INDUCTION FEEDING OF HONEY-BEES TO IMPROVE *ACTINIDIA DELICIOSA* POLLINATION

T. GARDI[1], F. FAMIANI[1], M. MICHELI[1], M. MOSCHINI[2]

[1]Department of Arboriculture and Plant Protection, ITALY
Tel.: (+39) 75-5856260, Fax: (+39) 75-5856255, E-mail: gardidapp@tiscalinet.it
[2]Department of Animal Production Science University of Perugia, Via Borgo XX Giugno, 74 – 06121 Perugia, ITALY

Abstract

Good pollination is essential in order to obtain large kiwifruits. While honey-bees are the primary pollinators of kiwi, pollen can also be brought to female flowers by wind and other insects. In some areas of Italy pollination problems exist due to the simultaneous flowering of other crops that are more attractive to honey-bees. In order to evaluate the effects of different treatments on kiwi fruit growth and quality, trials were carried out in 1998 and 1999 and again in 2001 and 2002 to: 1) measure the relative contribution of wind and insect pollination, 2) increase the attraction of honey-bees towards kiwi flowers, 3) improve pollination by artificially applying pollen, and 4) overcome the negative consequences of inadequate pollination by using growth regulators. Before flowering, some fruiting shoots were bagged with nets to allow only wind pollination. Some beehives were fed with Actinidia *male pollen (induction feeding) to increase the attractiveness of the kiwi flowers. During flowering, pollen was collected from flowers of male vines and the pollen was used to artificially pollinate just-opened flowers using a "tennis ball" or a hand sprayer, after making a suspension in water. Untreated flowers were used as the control. To better evaluate the effect of artificial pollination, immediately after the pollen was applied, some of the flowers were bagged with nets to prevent any insect visits. Fifteen days after full bloom, half of the fruits were treated (by dipping) with a solution of the growth regulator, Thidiazuron (20 ppm). The results of the trials showed that preventing insect pollination caused a marked fruit drop (≅ 30%), reduced fruit growth (- 50%), and resulting the fruit was rounder shaped and had fewer seeds. Induction feeding of bees resulted in an increase in* Actinidia *pollen gathered by the bees, indicating an improved attractiveness towards* Actinidia *flowers. Under both artificial pollination systems tested, the fruit tended to be larger than the control, regardless of flower bagging after pollination. In contrast, a significant decrease in fruit growth was observed in the control when flowers were bagged.. These results indicate that the pollination requirements of the flowers were completely satisfied by the artificial systems tested. The fruits from the artificially pollinated flowers had a higher length-to-diameter ratio and more seeds; they tended to have a higher soluble solids content and a lower flesh firmness at harvest. Treatment with Thidiazuron significantly increased growth in all the treated fruits and the weight of fruits from non-insect pollinated flowers approached the values of the control. Care must be taken when Thidiazuron is used because it tends to reduce the fruit length-to-diameter ratio. The results show that kiwi pollination problems can be reduced or eliminated by introducing induction feeding of beehives and/or by using artificial pollination and growth regulators.*

Keywords: *sunflower / bee pollination / hybrid seed production*

Introduction

Adequate pollination of kiwi flowers guarantees better fruit quality and higher fruit weight. The contribution of honey-bee to kiwifruit pollination is essential although other insects as well as the wind can bring pollen to female flowers (FREE, 1993). The simultaneous flowering of wild flora and other crops (i.e. *Trifolium incarnatum L.*) growing near kiwifruit may lure pollinators away from kiwifruit flowers (PALMER et al., 1974; PIAZZA and INTOPPA, 1988 and 1989) which are less attractive because they do not produce nectar.

Some attempts have been made to solve this problem (PINZAUTI, 1990; GOODWING et al., 1991; TSIRAKOGLOU et al., 1997). They were based on: feeding sugar syrup to honey-bees as a compensation for the lack of nectar secretion; removing pollen stores and spraying flowers with attractants. The results however were contradictory. Therefore, in 1998 and 1999 and again in 2001 and 2002, trials were carried out to improve kiwifruit quality. The aims of the study were:

1. to determine the relative contribution of wind and insect pollination;
2. to increase the attractiveness of kiwi flowers to honey-bees;
3. to compare the effect of hand pollination and growth regulators.

