

## COMPERASION STUDY ON LOW PRESSURE EMTF NOZZLES BASED ON DROPLETS SIZE CHARACTERISTICS

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### ABSTRACT

*The current study carried out in the Federal Biological Research Centre for Agriculture and Forestry (JKI) Braunschweig, Germany. The goals of this research were to measure the droplet size for the developing external mixing twin fluid nozzles (EMTF) that will target and spray the pesticide, especially biological and herbicides pesticides. As well as investigating to find the optimum combinations of the EMTF nozzles from the available nozzles that applied in the field of agriculture. Also the reduction of the water volume rate is an important aspect in the current research to reduce application costs. The tongue nozzle (Lechler FT5-608) for the air and the eight different nozzles from Lechler and Tee Jet for the liquid nozzle were selected to obtain the combinations of EMTF nozzles. Oxford lasers "VisiSizer" system PDIA was used to test and measured the droplets size from different EMTF nozzles.*

*The two levels of air pressures 150 (1.5 bar) and 200 kPa (2 bar) at liquid pressures 30 (0.3 bar) and 60 kPa (0.6 bar) and two co/angling (injection angles) 60° and 45° were tried to study their effect on droplets size, as well as to find the optimum EMTF nozzle configuration. It was found that the external mixing twin fluid could be producing the different droplet spectrum from medium to very fine droplet at low liquid pressure. The external mixing twin fluid nozzle combination N1 (TT11003+ Lechler FT 5 - 608) produce the medium spectrum compared to the N2, N2, N3, N4, N5, N6, N7 and N8 EMTF nozzles combinations. The spray characteristics droplets size  $Dv0.1$ ,  $Dv0.5$  and  $Dv0.9$  for N1 EMTF nozzle are 95.2  $\mu\text{m}$ , 226.6  $\mu\text{m}$ , and 486.3  $\mu\text{m}$  at 150 kPa (1.5 bar) air pressures; and 77.2  $\mu\text{m}$ , 171.2  $\mu\text{m}$ , and 450  $\mu\text{m}$  at 200 kPa (2 bar) air pressures respectively.*

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*On the other hand, the N5 (Lechler LU 120-015 POM +Lechler FT 5 – 608) nozzle produce the fine spectrum at the above air and liquid pressure conditions. As well as the result indicated that the external mixing twin fluid could be reducing the water volume rate. The increase of liquid pressure tends to decrease of the droplet size spectra. By changing the injection angle may able to produce the finest droplet without any increasing of the applied costs. Also it is able to use the widely available agricultural nozzles to make the external mixing twin fluid which are working at low spray pressure.*

**Key words:** Low pressure, Droplet size, Nozzles

### INTRODUCTION

The external mixing twin fluid principle is still in a theoretical stage and requires development toward practical application. The most important factor for applicable the living organisms is the nozzles size in External mixing twin fluid and the impact area of the turbo drop liquid atomizer. The challenge is to optimize the hydraulic system of the sprayer to avoid any additional shear stress to the living organisms (Sehsah, 2005 and Sehsah and Kleisinger 2007).

Hydraulic nozzles produce sprays with a range of droplet sizes and velocities (Lefebvre, 1989). These variations can affect the efficient application of agricultural sprays. The safe and efficient application of pesticides requires, among other things, the definition of an appropriate droplet size spectrum. A review of interests affecting the selection of parameters for spraying operations was given by Matthews (1979) and Hewitt (1997). The ideal spectrum will maximize spray efficiency for depositing and transferring a lethal dose to the target, while minimizing off-target losses such as spray drift and user exposure (Elliot and Wilson, 1983a). Take et al. (1996) showed that the droplet size spectrum of a spray application and the factors that affect this spectrum, are the most important variables affecting spray deposition levels downwind of the application area. Considering the importance of droplet size upon spray performance, drift minimization and the given range of nozzles available for spray application, it is logical that sprays should be classified according to droplet size. Systems have been developed by the British Crop Protection Council (BCPC) and American Society of Agricultural

Engineers (ASAE) for classifying agricultural sprays by droplet size. Sprays produced by the interaction of air and liquid are known to produce droplets with air inclusions (Rutherford et al., 1989). It has been recognized that these inclusions could cause difficulties with techniques that rely on diffraction and refraction (Tuck et al., 1997). This could limit the measurement systems that can reliably be used for these nozzle designs to those based upon imaging. The major atomizer categories have been defined according to the primary energy sources responsible for spray development (ASAE, 2003). For these devices, theory predicts and experiments confirm that mean droplet diameter size is roughly proportional to the square root of initial liquid jet diameter or sheet thickness.

Reduction of pesticides application is possible only when there is a real economic need, switching to new, more effective technologies, improving pesticides spraying equipment and technologies, changing old preparative to new ones more effective that are to be used in smaller doses. The current research study investigates the External mixing twin fluid nozzles as a suitable sprayer technology for Bio-pesticides and herbicides. The main objectives of the current research part are:

- To measure the spray spectrum from the low pressure external mixing twin fluid nozzles which may be reduce the water volume rate and application costs.
- To obtain the optimum external mixing twin fluid nozzles combinations from different available agricultural nozzles.

## **MATERIALS AND METHODS**

### **PDIA Instrumentation and Technique**

The PDIA system was used in the laboratory of the Federal Biological Research Centre for Agriculture and Forestry (JKI) Braunschweig, Germany.

