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Original article

Evaluation of Residue Distribution of Spraying Nozzles Produced for the Prevention of Spray Drift

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Abstract

The widespread use of pesticides has negative impacts on human health and the environment. This situation increases the severity day by day. Especially spray drift is one of the factors that should be controlled. In addition, pesticide costs have led to new solutions. Conventional spraying nozzles and anti-drift spraying nozzles are discussed in this study. The study carried out in viticulture areas. Pesticide residual amounts were determined by sampling surfaces placed in different parts of the plant. The sampling surfaces were placed on the top and bottom surfaces of the leaves. Pesticide residue rates were determined in different regions of the plant. The average pesticide residual amounts on the leaves with the anti-drift spray nozzles AITX 8002 VK and ITR 8002 were found to 63.5% and 49.9% higher than the conventional TX VK12 spray nozzle, respectively, also 44.2% and 32.2% higher than the other conventional spray nozzle TR 8002, respectively. The lowest value of top to bottom pesticide residue ratio for leaves was 2.22 at anti-drift ITR 8002 spray nozzle and the highest value of top to bottom pesticide residue ratio for leaves was 2.95 with the conventional spray nozzle TR 8002. All the type of spray nozzles except anti-drift AITX 8002, produced less residue in the inner parts compared to outer parts. The highest penetration rate was 90% with the AITX 8002 VK spray nozzle and the lowest penetration was 55% with the conventional TX VK12 spray nozzle type.

Keywords: Pesticide, Pesticide Drift, Residue, Spray Nozzle, Penetration, Viticulture.

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INTRODUCTION

Viticulture has spread between 20-50 degrees of latitude in northern and 20-40 degrees of latitude in the southern hemisphere (Winkler, 1974). Temperature is the most important limitation of the spreading of viticulture outside these latitudes.

It is estimated that there are over 10000 grape varieties all around the world. World fresh grape production is carried out in approximately 7.5 million hectares of land, and the production amount is around 65 million tons per year, which is varying with climatic conditions. World grape production is consumed in dry, wine, edible and different ways depending on demand. Approximately 800 thousand tons of production is dried and consumed each year, 64.3% of the production is processed in wine production and 20.9% is consumed as edible. Our country is ranked 5th in terms of production area after Spain, France, Italy, and China. (Nazli, 2007; Toy, 2014).

Turkey is one of the most important country of the world in the mean of viticulture. Viticulture is the livelihood of many farms throughout the country because of suitable climatic and growing conditions. Statistics show total viticulture area is reduced %8 in Turkey between the years 2012-2018. Turkey is an important viticulture country due to make 5% of the total world production and have 472 273 ha of vineyard area (FAO, 2018).

The use of air-assisted pulverization in viticulture is common. These spraying machines are widely used with conical and flat tips hydraulic spray nozzles. The wind drift potential of the droplets formed in these applications is very high due to the effect of the air flow used. Spray nozzle manufacturers are therefore searching for the new type of spray nozzles. The purpose of this new type of spray nozzles is to produce larger diameter droplets and consequently to reduce the proportion of drift-prone droplets (Wenneker et al., 2008). Evaluating the residue distribution of this new spray nozzles is very important to demonstrate the success of pesticide applications.

In this study, anti-drift spray nozzles AITX 8002 VK and ITR 8002, which are designed to prevent spray drift were compared with the conventional spray nozzles TX VK12 and TR 8002. in terms of residue distribution.

Material and Methods

All experiments were carried out in the Cabernet Sauvignon vineyards (K 40 58 13 D 27 28 25) of the Tekirdag Viticulture Research Institute, which was installed at 2.5 m row space and 1.5 m intrarow space according to fixed cord wire system. The height of the trunk is 60 cm and the canopy height is 160 cm.

The experiments were carried out using a Taral TA400 Piton (Taral Co.) air-assisted hydraulic sprayer mounted on the FIAT 8066 tractor. The sprayer has 400-liter tank and 16 spray nozzles. The axial fan with a diameter of 750 mm takes its movement from a gearbox connected to the pump output shaft. The fan is rotating at 1900 rpm and has an air velocity of 30 m / s. The fan blade angles can be adjusted to change the air velocity of the sprayer. The position angles of the spray nozzles can also be adjusted.

