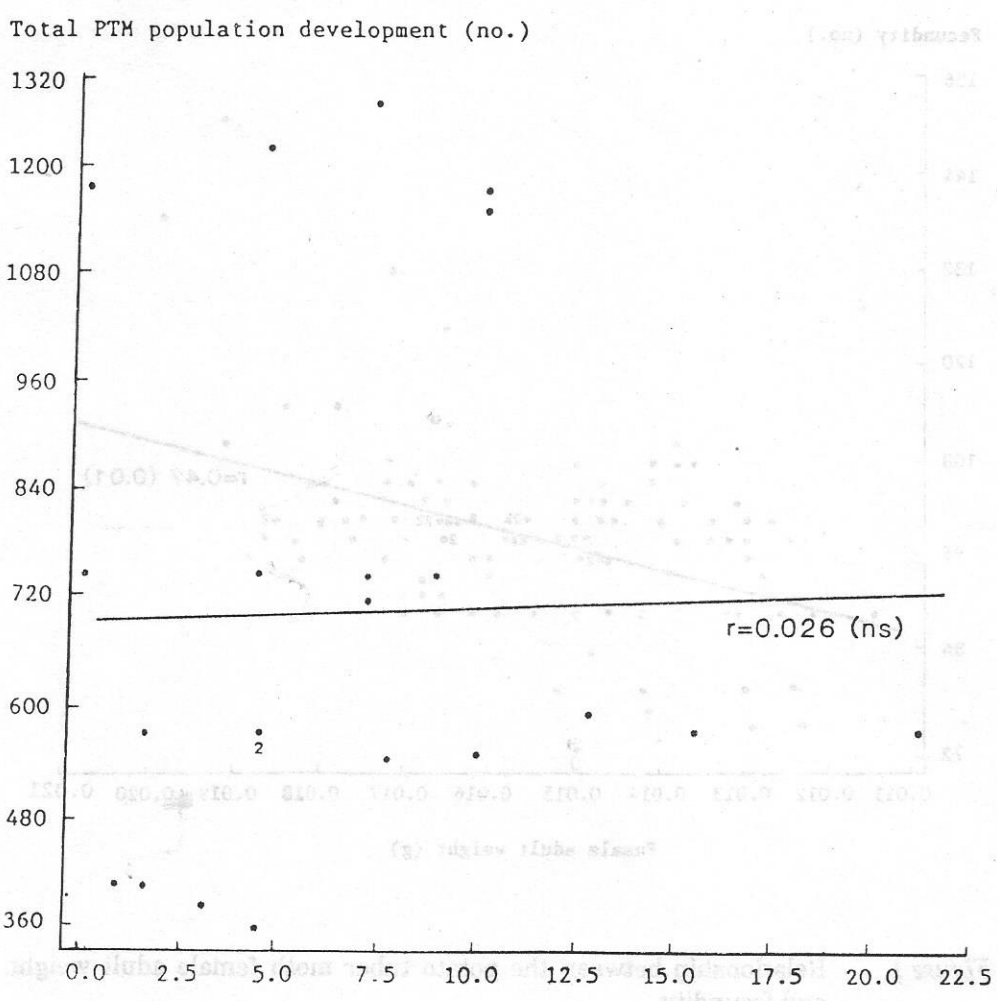

Figure 2. **Relationship between total glycoalkaloids and total potato tuber moth population (larva + pupa + adult) development in different potato genotypes.**

