Air Blowers Are Less Effective Pollinators of Greenhouse Tomatoes than Electric Vibrators but Cost Less to Operate

H.Y. Hanna[1]

ADDITIONAL INDEX WORDS. *Lycopersicon esculentum,* vibrator-pollinated plants, blower-pollinated plants, bumblebee pollination

SUMMARY. A study was conducted to determine if air blowers would be less time consuming, more economical, and as effective as hand-held electric vibrators to pollinate two greenhouse tomato (*Lycopersicon esculentum*) cultivars. Vibrator-pollinated plants of each cultivar produced greater marketable yield than did blower-pollinated plants. Within cultivars, marketable yield was greater and yields of culls were lower with vibrator-pollinated plants. Fruit weight and diameter and the number of seeds per fruit were greater in vibrator-pollinated plants. Marketable yield of 'Trust' was greater and cull yield was lower than that of 'Caruso' in 1996. However, marketable yield of 'Caruso' was greater than that of 'Trust' and cull yield was about the same in 1997. Interactions between pollinating tools and cultivar were not significant except for fruit weight in 1997. The time needed to pollinate 640 plants for 13 weeks was 7.13 and 11.75 person-hours using the air blower and the electric vibrator, respectively. Labor cost for pollination was $49.92 for the air blower and $82.25 for the vibrator. Yield loss using the air blower for pollination was not offset by the savings in operating costs.

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[1]Professor, Louisiana State University Agricultural Center, Louisiana Agricultural Experiment Station, Red River Research Station, P.O. Box 8550, Bossier City, LA 71113. e-mail hhanna@agcenter.lsu.edu.

The flower of most commercial tomato cultivars has a short style that places the stigma well within the anther tube, assuring self-pollination and virtually eliminating the opportunity for out-crossing (Rick, 1978). Pollen is shed within the individual flowers during anthesis when there is a strong enough vibrating force, such as wind, to shake the plant and flower (Snyder, 2001). In the absence of naturally occurring wind in the greenhouse, tomato flowers have to be vibrated by some mechanical means to release the pollen. Most of the investigations on pollinating tomato flowers have been conducted in greenhouses in Europe using electric vibrators (Kerr and Kribs, 1955). Results have indicated that this treatment was necessary to obtain good fruit set and size in the absence of wind (Verkerk, 1957).

Using hand-held electric vibrators (Fig. 1) to pollinate greenhouse tomatoes is labor intensive and time consuming. In large greenhouse operations, tomato growers use multiple hives of laboratory-reared colonies of bumblebees (*Bombus impatiens*) to pollinate their crop (Morgan, 2000). However, in small operations of <1000 plants under one cover, bumblebee pollination was not trouble free. Problems encountered include excessive pollination leading to flower injury and abortion. The few opened flowers at any given time were not sufficient to supply enough pollen for the foraging bees from the smallest commercially available hive. As a result, bees visited the opened flowers repeatedly, destroyed the protective anther tube, and damaged the female organs (Fig. 2). In a recent study, Snyder (1995a) indicated that bumblebees or electric vibrators can be used to pollinate greenhouse tomato cultivars with equal effectiveness. However, he pointed out that bumblebees are an economically viable option for a greenhouse of size 0.25 acre (0.1 ha) or larger (i.e., >2500 plants under one cover).

Air blowers (Fig. 3) have been used successfully to assist natural wind pollination and enhance yield of field grown tomatoes (Hanna, 1999). Wollard and Carlisi (1986) reported that plant yield could be increased by 1.1 lb (0.50 kg) if tomatoes were pollinated with an electric vibrator as compared to an air blower. Some growers use air blowers to pollinate their greenhouse tomato plants in small operations, but economic assessment of their effectiveness has not been reported. This study was conducted to determine if air blowers would be less time consuming, more economical, and as effective as hand-held electric vibrators to pollinate greenhouse tomatoes.

Materials and methods

Studies were conducted from January to June in 1996, 1997, and 2002 in a 30 × 96-ft (9.1 × 29.3-m) double-polyethylene greenhouse at LSU AgCenter in Bossier City, La. The cultivars 'Caruso' and 'Trust' were planted during the first week of January 1996 and 1997 in 15-gal (56.8-L) polyethylene (poly) bags filled with ground pine bark (Phillips Bark Processing Co., Brookhaven, Miss.). Tomato seeds were sown in No. 38 growing trays (Growing Systems, Inc., Milwaukee, Wis.) and transplants were raised in a soilless mix (Pro-Mix BX, Premier Brands, Yonkers, N.Y.) for 5 weeks before being planted in the poly bags. Four transplants were planted in each polybag in two parallel rows at a 3-inch (7.6-cm) depth. Plants were spaced 17 inches (43.2 cm) apart within the row and rows were arranged to allow each plant ≈4 ft^2 (0.4 m^2) of greenhouse space. Cultural practices consisted of standard recommendations for growing greenhouse tomatoes for fresh-market production in Mississippi (Snyder, 2001).

