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A preliminary study of the effect of attacks by *Phloeotribus scarabaeoides* (BERN.) (Coleoptera: Scolytidae) on the productivity of the olive tree (*Olea europaea* L.)

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The olive bark beetle *P. scarabaeoides* BERN. is one of the most economically important phytophagous insects in present day olive culture. The damage it causes results from the construction of feeding galleries in young tree branches which cause a decrease in the number of flowers and fruit produced. The main aim of the study which was carried out on an olive orchard in the Granada region (Spain), is to evaluate insect impact on olive yield per tree.
The harvests from each of the 10 plots of the orchard were weighed from 1980 to 1989 and the plots were grouped according to the level of attack. Significant differences were observed between the mean yields in different years and different plots. In the first case, these are mainly due to climatic and nutritional factors while in the second case the results were mainly due to *P. scarabaeoides* action. Approximately 60% of the farm was free of damage and yield in the attacked plots was from 3% to 78%. The relationship between density of attack and yield fits a multiplicative function well. According to this function, *P. scarabaeoides* activity may eliminate approximately 73% of the potential yield in the area suffering the highest level of attack.

Keywords: *Phloeotribus scarabaeoides*, Scolytidae, *Olea europaea,* olive beetle, olive yield, Coleoptera.

INTRODUCTION

Bark beetles (Scolytidae) constitute one of the most important pests in the present day, exerting a large economic impact on forest and fruit trees (MENDEL, 1986; DOMINGUEZ GARCIA-TEJERO, 1953). In modern olive culture, the olive bark beetle *Phloeotribus scarabaeoides* (BERNARD, 1788) is cited as one of the main phytophagous insects (LIOTTA, 1981; JARRAYA, 1986; NEUENSCHWANDER & ALEXANDRAKIS, 1982). It is found throughout Mediterranean Europe, North Africa, the Near East and the Middle East as far as Iran. In the lower Mediterranean, *P. scarabaeoides* is found mainly on the olive tree (*Olea europaea* L.) and to a lesser extent on species of the genus *Phyllirea* and *Fraxinus*. In septentrional regions it is mainly found on *Fraxinus, Ligustrum* and *Syringa* (JARRAYA, 1986).

Although the insect may occasionally reproduce in weakened trees or diseased branches (ARAMBOURG, 1984; GONZALEZ & CAMPOS, 1990) it is mainly found on wood left over from the annual olive pruning (NEUENSCHWANDER & ALEXANDRAKIS, 1982).

Direct damage results from the construction of feeding galleries in the young branches of the tree which often cause important losses in fruit or flowers. The resulting scars can be seen on the tree for a long time afterwards in spite of the trees reaction to close up the open wounds produced. In recent spatial distribution studies, the density of these scars in the tree were used as a direct measure of the level of attack (GONZALEZ & CAMPOS, 1993).

Damage to the crop may be controlled by destroying the tree prunings (RUSSO, 1938; LIOTTA, 1981; VERA & GALAN, 1978; NEUENSCHWANDER & ALEXANDRAKIS, 1982; GONZALEZ, 1990) thus failure to observe the prevailing law concerning this matter favours the insects propagation throughout the olive crop. According to studies to date, the most seriously damaged trees are those closest to the reproduction foci. These trees may become completely unproductive in less than 5 years as a result of accumulated damage (CORTEZ & RODRIGUEZ, 1978). Estimations of the damage caused by *P. scarabaeoides* show that there may be up to a 60% decrease in yield in severely damaged trees (JARRAYA, 1986); this information does not permit us to quantify the damage as a function of the density of attack. It does however enable us to establish a maximum threshold of an economically tolerable population density.

According to previous studies, distance from the centre of dispersion and the directional tendency of the spatial distribution of the insect attacks (GONZALEZ & CAMPOS, 1993) greatly influence the damage provoked by *P. scarabaeoides* (JARRAYA, 1986). Starting from where the former study left off, the aim of the present research is to establish the relationship between the density of the damage caused by bark beetle feeding and the average yield of the tree.

