Electrostatic pollination of pistachio (Pistacia vera L.) - A novel technique of pollen supplementation in agriculture

Vaknin Y., Eisikowitch D., Gan-Mor S., Bechar A., Ronen B.

in

Ak B.E. (ed.).
XI GREMPA Seminar on Pistachios and Almonds

Zaragoza : CIHEAM
Cahiers Options Méditerranéennes; n. 56

2001
pages 53-57

Electrostatic pollination of pistachio (*Pistacia vera* L.) – A novel technique of pollen supplementation in agriculture

Y. Vaknin*, S. Gan-Mor, A. Bechar**, B. Ronen** and D. Eisikowitch***
*Department of Plant Sciences, George S. Wise Faculty of Life Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel
**Institute of Agricultural Engineering, Agricultural Research Organization, The Volcani Center, P.O. Box 6, Bet Dagan 50250, Israel

SUMMARY – Little is known about the possible contribution of electrostatic forces to pollination processes in nature. Earlier studies have shown that plants and pollinating insects possess surface electrical charges and are surrounded by electric fields. Accordingly, these electric fields should be more intense near sharp points on the edges, for example anthers and stigmas in the flowers. One mechanism for pollination involving electrostatic forces has been suggested, describing an electrically charged insect visiting flowers. As the insect approaches the flower it induces an opposite electrical charge on pollen grains located on the flower. The temporary forces of attraction created between the airborne insect and the flower could explain the detachment of some pollen grains from the flower and their deposition on the body of the insect, and the same temporary forces could explain their detachment from the body of the insect and their deposition on the flower, including the stigma. Our aim was to harness these electrostatic forces and use them as a method of pollen supplementation in agriculture. We have devised a machine that will electrostatically charge pollen and mechanically convey it to flowers. In field experiments in pistachio *Pistacia vera* L. in California, during April 1998, we found that electrostatically treated trees young female trees produced 16.2% more fruitlets per cluster, a 11.3% higher yield, 18.6% higher split percentages and 60% lower blank percentages than those which only received drifting pollen from nearby orchards. We conclude that electrostatic pollination of pistachio could replace natural wind pollination and may result not only in higher crops, but also in better quality of the nuts.

Key words: *Pistacia vera* L., pollination, pollen suplementation.

RESUME – *"Pollinisation électrostatique du pistachier (*Pistachia vera *L.) – Une technique nouvelle de supplémentation en pollen pour l'agriculture". On ne connaît que peu de chose concernant la contribution possible des forces électrostatiques aux processus de pollinisation dans la nature. Des études antérieures ont montré que les plantes et les insectes pollinisateurs possèdent des charges électriques superficielles et sont entourés de champs électriques. De la même façon, ces champs électriques devraient être plus intenses près des points saillants aux angles, par exemple les anthères et les stigmates des fleurs. Un mécanisme de pollinisation où interviendraient des forces électrostatiques a été suggéré, avec la description d'un insecte chargé électriquement visitant des fleurs. Quand l'insecte s'approche de la fleur, il induit une charge électrique opposée sur les grains de pollen qui se trouvent sur la fleur. Les forces temporaires d'attraction créées entre l'insecte transporté par l'air et la fleur pourraient expliquer que certains grains de pollen se détachent de la fleur, et se déposent sur le corps de l'insecte, et ces mêmes forces temporaires pourraient expliquer leur détachement du corps de l'insecte et leur dépôt sur la fleur, y compris le stigmate. Notre but était de maîtriser ces forces électrostatiques et de les utiliser comme méthode de supplémentation de pollen en agriculture. Nous avons conçu une machine qui chargera le pollen électrostatiquement et le transportera mécaniquement jusqu'aux fleurs. Dans les expériences de terrain chez les pistachiers* Pistachia vera *L. de Californie, pendant le mois d'avril 1998, nous avons trouvé que les jeunes arbres femelles traités électrostatiquement produisaient 16,2% de plus de jeunes fruits par grappe, avaient un rendement supérieur de 11,3%, des pourcentages de crevasses supérieurs de 18,6% et des pourcentages de vides inférieurs de 60% par rapport à ceux qui ne recevaient que du pollen de dérive des vergers environnants. Nous en avons conclu que la pollinisation électrostatique des pistachiers pourrait remplacer la pollinisation naturelle par le vent et pourrait donner non seulement des rendements plus élevés, mais aussi une meilleure qualité des fruits.*

