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Research Article

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Effects of Air Direction on Spray Distribution in Some Type Injection Nozzles

Ilker H CELEN*, Necdet OZDEN, Eray ONLER

University of Namık Kemal, Agricultural Faculty, Department of Biosystem Engineering, Tekirdag Turkey
*Email: icelen@nku.edu.tr

Abstract In order to minimize the risk potential to the practitioner and the environment, a large number of researches have been done in universities, research centers, and industry to develop new methods and equipment to achieve maximum effectiveness in pesticide use, and these studies are still ongoing. These studies aimed at reducing pesticide losses caused by drift, increasing the concentration efficiency of pesticide drops at the target area, increasing the pesticide penetration into the plant canopy, increasing the amount of residue collected on the bottom of the leaf, reducing pesticide consumption by preventing pesticide spraying into non-target areas, thus reducing the cost of spraying. This has caused the invention of different types of nozzles. As these nozzles are widely used, the characteristics of them have not been studied too much. In this study, specimens from a new type of spray nozzles (Lechler IDK 120-04; Lechler IDKT 120-04; Teejet XR 110-03) that were developed to reduce pesticide drift was received to show how change occurs in horizontal spray distribution in different wind conditions. The tests were carried out on the patternator using water as a spray liquid under different wind conditions (1-2-3 m/s) and without wind. The spray distribution of all the spray nozzles in the experiment showed a change in the wind direction. The conventionally used spray nozzle (Teejet XR 110-03) has been greatly influenced by the wind compared to other nozzle types. The spray distribution has deteriorated under all wind conditions. However, there has been a resistance to the wind in spray nozzles that are effective for drift. Even though the change in wind speed increases, the uniformity of distribution is not impaired.

Keywords Spray nozzle, pesticide Drift, Wind, Patternator, Spray distribution

1. Introduction

Pesticides have a very important place in the prevention of loss of crops caused by disease, harmful plants, and weeds. However, because of the negative impact of the pesticides used in chemical weeding on human health, environment, and natural balance, and due to increased production costs, agricultural pesticides should be applied as sensitive, careful and least likely to cause pesticide loss [1]. However, factors such as the use of non-purposeful equipment in pesticide applications, the wrong calibration of the pesticide equipment and accordingly the amount of spread pesticide into the unit area more or less than necessary, the wrong pesticide selection, not making the spraying at the right time, and the ignorance of the practitioner causes the decreased pesticide application efficiency, increased pesticide cost, and environmental pollution.

Recent researches show that only a small portion of the sprayed pesticide reaches the target and that a significant part goes to waste. Herrington *et al* [2] revealed that 9-22% of the pesticide sprayed in the new foliation period in shrub trees remained on target surfaces and 22-37% of it collected on target surfaces during the final foliation period. Fox [3] reported that only 55% of the pesticide applied during the period of full vegetation settled on the canopy, 25% of it poured into the soil and 20% of it moved out of the target with air. These results show that about 50-80% of the sprayed pesticide did not reach the target surface, either been moved out of the target by drifting or reached the surface of the soil within the same area. Pesticide drift is a serious health and safety problem. Because the reduction of pesticide drift not only improves application efficiency but also reduces environmental pollution and pesticide application costs.

Recent developments aimed at improving pesticide application technologies; some changes were made in existing equipment to achieve targets such as reducing pesticide losses caused by drift, increasing the concentration efficiency of pesticide drops at the target area, increasing the pesticide penetration into plant canopy, increasing the amount of residue collected on the bottom of the leaf, reducing pesticide consumption by preventing pesticide spraying into non-target areas, thus reducing the cost of spraying.

Almost all companies in the world have introduced new nozzles types called "Low- Drift" nozzles in recent years. These nozzles produce larger diameter droplets at the same discharge and working pressures than standard type fan spray nozzles. With this type of nozzles, the number of drops less than 200 µm can be reduced by 50 to 80%, thus making the droplets less prone to drift than the standard fan spray nozzles of the same size. These nozzles usually have a pre-orifice, and as the liquid passes through this anterior orifice, the velocity reduces allowing larger droplets than the original outlet orifice. In the nozzles outside the DriftGuard and Turbo TeeJet, the air and liquid which are sucked in through a hole in the body of nozzle intermix with each other and air bubbles come out as the liquid exits the nozzle tip. The air in the drops increases the drop size to some extent, increasing the drop rate [4].

Miller *et al* [5] tested the designs of two similar fan spray nozzles with hydraulic pressure and spraying angles at 3 and 5 bar pressures. At the end of the experiment, they concluded that the average drop size of the air-suction nozzle was larger than that of the conventional fan spray nozzle.

Visacki *et al* [6] conducted a study on the rightness of the distribution of three different nozzles (ST 12004, IDK 12004, IDKT 12004) at three different heights (40cm, 50cm, 60cm) and six different pressures (200, 250, 300, 350, 400, 450 kPa) in the recommended range. In the research, electronic spray sensor recorded variation coefficient of spray nozzles. As a result of the applications, there were significant differences in the conditions provided and all nozzles had different variation coefficients. The highest variation coefficient was detected in St 120-04 while the lowest coefficient in IDK 12004 spray nozzle.

Al-Gaadi [7] reported that the type and height of the spray nozzle were effective factors in the distribution of the spray density in the agricultural area. The researcher performed applications in the patternator using spray nozzles with six different drift resistance. Measurements made at a height of 15 cm indicated that water volumes in the hills and pits decreased at a significant rate on both sides of the nozzles. It was stated that the spray nozzle distribution that was observed at a height of 30 cm formed in a wider area and curves formed smoothly. It was found that the water accumulated in the channels in the patternator was more than 45 cm in height and the gaps between the peaks and pits were less. In the study carried out at a height of 60 cm, it was observed that the maximum amount of water accumulated in the channels where the curves were smooth and a distribution curve close to the smooth appeared for the spray nozzles in the middle of all nozzles [8].

