Bernd Niemöller and Hans-Heinrich Harms, Brunswick

Injection Fertilizing with a High Pressure Water Jet

Under agronomical aspects, injection fertilizing offers many advantages. However, the mechanical techniques of injection fertilizing which are currently available have some disadvantages in field use. At the Institute of Agricultural Machinery and Fluid Power of the Technical University of Brunswick/Germany, fundamental studies on the possibility of injection fertilizing with a high-pressure water jet are being carried out. Tests are being made on a stationary test rig with a high pressure water jet to determine the injection potential on different soils. The results show that altering diverse parameters, such as water pressure, volume flows, etc., make it possible to achieve various injection depths in the soil.

Dipl.-Ing. Bernd Niemöller is a research assistant at the Institute of Agricultural Machinery and Fluid Power of the Technical University of Braunschweig/Germany (director: Prof. Dr.-Ing. Dr. h. c. H.-H. Harms), Langer Kamp 19a, D-38106 Braunschweig; e-mail: *b.niemoeller@tu-bs.de*

The presented project is promoted by the German Research Foundation (DFG). Its planned duration is two years.

Keywords

Injection fertilizing, high-pressure water jet

Literature

Books are marked by •

[1] • *Sommer, K.*: CULTAN-Düngung. Verlag Th. Mann Gelsenkirchen, Bonn, 2005

[2] N.N.: Firmenprospekt Güstrower Maschinen- und Antriebstechnik GmbH und Co. KG

Injection fertilizing is a fertilizing technology in which ammonium fertilizer rich in nitrogen is injected into the soil near the plant roots. In order to achieve the best fertilizing effect, injection in the form of highly concentrated fertilizer depots into the soil has proven meaningful. One of the advantages of the ammonium fertilizer used compared to other fertilizers rich in nitrogen is that it cannot be leached out by the rain and remains in the soil as a stable source of nitrogen. In the literature, injection fertilizing according to this method is termed the CULTAN technique (Controlled Uptake Long-Term Ammonium Nutrition) [1].

In the current technical applications of this technique, the fertilizer is injected mechanically. With the aid of spokes, the fertilizer is injected into the soil such that it forms depots at a depth of 50 to 90 mm. The spokes are arranged in a star-like form on spoke wheels which are drawn over the soil. A hub-controlled valve in the spoke wheels controls fertilizer injection. In currently available machines, the distance between the injection points is 13 cm, and row distance is 25 cm. Working widths range from 1 m in plot cultivation to 18 m in large-area use [2].

Currently, the high purchasing price of the injection equipment is of disadvantage for technical application. In addition, the spokes are in constant contact with the soil. This can lead to nozzle clogging due to continuous penetration into the soil and may result in spoke wear. Moreover, the spokes may break in the case of contact with foreign bodies. Since the spokes use the own weight of the machine to penetrate into the soil, high machine weights are required for large working widths, which can lead to heavy soil compaction.

Objectives and set-up of the trial

At the Institute of Agricultural Machinery and Fluid Power of the Technical University of Brunswick/Germany, an alternative method for the injection of fertilizer into the soil is being studied. As part of a research project promoted by the German Research Foundation, trials are being carried out in order to

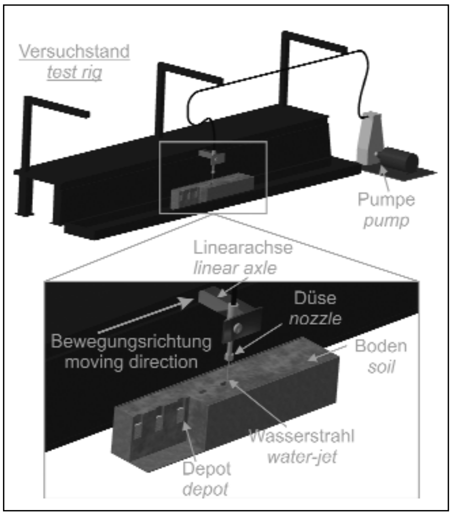

Fig. 1: Stationary test rig

determine whether it is possible to deposit liquid fertilizer in the form of a high-pressure water jet directly into the soil at the desired depth. The fundamental trials required for this purpose are not realized in field use, but with the aid of a stationary test stand for water jet cutting. At the beginning, exclusively pure water is used for these trials. The water is highly compressed by a pump. Then, this water flows through a pipe to the jet nozzle where the high-pressure water jet is generated. The nozzle is attached to a linear axle which is moved over a soil sample. *Figure 1* shows a schematic view of the test rig.

In the trials series, the possibility of injection fertilizing with a water jet and the marginal conditions which can be determined during this process are examined. In these trials, a large number of influencing parameters can be varied.

First, the influence of soil-specific parameters is examined. Thus, different kinds of soil (sandy, silty, and clayey soils) are studied. Soil moisture and compaction are varied. In addition, the possibility of injecting fertilizer into frozen soils is tested.

