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Performance of Different Types of Spraying Methods in Second Crop Maize Production

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Abstract: Due to suitable climate conditions, maize production can be done as the first crop and second crop in Çukurova Region/ Mediterranean of Turkey. Although there is no need to spray in the fist crop maize production, there are two main pests which are European corn borer (*Ostrinia nubilalis*) and Corn stalk borer (*Sesamia nonagrioides*) to be needed to control in the second crop maize production. Until 2006, pesticide applications to maize pests have been done by aerial application equipment with an application volume of 30 to 50 $l.ha^{-1}$. But aerial applications were banned in 2006 in Turkey. After banning of aerial applications, pesticide applications to maize plants have been a problem, especially in late season of plants since plants' height increases. To tackle this occurrence, 6 spraying methods that are known to achieve higher coverage and deposit but less drift potential in nozzle and sprayer market were chosen to spray the second crop maize plants against two main maize pests. The spray application methods chosen were: (1) standard boom equipped with hollow cone nozzles which were domestic nozzles used widely by farmers, (2) standard boom mounted with tail booms and hollow cone nozzles, (3) air induction nozzles, (4) twinjet nozzles, (5) air assisted spraying with domestic hollow cone nozzles and (6) air-assisted spraying with TX cone jet nozzles. A prototype sprayer with an air-assisted unit was manufactured and all methods were tested at two application rates (150 and 300 $l.ha^{-1}$). Field trials were carried out in year 2008 and 2009 and at two heights (plant height 50 to 60 and >175 cm) of plants. All methods were evaluated by measuring amount of deposition and coverage on maize plant and off target ground deposition of methods. A tracer (BSF) was sprayed to evaluate the efficacy of methods on plants and ground target. To evaluate biological efficacy achieved by the methods, a known pesticide was sprayed at the recommended dose. According to the results, the highest deposits, coverage and biological efficacy were achieved with the application of air assisted hollow cone nozzles at 300 $l.ha^{-1}$ application volume. The lowest off target ground deposition was evaluated by twinjet nozzles in early stage of plants and by air induction nozzles in the late stage of plants.

Key words: Pesticide applications to second crop maize, spray deposits and coverage, off-target ground deposits, European corn borer, corn stalk borer, biological efficacy

INTRODUCTION

Maize production in Turkey is 592.000 ha and maize is grown mainly in the Black Sea, Marmara, Aegean, and Çukurova/Mediterranean regions of Turkey. The Çukurova region produces nearly 40 percent of the nation's maize production, with approximately the same amount of area planted towards the first and second crops. Although there is no need to spray in the fist crop maize production, every year growers make up to 5 insecticide applications to control the second crop maize pests which are European corn borer (Ostrinia nubilalis) and Corn stalk borer, (Sesamia nonagrioides). In the second crop growing season, average losses of crop yield can be reached 80 % if maize pests can not be got under control (Şimşek and Sezer, 1983; Ataç and Şimşek,1987). These pests begin to make damages at early period of plants such as 50 to 60 cm of plant height (Tatlı et al., 2004). In the pest control process against both main pests, a chemical pesticide with the active substance *Lambda Cyhlatroin* is widely used and this pesticide is suggested to be applied at least three times during the second crop maize growing season (Şimsek and Güllü, 1996). Although availability mechanic, biological and chemical methods of IPM programs, farmers still prefer chemical methods. Because chemical methods enable getting rapid results, are cheaper when used consciously, protect the plant against organisms that secrete toxins; that's why this method is preferred. Recently, different kinds of nozzles and spraying methods are used in order to spray pesticide to the maize crop. In Turkey, agriculture planes have been used to spray pesticides to second crop maize till 2006. But in 2006, the Ministry of Agriculture and Rural Affairs has banned pesticide spraying by airplanes due to inefficacy and environmental concerns caused by this method. After this, second crop maize farmers have started to search new alternative methods of pesticide application especially for the second periods of plants in which the height of plants can reach to 2.5 m and taller. To tackle this problem, some tractor repairing workshops have made the conventional boom sprayer possible to be used with a tractor by increasing the height of old tractors' frame. But due to low operator security and hard driving after irrigation in the field, this method is scarcely preferred.

