Efficiency of different spray application methods in second crop maize

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Abstract

In Çukurova region of Turkey, about 120.000 hectares of arable fields are planted each year by maize and approximately 50 % of these areas are planted as second crop maize. In the maize plants which are grown as second crop, there are two main pests, *Sesamia nonagrioides* Lefebvre (Lepidoptera: Noctuidae), *Ostrinia nubilalis* Hübner (Lepidoptera: Crambidae) that need to be controlled and in the event of not being controlled that caused big yield losses in plant and eventually in the product. Spray applications in controlling two main maize pests have been carried out by airplane until the year 2006 but anymore aerial applications are banned due to environmental concerns of spray drift and low efficiency in Turkey. This action caused some difficulties to spray the chemicals such as taller than 2.5 m heights of maize plants and some farmers modified their conventional boom sprayers especially by increasing the height of their tractors' frame with a new system. In spite of these efforts, spraying problems in second crop maize fields are continuing. In this work, 6 spraying methods as air assisted spraying with TX cone jet and domestic cone nozzles, twinjet nozzles, air induction nozzles, and standard boom equipped with domestic cone nozzles and tail booms at two application rates (150 and 300 $l.ha^{-1}$) were used by a sprayer which can be operated at different spraying boom height such as 3.5 m height on ground. All methods were evaluated by measuring deposition and coverage on maize plant and ground deposition for endo-drif potential of methods. All methods were tested at two stage of plants in which plant heights were 50-60 cm in stage I and > 210 cm in stage II. According to the results, it was examined in terms of deposits, statistical differences were determined between the methods in Stage I (plant height 50 to 60 cm) and Stage II plant height > 210 cm). Air-assisted domestic cone nozzles with application volume of 300 $l.ha^{-1}$ achieved the highest deposits in both plant stages. The coverage rate at stage I and stage II on targets for Air-assisted domestic cone nozzle method was 21.3 % and 27.6 % respectively. Comparing the deposits on the ground in stage I for endo-drift potential, the highest ground deposition was obtained as 0.69 ($\mu g.cm^{-2}$) with air-assisted domestic cone nozzles with 150 l.ha-1 application volume. However, in stage II, 300 l.ha-1 application volume of air assisted domestic cone nozzles provided higher ground deposits.

Introduction

Due to suitable climate conditions, maize production can be done as the first crop (March-October) and second crop (June-November) in Çukurova Region of Turkey. As the density of pests in the first crop maize growing season is generally low in Çukurova, there is usually no need for pesticide applications. But in the second crop growing season, average losses of crop yield can reach 80% if maize pests can not be got under control [9,1]. In the second crop maize growing season pests like especially maize Corn Stalk Borer, *S. nonagrioides* Lefebvre (Lepidoptera:Noctuidae), European Corn Borer, *O. nubilalis* Hübner (Lepidoptera:Crambidae) and maize harm the crops. Both pests begin to make damage early period of plants such as 50 to 60 cm of plant height [11,12]. 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 three times during the second crop maize growing season [10].

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. Today 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 planes due to inefficiency and environmental concerns caused by this method.

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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. Recently 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 drops with low drift, transporting drops to the target and ensuring that drops deposit on the target. With the growing importance of environmental protection, it is necessary to decrease the drift of the pesticide and increase efficiency of the pesticide by applying them directly on the target [6].

In recent years, air-assisted spraying is widely used in order to increase the efficiency 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 drops and large coverage on the underside surface of the leaves are achieved [2]. 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 [7, 4]. 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 [7, 8].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 [3,5]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 efficiency of different types of new nozzles and air-assisted spraying in second crop maize by measuring spray deposits, coverage, and deposits as losses on the ground.

Materials and Methods

Field works of the research have been conducted in the experimentation area of Çukurova Agricultural Research Institute, Adana in 2008. 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 nozzle (AATX; Spraying System Co. USA), Each method used in the research was experimented at 150 and 300 $1.ha^{-1}$ application volumes and two stage of plants as early season (plant height 50 to 60 cm) and late season (plant height 210 to 230) of maize plants.

To test all methods, a prototype air-assisted sprayer was manufactured (Fig. 1) and all methods were tested on the same sprayer by changing the only boom spray system and nozzles. 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 $m^{3}\cdot h^{-1}$ 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 be able 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. The nozzles were attached on the spraying boom 25 cm interval in all air-assisted applications and 50 cm interval in spraying with AI, twin jet and domestic cone nozzles. For tail boom application, top spraying nozzles were attached as 70 cm interval and tail booms that each boom had four nozzles were attached between top nozzles just between maize rows (Fig. 2).