Weeds can cause up to 100% product losses if they are not controlled in agricultural production areas. Many methods are used to control weeds; most of these methods is undoubtedly the chemical struggle. The herbicides used in chemical control come out from the other plant protection methods in the plants which are planted frequently on the queue, especially with their benefits such as being able to be applied in a short time and giving results, decreasing their production costs, having a long effect time effect (output in previous applications). These benefits include herbicides; In case of drift during the application, it is one of the riskiest agricultural chemicals in terms of its effects on the environment.

In herbicidal applications, fan nozzles are preferred. The fan beam nozzles used in herbicide applications are hydraulic spray nozzles with a size of 1-4 mm orifice, which can be used at application pressures of 2- 5 bar. Dursun *et al* [9], a small portion of the pesticide used during the pulverization reached the target, a large part of the target could not reach the target.

In this study, the effects of the spray distribution in the presence of wind from different directions were investigated using samples taken from novel developed spray Fan nozzles (IDK 12004, IDK 12004, XR11003) to solve the pesticide drift problem (in parallel with movement, cross with the direction of movement, 90^{o}angle to direction of movement). Using a static spray nozzle test apparatus, air flow velocities (1-2-3 m/s) were created in different directions and spray distributions were evaluated in different pressure (2-4-6 bar) applications. All measurements were compared with applications made in a windless environment.

Materials and Methods

For this purpose, different spray nozzles (IDK 12004, IDKT 12004 (by Lechler GmbH Germany) and XR 110-03 (by Spraying Systems Inc. Wheaton, Illinois USA)) were used in the tests. They were produced in order to prevent the pesticide drift of novel type fan spray and were easily available in the Thracian region (Figure 1). All experiments were carried out on 3 each sample.

Figure 1: Spray nozzles used in tests

Pattern uniformity can be measured by static methods. Static methods typically employ a patternator table with graduated cylinders to catch and measure the spray across the boom width [10], although more technically advanced static systems [11] have been used. The cross-flow was simulated in the laboratory to study the effect of wind speed (cross-flow) on the spray distribution, because it is difficult to control the crosswind under field conditions.

It is known that pesticide applications should not be applied in conditions which are more than 10 km/h wind speed. For this reason, the wind speed was chosen as 1-2-3 m/s as lower wind speeds. It is important how the distribution is affected under these conditions, as farmers will not hesitate to spray them under these conditions.

After the distribution of each spray nozzle was analyzed on patternator [12-15]. Tests were performed under windy and windless conditions. Therefore a fan was placed at different angles (in parallel with movement, cross with the direction of movement, 90^o angle to the direction of movement) as shown in Figure 2. The tests conducted in parallel direction was carried out to reveal the difference with others. Normally too much change in tubes is not expected. The air speed can be adjusted with a button on the fan. The air velocity was measured at the midpoint of the paternator for 1 minute before the tests and the tests were started by fixing the desired speed. The spray liquid was exposed to the effect of wind. Tests were carried out at different pressures (2-4-6 bar) by taking into consideration different wind directions. All applications were made at 65 cm high [16].

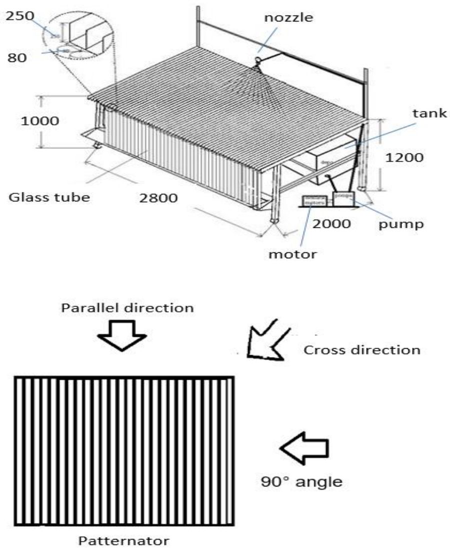

Figure 2: The airflow direction

The patternator was designed in accordance with the S386T standard and is available at NKU agricultural Faculty agricultural machinery workshop. In the experiment, water from the municipal water system was used as spray liquid. When the spray distribution of spray nozzles was determined, pulverization was performed within 60 seconds. When determining the height and pressure values used in the experiment, the recommended values by the manufacturers and its upper and lower values were taken.

The pulverization liquid that is sprayed into the ducts is filled through the ducts into the plastic tubes with scale. The amount of liquid accumulated in the plastic tubes will be read with the eye as ml.

In order to determine the spray distribution of the nozzles used in each experiment, the patternator shown in Figure 2 was used. There are 80 channels on the patternator. The ducts are made of galvanized sheet material as a precaution against corrosion. Each channel width is 3 cm and the thickness of the sheet separating the channels is 0.5 mm. The height of the channel walls is 25 cm [17].

As a pulverization liquid, water was used, and spray distribution was detected. The water is kept in a 400-liter tank. Hydraulic mixing is performed under the influence of liquid with excess pressure coming from the regulator inside the tank.

In addition, industrial type fan (250Watt, 220-240 V ~ 50Hz) was exposed to air flow (1-2-3 m/s) in 3 repetitions, studies were carried out in three different ways. Spray distribution patterns belonging to fan spray nozzles were evaluated by comparing. Analysis of variance according to the Anderson-Darling normality test for spray distribution of nozzle type (Kruskal-Wallis test) was realized after the trials.

