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Comparing Quality of a Telescopic Boom Sprayer with Conventional Orchard Sprayers in Iran

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ABSTRACT

In small orchards, gardeners face several problems such as irregular tree planting, hard trafficability for tractors, economic problems for buying tractors, high drift in high height sprayers, low height of spraying, and difficulty of working with conventional sprayers. In this study, in order to solve some of these problems, a telescoping boom sprayer was designed and fabricated. The sprayer equipped with This Boom (TS) was evaluated in comparison with the conventional sprayers [Wheel Barrow (WBS), Electrostatic (ES), Side Pump (SPS) Sprayers] in terms of drift, spraying quality, solution consumption, fuel consumption, spray height, spraying time, and spray loss. Results showed that the spraying quality coefficient of ES was better than that of SPS; WBS and TS could not be evaluated because the surface of sensitive papers was wetted completely, but distribution of droplets on each card and between the cards was more uniform in TS. Due to differences in drift, WBS had the highest mean of droplet area and TS had the lowest. Also, WBS, TS, SPS, and ES had the maximum amount of solution consumption while ES, TS, and WBS had the minimum. SPS and ES did not spray at high height; however, TS and WBS could spray at high height. The maximum and minimum spraying times were recorded for WBS and SPS, respectively. Values of 9.93 and 2.80 mm^2 were obtained for mean spray loss area of SPS and ES, respectively. Spray loss area of the TS and WBS was not calculated.

Keywords: Electrostatic sprayer, Side pump sprayer, Telescoping boom, Wheel barrow sprayer.

INTRODUCTION

Every year, about 25 to 35% of the world's crops are destroyed by insects, plant pathogens, and weeds. Without plant protection, this figure could increase to 80%. According to Ministry of Jihad-e-Agriculture's report in Iran, annual damage of pests to crop production is about 30%. Therefore, pest control is necessary (Mansourirad, 1989).

On the other hand, the widespread use of chemical pesticides will result in some serious environmental problems. These issues should be seriously considered by the users and designers of spraying devices. Drift may lead to contamination of the nearby plants which have been cultivated for human consumption or animals. Residues of chemical pesticides can enter the environment by surface water flow or sewage, and by the wind carrying the material (Shafii, 1992).Wasted pesticides can cause soil contamination and the residual small droplets due to drift will also cause environmental pollution (Afshari, 1992).

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Under current conditions, no scientific studies are available on the functional status of sprayers commonly used in orchards in Iran. In order to increase the height of the spray (without needing to buy imported sprayers) and reduce gardeners' economic problems, making a tiller garden sprayer was proposed (Saeedi, 1996). In this plan, a piston sprayer pump was connected to a tiller so that the required pump power was supplied by the engine tiller. The higher spraying height of this sprayer compared to the conventional ones showed that the project was successful. Also, the final cost of this sprayer was about 20% of the price of wheel barrow sprayer in performing the same operation. So, farmers' economic costs are reduced for those who have tiller.

To improve the spraying efficiency and achieve better droplet deposition on plants, the plan of constructing electrostatic sprayer was proposed (Mostafayi Meinagh *et al*., 2008, 2009). In this research, design and evaluation of an electrostatic sprayer were described. In this sprayer, the electric charging of droplets was performed using the induction method. Atomization of the nozzle flow was accomplished by ultrasonic method and the buoyancy and guidance of the generated droplets were achieved by the airflow of a fan. The results demonstrated the positive effect of inductive voltage on the creation of the charged droplets. Increasing the fan speed improved the charge of the droplet through increasing the passed air flow rate. However, because of wetting phenomenon, higher spray flow rate had a negative role in the charging process.

Drift potential factors in gardens air-assisted sprayers and the sprayers which need air energy for better spraying have been studied at University of Florida (Salyani and Farooq, 2003; 2004). According to these studies, wind speed and direction could affect the amount of drift and air volume could have a significant effect on the amount of chemical injected in the locations close to the sprayer; but, this effect is reduced on distant areas. Lower air flow rate could reduce the sprayer's fan energy requirement by up to 67%.

Manufacturing micronair (spinning plates) and using it in sprayers can be another solution for achieving some of the considered goals. In 2003, disc sprayer nozzle centrifugal design was proposed and evaluated (Aryan, 2003). In the method, the liquid was entered into the center of a rotary disc or cup; then, it was expanded in the form of an attenuating sheet and was finally broken up into individual droplets. In this case, the size of the droplets could be controlled by adjusting the rotating speed of the disc. Compared to the sprayer equipped with micronair nozzles (CDA) and Hydraulic Lance Sprayers (HLS) for the chemical control of sunn pest nymphs, it was shown that, in all of the micronair treatments, insecticide deposit on high canopy was more than HLS treatment. The waste of spray and mechanical damage to wheat fields by CDA was found to be much lower than that by HLS. CDA was light and easy to use and required 10-50 L ha^{-1}, whereas HLS required 200-400 L ha^{-1}. CDA could be a proper sprayer for the fields in which the conventional sprayers, even aerial sprayer, could not be used. It was concluded that light weight, accurate delivery, and controlled droplet application in CDA developed a more efficient technique for dealing with pesticides, which was not available previously.