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.

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 parcels. There was 5 m security zone between blocks and parcels.

In order to compare the efficiency 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. 3). Besides leaf targets, filter papers and water sensitive papers were attached on the plant steam in each zone.

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). 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 amount of mean deposits and coverage calculated in the first period applications (stage I) with different application volumes are shown in Table2 and 3.

As shown in Table 2, in the first period of plants, the highest deposits in 150 $l.ha^{-1}$application volume were achieved with AADCN method followed by the AATX3 method with 0.29 $\mu g.cm^{-2}$mean deposit. Considering the coverage rates on the plant surfaces, the AADCN method was in the first rank with 18.7%. In the first period with 300 $1.ha^{-1}$ application volume, AADCN provided the highest deposit with 0.52 $\mu g.cm^{-2}$and the AATX6 method gave the best results in coverage rates with 21.3% (Table 3). Increasing the application volume in the first period from 150 $1.ha^{-1}$ to 300 $1.ha^{-1}$ provided better results in both coverage rates and deposits (Table 2 and 3). In both application volumes conducted in the first period, the deposit amount and the coverage rates achieved on the upper surface of the leaves is higher than the values achieved on leaf undersides and stem surfaces. In the 150 $1.ha^{-1}$ application volume, the best deposition rate that should be 1/1 ideally on upper /lower surfaces of leaves was 2.8 with AATX3 method and for coverage rate AADCN method achieved the better rate as 2.8. In 300 $1.ha^{-1}$ application volume, the best deposition rate on upper /lower surfaces was achieved with TJ method and regarding the coverage rate for upper / lower surfaces AATX6 method provided the best result.

In both applications conducted in the first period, deposition and coverage rates on upper/lower surfaces of leaves were so far from 1/1. However, especially in air assisted applications, this rate improved a little bit. In both application volumes conducted in the first period, air assisted applications provided higher deposits and coverage rates on stem comparing the other methods used.

The mean deposit and coverage rates calculated in the second period (Stage II) of applications with different application volumes are shown in Table 4 and 5.

As shown in Table 4, the highest mean deposits in the second period 150 $1.ha^{-1}$ applications were achieved with AADCN method as 0.54 $\mu g.cm^{-2}$ followed by TBDCN method as 0.53 $\mu g.cm^{-2}$. Regarding the coverage rates, the highest mean coverage rate was achieved with the AATX3 method as 22.4% followed by AADCN method as 21.9%. Considering the mean deposit t and the coverage rates achieved in the second application period, AADCN method provided the highest rates as 0.65 $\mu g.cm^{-2}$ deposit amount and 27.6% coverage rate (Table 5).

The mean ground deposits that mean pesticide loses are given Table 6 according to the methods and application volumes.

Considering data given in Table 6, in the first period of the research (stage I), the mean deposits on ground surface due to endo-drift were range of 0.69 to 0.31 $\mu g.cm^{-2}$ and the highest ground deposits were observed with AADCN method. In the same application period, in both 150 and 300 $l.ha^{-1}$application volumes, highest ground deposits were observed by the AADCN method with the results 0.33 ve 0.34 $\mu g.cm^{-2}$. But in stage II, the highest ground deposits was provided by AADCN with 300 $l.ha^{-1}$

Conclusion

The results below can be concluded from the research;

1. In the first period applications the highest deposits were achieved with the AADCN method in 300 $l.ha^{-1}$application volume. The highest rate of coverage was achieved with the AATX6 method in 300 $l.ha^{-1}$ application volume.
2. In the second period applications the highest deposits were achieved with the AADCN method in 300 $l.ha^{-1}$ application volume. The highest rate of coverage was achieved with the AADCN method with 27.6%.
3. The ground deposits as losses in both application volumes in second period were lower than the deposits comparing the first period.
4. In the air assisted spraying with both application volumes, the deposit and the coverage rates were observed to be increased. This increase was remarkable especially in the second application period on the middle and bottom parts of plants.

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References

[1] Ataç, A., N. Şımşek, 1987. *İkinci Ürün Mısır Üretimi Problemleri ve Çözüm Yolları Sempozyumu*. 21-25 Aralık 1987. Adana, 26 27 (written in Turkish).