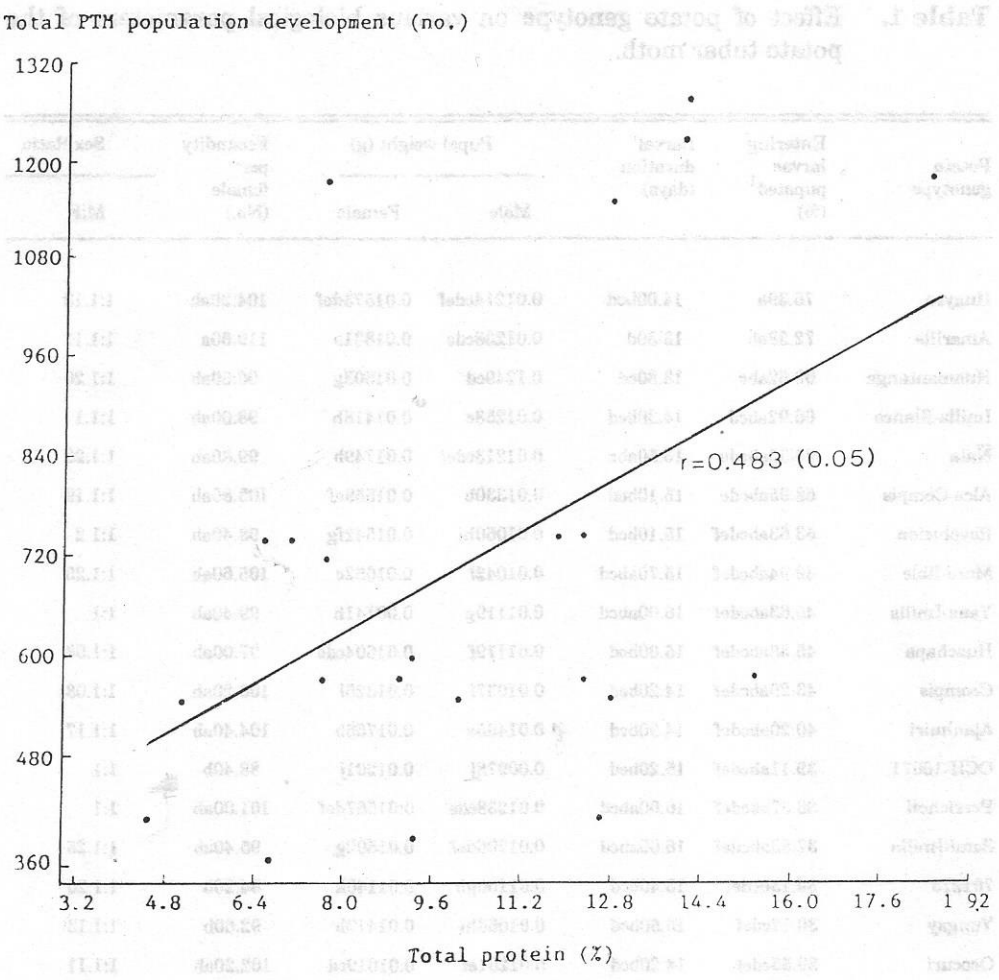

Figure 3. Relationship between total protein and total potato tuber moth population (larva + pupa + adult) development in different potato genotypes.

Table 1. Effect of potato genotype on various biological parameters of the potato tuber moth.

