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APPLICATION OF HERBIZIDES BY DIRECT INJECTION FOR SITE - SPECIFIC SPRAYERING

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Abstract. A laboratory model for an direct injection system was designed for the metering of appropriate herbicide into a carrier close to the nozzles. Two experiments were performed to investigate the dynamic behavior of this system. In the first experiment the position of the injection point was the center of a boom section and in the second experiment the chemical ingredient was injected close the nozzle. For these experiments a laboratory model of an injection sprayer system was employed. The concentration of metered chemical ingredient was measured down-stream of the injection point using a conductivity sensor based on sensing the electrical conductivity of a salt solution. This sensor was developed for the evaluation of the system time response characteristic of the sprayer.

The direct nozzle injection assembly provided a minimal response time from injection point to nozzle tip with less than 2.8 s. The injection applied to a boom section caused response time with a maximum of 7.5 s. This implies a maximum position error of 6.8 to 16.7 m at 8 km h^{-1} forward speed of the sprayer with camera system for weed detection.

Key words: *direct injection sprayer, weed detection, online herbicide application, response time.*

1. INTRODUCTION

In order to use the full advantages of site-specific weed control herbicide application based on information about the distribution of weed species it is necessary to use an application technology which is able to change the application rate and the type of herbicide rapidly. One option is to employ sprayers with an integrated direct injection system. In injection sprayers, herbicides and carrier are kept separate. According to the indications of the weed treatment map (offline application) or directly from the weed analysis camera system (online or real time application) (Gerhards et al., 2001), the herbicides are metered into the carrier and mixed immediately before entering the nozzles. One crucial factor in current direct injection systems - is respnse time, i.e., the time it takes for the mixed solution to flow from the injection point to the spray nozzles.

As it is required to carry out online application, the distance between the point of injection and nozzle has to be minimized. Nozzle injection promises very short response times less than 3 seconds. However, it has the disadvantage of inappropriately mixing of the carrier with the chemical in the nozzle. This problem is not significant in boom injection systems due to the long time for mixing. Frost (1990) described a method for response time minimization in boom injection systems by reducing boom diameter. Another benefit of this system is that it does not require additional plumbing to deliver the chemical to each nozzle.

In the proposed direct injection system, the proportional valve was used for the metering of appropriate herbicide into the carrier close to the nozzles. Two points of injection were investigated for response time characteristics. One of the points of injection was placed in the middle of the boom and the second one before the individual nozzle.

For measuring the response time, a method for the dynamic measurement mixture concentration in the nozzle was developed. A conductivity sensor was applied for the dynamic measurement of the mixture concentration of injected salt solution as described by Paice (1997). This method was used in a laboratory model of an injection sprayer system for the immediate determination of response time parameters.

2. DIRECT INJECTION SPRAYER DESIGN

The direct injection sprayer system in combination with a weed detection camera system was designed to fulfil the requirements of real time herbicide application. The main limiting factor of online application is the total response time of the sprayer system T_S consisting of the individual periods of time elapsing during each step of the online application process.

