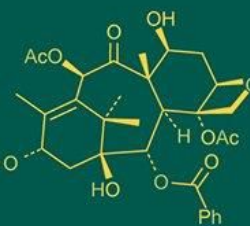
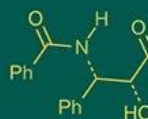
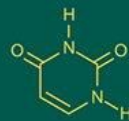
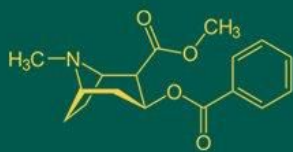


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
 ISSN Online: 2617-4707
 IJABR 2025; SP-9(4): 725-729
www.biochemjournal.com
 Received: 26-02-2025
 Accepted: 29-03-2025

Aditya Sirmour
 Assistant Professor, College of
 Agriculture and Research
 Station, Mahasamund, IGKV,
 Raipur, Chhattisgarh, India

Effect of operating parameters of hydraulic nozzle on spray droplet characteristics

Aditya Sirmour

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i4Sh.4256>

Abstract

Chemical weed management in agriculture has gained popularity due to its simplicity, efficiency, and effectiveness in weed control. Herbicides are typically applied using low-pressure agricultural sprayers in crop fields. The nozzle plays a crucial role in achieving proper spray atomization. Selecting the right nozzle is critical to ensure the development of the desired spray pattern. Droplets smaller than 150 microns present a significant risk of drift. Choosing the correct nozzle not only helps achieve the desired spray pattern but also minimizes spray drift. Optimal spray uniformity is achieved with 50 to 100% overlapping of the nozzle spacing. Standard flat fan nozzles are recommended for broadcast application, while even flat fan nozzles are ideal for band application. In testing, N1-Hollow cone (HCN/PB), N2- Flat fan (XLCC/900), N3 - Flood type (XLP/WP40), N4- Flat fan (F 110/16/3) nozzles were tested on patternator and spraytec laser droplet analyzer at three different pressures (2, 3 and 4 kg/cm²) and three different heights (250, 350 and 450 mm). It was found that the flat fan type nozzles N2 and N4 were suitable for pre-emergence application of herbicide. They have produces medium to coarse droplets depending on the working pressure, type and height. But at treatment N2H3P2, it produces droplet size of 360.99 μ m and uniformity coefficient as 6.9 which is less than N4 i.e. 7.1. A wide range of pressure and height settings would have created a distribution that would have been considered acceptable (i.e., CV < 10%) for the N2 nozzle at height H3 and pressure P2 with spray angle of 81.42° and swath width 60.57 cm.

Keywords: Nozzle, droplet size, pressure, uniformity coefficient and spray height

Introduction

The spray characteristics of agricultural spray nozzles are important criteria in the application of herbicide because of their ultimate effect on the efficiency of the herbicide application process. Droplet size and velocity affect the structure of the spray deposits and the driftability of the droplets. Hence, the ideal nozzle-pressure combination will maximise spray efficiency for depositing and transferring a lethal dose to the target, whilst minimising off-target losses. The spray characteristics influencing the efficiency of the herbicide application process are the droplet size and uniformity pattern, the volume distribution pattern, the spray structure and the structure of individual droplets (Miller & Butler Ellis, 2000) [1].

The issue of weeds and the methods used to control them has been a concern for farmers since the early days of agriculture. Over time, traditional labor-intensive methods of weed control have been replaced by more advanced techniques such as cultural, mechanical, chemical, and biological methods. Among these methods, chemical weed control has become popular due to the growing scarcity of labor and the increasing cost of manual weeding. Chemical weed control is favored for its cost-effectiveness and higher efficiency in controlling weeds (Choudhury *et al.*, 2016) [2]. Herbicides are chemicals specifically designed to kill or control unwanted plants, or weeds, in both cropping and non-cropping situations. The effectiveness of herbicides and the tolerance of crops to them depend on the sensitivity of the weed species to the herbicide and the size of the weed or crop at the time of application. To ensure successful use of herbicides, accurate and uniform application is crucial (Miller and Bellinder, 2001) [8]. In agriculture, herbicides are applied before planting, after emergence, or post-emergence, depending on the specific crop and weed situation in the field. Various methods can be used to apply herbicides, including boom sprayers, aerial sprayers, misters, blanket wipers, rope wick applicators, weed seekers, backpack sprayers,

Corresponding Author:
Aditya Sirmour
 Assistant Professor, College of
 Agriculture and Research
 Station, Mahasamund, IGKV,
 Raipur, Chhattisgarh, India

and broadcasting of granular formulations (Peltzer, 2016; Choudhury *et al.*, 2016) ^[11, 2].

