Effects of 2-Naphthaleneacetic acid on alternate bearing of Pistachio.

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EFFECTS OF 2-NAPHTHALENEACETIC ACID ON ALTERNATE BEARING OF PISTACHIO.

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ABSTRACT - Alternate bearing in the pistachio is the result of abscission of premature inflorescence buds during a heavy crop year. The aim of this work is to investigate if the auxin 2-NAA could decrease bud abscission. Sprays of 2-NAA at 5 000 ppm and in five-fold applications at 30 day intervals (started from mid June) retained 90.1 % of inflorescence buds until the bloom period. Of these buds only 8.7 % produced weak inflorescences (in some cases more than one per bud) and fruits.

EFFETS DE L'APPLICATION D'ACIDE NAPHTALENE ACETIQUE SUR L'ALTERNANCE DU PISTACHIER.

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RESUME - L'alternance observée chez le pistachier résulte de l'abscission des bourgeons de l'inflorescence avant maturité, durant une année de forte récolte. L'étude vise à rechercher si l'ANA peut atténuer le phénomène. Des pulvérisations à 5 000 ppm, répétées cinq fois à des intervalles de 30 jours (à partir de mi-juin) maintiennent 90,1 p. 100 des bourgeons floraux jusqu'à la période de floraison. De ceux-ci seulement 8,7 p. 100 donnaient des inflorescences et des fruits chétifs (dans certains cas plus d'un par bourgeon).

INTRODUCTION

The pistachio is an alternate bearing species. The female tree forms its inflorescence buds laterally on current season's shoots, and bears its fruit on 1-year-old growth. When a tree, or a branch of a tree has a heavy crop, inflorescence buds abscise during the summer and little or no fruit is produced the next year. Alternate bearing in the pistachio is the result of abscission of premature inflorescence buds during a heavy crop year rather than lack of bud formation (1).

Inflorescence bud differentiation begins at the end of April, ceases during July, August and early September, and continues with pistil initiation from early October to March in both bearing and nonbearing trees (16). Bud abscission occurs from the end of June until mid August during the rapid seed growth and development (11, 13).

In spite of the similarity in carbohydrate levels between bearing and nonbearing branches during the bud drop period, a heavy crop of nuts usually depresses inflorescence bud growth during the summer (16) and shoot extension the following year (4).

Carbohydrate deficiency in the buds themselves may be responsible for the bud drop phenomenon, since inflorescence buds compete poorly with the developing fruit for photosynthates (17).

Attempts to reduce bud abscission during the on-year, as defruiting, girdling, and crop load reduction, either are impractical or have not been successful (2).

Mouloulis (11) reported that multiple applications of BOA (benzothiazole-2-oxyacetic acid) retained 60 to 98% of inflorescence buds until the bloom period. However, a high percentage of them (52.2 to 76.2%) failed to bloom. A single spray treatment, on June 23, with the auxin PCPA (parachlorophenoxyacetic acid) (2) delayed, but failed to prevent bud abscission. Recently, Gawad and Ferguson (7, 8) reported that PCPA (parachlorophenoxyacetic acid) and 2,4-D (2,4-dichlorophenoxyacetic acid) may be effective anti-abscission agents for pistachio inflorescence buds.

The objective of this work to investigate if the auxin 2-NAA could decrease inflorescence bud abscission in pistachio during an on-year.

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MATERIALS AND METHODS

The work was carried out in the pistachio orchard of the Agricultural University of Athens on 40-year-old *'Aegenes'* pistachio trees on *P. terebinthus* cv. *Tsikoudia* seedling rootstock from 1979 to 1988. The trees were selected for uniformity of vigor, growth and nut load.

