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Opportunities and Challenges for Real-time Control of Seeding Depth

Infinite seeding depth variation plays no role in agricultural application. Modern spacing drills have a mechanically adjustable seeding depth which is seldom used, because operators lack the necessary facts about the appropriate settings. Differing soil types and topographic variations cause varying water contents in the top soil layer. A simulated model for maize incorporates this small-site spatial variability. Through seeding depth variation, almost uniform conditions for germination can be established.

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Germination and emergence is an important process in growing vegetable products. For a quick and even germination a sufficient amount of water, oxygen and heat must be available for the seeds. Soil and it's physical properties play a decisive role for the germination conditions. Laboratory trials showed that optimum temperatures, free water availability and a shallow seeding depth guarantee a quick emergence. But outdoor conditions are more complex. The inverse vertical gradients of soil temperature and soil moisture [1] make optimum temperatures and free water availability impossible.

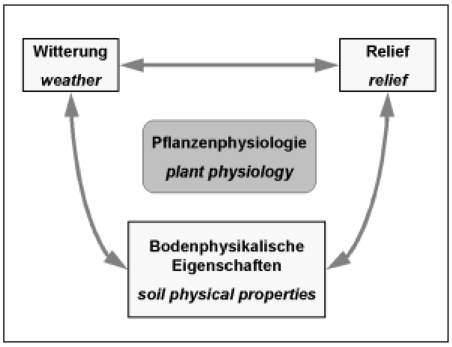

Fig. 1: Factors in the soil determining germination

Soils as place for germination are part of a complex system consisting of soil physical properties, weather and relief (*Fig. 1*). Different germination conditions depending on time and location cannot be expressed in recommendations for seeding depths. Up till now maize is sown, depending on the kind of soil in four centimetre on heavy and six centimetres on light soils [3, 7].

Germination determining factors

Temperature has a major influence on the germination duration of corn [6]. As temperature raise the imbibition rate of the seeds also increase, not depending of the soil matrix potential [5]. Maize needs a sufficient temperature supply because of the physiological minimum temperature of 10° C. At low soil temperatures the growth of the coleoptile ceases and the first leafs break through the coleoptile below soil level.

Cool and moist conditions impede the maize development but the moist environment is favourable for fungi pathogens. This results in reduced seedling emergence and increased fungi infections.

After temperature soil moisture has the greatest effect on germination as germination occurs only after water imbibition. The imbibition rate of the seed depends on the matrix potential of the soil, the hydraulic conductivity of seed and soil as well as the contact area between soil and seed [6].

It's easy to transport enough water necessary for germination in a wet soil. But in a dry soil water movement is too less for germination [2]. Water potential in soil and seed become even and therefore the missing gradient is responsible that the water adaptation of soil and seed become zero.

Opportunities of soil physical and plant physiological models

The determination of the best seeding depth requires the consideration of spatial variability and plant physiological properties. With soil physical properties and weather data (air temperature, precipitation, irradiation, relative humidity and wind speed) it is possible to describe temperature and soil moisture in dependence of time and place. In a field trial in April 2004, measured and calculated temperatures and soil moisture contents were compared. *Figure 2* shows the temperature values in depths of four and six centimetres. A correlation coefficient of r=0,96 was found. Temperature and moisture courses calculated in this way build the basis of plant physiological models that enable the description of germination and emergence processes. A satisfactory description of the germination and emergence duration but on condition that the weather conditions are known. For detecting a favourable seeding depth it is necessary to calculate germination and emergence duration before sowing and therefore the future weather conditions must be estimated. Stochastic weather models can be used to generate conceivable weather data, based on history weather conditions.