Mots-clés : Pistachia vera *L., pollinisation, supplémentation en pollen.*

Introduction

Pollination of crop plants is a major factor in achieving sufficient crop set (McGregor, 1976; Free, 1993). In recent years, insufficient pollination has been found to be one of the important causative factors for low yield in many field and orchard species (McGregor, 1976; Shivanna and Sawhney, 1997). Some species require management of pollinating agents, while others require artificial means of pollination, one of which is pollen supplementation (Hopping and Jerram, 1980a,b), involving three major steps: (i) pollen collection; (ii) pollen storage; (iii) pollen deposition on receptive stigmas.

Electrostatic pollination in agriculture

Over the past 35 years, electrostatic forces have been employed in numerous technologies including printing, and the transportation, collection, or separation of material in the form of powder or small droplets.

In the past years, several groups of researchers have tried to use several techniques in supplementary pollination: Bechar (1996) and Bechar *et al.* (1999) used electrostatic dusting techniques in pollination experiments on date palms. They had shown that, depending on the amount of pollen used, applying an electrostatic charge to the pollen, could raise fruit set by an average of 85% to 175%.

Electrostatic dusting techniques of various commercially grown plants including almond, apple, olive, walnut, and pistachio in California, were described by Oltman (1997) in a non-scientific paper. The machinery, described in the past, consisted of pollen blowers with discharge nozzles that provided an electrostatic charge to the pollen grains. Although comparison to non-charged applications was not available, it seems that farmers in California have begun to use this technique regularly.

Electrostatic dusting of larch (*Larix eurolepis* Henry) was described by Philippe and Baldet (1997). Compared to conventional pollen blowing, electrostatic dusting resulted in three times more pollen on the flowers (15 vs five pollen grains per bract) and enhanced full seed percentage (32% vs 23%) without reduction in pollen viability, although the amount of pollen used was much smaller.

The aim of this study was to test the effects of electrostatically assisted pollen supplementation on yield and nut quality in pistachio.

Materials and methods

The experiments were conducted in San Joaquin Valley, California, USA.

The plant

The pistachio is a deciduous, dioecious wind-pollinated woody tree species member of the Anacardiaceae. It is cultivated mainly in the Mediterranean regions of Europe, the Middle East, and California. The main producing countries are Iran and the USA followed by Turkey, Syria, Greece and Italy. Usually female and male trees are inter-planted in the orchard, with one male per eight or 14 females depending on the orchard (Monselise, 1986). Some growers plant a solid row of male trees along the side of the orchard that is facing the wind. The main problems at harvest are low yield, non-split, blank and semi-blank fruits (Crane, 1973; Nevo *et al.*, 1974). The pistachio is an alternate bearing species. It produces abundant inflorescence buds every year but they abscise in such numbers during the summer of a heavy crop that few remain to produce a light crop the next year (Monselise, 1986).

The electrostatic pollination device

In an ongoing project, since 1994, we developed a powder-coating device especially designed for electrostatic pollination. Our method of pollen application was an ionized-field particle charging (corona charging) of the pollen grains (Bright *et al.*, 1978). As the mass of negatively charged pollen grains approach the targeted plant, they induce charging by creating an electron flow inside the plant thus keeping the earthed plant close to zero potential. The electrons flow down into the soil, leaving the exposed plant surfaces with a temporary positive charge. The resulting electric field forces the charged pollen grains towards the charged plant parts.

Electrostatic pollination of pistachio

Pistachio pollen grains of cv. 'Peters' were collected by removing male inflorescences with dehiscent anthers, which were then spread over white paper at constant room conditions (25°C and 35% RH). Pollen shed overnight was cleaned and collected by passing it through a 100 µm mesh sieve. The pollen was then sealed in plastic bags and stored in 4°C for several days until the female blooming started. Pollen germinability was tested *in vitro* according to Polito and Luza (1988). Only pollen grains with germinability of more than 50% were used for the experiment.