Preliminary experiments showed that 2-NAA at 2 500 ppm and 5 000 ppm, applied with a hand sprayer to selected trees in the middle of June, just before the beginning of seed enlargement, retarded inflorescence bud abscission compared to the untreated control. Since the treatment with 5 000 ppm was twice as effective as the 2 500 ppm treatment J applied the treatment at 5 000 ppm. Bud abscission was delayed but not prevented. For this reason J hypothesized that bud abscission may be due to a gradual reduction of 2-NAA effective concentration in the buds. Reduction in concentration might be overcome by multiple applications or higher concentrations of 2-NAA. Since higher concentrations might cause bud damage, multiple applications, beginning in the middle of June and every 30 days, were used.

2-NAA at 5 000 ppm was sprayed on entire trees once on June 15; twice on June 15 and July 15; three times on June 15, July 15 and August 15; four times on June 15, July 15, August 15 and September 15; and five times on June 15, July 15, August 15, September 15 and October 15. The aqueous solution was applied with a 15 L hand sprayer to the nuts, buds, and leaves to the point of drip. Five trees were used every year (the same every second year) one for each single, double, triple, fourfold and fivefold applications.

The numbers of inflorescence buds on four random branches, which were selected and tagged on each tree before the first application date, were recorded. The numbers of inflorescence buds retained were counted periodically and at bloom (usually in the beginning of April) and were expressed as percentage of the original number of buds at the first application date.

The data were analyzed across the years as replicates for statistical significance by analysis of variance with angular transformation of percentages where required and with mean separation by Duncan's Multiple Range test.

TABLE 1 - Percent inflorescence bud retention and opening of *'Aegenes'* pistachio in response to a single (June 15), double (June 15, July 15), triple (June 15, July 15, August 15), fourfold (June 15, July 15, August 15, September 15) and fivefold (June 15, July 15, August 15, September 15, October 15) sprays with 2-NAA at nine dates and at bloom.

2-NAA sprays treatments (5 000 ppm)	Percent bud retention									Percent bud opening
	July 15	July 31	Aug. 15	Aug. 31	Sept. 15	Sept. 30	Oct. 15	Oct. 31	March 31	Beginning of April
Fivefold	98.7*a**	98.7 a	98.7 a	98.7 a	98.7 a	98.7 a	98.7 a	96.2 a	90.1 a	8.7 a
Fourfold	98.8 a	98.8 a	98.8 a	98.8 a	97.6 b	95.6 b	94.4 b	80.3 b	60.4 b	5.8 b
Triple	98.4 a	98.4 a	98.4 a	88.3 b	80.5 c	76.5 c	60.6 c	40.4 c	30.5 c	2.7 c
Double	98.6 a	98.6 a	96.6 b	60.4 c	30.3 d	8.5 d	4.2 d	3.4 d	1.5 d	-
Single	98.1 a	98.1 a	95.1 c	51.8 d	10.2 e	-	-	-	-	-
Control	50.2 b	10.4 b	-	-	-	-	-	-	-	-

* - Means of ten replications (years).
** - Values with each column separated by Duncan's multiple range test, P = 0.01.