As known early, sprayers and their operating parameters have big effects on chemical control results. Today, many researches are made on the issues of producing homogeneous droplets with low drift, transporting drops to the target and ensuring that droplets deposit on the target. With the growing concerns of environmental protection, it is necessary to decrease the drift of the pesticide and increase efficacy of the pesticide by applying them directly on the target (Gajtkowski et al, 2006). In recent years, air-assisted spraying is widely used in order to increase the efficacy of pesticide application with conventional types of field sprayers (Degania Sprayer/Israel, Hardi Sprayer/Denmark etc.). In this kind of sprayers, drops produced by hydraulic nozzles are carried onto the target by air current. Thus, more penetration, possibility to apply pesticide with smaller droplets and large coverage on the underside surface of the leaves are achieved (Bayat et al, 1996). It is known by many researchers that a sprayer equipped with a well designed air assisted unit achieves better deposition on target surfaces than a standard boom sprayer (Panneton et al, 2000; Gajtkowski, 2002). Some researchers note that in pesticide applications by air assisted, the air current increase the drop speed and pesticide penetration conveying more pesticide especially on the underside surfaces of the plant and decreasing drift (Panneton et al, 2000; Sumner and Herzog, 2000). Although many researches bring out that with air assisted applications more efficient results are achieved, Turkish sprayer manufactures don't tend to manufacture this kind of sprayers because of high cost of that equipment. Furthermore, both farmers and sprayer manufactures in Turkey seem to focus on modified versions of standard boom sprayers rather than new alternative spraying methods.

In additional to air assisted spraying, as an alternative to the conventional type nozzles, new types of hydraulic nozzles (air induction, twinjet, turbo drop, twin fluid nozzles etc.) have been developed. Among these new nozzles developed by various companies, air induction and twinjet nozzles are mostly preferred. Nozzle manufacturer companies and some researchers (Bayat et al, 1999; Gajtkowski et al, 2005) claim that air induction nozzles have a lower drift potential and higher coverage rate on target surfaces comparing the standard flat fan nozzles. On the other side, company that produces twinjet nozzles defined the advantages of this type nozzles such as; (1) sprays forwards as well as backwards, (2) fine droplets by high coverage, (3) good penetration in a dense crop (Spraying System Co.). Apart from these new nozzle technologies, tail boom sprayers are used to spray underside leaf surface and also penetrate the spray to bottom parts of plants. But for tall plants like maize, an appropriate tail boom nozzle configuration should to be developed.

Objectives of this study are to determine efficacy of different types of new nozzles and air-assisted spraying in second crop maize by measuring spray deposits, coverage, and biological efficacy.

MATERIALS and METHOD

Field works of the research have been conducted in the experimentation area of Çukurova Agricultural Research Institute, Adana in 2008 and 2009. Spraying methods used in the experimentation were: (1)

conventional boom manufactured with domestic cone nozzles (DCN; Toyman Company İzmir, Turkey), (2) boom with tail boom plus domestic nozzles (TBDCN), (3) air induction nozzles (AI; Spraying System Co. USA), (4) twin jet nozzles (TJ; Spraying System Co. USA), (5) air assisted spraying with domestic cone nozzles (AADCN) and (6) air assisted TX cone nozzles (AATX; Spraying System Co. USA), Each method used in the research was experimented at 150 and 300 l.ha^{-1} application volumes and two stage of plants as early season (plant height 50 to 60 cm) and late season (plant height 210 to 230 cm) of maize plants.

To test all methods, a prototype air-assisted sprayer was manufactured (Fig. 1). Prototype sprayer had a 600 l tank capacity, a piston-membrane pump, an axial blower operated hydraulically, an inflatable PVC air jacket throughout the boom and connected to tractor's three-point linkage system. The air supply blower and boom can be operated until 3 m height as hydraulically. Air supply unit on the sprayer consisted of an 80 cm diameter axial blower with about 30.000 m3.h^{-1} air capacity and 32 m.s^{-1} air velocity at air outlet of inflated PVC jacket. Since it is hard to operate the blower in variable heights with mechanic system (telescopic shaft), the blower of the sprayer produced was operated by a hydraulic motor and control system. Thus, the blower could be operated in required heights more safely. And since the hydraulic oil capacity within the tractor's hydraulic system was not provided the adequate flow rate, the hydraulic motor which is installed on the blower was supplied with another oil tank. For this purpose, a hydraulic oil tank with a 30 l capacity (8) was installed on the sprayer under the tank.