Results and Discussion

IDK 12004 Spray Nozzle

The lowest coefficient of variation in the results obtained during the tests was read on the IDK 12004 nozzle [6]. The results are analyzed in detail below.

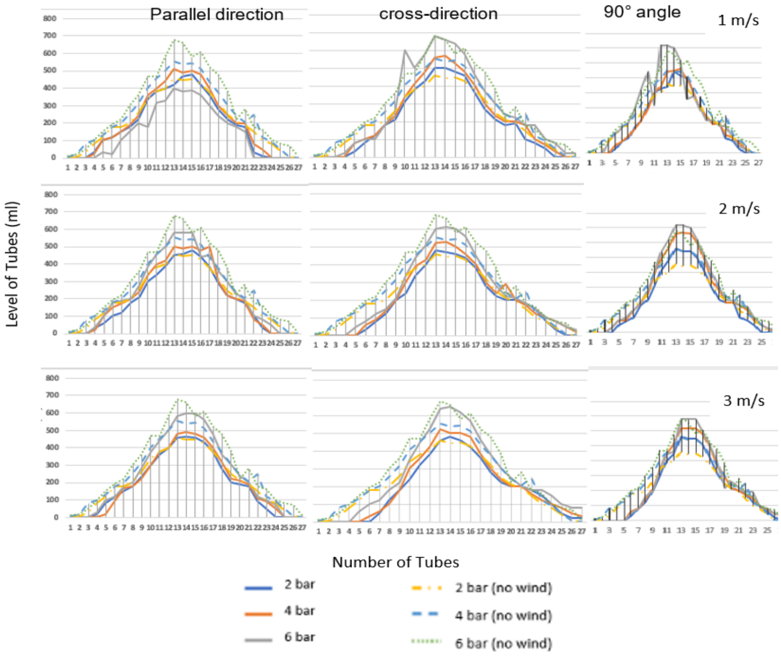

Figure 3: When IDK 12004 spray nozzle exposed to wind speeds 1-2-3 m/s in different directions, spray distribution at different pressures in the windless environment are presented

In the measurement carried out in the windless environment, under pressure of 2 bar, 450 ml of spray liquid accumulated in the tube 14 which was considered as the central tube, and the tubes in which liquid was detected were the tube 2 and tube 26. Under 4 bar pressure, the wetting width occurred between the tube 1 and 26, and the amount of liquid accumulated in the tube 14 was 540 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 in the windless environment was 660 ml and the tubes containing liquid were those between 1 and 27 (Figure 3). As the pressure increases, the amount of spray in the tubes also increased [18]. Also, the wetting area was enlarged.

In the measurements carried out in the environment where the wind speed is 1 m/s in parallel with the direction of movement; under pressure of 2 bars, 470 ml spray liquid was collected in the tube 14, which is accepted as the central tube, and the liquid was detected in tubes 4 and 23. Under 4 bar pressure, the wetting width was in tube 4 and 23, and the amount of liquid accumulated in the tube 14 was 490 ml. When the pressure is increased to 6 bar, the amount of liquid accumulated in the tube 14 was 380 ml and the liquid was found to be between tubes 5 and 21 (Figure. 3). Wind speed hardly affected liquid distribution at 2 bar pressure. However, the decrease in liquid distribution was observed at 4 and 6 bar pressures. The same results were obtained in measurements performed in environments where wind speed is 2 m/s and 3 m/s. Under 2 bar pressure, 460 ml of spray liquid was accumulated at wind speed at 2 m/s in the tube 14, which was considered as the central tube, while 465 ml of spray liquid was accumulated at wind speed at 3 m/s, and tubes 4 and 23 collected the liquid. Also, under 4 bar pressure, wetting width occurred between tubes 4 and 23, and the amount of liquid accumulated in the tube 14 was measured as 490 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in tube14 at 2 m/s wind speed was 580 ml and the liquid detected tubes were those numbered between 4 and 24 (Figure 3). As the pressure increased, the observed values increased. However, the losses in distribution due to the increase in wind speed caused lower values than those of windless measurement.