Also, some researchers have evaluated impact of air-assisted system to help spraying quality (Panneton and Lacasse, 2004; Holownicki *et al*., 1996; Walklate, 1992). They have used two vertical air sleeves to create two air jets: one on each side of the row. They have studied the effect on spray coverage and spray recovery potential of different air jet angles relative to the row of vines, sprayer ground speed, and partition of the air flow rate between the two air sources. Results have demonstrated that the orientation of air sources has a significant effect on both spray coverage and spray recovery. In the centre of the row, decreasing the sprayer's ground speed could improve coverage. For spray recovery, the distribution of the total air flow rate among the two sources is the most important variable. The best compromise for coverage and recovery is to partition total air flow rate such that 35% is emitted from the sleeve on the sprayer side and this source of air is directed at the angle of 45° to the row to operate the sprayer at the lowest ground speed (4.4 km h^{-1}).

Some researchers have proposed to use the dual-fan concept to spray on high trees (up to 5 m) (Godyn *et al*., 2008). The aim of the preliminary trials was to evaluate the idea of a dual-fan orchard sprayer before producing sprayer prototype. After the laboratory measurements of spray and air distribution, measurements of air distribution, spray distribution and spray drift potential were made in an apple orchard. Four fan settings were studied. The applied spray volumes (150-400 L ha^{-1}) caused significantly different spray deposits in the tree canopy. The highest deposit was observed for the lower fan alone. The coverage on lower surfaces for "Lower+Upper+30 cm" fan was higher than the one for the other combinations. Total losses were proportional to the deposits in the trees.

Marucco *et al*. (2008) studied air velocity adjustment to maximize spray deposition in peach orchards. A set of tests was carried out in a peach orchard to investigate which combinations of air velocity measured on the target, sprayer forward speed, and application rate were more suitable to get a high and uniform spray deposition within the whole canopy. Combinations of six different air velocities, ranging from 3.7 to 23.0 m s^{-1}, four different forward speeds (from 3.9 to 13.0 km h^{-1}), and four different volume rates (from 200 to 1,000 L ha^{-1}) were also examined. Test results pointed out that working at 7 km h^{-1} employing the air velocity of 14 m s^{-1} enabled the achievement of the best performance in terms of getting uniform coverage of the canopy, especially when low volumes (up to 400 L ha^{-1}) were sprayed.

In order to reduce drift in orchards, it was proposed to use a cross flow sprayer equipped with reflection shields (Wanner) and air injection nozzles (Wenneker and van de Zande, 2008). For the Wanner sprayer with reflection shields and Albuz ATR lilac nozzles, the spray drift was reduced in the area of 3-7 m downwind of the last tree row by 69 and 58%, respectively, for the early growth and fully developed foliage stages. At 4.5–5.5 m downwind of the last tree row, the spray drift deposition was reduced by 71 and 62%, respectively, for the early growth and the fully developed foliage stages. In this situation, the spray drift was reduced in the area of 3-7 m downwind of the last tree row by 95 and 94% for the early growth and the fully developed foliage stages, respectively. At 4.5–5.5 m downwind of the last tree row, the spray drift deposition was reduced by 95% both for the early growth and fully developed foliage stages. From the experiments, it was concluded that the combination of drift reducing methods consisting of a sprayer with reflection shields and coarse droplets application was a very effective method for reducing spray drift in the Netherlands.

Khot *et al*. (2012) adapted an air-assisted sprayer for precision horticulture and evaluated the spray patterns and deposition in small-sized citrus canopies. An axial-fan air-assisted sprayer, adapted with variable rate nozzles and adjustable air-assist flow control, for citrus tree-specific precision spraying, was tested. The experiments included two nozzle treatments: (a) Nozzles 1-6, and (b) Nozzles 2-3, at 100% output rates, and three levels of air assistance i.e. 40, 70, and 100%, which were selected based on spray patterns. The results suggested that, within the treatments of nozzles 1-6 with varied air-assist, 70% air-assistance was more effective for small-sized canopies than 100% air-assistance. It appeared that the latter propelled the spray beyond the canopy and reduced the efficiency of the spray deposition. Also, for the studied citrus canopies, the use of two or three nozzles instead of lower six nozzles

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(i.e. the control treatment) might be more suitable, since they would result in 50% or less chemical usage while having comparable spray deposition to that of the control.