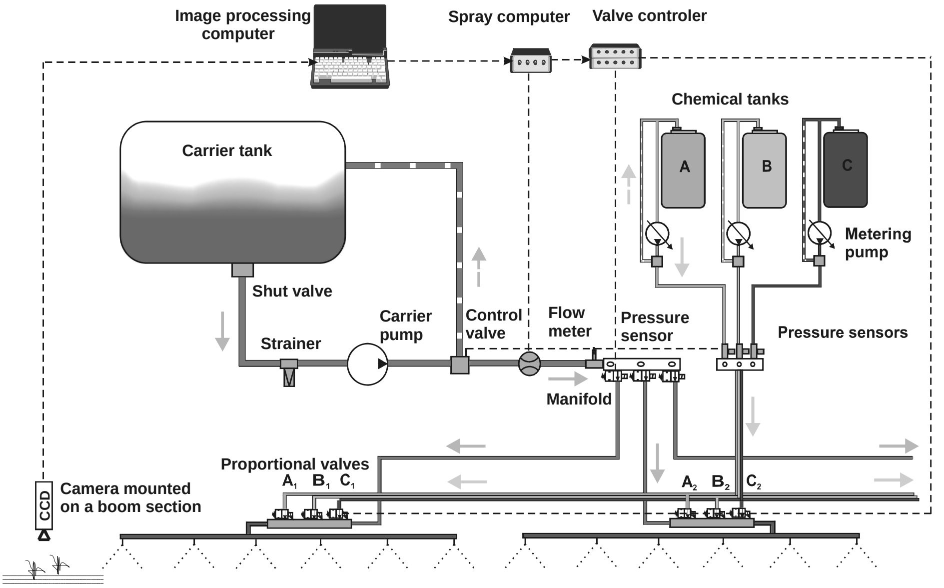

Fig. 1: Scheme of the proposed direct injection system

The first part in the sum is the time required for the detection and recognition of the weeds T_d, because of the high processing requirements the time of detection for a system with 3 CCD cameras is about 1 second (Gerhards et al. 2002). The second part is the response time T_r, which depends on the number, the length and diameter of the nozzle supply lines and on the mixture flow rate.

In the proposed system (Fig. 1), a CCD camera with a spatial resolution of 3 m is mounted to each boom section. The distance between the camera and the boom is about 1 m. The camera system provides information about the amount and type of herbicide of weed to the spray computer, which controls the flow rate in the system (Gerhards and Soekefeld, 2001).

3. MATERIALS AND METHODS

3.1 Experimental Arrangement

An experimental arrangement was assembled to evaluate the accuracy and time response of the direct injection system (Fig. 2). The hydraulic system delivers the active ingredient to the point of injection, which was placed at the boom (T-configuration, Fig. 3 I.) and at the nozzle (straight configuration, Fig. 3 II.).