For the application performed under pressure of 2 bars with wind crossing in the direction of movement at the speed of 1 m/s, 500 ml of spray liquid was accumulated in the tube 14, and the liquid was detected in tubes 5 and 24. For the application performed under 4 bar pressure, the wetting width occurred in tubes 5 and 25, and the amount of liquid accumulated in the tube 14 was 570 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 660 ml and the tubes containing liquid were those between 4-27 (Figure 3). The observed values displayed some changes in high pressure. The change in wind speed caused the distribution to shift to the right and the values to be read to slightly higher than the left. For the application performed under the pressure of 2 bars with wind crossing with the direction of movement at the speed of 2 m/s, 570 ml of spray liquid was accumulated in the tube 14 and the liquid was detected in tubes 6 and 25. For the application performed under 4 bar pressure, the wetting width occurred in 6 and 27 tubes, and the amount of liquid accumulated in the tube 14 was 530 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 610 ml and the liquid was found in tubes between 5 and 27 (Figure 3). Increases in the values of tubes occurred with the increase in pressure. As wind speed increased, the density of the liquid in the distribution became more intense in the opposite direction of the wind. For the application performed under pressure of 2 bars at the speed of 3 m/s, 480 ml of spray liquid was accumulated in the tube 14 and the liquid was detected in tubes 6 and 25. For the application performed under 4 bar pressure, the wetting width occurred in tubes 6 and 27, and the amount of liquid accumulated in the tube 14 was 500 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 at 2 m/s wind speed was 650 ml, and the liquid was detected in the tubes 5-27. The higher the pressure, the higher the density of the liquid. The higher the intensity of the change in wind speed, the more liquid density in the distribution is concentrated in the direction of the wind. For the application performed under pressure of 2 bars and where wind speed is 1 m/s directed 90^o angle to the movement course, 540 ml spray liquid accumulated in the tube 14 and the tubes in which the liquid was detected were tube 5 and 24. For the application performed under 4 bar pressure, the wetting width occurred in 5 and 25 tubes, and the amount of liquid accumulated in the tube 14 was 550 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 700 ml and the liquid was detected in tubes between 4 and 25 (Figure 3). For the application performed under pressure of 2 bars and where wind speed is 1 m/s directed to the movement course by 90^0, 540 ml spray liquid accumulated in the tube 14 and the tubes in which the liquid was detected were tube 5 and 26. For the application performed under 4 bar pressure, the wetting width occurred in tubes 4 and 27, and the amount of liquid accumulated in the tube 14 was 670 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 720 ml and the liquid was detected in tubes between 4 and 26. As wind speed changes, the liquid distribution concentrated in the tubes in direction of the wind. For the application performed under pressure of 2 bars with wind crossing with the direction of movement at the speed of 3 m/s, spray liquid of 480 ml was accumulated in the tube 14 and the liquid was detected in tubes 6 and 25. For the application performed under 4 bar pressure, the wetting width occurred in tubes 6 and 27, and the amount of liquid accumulated in the tube 14 was 500 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 650 ml and the liquid was found in tubes between 5 and 27. As the pressure increased, the amount of liquid sprayed to the tubes increased. In the case of wind speed changes, the more the wind intensity is, the higher the density in the distribution of the tubes in the direction of the wind. In other words, the regions where the spray fluid is expected to be dense due to air flow have been displaced.

IDKT 12004 spray nozzle

In the measurements performed under pressure of 2 bars carried out in the environment where the wind speed is 1 m/s in parallel with the movement, 480 ml of spray liquid collected in the tube 14 and the tubes in which liquid was detected were tube 6 and 24. For the application performed under 4 bar pressure, the wetting width occurred in 4 and 23 tubes, and the amount of liquid accumulated in the tube 14 was 490 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 580 ml and the liquid was found in tubes between 4 and 23 (Figure 4).

With the increase in wind speed, losses in liquid distribution were observed. As the pressure rises, the losses became a little more. In the measurements performed under pressure of 2 bars carried out in the environment where the wind speed is 2 m/s in parallel with the movement, 450 ml of spray liquid collected in the tube 14, and the tubes in which liquid was detected were tube 5 and 23. For the application performed under 4 bar pressure, the wetting width occurred in 4 and 23 tubes, and the amount of liquid accumulated in the tube 14 was 480 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 560 ml, and the liquid was found in tubes between 4 and 24 (Figure 4). With the increase in wind speed, decreases in liquid distribution in tubes were observed. A 30% decrease was observed at the 4 and 6 bar pressure. In the measurements performed under pressure of 2 bars carried out in the environment where the wind speed is 3 m/s in parallel with the movement, 350 ml of spray liquid collected in the tube 14, and the tubes in which liquid was detected were tube 4 and 24. For the application performed under 4 bar pressure, the wetting width occurred in 5 and 26 tubes, and the amount of liquid accumulated in the tube 14 was 380 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 460 ml and the liquid was found in tubes between 4 and 26 (Figure 4). Due to the increase in wind speed, the values in the tubes changed. With these changes and increased pressure, the loss of liquid increased even more.

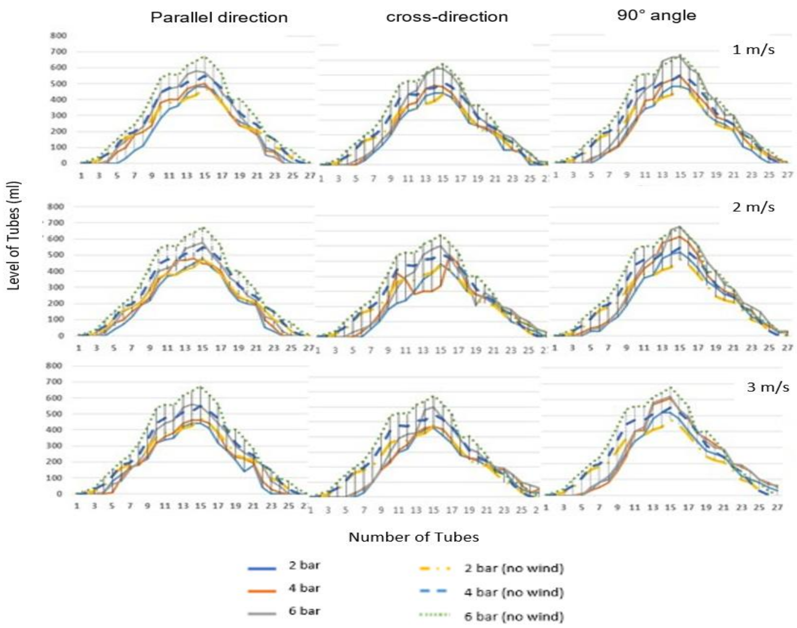

Figure 4: When IDKT 12004 spray nozzle exposed to wind speeds 1-2-3 m/s in different directions, spray distribution at different pressures in the windless environment are presented