Osterman *et al*. (2013) proposed an algorithm for positioning spraying arms based on laser scanner measurements for a variable-geometry air-assisted orchard sprayer. The algorithm calculated the optimal position for each of the three height segments of a tree based on a simplified contour of the measured canopy of the corresponding row section. The optimal position for each arm was then calculated so that the nozzle was directed normally to the linear fit of the contour at the distance for which the full coverage of the tree height segment was achieved. To obtain physically feasible displacements, the calculated positions were smoothed using the unweighted moving average. The effect of moving average width was also described in the results. With more target-directed spraying, the drift and ground deposits of the pesticides were expected to be reduced. In addition, more effective spraying enabled some changes in the effective dose, which resulted in smaller amounts of used pesticides.

Duga *et al*. (2015) studied the effects of sprayer design, training system, and tree canopy characteristics for obtaining spray deposition profiles in some fruit trees. They presented the in-field analysis of the on-target deposition profiles from three distinct sprayer types in trees of four different apple and pear training systems. The obtained results showed that there was a strong relationship between the vertical leaf deposition profile and the outlet air flow pattern from the sprayers. Stronger air assistance (higher air speed) was directly correlated to the higher on-target deposition. It was also observed that directing nozzles toward the target was always an advantage irrespective of tree architecture. Tree characteristics such as total leaf cover, leaf wall porosity, and tree volume strongly affected the total on-target deposition, which further confirmed the previous claims that ground surface area alone is an incorrect measure for dose calculation in fruit trees.

Given the above points, to increase the spraying quality of horticultural crops (especially for small gardens, which have common borders with adjacent lands and irregularly planted trees) and to reduce the disadvantages of conventional sprayers such as high drift, high acquisition costs, environmental pollution, poisoning people, loss of beneficial insects, high consumption of pesticides and fuel, and need for tractors, it is necessary to conduct more studies in this regard. The aim of this study was to solve some of these problems by designing and making a telescoping boom sprayer, and to evaluate the wheel barrow sprayer equipped with this boom in comparison with the conventional sprayer (wheel barrow sprayer with normal lance, electrostatic sprayer, and side pump sprayer) in terms of drift, spraying quality, solution consumption, fuel consumption, spray height, spraying time, and spray deposited on bare ground (spray loss).

MATERIALS AND METHODS

Designing the Telescoping Boom and its Construction

The telescopic boom components were designed using SolidWorks 2010 software. The prototype was built with the height of 3 m and the telescope in 5 parts. The hydraulic system was used for opening telescoping boom. In this system, hydraulic fluid and system pump were the solution consumption and sprayer pump, respectively. The boom was closed by the towing wire. The pipes were made of stainless steel, because the work environment was toxic and the boom was supposed to have physical strength and corrosion- resistance; yet, it should be light for user convenience. Thus, 5 pieces of stainless steel pipes were selected with the length of 0.7 m, diameters of 10, 14, 18, 22, and 25 mm, and thickness of 1 mm (less

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thickness could damage the pipe as a result of potential impact and higher thickness would make it heavy) .

The canvas had three mechanisms:

1. Sealing mechanism
2. Spray control and open boom mechanism
3. Closing boom mechanism.

Figures 1-a and -b show the outline of telescopic boom and its mechanisms in the software environment.

Sealing Mechanism

For rigid and sealed connection between tandem pipes, the interface pieces were made of polyethylene material (Teflon). Teflon was selected because most of the sealing was made of this stuff. Interfaces (Figure 2 and Section 2 in Figure 1-b) were composed of two parts: a part was similar to a bolt (Figure 2-b) with the length of 4 cm, through which there was a hole with smaller pipe diameter. The other part was similar to a nut (Figure 2-c) with the length equal to the size of the threaded bolt, through which there was a hole with larger pipe diameter. The bolt-like part must be long enough to achieve optimal sealing without causing great friction, because increasing the friction force will increase the amount of force required to open the tubes. Optimal sizes were obtained after several experimental trials. For better sealing and better rigidity, an O-ring and two metal washers were used.