The experimental design was a 2 × 2 factorial, arranged in a randomized complete block with three replications (eight plants each). Treatments were 1) pollination with the air blower versus pollination with the electric vibrator and 2) 'Caruso' vs. 'Trust'. Tomato plants in the air blower-pollinated treatment were vigorously vibrated on Monday, Wednesday, and Friday

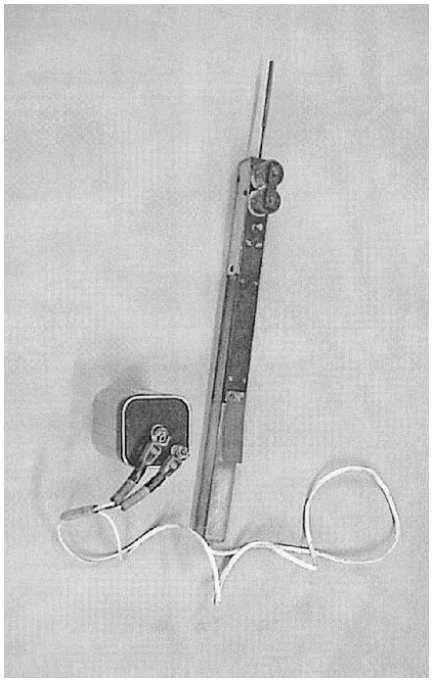

Fig. 1. A hand-held electric vibrator operated by 6-V battery.

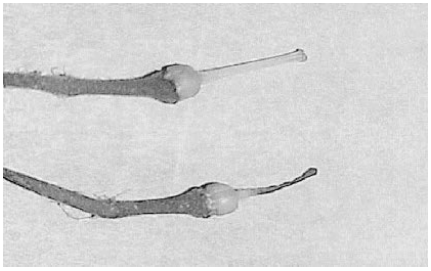

Fig. 2. The female organs of the tomato flower on the left are healthy. The flower on the right shows injured female organs by bumblebee pollination.

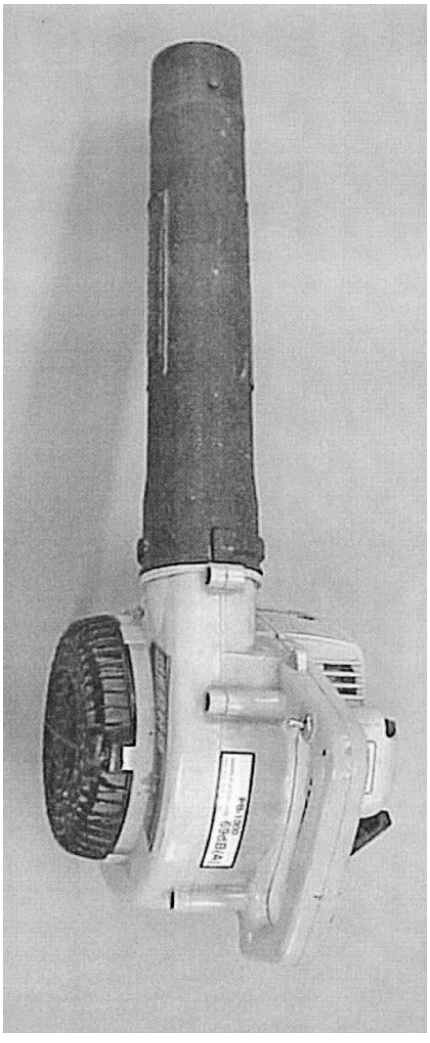

Fig. 3. An air blower.

Table1. Time and expense needed to pollinate 640 tomato plants with an air blower and an electric vibrator in each of two 30 × 96-ft (6.1 × 29.3 m) greenhouses at Louisiana State University Agricultural Center, Bossier City, in 2002.

Week	Time (min)		Expense ($)	
(no.)	Blower	Vibrator	Blower	Vibrator
1	27	66	3.15	7.70
2	30	64	3.50	7.47
3	34	57	3.97	6.65
4	38	75	4.43	8.75
5	41	55	4.78	6.42
6	41	50	4.78	5.83
7	37	41	4.32	4.78
8	33	42	3.85	4.90
9	33	53	3.85	6.18
10	29	56	3.38	6.53
11	26	36	3.03	4.20
12	29	54	3.38	6.30
13	30	56	3.50	6.53
Total (min)	428	705		
Total (h)	7.13	11.75	49.92	82.25

of each week. Vibration took place around noon using an Echo P.B.-1000 air blower (Echo Inc., Lake Zurich, Ill.). The vibration started at the beginning of anthesis and continued for 13 weeks. The air outlet was held ≈15 inches (38.1 cm) from the tomato plant, and the blower was operated at high speed directing the air toward the flower clusters as the operator was walking between the tomato rows (Hanna, 1999). Every effort was made to eliminate the effect of the air flow on other treatments by having a buffer zone next to the air blower-pollinated treatment. Flower clusters in the other treatment were vigorously vibrated by touching the flower peduncle for about two seconds. Pollination was also conducted on Monday, Wednesday, and Friday of each week around noon using the Dutch-made electric vibrator shown in Fig.1 (growers Supply Center, Lynn Haven, Fla.). Two additional greenhouses having 640 plants each were pollinated for 13 weeks in 2002 by the same persons using either tool to determine pollination time more accurately. Cost of pollination by either tool was calculated based on a 13 week period at $7.00/h per person.