For the application performed under pressure of 2 bars with wind crossing with the direction of movement at the speed of 1 m/s, 480 ml of spray liquid was accumulated in the tube 14, and the liquid was detected in tubes 6 and 24. For the application performed under 4 bar pressure, the wetting width occurred in 6 and 25 tubes, and the amount of liquid accumulated in the tube 14 was 530 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 640 ml and the tubes containing liquid were those between 4-27 (Figure 4). In line with the direction of the wind, the values of the tubes changed. As the pressure increased, the lost in the values of liquid distribution occurred. For the application performed under pressure of 2 bars with wind crossing with the direction of movement at the speed of 2 m/s, 420 ml of spray liquid was accumulated in the tube 14, and the liquid was detected in tubes 7 and 26. For the application performed under 4 bar pressure, the wetting width occurred in 6 and 27 tubes, and the amount of liquid accumulated in the tube 14 was 300 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 540 ml and the tubes containing liquid were those between 5-27 (Figure 4). In the measurements performed under pressure of 2 bar carried out in the environment where the wind speed is 3 m/s in parallel with the movement, 450 ml of spray liquid collected in the tube 14 and the tubes in which liquid was detected were tube 7 and 27. For the application performed under 4 bar pressure, the wetting width occurred in 6 and 27 tubes, and the amount of liquid accumulated in the tube 14 was 460 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 580 ml, and the liquid was found in tubes between 6 and 27 (Figure 4.).

For the application performed under pressure of 2 bars and where wind speed is 1 m/s directed 90^o angle to the movement course, 480 ml spray liquid accumulated in the tube 14 and the tubes in which the liquid was detected were tube 6 and 24. For the application performed under 4 bar pressure, the wetting width occurred in tube 5 and 26, and the amount of liquid accumulated in the tube 14 was 520 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 660 ml and the liquid was detected in tubes between 5 and 25. For the application performed under pressure of 2 bars and where wind speed is 2 m/s directed to the movement course by 90^o, 510 ml spray liquid accumulated in the tube 14, and the tubes in which the liquid was detected were tube 5 and 27. For the application performed under 4 bar pressure, the wetting width occurred in tube 4 and 27, and the amount of liquid accumulated in the tube 14 was 600 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 660 ml and, the liquid was detected in tubes between 5 and 27 (Figure 4.). In the measurements performed under the pressure of 2 bars carried out in the environment where the wind speed is 3 m/s in parallel with the movement, 520 ml of spray liquid collected in the tube 14 and the tubes in which liquid was detected were tube 6 and 27. For the application performed under 4 bar pressure, the wetting width occurred in 5 and 27 tubes, and the amount of liquid accumulated in the tube 14 was 490 ml. When the pressure was increased to 6 bar, at 2 m/s wind speed, the amount of liquid accumulated in the tube 14 was 600 ml and the liquid was found in tubes between 6 and 27. The values in tubes were increased along with the increase in pressure. However, a shift of the values in the tubes occurred in direction of the wind.

XR 11003 Spray Nozzle

In the measurement carried out in the windless environment, under pressure of 2 bar, 445 ml of spray liquid accumulated in the tube 14 which was considered as the central tube, and the tubes in which liquid was detected were the tube 2 and tube 26. Under 4 bar pressure, the wetting width occurred between tube 1 and 26, and the amount of liquid accumulated in the tube 14 was 540 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 in the windless environment was 660 ml and, the tubes where the liquid was detected were those between 1 and 27 (Figure 5).

In the measurements performed under pressure of 2 bars carried out in the environment where the wind speed is 1 m/s in parallel with the movement, 240 ml of spray liquid collected in the tube 14 and the tubes in which liquid was detected were tube 6 and 22. For the application performed under 4 bar pressure, the wetting width occurred in tubes 6 and 23, and the amount of liquid accumulated in the tube 14 was 250 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 290 ml and the liquid was found in tubes between 5 and 23 (Figure 5). In the measurements performed under pressure of 2 bars carried out in the environment where the wind speed is 2 m/s, 210 ml of spray liquid collected in the tube 14, and the tubes in which liquid was detected were tube 6 and 22. For the application performed under 4 bar pressure, the wetting width occurred in tubes 5 and 23, and the amount of liquid accumulated in the tube 14 was 240 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 380 ml, and the liquid was found in tubes between 4 and 24 (Figure 5).

The distribution of the spray liquid to the tubes changed with wind speed. In the measurements performed under pressure of 2 bars carried out in the environment where the wind speed is 3 m/s in parallel with the movement, 200 ml of spray liquid collected in the tube 14 and the tubes in which liquid was detected were tube 7 and 21. For the application performed under 4 bar pressure, the wetting width occurred in tubes 5 and 22, and the amount of liquid accumulated in the tube 14 was 260 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 300 ml and the liquid was found in tubes between 4 and 24 (Figure 5). Losses in liquid distribution occurred due to increased pressure and wind.