[2] Bayat, A., Üremiş,İ., Ulubilir, A., Yarpuz, N. 1996. *2000' li Yıllara Girerken Pestisit Uygulama Yöntemlerindeki Gelişmeler.* II. Ulusal Zirai Mücadele İlaçları Simpozyomu. 18-20 Kasım. ANKARA(written in Turkish).

[3] Bayat,A., Özkan, H.E., Derksen, R.C., Fox, R.D., 1999. *Droplet Spectrum and Drift Potential of Turbo Teejet andA ir Induction Nozzles.* 7th International Congress on Agricultural Mechanisation and Energy 26-27 May, 1999 Adana, Turkey

[4] Gajtkowski, A., 2002. *The Spray Coverage Of Wheat With An Air Assisted Sprayer And Air İnduction Nozzles Id.* Journal article Accession Number: 20033034550 Journal of Plant Protection Research 42 (2) : 173-180.

[5] Gajtkowskı, A., Bzdega, W., Mıgdalska, P. 2005. Spray Coverage In Potatoes With Low Drift And Air-Induction Nozzles. Journal article Accession Number: 20063065840 Journal of Plant Protection Research 45 (1) : 17-23.

[6] Gajtkowski, A., Kustosık, P.M., Bzdega, W. 2006. *Quality Evaluation of Working With Drift Guard Nozzle and Air Induction Nozzles In Maize Spraying.* Journal of Plant Protection Reserach Vol. 46, No.4 2006.
[7] Panneton, B., Philion , Theriault, H., Khelifi, M. 2000. *Spray Chamber Evaluation of Air-assisted Spraying on Brocoli*. Published in Crop Sci.: 40: 444-448.
[8] Sumner H.R., Herzog, A.G., 2000. *Assessing the Effectiveness of Air –assisted and Hydraulic Sprayers in Cotton.* Via Leaf Bioassay. The Journal of Cotton Science 4: 79-83.
[9] Şımşek, N., C. Sezer, 1983. *Akdeniz Bölgesinde İkinci Ürün Olarak Ekilen Mısırda Görülen Zararlı ve Faydalılar Üzerinde Sürvey Çalışmaları* Adana Zirai Mücadele Araştırma Enstitüsü (Proje No: E/103.657, Nihai Raporu, written in Turkish).
[10] Şimşek, N. ve Güllü, M. 1996. *Akdeniz Bölgesi'nde Mısır Koçankurdu (Sesamia nonagrioides Lef., Lep.: Noctuidae) ve Mısırkurdu (Ostrinia nubilalis Hbn., Lep.: Pyralidae)'nun Mücadelesinde tahmin ve uyarı Olanakları Üzerinde Araştırmalar.* Türkiye 3. Entomoloji Kongresi Bildirileri,24-28 eylül, Ankara, 109-119 (written in Turkish).
[11] Tatlı, F. , Güllü, M., Özdemir, F., 2004. *Determination of Fungi Species Relationships Between Ear Infestation Rates and Fumonisin Quantitaties in Bt Maize.* IOBC / Wprs Bulletin 27(3): 161-164.
[12] Tatlı, F., Özdemır, F. 2005. *Adana ve Osmaniye İllerinde 2. Ürün Mısır Tanelerinde Bulunan Funguslar ve Mikotoksinler*. II. Ulusal Mikotoksin Simpozyumu Bildiriler Kitabı p: 190-191. İstanbul (written in Turkish).

Table 1. Spraying methods and operating parameters

Spraying Methods	Pressure (bar)	Nozzle flow rate ($l.min^{-1}$)	$Dv_{0,5}$ µm	Sprayer speed ($km.h^{-1}$)	
				150 $l.ha^{-1}$	300 $l.ha^{-1}$
DCN	7	1.10	144.9	8.8	4.4
AI (11002)	4	1.10	354.4	8.8	4.4
TJ (TJ60-11002)	4	1.00	356.6	8.0	4.0
AADCN	4	0.90	169.7	14.4	7.2
AATX3	4	0.28	139.1	4.4	-
AATX6*	4	0.54	146.1	-	4.3
TBDCN	3	0.30	174.3	8.4	4.2

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

Table 2. The mean deposits and coverage rates in the stage I with 150 $l.ha^{-1}$ application volume