AITX 8002 VK and ITR 8002 as new nozzles (air injection, low drift), and TX VK12 ve TR 8002 as conventional nozzles were used in the tests. The working pressure of the nozzles was 10 bar and the forward speed was 6 km / h. In applications, air-speed is fixed to 20 m / s.

TX VK12 (VisiFlo® Hollow Cone Spray Tips) nozzles assure finely atomized spray droplets reach target areas. They are excellent for post-emerge contact herbicides, fungicides, and insecticides. They use with defoliants and foliar fertilizers at pressures 3 bar and above. Finely atomized spray pattern provides thorough coverage. Maximum operating pressure is 20 bar. Spray angle is 80° . The flow rate is 280 l/ha at 10 bar. It is Ceramic with VisiFlo brown color-coding (Teejet Catalog a, 2018).

TR 8002 (Hollow cone) nozzles used for directed applications in air blast spraying for orchards and vineyards and other specialty crops. They are good for greenhouse, orchards and backpack sprayer. Also they are well-suited for applications of insecticides, fungicides, defoliants and foliar fertilizers at pressures of 3 bar and above. They produce fine droplets. They have optimized narrow droplet spectrum. Fine droplets ensure high coverage. They resistant to clogging due to the round bore. Maximum operating pressure is 20 bar. Spray angle is 80° . They produce 1.45 I/min at 10 bar. It is Ceramic with ISO red color-coding (Teejet Catalog a, 2018).

ITR (Air injector hollow cone) nozzles are exceptionally low drift and resistant to clogging due to round bore. Maximum operating pressure is 30 bar. Spray angle is 80° . They produce 1.45 I/min at 10 bar. It is Ceramic with ISO green color-coding (Teejet Catalog a, 2018).

AITX (ConeJet® Air Induction Hollow Cone Spray Tip) nozzles is ideal for airblast and directed spray applications. They construct ceramic for wear resistance. Also, it is ideal for sprayers equipped with automatic control systems. Larger droplets are produced, as compared to standard TX ConeJet, through the use of a venturi air aspirator resulting in reduced drift and improved canopy penetration. Suggested spray pressure is 4–20 bar. Spray angle is 80° . They produce 1.46 I/min at 10 bar. It is Ceramic with ISO yellow color-coding (Teejet Catalog a, 2018).

TESTO 400 sensor was used to determine the air velocity and meteorological data. The bottom and top two nozzles located on the right and left ends are closed to prevent spraying out of the plant crown which causes environmental pollution. A total of 10 spray nozzles are used on both sides of the sprayer in this way.

Only the right side of the sprayer was used in the trials. Sprayer passed from both sides of the sampled vine row to meet the trial plan. The water in the tank is mixed with the food dye instead of the pesticide, which is easily soluble in water. The food dye Tartrazine has a concentration of 1 g/l. Since the spray nozzles used in the experiments have different flow rates, they were multiplied by a correction coefficient in order to eliminate the effects of differences in pesticide application volumes (Celen, 2008).

The experiments were carried out with three replications in a 100 m long vine row. Three plants were selected as sampling plants. In order to determine residual amounts, plants were divided into top, middle and bottom regions. In addition, each region was divided into inner, middle and outer regions. Filter papers were placed on the top and bottom of the leaf at the sampling points. Thus, a total of 108 filter papers were used. SchleicherSchuell MicroScience 589/3 filter paper with a diameter of 125 mm was used as a filter paper.. These papers were divided into 6 equal pieces and attached to the leaves (Figure 1.).