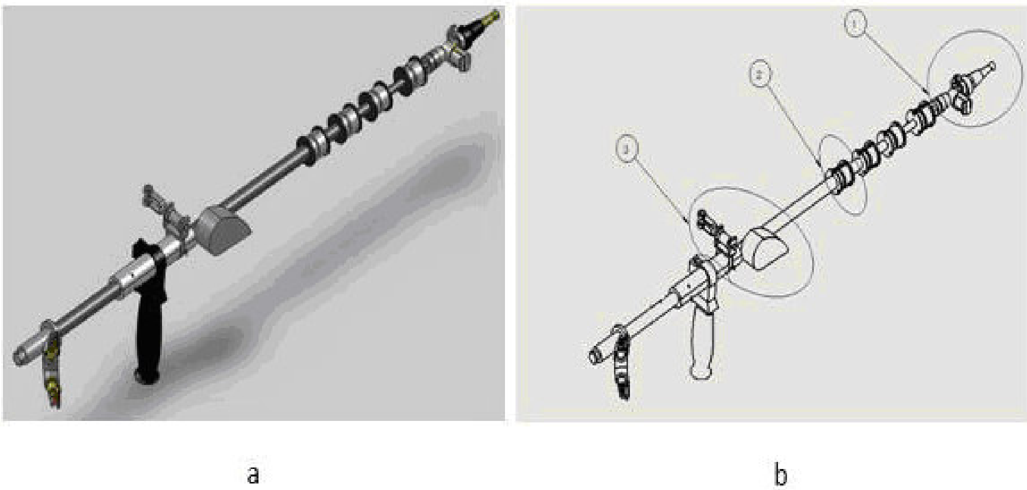

Figure 1. Outline of the boom in the software environment. (a) Three-dimensional view of the telescopic boom, (b) 3 mechanisms telescopic boom.

Figure 2. Sealing mechanism. (a) Sealing parts; (b) The bolt- like, and (c) The nut-like.

[DOR: 20.1001.1.16807073.2016.18.3.1.3]

Spray Control and Open Boom Mechanism

At the beginning of spraying pipe (Lances), a nozzle is usually installed that determines the amount and form of a spray (jet). For mated boom in this study, a nozzle was used (Figure 3-a), in which the amount of the spray was determined by turning the pipe attached to it (the pipe was threaded).

Because the opening boom system was hydraulic, the beginning of the pipe (the nozzle) would be closed and opened by the solenoid valve (1 in Figure 1-b). To open the boom, the valve was shut to close the flow route and, thus, the boom was opened. Also, the valve was opened for spraying. In this situation, the valve's back pressure would diminish and thereafter the boom would not be opened. At any desirable height, the valve can be opened by the electrical switch mounted on the handle until spraying begins and boom opening is stopped. The pressure required for opening the boom was 4 bar measured by pressure gauges.

Closing Boom Mechanism

Closing telescopic boom mechanism was developed the mechanical (Figure 4-b and Section 3 in Figure 1-b). To connect the valve to the battery, an electricity wire was needed. For the designed system, collection mechanism of metal meters was used from collection mechanism of metal Meters (Figure 4- c).

Evaluation

The sprayer equipped with this boom was assessed in comparison with the conventional sprayer (wheel barrow, electrostatic, and side pump sprayers) in terms of drift, spraying quality, solution consumption, fuel consumption, spray height, spraying time, and spray deposited on the ground (spray loss). The experiments were conducted in Randomized Complete Block Design (RCBD) with three replications. The data obtained from the evaluation process were analyzed by SPSS and Excel software. Figure 5 shows the telescopic sprayer in the spraying. Figure 6 shows the used sprayer. Specifications of the tested garden, weather conditions, and characteristics of the sprayers are given in Tables 1, 2, and 3, respectively.

(a) (b)

Figure 3. Spraying control mechanism and open boom. (a) Nozzle, (b) Solenoid flow control valve.

(a) (b) (c)

Figure 4. Closing boom mechanism. (a) Section 3 telescoping boom in software; (b) Wire collection, and (c) Metal meter box (as a collection of electricity wire).

Figure 5. Designed and fabricated telescoping sprayer in operation.

Figure 6. Sprayers used in the study (From right to left: Atomizer equipped with electrostatic head, side pump, wheel barrow equipped with telescoping boom, wheel barrow with normal lance).

Table 1. Characteristics of the orchard used for evaluating the sprayer.

Product type	Tree height (m)	Within the block (m)	Length block (m)	Area (ha)	Distance between canopies of the tree and land (m)
Walnut	5	15	45	0.5	0.7

Table 2- Weather conditions during the spraying test.

	Hour					
	13	14	15	16	17	18
Temperature (°C)	28.8	28.4	28.4	27.6	26.6	25.8
Relative humidity (%)	13	13	12	14	17	23
Wind speed (m s^{-1})	2	3	3	4	2	-

Table 3. Characteristics of sprayers.

Sprayers	Manufacturer	Model	Engine	Pump	Lance/Spray shape
Wheel barrow	Japan	SF1022	G100 2.5 Hp	AP22 30 bar	Lance SG403/ Hollow cone
Wheel barrow	Japan	SF1022	G100 2.5 Hp	AP22 30 bar	Telescoping boom/Hollow cone
Atomizer	STIHL-USA	SR450	2.9 Kw	----	Electrostatic
Side pump	Shixia-China	---	---	---	Manual spray gun/Flat fan

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Spraying Quality Coefficient

