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Forming of depots during the ground injection with a high pressure water jet

During the ground injection the fertilizer is not spread out wide-flatly on the soil surface. It is injected into the soil as a fluid fertilizer. Using conventional fertilizing methods nitrate is the nitrogen-source, in the ground injection ammonium is the nitrogen-source. This has many advantages for the fertilized plants [1]. Fundamental studies on the direct, contactless injection of liquids into the soil with the aid of a high-pressure jet are being carried out at the Institute of Agricultural Machinery and Fluid Power of the Technische Universität Braunschweig. The potential and the possibilities of injection by a high-pressure jet are being examined in trials with pure water as an example fluid on a stationary test rig. The results of the trials show, that the injection with the high pressure jet is possible.

Keywords
Ground injection, high pressure water jet, forming of depots

Abstract
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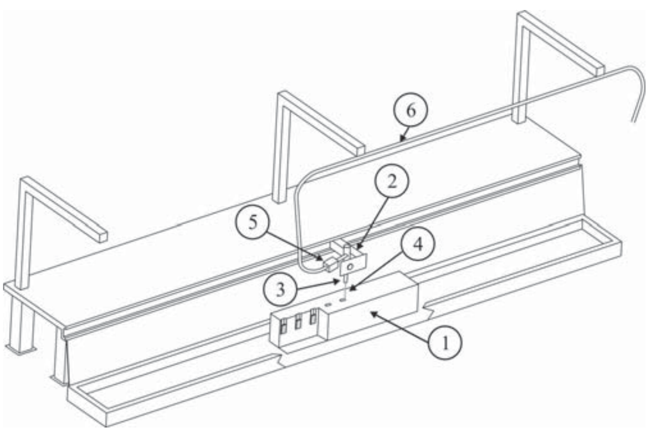
In former publication the injection depth and the specific energy at the ground injection with a high pressure water jet were mentioned [2]. In this publication forming of depots during the ground injection with a high pressure water jet is focussed. The explained trials were carried out with the aid of a stationary test rig for high-pressure jet cutting (**figure 1**). An injection box (1) filled with soil is placed inside the test rig. Pure water is used. The injection box is driven over by a jib boom (2) installed on a linear axle. Several cutting heads (3) can be attached to the jib boom and carried by it. The cutting heads produce a high-pressure jet (4) which acts vertically downwards. The cutting heads used are supplied with pressure by a pipe system (6) which receives water pressure from a high-pressure pump in the dry area. In the pipe system next to the cutting head a frequently pulsating valve (5) is mounted. The valve generates depots inside the ground.

Theoretical consideration of forming depots into the soil

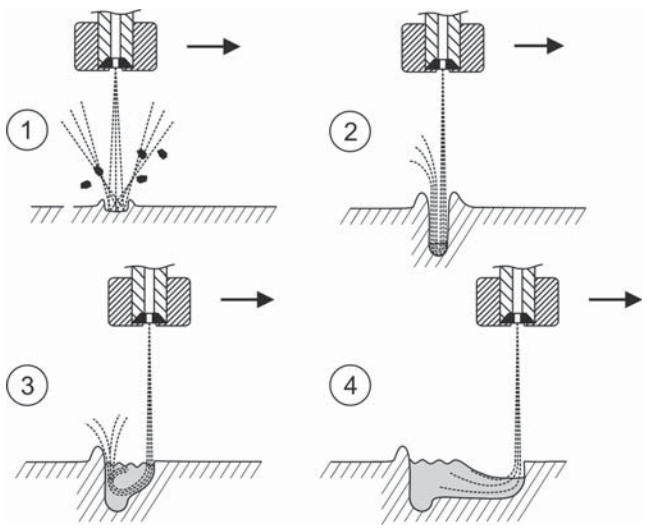
The water jets impacts point-shaped on the soil surface. The impulse of the impact decreases the binding mechanisms of the soil grains. Furthermore the injected water decreases the binding mechanisms of the soil grains. This decrease of the binding mechanisms makes the soil grains movable. That's why rearrangements of the grains inside the soil take place and as a result a crater in the soil surface is formed out. Due to the linear, horizontal movement of the cutting head driven by the linear axis not only a crater but also a slit is formed out in soil. In the following explanation the cutting head is driven over the injection box. The pulsating valve is opened abruptly. The processes taking place in the soil are ex-