The nozzle is a critical component of the spraying system as it is responsible for atomizing the liquid herbicide. Using a single nozzle lance for herbicide application can make the spraying operation complex and challenging, as it can be difficult to achieve a straight swath with proper overlapping. To achieve optimal spray efficiency, it is crucial to find the perfect combination of nozzle pressure. This combination should aim to maximize the deposition of the spray and ensure a lethal dose is delivered to the intended target. At the same time, it is important to minimize any residues and losses that may occur off-target, such as spray drift and user exposure (Smith *et al.*, 2000; Nuyttens *et al.*, 2007; Nuyttens *et al.*, 2009a) ^[16, 9, 10]. Various spray parameters, including droplet size and velocity distribution, spray pattern, entrained air characteristics, spray sheet structure, and individual droplet structure, play a significant role in determining the efficiency of the spraying system (Miller and Butler Ellis, 2000) ^[7]. Therefore, it is crucial to carefully consider all these factors and select the appropriate nozzle with the correct operational parameters for successful spraying operations.

Materials and Methods

Selection of hydraulic nozzles and spray operating pressures

Nozzle selection is the most important decision. The selected nozzle should develop desired spray pattern (Klein and Kruger, 2011; Sumner, 2012) ^[5, 17]. The proper selection of a nozzle type and size is essential for effective herbicide application. A nozzle breaks the spray liquid into droplets to form a spray pattern and simultaneously propel the droplets in proper direction. It also determines the amount of spray volume at particular operating pressure, travel speed and spacing (Grisso *et al.*, 2013; Slocombe and Sharda, 2015) ^[4, 15].

For investigation of application on herbicide, four popular and commercially available hydraulic nozzles i.e. N1-Hollow cone HCN/PB, N2- Flat fan XLCC/900, N3- Flood type XLP/WP40 and N4- Flat fan F 110/16/3 (American Spring and Pressing Works Pvt. Ltd., Mumbai, MH, India) were selected Fig.1. The specifications of selected nozzles are given in Table 1. The operating pressure required for spraying of herbicide by standard nozzle ranged from 100 to 400 kPa (Matthews, Bateman, and Miller 2014; Grisso, *et al.* 2019). ^[6, 3]

Measurement of uniformity of spray transverse distribution

The uniformity of transverse distribution of the spray is calculated by coefficient of variation (CV). The lower value of the CV represents better uniformity of spray in transverse direction for a particular nozzle. The spray distribution pattern was measured for four different types of nozzles at different operating pressures and heights using the standard spray patternator (Sirmour *et al.* 2019) ^[13]. The nozzle was mounted at a height between 250 mm to 450 mm so that the sprayed liquid could be projected towards the patternator. The variation in collected spray liquid at each individual channel on the spray patternator was expressed by the coefficient of variation (CV) (Sirmour *et al.* 2019) ^[14]. The same procedure was repeated to determine the coefficients of variation of spray distribution of selected hydraulic

nozzles at different operating pressures.

The different dependent and independent parameters studied in the patternator test of all the four nozzles are presented in Table 1 and the treatments on uniformity of spray pattern are presented in Table 2.

Table 1: Experimental plan for patternator testing of the nozzles

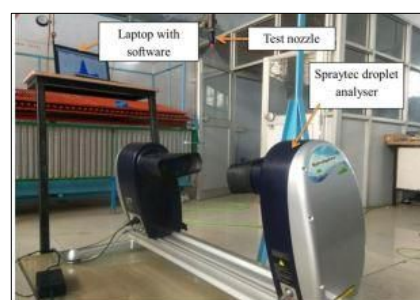
Independent Parameters	Levels	Dependent Parameters
Nozzle Type	(N1) Hollow cone (HCN/PB) (N2) Flat fan (XLCC/900) (N3) Flood type (XLP/WP40) (N4) Flat fan (F 110/16/3)	Discharge rate, ml/min Swath width, mm Spray angle, degrees Uniformity of distribution
Fluid pressure	(P1) 2 kg/cm ² (P2) 3 kg/cm ² (P3) 4 kg/cm ²	
Nozzle height	(H1) 250 mm (H2) 350 mm (H3) 450 mm	

