Technical Efficiency of Spraying

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The need to satisfy the growing demand for food products as well as a falling share of workforce engaged in the agricultural sector have placed a number of challenges which can be met only through the introduction of sustainable intensive technologies for crop production. These technologies, in turn, stipulate the necessity for regular control of weeds, pests and diseases in crops. The share of expenses for chemical plant protection in the total costs of production is increasing rapidly, however, because of pests, diseases and weeds, the global agriculture continues to suffer losses amounting to more than one-third of planned crop yields. The application of pesticides has serious negative consequences because of the poisonous effects of chemicals not only to the harmful target organisms, but also to the environment where they are applied or incidentally travel to.

The requirements to spray nozzles for pesticides have always been, and still are, very strict. Indeed, it is **the nozzle that predetermines the efficacy of spraying operations, the economic, operational and ecological parameters in the sprayer, as well as the level of adverse effects of pesticides on the environment.**

It is generally known that as much as 98 per cent of insecticides and fungicides and 60-95 per cent of herbicides do not reach the harmful target organisms, but merely contaminate the environment. In the book "Spraying…" (2004), the contributing authors, the experts from the Russian Academy of Agricultural Sciences and the All-Russian Research Institute of Plant Protection (GNU VIZR), have formulated a disappointing conclusion: "Pesticide chemistry has advanced far into the 21st century, but the agricultural technologies by which these pesticides are currently sprayed, got stuck in the 19th century."

Application of spraying for chemical protection of plants in agriculture began more than 130 years ago. In 1884, Victor Vermorel, a French viniculturist, developed the world's first sprayer and equipped it with the nozzle, which had been invented by Charles Riley, an American entomologist. In the following years, working together, the authors continued to improve their sprayer. Since then, an infinite number of alternative spray nozzle designs have been devised and the process of development of further improvements into spray nozzles is still under way nowadays. For instance, Spraying Systems Co., a US company, the manufacturer of the spray nozzles under the TeeJet brand name, offers the assortment of more than a thousand of spray nozzles for pesticides! Why should they have this huge range of products? As a matter of fact, **the technological spraying efficiency is attested by the principal, and the only one, parameter, i.e., the amount of droplets of the working fluid retained on the unit area of the target plant surface, which is measured in droplets per cm^2.**

The Table given below summarizes information from the Nozal Company (France) on the minimal quantities of retained droplets, which are to be attained for different types of pesticides.

Important! It is particularly the quantity of retained droplets and exactly the droplets of the working fluid that matter. No other droplets, either a splashed one, bounced off the target surface or slipped off onto the ground, even though it could have left a wet trace on the target surface, should be taken into account. Those droplets, which do not contain pesticide, should not be taken into account either, because they are just the drops of water. At first sight, all that looks quite simple. All other spraying parameters are derivative values of the droplet retention efficiency rate. The significance of these parameters and their effects to droplet deposition onto a target surface will be discussed in the forthcoming articles.

Table

Applications and chemical properties	Droplets per cm^2
Systemic insecticide	**20 – 30**
Contact insecticide	**30 – 40**
Systemic fungicide	**30 – 40**
Contact fungicide	**50 – 70**
Pre-emergence herbicides	**20 – 30**
Systemic herbicide of vegetation development	**30 – 40**
Contact herbicide	**50 – 70**

Another very important and indisputable regularity in spraying is that **the smaller the droplet, the more efficient it is.** Therefore, in theoretical terms, it is necessary to perform spraying with the immediate pesticide molecules obtained in disintegration. Regretfully, the disintegration of fluids into molecules is a rather energy-consuming process. For example, water disintegrates into molecules at a critical temperature of 374 °C and a pressure of 2 MPa. But even with the disintegrated fluid, the efficient deposition of the molecules remains a challenging task.

It is generally known that reduction of the droplet size in half in a certain volume of fluid results in multiplication by the factor of eight in the number of droplets in the same volume (Figure 1).