Fig. 1



Design of the stationary test rig: (1) injection box, (2) jib boom, (3) cutting head, (4) high-pressure jet, (5) pulsating valve, (6) pipe system

Fig. 2



Flow of the waterjet inside the soil (according to [3]): (1) water jet impacts the soil surface, (2) crater is formed in the soil, (3) slit in the soil filled with water, (4) constant depth of the slit filled with water

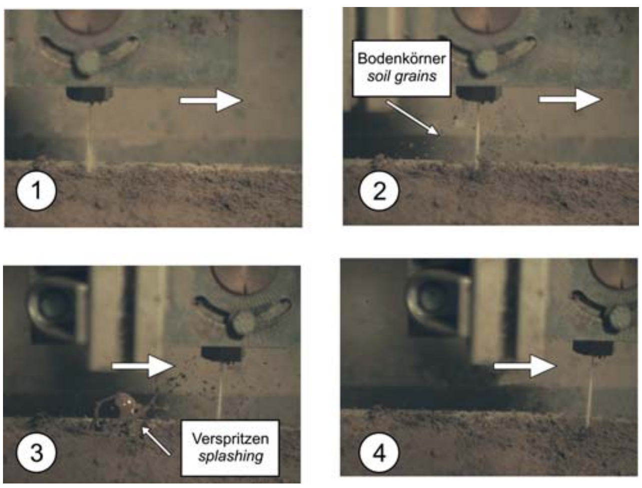
plained in four process steps in **figure 2** according to [3]. In the first process step the water jet impacts the soil surface. A few soil grains are ejected of the surface and a crater is formed in the soil. In the second process step the crater gets deeper and the ground of the crater is filled with water. In the third process step a slit in the soil filled with water is formed. The water damps the water jet. That's why the injection depth at this process step is not as deep as immediately after the abrupt opening of the valve in the first process step. Furthermore a turbulence of the water in the slit can be seen, which causes a water splash out of the slit. In the fourth process step a constant depth of the slit filled with water can be seen. The water jet permeates the water in the slit and is tangent to the ground of the soil for a short time. Afterwards it streams up to the surface of the soil with a small angle. The reason for this is the water inside of the slit. When the jet penetrates the water in the slit it affects as a resistance. The water jet bounces at the surface of the water in the slit and has the tendency to stream out of the water. This leads to a deflection of the water jet. In the process some soil grains are carried by the deflected water jet and are put down in an upper position. The whole injection process affects damping to the water jet. This leads to a decrease of the energy of the water jet.

Only a few soil grains and water are ejected out of the slit in the soil. That is why this method can be termed as an injection of water into the soil.

Results of the trials

Water splashing during the injection process. Against the background of the fertilizer injection water splashing out of the slit is not useful. If water splashing takes place the splashed fertilizer is laying down on the surface of the soil. There it is not available for the plants. **Figure 3** shows four details of a picture taken by a high-speed camera. The goal of the examination is the analysis of the jet structure and the injection behaviour of the high-pressure jet into the soil. For this purpose, the valve is opened suddenly while the nozzle is moving over the soil sample. As shown in detail 1, the high-pressure jet forms after the sudden opening of the valve and hits the soil surface. Detail 2 shows how the high-pressure jet penetrates into the soil without water splashing. Only the ejection of a few soil grains can be discerned. This process continues while the linear axle is moving on, as shown in detail 3. Meanwhile, the slit which is forming in the soil is filling with injected water. This causes heavy turbulence in the injected water so that briefly water splashing out of the slit can be observed, as shown in detail 4. As the linear axle moves on, the slit in the soil becomes longer, and the resul-

Fig. 3



Splashing of water after opening the valve: (1) sudden opening of the valve, (2) high-pressure jet penetrates into the soil, (3) briefly water splashing out of the slit, (4) quasi-static condition ting growing cushioning effect of both the injected water and the slit walls reduces the turbulence in the slit. Therefore, the splashing shown in detail 4 subsides, and a quasi-static condition comparable with detail 3 establishes itself.