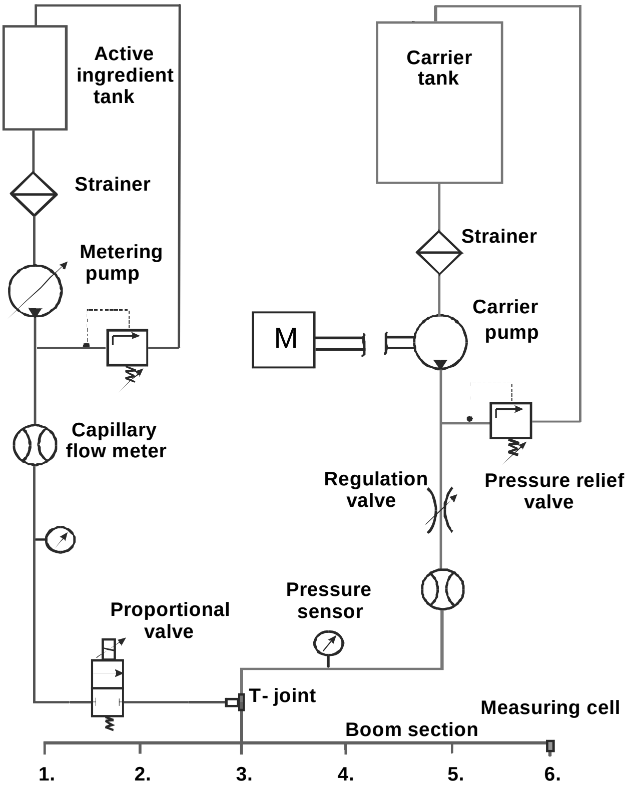

Fig. 2: Experimental arrangement of chemical injection system

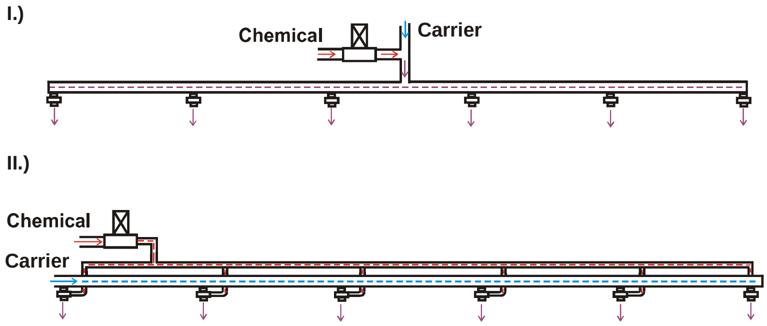

Fig. 3: Boom configurations, section of 3 m width

The system included an active ingredient tank. A gear injection pump and a proportional valve (pulse width modulated) were used for the metering of an appropriate amount of tracer into the carrier. The same type of valve was used for both above mentioned configurations. The active ingredient flow was measured with a capillary flow sensor. The relative pressure in the active ingredient tubes was measured by a pressure transmitter.

A sprayer diaphragm pump supplied the carrier flow through the manifold to one boom section. The carrier pressure was measured by a pressure transmitter, while a magnetic-induction flow meter measured the carrier flow. In the boom injection configuration, the carrier and active ingredient lines were connected by means of one T- connector to the 3 m long sprayer boom with 6 nozzles spaced 50 cm apart.

In the nozzle injection configuration, the T- connector was located immediately before the conductivity sensor at nozzle position 3 (Fig. 2). The distance between the centre of the T- connector and both electrodes was 40 mm.

3.2 Dynamic Measurement of Spray Mixture Concentration

For determination of response time, a method for the dynamic measurement of spray mixture concentration was developed (Hlobeň et al., 2003). This method is based on sensing the electrical conductivity of a sodium chloride (NaCl) solution which flows between electrodes in a measuring cell. The sensor causes the voltage to break down according to the conductivity of the spray mixture. NaCl diluted in water at a basic concentration of 20 g l^{-1} was used as an active ingredient for this method.

The conductivity inline measuring cell was installed at one nozzle location immediately before the nozzle in the spray boom of a laboratory model of a direct injection sprayer system. The system pressure was set by degrees to 1, 3, and 5 bar. The carrier flow through the measuring cell was maintained at a constant level using XR 80015, 8003, 8005 flat fan nozzles. The active ingredient flow ranged from 0.0 to 520 ml min^{-1} depending on the differential pressure and the proportional valve control signal.

The mean of active flow rate, the carrier flow rates and the concentration of the basic solution were used to calculate the mixture concentration. Mean and standard deviations (SD) of the output voltages from 6 replications were determined for each system pressure and mixture concentration.

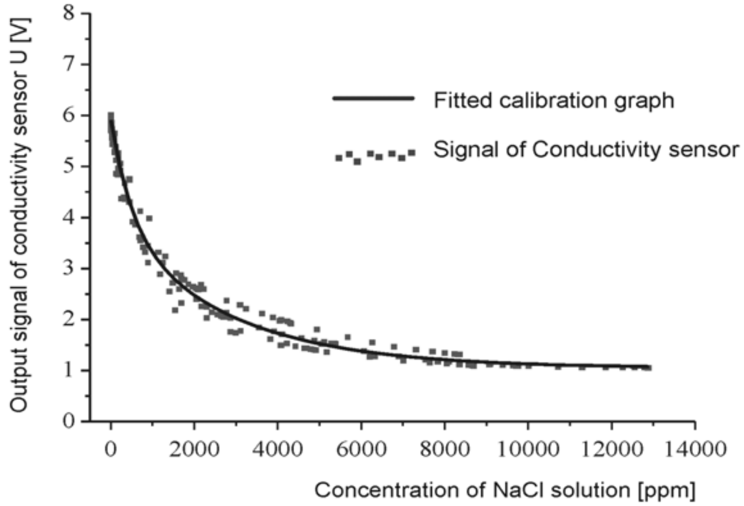

Fig. 4: Calibration graph for conductivity sensor

3.4 Measurement of Response Time

The objective of these experiments was to measure the dynamic response parameters which can be used to evaluate the applicability of the tested systems for variable-rate herbicide application. Response times at the nozzle were measured for both configurations (nozzle and boom injection) and for the whole range of applied nozzles and system pressures. Two transient characteristics for the mixture concentration were measured in the flow-through the cell to evaluate the response time of the injection system.