Oxford lasers “VisiSizer” system provides an automated PDIA method to obtain average diameter information from a set of images of a spray. The system comprises of a pulsed light source, camera, timing and PC. The PDIA technique uses backlit-imaging arrangement, where the output from the laser is expanded through a diffuser to break up the coherence of the laser light. A CCD digital camera captures images at 30 Hz, with

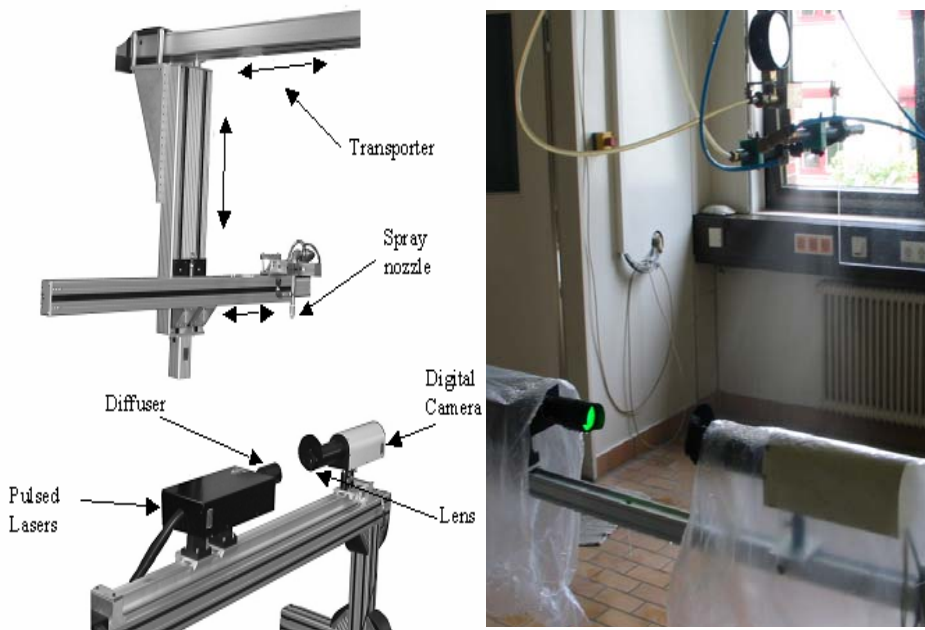
image resolution of 1008 x 1008 pixels and data rates up to 7500 droplets per second. The sized droplets are numbered and the X indicates a focus rejection. Images of droplets touching the image border have been automatically rejected along with those that occupy fewer than 10 pixels. The pulsed laser freezes the motion of the droplet (maximum allowed movement is 1.0% of the particle diameter, during the laser pulse), and provides illumination for the images. A threshold grey-level is set on the images, and the automated algorithm then effectively scans across the image pixel by pixel and based on the set threshold level, determines which pixels correspond to the background and which correspond to the droplet. In order that the droplets are accurately sized, the intensity gradient at the edge of the droplet is measured to determine the degree of focus.

### **Measuring Protocol**

Before any PDIA Leaser measurements, the flow rate of each nozzle combinations are tested at two liquid nozzles by the standard cylinder and stopwatch. For the PDIA measurements in these tests, the different combinations nozzles were selected. The combination of the EMTF nozzle were selected and illustrated in Table 1. The measured droplet spectra as the nozzle discharge was scanning through the laser sampling volume located 50 cm below the plane of the nozzle (Pearson et al., 1993). Each scan yielded data for at least 10000 droplets as recommended by Adams et al (1990). All measurements were made spraying water at a temperature of approximately 20° C. Environmental conditions were kept constant at a temperature of 20° C and a relative humidity between 70 and 80 %. To enable the whole of sprays to be sampled, the nozzle was mounted on the transporter. A different scan trajectory (fig.1) was programmed depending on the type of nozzle combinations. All measurements were carried out through the long axis of the spray could at a constant scan speed. The Y and X values were controlled at 250 mm and 800 mm respectively. In the current research, the droplets spectra are measured in different optical path lengths to scan the all trajectory for the different combinations of the EMTF nozzles as shown in figure 2.

### External Mixing Twin Fluid nozzles (EMTF)

The EMTF nozzle was developed in Hohenheim University, Germany as the part of the applicable technique for the biological material (Sehsah, 2005). Figure 3 indicate the functional diagram of an external mixing twin fluid (EMTF) nozzle and the contact angle between air jet and liquid sheet. The principle of the external mixing twin fluid nozzle is the injection of a liquid sheet into air sheet, both produced by tongue nozzles. At the merging line, the high-speed air stream will disintegrate the liquid sheet and produce droplets. With External mixing twin fluid nozzles, the liquid sheet or jet exposed to the atomizing air has little initial momentum and the droplets formed in atomization are entirely dependent on the kinetic energy of the atomizing air to transport them away from the nozzle into the target.



**Fig. 1: Layout of main components of the PDIA Oxford Lasers VisiSizer system.**

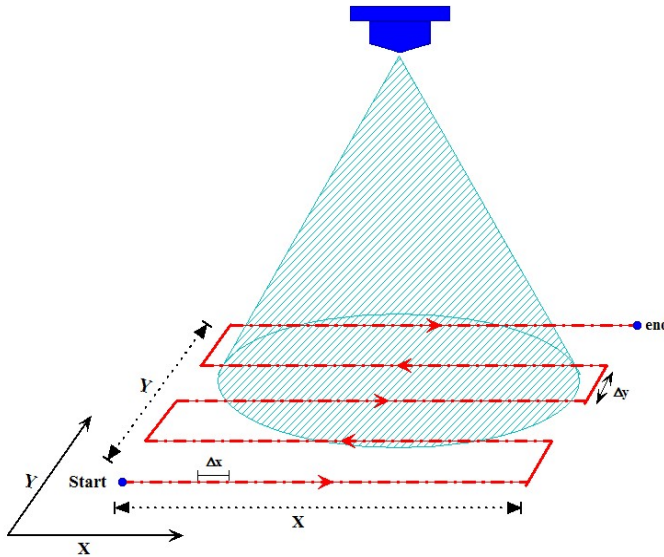
The injection angle between the liquid sheet and the air sheet can be calculated by the well known trigonometric function:

$$\tan \phi = \left[ \frac{Y''}{X''} \right]$$

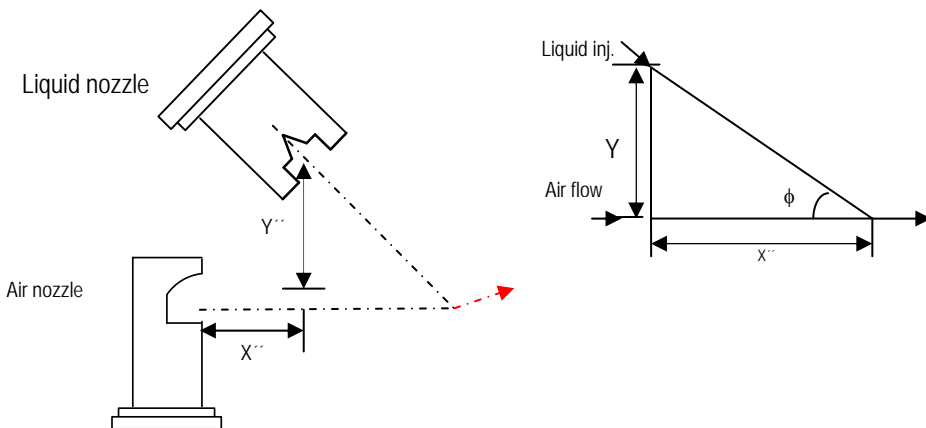
Where:

$Y''$  = the vertical distance of liquid nozzle position [mm]

$X''$  = the horizontal distance of liquid nozzle position [mm]



**Fig. 2:** Measuring of the droplets spectrum by scanning through the trajectory.



**Fig. 3:** Functional diagram of an external mixing twin fluid (EMTF) nozzle and the contact angle between air jet and liquid sheet  $\phi$  contact angle between air and liquid boundary,  $X'$  horizontal distance between the air and liquid nozzles,  $Y''$  Vertical distance of liquid nozzle position and  $X''$  Horizontal distance of liquid nozzle position

The flow rate from the different EMTF nozzles was measured and listed in table 2. The hypotheses of the data analysis were to assume that the droplets spectrum is affected by a number of factors and situations. The factors are the combination of EMTF nozzles and injection angle. These include the liquid pressure, as well as pressure of air which used to atomize the liquid spray by FT 5 nozzle of air.

### Data Interpretation

Test results conform that the main factor affecting droplets size are combinations of the external mixing twin fluid (EMTF) nozzles, air pressure liquid pressure and injection angle. A higher air pressure and liquid pressure, for different EMTF nozzles results suggest that droplets size were fine. Higher air and liquid pressure caused more shear a cross the atomizer, which can produce finer sprays, although the relative liquid to air velocity is an important consideration. By itself, Injection angle did not have a large effect on the droplets size. On the other hand, the injection angle was significant effect when it interacted with the other factors, nozzle combinations air and liquid pressure.

The JKI recommendation for classification of the droplets size spectrum was used to classify the different selected external mixing twin fluid nozzles in the current research. Droplet size classes are shown in the following tables to assist in choosing an appropriate spray tip table 3.



**Fig. 4:** Illustrates the combination of a tongue nozzle (Lechler FT5.0) for the air and a LU 110-015 for the liquid.

**Table 1.** The combinations of the external mixing twin fluid (EMTF) nozzles.

EMTF Nozzles	Nozzles	
	Air nozzles	Liquid nozzles
N 1	Lechler FT 5 - 608	Tee Jet TT11003 POM
N 2	Lechler FT 5 - 608	Lechler AD90-03 C
N 3	Lechler FT 5 - 608	Lechler AD120-03 POM
N 4	Lechler FT 5 - 608	Lechler LU90-04 POM
N 5	Lechler FT 5 - 608	Lechler LU 120-015 POM
N 6	Lechler FT 5 - 608	Lechler LU 120-03 POM
N 7	Lechler FT 5 - 608	Tee Jet XR11003 VP
N 8	Lechler FT 5 - 608	Tee Jet XR8004 VK

**Table 2.** Measuring flow-rate for different EMTF Nozzles combinations, l/min.

Nozzles of liquid	Flow-rate, l/min	
	Liquid Pressure, 30 kPa	Liquid Pressure, 60 kPa
Tee Jet TT11003	0.39	0.64
Lechler AD90-03 C	0.35	0.50
Lechler AD120-03 POM	0.40	0.56
Lechler LU 90-04 POM	0.40	0.54
Lechler LU 120-015 POM	0.20	0.31
Lechler LU 120-03 POM	0.48	0.69
Tee Jet XR11003 VP	0.43	0.54
Tee Jet XR8004 VK	0.44	0.71

**Table 3.** Classification of the droplet size by the recommendation of JKI.

Droplet Spectrum	Droplet size, $\mu\text{m}$
Very fine (VF)	< 130
Fine (F)	130-224
Medium (M)	224-283
Coarse (C)	283-435
Very coarse (VC)	> 435

JKI: Julius Kühn-Institut ; The federal research centers of the German Federal Ministry of Food, Agriculture and Consumer Protection, AT division, Braunschweig, Germany.