The experiment was conducted on a ranch of 80 acres. The ranch was planted in 130 rows (from east to west), 84 trees in each row. The female trees were of cv. 'Kerman', grafted onto 'Pioneer Gold' rootstock, and the male trees of cv. 'Peters' were interplanted in the orchard at a proportion of one male per 24 females (4%).

The trees were 5-years old and coming into production for the first time. Most males did not bloom at all and the few that did bloom were not fully overlapped with the female ones. Therefore, pollen was in certain limitation during the female bloom.

The experiment consisted of two treatments:

(i) Electrostatic pollination of the trees throughout the blooming period (14.4-22.4.98) in two applications of 0.2 g pollen per tree per application. We applied the pollen onto the trees on the side facing north during the morning hours.

(ii) Open wind pollination as control.

Because of restrictions imposed on us by the growers, we limited the control to the 12 most northern rows and electrostatically pollinated the other 118 rows. Fruitlet count took place about 30 days after the blooming period ended. In the middle of each control row we selected five trees and in each tree we randomly selected five clusters. Then we counted fruitlet number per cluster. Similar counts took place for the pollinated trees on rows 1, 6, 12, 24 and 48 starting from the row adjacent to the control rows (no. 1). During harvest we weighed the yield of the 12 untreated rows together as well as the adjacent 12 rows of the electrostatic pollination treatment. Then we took a sample of 5 kg from each treatment and tested it for nut quality, i.e. percentages of split nuts (endocarp dehiscence) and percentages of blank nuts.

Analysis

Statistical analysis were carried out using SPSS 7.5.1 SPSS Inc., 1989-1996. Data was analysed by t-test. Square root transformation was applied on counts of fruitlets per cluster prior to the statistical analysis.

Results

The electrostatically pollinated trees showed a significant increase of 16.2% in fruitlet number per cluster compared to the control (t-test, $t_{248} = -3.491$, $P < 0.001$). Due to electrostatic pollination yield was improved by 11.3%, percentage of split nuts was improved by 18%, and percentage of blank nuts was reduced by 60% (Table 1).

Discussion

Natural pollination was a very important limiting factor in this ranch. The only pollen source consisted of several late blooming male trees. Lanner (1966) has shown that in wind pollinated plants the concentration of pollen grains in the air was negatively and exponentially proportional to the distance from the pollen source. Erdogan *et al.* (1997) studied the distance and direction of pollen travel in a pistachio orchard in order to estimate the appropriate male to female ratio. They found that most of the pollen grains were travelling with wind direction, which they considered as the most important factor in pollen dispersal. According to their calculations, 20 m was the farthest effective distance between male and female trees in which one viable pollen grain reaches each receptive female flower. In the present study maximal distance between the male row and the female trees exceeded 20 m and therefore could also be considered as a possible limiting factor.

Table 1. Results of electrostatic pollination of pistachio† (Ranch 443, 1998)

Treatment	# fruitlets††	Yield††† (kg)	Split nuts (%)	Blank nuts (%)
Electrostatic pollination	15.4 $\pm$ 0.49 a	7.9	57.5	4.3
Control	13.3 $\pm$ 0.64 b	7.1	48.8	10.9

†t-test was only performed for the number of fruitlets.
††Mean number of fruitlets per cluster (n = 50); different letters, signify statistical significance.
†††Mean yield per tree (n = 986 for the electrostatically pollinated trees and n = 954 for the control).

The control treatment produced a fair amount of nuts; however, application of pollen with our technique dramatically improved all aspects of nut set and nut quality. As electrostatic pollination was so effective we can safely determine that the addition of electrostatically charged pollen probably reached many non-pollinated flowers and supplied them with a high quality of pollen which resulted not only in more nuts per cluster therefore with higher yield, but also with more split nuts and fewer blank nuts. It had been shown that size and weight of the embryo and the nut, which are considered to be a major factor in nut dehiscence were affected by pollen source (xenia) as well as the female (Nevo *et al.*, 1974; Sedgley and Griffin, 1989; Hormaza and Herrero, 1998). We used cv. 'Peters' which is considered by the farmers as the best pollen source (Nevo, pers. comm.), therefore, we could by this method control nut quality.