Potato genotype	Entering larvae pupated[1] (%)	Larval duration (days)	Pupal weight (g)		Fecundity per female (No.)	Sex Ratio
			Male	Female		M:F
Huayro	76.39a	14.00bcd	0.01214cdef	0.01573def	104.20ab	1:1.13
Amarilla	72.38ab	13.50d	0.01238cde	0.01831a	119.00a	1:1.11
Huamantanga	69.62abc	13.80cd	0.1249cd	0.01503g	96.60ab	1:1.20
Imilla-Blanca	66.92abcd	14.30bcd	0.01258c	0.01418h	98.00ab	1:1.1
Ñata	60.33abcde	16.50abc	0.01213cdef	0.01749b	99.80ab	1:1.23
Alca-Compis	58.95abcde	15.10bcd	0.01330b	0.01559ef	103.80ab	1:1.19
Revolucion	53.63abcdef	15.10bcd	0.01060hi	0.01542fg	98.40ab	1:1.2
Moro-Bole	49.94abcdef	15.70abcd	0.01042i	0.01652c	105.60ab	1:1.25
Yana-Imilla	45.63abcdef	16.00abcd	0.01119g	0.00141h	99.40ab	1:1
Huachapa	45.38abcdef	15.00bcd	0.01179f	0.01604cde	97.00ab	1:1.08
Ccompis	43.29abcdef	14.20bcd	0.01037i	0.01325i	100.20ab	1:1.08
Ajanhuiri	40.20abcdef	14.90bcd	0.01405a	0.01755b	104.40ab	1:1.17
OCH-10071	39.11abcdef	15.20bcd	0.00978j	0.01201j	88.40b	1:1
Perricholi	38.37abcdef	16.00abcd	0.01238cde	0.01567def	101.00ab	1:1
Sami-Imilla	37.83abcdef	16.00abcd	0.01206def	0.01502g	95.40ab	1:1.25
701273	34.13bcdef	15.40bcd	0.01106gh	0.01140k	84.20b	1:1.20
Yungay	30.57cdef	15.50bcd	0.01068hi	0.01417h	92.60b	1:1.13
Ococuri	29.35cdef	14.20bcd	0.01201ef	0.01619cd	102.20ab	1:1.11
Huagalina	29.01def	15.60bcd	0.01065hi	0.01246j	99.0ab	1:1.22
Tahuaqueña	26.33def	16.20abcd	0.01046i	0.01419h	97.00ab	1:1
Cica	25.26ef	18.60a	0.01099gh	0.00132i	97.60ab	1:1.12
Liberteña	21.97f	16.90ab	0.01063hi	0.01231j	95.40ab	1:1.17
Capiro	16.70f	16.80ab	0.01035i	0.01354i	94.60b	1:1

[1]Data were transformed to arc sine prior to analysis.
Means followed by the same or no letter in the same column do not differ significantly from each other at 5% level by Tukey's test.

Table 2. Effect of potato genotype on the growth indices of the potato tuber moth (based on one - tuber test)

Potato genotype	Larval-pupal period index	Pupal weight index	Adult longe-vity index	Ovipo-sition index	Sur-vival index	Adult weight index	Success index
Sani-Imilla	0.970	1.041	1.106	0.970	0.500	1.040	0.938(14)
Tahuaqueña	0.966	0.947	1.061	0.986	0.333	0.945	0.873(19)
Ococuri	1.055	1.024	0.091	0.039	0.528	1.085	0.970(10)
701273	1.018	0.863	1.061	0.856	0.611	0.858	0.878(18)
OCH-10071	1.032	0.837	1.015	0.898	0.444	0.833	0.843(21)
Ajanhuiri	1.041	1.214	1.015	1.061	0.722	1.218	1.045(7)
Cica	0.898	0.930	1.045	0.992	0.305	0.927	0.849(20)
Yana-Imilla	0.983	0.972	1.015	1.010	0.667	0.970	0.936(15)
Amarilla	1.101	1.179	0.985	1.209	1.528	1.182	1.197(1)
Revolucion	1.000	1.000	1.000	1.000	1.000	1.000	1.000(9)
Perricholi	0.962	1.077	1.000	1.026	0.611	1.078	0.959(12)
Capiro	0.950	0.918	0.954	0.961	0.333	0.917	0.839(22)
Liberteña	0.908	0.882	1.015	0.969	0.361	0.877	0.835(23)
Huagalina	1.004	0.888	0.939	1.006	0.555	0.884	0.879(17)
Ñata	0.946	1.138	0.985	1.014	1.055	1.140	1.046(6)
Huachapa	1.013	1.069	0.947	0.986	0.694	1.070	0.963(11)
Moro-Bole	0.978	1.035	0.954	1.073	1.000	1.035	1.012(8)
Huayro	1.075	1.071	1.015	1.059	1.778	1.073	1.178(2)
Yungay	0.987	0.955	1.045	0.941	0.500	0.956	0.897(16)
Ccompis	1.041	0.908	1.015	1.018	0.750	0.906	0.940(13)
Alea-Compis	1.000	1.110	1.015	1.055	1.280	1.111	1.095(4)
Huamantanga	1.055	1.058	1.015	0.982	1.528	1.058	1.116(3)
Imilla-Blanca	1.036	1.028	1.030	0.996	1.167	1.028	1.048(5)

Values in parenthesis indicate ranking in terms of suitability of the genotype for the growth and developmet of the insect.