Second, the settings of the water jet injector are varied. Different water pressures of up to 120 MPa (1,200 bar), different volume flows, different passing speeds, the frequency of a pulsed water jet, distance between the

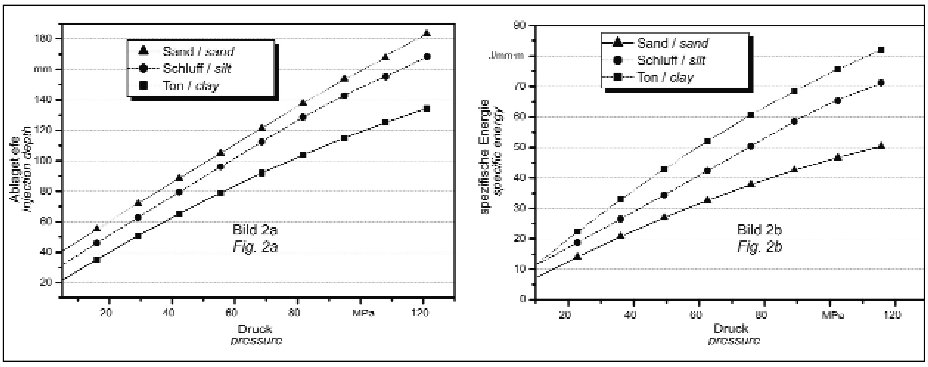

Fig. 2: Injection depth and specific energy at different water pressures

nozzle and the soil as well as the injection angle between the nozzle and the soil surface are examined.

For the evaluation of the trials, injection depth, the power required at this depth, and specific energy input are used as measurable values. Additionally, the behaviour of the water jet in the soil and the splashing-back of the water jet from the slit in the soil are assessed as visually detectable properties.

Results

Previous trials in different kinds of soil showed that a speed of 2 m/s, a pressure of 40 MPa (400 bar) and a volume flow of 7.5 l/min are sufficient to reach injection depths of 70 to 90 mm (depending on the kind and properties of the soil). Therefore, these settings of the water jet injector were used as initial settings. Based on these settings, one parameter each was varied in extensive trial series. Below, two results of these trials are described as examples.

Figure 2 shows measured injection depths in the three different kinds of soil under the conditions of varying water pressure. *Figure 2a* illustrates the development of injection depth as a function of water pressure variation. The diagrams show that injection depth increases with higher water pressure in all kinds of soil. In lighter soil (sandy soil), maximum possible injection depth turns out to be higher than in heavy soil (clay soil). This is the result of different aggregates in the individual kinds of soil. By interacting (Van-der-Waals force, etc.), the aggregates form a stable soil structure. Heavy soils have a far more stable soil structure. This soil structure must be broken up by the water jet, which requires more energy in these soils than in lighter ones.

The course shown in *Figure 2a* slightly flattens at higher pressures. This has two reasons: First, friction occurs in the soil between the water jet and the sides of the slit in the soil. With growing injection depth, this friction increases. This leads to a reduction of the energy of the water jet. As a result, injection depth increases at a slightly lower rate. In addition, greater water pressure causes the water volume flow to grow. This water forms a cushion in the soil. When the water jet penetrates the water cushion, friction occurs between the water jet and the water cushion, which results in a reduction of the energy of the water jet. With increasing volume flow, the water cushion grows, which causes more friction and is the reason for the slightly reduced injection depth increase.

Figure 2b shows the required specific energy at varying water pressures. Specific energy is defined as energy input in relation to injection depth and injection length. The diagram shows that specific energy grows at high pressures. Since specific energy is the quotient of energy input and injection depth, the increase in energy input is far greater than injection depth increase. Under energetic aspects, lower pressures are therefore preferable.

As another example of measurement-technological examinations, injection depth and specific energy at different soil moistures are shown in *Figure 3*.

The diagram shows that injection depth increases very significantly with growing soil moisture (*Figure 3a*). Water pressure and volume flow were the same in all trials. At low degrees of soil moisture, maximum injection depth is very small, whereas it is very large at high degrees of moisture given otherwise identical settings. Interactions (Van-der-Waals force, etc.) between the individual soil aggregates can be considered the reason for this phenomenon. If the soils are dry, these interactions are very strong, which results in the formation of a stable soil structure. The moister the soil is, the weaker these interactions become. Therefore, the amount of energy required in moister soils in order to reach great injection depth is far smaller. This behaviour is also shown in *Figure 3a*. If soil moisture is very low, specific energy requirements in heavy clay soil are many times higher than if soil moisture is high.

Summary and outlook

Initial fundamental examinations with pure water show very good results of injection fertilizing with a high-pressure water jet. The examined kinds of soil show different properties. Especially soil moisture has a significant influence on maximum possible injection depth.

Initial trials of water jet pulsation have already been carried out. Here, more studies are necessary. In other trials, the possibilities of injection fertilizing in frozen soil and under the conditions of mulch and direct drilling are being examined. Finally, initial studies on the control of injection depth are planned.

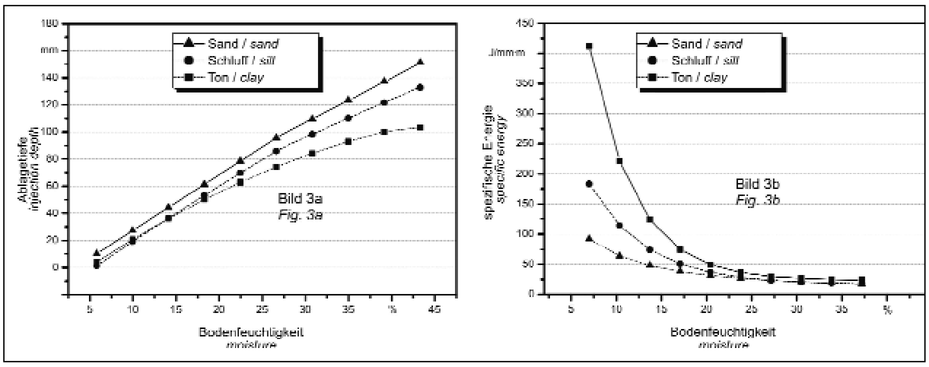

Fig. 3: Injection depth and specific energy at different soil moistures