The oil in the hydraulic oil tank was pressurized with an inclined-axial hydraulic pump (6) into a flow separator and then into the hydraulic motor (4). The oil that heats while operating the motor was directed to a radiator (5) with 400 bar pressure and 100 1.min^{-1} flow rate in order to be cooled.The flow separator placed on the outlet line of the hydraulic pump (6) regulates the oil pressure and the pressure value could be observed via a manometer. The blower and the spraying boom can be moved up and down by means of telescopic piston on a skidder system built joint to the sprayer main chassis. The blower was operated by the driver through an electronic system. The air current provided by the blower was directed to the sprayer's spraying boom by an air router (10). Air is directed through two circular outlets (Ø 42 cm) to the air jackets placed on the spraying boom. The air jacket was made of PVC. Air was discharged out through 4 cm diameter outlets placed every 10 cm interval on the air jacket. The air jacket diameter, which was 42 cm at the air router outlet, was 25 cm at the end of the spraying boom. Thus, a uniform air distribution was achieved. In order to perform other methods of spraying with the same prototype of sprayer, 4 separate booms with 5 m long spraying width which can be easily attached to on the same sprayer were produced.

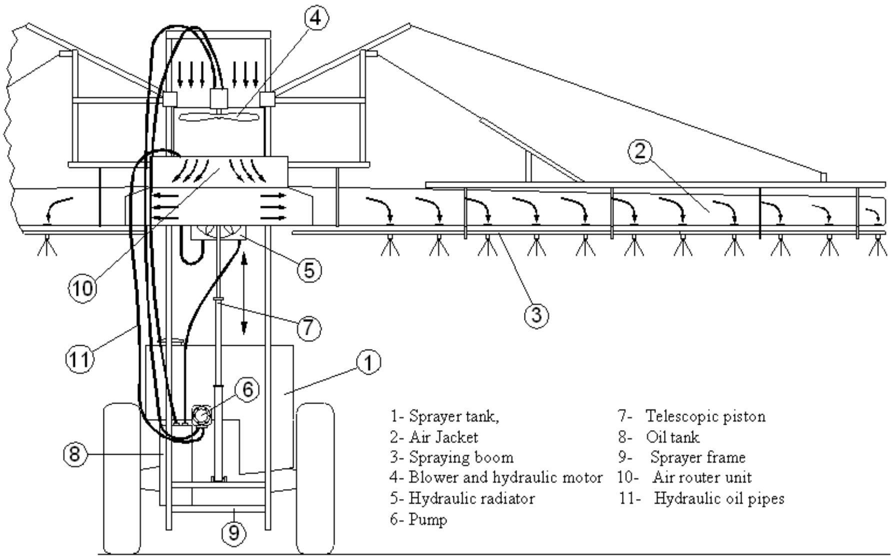

Figure 1. Schematic view of the prototype sprayer manufactured for maize plant spraying

The nozzles were attached on the spraying boom 25 cm intervals in all air-assisted applications and 50 cm intervals in spraying with AI, twin jet and domestic cone nozzles. For tail boom application, top spraying nozzles were attached as 70 cm intervals and tail booms that each boom had four nozzles were attached between top nozzles just between maize rows. The air temperature and wind velocity values have been measured by an anemometer during the researches. Average temperature was 37.2 °C and the wind velocity was <1.5 $m.s^{-1}$. The spraying methods and sprayer operating parameters in the research are given in Table 1.