Table 2: Treatments on uniformity of spray pattern

Nozzle type	Pressure (kg/cm ²)	Height of nozzle		
		H1	H2	H3
N1-Hollow cone (HCN/PB)	P1	N1P1H1	N1P1H2	N1P1H3
	P2	N1P2H1	N1P2H2	N1P2H3
	P3	N1P3H1	N2P3H2	N1P3H3
N2- Flat fan (XLCC/900)	P1	N2P1H1	N2P1H2	N2P1H3
	P2	N2P2H1	N2P2H2	N2P2H3
	P3	N2P3H1	N3P3H2	N2P3H3
N3- Flood type (XLP/WP40)	P1	N3P1H1	N3P1H2	N3P1H3
	P2	N3P2H1	N3P2H2	N3P2H3
	P3	N3P3H1	N4P3H2	N3P3H3
N4- Flat fan (F 110/16/3)	P1	N4P1H1	N4P1H2	N4P1H3
	P2	N4P2H1	N4P2H2	N4P2H3
	P3	N4P3H1	N4P3H2	N4P3H3

Spray Particle Size Measurements

A variety of different particle sizing techniques have been used for the characterization of agrochemical sprays in the past. These vary from those based on intrusive collection methods, to imaging techniques and those using laser light scattering or absorption. Of those available, laser diffraction provides a flexible and rapid method for the assessment of the delivered particle size. The Malvern Particle Analyzer, which is considered a spatial sampling device, utilizes the fact that a spray drop will cause laser light to scatter through an angle dependent on the diameter of the drop (Sirmour *et al.* 2019) ^[13]. The laser diffraction technique was used to measure VMD of the liquid solutions using particle laser analysis system (Sehsah and Kleisinger 2009) ^[12]. The set-up of system laser diffraction (Spraytec, Malvern P Analytical Ltd., Malvern, United Kingdom; Range =0.1-2000 µm, Precision/Repeatability= > ±1%) is shown in Figure 1.



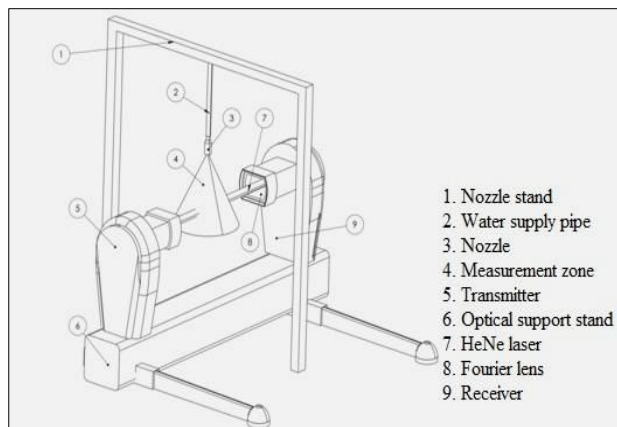


Fig 1: Spraytec instrument laser droplet size analysis

Results and Discussion

Effect of spray parameters

The performance parameters *viz.* discharge rate, droplet size, spray uniformity, droplet density and coefficient of variation in volumetric distribution were determined and analysed at different levels of the operating parameters. A series of laboratory measurements were conducted to examine the spray uniformity distribution Figure 2. In total, 36 combinations of nozzle type, height and pressure were tested corresponding with 108 measurements for N1-Hollow cone (HCN/PB), N2- Flat fan (XLCC/900), N3- Flood type (XLP/WP40), N4- Flat fan (F 110/16/3). It was observed that treatment N2H3 gave the better uniformity distribution as 7.16% compared to other interaction of nozzle and height followed by N4H1 as 7.32%, N1H1 8.18%, N1H2 8.57% and N4H3 9.54%. The coefficient of variation is tolerated up to 11% or over this limit uniformity of distribution is declared as insufficient. The value of coefficient of variation of N3 at all respective height of H1, H2 and H3 were found greater than 11% CV.