Table 3. Comparison of the different growth indices (based on one tuber test) of the potato tuber moth reared on different potato genotypes.

Potato genotype	Success index	Pant and Dang index (1969)	Howe index (1971)
Sani-Imilla	0.938(14)	1.180(17)	0.183(16)
Tahuaqueña	0.873(19)	0.741(21)	0.153(17)
Ococuri	0.970(10)	1.338(16)	0.207(11)
701273	0.878(18)	1.558(13)	0.206(12)
OCH-10071	0.843(21)	1.118(19)	0.186(15)
Ajanhuiri	1.045(7)	1.745(10)	0.218(9)
Cica	0.849(20)	0.591(23)	0.129(20)
Yana-Imilla	0.936(15)	1.689(11)	0.206(12)
Amarilla	1.197(1)	4.222(2)	0.299(1)
Revolucion	1.000(9)	2.516(6)	0.241(6)
Perricholi	0.959(12)	1.437(14)	0.196(13)
Capiro	0.839(22)	0.714(22)	0.148(19)
Liberteña	0.835(23)	0.769(20)	0.152(18)
Huagalina	0.879(17)	1.346(15)	0.195(14)
Ñata	1.046(6)	2.485(7)	0.225(8)
Huachapa	0.963(11)	1.667(12)	0.214(10)
Moro-Bole	1.012(8)	2.420(8)	0.232(7)
Huayro	1.178(2)	4.571(1)	0.297(2)
Yungay	0.897(16)	1.161(18)	0.186(15)
Ccompis	1.940(13)	1.901(a)	0.253(7)
Alca-Compis	1.095(4)	3.046(4)	0.253(5)
Huamantanga	1.116(3)	3.985(3)	0.290(3)
Imilla-Blanca	1.048(5)	2.937(5)	0.261(4)

Values in parenthesis indicate ranking in terms of suitability of the genotype for the growth and development of the insect.

Table 4. Total potato tuber moth population (larva + pupa + adult) development after three months of storage of tubers (figures based on 20-tuber test)

Potato genotype	Total population[1]	Sex ratio (M:F) Pupa	Adult
Huayro	1263.6a	1:1.10	1:1.11
Huamantanga	1222.4ab	1:1	1:1
Amarilla	1173.6ab	1:1	1:1
Alca-Compis	1167.6b	1:1.13	1:1
Ajanhuiri	1143.2b	1:1	1:1.13
Revolucion	798.0c	1:1	1:1.10
Yana-Imilla	744.4c	1:1.05	1:1.11
Ccompis	740.0c	1:1.1	1:1
Sani-Imilla	734.8c	1:1.12	1:1
Yungay	725.2c	1:1	1:1.12
Moro-Bole	602.4d	1:1	1:1
OCH-10071	576.0d	1:1.10	1:1
Imilla-Blanca	574.8d	1:1	1:1
Liberteña	566.0d	1:1	1:1
Capiro	565.6d	1:1.12	1:1
701273	553.2d	1:1	1:11
Ñata	551.6d	1:1	1:1
Perricholi	548.8d	1:1	1:1.10
Huachapa	546.8d	1:1.10	1:1.05
Huagalina	413.6e	1:1.11	1:1.09
Tahuaqueña	409.6e	1:1	1:1
Ococuri	388.0e	1:1	1:1
Cica	365.2e	1:1	1:1.10

[1] Data were transformed to square root prior to analysis.
Means followed by the same or no letter in the same column do not differ significantly from each other at 5% level by Tukey's test.