Table 1. Spraying methods and operating parameters

Spraying Methods	Pressure (bar)	Nozzle flow rate ($l.min^{-1}$)	Droplet size ($Dv_{0.5}$)	Relative span
DCN	7	1.10	144.9	0.99
AI (11002)	4	1.10	354.4	1.56
TJ (TJ60-11002)	4	1.00	356.6	1.52
AADCN	4	0.90	169.7	0.92
AATX3	4	0.28	139.1	0.69
AATX6*	4	0.54	146.1	0.84
TBDCN	3	0.30	174.3	0.95

DCN; 1.2 mm orifice size and 2 canals swirl plate
***:** AATX6 nozzles were used for 300 $l.ha^{-1}$application rate.

The experimentations were designed as randomized block with split-split plot arranged with 4 replications. On the experimentation field, P 3394 (Pioneer) sort of maize was sowed and sowing was done by 8 blocks and on 56 plots. There was 5 m security zone between blocks and plots. In order to compare the efficacy of spraying methods, deposition and leaf coverage rate and spray loses reaching on ground were measured in two plant height. In the first period (early season) applications, plant height was 50 to 60 cm and leaf area index was 1.6; in the second period (late season) application, plant height was 210 to 230 cm and leaf area index was 3.1. In the research, in order to measure the amount of deposition on target surfaces, a tracer called as Brilliant Sulpho Flavin (BSF; Chorma-Gesellschaf, Schmid GmBH. Co., Germany) was sprayed with a contains 1g/L. Filter papers (Watman No 4) having a 4 cm diameter were used to collect the BSF deposits on plants. For determining coverage rate achieved by methods, water sensitive papers with 26x52 mm size (Water sensitive paper, Syngenta) were used. In the first period of applications (plant stage I), as the plants were not much high, sampling was done on 5 plants in each parcel and 4 leaves on each plant. Thus, filter papers and water sensitive papers were attached on upper, lower surfaces leaves and plant stem randomly selected (Fig. 3). To measure spray deposits on the ground which were evaluated as loses, filter papers were put on the left, right and in the row spaces on the battens placed on the soil surface. Due to the fact that plants were higher in the second application period (Stage II), the plants were divided into 3 zones vertically and in each zone filter and water sensitive papers were attached on three leaves on both upper and lower surfaces (Fig. 2). Besides leaf targets, filter papers and water sensitive papers were attached on the plant stalk in each zone.

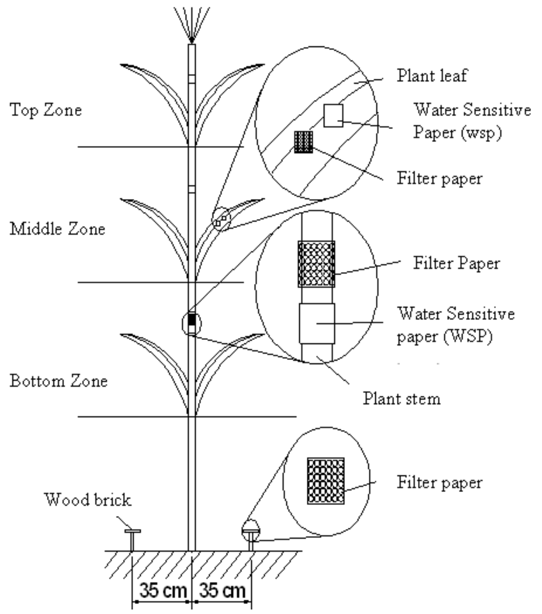

Fig. 2. Schematic view of sampling targets on plant and ground in stage II

After having attached the testing materials mentioned above, the BSF solution was sprayed on each spraying method parcel. After the spraying process is completed, filter papers were put into jars and water sensitive papers are put into envelopes and samples were taken to laboratory for analyzing deposits and coverage rate. A solution of %3.33 methyl alcohol and 50 ml pure water were poured into the filter paper jars and the jars were shaken by a shaker. Then, samples are taken from the jar with standard fluorometer tubes and amount of BSF was measured by the fluorometer (2001 A Fluoro-Tec, USA). The mean deposits were calculated the total deposits on the target surfaces by dividing number of targets for each plant. In order to determine the coverage rate, stains on the water sensitive papers were scanned in a 600 dpi resolution scanner (HP Scanjet 1510) and the images achieved were evaluated in an image processing program (Image Tool Free Version 3.0) to calculate the coverage percents. In the evaluations, the water sensitive papers which turned completely from yellow to blue were presumed to be 100%. The data were evaluated according to the variance analyze in statistic program and LSD test was used for the differences among averages.