## **RESULTS AND DISCUSSIONS**

The statistical software package used in the analysis was JMP, version 8 (SAS Institute, Inc., Cary, N.C). The approach was the factorial analysis: the combination of the EMTF nozzles was the main factor affecting on droplets size. The two levels of air pressures 150 (1.5 bar) and 200 kPa (2 bar) at liquid pressures 30 (0.3 bar) and 60 kPa (0.6 bar) and two injection angles 60° and 45° were tried to study their effect on droplets size, as well as to find the optimal nozzle configuration. An important point to select a spray nozzle which produces a droplet size in one of the three categories is that one nozzle can produce different droplet size classifications at different pressures. A nozzle might produce medium droplets at low pressure, while producing fine droplets as pressure is increased. Table 4 indicates the classification of the references nozzles by using the JKI recommendation at low (1 bar) and high liquid (6 bar) pressures. The reference nozzles are used to define the boundaries of the six spray categories. This classification is based on the comparison of the droplet size spectrum ( $D_{v0.1}$ ,  $D_{v0.5}$  and  $D_{v0.9}$ ) produced by a nozzles at a given pressure with these reference spectra as shown in table 4.

### **Effect of the Nozzles Combinations in EMTF**

The interaction of the effect of the nozzles combinations in EMTF nozzles, injection angle air and liquid pressures on  $D_{v0.1}$ ,  $D_{v0.5}$  and  $D_{v0.9}$  illustrated in table 5, 6, 7 and 8. It is clear that the external mixing twin fluid nozzles may be producing the different droplet spectrum from medium to very fine droplet at low liquid pressure. It is observed that the combination of the external mixing twin fluid nozzles gave the highly effect on the droplet spectrum compared to the factors injection angle air and liquid pressures.

It may therefore be concluded that the droplets size are more strongly dependant on the combinations of nozzles in the EMTF nozzles, which is highly significant in data. The external mixing twin fluid nozzle N1 (TT11003+ Lechler FT 5 - 608) produce the medium spectrum compared to the other EMTF nozzles combinations at 150 kPa (1.5 bar) air pressure and low liquid pressure 30 kPa (0.3 bar). On the other hand, the N5 (Lechler LU 120-015 POM +Lechler FT 5 – 608) nozzle produce the fine spectrum at the above air and liquid pressure conditions. The N1 EMTF

nozzle droplets size  $D_{v0.1}$ ,  $D_{v0.5}$  and  $D_{v0.9}$  are 95.2  $\mu\text{m}$ , 226.6  $\mu\text{m}$ , and 486.3  $\mu\text{m}$  at 150 kPa (1.5 bar) air pressures; and 77.2  $\mu\text{m}$ , 171.2  $\mu\text{m}$ , and 450  $\mu\text{m}$  at 200 kPa (2 bar) air pressures respectively. It is also observed that both N1(TT11003+ Lechler FT 5 - 608) and N5 (Lechler LU 120-015 POM +Lechler FT 5 – 608) EMTF nozzles are worked at low flow rate 0.64 l min<sup>-1</sup> and 0.31 l min<sup>-1</sup> at 60 kPa (0.6 bar) spray or liquid pressure respectively. It's clearly that, the external mixing twin fluid able to reduce the water volume application when it's used to apply the living organisms and the other pesticides spatially the herbicides.

It was also found that the EMTF nozzles N4, N5 and N6 produce the very fine droplets size compared to the N1, N2, N3, N7 and N8 at same operating conditions. The EMTF nozzles could be gave the same droplet spectrum at low liquid pressure compared to the references nozzles or standard flat fan nozzles which should be operating at highest liquid pressure. It means also, the EMTF nozzles could be reduce the costs of the spray application, and further more reduce the water volume.

**Table 4.** The droplets size spectrum of the reference nozzles in the external mixing twin fluid nozzles.

Nozzle	droplets spectrum of reference nozzles at lower and higher pressure									
	Pressure, kPa	$D_{v0.1}$	$D_{v0.5}$	$D_{v0.9}$	Droplet Spectrum	Pressure, kPa	$D_{v0.1}$	$D_{v0.5}$	$D_{v0.9}$	Droplet Spectrum
N1	100	240.0	440.0	654.0	VC	500	126.0	256.0	453.0	M
N2	200	138.5	301.0	587.2	C	600	117.0	237.0	413.0	M
N3	150	137.5	296.9	564.7	C	600	102.7	202.7	391.6	F
N4	150	134.1	287.9	423.0	C	600	102.0	187.0	289.3	F
N5	150	113.7	223.0	311.0	F	600	105.1	169.9	243.0	F
N6	150	121.0	238.0	354.0	M	600	86.0	174.0	277.0	F
N7	150	135.0	265.0	405.0	M	600	92.0	188.0	298.0	F
N8	150	192.0	382.0	570.0	C	600	116.0	233.0	405.0	M

### Effect of spray liquid pressure

In table 6, the air pressure was none highly significant effect on the spray droplet spectra for all combinations of nozzles N1, N2, N3, N4, N5, N6, N7 and N8. In figure 5, the study of the interaction of the effect of the air

and low liquid pressure was significant effect only on the  $D_{v0.5}$  and highly effect on the  $D_{v0.9}$ . On the other hand, it was none significant effect on the  $D_{v0.1}$ . The increase of liquid pressure tends to decrease of the droplet size spectra. As well as, the statistical analysis indicated that, the interaction between the low liquid pressures with injection angle was none significant on the spray spectra. It is clearly that the liquid pressure is one importance factor affecting on the spray spectrum. The spray droplet characteristics  $D_{v0.1}$ ,  $D_{v0.5}$  and  $D_{v0.9}$  for N1 (Lechler FT 5-608 & TT110-03) nozzle were 89.1  $\mu$  m, 213.3  $\mu$  m and 539.5  $\mu$  m at 30 kPa liquid pressure respectively. As well as, the spray droplet characteristics  $D_{v0.1}$ ,  $D_{v0.5}$  and  $D_{v0.9}$  for N1 (Lechler FT 5-608 & TT110-03) nozzle were 83.3  $\mu$  m, 184.4  $\mu$  m and 397  $\mu$  m at 60 kPa liquid pressure respectively. In addition to, the spray droplet characteristics  $D_{v0.1}$ ,  $D_{v0.5}$  and  $D_{v0.9}$  for N5 (Lechler FT 5-608 & LU120-015) nozzle were 47.7  $\mu$  m, 109.7  $\mu$  m and 200.2  $\mu$  m at 30 kPa liquid pressure respectively. As well as, the spray droplet characteristics  $D_{v0.1}$ ,  $D_{v0.5}$  and  $D_{v0.9}$  for N5 (Lechler FT 5-608 & LU120-015) nozzle were 44.5  $\mu$  m, 100.9  $\mu$  m and 180.3  $\mu$  m at 60 kPa liquid pressure respectively .