For the application performed under pressure of 2 bars with wind crossing with the direction of movement at the speed of 1 m/s, 320 ml of spray liquid was accumulated in the tube 14 and the liquid was detected in tubes 6 and 25. For the application performed under 4 bar pressure, the wetting width occurred in 6 and 27 tubes, and the amount of liquid accumulated in the tube 14 was 380 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 490 ml and the tubes containing liquid were those between 6-27 (Figure 5)., there was a density towards the right side in the values of the tubes in the liquid distribution according to the direction of the wind. For the application performed under pressure of 2 bars with wind crossing with the direction of movement at the speed of 2 m/s, 280 ml of spray liquid was accumulated in the tube 14 and the liquid was detected in tubes 7 and 27. For the application performed under 4 bar pressure, the wetting width occurred in tubes 6 and 27, and the amount of liquid accumulated in the tube 14 was 320 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 420 ml, and the tubes containing liquid were those between 6-27 (Figure 5). As a result of an increase of the pressure, the distribution of liquids in the tubes changed. However, due to the effect of the wind, the amount of liquid passing through the tubes decreased, and there was a density in the direction of the wind. In the measurements performed under pressure of 2 bars carried out in the environment where the wind speed is 3 m/s, 260 ml of spray liquid collected in the tube 14, and the tubes in which liquid was detected were tubes 7 and 27. For the application performed under 4 bar pressure, the wetting width occurred in tubes 6 and 27, and the amount of liquid accumulated in the tube 14 was 300 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 in the wind speed of 3 m/s was 400 ml, and the liquid was found in tubes between 6 and 27 (Figure 5). As the pressure increased, the amount of spray in the tubes also increased. As the wind speed increased, the amount of liquid increased in the tubes in direction of the wind, and the amount of liquid near the wind decreased.

For the application performed under pressure of 2 bars with wind crossing with the direction of movement at the speed of 1 m/s, 340 ml of spray liquid was accumulated in the tube 14, and the liquid was detected in tubes 6 and 24. For the application performed under 4 bar pressure, the wetting width occurred in tubes 6 and 27, and the amount of liquid accumulated in the tube 14 was 380 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 520 ml, and the tubes containing liquid were those between 5-25 (Figure 5). For the application performed under pressure of 2 bars with wind crossing with the direction of movement at the speed of 2 m/s, 360 ml of spray liquid was accumulated in the tube 14, and the liquid was detected in tubes 7 and 27. For the application performed under 4 bar pressure, the wetting width occurred in 5 and 25 tubes, and the amount of liquid accumulated in the tube 14 was 480 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 550 ml and the tubes containing liquid were those between 5-26 (Figure 5). In the measurements made at 3 m/s wind speed environment, 320 ml spraying liquid was collected at 14 bar and under the pressure of 2 bar, and the liquid was detected in tubes 7 and 27. For the application performed under 4 bar pressure, the wetting width occurred in tubes 5 and 26, and the amount of liquid accumulated in the tube 14 was 440 ml. When the pressure was increased to 6 bar, the amount of liquid accumulated in the tube 14 was 460 ml and the tubes containing liquid were those between 6-27 (Figure 5). As the pressure increased, the amount of spray in the tubes also increased. In addition, the wetting area was enlarged. In addition, wind speed changed the liquid distribution in the tubes.

Figure 6 is showing the change in coefficient of variance for 3 different nozzles based on 3 different pressure rates and no-wind + 3 wind direction cases. No wind case gave the lowest coefficient of variance at all 3 pressure rates. IDK nozzles showed lower variance at all 3 wind direction cases.

Figure 7 is showing the change in coefficient of variance for 3 different nozzles based on 3 different pressure rates and no-wind + 3 wind speed cases. No wind case gave the lowest coefficient of variance at all 3 pressure rates. IDK nozzles showed lower variance at all 3 wind speed cases.

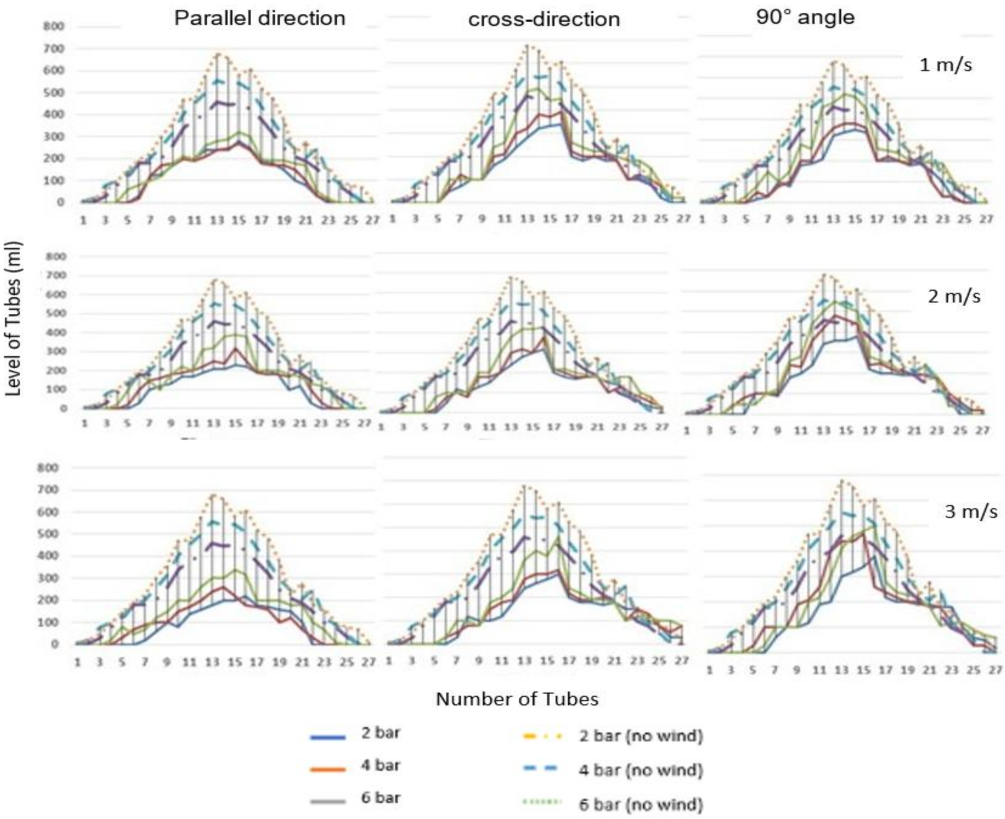

Figure 5: When XR11003 spray nozzle exposed to wind speeds 1-2-3 m/s in different directions, spray distribution at different pressures in the windless environment are presented

