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Direct Injection of Plant Protection Agents

Uniform herbicide application is linked with a high misapplication rate. Knowledge about weed distribution, which was acquired through precision farming in recent years, shows that weed areas requiring treatment must be identified. This has lead to weed detection technology development. Just as necessary are technologies for site-specific herbicide application, which make it possible to precisely apply plant protection agents. These so-called direct injection systems are one path towards this development task.

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Keywords

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In recent years, weed detection and weed identification for the purpose of site-specific herbicide application or for yield mapping have repeatedly and successfully been carried out and documented under practical conditions [1, 2, 3,4, 5]. In order to make full use of the knowledge about the weed distribution in agricultural plots, which is based on weed detection, and to gain economic as well as ecological advantages, it is necessary to use an application system that is able to change the application rate and the type of herbicide rapidly during application. However, the present state of the art in plant protection sprayers is that the carrier fluid and the active ingredient are mixed in a large container and applied uniformly throughout the entire plot. This procedure is not only to the concept of precision farming but, strictly speaking, to the guidelines of good agricultural practice as well. They demand that „all measures of plant protection must be site-, crop-, and situation-specific, and the application of plant protection products must be limited to the necessary minimum."

One option to change the kind and amount of active ingredient during the field passage is to use a so-called direct injection system, in which the active ingredients are fed into the water flow of a field sprayer at a defined point [5]. The only direct injection system currently available in the German market has a reaction time of up to 40 sec because the active ingredient is fed into the carrier fluid immediately before the feed pump [6]. The advantage of decentralised injection at a boom section or immediately at a nozzle lies in a shorter distance between the injection point and the atomiser nozzle and hence in a reduction in reaction time.

Investigations on a test stand

The focus of investigations so far was the development of online methods to measure concentrations in the tube systems of sprayers in order to gain information on the dynamics of concentration increases and decreases during injection.

The research dealt with the influence of the active ingredients' viscosity and of the injection point (boom section, nozzle) on the build-up of the concentration. To this end, a test stand was developed and constructed. This article will report about partial results.

The great variations in the required amounts of the individual herbicides place great demands on a direct injection system's metering pumps and metering valves. At present, the use of herbicides with application rates of less than 100 ml/ha and with up to 5 l/ha is common practice. At forward speeds between 6 and 12 km/h, the resulting amounts of herbicide that have to be fed into the water flow of the sprayer are between 3 and 300 ml per minute for a boom section with six nozzles.

Fluid herbicides have viscosities in the order of 10 to 500 mPa•s (for comparison: water ≈ 1 mPa•s, olive oil ≈ 84 mPa•s, lubricat-

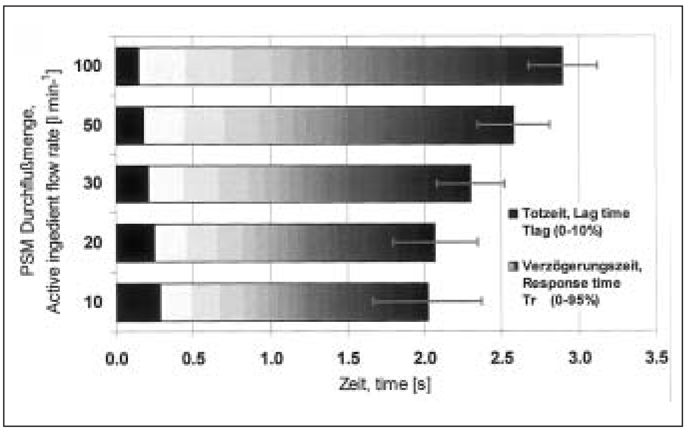

Fig. 1: Comparing lag and response time at constant nozzle flow rate (1.14 l min^{-1}) for different active ingredient flow rates

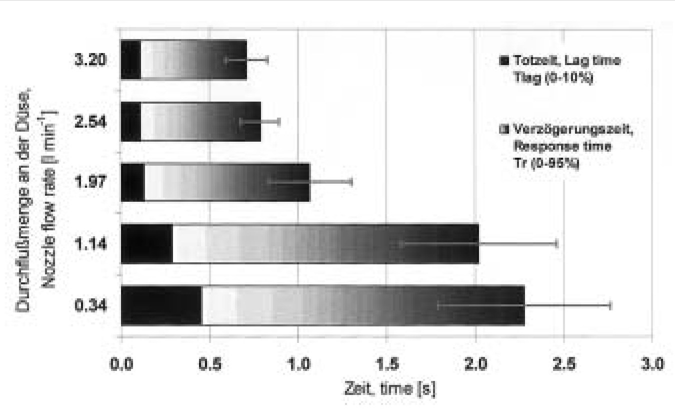

Fig. 2: Comparing lag and response time for different carrier nozzle flow rates at a constant active ingredient flow rate (10.0 ml min-1)