RESULTS and DISCUSSION

The mean deposits, coverage achieved by methods at two application rates and in early(Stage I) and late (Stage II) period of maize plants are given in Table 2 and 3 for the years 2008 and 2009.

As shown in Table 2, the highest deposits were achieved by air assisted spraying methods with conventional cone nozzles in both years. Considering the coverage rates provided by the methods, the highest coverage rates were achieved by AATX6 cone nozzles in both years. The maximum deposits and coverage rates provided with application rate of 300 $l.ha^{-1}$ in all methods. Increasing application rate improved deposition and coverage. Considering data for stage II, as similar stage I, the highest deposits were achieved by air assisted spraying methods with conventional cone nozzles and tail boom application (vertical boom between rows) in both years (Table 3). But, the coverage rate results were in different group, in terms of statically evaluations. The coverage rates were lower in stage II comparing to stage I results. The reasons of this reduction could be increases in plant height and leaf surface areas of plants. Known as new nozzles AI and TJ did not improve deposit and coverage rate compared to DCN nozzles in both sateges and years. The highest coverage rate was 9.2% in 2008 and 9.1 in 2009 by AADCN method at 300 $l.ha^{-1}$ application rate.

The mean ground deposits that mean pesticide loses are given in Table 4 according to the methods and application volumes. Although the same doses of BSF tracer were applied with all methods for each application rate, as shown in Table 4.

Table 2. The amount of mean deposits and coverage at two application rate (Stage I)

Spraying Methods	2008				2009			
	Deposit (µg/cm²)		Coverage (%)		Deposit (µg/cm²)		Coverage (%)	
	150	300	150	300	150	300	150	300
DCN	0.21 c*	0.50 a*	14.6 b*	17.9 b	0.18 d*	0.41 c	12.8 b*	18.2 d*
AI	0.20 c	0.44 b	9.2 d	11.5 d	0.18 d	0.31 e	9.8 c	13.3 d
TJ	0.20 c	0.43 b	12.1 c	14.9 c	0.21 c	0.37 d	12.3 b	14.9 c
AADCN	0.40 a	0.52 a	18.7 a	19.9 ab	0.41 a	0.50 a	17.2 a	20.2 b
AATX3/TX6	0.29 b	0.51 a	17.4 a	21.3 a	0.31 b	0.46 b	16.8 a	22.9 a
$LSD_{0.01}$	0.015	0.054	1.97	2.38	0.013	0.021	1.01	1.60

*: the values shown with the same letters on the column are not significant in the level of p<0.01

Table 3. The amount of mean deposits and coverage at two application rate (Stage II)

Spraying Methods	2008				2009			
	Deposit (µg/cm²)		Coverage (%)		Deposit (µg/cm²)		Coverage (%)	
	150	300	150	300	150	300	150	300
DCN	0.13 c*	0.16 b*	6.7 c	7.5 c*	0.13 b*	0.17 c*	5.9 d	7.2 c*
AI	0.09 d	0.14 c	4.8 d	6.9 d	0.09 c	0.14 d	6.3 cd	5.3 d
TJ	0.08 d	0.13 d	3.9 e	4.6 e	0.08 c	0.12 e	4.3 e	4.7 e
AADCN	0.18 a	0.22 a	7.3 ab	9.2 a	0.17 a	0.21 a	8.1 a	9.1 a
AATX3/TX6	0.14 b	0.20 a	7.4 a	8.4 b	0.13 b	0.19 b	7.4 b	8.6 b
TBDCN	0.17 a	0.21 a	6.8 bc	9.1 a	0.16 a	0.20 a	6.7 c	8.4 b
$LSD_{0.01}$	0.010	0.014	0.451	0.511	0,011	0.079	0.517	0.542

*: the values shown with the same letters on the column are not significant in the level of p<0.01