MATERIAL AND METHODS

The study area is an olive orchard 20 km north of the city of Granada between longitudes 44030 and 444420 and latitudes 413230 and 41295 U.T.M. It covers an area of 525 hectares of which 371 are dedicated to olive culture with a total of 28388 trees. The land is divided into 10 plots. The distribution of which is shown in Fig. 1. The cultivated area of each plot and the number of trees is shown in Tab. 1.

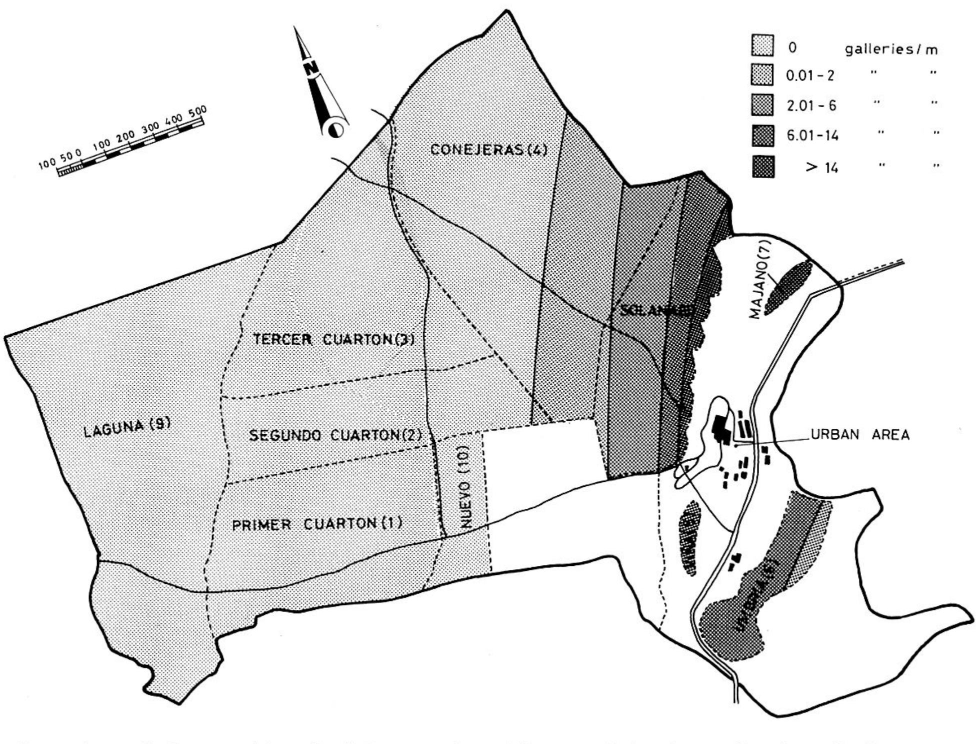

Fig. 1 - Location of plots and level of *P. scarabaeoides* attack in the orchard studied.

All the plots were kept under drought conditions except for #8 and #9 which underwent an irrigation regime.

Approximately 80% of the trees were of the "picual" variety and most of the rest were the "hojiblanco" variety. Trees were aged between 60 and 80 years except in plot #10 where they were aged from 25 to 30 years. Those in plot #10 were in their period of low yield which occurs between 15 and 50 years whereas the rest of the trees were in their period of highest production which occurs between 50 and 150 years (Lopez Gonzalez, 1982).

The olive pruning takes place annually (winter-early spring) and a large proportion of the prunings are stored in the SE margin of the crop (Fig. 1) where they remain until the following winter to be used for domestic consumption.

Table 1. Area of grow (hectares) and number of trees in plots in the study area.