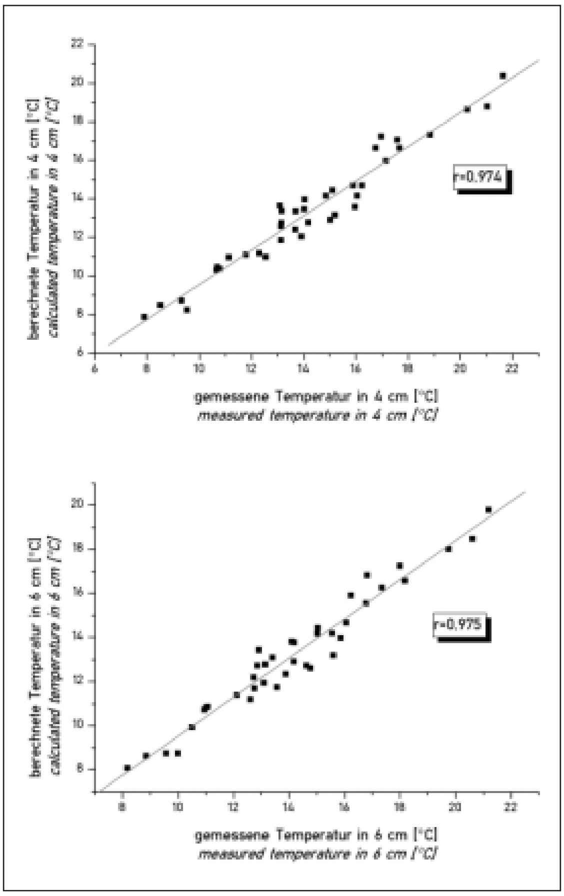

Fig. 2: Calculated and measured soil temperature in a depth of 4 cm (above) and 6 cm (below)

Real time control of seeding depth

A real time control of seeding depth requires more than the simulation of soil physical and plant physiological processes. The current temperature and moisture conditions in the field play an important role. Therefore the current soil temperature and soil moisture needs to be measured while crossing the field [4]. The site properties and the models mentioned before allow to predict future temperature and moisture conditions and with that possible germination and emergence durations. But the present computer power precludes an online execution of all calculation steps on the drill with a satisfying spatial resolution. To ensure a quick control of the seeding depth it is practical to use a multi-stage procedure. First temperature and moisture conditions as well as germination and emergence durations are simulated for different surroundings and saved into an array. During seeding the seeding depths are then retrieved from a database in dependence of the position, soil temperature and soil moisture and adjusted on the drill unit (*Fig. 3*).

Outlook

The online variation of seeding depth supplements precision farming with another procedure. Field trials on different locations will now show whether this new procedure provides faster emergence and a more homogeneous crop. This might reduce the weed pressure and therefore the application rates of herbicides. Another positive effect is the reduction of soil erosion because of the fast soil coverage as well as a process improvement in no-till farming. It also improves dryland farming as a moisture depending seeding procedure and cost and energy intensive irrigation might become unnecessary. A homogeneous crop could also lead to higher yields.

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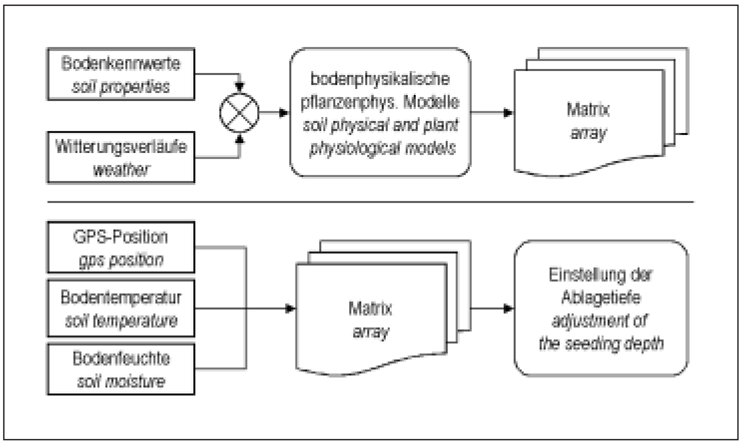

Fig. 3: Multi-stage procedure for real-time control of seeding depth