Flow behaviour of the water jet and whereabouts of the water in the soil. If coloured sand poured layerwise into the box is used, the flow behaviour of the water jet in the soil can be discerned very well. Therefore the soil is taken out of the injection box in one piece, and the individual layers are removed along the slit direction and at right angles to the slit. The face cut allows conclusions about the course of the high-pressure jet in the soil to be drawn. **Figure 4** shows a cross-section of a soil sample.

The coloured sand layers and the slit formed in the soil can be distinguished very well. At the bottom of the slit, an area can be seen where grains of all coloured sand layers are found in a mixed form. This mixing of the soil indicates heavy turbulence in the water at this place. Soil mixing cushions the high-pressure jet so that the water does not splash out of the slit. One also sees that the grains of the lower sand layer cannot only be found in the lower sand layer, but also in the area of the slit above the mixed soil and, hence, up to two layers above the lower sand layer. This indicates that in particular the water in the area of the lower sand layer has the tendency to flow upwards out of the slit. The soil grains carried along by the water settle in the upper layers. However, one can assume that the motion of the water flowing upwards is reduced very strongly because no water splashing out of the slit was observed during the trials.

Other trials focus on whereabouts of the water in the soil. For this purpose, black-light liquid is added to the high-pressure jet and the trial is done as described above. **Figure 5** shows a cross section of a soil sample illuminated by black light. Here, the slit which is forming in the soil can also be distinguished very clearly. In addition, the black-light liquid shows that the injected water remains at the bottom of the slit. The injection depth measured here is about 75 mm. There, the injected water forms a depot, and some water seeps into deeper soil layers.

Literature

Books are signed with ●

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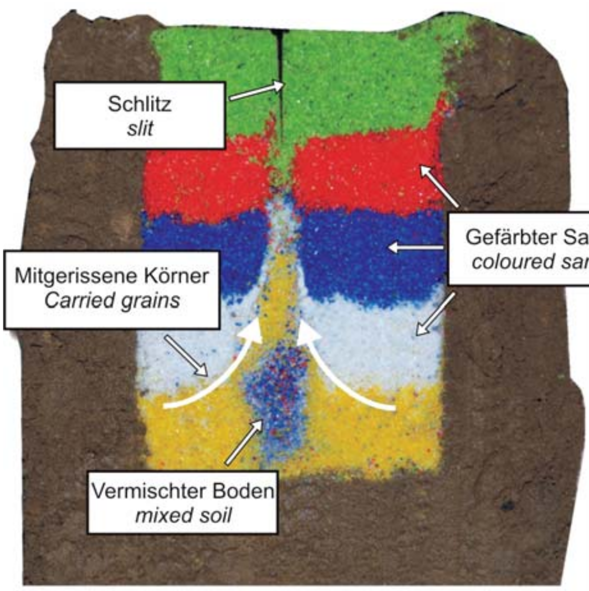
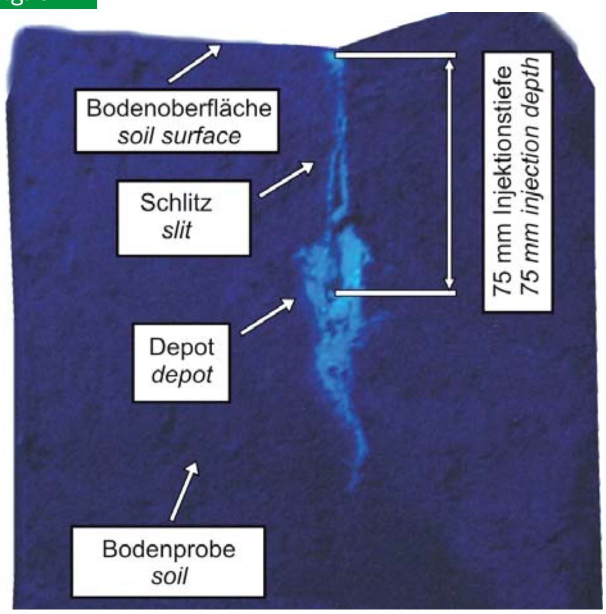
Fig. 4



Cross-section of a soil: Coloured sand poured layerwise

Fig. 5



Cross-section of a soil Injektion with black-light liquid