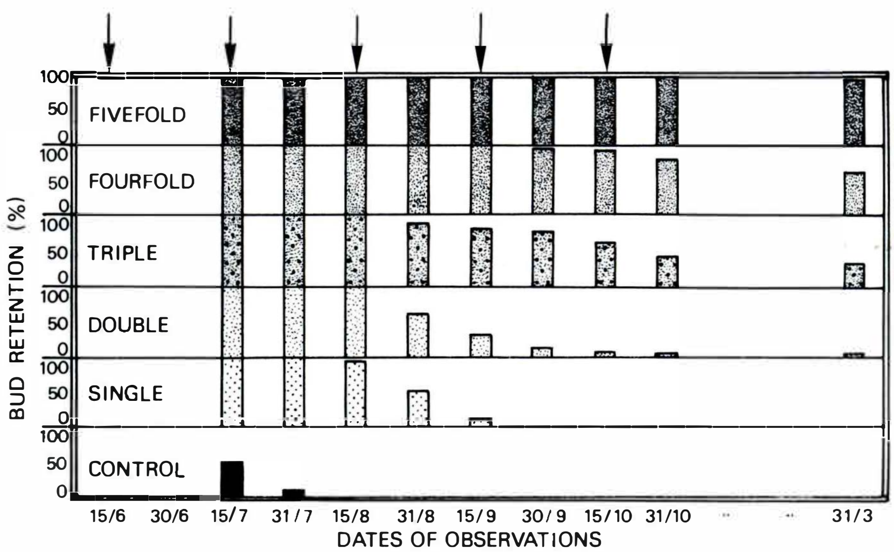

Fig. 1 — Percent inflorescence bud retention of *'Aegenes'* pistachio at nine dates in response to single, double, triple, fourfold and fivefold spray treatments with 2-NAA. Spray dates are indicated by arrows.

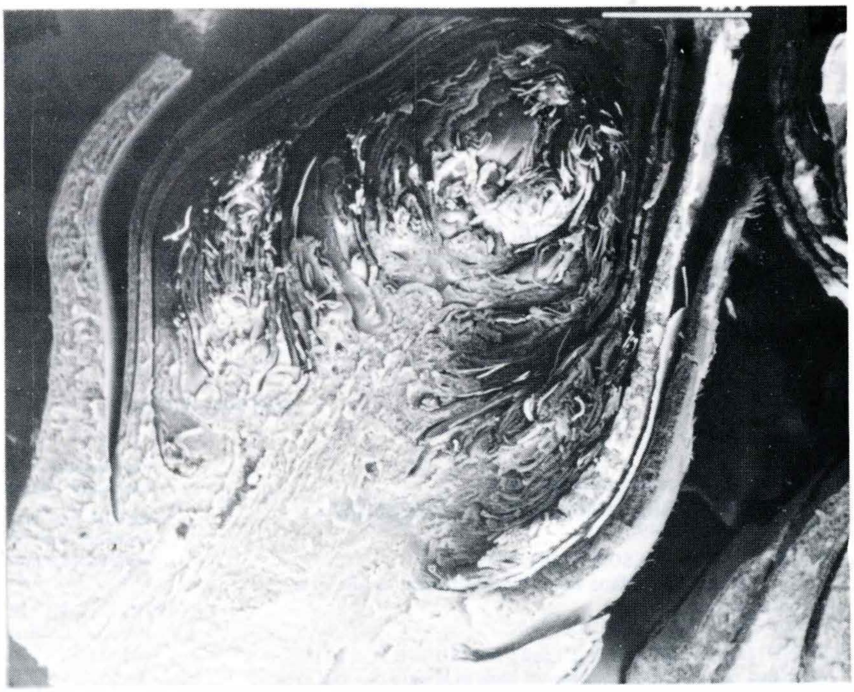

Fig. 2 – Median longitudinal sections of inflorescence buds of female pistachio indicating the differentiation early in January (50x). High : flower bud sprayed with 2-NAA; the whole flower bud structure is abnormal. Embryonic axis is not evident. Lateral branches with imperfect formation of flower primordia and structure are not evident. Apical meristem formation abnormal. Right : flower bud from non bearing tree (control); the flower bud development is normal. Embryonic axis is evident. Lateral branches with normal formation of flower primordia are evident. Apical meristem formation normal.

RESULTS AND DISCUSSION

One spray of 2-NAA retarded inflorescence bud abscission and 95.1% were maintained until mid August (Table 1, Fig. 1). At that time, all control buds had abscised (Table 1, Fig. 1). The abscission of the treated buds continued until the last week of September (Table 1, Fig. 1). Double, triple and fourfold applications were more effective in delaying bud abscission but failed to prevent satisfactorily percentage bud abscission until the bloom period -1.5, 30.5 and 60.4% (Table 1, Fig. 1). The fivefold application retained 90.1% of inflorescence buds until the bloom period (Table 1, Fig. 1). This suggests that applications of 2-NAA from mid June till mid October are necessary to maintain a high percentage of buds until the bloom period. Of the retained inflorescence buds a low percentage bloomed and produced weak inflorescences (in some cases more than one per bud) and fruits (Table 1). All the others abscised when the vegetative buds sprouted.