Spraying Methods	Deposition on leaves ($\mu g.cm^{-2}$)			Deposit rate (upper /lower)	Mean Deposit ($\mu g.cm^{-2}$)	Coverage on leaves (%)			Coverage rate (upper /lower)	Mean Coverage (%)
	Upper side	Lower side	Plant stem			Upper side	Lower side	Plant stem		
DCN	0.36	0.10	0.19	3.6	0.21 c*	30.4	6.4	7.1	4.7	14.6 b*
AI	0.37	0.11	0.14	3.4	0.20 c	19.8	2.3	5.6	8.3	9.2 d
TJ	0.42	0.08	0.12	5.3	0.20 c	28.0	2.8	3.1	9.8	12.1 c
AA-DCN	0.56	0.16	0.49	3.5	0.40 a	31.9	11.5	12.6	2.8	18.7 a
AATX3	0.39	0.14	0.37	2.8	0.29 b	30.6	7.9	13.6	3.8	17.4 a
$LSD_{0,01}$					0.015					1,97

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

Table 3. Mean deposits and coverage rates in the stage I with 300 $l.ha^{-1}$ application volume

Spraying Methods	Deposition on leaves (µg.cm^{-2})			Deposit rate (upper /lower)	Mean Deposit (µg.cm^{-2})	Coverage on leaves (%)			Coverage rate (upper /lower)	Mean Coverage (%)
	Upper side	Lower side	Plant stem			Upper side	Lower side	Plant stem		
DCN	0.98	0.16	0.38	6.1	0.50 a*	30.9	7.0	15.8	4.4	17.9 b*
AI	0.99	0.12	0.23	8.3	0.44 b	22.4	2.7	9.9	8.3	11.5 d
TJ	0.81	0.13	0.36	6.2	0.43 b	27.5	3.8	13.3	7.1	14.9 c
AA-DCN	0.97	0.17	0.43	5.7	0.52 a	35.8	6.0	19.4	5.9	19.9 ab
AATX3	1.01	0.15	0.40	6.7	0.51 a	35.2	8.5	20.4	4.1	21.3 a
$LSD_{0,01}$					0.054					2.38

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

Table 4. Mean deposits and coverage rates in stage II with 150 $l.ha^{-1}$ application volume

Spraying Methods	Deposition on leaves (µg.cm^{-2})			Mean Deposit (µg.cm^{-2})	Coverage rate on leaves (%)			Mean Coverage (%)
	Top	Middle	Bottom		Top	Middle	Bottom	
DCN	0.61	0.35	0.20	0.38 c*	33.4	14.8	12.3	20.1 c
AI	0.36	0.25	0.19	0.26 d	24.8	9.7	9.4	14.6 d
TJ	0.41	0.18	0.17	0.25 d	14.4	10.9	10.1	11.8 e
AADCN	0.76	0.53	0.32	0.54 a	30.5	16.8	18.3	21.9 ab
AATX3	0.52	0.39	0.36	0.42 b	28.7	18.5	20.1	22.4 a
TBDCN	0.96	0.35	0.27	0.53 a	24.4	22.3	14.9	20.5 bc
$LSD_{0.01}$				0.031				1.35

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

Table 5. Mean deposits and coverage rates in stage II with 150 $l.ha^{-1}$ application volume

Spraying Methods	Deposition on leaves (µg.cm^{-2})			Mean , Deposit (µg.cm^{-2})	Coverage rate on leaves (%)			Mean Coverage (%)
	Top	Middle	Bottom		Top	Middle	Bottom	
DCN	0.79	0.40	0.34	0.50 b*	31.4	23.0	13.5	22.6 c*
AI	0.69	0.38	0.25	0.44 c	31.2	19.6	11.5	20.8 d
TJ	0.56	0.35	0.27	0.39 d	22.0	12.1	8.0	14.0 e
AADCN	0.90	0.62	0.46	0.65 a	39.0	25.7	18.2	27.6 a
AATX6	0.90	0.56	0.39	0.61 a	30.9	26.1	18.8	25.3 b
TBDCN	1.00	0.61	0.34	0.64 a	35.7	34.6	12.2	27.5 a
$LSD_{0.01}$				0.042				1,53

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

Table 6. The mean ground deposits in both spraying stages of plant

Spraying Methods	Ground Deposits (µg.cm^{-2})			
	Stage I		Stage II	
	150 $l.ha^{-1}$	300 $l.ha^{-1}$	150 $l.ha^{-1}$	300 $l.ha^{-1}$
DCN	0.38 c*	0.47 bc*	0.17 de*	0.21 c*
AI	0.33 cd	0.47 bc	0.19 d	0.28 b
TJ	0.31 d	0.44 c	0.15 e	0.26 b
AADCN	0.69 a	0.58 a	0.33 a	0.34 a
AA(TX3-TX6)	0.54 b	0.53 ab	0.27 b	0.33 a
TBDCN§	-	-	0.23 c	0.24 bc
$LSD_{0.01}$	0.057	0.077	0.038	0.047

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

§: not used in the first application period.