In conclusion, this study stresses the need for proper monitoring of overlap between males and females in pistachio orchards, amount of pollen in the air during peak female bloom and other factors which may be essential in producing high yields. It also suggests that in extreme cases, electrostatic pollination could replace natural pollination and ensure high yields with high nut quality.

Acknowledgements

The study was funded by grant no. US-1996-91 from the United States–Israel Binational Agricultural Research and Development Fund (BARD). The study was also partially funded by Paramount Farming Company. We are especially indebted to Dr Joe McIlvaine and Mr Nadav Ravid that provided the necessary facilities and the pollen for the experiments.

References

Bechar, A. (1996). *Pollen deposition in electrostatic field*. MSc Thesis, The Faculty of Agricultural Engineering, The Technion-Israel Institute of Technology (in Hebrew).

Bechar, A., Shmulevich, I., Eisikowitch, D., Vaknin, Y., Ronen, B. and Gan-Mor, S. (1999). Modelling and experiment analysis of electrostatic date pollination. *Trans. ASAE*, 42(6): 1511-1516.

Bright, A.W., Corbett, R.P. and Hughes, J.F. (1978). *Electrostatics – Electrostatic Engineering Design Guide*, no. 30. Oxford University Press, Oxford.

Crane, J.C. (1973). Parthenocarpy – A factor contributing to the production of blank pistachios.

HortScience, 8: 388-390.
Erdogan, V., Kunter, B. and Ayfer, M. (1997). Pollen dispersal in pistachio (*Pistacia vera* L.). In: Proceedings of the Second International Symposium on Pistachios and Almonds, Davis (CA), 24-29 August 1997, Ferguson, L. and Kester, D. (eds). *Acta Horticulturae*, 470: 286-293.
Free, J.B. (1993). *Insect Pollination of Crops*. Academic Press Limited, London.
Hopping, M.E. and Jerram, E.M. (1980a). Supplementary pollination of tree fruits. I. Development of suspension media. *N. Z. J. Agr. Res.*, 23: 517-521.
Hopping, M.E. and Jerram, E.M. (1980b). Supplementary pollination of tree fruits. II. Field trials on kiwifruit and Japanese plums. *N. Z. J. Agr. Res.*, 23: 517-521.
Hormaza, J.I. and Herrero, M. (1998). Pollen effects on fruit and seed characteristics in pistachio (*Pistacia vera* L.). *Annual Journal of Applied Biology*, 132: 357-364.
Lanner, R.M. (1966). A new approach to the study of pollen dispersion. *Silvae Genet.*, 15: 50-52.
Monselise, S.P. (1986). *Handbook of Fruit Set and Development*. CRC Press, Boca Raton (FL).
Nevo, A., Werker, E. and Ben-Sasson, R. (1974). The problem of indehiscence of pistachio (*Pistacia vera* L.) fruit. *Isr. J. Bot.*, 23: 1-13.
Oltman, D. (1997). Gaining an edge – Supplementing the amount of pollen normally distributed in an orchard is proving to be an effective form of crop insurance for many commodities. *California Farmer*, April, pp. 8-9, 18, 47, 76.
Philippe, G. and Baldet, P. (1997). Electrostatic dusting: An efficient technique of pollination in larch. *Ann. Sci. Forest.*, 54: 301-310.
Polito, S.V. and Luza, J.G. (1988). Longevity of pistachio pollen determined by *in vitro* germination. *J. Amer. Soc. Hort. Sci.*, 113: 214-217.
Sedgley, M. and Griffin, A.R. (1989). *Sexual Reproduction of Tree Crops*. Academic Press, London.
Shivanna, K.R. and Sawhney, V.K. (1997). Pollen biology and pollen biotechnology: An introduction. In: *Pollen Biotechnology for Crop Production and Improvement*, Shivanna, K.R. and Sawhney, V.K. (eds). Cambridge University Press, Cambridge, pp. 1-11.