**Table 5.** The interaction of the effect of the EMTF nozzle types and air pressure on the droplets size spectrum.

Nozzles	Air Pressure						Droplet Spectrum	
	150 kPa			200 kPa			150 kPa	200 kPa
	$D_{v0.1}$	$D_{v0.5}$	$D_{v0.9}$	$D_{v0.1}$	$D_{v0.5}$	$D_{v0.9}$		
N1	<b>95.2</b>	<b>226.6</b>	<b>486.3</b>	<b>77.2</b>	<b>171.2</b>	<b>450.4</b>	medium	Fine
N2	56.2	134.4	274.5	46.7	107.0	206.7	Fine	Very fine
N3	63.1	153.1	291.9	54.7	132.1	241.1	Fine	Fine
N4	55.2	124.7	251.4	48.9	108.2	202.9	Very fine	Very fine
N5	<b>49.4</b>	<b>112.5</b>	<b>196.2</b>	<b>42.8</b>	<b>98.0</b>	<b>184.3</b>	Very fine	Very fine
N6	51.5	115.1	218.0	50.8	112.3	199.5	Very fine	Very fine
N7	69.0	145.9	277.7	63.1	138.0	261.1	Fine	Fine
N8	66.4	146.3	281.6	60.8	137.1	242.1	Fine	Fine

**Table 6.** The interaction between types of EMTF nozzles and air pressure, and their effects on the droplets size spectrum.

Nozzles	Liquid Pressure						Droplet Spectrum	
	30 kPa			60 kPa			30 kPa	60 kPa
	D <sub>v0.1</sub>	D <sub>v0.5</sub>	D <sub>v0.9</sub>	D <sub>v0.1</sub>	D <sub>v0.5</sub>	D <sub>v0.9</sub>		
N1	<b>89.1</b>	<b>213.3</b>	<b>539.8</b>	<b>83.3</b>	<b>184.4</b>	<b>397.0</b>	Fine	Fine
N2	52.9	125.0	257.9	50.0	116.4	223.4	Very fine	Very fine
N3	62.1	155.1	313.4	55.7	130.1	219.7	Fine	Fine
N4	52.8	121.1	245.3	51.3	111.9	209.0	Very fine	Very fine
N5	<b>47.7</b>	<b>109.7</b>	<b>200.2</b>	<b>44.5</b>	<b>100.9</b>	<b>180.3</b>	Very fine	Very fine
N6	52.8	119.8	229.0	49.5	107.7	188.6	Very fine	Very fine
N7	68.8	153.9	308.9	63.3	130.0	229.9	Fine	Fine
N8	67.3	151.2	295.1	59.9	132.2	228.6	Fine	Fine

### Effect of Air Pressure

In table 5, the air pressure was none highly significant effect on the spray droplets size spectrum for the nozzles combinations N3, N4, N5, N6, N7 and N8. On the other hand, it gave the significant effect for the nozzles combinations N1 and N2. In figure 5, the effect of the air liquid pressure was significant effect on the D<sub>v0.5</sub> and highly effect on the D<sub>v0.9</sub>. The increasing of the air pressures tends to decrease the droplet size. As well as, the statistical analysis indicated that, the interaction between the air pressures with injection angle was significant on the spray spectra. It means that the air pressure is the important factor which effect on the droplet size in the EMTF nozzles. It is also observed that the injection angle 45° at 150 kPa (1.5 bar) air pressure gave the highest value of the spray droplet characteristics as shown in figure 6. The spray droplet characteristics D<sub>v0.1</sub>, D<sub>v0.5</sub> and D<sub>v0.9</sub> for N1 (Lechler FT 5-608 & TT110-03) nozzle were 95.2 μ m, 226.6 μ m and 486.3 μ m at 150 kPa air pressure respectively. As well as, the spray droplet characteristics D<sub>v0.1</sub>, D<sub>v0.5</sub> and D<sub>v0.9</sub> for N1 (Lechler FT 5-608 & TT110-03) nozzle were 77.2 μ m, 171.2 μ m and 206.7 μ m at 200 kPa air pressure. In addition to, the spray droplet characteristics D<sub>v0.1</sub>, D<sub>v0.5</sub> and D<sub>v0.9</sub> for N5 (Lechler FT 5-608 & LU120-015) nozzle were 49.4 μ m, 112.5 μ m and 196.2 μ m at 150 kPa air pressure respectively. As well as, the spray droplet characteristics D<sub>v0.1</sub>, D<sub>v0.5</sub> and D<sub>v0.9</sub> for N5 (Lechler FT 5-608 &

LU1120-015) nozzle were 42.8  $\mu$  m, 98  $\mu$  m and 184.3  $\mu$  m at 200 kPa air pressure respectively .