Spraying quality was evaluated based on the standards of Institute of Standards and Industrial Research of Iran (Anon., 2007; 2008). Accordingly, because the width of the tree crown was 50 cm, three vertical profiles were chosen on the tree (one in the middle and two on either side of the tree). Then, the sensitive papers (yellow card) were placed on these profiles (intervals of 25 cm) according to Figure 7. This paper is similar to litmus paper, which is discolored after contact with the solution droplets. These papers were used to determine the droplet diameter and number in 1 cm^2. One cm of water sensitive paper was randomly selected. Paper photographs were taken by a camera. After enlarging the image, the number of droplets was counted by naked eyes and their diameters were measured. After enumerating and measuring the diameter of the droplets and classifying drop sizes, the median (50^{th} percentile) was considered to provide Volume Median Diameter (VMD), Numeric Median Diameter (NMD), and, finally, spraying quality coefficient by Equation (1) (Safari, 2008; Srivastava *et al*., 1993).

$$Q_c = VMD/NMD \quad (1)$$

Where, Q_c, *VMD, and NMD* are spraying quality coefficient (dimensionless), volume median diameter (micron), and numeric median diameter (micron), respectively.

Drift

Drift causes problems such as environmental pollution, toxicity to users, and elimination of beneficial insects. To determine drift, the sensitive cards were placed on a nearby tree (distance from the tree that was sprayed was 10 m) at the intervals of 50 cm from each other, according to Figure 7. After spraying, the cards were collected and area of the droplets sitting on the cards and the average were calculated by measuring the number and diameter of the droplets in 1 cm2. 1 cm of water sensitive paper was randomly selected. Then, paper photographs were taken using a camera. After enlarging the image, the number of droplets was counted by naked eye and their diameters were measured. The mean diameters of the drops were determined and the area was calculated according to the formula for calculating the area of a circle. Then, the areas were summed and considered as the area of droplets sitting on the card. The calculations were

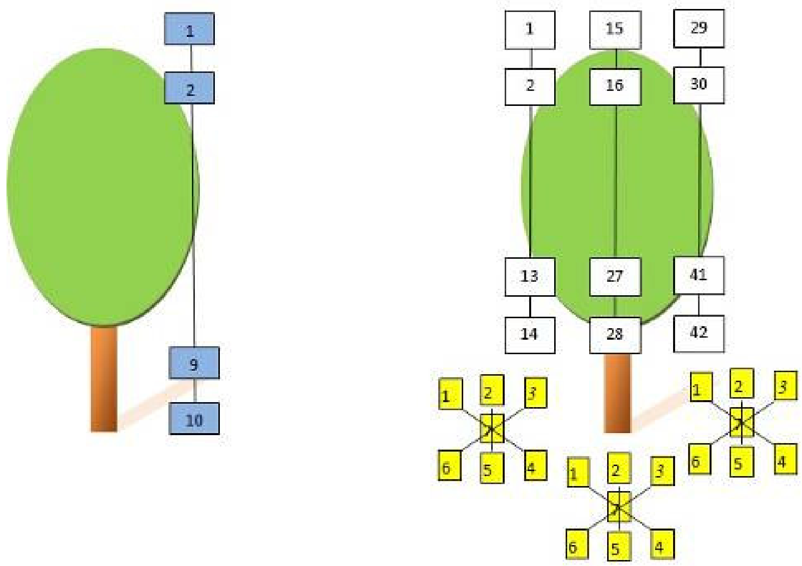

Figure 7. Layout of collectors for spray deposit (white squares), the chemical spilled on the ground (yellow squares) and drift (blue squares) measurements.

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performed for all the test cards. Then, the average was calculated and statistical analysis was performed on those numbers.

Solution Consumption for each Tree

To obtain the solution consumption for every tree, the sprayer tank was completely filled with water before spraying. After spraying, the tank was filled and the amount of fluid consumed was determined by graded bottles and tubes.

Fuel Consumption for each Tree

To obtain the fuel consumption for every tree, the sprayer's fuel tank was completely filled with petrol before spraying. After spraying, the tank was filled and the amount of fuel consumed was determined by graded bottles and tubes.

Spray Height

Sensitive cards placed on the tree were assessed and the spray height was evaluated.

Spraying Time for Trees

Spraying time of each tree was measured by stopwatch.

Shedding on the Ground (Spray Loss)

The spray shed on the ground cause pollution of environment and soil. To determine it, three groups of sensitive cards were placed under every tree that was sprayed according to Figure 7. After spraying, the cards were collected and area of the droplets sitting on the cards and the average were calculated by measuring the number and diameter of the droplets in 1 cm^2. 1 cm of water sensitive paper was randomly selected. Paper photographs were taken by a camera. After enlarging the image, the number of droplets was counted by naked eye and their diameters were measured. The mean diameters of the drops were calculated and the area was calculated according to the formula for calculating the area of a circle. Then, the areas were summed and considered as the area of droplets sitting on the card. The calculations were performed for all the test cards. Then, the average was calculated and statistical analysis was performed on those numbers.

