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Measuring device for detecting the salt distribution in water

For a better understanding of the control characteristics of direct injection systems, which are a promising technology in the field of site-specific chemical plant protection, it is crucial to be able to describe the flow of fluid within the system. Therefore, a measuring device was developed allowing to detect the distribution of salt (NaCl) and the resultant change in the electrical conductivity of the carrier stream (water). This should provide conclusions about the control behaviour of sprayers. It is, for that reason, suitable for the description of direct injection systems.

Keywords
Sprayer, direct injection systems, conductivity, plant protection

Abstract
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Weeds are in no case distributed homogenously within a field, but rather aggregate in nests. Therefore, site specific weed management is required with respect to environmental and economic aspects [1]. Technology like automated boom section control via GPS may decrease the total amount of herbicide used during applications with regards to field configuration [2], nevertheless the chemical dose (l/ha) within the mixture is still fixed and cannot be varied during the application. An approach to avoid this problem is the development of a direct injection system. These systems allow keeping the concentrated pesticides and the carrier substance (water) separated, and are able to meter the pesticide into the carrier flow on demand. This technology can only withstand if key aspects such as mixing quality or rather the homogeneity of the mixture, and delay time can be studied and described reliably.

In this context the delay time is defined as the time period between the setting of a new target concentration of a pesticide and obtaining this target concentration at the nozzle [3]. To date, only two methods, the measurement of the electrical conductivity and the spectral absorption of the carrier substance, are available to analyse this key aspects [4, 5]. For the present study electrical conductance has been used to determine the electrical properties of the mixture used during applications. Unlike the described electrical conductivity, conductance can be determined without a cell constant K [6], which describes the ratio of the distance l [m] between the two sensing electrodes and their surface area A [m²], representing the length and the diameter of the conductor. In this case the conductor is the salt water which flows between the two sensing electrodes. The conductance is detected by sensors of the measuring scheme, placed at different key points such as injection point, homogenization device and nozzles, within the direct injection system.

Conductance measurement

The conductance G [S] of water can be varied by adding salt (NaCl), which dissociates in Na^+ and Cl^- ions. Cations and anions are moved in opposite direction [7] by an electical field, which can be measured as electricity. The more dissociated ions are available, the further the electrical resistance of the water will decline. In addition to the number of ions present, the conductance also depends on the current temperature of the water, and thus its density. For the closed loop of a plant protection sprayer, a constant temperature distribution can be assumed throughout the system, and therefore temperature measurement is not required.

The test setup is in accordance with a series circuit of two resistors R1 and R2, where R1 is fixed to 220 Ω and R2 is represented by the salt water and is, for that reason, variable. Following the laws regarding series connection of resistors, the amperage I [A] at each resistor is constant. The voltage U [V] at each resistor R [Ω] is calculated according to equation 1.

$$U_x = I \cdot R_x \qquad \text{(eq. 1)}$$

Via transforming equation 1 to the amperage I and equating, resistance can be calculated according to equation 2.

$$\frac{U_1}{U_2} = \frac{R_1}{R_2} \rightarrow R_2 = \frac{U_2 \cdot R_1}{U_1} \qquad \text{(eq. 2)}$$

The electrical conductance is further calculated by forming the inverse of equation 2 [8]. For the resistor R2, which represents the resistance of the saline water, and therefore the number of dissociated ions, the conductance G2 can be determined according to equation 3.

$$G_2 = \frac{U_1}{U_2 \cdot R_1} \quad \text{(eq. 3)}$$

G_2 = conductance of salt water [S]
U_1 = Voltage at resistor R_1 [V]
U_2 = Voltage at resistor R_2 [V]
R_1 = fixed resistor of 220 Ohm [Ω]
R_2 = variable resistance of the saline water [Ω]
I = amperage [A]

Sensors for in-tube and nozzle-holder measuring were developed (**Figure 1**).

Results

A gradual application of various application rates (50 up to 400 l/ha) over intervals of 300 seconds was performed during experiments (**Table 1**). Ground speed was simulated by a separate module suitable to the application rates, in order to provide a constant droplet size (475 µm). The module is integrated into the control software and is not further described in this article. The application rate was composed of a constant amount of salt water (25 l/ha) and a variable rate of fresh water (25 up to 375 l/ha). The injected salt water had a salinity of 3.3 %. In the presented trial, the measuring device was able to detect the variation of the conductance regarding different salinity variants. **Figure 2** provides the exemplary trend of the conductance at a nozzle-holder and shows the adjustment of the direct injection system to a new variant in steps of 300 seconds. The sensors had a low hysteresis, which is defined as the difference between the conductance of multiple measurements of a constant mixing ratio of freshwater and saline water.