Material and Methods

The trials were carried out in central Italy in two mature commercial kiwifruit orchards (*Actinidia deliciosa* – A. Chev.) of the cv. *Hayward*, with the cv. *Matua* as pollinizer (5:1). Fields of *Trifolium incarnatum* surrounded the kiwi orchards. The vegetative and reproductive characteristics of the two kiwi orchards were very similar.

In both orchards, some fruiting shoots were bagged with nets before flowering, so as to allow only wind pollination.

When kiwi flowering reached 10%, 8 honey-bee colonies/ha of the *Apis mellifera ligustica* race, were introduced into both orchards.

Before being placed, the colonies in one orchard were fed a suspension of *Actinidia* male pollen (induction feeding – 2.5 g/l of pollen in a 50% sucrose solution) for 2 days, to increase the attractiveness of the flowers. The colonies in the other orchard were fed a 50% sucrose solution only. To evaluate the effects of the induction feeding, pollen traps were put at the entrances of all the hives, to collect the pollen foraged by the honey-bees.

In the orchard with "normal" (non-*Actinidia*-fed pollen suspension) honey-bee colonies, pollen was collected from the flowers of some male vines with an aspirator and was used to hand-pollinate just-opened flowers. The pollen was applied with a "tennis ball" or, after being suspended in water (0.5 g/l), with a hand sprayer. Untreated flowers were used as control. To better evaluate the effects of hand-pollination, immediately after the pollen was applied part of the hand-pollinated and part of the control flowers were bagged with nets to prevent insects from visiting them. Fifteen days after full bloom, half of all the fruits collected was dipped in a 20 ppm solution of thidiazuron (TDZ).

During the experiment the following data were collected:

a – Amount and types of pollen collected by honey-bees during the trail;

b – fruit drop during the growing;

c – weight, shape, flesh firmness and soluble solids content of the fruit at harvest (end of October) and number of seeds;

d – flesh firmness and soluble solids content of the fruits at full ripening (20 days after harvest).

Results

Types of pollen collected by honey-bees, effect of pollination method on fruit traits (Tables I, II, III).

Table I

Effect of wind and insect pollination and of honey-bee induction feeding on fruit characteristics at harvest*

		Weight (g)	Maximum diameter (mm)	Minimum diameter (mm)	Length (mm)	Length/ average diameter	Maximum diam. /minimum diam	Average core diameter (mm)	Seed number** (n°)
Orchard with "normal" honey-bee colonies	Wind + insect pollination	70.5 b	48.5 b	43.6 b	53.1 b	1.15 b	1.11 a	13.3 b	131.3 b
	Wind pollination	43.0 a	42.4 a	38.7 a	43.3 a	1.07 a	1.09 a	11.3 a	71.3 a
Orchard with colonies submitted to induction feeding	Wind + insect pollination	81.1 c	51.0 c	45.1 c	56.9 c	1.18 b	1.13 a	14.4 c	160.7 c
	Wind pollination	46.1 a	42.4 a	38.0 a	46.2 a	1.15 a	1.12 a	10.7 a	86.8 a

In each column, means followed by the same letter are not significantly different at P ≤ 0.05.
** Average values of four years (1998, 1999, 2001, 2002).*
*** Estimated by counting the visible seeds in proximal, central and distal cross sections of the fruits.*

Table II

Effects of pollination type on the qualitative characteristics of fruits at harvest and at consumption ripening*

		Soluble solids content (°Brix)		Flesh firmness (kgf)	
		At harvest	At consumption ripening	At harvest	At consumption ripening
Orchard with "normal" honey-bee colonies	Wind + insect pollination	6.7 a	13.6 a	8.0 a	1.1 a
	Wind pollination	6.5 a	13.3 a	8.6 a	0.9 a
Orchard with colonies submitted to induction feeding	Wind + insect pollination	6.8 a	13.7 a	7.9 a	1.0 a
	Wind pollination	6.6 a	13.5 a	8.1 a	1.0 a