RESULTS AND DISCUSSION

Spraying Quality

According to the measurements made on the sensitive card and calculations, volume median diameter and numeric median diameter values of 1857.82 and 362.86 micron were obtained for the side pump sprayer and 768.57 and 158.57 micron for the electrostatic sprayer, respectively. Therefore, spraying quality coefficient was calculated as 5.12 and 4.85 in the side pump and electrostatic sprayer, respectively. The closer the quality coefficient is to one, the better the spray quality would be. Thus, the spray quality of the electrostatic sprayer was better than that of the side pump sprayer. Spraying quality coefficient for the wheel barrow and telescopic sprayers could not be evaluated, since the surfaces of the sensitive paper for the telescopic and wheel barrow sprayers were dark (they were wetted completely), their spraying quality coefficient was not calculated. Complete wetting of the sensitive cards for the telescopic sprayer was related to the nozzle used for this boom. This case could be probably resolved by changing the design of the nozzle and decreasing spray exit holes, or using a boom equipped with electrostatic heads. Although the quality coefficient was not calculated for these sprayers, the distribution of the droplets on each card and between the cards was more uniform in the case of the telescoping boom (Figure8).

Drift

Studying the sensitive cards placed on the trees and the area of droplets sitting on the

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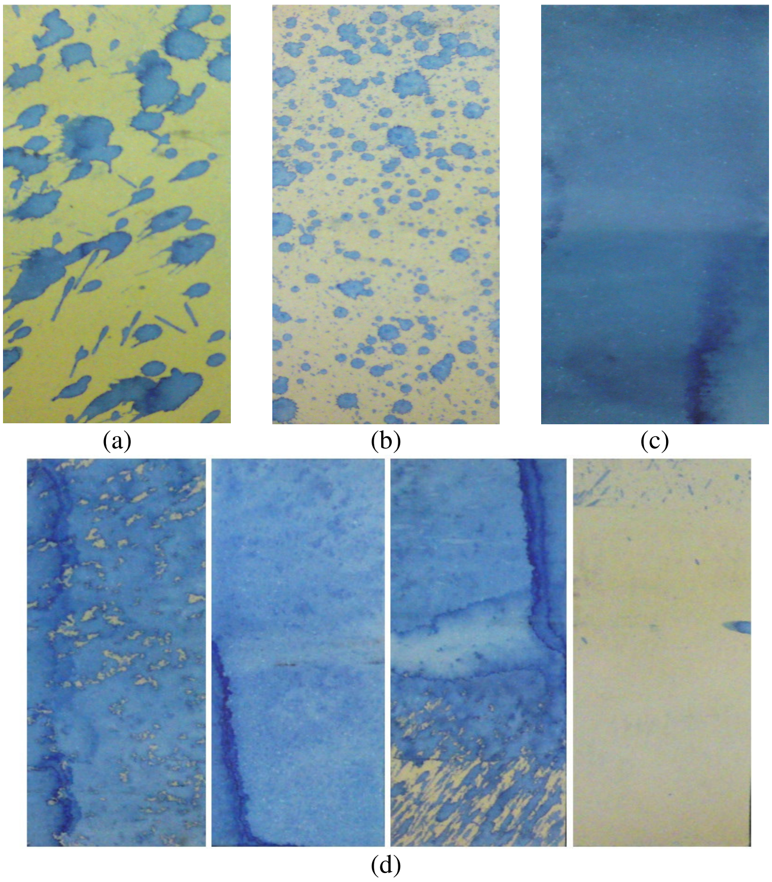

Figure 8. Cards of spraying quality. (a) Side pump, (b) Electrostatic, (c) Telescopic, and (d) Wheel barrow sprayers.

Table 4. Analysis of variance of the effects of changes in resources drift (mm^2), solution consumption (liters per tree) and spraying time for each tree (seconds).[a]

Source	*df*	Mean square		
		Drift	Solution consumption	Spraying time
Treatment	3	20.103 **	128.253 **	50.528 ns
Block	2	1.708 ns	0.136 ns	93.083 ns
Error	6	1.880	0.661	42.194
Total	11			

[a] ns: Non-significant, ** Significant at 1% level.

cards, drift results were obtained (Table 4). Using analysis of variance, there was a significant difference between the sprayers in terms of drift at 1% significance level. Mean comparison drift is shown in Table 5. As can be seen, drift of the wheel barrow sprayer (5.698 mm^2) was significantly higher than that of the sprayer equipped with telescopic boom (0.108 mm^2). The main reason for higher drift with the wheel barrow sprayer was that spraying at high height involved too much work pressure, while the telescopic sprayer had less drift, because it had low pressure and injection distance. The side pump and electrostatic sprayer had the maximum drift of 3.027 and 0.504 values, respectively, after the wheel barrow sprayer. Thus, drift of the electrostatic sprayer was

Table 5. Mean comparison of drift and solution consumption for sprayers.[a]

Sprayer	Drift (mm^2)	Solution consumption (L tree^{-1})
Telescoping	0.108^c	11.183^b
Wheel barrow	5.698^a	15.683^a
Electrostatic	0.504^{bc}	2.133^c
Side pump	3.027^{ab}	3.033^c

[a] The means with the same letter were not significant at 5% level according to Duncan's multiple ranges test.

less than that of the side pump sprayer, since the spray quality was better than that of the side pump sprayer. Thus, drift is inversely related to spraying quality coefficient.