The data obtained from the experiments were used to determine descriptive statistics for CV values [14, 16]. The mean of CV values was 80,927, the standard deviation was 8,317, the variance was 69,171 and the median value was 75,762. CV values do not have a normal distribution according to the Anderson-Darling normality test for $p < 0.05$. For this reason, non-Parametric Kruskal-Wallis test was applied separately to spray nozzle type, pressure, wind speed and wind direction factors. Skew of the data is 0.049 and Kurtosis is 1.752.

The Kruskal-Wallis test was carried out to determine whether three different types of nozzles, pressure and wind speed have a significant effect on CV. The results showed that the nozzle type did not create a statistically significant change in the CV median value ($P > 0.05$), but it was found that the pressure of the application caused a statistically significant change in the CV value ($p < 0.05$).

The Kruskal-Wallis test was conducted to determine whether three separate wind directions caused a significant change in the CV median value. According to the results, the wind direction caused a significant change in the CV median value ($p < 0.05$) (Table 1).

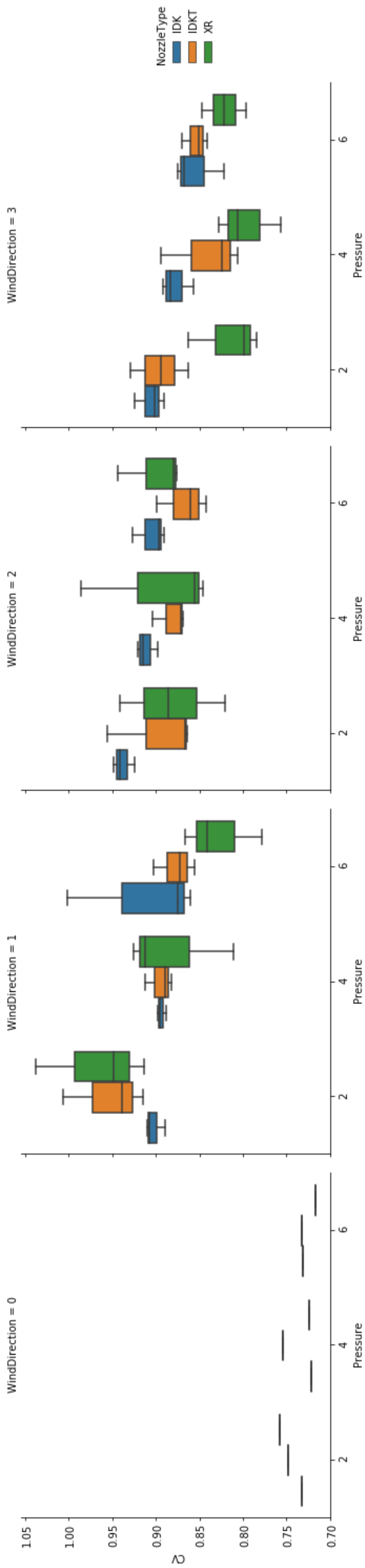

Figure 6: CV Variability for 3 Different Spraying Nozzles Based on Wind Direction and Pressure

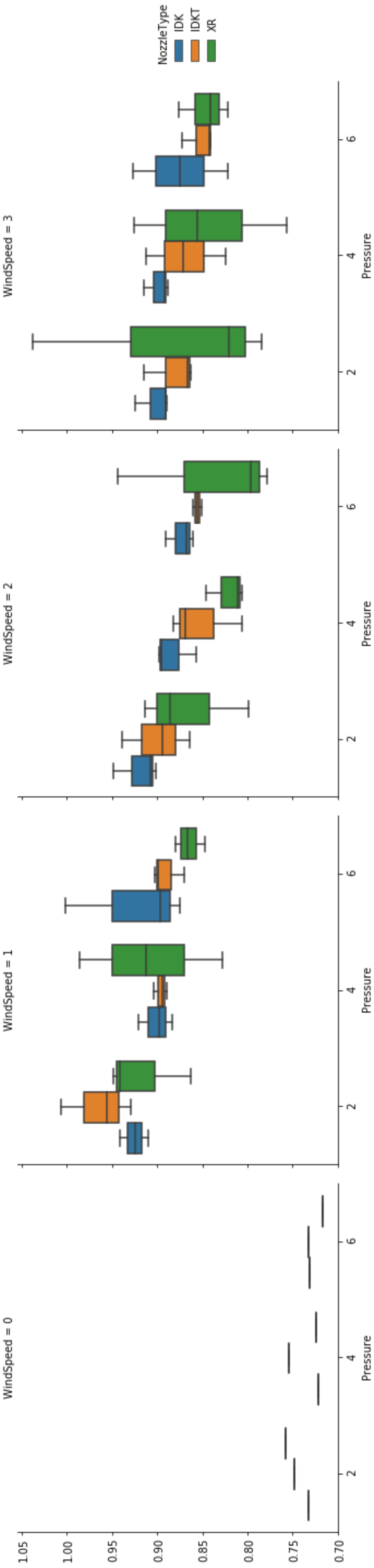

Figure 7: CV Variability for 3 Different Spraying Nozzles Based on Wind Speed and Pressure