### **Effect of the Injection Angle**

In table 7, the injection angle was none significant effect on the spray droplet spectra for the N1, N3, N4, N5 and N6 nozzles combinations. On the other hand, it gave the significant effect for the N2, N7 and N8 nozzles combinations. The spray spectrum changed from fine to very fine by only change the injection angle from 45° to 60°. In figure 7, the study of the interaction of the effect of the injection angle and air pressure was significant effect only on the  $D_{v0.5}$  and highly effect on the  $D_{v0.9}$ . On the other hand, it was none significant effect on the  $D_{v0.1}$ . The increase of injection angle tends to decrease of the droplet size spectra. As well as, the statistical analysis indicated that, as above mentioned, the interaction between the low liquid pressures with injection angle was none significant on the spray characteristic  $D_{v0.1}$  and  $D_{v0.5}$ . On the other hand, it was significant effect on the  $D_{v0.9}$ . The injection angle 45° at 30 kPa (0.3 bar) spray pressure gave the highest value of the spray droplet characteristics as shown in figure 7. It was found that the 45° at 30 kPa (0.3 bar) gave a highly effect compared to the 60° injection angle. The injection angle 60° was produced the very fine droplets size spectrum at air pressure 200 kPa (2 bar) and also 60 kPa (0.6 bar). In the statistical analysis, the all interaction of the factors were highly significant effect on the  $D_{v0.9}$  and  $D_{v0.1}$  and it's were significant only on the  $D_{v0.9}$  as shown in figure 8. The coarse and fine droplets are more preferred because they have the least chance of drift from the target area. However, smaller droplets increase the efficacy while increasing the amount of drift. Large droplets also reduce effectiveness of the application coverage but not enough to risk the occurrence of drift. Also, large droplets may rebound from the plants surface or run off (Fox et al., 1994). In this case study, the droplets from EMTF nozzles may be taken the air velocity from the air nozzle. It means also, the medium, fine and very fine droplets which produced by EMTF nozzles have the least chance of drift from the target area. We will discuss this result in the second part from this research work.

**Table 7.** The interaction of the effect of the combinations of EMTF nozzles with injection angle on the droplets size spectrum.

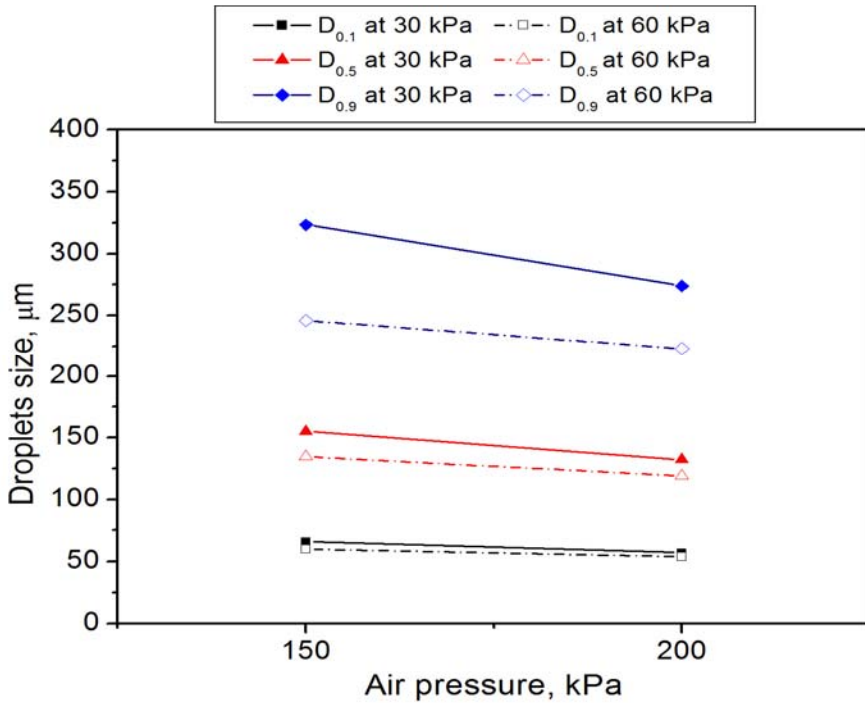
Nozzles	Injection angle						Droplet Spectrum	
	45°			60°			45°	60°
	D <sub>v0.1</sub>	D <sub>v0.5</sub>	D <sub>v0.9</sub>	D <sub>v0.1</sub>	D <sub>v0.5</sub>	D <sub>v0.9</sub>		
N1	<b>85.5</b>	<b>197.8</b>	<b>539.1</b>	<b>86.8</b>	<b>199.9</b>	<b>397.6</b>	Fine	Fine
N2	61.5	146.7	296.3	41.4	94.6	185.0	Fine	Very fine
N3	57.7	141.4	272.5	60.1	143.8	260.5	Fine	Fine
N4	52.4	114.1	212.2	51.7	118.9	242.1	Very fine	Very fine
N5	<b>46.6</b>	<b>103.7</b>	<b>184.7</b>	<b>45.6</b>	<b>106.8</b>	<b>195.8</b>	Very fine	Very fine
N6	51.2	113.9	212.1	51.1	113.5	205.5	Very fine	Very fine
N7	75.4	154.0	315.9	56.8	129.9	222.9	Fine	Very fine
N8	75.9	169.7	327.2	51.3	113.7	196.6	Fine	Very fine