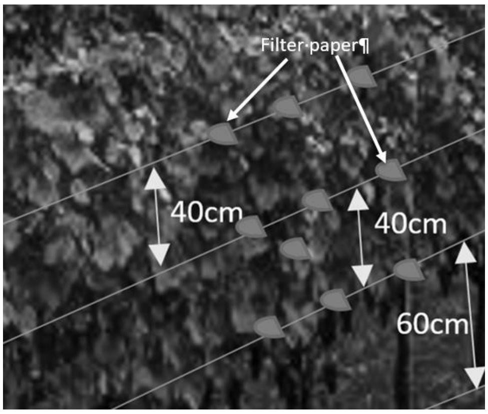

Figure 1. Locations of filter papers

Filter papers were kept in aluminium foils and kept in a cool place after spraying in all experiments. The trace substances collected on filter papers were analyzed using a spectrophotometer (Erman, 2003). A standard series of known concentrations (1-10 ppm) was prepared using tartrazine. The mean slope factor was calculated by utilizing the relationship between the absorbance values read at the spectrometer and the known concentration values (ppm) of the standard series. The filter papers were kept in petri dishes with 100 ml of pure water for 24 hours and the residue of Tartrazine was transferred to the water. The concentration and residual amounts of the dyed water were calculated by reading the absorbance values in the spectrophotometer. Coefficients of variation (CV%) were calculated for the determination of the distribution uniformity in different regions on the canopies (Derksen, 2007). When calculating penetration (%), residual quantities in the inner, middle and outer regions were taken into consideration.

Variation coefficients were calculated for the determination of the distribution uniformity of residues on the vine canopies in different regions (Derksen et al., 2007). After calculating the variance analysis of the residual quantities according to the type of spray nozzle, significant differences between the mean values were determined by LSD test. SPSS program was used for statistical analysis.

Results and Discussion

At the time of application, the leaf area (LAI) was measured as 1.71. The experiments were carried out in August 2018 and the temperature was 30 ^{0}C and the humidity was 53% and the wind speed was measured as 0.8 m / s.

The coefficient of variation, which represents the distribution uniformity of the residue collected in different regions of the canopy and the average residue amounts collected on the vine leaves, according to the type of spray nozzle are given in Table 1. It is easy to see that anti-drift spray nozzles provide more residue on vine leaves than conventional spray nozzles (Table 1). The maximum amount of residues on the vine leaves was 1.104 µg / cm^2 with anti-drift AITX 8002 VK nozzle and the lowest residual amount was 0.710 µg / cm^2 with conventional TX VK12 nozzle type. The anti-drift AITX 8002 VK and ITR 8002 spray nozzles provided higher average residues on the vine leaves than conventional nozzle types TX VK12 nozzle (56.9% and 43% higher respectively) TR 8002 (37.6% and 25.2% higher respectively). When the average amount of residue collected on the leaves was examined, the air inlet nozzles showed better spray distribution than the conventional spray nozzles (Panneton et al., 2011; Silva et al., 2013). In the outer part of the canopy, we can say that conventional cone spray nozzles provide more residues on the leaves than ITR 8002 nozzles with low drift and air intake.

As a result of the statistical analysis, it was observed that the relationship between the spray nozzle type and the average residual amount on the vine leaves was statistically significant at 1% level ($p < 0.01$). According to the results of the LSD multiple comparison tests, the difference between the average residual amount between anti-drift and conventional spray nozzles were significant, while the difference within spray nozzle groups was not statistically significant ($P > 0.05$ I think it was determined according to Duncan's multiple range test results).

When the variation coefficients obtained from the applications with conventional and anti-drift nozzles were examined, the best result in terms of distribution uniformity was obtained with conventional TR 8002 spray nozzle (21%) and the lowest with AITX 8002 VK spray nozzle ok(49%). In the application with the anti-drift ITR 8002 spray nozzle, the coefficient of variation was obtained as 35%, whereas 33% CV was obtained in the application with the TX VK12 spray nozzle. CV values between residual distributions were lower in applications with conventional spray nozzles. Conventional spray nozzles provided a smoother dispersion on the vine canopy than the anti-drift spray nozzles. Derksen et al. (2007) reported that the residual distribution CV values obtained in the application with the air-inlet spray nozzles on the apple trees were higher in the areas closer to the spray nozzles and lower in the remote areas.

Table 1. Average residue amounts and CV values of residue distributions according to spray nozzle type

Spray Nozzle Type	Average Residue Amounts ($mg/cm^{2)}$)	CV (%)
TX VK12	0.710^{b}	33
TR 8002	0.811^{b}	21
AITX 80002 VK	1.114^{a}	49
ITR 8002	1.016^{a}	35

*The difference between the averages shown in different letters in the same column is important(p<0.01).