The inability of inflorescence buds to bloom was not due to an inducing dormancy effect of 2-NAA, since the use of some budbreak dormancy chemicals (hydrogen cyanamide, mineral oil-DNOC) failed to force them to bloom. None of the applications, single or multiple, were phytotoxic to inflorescence buds (at least obviously), except for some bud-tip necrosis which occured in about 10% of the buds. Moreover, inflorescence buds of non-bearing trees (off-year) sprayed with 2-NAA, as previously, bloomed normally and produced normal inflorescences and fruits.

The use of 2-NAA promoted inflorescence bud retention of 1.5, 30.5, 60.4 and 90.1% for double, triple, fourfold and fivefold applications, respectively.

Induction of flower bud abscission coincides with the early stage of rapid seed growth (13). The developing fruit and particularly the rapid growing kernel possess great ability for nutrient mobilization (13). Moreover, the developing flower buds compete rather poorly with nuts for carbohydrates and they receive twice as much photosynthates on defruited branches as on fruiting ones (17). Also, bud abscission rate and final percentage are correlated with fruit number (13). It is evident that alternate bearing in pistachio is a consequence of flower bud abscission due to the correlative effect of competition between the fruits and buds for metabolites (13, 17).

A multiple aqueous spray application of 5 000 ppm of 2-NAA was effective in reducing the competitive effect of crop load on flower bud abscission. Wardlaw (18) concluded that «... buds appear to be the poor relations among the plant organs, receiving only material in excess of the requirements of other parts».

Harley *et al.* (9) have demonstrated, by treating apple-spur leaves with NAA tagged with C^{14}, that NAA accumulated in buds. Hormone-directed transport of metabolites has been demonstrated in numerous instances (6, 10, 12, 15) and evidence indicates a strong synergistic interaction among the hormones in this respect (14).

It seems that 2-NAA redirected at least part of the flow of metabolites from the developing nuts to the buds and contributed in this way to the inflorescence bud differentiation and retention until the bloom period.

The fact that kernel development occurs at the same time as flower bud abscission suggests that there is competition from this organ, in particular, that is primarily responsible for the regular bud growth and the final abscission (13).

The results show that although 2-NAA redirected part of the flow of the photosynthates from the developing nuts to the buds, the photosynthate resources in the buds rather continue to be limited, and this may affect the regular bud differentiation (Fig. 2) and might be responsible for bud abscission. The positive effect of 2-NAA on the mechanism responsible for flower bud differentiation and the inability of the retained inflorescence buds to bloom in a satisfactory percentage confirm the results of Harley *et al.* (9) and Mouloulis (11). Finaly, my results support those of Crane *et al.* (3, 4, 5) and Takeda *et al.* (17).

The shoot growth and nut splitting were not affected. The leaf drop was delayed until mid December (normally the leaves drop in mid November) and unharvested fruits maintained in the normal maturity stage until that time (usually are ripening and harvesting at the end of August otherwise start to dry up). Also, the yield was poor.

In conclusion, the results show that auxins are a possible messenger in the mechanism of this phenomenon-not the cause.

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EFECTOS DE LA APLICACION DE ACIDO NAFTALENO ACETICO SOBRE LA ALTERNANCIA DEL PISTACHERO.

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RESUMEN - La alternancia observada en el pistachero resulta de la abscisión de los brotes de la inflorescencia antes de madurez, durante un año de fuerte cosecha. El estudio tiene como objetivo buscar si el ANA puede atenuar el fenómeno. Pulverizaciones a 5 000 ppm, repetidas cinco veces a intervalos de 30 días (a partir de mediados de junio) mantienen 90,1 % de los brotes florales hasta el período de floración. De éstos sólo 8,7 % daban inflorescencias y frutos raquíticos (en ciertos casos más de uno por brote).