Tomatoes were harvested from each treatment at the pink stage three times per week for 13 weeks. Fruit with blossom-end rot and other defects were removed, and the rest were graded by hand according to U.S. Dept. of Agriculture standards (U.S. Dept. of Agriculture, 1991). Marketable yield was determined by weighing fruit graded medium or larger in all harvests. Cull yield was the weight of all fruit with visible defects and small size. Mean fruit weight and diameter were determined on a 10-marketable-fruit sample collected at random around midharvest. Seeds were extracted from the fruit sample and the mean seed number per fruit was determined. Data were subject to analysis of variance (SAS Institute, 1990).

Results and discussion

The time required to pollinate 640 plants for the entire 13-week season in 2002 was 7.13 and 11.75 person-hours using an air blower and an electric vibrator, respectively (Table 1). Assuming that wages were $7.00/h, it would cost $49.92 and $82.25 to pollinate these plants with the two devices, respectively. It would cost about $200 to pollinate these plants with bumblebees (International Technology Services, personal communication).

Vibrator-pollinated plants of each

Table 2. Effects of use of pollination tools on yield, weight, diameter, and seed number of tomato fruit in two cultivars planted in 1996 and 1997 at Louisiana State University Agricultural Center, Bossier City.

				Fruit		
		Yield (lb/plant)[z]		Wt[y]	Diameter[x]	Seeds
Cultivar	Tool	Marketable	Culls	(oz)	(inches)	(no.)
1996						
Trust	Vibrator	19.5	1.6	7.8	3.1	239
	Blower	16.0	2.0	7.0	2.8	161
Caruso	Vibrator	16.4	3.8	7.7	2.9	203
	Blower	15.1	5.5	7.2	2.8	159
Significance						
Tool (T)		***	*	***	***	***
Cultivar (C)		**	***	NS	*	NS
T × C		NS	NS	NS	NS	NS
1997						
Trust	Vibrator	13.2	0.9	6.9	2.8	204
	Blower	12.6	1.1	6.7	2.7	135
Caruso	Vibrator	15.2	0.8	7.4	3.1	196
	Blower	13.6	1.2	6.9	2.9	136
Significance						
Tool (T)		***	*	***	*	***
Cultivar (C)		***	NS	***	**	NS
T × C		NS	NS	*	NS	NS

[z]1.0 lb = 0.45 kg.
[y]1.0 oz = 28.35 g.
[x]1.0 inch = 2.54 cm.
[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, or 0.01, or 0.001, respectively.

cultivar produced greater marketable yield than did blower-pollinated plants in 1996 and 1997 (Table 2). Within cultivars, marketable yield was significantly greater and yields of culls were lower in both years for vibrator-pollinated plants. Fruit weight and diameter and the number of seeds per fruit were increased in vibrator-pollinated plants in both years (Table 2). Marketable yield of 'Trust' was greater and cull yield was smaller than that of 'Caruso' in 1996. However, marketable yield of 'Caruso' was greater than that of 'Trust' and cull yield was about the same in 1997. Interactions between pollinating tools and cultivar for all evaluated traits were not significant at $P \leq 0.05$ except for fruit weight in 1997 (Table 2). Thus the beneficial effect of using the electric vibrator was not limited to a specific cultivar. We did not determine pollen number on the stigma of plants pollinated by either tool, but the yield data and seed number suggest that pollinating tomato plants by vibrating the plants with an electric vibrator may have forced the anthers to release more pollen, resulting in more efficient pollination and fertilization of the ovules inside the ovary. As a result, seed number, fruit weight, and diameter were increased, yield of culls was reduced, and marketable yields were enhanced. Verkerk (1957) indicated that the more pollen used in pollination, the more seed set, resulting in faster-growing fruit and a more profitable crop. Shelby et al. (1978) concluded that insufficient pollination probably was the major cause of yield reduction in field tomatoes grown under heat stress.

Most of the greenhouse tomato operations in the southern U.S. are small (Snyder, 1995b). During anthesis, the number of opened flowers in these limited space greenhouses may not be sufficient to sustain the smallest colony of bumblebees (class C hive). Growers may have to choose between using a household air blower or an electric vibrator to pollinate their crop. Air blowers are more appealing because they are popular tools at many homes, inexpensive, and require very little maintenance. However, results of this investigation indicate that 'Trust' and 'Caruso' would lose an average of 2.05 and 1.45 lb/plant per season (0.930 and 0.658 kg), respectively if pollinated with the air blower instead of the vibrator. Total yield reduction in 13 weeks of harvest from one greenhouse of the size mentioned can be as much as 1312 and 928 lb (595.1 and 420.9 kg) for 'Trust' and 'Caruso,' respectively. Estes and Peet (1999) indicated that greenhouse tomatoes can be sold at $1.57/lb ($3.46/kg). These estimates indicate that economic losses from yield reduction can be far greater than gains from saving pollination time by the air blowers.

We conclude that small greenhouse tomato growers should use the handheld electric vibrators to pollinate their crop for maximum fruit yield, size and profit.

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