PLOT		SURFACE OF GROW	No TREES
PRIMERO	(#1)	54.00	3851
SEGUNDO	(#2)	39.80	2872
TERCERO	(#3)	53.50	4185
CONEJERAS	(#4)	101.00	6729
SOLANA	(#5)	40.40	2580
UMBRIA	(#6)	5 70	1807
MAJANO	(#7)	0.50	130
VIÑA	(#8)	3.10	211
LAGUNA	(#9)	65.00	4763
NUEVO	(#10)	8.40	1260

The olive harvest takes place annually from November to February and the yields collected from each plot from 1980 to 1990 were weighed.

The part of the orchard (plots #8 and #9) which had experienced the irrigation regime gave a much greater average yield per tree compared to the rest of the crop. In plot #10, yield was limited to lower than normal levels because of the trees comparative immaturity. In order to rule out any differences caused by these factors, plots #8, #9 and #10 were excluded from the study.

Estimation of the level of damage to the tree

This was established from the density of feeding gallery scars using samples taken from a previous study carried out in the same area (Gonzalez & Campos, 1993). The samples were taken from linear transects departing radially from the centre of dispersion in the urban area (Fig. 1). Observation sites were situated at regular 100 m intervals. Four trees were examined at each site and the number of feeding galleries in the terminal 35 cms of 10 branches, aged between 1 and 3 years, were counted. These branches were randomly selected from the upper northern region of the tree (eight above ground > 2,5 m).

In the study mentioned there is a curvilinear decrease in the *P. scarabaeoides* attack and the values in each transect fit a polynomial function of the type y= a +

b/X. According to this type of distribution, the level of attack largely depends on the distance from the centre of dispersion with a directional tendency along the SW-NE axis. The distribution gradient of the *P. scarabaeoides* attack in the crop area is shown in Fig. 1.

Most of the farm is north-west of the *P. scarabaeoides* dispersion centre (Fig. 1), in this direction the density of the attack on the trees approaches zero approximately 800 m from the centre. The damaged trees are found in plots #4, #5, #6, #7 and #8. Infestation level varies greatly in the plots due to the influence of the distance from the dispersion centre and is greater in the plots which cover a wider area (Tab. 2).

The median density distribution was selected as the statistic which best represents level of attack.

Table 2. Summary of the statistical parameters of the distribution of the density (twig-feeding galleries/m) of trees attacked in the plots affected by *P. scarabaeoides* (data from GONZALEZ & CAMPOS, 1993).

STATISTICS	CONEJERAS (PLOT #4)	SOLANA (PLOT #5)	UMBRIA (PLOT #6)	MAJANO (PLOT #7)
AVERAGE	1.46	5.17	10.10	36.40
MEDIAN	0.00	2.86	8.57	37.10
MODE	0.00	0.00	11.40	40.00
VARIANCE	1.57	16.10	5.43	42.11
S.D.	2.11	6.77	3.94	10.97
S.E.	0.14	0.46	0.23	1.09
MINIMUM	0.00	0.00	0.00	11.43
MAXIMUM	11.40	40.00	22.80	62.90

Statistical analysis

Data were first processed using the Lotus-123® software, and afterwards analyzed using the Statgraphics® software (Statistical Graphics Corporation).

The yield values observed for each plot and year were first compared by means of a graphical representation of the accumulated frequencies. The Chi-squared test was used to compare the frequencies observed with those of a normal distribution.

Average yield values per plot and per year were adjusted to fit a normal distribution using the $X^{1/2}$ transformation.

Two-way ANOVA was used to determine the differences between yields collected from different plots or years. Multiple range analysis was used to determine statistically significant differences between groups ($p < 0.05$). Cochran, Bartlett and Hartley tests were used to test homogeneity of the variances between the different groups.

Regression analysis was applied to relate the density of the attack and loss of yield in the tree.

Dependent variable values were normalized by applying the function $Y = (100\ Y_1/Y_T)^{1/2}$; where: Y_1 is the mean yield per tree in each plot, and Y_T is the mean value per year in all the plots.