In each column, means followed by the same letter are not significantly different at P ≤ 0.05.
** Average values of four years (1998, 1999, 2001, 2002).*

Table III

Amounts of pollen collected by honey-bee colonies submitted to "normal"and induction feeding during kiwifruit flowering *

Plant's species	Pollen collected by "normal" honey-bee colonies (1)	Pollen collected by induction feed honey-bee colonies (2)	Differences (2) – (1)
Actinidia	**10. 2%**	**30. 3%**	**+ 20. 1**
Papaver	9. 4%	7. 8%	- 1. 6
Sinapis	18. 6%	15. 6%	- 3. 0
Taraxacum	3. 5%	2. 9%	- 0. 6
Trifolium	51. 1%	45. 8%	- 5. 3
Vicia	7. 2%	7. 6%	+ 0. 4

Average values of four years (1998, 1999, 2001, 2002).

Pollen from *Actinidia, Papaver, Sinapis, Taraxacum, Trifolium and Vicia,* were collected by the honey-bees during the trial. *Trifolium incarnatum* pollen was the most represented species. The induction feeding treatment increased the relative amount of Actinidia pollen foraged (30% vs 10% of total) indicating an improved attractiveness of the flowers to honey-bees. The higher pollination rate was correlated with heavier fruits (+ 15%) and a higher number of seeds (+ 22%).

PINZAUTI (1990) and TSIRAKOGLOU et al. (1997), also reported a significant increase in the kiwi fruit pollen collected by honey-bees through the strategy of removing pollen stored in combs.

Wind pollination gave unsatisfactory results for all the parameters evaluated: lower fruit weight (-41%), seeds number (- 46%), and rounder shaped fruits.

Hand pollination, regardless of the method used, completely satisfied the pollen requirements of the flowers resulting in larger fruit (+ 24%) with a greater length to diameter ratio than that found in the freely pollinated fruit.

The method of pollination did not affect the soluble solids content or flesh firmness of the fruits.

Effect of the growth regulator on the fruit traits (Tables IV, V).

Table IV

Effects of hand pollination and of TDZ treatment on fruit characteristics at harvest*

		Weight (g)	Maximum diameter (mm)	Minimum diameter (mm)	Length (mm)	Length/ average diameter	Maximum diam. /minimum diam	Seed number** (n°)
Control (free pollination)	- TDZ	70.5 b	48.5 b	43.6 b	53.1 b	1.15 cd	1.11 abc	131.3 b
	+ TDZ	116.2 d	57.7 d	50.4 d	61.2 c	1.13 c	1.14 c	124.2 b
Wind pollination	- TDZ	43.0 a	42.4 a	38.7 a	43.3 a	1.07 b	1.09 a	71.3 a
	+ TDZ	74.6 b	52.7 c	46.5 bc	51.1 b	1.03 a	1.13 bc	81.4 a
Hand pollination with a tennis ball	- TDZ	86.2 c	50.9 c	46.4 bc	61.8 c	1.27 f	1.10 ab	197.9 c
	+ TDZ	128.6 e	59.4 d	52.8 d	66.4 de	1.18 de	1.13 bc	185.4 c
Hand pollination with a sprayer	- TDZ	88.8 c	52.0 c	46.9 c	62.8 cd	1.27 f	1.11 abc	179.2 c
	+ TDZ	126.7 e	59.3 d	52.8 d	67.5 e	1.20 e	1.12 abc	184.3 c

In each column, means followed by the same letter are not significantly different at $P \leq 0.05$.
** Average values of four years (1998, 1999, 2001, 2002).*
*** Estimated by counting the visible seeds in proximal, central and distal cross sections of the fruits.*

Table V

Effects of hand pollination and of TDZ treatment on the qualitative characteristics of fruits at harvest and at consumption ripening*