The response time was defined as duration required for the output response to a step input to reach 95% of concentration. The value of 95% of concentration was chosen as efficacy threshold (a concentration of chemical for satisfactory weed control) (Bennett et al., 1997). The lag time is the time from starting the injection of ingredient to 10 % of the concentration is exceeded.

Nozzle Injection

For the nozzle injection configuration, the step change tests were performed only for one nozzle. The chemical supply line (6 m length) from the proportional valve was connected directly to the nozzle T-connector and to the conductivity sensor at position 3 on the boom. The nominal nozzle flow rates from 340 to 3200 ml min^{-1} are equivalent to the application rates required in a real-time application approach using cameras for the recognition of weeds. The proportional valve was operated to inject a constant volume of the active ingredient. Different constant carrier flow rates were maintained during each measurement. In a second experiment the carrier flow rate was kept constant, while the ingredient flow rate was varied from 10 to 100 ml min^{-1}. In a third part of the experiment the influence of viscosities on the response time were studied. The range of viscosities was chosen among the current active ingredients varying from 1 to 200 mPa.

Boom Injection

For the measurement of response parameters for the boom injection configuration, the conductivity sensor was located at the outermost nozzle. Spray booms with 6, 8 and 12 mm ID were used during the test, in order to investigate the influence of different boom diameters on the response time. The nominal flow rate of the XR 8005 nozzle ranged between 1140 and 2540 ml min^{-1} at system pressures set by degrees to 1, 3 and 5 bar. The flow rates in the system were calculated from measurements of the weight of water sprayed from each nozzle over a time period. The flows in the system had Reynolds numbers in the range between 4000 and 20 000. This ensures adequate mixing of the carrier with an active ingredient.

4. RESULTS AND DISCUSSION

4.1 Dynamic Response Results

Nozzle Injection Results

Measurements of response parameters were well repeatable with the largest SD being 0.6 for the 6 replications of data collected. Generally, it was possible to conclude that the shortest times were obtained for all measurements by the greatest flow rates.

Fig. 5 compares average lag and response times for a constant nozzle flow rate. The active ingredient flow rates rise from 10 to 100 ml min^{-1}. The graph indicates that increasing the ingredient flow rate greatly reduced the total lag time. The greatest lag time 0.25 s was obtained at the a flow rate of 10 ml min^{-1}, while the shortest lag time measured was 0.1 s at an active ingredient flow rate of 100 ml min^{-1}. Response time varied in this configuration between 2.05 and 2.8 s.

Lag and response times at constant flow rates of active ingredient are displayed in Fig. 6. The constant ingredient flow rate was maintained at 10 ml min^{-1}. There is a decrease of lag time and response time with increasing flow rates of carrier.

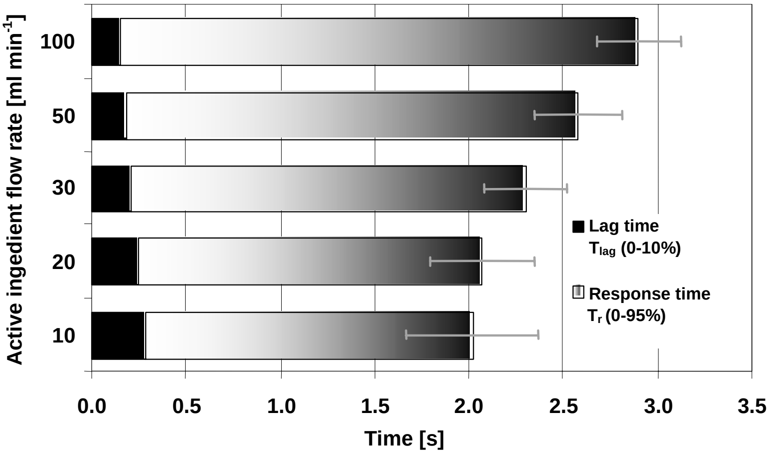

Fig. 5: Comparison of lag (T_{lag}) and response time (T_r) at constant nozzle flow rate (1.14 l min^{-1}) for different active ingredient flow rates (location of injection: nozzle)