RESULTS AND DISCUSSION

Initially, the average yield values registered in each plot and year (Tab. 3) did not fit the normal distribution (Chi-square = 12.53, 8 d.f., $p = 0.131$). However, following the application of the $X^{1/2}$ transformation, data fitted the normal distribution well (Chi-square = 2.06, 6 d.f., $p = 0.914$) .

The average yields per year are very variable (Tab. 3) with an average total value of 22.51 kg/tree (s.d. = 15.63). Analysis of the transformed data shows the existence of significant differences between the yields corresponding to different years (two-way ANOVA: $F = 17.18$, 9 d.f., $p < 0.0001$). The test used showed that the variances between the different groups were homogenous (Cochran's test: 0.16, $p = 1$; Bartlett's test: $B = 1.18$, $p = 0.37$, and Hartleys test: 7.39). Average yields were classified into 7 statistical groups ($p < 0.05$, Tab. 3), the lowest and highest values of 8.33 and 47.16 kg/tree corresponded to 1982 and 1988 respectively. The great variation observed in average olive production in different years is a phenomenon frequently cited for olive culture (GUERRERO, 1991) and is mainly attributed to climatic factors. HARTMANN & PANETSOS (1962) shows that flowering is greatly influenced by the number of cold-hours and that pollen germination is hindered by water deficit; adequate rainfall therefore increases production. Another factor which exerts a strong influence on yield is the nutritive state of the plant, particularly the K ion (CAUMEL, 1958; FOX & AYDENIZ, 1964).

Significant differences were also observed between the production from different plots (two-way ANOVA: $F = 14.78$, 6 d.f., $p < 0.0001$; Cochran's test: 0.29, $p = 1$; Bartlett's test: $B = 1.03$ $p = 0.50$; Hartley's test: 2.46). The first group is made up of the plots #1, #2, #3, #4 and #5 and registered an average yield of 28.65 kg/tree (s.d. = 12.89). The yields registered in plots with a low level of attack (median < 3 galleries/m: plots #4 and #5) were not significantly different from those registered in plots which remained unattacked (#1, #2 and #3), therefore no reduction in yield was registered. In plot #5 which reveals a wide gradient of level of attack (0-40 galleries/m), the decrease in production of the most heavily attacked trees on the SE margin is masked when all the trees in the plot are considered as a whole.

Table 3. Yield in each plot (kg/tree) from 1980 to 1990. Small letters indicate statistically significantly different groups ($p < 0.05$).

YEAR	PLOTS							MEAN	SD	GROUPS
	#1	#2	#3	#4	#5	#6	#7			
1980	25.47	20.45	19.35	28.14	27.62	3.84	3.62	18.35	9.75	cd
1981	34.09	27.13	35.73	26.15	30.62	7.45	6.77	23.99	11.14	de
1982	7.84	12.44	6.08	17.76	11.41	1.76	1.00	8.33	5.57	a
1983	29.68	37.88	39.63	32.28	17.54	14.91	7.54	27.07	10.59	e
1984	19.40	12.62	17.23	22.30	18.03	2.37	1.00	13.28	7.81	ab
1985	30.03	18.56	9.20	34.08	31.48	22.53	16.79	24.67	6.52	e
1986	43.93	44.31	24.05	38.09	24.39	6.51	7.00	26.90	14.85	de
1987	20.38	10.28	16.84	17.67	14.97	6.98	7.00	13.45	4.97	bc
1988	40.17	65.96	67.69	63.15	55.39	24.74	13.00	47.16	20.06	f
1989	32.40	25.70	17.42	28.02	13.92	10.42	7.01	19.17	9.01	cd
MEAN	28.34	27.53	26.32	30.76	24.54	11.15	6.81			
S.D.	10.04	16.57	16.56	12.51	12.31	8.81	4.92			
GROUPS	c	c	c	c	c	b	a			

The lowest production ($p < 0.05$) is registered in the plot with the highest level of attack (plot #7: median = 37.14 galleries/sample). Here the yield ranged from < 1 kg/tree to 13 kg/tree with an average value of 7.01 kg/tree (s.d. = 4.65). An intermediate and statistically different value was registered in plot #6 (Median = 8.57 galleries/m), where the harvest ranged from 1.76 kg/tree to 24.74 kg/tree, with an average of 11.15 kg/tree (s.d. = 8.81).