### CONCLUSION

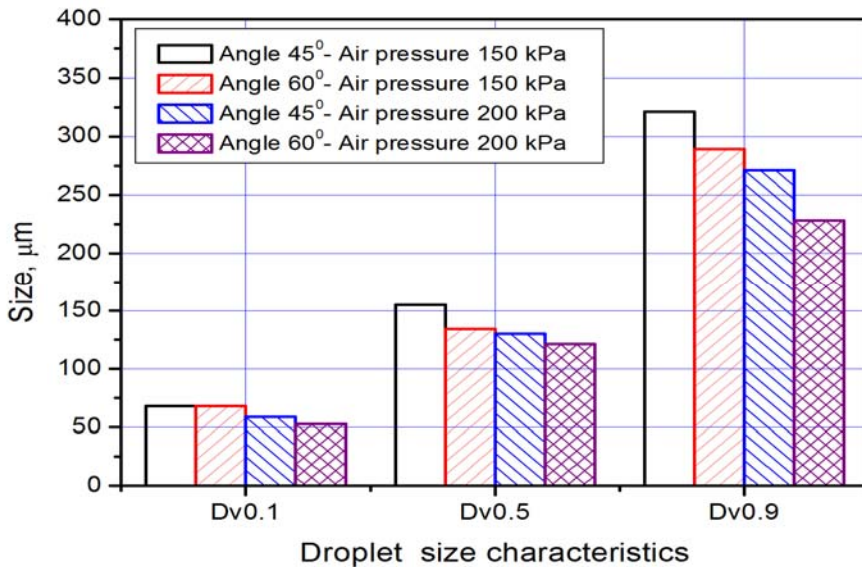
The results shown here demonstrate highly significant the combinations of nozzles on the droplets spectrum through to be important in the selection of the EMTF nozzles. From the results, the importance of the tongue nozzle FT5.0-608 type on the droplet is clear. The N1 EMTF nozzle produces the medium droplet size spectrum at lower spray pressure. For the same nozzles and spray pressure, the TT11003 produced the finest droplet size spectrum followed at air pressure 200 kPa (2 bar) and 60° injection angle. By increasing the injection angle, it may be able to produce the finest droplet without increase the energy and costs. The low pressure application is of advantage. It reduces wear, saves energy and spares the equipment. The External mixing twin fluid nozzles EMTF may be able to reduce the water volume and application costs. In the second paper, we will investigate to test the external mixing twin fluid under wind conditions. The external mixing twin fluid may be able to reduce the drift potential.

### **Acknowledgements**

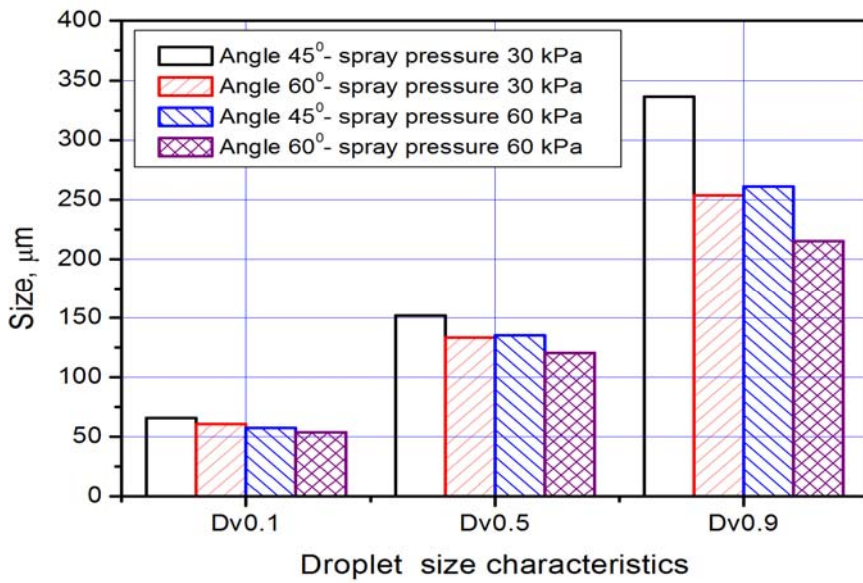
The authors would like to acknowledge the JKI, Applied Technique Division in Braunschweig, Germany and Research Unit staff for their support and use of the wind tunnel to complete this study. Special thanks are offered to Dr. Herbst, Mr. S. Nolte, and L. Oelman in JKI and Dr. R. Heinkel from Lechler Company.



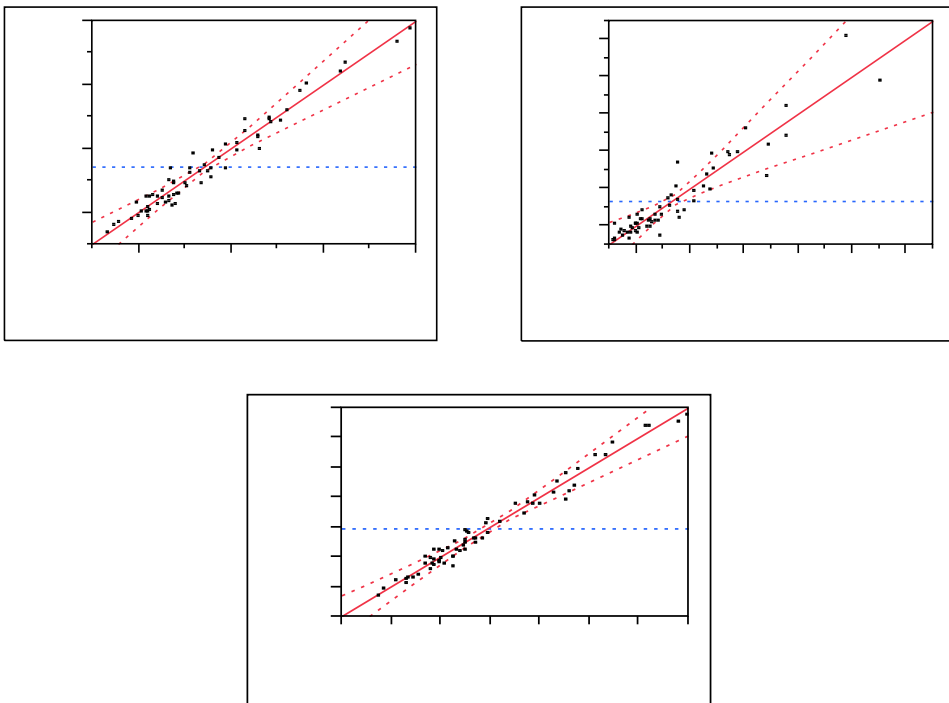
**Fig. 5:** External mixing twin fluid nozzle – effect of air pressure and liquid pressure on droplets size for the tongue nozzle FT5.0-608 (Lechler).