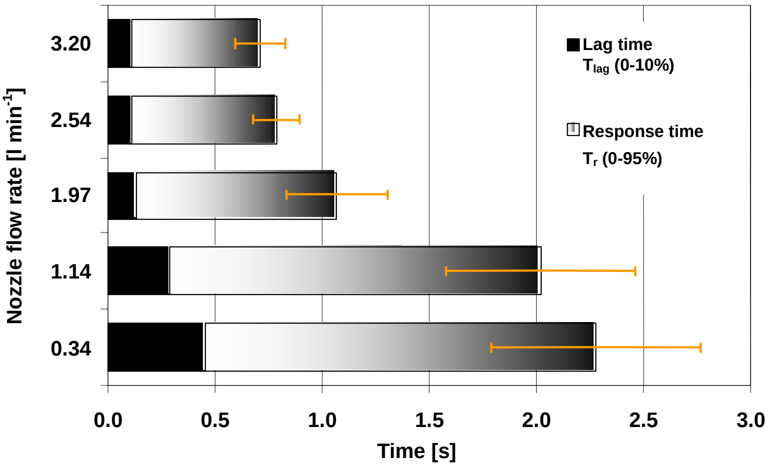

Fig. 6: Comparison of lag (T_{lag}) and response time (T_r) for different carrier nozzle flow rates at constant active ingredient flow rate (10.0 ml min^{-1}, location of injection: nozzle)

Fig. 7 presents the influence of different viscosities of the active ingredients on the time parameters. The tests was performed with a constant carrier flow rate of 1.97 l min^{-1} and two different injection flow rates of 10 and 30 ml min^{-1}. Response time increases with higher viscosities and when the injection flow rate is enlarged.

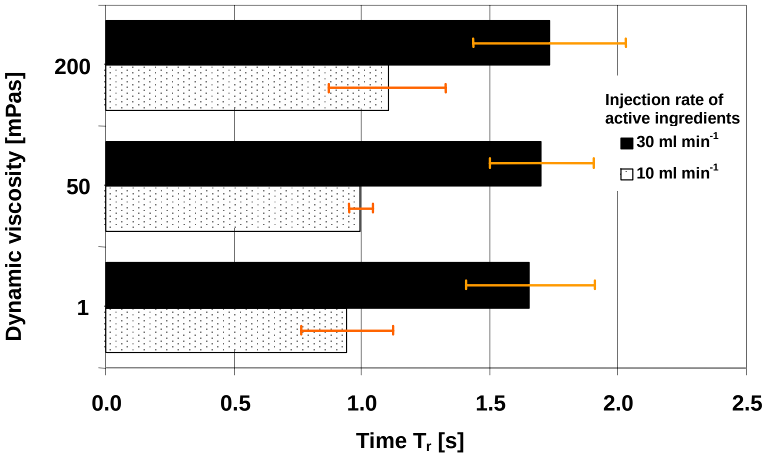

Fig. 7: Comparison of response time (T_r) for different viscosities of active ingredients (1 to 200 mPa s; 1 mPa s = viscosity of water) at constant carrier flow rate (1.97 l min^{-1}) and with two flow rates of the active ingredient

Boom Injection Results

The minimum response time was determined at 1.7 s at boom diameter of 6 mm and a flow rate of 2.5 l min^{-1}. The maximum lag time of 7.3 s was obtained with the boom diameter of 12.7 mm and the lowest flow rate of 1.1 l min^{-1}. Thus with the boom diameter the time parameters of an direct injection system can be changed as it is expected. But the magnitude of response times requires a disconnection of weed detection system and application technique. At a forward speed of 7 km h^{-1} the distance of 3.4 to 14.6 m would be passed till an accurate application would appear. Boom injection therefore is appropiate just for the mapping concept.