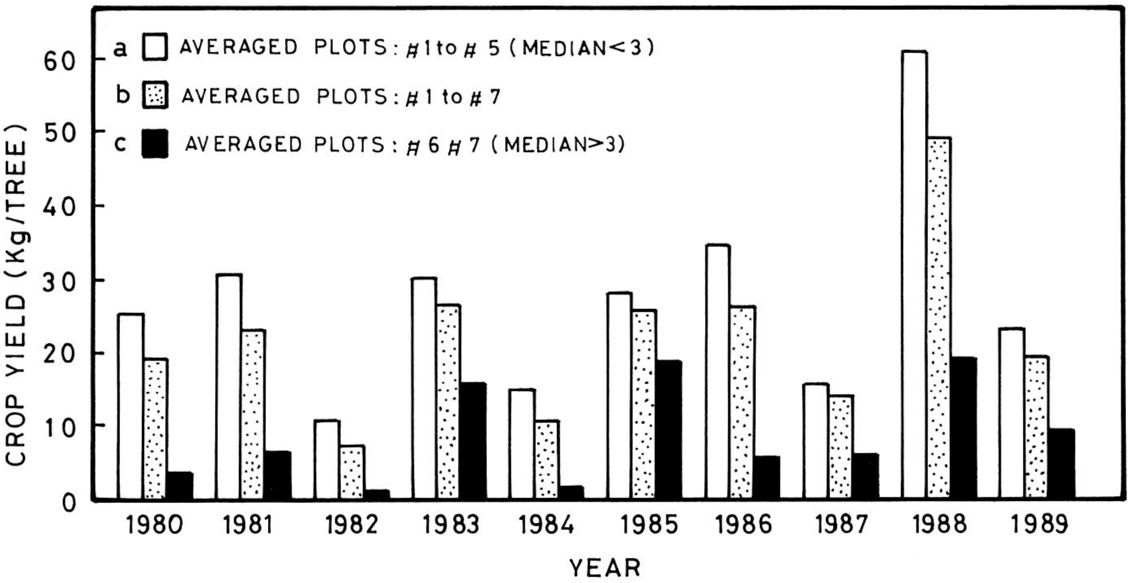

Fig. 2 - Mean yield per tree from 1980 to 1989 in: a) control plots, b) all the plots and c) attacked plots.

Fig. 2 shows the effect of the *P. scarabaeoides* attack on the average olive yield/tree in 1980/89. It compares the average yield in the most heavily attacked plots (Median > 3 galleries/m: plots #6 and #7) with those produced in the other plots (Median < 3 galleries/m; plots #1 to #5). The yield in the first group ranges from 3.36% (1982) to 75% (1985) of the potential average crop, with an average of 34.26%. The average reduction in yield in the attacked zone was therefore 65.74%. Comparing the two affected plots, the reduction in yield was less in plot # 6, where production ranged from 14.66% (3.84 kg/tree in 1980) to 78.57% (24.91 kg/tree in 1983) with an average of 37.49%. The greatest reduction in yield was observed in plot #7 where the production ranged from 3.1% (1984) to 58.57%, with an average of 23.82%. The average production in attacked trees represents a decrease of 76.18% with respect to the potential average production in unattacked trees.