Table 1: Spray distribution Variation Analysis (Kruskal-Wallis test) according to nozzle type, pressure, wind speed and direction

P nozzle type	**N**	**Mean**	**Ave. rank**	**Z**
IDK 12004	54	77.74	81.6	0.02
IDKT 12004	54	77.98	88.7	1.38
XR11003	54	75.76	74.2	1.41
Total	162	81.5		
H	2.59			
P	0.273			
P nozzle type	**N**	**Mean**	**Ave. rank**	**Z**
IDK 12004	54	77.10	97.7	3.11
IDKT 12004	54	77.53	77.1	0.85
XR11003	54	75.56	69.7	2.26
Total	162	81.5		
H	10.35			
P	0.006			
Wind speed	**N**	**v**	**Ave rank**	**Z**
1 m/s	27	90.22	134.6	6.44
2 m/s	27	86.77	115.0	4.07
3 m/s	27	87.25	116.0	4.19
Windless (0 m/s)	81	73.26	41.1	10.96
Total	162	81.5		
H	123.07			
P	0.000			
Wind direction	**N**	**Mean**	**Ave rank**	**Z**
Cross direction	27	85.61	107.1	3.11
parallel direction	27	89.77	129.4	5.82
90^o angle	27	73.26	129.1	10.96
Windless	81	73.26	41.1	10.96
Total	162	81.5		
H	124.09			
P	0.000			

Conclusion

Drift problems encountered in fan spray nozzles used in herbicide applications are tried to be eliminated every day. A very small amount of pesticide discarded reaches the plants. Unfortunately, the applications made without considering the spray nozzle application conditions prevent success. Farmers sometimes do not take these conditions into account because they compete over time. They continue their application with conventional nozzles. This is why they need spray nozzles to eliminate this problem. This creates environmental pollution and causes economic losses. These problems were reduced with the spray nozzles we used in the tests. Fan spray nozzles (IDK 12004; IDKT 12004), which are the subject of this article, showed that they are more resistant to wind than conventional spray nozzles (XR110 03).

We observed that the CV values obtained statistically do not have a normal distribution, that as a result of the Kruskal-Wallis test, the effects of application pressure, wind speed and wind direction on CV median values were found to be statistically significant, and that the spray nozzles did not produce a significant change in the CV median values.

Studies are being carried out continuously on the fan spray nozzles which are widely used in spraying pesticides. The spray distribution of nozzles IDK 12004; IDKT 12004; XR11003 were tested separately on the patternator, which has been newly introduced in Turkey, developed to prevent pesticide drift. At 65 cm height and different spray pressures (2-4-6 bar), spray liquid distributions were determined separately, and the results were statistically evaluated and revealed in the present study.

According to the spraying distributions results, in general, the amount of spraying liquid in the tubes at the center of the patternator was high but reduced at the edges. As the pressure increased, the wetting area was enlarged.

By maintaining the same height on the patternator, the amount of liquid in the center increased when pressures were changed. The amount of spray liquid in the tubes decreased at the edges. Depending on this, the wetting area enlarged. As a result, when the nozzles are placed on the boom, the distance between the nozzles should be taken into account by considering the cover ratio, the amount of spray liquid on the unit area varies. We think that this will be important in terms of the success of the pesticide and the reach of spraying liquid to the target surface.

When the distribution is examined, the differences between the values of the windless environment and windy environment at the rate of 1 m/s, 2 m/s, and 3 m/s are observed in IDK 12004 nozzles. These differences vary according to the direction of the wind. Depending on the speed of the wind and the direction, the decreases and increases in the values measured in the tubes observed.

The difference between the windy and windless environment was observed in the IDKT 12004 nozzle as in the IDK 12004 nozzles. Depending on the changes in wind direction, speed and changes in pressure, the losses in the values read on the tubes and the spray liquid and the shift in the distribution chart occurred.

When we look at the XR11003 nozzles, we see the big changes in the values at the different pressures in the tubes in the windless environment, when the pressure and the direction of the wind were changed in the windy environment, unlike other nozzles. When the wind is present, the recorded values are lower than the values in the windless environment. The reason for this may be related to the spray angle and the drop diameter of the nozzle. Although XR11003 spray nozzle provides a wide coverage area for weed control, it is not recommended for weed control as the distribution has a high potential for wind exposure [19].

As a result; In order to achieve the expected benefit from pesticides, it is necessary to distribute these to the target areas at the desired doses, and these operations should be done in the most economical way with minimum environmental pollution. However, from the ground and air pesticides applications; Pesticides are used in excess or often due to reasons such as drift, uneven spray distribution, inadequate surface coating, insufficient amount of pesticide collected on target surfaces, and unconscious application. In addition to the above mentioned problems, this situation does not allow an economic struggle.

Drift is often associated with the physical movement of spray droplets away from the target site during spraying. As in the scenario drawn in this article, the effect of wind that disrupts distribution uniformity is due to factors related to pesticides application methods and machines. In addition, small droplets can move very far before they settle on target surfaces. This dispersion disturbance can be minimized by operating the machine under optimum operating conditions.

Considering that we will be exposed to wind when applying pesticides, spray nozzles resistant to dispersion and drift problems should be preferred. In recent years, nozzle manufacturers have developed various types of flat fan nozzles and new conical jet nozzles. Tested nozzles called "low drift" nozzles provide a suitable drug coating. It has been observed that the new generation of spray nozzles (IDK and IDKT) designed to reduce drift are better conventional fan (XR) nozzles when compared to the three different wind speeds [20].

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