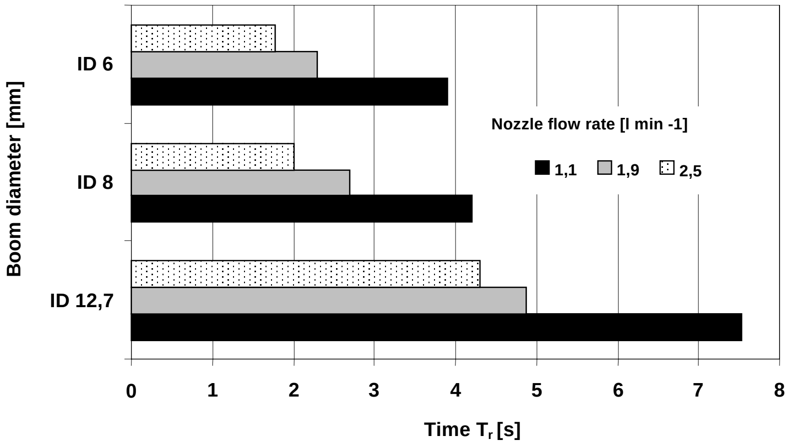

Fig. 8: Comparison of reponse time (T_r) for different boom diameters and 3 carrier flow rates (location of injection: boom section)

5. CONCLUSIONS

The proposed laboratory model of a direct injection system was proved suitable for the measurements of response time characteristics. The results from the dynamic measurements of mixture concentration showed good level of accuracy of the conductivity sensor and proved the practicability of this method. There are significant functional relations between mixture concentration and output signal. The inline measuring cell can be installed in any place throughout the length of the spray boom. Thus, it can be used to determine lag and response time.

The results obtained from the series of tests indicate that it is feasible to construct a sprayer with a direct nozzle injection system, in which the flow of the chemicals is controlled by means of a proportional valve. With near to nozzle injection response time is less than 2.8 s. When using the boom section as location of injection the boom diameter greatly influences the response time. The shortest response time for this case is 1.7 s at the highest nozzle flow rate of 2.5 l min^{-1}. However compared to the nozzle injection there is no improvement possible. Even if the boom diameter is reduced an acceptable response time will not be obtained. For the nozzle injection, improvements by optimization of the mixing process are still possible and hence reduce the response time.

With evolving computer technology, it will be possible to reduce the time necessary for image processing, thus gaining greater time reserves for a successful application.

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APLIKACIJA HERBICIDA DIREKTNIM INJEKTIRANJEM U KONCEPTU PRECIZNOG PRSKANJA

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***Sadržaj*:** Labaratorijski model dirketnog injektorskog sistema je razvijen u smislu odgovarajuće aplikacije herbicida u blizini radnog rasprkivača. Dva eksperimenta su izvedena u cilju istraživanja dinamike ovog sistema. U prvom, pozicija injekcione tačke je bila centar krila prskalice a u drugom hemikalija je injektirana u blizini rasprskivača. U svrhu ovog eksperimenta, labaratorisjki model injektorskog uređaja je upotrebljen. Koncentracija aktivne supstance je merena ispod struje injekcione tačke upotrebom konduktivnog senzora baziranog na električnoj provodljivosti slanog rastvora. Ovaj senzora je razvijen za procenu vremena odgovora sistema prskalice.

Uređaj za direktno injektiranje pokazuje minimalno vreme reakcije od injekcione tačke do vrha rasprskivača, manje od 2.8 s. Injektiranje primenjeno na sekcijama krila pokazalo je reaktivno vreme maksimalno do 7.5 s. Ovo implicira maksimalnu pozicionu grešku od 6.8 do 16.7 m pri 8 km/h brzine prskalice sa detekcionim sistemom korova snimanjem kamerom.

Ključne reči: *direktno injektiranje, prskalica, detekcija korova, linijska aplikacija herbicida, vreme reakcije.*