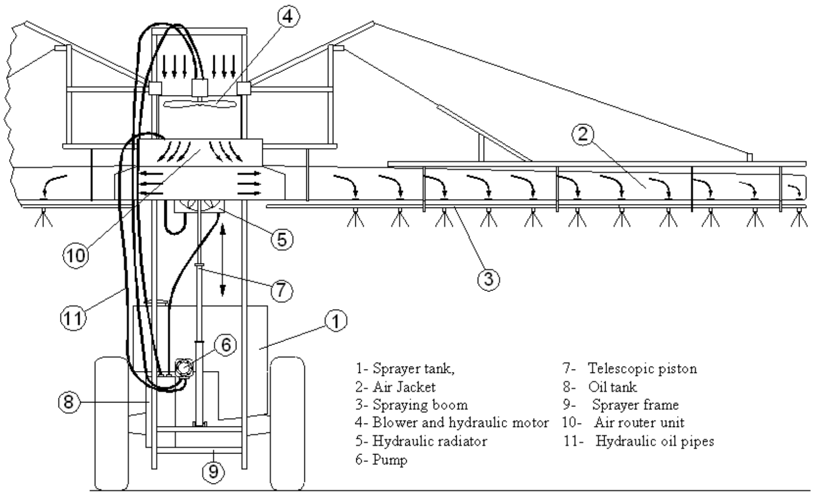

Figure. 1. Schematic view of the prototype sprayer manufactured for maize plant spraying

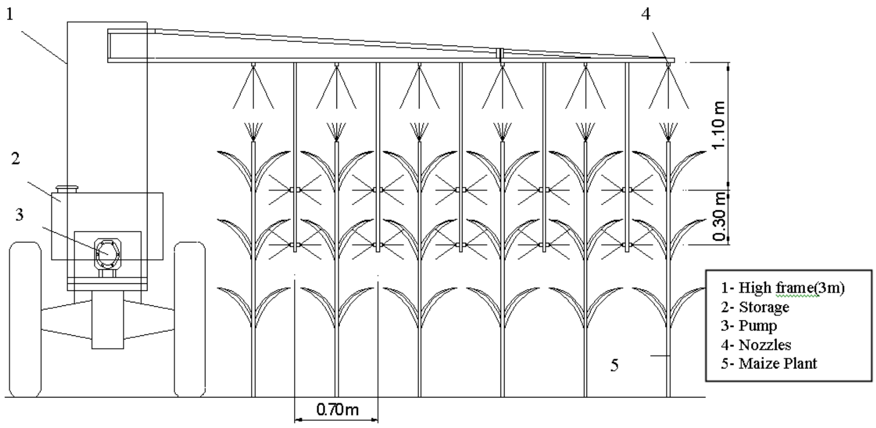

Figure. 2. Schematic view of tail booms and nozzles

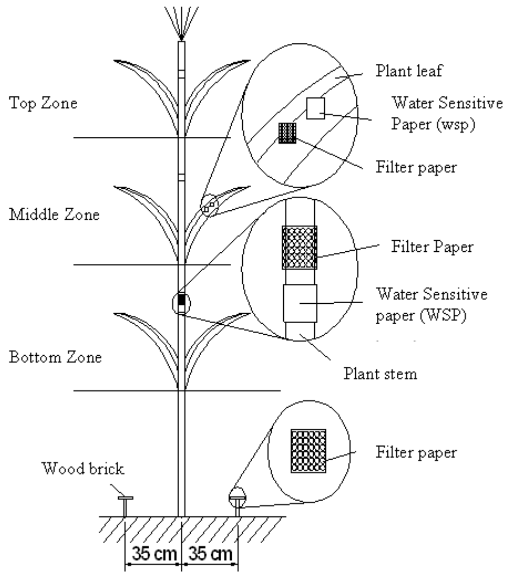

Figure. 3. Schematic view of sampling targets on plant and ground in stage II