Effect of nozzle type, pressure and height on spray angle and swath width

Spray angle is dependent on type of nozzle, height and operating pressure. A series of laboratory measurements were conducted to examine the spray angle and swath width. In total, 36 combinations of nozzle type, height and pressure were tested corresponding with 108 measurements for N1-Hollow cone (HCN/PB), N2- Flat fan (F 110/16/3), N3 - Flood type (XLP/WP40), N4- Flat fan (XLCC/900). As pressure increases, spray angle and swath width also increases. It was found that as the nozzle height was increased from 250 mm, 350 mm & 450 mm, the maximum spray angle for nozzle N1, N2, N3 and N4 increased from 78.66° to 73.11°; 84.19° to 75.79°; 126.37° to 106.31°; 90.23° to 85.07°, respectively. This decrement is due to gradual increase in height of nozzle shown in Figure 2.

Effect of operating pressure on discharge rate of nozzles

Discharge rate of each selected nozzle for research was measured by collecting the liquid in glass tube in one minute at operating pressure of 2 kg/cm², 3 kg/cm² and 4 kg/cm². The effect of operating pressure on discharge rate of nozzles was presented in Figure 3.

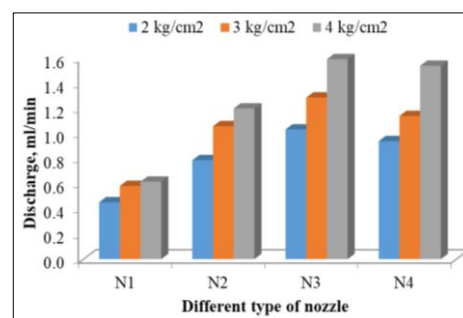
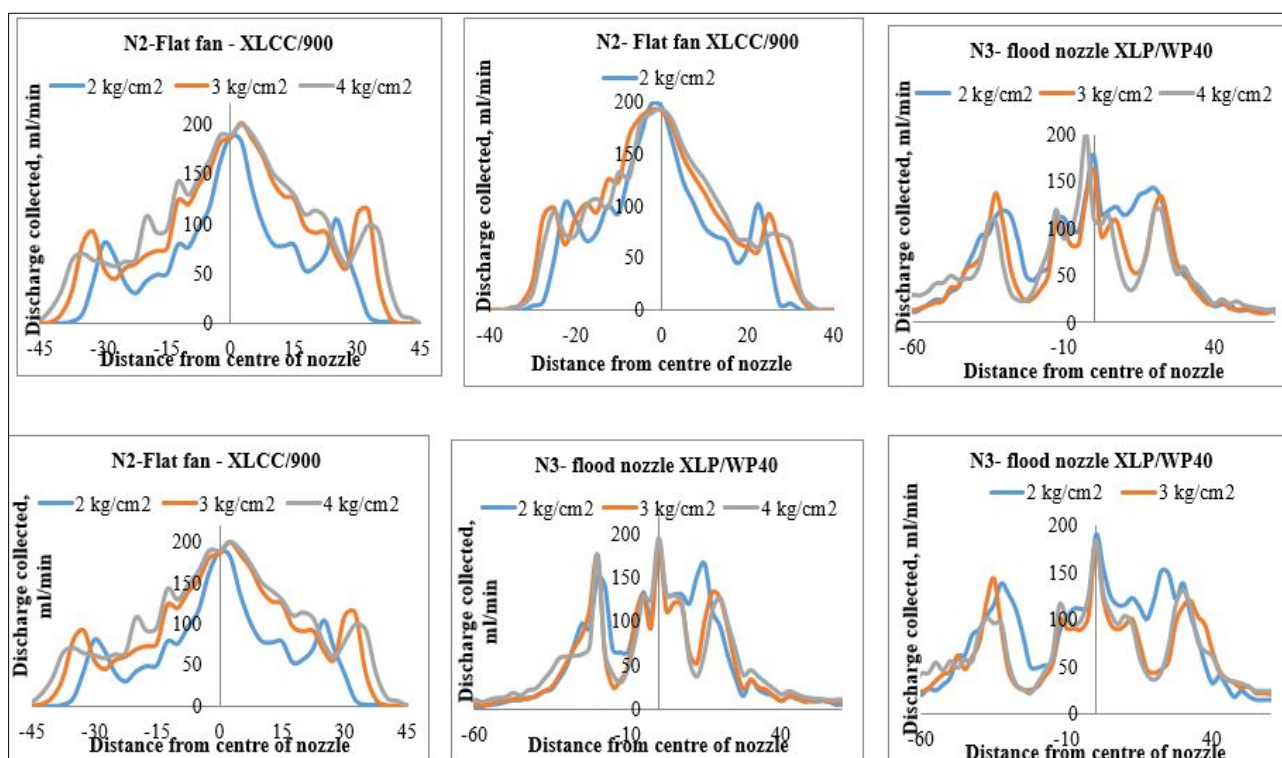