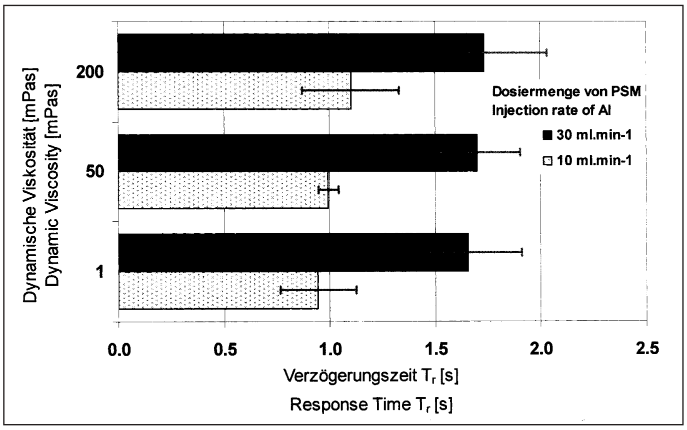

Fig. 3: Comparing lag and response time for three dynamic viscosities of plant protection agent at a constant carrier flow rate (1.97 l min-1) and with two flow rates of active ingredient

ing oil ≈ 350 to 3500 mPa•s). However, the herbicides used most frequently have viscosities under 100 mPa•s. Zhu et al. [7] have shown that the viscosity of a herbicide has an influence on the homogeneity of the active ingredient-water mix.

Online measurement of active ingredient concentration in the hydraulic system

Two methods to measure active ingredient concentration in the hydraulic system were developed, based on two different measuring systems. Both systems consist of a measuring cell that can be installed at any place in the tube system and of a corresponding electronic assembly.

The first method is based on spectral absorption measurements. A colorant (E 161) was used to replace the active ingredient. By means of a spectrophotometer, the maximum of absorption of the colouring agent was determined at 570 nm.

The second method is based on determining the electrical conductivity of a sodium chloride (NaCl) solution flowing between two stainless steel electrodes in a measuring cell.

Test results

In order to determine the suitability of the systems under test to variable dosing during herbicide application, a number of parameters were defined on the basis of which it was possible to characterise reaction times. The response times of both variants under test - injection at a nozzle and injection in a boom section - were determined directly at the nozzle for all nozzle sizes and system pressures. Two transition parameters were determined inside the flow-through cells to enable assessments of the response times of the different injection variants.

Figure 1 shows the total response times during the opening and closing of the proportional valve. Active ingredient injection took place directly at the nozzle and at rates of 10 to 100 ml min^{-1}. The figure shows that a reduction in injection rate results in a reduction in response time (T_r). The results indicate that the amount of plant protection product injected at the nozzle is a crucial parameter for response time. If the plant protection product is injected into the constant carrier flow at a lower rate, the material transfer in the hydraulic system is accelerated.

Moreover, the behaviour of the hydraulic system was tested at a constant ingredient injection rate by changing the carrier flow rates as required for the application rate per ha. Lag times (time elapsing until the concentration of the plant protection product in the carrier reaches 10 %) and response times are depicted in *Figure 2*. A rise from 0.34 to 3.20 l min^{-1} in carrier flow rate leads to a change in reaction time from 2.28 sec to 0.6 sec. Within the range in which the flow rates were varied, this time difference leads to a higher influence of the carrier on the response time than changes in the active ingredient flow rates.

Finally, the influence of active ingredient viscosity on the response behaviour during direct injection at the nozzle was investigated. *Figure 3* shows the results for three different dynamic viscosities at constant carrier flow rates (1.97 l min^{-1}) and two injection rates (10 and 30 ml min^{-1}) at the nozzle. With regard to the influence of changes in viscosity at a certain injection rate, changes in response time are less than 0.2 sec at a low flow rate and 0.15 sec at a higher flow rate. Thus, the influence of viscosity on reaction times is markedly lower than the influence of changes in the carrier flow rate.

Conclusions

The investigations carried out to determine the temporal parameters under different conditions have shown that the response times during nozzle injection are predominantly dependent on the carrier flow rate and less so on the flow rate or the viscosity of the plant protection product. With nozzle injection at a forward speed of seven km/h, the distance travelled during the time required for adaptation is between 1 and 4.4 m. The choice and the specifications of valves and pumps for very low flow rates will constitute a substantial step in the development of systems for direct injection at individual nozzles.

Moreover, it must be pointed out that for injection at the nozzle the tubing for the concentrated active ingredient must reach all the way to the nozzles. This raises questions of safety with regard to user protection as well as environmental protection. Such risks can be minimised by the use of suitable protecting devices.

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