Solution Consumption

Analysis of variance of the data obtained from measuring the amount of solution consumption for each tree is shown in Table 4. The results demonstrated that there were significant differences between the treatments at 1% significance level. Means of the solution consumption are shown in Table 5. According to the mean comparison, solution consumption of the wheel barrow sprayer (15.683 L tree^{-1}) was higher than that of the other sprayers, because drift of the wheel barrow sprayer was maximum, which required the user to spray longer for the optimal spraying. Telescopic, side pump, and electrostatic sprayers ranked next with the values of 11.183, 3.033, and 2.133 L tree^{-1}, respectively. Considering that no previous research has been reported on evaluation of orchard sprayers, it was not possible to compare these results with those of other studies.

Fuel Consumption

Side pump sprayer did not consume fuel. ANOVA results of the data obtained from measuring the amount of fuel consumption for each tree are shown in Table 6. The results demonstrated significant differences between the treatments at 5% significance level. Mean of fuel consumption is shown in Table 7. According to the mean comparison, fuel consumption of the electrostatic sprayer (0.016 L tree^{-1}) was less than that of any other sprayer. The telescopic and wheel barrow sprayers ranked next with the values of 0.036 and 0.052 L tree^{-1}, respectively, which could be attributed to the difference in sprayers' pressure (wheel barrow sprayer worked with pressure of 20 bar) and drift that would require longer spray time to achieve optimal spraying. Given that no research has been reported on evaluation of sprayers in orchards, it was not possible to compare these results with those of other studies.

Table 6. Analysis of variance in terms of fuel consumption (liters per tree).[a]

Source	*df*	Mean square
Treatment	2	0.001 *
Block	2	0.000 ^{ns}
Error	4	0.000
Total	8	

[a] ns: Non-significant, * Significance at 5% level.

Table 7. Mean comparison of fuel consumption for sprayers.[a]

Sprayer	Mean
Telescoping	0.036^{ab}
Wheel barrow	0.052^a
Electrostatic	0.016^b

[a] The means with the same letter were not significant at 5% level according to Duncan's multiple ranges test.

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Spray Height

On the sensitive cards 1, 2, 15, 16, 29, and 30 (the first and second rows of white cards, Figure 7) for the side pump sprayer and cards 1, 15, and 29 (first row of white cards, Figure 7) for the electrostatic sprayer, no drops were observed. The results showed that, although the side pump and electrostatic sprayers had better spraying quality coefficient, these two sprayers were not able to spray at high altitude (more than 3.5 m). The telescopic and wheel barrow sprayers could spray at high height due to high length and high injection pressure, respectively.

Spraying Time

Results of the measured spraying time are given in Table 4. ANOVA results showed that there was no significant difference between the sprayers in terms of spraying time at 5% significance level. The comparison of mean spraying time is shown in Figure 9. Maximum and minimum spraying times belonged to the wheel barrow (119 seconds) and side pump (110 seconds) sprayers, respectively.

Spray Loss

Using the sensitive cards and calculations for the side pump and electrostatic sprayers, the mean spray loss areas of 9.93 and 2.80 were obtained, respectively. Therefore, the electrostatic sprayer had the minimum spray loss and was less likely to cause soil contamination. Thus, the spray loss of the electrostatic sprayer was less than that of the side pump sprayer, since the spray quality was better than that of the side pump sprayer. So, spray loss was inversely related to the spraying quality coefficient.

Since the surfaces of the sensitive paper for the telescopic and wheel barrow sprayers were dark (they were wetted completely), their spray loss area was not calculated. Complete wetting of the sensitive cards for the telescopic sprayer was related to the nozzle used for this boom. This case could be probably resolved by changing the design of the nozzle and decreasing spray exit holes, or using a boom equipped with electrostatic heads.