Table 4. The mean ground deposition (pesticide loses) according to the methods

Spraying Methods	2008				2009			
	Stage I		Stage II		Stage I		Stage II	
	150	300	150	300	150	300	150	300
DCN	0.38 c	0.47 bc*	0.17 de	0.21 c*	0.38 c	0.42 b*	0.17 cd	0.23 d
AI	0.33 cd	0.47 bc	0.19 d	0.28 b	0.34 d	0.44 b	0.13 e	0.27 bc
TJ	0.31 d	0.44 c	0.15 e	0.24 b	0.34 cd	0.41 b	0.15 de	0.25 c
AADCN	0.69 a	0.58 a	0.33 a	0.34 a	0.64 a	0.51 a	0.33 a	0.34 a
AATX3/TX6	0.54 b	0.53 ab	0.27 b	0.33 a	0.45 b	0.54 a	0.26 b	0.28 b
TBDCN	-	-	0.23 c	0.24 bc	-	-	0.21 c	0.24 cd
$LSD_{0.01}$	0.05	0.07	0.03	0.04	0.04	0.04	0.03	0.03

*: the values shown with the same letters on the column are not significant in the level of p<0.01

Table 5. Biological efficacy (%) of methods in controlling European corn borer and Corn stalk borer

Spraying Methods	2008						2009					
	Number of holes on stalk		Number of infected plants		Number of larvae + pupae		Number of holes on stalk		Number of infected plants		Number of larvae + pupae	
	150	300	150	300	150	300	150	300	150	300	150	300
DCN	34.8 b*	43.6 cd	34.8 b*	35,1 b*	42.6 c*	69.3 a*	51.3 b*	45.4	33.0 b*	42,0 a*	39.6	43.7 bc*
AI	22.5 c	46.8 c	22.5 c	36,4 b	44.9 c	49.9 b	47.5 bc	38.7 c	21.0 c	22,0 b	35.9 c	22.5 d
TJ	24.5 c	40.3 d	24.5 c	23,6 c	25.0 d	43.8 b	44.6 c	45.6 b	14.0 c	24,0 b	19.2 d	38.6 c
AADCN	52.5 a	64.3 ab	52.5 a	47,8 a	70.3 a	71.3 a	59.7 a	63.9 a	39.0 b	47,0 a	54.4 a	59.7 a
AATX3/TX6	44.3 ab	66.1 a	44.3 ab	54,1 a	69.0 ab	79.1 a	59.6 a	64.0 a	45.0 a	47,0 a	50.5 ab	56.7 a
TBDCN	42.2 ab	58.4 b	42.2 ab	35,2 b	59.5 b	55.3 b	37.8 d	44.2 b	32.0 b	44,0 a	52.9 a	46.8 b
$LSD_{0,01}$	8.97	6.27	8.97	10,47	10.02	12.59	3.32	2.47	5.96	4,78	7.44	3.60

*: the values shown with the same letters on the column are not significant in the level of p<0.01

In both years the highest ground deposits were provided by AADCN application method at 150 l/ha in Stage I (Table 4). As one would expected, ground deposits were lower in Stage II than Stage I because of increasing in leaf area index of maize plants. That means many spray droplets filtered by plants in stage II. Besides AADCN method, 300 $l.ha^{-1}$ application rate resulted in higher ground deposits than 150 $l.ha^{-1}$ application rate. Biological efficacy rates in controlling European corn borer (Ostrinia nubilalis) and Corn stalk borer, (Sesamia nonagrioides) are given in Table 5.

As shown in Table 5, the highest biological efficacy was provided as 79.1% by AATX6 method at 300 $l.ha^{-1}$ in 2008. Similar to deposits and coverage results, air assisted spraying methods improved the biological efficacy comparing to other methods. Mostly lower efficacy provided in reducing number of holes on stalk than in controlling number of larvae+pupae. That means risk potential is still higher in all methods used in this research. So, more research studies should be done to have higher biological efficacy on plant stalk. To reduce loses of crop yield, the number of holes on stalk should be decreased to prevent tilt of plant. The results of this research have shown that air-assisted spraying provided better results in terms of amount of deposit, coverage and biological efficacy. But the level of biological efficacy achieved by all methods used here still needs to increase to higher rate at least 90% level.

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