A positive linear correlation exists between the average production in the attacked zone (plots #6 and #7) and the average potential production per year (average of plots #1 to #5). The variables are related by the equation $y = -0.39 + 0.68 X$ (Fig. 3a), the variance given by the fitting is 49%. On the other hand, the percentage decrease in yield per year seems to be independent from the potential average yield (Fig. 3b; linear regression: $r = 0.21$, $n = 20$). In this respect it was observed that the yield from plots not attacked remained relatively stable in most years (between 25 and 35 kg/tree) whereas the percentage loss was very variable and

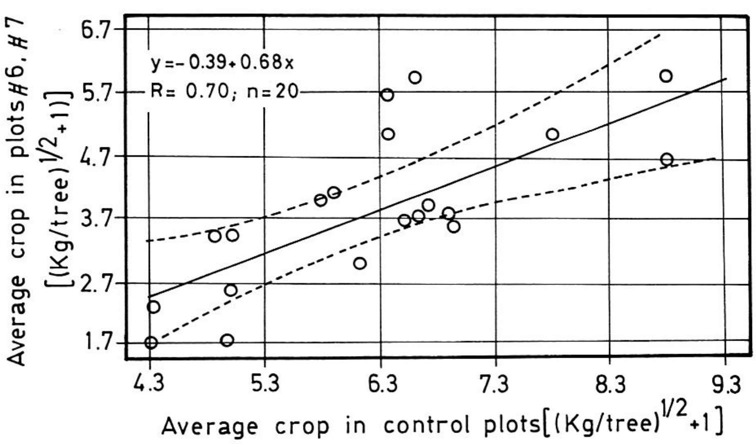

Fig. 3a - Relationship between mean yield in plots attacked and those not attacked by *P. scarabaeoides*.

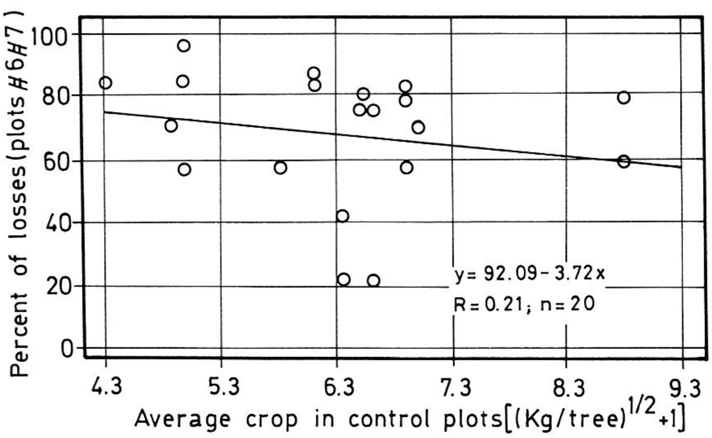

Fig. 3b. Relationship between percentage decrease in yield provoked by *P. scarabaeoides* and the mean production in the control plots (#1 to #5).

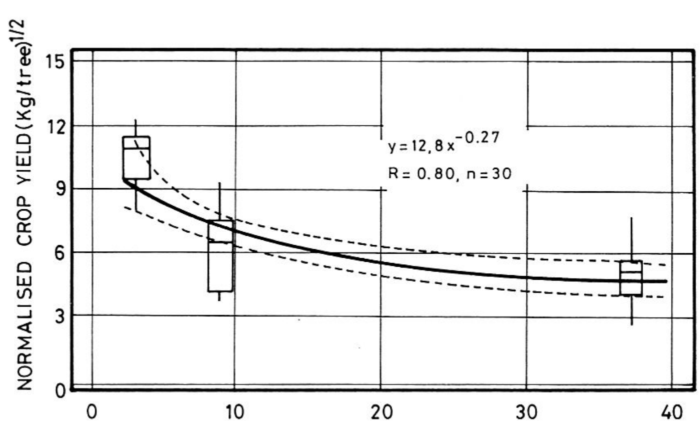

Fig.3c. Relationship between density of attack and olive yield/tree. The three groups correspond to plots #4, #6 and #7 respectively.

ranged from 20% to 85%. Likewise, a similar level of loss was observed in years where the average yield values were very different. Therefore, in contrary to what we would expect the trees are not more susceptible to *P. scarabaeoides* attack in years of lower productivity. In spite of the fact that the wounds produced by *P. scarabaeoides* attack have a cumulative effect on the tree and determine the overall level of damage, we must also take into account the effect produced by the annual variation in the scolytidae population. Among the factors influencing the population dynamics, the following two play a fundamental role:

(i) Location of the olive grove in which the pruning was carried out: Localization and attack of the wood by the insects is hindered by their limited dispersion capacity in years when the pruning is carried out far from the main insect distribution area, as opposed to when it is undertaken in the most highly populated areas (plots #5, #6, #7 and #8). In the latter case in addition to increasing the probability of success when searching for the host, the time of exposure to predatory action is decreased.

(ii) Volume of infested wood in the dispersion focus: After insect attack a certain proportion of the wood may be extracted from the focus.

The annual insect population level would be determined by the combination of both these factors, which could explain the variation observed in the percentage decrease in yield in different years in the same area.

Regression analysis was used to explore the relationship between the variation in mean tree yield and increased damage level of the tree. Normalization of the data eliminated fluctuations in yield due to climatic and/or nutritional factors and data fitted a normal distribution well (Chi-square = 0.63, 1 d.f., p = 0.54).

The best coefficient relating both variables is obtained by applying a multiplicative function (Fig. 3c) (s.e. = 0.28, r = 0.80, n = 30). According to this function, the mean yield estimated in plots #6 and #7 is respectively of 50.12% (± 14,23) and 22,05% (± 6.17) respect to the potential mean. The experimental average values of yield observed in these two plots (37.49% and 23.82% respectively) are therefore included in the interval given by this regression.

CONCLUSIONS

The results indicate that accumulated damage in the trees caused *by P. scarabaeoides* feeding provokes a decrease in the yield of the most heavily attacked trees of up to 75% of the average potential. This decrease in average production is first seen when the level of attack is greater than ca. 3 galleries/m.

The density of attack and mean yield per tree are best related using the function $Y = a X^{-0.27}$. This may prove to be an important tool in the estimation of the impact of *P. scarabaeoides* on crop yield as a whole. The variation in loss in the same crop area from 1 year to the next seems to result from annual changes in the insect population. This points to the need to carry out observations during the feeding period allowing for the short term impact caused by annual fluctuations of the population on overall tree damage to be estimated.

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ZUSAMMENFASSUNG

Im modernen Olivenanbau wird der Olivenbohrkäfer, *Phloeotribus scarabaeoides* (BERNARD, 1788), als einer der Phytophagen mit grösstem wirdtschaftlichem Schaden zitiert. Die direkten Schäden sind die Konsequenz der in die jungen Zweige des Baumes gebauten Nährgänge; die Folge ist häufig das Abfallen von Blüten und Frucht.

Das Hauptziel dieser Studie, die in einem Olivenhain der Provinz Granada (Spanien) durchgeführt wurde, ist, die Auswirkung auf den Durchschnittsertrag des Baumes zu messen.

Der Olivenhain wurde in zehn Parzellen eingeteilt; innerhalb jeder Parzelle wurden von 1980 bis 1989 die Erträge gewogen. Die Einteilung der Parzellen basierte auf der Intensität des Schädlingsbefalls.

Dabei wurden bedeutende Unterschiede im Durchschnittsertrag der einzelnen Jahre und Parzellen beobachtet. Im ersten Fall werden diese hauptsächlich Klima und Ernährungsfaktoren zugeschrieben, während sie im zweiten Fall besonders auf die Aktion des *Phloeotribus scarabaeoides* zurückzuführen sind.

Ca. 60% des Olivenhains war schädlingsfrei; der Ertrag der befallenen Parzellen schwankte zwischen 3% und 78%. Die Relation zwischen Befallsdichte und dem erzielten Ertrag stimmt proportional mit dem potentiellen Ertrag überein. So vermindert sich der Ertrag in der Zone mit dem grössten Schädlingsbefall durch den *Phloeotribus scarabaeoides* um ca. 73%.

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