The average residual amounts on the bottom and top surfaces of the leaves, ratios between the bottom and top surface residues and CV values depends on nozzle type were shown in Table 2. As shown in Table 2, the average residue amounts collected on the top and bottom surfaces of the leaves were higher in the anti-drift spray nozzles than in the conventional spray nozzles. The highest residual amount on the leaf was 1.494 µg / cm^2 with the anti-drift AITX 8002 VK spray nozzle and the lowest residual amount was 0.883 µg / cm^2 with conventional TX VK12 spray nozzle. AITX 8002 VK and ITR 8002 anti-drift spray nozzles were provided 63.5% and 49.9% more residues compared to the conventional TX VK12 nozzle type, respectively in the terms of the average top surface leaf residue. Also, same anti-drift spray nozzles were provided at 44.2% and 32.2% more residues compared to the conventional TR 8002 nozzle type, respectively in the terms of the average top surface leaf residue. The highest average residue amount at the bottom the leaf provided by an anti-drift AITX 8002 VK spray nozzle with 0.614 µg / cm2, while the other anti-drift spray nozzle ITR 8002 provided almost the same amount of residue. According to the results of variance analysis (ANOVA), the difference between the spray nozzle types was statistically significant at the level of $p < 0.05$ and the results of LSD test were shown in Table 2.

Table 2. The average residual amounts on the bottom and top surfaces of the leaves, ratios between the bottom and top surface residues and CV values depends on nozzle type

Spray Nozzle Type	Average Residue Amounts ($mg/cm^{2)}$)			CV (%)	
	on	**under**	**on/under**	**on**	**under**
TX VK12	0.883^{b}	0.385	2.29	63	23
TR 8002	1.001^{b}	0.339	2.95	31	36
AITX 80002 VK	1.444^{a}	0.614	2.35	59	25
ITR 8002	1.324^{a}	0.596	2.22	39	20

*The difference between the averages shown in different letters in the same column is important (p<0.05).

AITX 8002 VK and ITR 8002 spray nozzles were caused 59.4% and 54.8% more residues on the bottom surfaces of leaves, respectively compared to conventional TX VK12 spray nozzles and 81.1% and 75.8% more residues on the bottom surfaces of leaves than the other conventional spray nozzle. The average residual amounts of the anti-drift spray nozzles on the top surfaces of leaves were higher as in the case of bottom surfaces of leaves. According to the results of variance analysis, it was seen that there was no statistically significant difference between the spray nozzle types considering the amount of residues on the bottom surfaces of the vine leaves.

When the residual ratio of bottom and top surfaces residue amounts of the leaves is examined, it can be seen that the anti-drift ITR 8002 nozzle type has the lowest value (2.22). The highest ratio is obtained with TR 8002 spray nozzle type with 2.95 value. This can be expressed as the most unstable residue distribution. In both conventional and anti-drift spray nozzles, the amount of residues collected on the top surfaces of the leaves was higher than the bottom surfaces of the leaves (Manktelow and Praat, 2000).

When the CV% (coefficient of variation) on the top and bottom surfaces of the leaves are examined, the best residual uniformity (lowest CV%) is obtained at TR 8002 spray nozzle with a value of 33%. The other conventional spray nozzle TX VK12 gave the worst distribution with a coefficient of variation of 56% in terms of uniformity of residue distribution. TR 8002 gave the best result of CV% (44%) in terms of distribution uniformity at the top surfaces of the leaves. ITR 8002 anti-drift nozzle gave the best result of CV% (24%) in terms of distribution uniformity at the bottom surfaces of the leaves.

When the results of penetration in the middle part of the vine plants are examined, the amount of residues collected in the outer regions of the vine canopy is higher than the amount of residues collected in the middle region (Manktelow and Praat, 2000). The highest penetration value (90%) was observed in the application with anti-drift AITX 8002 VK spray nozzle. This ideal penetration value shows that the amount of residue collected in the outer regions of the grapevine and the amount of residue collected in the middle region of the grapevine is quite close to each other. The lowest penetration value was 55% with the conventional TX VK12 spray nozzle type. This result shows that the amount of residue collected in the middle region of the vine is about half the amount of residue collected in the outer regions. The penetration values for the anti-drift spray nozzle ITR 8002 and conventional spray nozzle TR 8002 were very close to each other and were respectively 90% and 69% (Landers et al., 2007; Jamar et al., 2010).