Fig 3: Discharge of different type of nozzle with different operating pressure



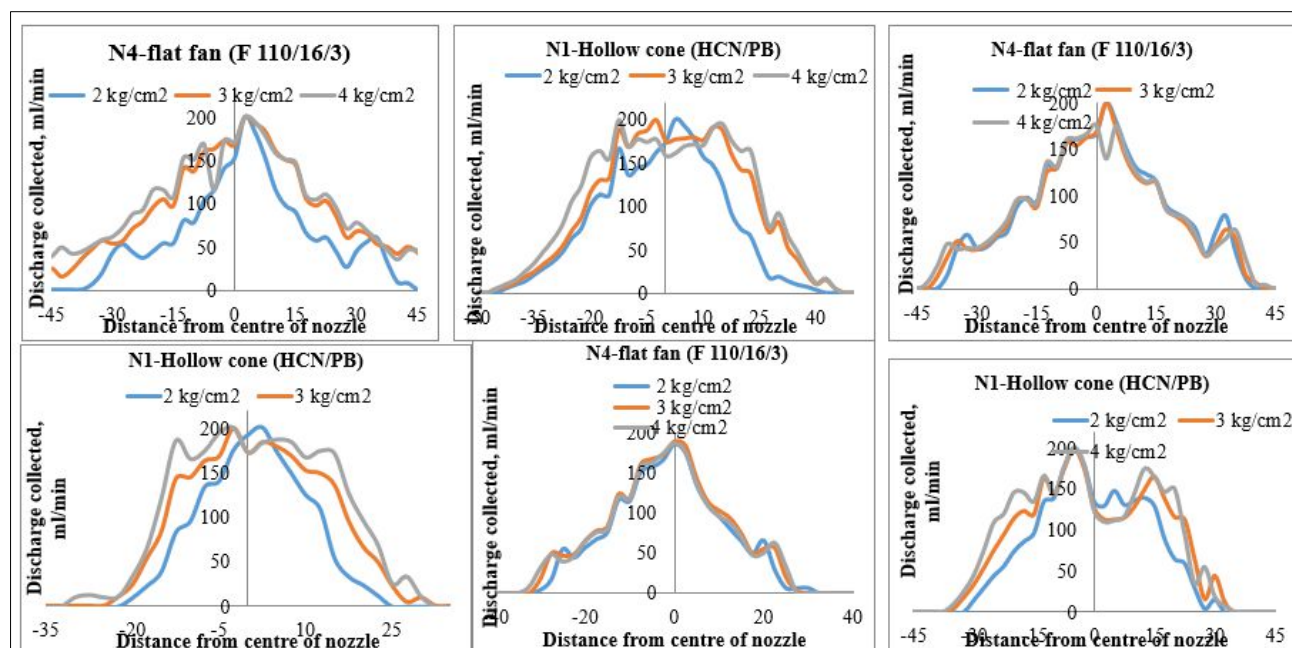


Fig 2: Spray Distribution curve of nozzles at different operating parameters

Volume based droplets size distribution by laser dropler technique

The volume median diameter (Dv_{50}) of droplets produced by spray of different type nozzle from three different heights were recorded larger ($218.71\mu\text{m}$) by N3 with height H1 were as smaller ($138.65\mu\text{m}$) in case of hollow cone nozzle, N1 with height of H2. The value of Dv_{10} was recorded higher ($94.05\mu\text{m}$) by nozzle N3 (flood type) with height H1 and lower ($64.77\mu\text{m}$) by nozzle, N1 at height of H2. The value of Dv_{90} was recorded higher ($1095.80\mu\text{m}$) by N1 at height of H1 and lower ($424.47\mu\text{m}$) by nozzle N3 at height H1. The treatment which shows greater value of Dv_{10} has smaller value of Dv_{90} . From the result it was seen that VMD of all the nozzles may be decreased with increase in height of the nozzle.