		Soluble solids content (°Brix)		Flesh firmness (kgf)	
		At harvest	At consumption ripening	At harvest	At consumption ripening
Control (free pollination)	- TDZ	6.7 a	13.6 a	8.0 b	1.1 a
	+ TDZ	7.2 b	13.4 a	7.1 a	1.0 a
Wind pollination	- TDZ	6.6 a	13.5 a	8.3 b	1.0 a
	+ TDZ	7.3 b	13.2 a	7.1 a	1.1 a
Hand pollination with a tennis ball	- TDZ	6.5 a	13.7 a	8.2 b	1.2 a
	+ TDZ	7.4 b	13.2 a	7.4 a	0.9 a
Hand pollination with a sprayer	- TDZ	6.8 a	13.5 a	8.5 b	1.2 a
	+ TDZ	7.5 b	13.5 a	7.3 a	1.0 a

In each column, means followed by the same letter are not significantly different at $P \leq 0.05$.
** Average values of four years (1998, 1999, 2001, 2002).*

Treatment with TDZ always significantly increased fruit weight and solids content and decreased flesh firmness at harvest. These differences however disappeared once fruits had reached full ripennes. This indicates that TDZ tends to hasten fruit ripening.

Conclusions

Adequate pollination of kiwifruit flowers is essential to obtain good fruit size and shape.

Wind pollination is minimal so insects are necessary for effective pollination. Honey-bees were efficient pollinators when stimulated with sugar syrup containing *Actinidia* pollen (induction feeding). Hand pollination and growth regulators also improved pollination and fruit growth.

Induction feeding of honey-bee colonies combines significant pollination improvement with low application cost which seems to increase pollination efficacy.

Hand-pollination is very effective, but it is also very expensive. It should be used only when conditions for good pollination are very critical. Spraying a pollen suspension with an atomiser gives good results and reduces the cost of application.

The use of TDZ greatly increases fruit growth, which effectively overcome pollination deficiency. However, the use of such chemicals tends to modify fruit shape and could compromise the health fulness of the product.

R E F E R E N C E S

Clinch P.G. (1989), Honey-bee management for kiwifruit pollination. In: Kiwifruit: Science and management. Warrington I.J., Weston G.C. (eds). NZ Soc. Hort. Sci., Wellington, New Zealand

Famiani F., Battistelli A., Moscatello S., Boco M., Antognozzi E. (1999), Thidiazuron affects fruit growth, ripening and quality of *Actinidia deliciosa*. *Journal of Horticultural Science & Biotechnology*, 74 (3): 375-380

Free J.B. (1993), Insect pollination of crops. Second edition, Academic Press Limited. London, 107-114

Goodwin R.M., Hooten A. Ten (1991), Feeding sugar syrup to honey bee (*Apis mellifera*) colonies to increase kiwifruit (*Actinidia deliciosa*) pollen collection: effect of frequency, quantity and time of day. *Apic. Res*. 30 (1): 41-48

Palmer-Jones, T., Clinch, P.G. (1974), Observations on the pollination of Chinese gooseberry variety "Hayward". New Zealand *Journal of Experimental Agriculture*, 2: 455-458

Piazza M.G., Intoppa F. (1988), *Actinidia deliciosa*. Chev.: Attività pronuba delle api e impollinazione anemofila artificiale. *Apicoltura*, 4: 99-111

Piazza M.G., Intoppa F. (1989), Impollinazione naturale ed artificiale dell'Actinidia. *Apicoltura*, 5: 157-166

Pinzauti M. (1990), Kiwi pollination: several ways of increasing the activity of honeybees. *Acta Horticulturae*, 282: 149-150

Succi F., Costa G., Testolin R., Cipriani G. (1996), Impollinazione dell'Actinidia: Una via per migliorare la qualità dei frutti. Proceedings "La coltura dell'*Actinidia*", Faenza (FO), October 10-12, 1996: 123-129

Testolin R., Costa G., Biasi R. (1990), Impollinazione e qualità dei frutti nell'Actinidia. *Frutticoltura*, 10: 27-35

Tsirakoglou V., Thrasyvoulou A., Hatjina F. (1997), Techniques to increase the attractiveness of kiwi flowers to honey bees. *Acta Horticulturae*, 444: 439-443

Vasilakis M., Papadopoulos, Papageorgiou (1997), Factors affecting the fruit size of "Hayward" kiwifruit. *Acta Horticulturae*, 444: 419-424