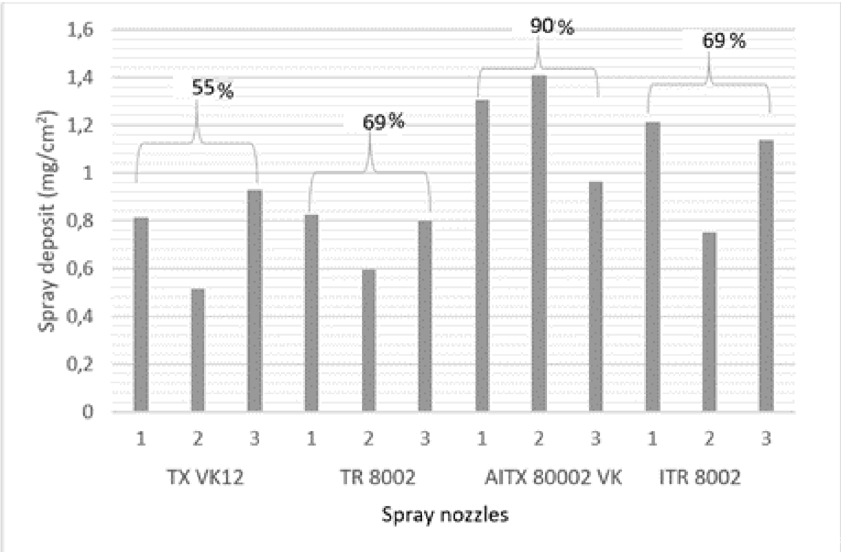

Figure 2. Residue quantities and penetration values collected in sampling zones (1,3: outer region; 2: inner region) according to spray nozzle type (%)

Conclusions

In order to achieve a successful result in the application, it is very important that the amount of the residue provided on the plant and the proper distribution of pesticide in the canopy. For effective control of diseases and pests, the amount of pesticide residues collected on the lower surfaces of the leaves should be increased and a uniform distribution of pesticides should be provided on both sides of the leaves. The results showed that the low drift spray nozzles were good to conventional spray nozzles in terms of the amount of residues collected in the plant canopy. The average residual amounts provided on the plant leaves with low-drift spray nozzles AITX 8002 VK and ITR 8002 were determined to be 44.2% and 32.2% higher than the conventional spray nozzle TR 8002, respectively. The amounts were determined to be 63.5% and 49.9% higher than the conventional spray nozzle TX VK12 respectively. In contrast, conventional spray nozzles provide smoother residual distribution on the plants compared to low drift spray nozzle types. The coefficient of variation for the residual distributions on the leaves was 59.4% and 54.8% for conventional TR 8002 and TX VK12 spray nozzles, while the low drift spray nozzles were 81.1% and 75.8% for ITR 8002 and AITX 8002 VK nozzles. When the ratio of the amount of residue on the top surface of the leaf to the amount of residue on the bottom surface of the leaf was examined, the lowest value was determined as 2.22 with a low drift spray nozzles ITR 8002. The highest value was obtained with 2.95 for TR 8002 conventional spray nozzle type. The penetration values of the grapevine with respect to the crown width of the plants changed according to the type of spray nozzle. With the exception of the AITX 8002 VK low-drift nozzle, all other types of spray nozzles produced less residue in the interior of the plants. The highest penetration rate was 90% with the AITX 8002 VK spray nozzle and the lowest penetration was 55% with the conventional TX VK12 spray nozzle type.

The new type of low-drift spray nozzles will play an important role in reducing the risk of endangering the health of living organisms and in causing the risk of pesticides that cause environmental pollution in agriculture. Air injection nozzles will be effective in viticulture applications and accordingly reduce pesticide consumption.

Additional Declaration

Research and publication ethics principles were comply with in this study. Authors contributed equally to the study.

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