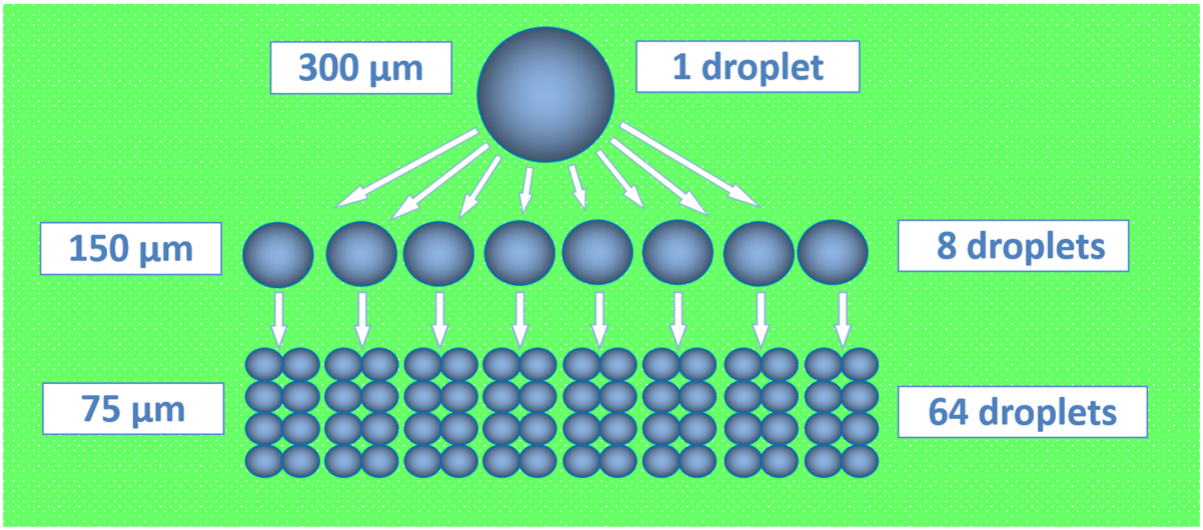
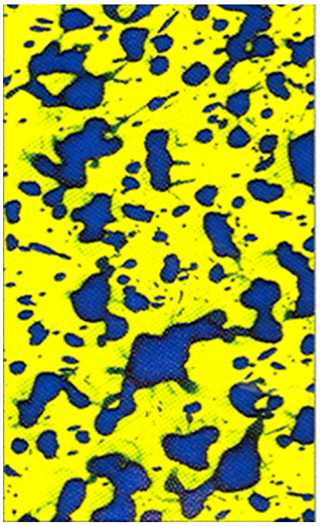


Figure 1. Relationship between droplet size and the number of droplets

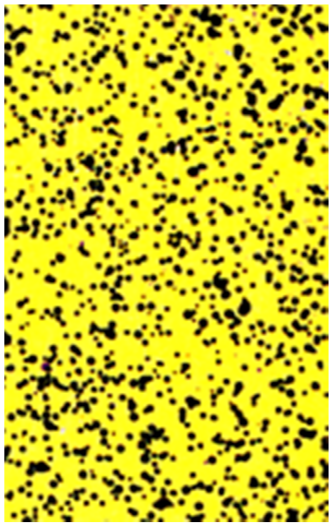
Currently, enhanced productivity in sprayers is achieved solely due to higher travel speeds, an expanded operating width and as well as by providing a tank of a greater capacity. For these reasons, a number of the leading European manufacturers of sprayers have abandoned the production of trailed sprayers with the tanks of a 2,000 L capacity and less, and they do not include the latter into the model series of the company's products.

Recently, AMAZONEN-WERKE H.Dreyer GmbH & Co. KG, a German company, have introduced to the market the UX 11200 trailed sprayer with the tank of a 12,000L capacity (Figure 2). Noteworthy is that the booklet to the above mentioned sprayer does not contain any recommendations pertaining to the spray nozzles. While comparing two sprayers, one with the tank of a 12,000 L capacity and operating at a working fluid flow rate of 300 L/ha, and another sprayer with the tank of a 2,000 L capacity and operating at a working fluid flow rate of 50 L/ha (Figure 3), the same result has been obtained as to the efficient throughput in both sprayers, i.e., 40 ha. Certainly, provided both sprayers have the same swath widths and the same travel speeds, the higher throughput per shift will be in the sprayer equipped with the 2,000 L tank because this tank can be refilled six times faster than the other tank.

Figure 2. Trailed sprayer UX 11200, AMAZONE H. Dreyer GmbH & Co. KG., (Germany) (the photo from the site: www.amazone.de).



Lechler
3 atm, 6.4 km/h
300 l/ha max
Spray nozzle IDK 120-04



Agromodul
3 atm, 8.25 km/h
50 l/ha max
Atomizer R.03.0.4

Figure 3. Snapshots of the working liquid on the laboratory cards (magnified view)

Just like the technical efficiency of spraying is assessed according to the quantity of retained droplets, in the similar way, the spray nozzle properties determine a working fluid flow rate per hectare. Ultimately, **the greater quantity of droplets the nozzle is capable to produce and deposit on the target surface, the less working fluid volume and the less pesticide amount are required to attain the efficient spraying.**