Fig. 1

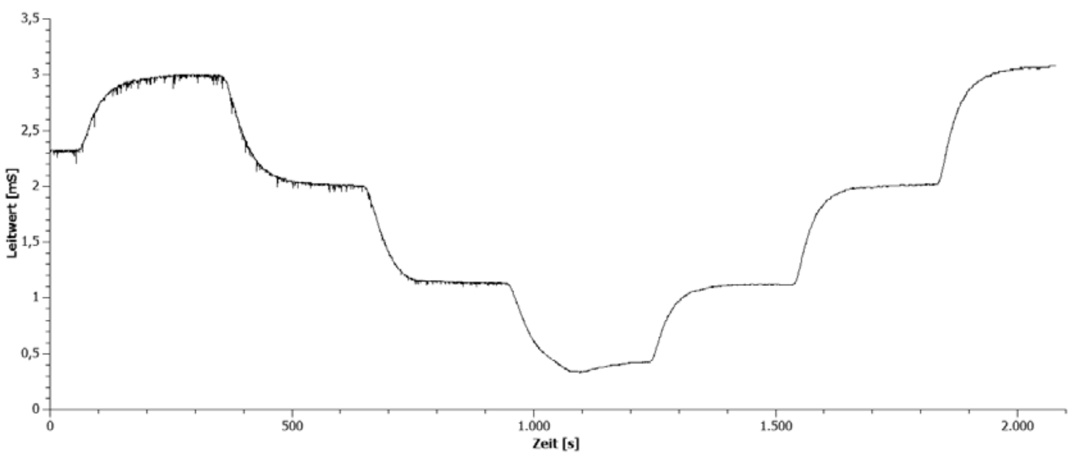
Sensor for in-tube and nozzle holder measurement (Photo: J. Geiß)

Table 1

Exemplary experimental run

Zeit *Time* [s]	Applikations-menge *Application rate* [l/ha]	Salzwasser *Salt water* [l/ha]	Reinwasser *Clean water* [l/ha]	Geschwindigkeit *Speed* [km/h]
0	50	25	25	12,8
300	100	25	75	6,4
600	200	25	175	3,2
900	400	25	375	1,6
1200	200	25	175	3,2
1500	100	25	75	6,4
1800	50	25	25	12,8

Fig. 2



Change in conductance for different salinities

Conclusion

The measurement device is able to observe the processes within sprayer at any point inside the liquid loop and provides detailed knowledge about the control behaviour and the characteristics of this sprayer. This knowledge leads to a better understanding of common sprayers and significantly assists in future developments, such as direct injection systems. Furthermore, the system can be used to describe and observe machine specific features, such as delay time and the homogenization of various liquids (fresh water and salt water), which represent the key aspects of a direct injection system. Results shown in this article have to be considered against the background of the physical properties of salt water used as a pesticide substitute. The viscosity of salt water is very low and therefore has only a small effect on the flow dynamics within a sprayer. Thus, findings regarding with salt water are not directly comparable to pesticide implementations. It is nevertheless possible to discern and gather general tendencies within the system.

References

[1] Wartenberg, G. (2000): Teilflächenspezifisches Spritzen von Pflanzenschutzmitteln. Landtechnik 55(6), S. 438–439

[2] Luck, J.D.; Zandonadi, R.S.; Luck, B.D.; Shearer, S.A. (2010): Effects of field shape and size on application errors using manual and automatic boom section control on a self-propel led agricultural sprayer. American Society of Agricultural and Biological Engineers, Annual International Meeting 2010, Pittsburgh, Pennsylvania, 6, pp. 5234–5241

[3] Zhu, H.; Fox, R.D.; Ozkan, H.E.; Brazee, R.D.; Derksen, R.C. (1998): Time delay for injection sprayers. Transactions of the American Society of Agricultural Engineers 41(3), pp. 525–530

[4] Sökefeld, M.; Hloben, P.; Schulze Lammers, P. (2004): Möglichkeiten und Grenzen der Direkteinspeisung von Pflanzenschutzmitteln zur teilschlagspezifischen Unkrautkontrolle. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, Sonderheft XIX

[5] Downey, D.; Crowe, T.G.; Giles, D.K.; Slaughter, D.C. (2006): Direct nozzle injection of pesticide concentrate into continuous flow for intermittent spray applications. American Society of Agricultural and Biological Engineers 49(4), pp. 865–873

[6] Rommel, K. (1988): Leitfähigkeitsfibel, Einführung in die Konduktometrie für Praktiker. Fa. WTW, Weilheim

[7] Dickerson, R.E.; Gray, H.B.; Darensbourg, M.Y; Darensbourg, D.J. (1988): Prinzipien der Chemie. Berlin, de Gruyter GmbH, 2. Aufl.

[8] Frohne, H.; Löcherer, K-H.; Müller, H.; Harriehausen, T.; Schwarzenau, D. (2011): Moeller Grundlagen der Elektrotechnik. Wiesbaden, Vieweg + Teubner Verlag, 22. Aufl.

[9] Schnabel, P. (2010): Elektronik-Fibel. Selbstverlag, 5. Aufl.

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