Conclusion

In laboratory testing, N1-Hollow cone (HCN/PB), N2- Flat fan (XLCC/900), N3 - Flood type (XLP/WP40), N4- Flat fan (F 110/16/3) nozzles were tested on patternator and spraytec laser droplet analyzer at three different pressures (2, 3 and 4 kg/cm^2) and three different heights (250, 350 and 450 mm). The most uniform volumetric distribution obtained from N1 at 4 kg/cm^2 and 450 mm nozzle height on the patternator. The C.V of distribution was 6.13%. The volumetric distribution obtained from N2 at 3 kg/cm^2 and 450 mm height on the patternator was 9.23%. The most uniform volumetric distribution obtained from N3 at 2 kg/cm^2 with nozzle height 350 mm on the patternator test. The C.V of distribution was 5.70%. The most uniform distribution obtained from N4 at 4 kg/cm^2 with nozzle height 450 mm on the patternator test. The C.V of distribution was 7.87%. It was observed that as the nozzle height was increased from 250 mm, 350 mm and 450 mm, the maximum spray angle for nozzle N1, N2, N3 and N4 increased from 78.66° to 73.11° ; 84.19° to 75.79° ; 126.37° to 106.31° ; 90.23° to 85.07° , respectively. This decrement was due to gradual increase in height of nozzle. With the increase in nozzle height from 250 mm to 450 mm, the maximum swath width for nozzle N1, N2, N3 and N4

increased from 41.25 to 79.88 cm; 45.39 to 70.17 cm; 99.02 to 120.19 cm; 50.40 to 83.43 cm, respectively

References

- ASABE. Spray nozzle classification by droplet spectra. Trans ASABE. 2009;1:1-6.
- Choudhury PP, Singh R, Ghosh D, Sharma AR. Herbicide use in Indian agriculture. Jabalpur (India): ICAR - Directorate of Weed Research; 2016. Technical bulletin. p. 110.
- Grisso RD, Askew S, McCall DS. Nozzles: selection and sizing. Virginia State University Publication 442(32). 2019. [Accessed 2021 Mar 26].
- Grisso RB, Hipkins P, Askew SD, Hipkins L, McCall D. Nozzles: selection and sizing. Virginia Cooperative Extension Publication 442-032. Virginia Polytechnic Institute and State University; 2013.
- Klein RN, Kruger GR. Nozzles - selection and sizing. University of Nebraska Lincoln Extension (EC141); 2011.
- Matthews GA, Bateman R, Miller P. Pesticide application methods. 4th ed. Chichester (UK): John Wiley and Sons Ltd.; 2014. p. 517.
- Miller PCH, Butler Ellis MC. Effects of formulation on spray nozzle performance for applications from ground-based boom sprayers. Crop Prot. 2000;19:609-615.
- Miller A, Bellinder R. Herbicide application using knapsack sprayer. New Delhi: Rice-Wheat Consortium for the Indo-Gangetic Plains, NASC complex; 2001. p. 12.
- Nuytens D. Drift from field crop sprayers: the influence of spray application technology determined using indirect and direct drift assessment means [Ph.D. thesis]. Leuven (Belgium): KU Leuven; 2007.
- Nuytens D, De Schampheleire M, Verboven P, Brusselman E, Dekeyser D. Droplet size and velocity characteristics of agricultural sprays. Trans ASABE. 2009;52(5):1471-1480.
- Peltzer S. Herbicide application. Western Australia: Department of Agriculture and Food, Government of Western Australia; 2016.

12. Sehsah EME, Kleisinger S. Study of some parameters affecting spray distribution uniformity pattern. *Misr J Agric Eng.* 2009;26(1):69-93.
13. Sirmour A, Verma A. Droplet size characterization of agricultural sprays using laser diffraction. *Int J Chem Stud.* 2019;7(6):2895-2899.
14. Sirmour A, Verma A. Mechanised spraying systems for herbicide application. *Int J Chem Stud.* 2019;7(6):1109-1113.
15. Slocombe JW, Sharda A. Agricultural spray nozzles: selection and sizing. *Application Technology Series (MF3178).* Kansas State University; 2015.
16. Smith DB, Askew SD, Morris WH, Boyette M. Droplet size and leaf morphology effects on pesticide spray deposition. *Trans ASAE.* 2000;43(2):255-259.
17. Sumner PE. Sprayer nozzle selection. *Cooperative Extension Bulletin 1158.* The University of Georgia; 2012.