CONCLUSIONS

In this study, a telescoping boom was designed, fabricated, and evaluated to reduce

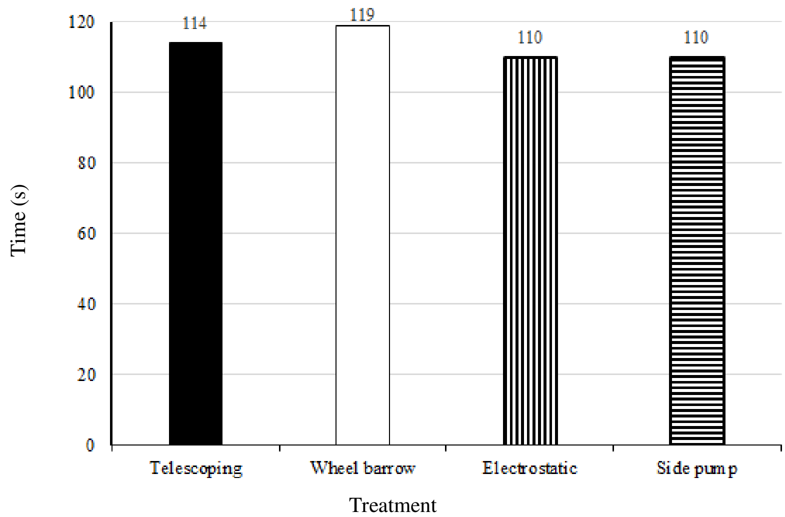

Figure 9. Comparison of the mean spraying time for each tree.

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the spray distance of tree canopies. The results can be summarized as follows:

Drift was significantly reduced compared with the conventional sprayer. As a result of using this device, problems such as environmental pollution, toxicity to users, and elimination of beneficial insects were reduced.

Electrostatic sprayer was more suitable in terms of solution consumption, fuel consumption, and spray loss. But, this sprayer could not spray tall trees.

Although the quality coefficient was not calculated for telescopic sprayers, observations showed that uniformity of the droplets was more desirable and spraying quality and uniform was improved with better design of nozzle. Also, the boom can be fitted to the electrostatic head and benefited from its advantages.

The spraying quality coefficient was inversely related to spray loss. When spraying quality was better, spray loss was reduced.

Moreover, the spraying quality coefficient was inversely related to drift. When spraying quality was better, drift was reduced.

In this study, the telescopic and wheel barrow sprayers were similar and both used a similar pump and engine. But, the sprayer equipped with telescopic boom worked with pressure of 4 bar and did not require an engine with high power. Therefore, in mass production, the amount of solution and fuel consumption can be minimized using the pumps and engines with less power. Also, sprayer price could be reduced greatly, which is significant from an economic viewpoint.

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مقایسه کیفیت سمپاش مجهز به بوم تلسکوپی با سمپاش‌های مرسوم در باغات ایران

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چکیده

در باغات کوچک، باغداران با مشکلاتی نظیر کشت نامنظم درختان، سختی عبور و مرور تراکتورها، مشکلات اقتصادی برای خرید تراکتور، بادبردگی زیاد سم در سمپاش‌های با ارتفاع پاشش زیاد، ارتفاع کم پاشش و سختی کار با سمپاش‌های معمولی، مواجه هستند. هدف از انجام این تحقیق ساخت و ارزیابی یک بوم تلسکوپی برای سمپاش‌ها به منظور مرتفع نمودن مشکلات بود. سمپاش مجهز به این نوع بوم از نظر بادبردگی، کیفیت سمپاشی، ارتفاع پاشش، زمان سمپاشی، سم تلف شده و محلول و سوخت مصرفی در مقایسه با سمپاش‌های مرسوم (فرقونی، کتابی و الکترواستاتیک) مورد ارزیابی قرار گرفت. نتایج نشان داد که ضریب کیفیت سمپاشی سمپاش الکترواستاتیک بهتر از نوع کتابی بود و به دلیل خیس شدگی کامل کارت‌های حساس برای دو نوع دیگر قابل

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محاسبه نبود، اما توزیع قطرات بر روی هر کارت و بین کارت‌ها در نوع تلسکوپی یکنواخت‌تر بود. سمپاش فرقونی بیشترین و سمپاش تلسکوپی کمترین بادبردگی را داشت. سمپاش فرقونی، تلسکوپی، کتابی و الکترواستاتیک به ترتیب بیشترین مقدار محلول مصرفی را داشت. سمپاش های الکترواستاتیک، تلسکوپی و فرقونی به ترتیب کمترین مقدار سوخت مصرفی را داشتند. سمپاش های کتابی و الکترواستاتیک توانایی پاشش ارتفاع‌های زیاد را نداشتند. سمپاش های تلسکوپی و فرقونی توانایی پاشش ارتفاع زیاد را داشتند. بیشترین و کمترین زمان سمپاشی به ترتیب مربوط به سمپاش های فرقونی و کتابی بود. میانگین مساحت سم تلف شده به ترتیب ۹/۹۳ و ۲/۸۰ میلیمترمربع برای سمپاش های کتابی و الکترواستاتیک بدست آمد و برای دو نوع دیگر قابل محاسبه نبود.

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