**Fig. 6:** Droplet size characteristics  $Dv_{0.1}$ ,  $Dv_{0.5}$  and  $Dv_{0.9}$  for different injection angles and air pressure in EMTF nozzles.



**Fig. 7:** Droplet size characteristics Dv0.1, Dv0.5 and Dv0.9 for different injection angles and spray pressure in EMTF nozzles.



**Fig. 8:** Droplet size characteristics Dv0.1, Dv0.5 and Dv0.9 for all interaction effect of factors in EMTF nozzles.



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### المخلص العربي

## دراسة مقارنة للفوانى ذات الضغط المنخفض و الخلط الخارجى لممانعين على أساس خصائص حجم القطيرات

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أجريت هذه الدراسة بمركز البحوث الفدرالى للعلوم الزراعية و الغابات معهد **JKI (Application Techniques Division)** بمدينة برون شفيج بألمانيا فى ثلاثة أجزاء. حيث تهدف هذه الدراسة فى الجزء الأول منها الى قياس حجم خصائص قطيرات السائل الناتج من الفوانى ذات الضغط المنخفض و الخلط الخارجى لممانعين **EMTF** و التى قد سبق تطويرها بجامعة هوهنهايم بألمانيا وذلك لغرض أستعمالها فى المكافحة الحيوية علاوة أيضا على إمكانية أستعمالها فى مكافحة الحشائش. كما أن من أهم أهداف البحث إضافة الى ما سبق ، البحث فى ايجاد أفضل تركيبية من الفوانى **EMTF** المطورة من الفوانى المستعملة فى رش السوائل و الموجودة بالأسواق و المستعملة فى التطبيقات الزراعية. و الفوانى ذات الضغط المنخفض و الخلط الخارجى لممانعين **EMTF** تعمل عند ضغوط منخفضة فهى بذلك مناسبة للتطبيقات المكافحة الحيوية وهى أيضا تقلل من حجم المياه المستعملة فى الرش نظرا لقلّة معامل تصرفها و كذلك الطاقة و التكاليف اللازمة لعمليات المكافحة.

و لأجراء ما سبق من دراسة تم أستعمال الفوانى **Lechler FT5.0 608** كمصدر للهواء و الذى يعمل على ترزيز سائل الرش مع ثمانية أنواع من الفوانى لسائل الرش بغرض الحصول على ثمانية تركيبات من الفوانى **EMTF** ذات الخلط الخارجى لممانعين (الهواء + السائل). و لقياس قطر قطيرات السائل الناتج من التركيبات الثمانية التى تم أختيارها ( **N8 , N7, N6, N5, N4 N3, N2, N1**) و تطويرها لتعمل عند ضغطين هما 60 ك.بسكال 100 ك.بسكال للسائل و 150 ك.بسكال ، 180 ك.بسكال لفوانى الهواء

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وبزاويتين لحقن السائل هما  $45^\circ$  ،  $60^\circ$  أستعمل نظام الليزر **Oxford Laser PDI (VisiSizer) system** و المزود بكاميرا **CDD** فائقة السرعة التي تقوم بالتقاط 15 لقطه كل ثانية أى ما يعادل 7500 قطيرة فى الثانية و أرسلها الى برنامج معالجة الصور **Imaging processing program** لتحديد و عد وقياس أحجام القطيرات و تصنيفها و تخزينها فى الحاسوب.  
أهم النتائج المتحصل عليها :

وجد من النتائج المتحصل عليها أنه يمكن الحصول على قطيرات مختلفة الحجم و الخصائص لمواصفات الرش القياسية بتغيير فوانى السائل أو زاوية حقن السائل عند أقل ضغط تشغيل له أى السائل وهو 60 ك.بسكال وهو ما يعنى أيضا خفض الطاقة اللازمة للتشغيل و بالتالى تكاليف عملية الرش علاوة على أنه يمكن أستعمال الفوانى فى المقاومة البيولوجية و التى يصعب تطبيقها فى الآلات التقليدية. الفوانى ذات التركيب **N1 (TT11003+ Lechler)** أعطى خصائص متوسطة من أحجام القطيرات مقارنة بباقى الفوانى المستعملة موضع الدراسة حيث كانت قيم  $D_{v0.1}$  ,  $D_{v0.5}$  ,  $D_{v0.9}$  هى 95.2 ميكروميتر، 226.6 ميكروميتر و 486.3 ميكروميتر عند ضغط 150 ك.بسكال على الترتيب.

بينما كانت قيم  $D_{v0.1}$  ,  $D_{v0.5}$  ,  $D_{v0.9}$  هى 77.2 ميكروميتر، 171.2 ميكروميتر و 450 ميكروميتر عند ضغط 200 ك.بسكال للهواء على الترتيب. من ناحية أخرى أعطت الفوانى **N5** ذات التركيب **(Lechler LU 120-015 POM +Lechler FT 5 – 608)** أحجام للقطيرات دقيقة جدا مقارنة بباقى الفوانى المستعملة.

أيضا وجد أنه بزيادة ضغط السائل يودى الى تقليل قطر قطيرات الرش ، كما أنه يمكن الحصول على قطيرات دقيقة بتغيير زاوية الحقن لسائل الرش فقط دون إضافة أى تكاليف من زيادة الضغط و بالتالى الطاقة اللازمة للتشغيل أو أستبدال الفوانى بأخرى مرتفعة السعر. أيضا يمكن الحصول على عدد كبير من الفوانى **EMTF** ذات الخلط الخارجى لمائعين و ذلك بالدمج بين نوعين من الفوانى أحدهما للسائل و الذى يعمل عند ضغوط منخفضة مع آخر للهواء و الذى يعتبر مصدر للطاقة اللازمة لترزيز سائل الرش.