Response of plants to changes in the soil that are controllable by tillage

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Preparing the programme of this conference we found the best way to discuss this subject would be to raise the following question and to try how many answers we can find:
"Is it possible to indicate which relations between soil tillage and crop growth are the most important ones, which relations we suppose and which we have proved for different climates, soil types and plants?"
As a matter of fact investigations concerning the relations between certain tillage operations and plant growth have been carried out on many places all over the world. But it is also a fact that their results (e.g. the influence of a special tillage operation for a certain crop) will differ very often not only from place to place but also at the same location depending on varying climatical conditions throughout the year. The difficulty and the reason for many wrong conclusions is that a special tillage method we use in most cases is not the only and direct cause for a certain response of the yield. Mostly it is not more than an initial factor which may influence in a very different and changing way many other factors which are of importance for plant growth during the whole vegetation time.
Therefore, I doubt if we are on the right way when we ask whether we can achieve a higher yield by ploughing the soil to a certain depth or by using a special method of seedbed preparation. We probably better should ask: what happens under the given circumstances (soil, location, climate, kind of crop) during the whole vegetation period with regard to the physical, chemical and biological components in the soil and with regard to its temporary, changing, mutual and overlapping influence on plant growth and why did it happen. How complicated and complex these reactions are, can be easily demonstrated by the following facts:
Millions of able and experienced farmers operate their soils year by year to the best of their knowledge and fertilize, saw and protect their plants carefully. So it seems that they have done their best to get high yields. Nevertheless the yields change even under relatively normal conditions not only from year to year but also from field to field on the same farm very often within a range of about $\pm$ 20 %. The decisive reasons for these big changes are the meteorological conditions. Their influence is twofold: One is the direct influence on the growing plant, the other one is acting through the soil because many biological and chemical processes will depend on the physical factors like temperature, aeration and water-household. We all know how many-fold and complicated these interactions between the different factors are.
One great difficulty we always face is the impossibility to predict the climatical conditions throughout the year and to adapt our operations to these unknown conditions. The second difficulty, and from the scientific point of view by far the greater one, is the fact that we don't have a clear knowledge which factors or constellation of factors during a certain period may be of decisive importance to promote

or to hamper plant growth. Furthermore some physical properties which we regard to be unfavourable during a certain period may become favourable ones during another period. So long as we restrict ourselves to find out how a certain initial status (e.g. certain tillage operation) will influence the final result (e.g. the yield) we never will come to satisfactory scientific results and we will never be able to draw practical conclusions for our work under field conditions.
This will only be possible if we find new ways and new methods to follow the permanent changes of the most important factors and their mutual constellations continuously throughout the whole vegetation period and their respective influence on plant growth. With other words, we should be able to record in situ all factors we assume as important for plant growth and we should not have only one harvest but several ones within relatively short periods to analyse plant growth and to find out the interrelations between it and the many factors working in the soil and influencing it.
This seems to be rather difficult. But we did not come together to resign in view of all these difficulties but to discuss the open problems and to find new ways to solve it. As a starting point and a general frame for the special papers which will be presented later on the wide range of the following items have been discussed. This has been done by demonstrating the different aspects according to the observations and the results of scientific experiments of various authors, but mainly to the work of our own institute. As the lecture was completely based on pictures, diagrams and figures, which cannot be reproduced here, only a few catchwords are given to outline the papers' content.

Temperature requirements of plants

a. during germination (e.g. germination-temperature, seedbed-temperature)
b. during growth (e.g. influence of temperature and transpiration on tillering and shooting)
c. manipulating soil-temperature by tillage (e.g. early spring-loosening, influence of consolidation or loosening on soil-temperature, mulches, preventing of frost damages by hoeing)

Aeration requirements of plants

a. needs of the germinating seed (e.g. structure of the seedbed and the rootbed, reaction of roots on soil aeration)
b. physiological effect of oxygen deficiencies (e.g. reduction processes and plant-reaction, importance of air capacity on heavy soils)
c. temperature and CO_2-production
d. tillage that enhances soil aeration (e.g. requirements of different crops with respect to aeration, adaptation of soil structure to these requirements)

Water needs of plants dependent on tillage

a. location in soil from which water is drawn (e.g. water consumption from different horizons by seed, seedlings and mature plants according to field investigations and trials with suction-lysimeters)

b. how much packing of soil around the seed? (e.g. influence of packing on water capacity especially in light soils, no sharp structure differences within the root zone)
c. aggregate size and water retention (e.g. model experiments about the flex-point of the water retention curve)
d. tillage to reduce soil evaporation (e.g. studies with suction-lysimeters about evaporation on consolidated and loose soils)

Response of plants to

a. depth of tillage (e.g. influence of the depth of the cultivated layer depending on soil type, climate, intensity of rain-fall, topography)
b. fall vs spring plowing (e.g. results of different field experiments)
c. aggregate stability and ways to increase it (e.g. results of model and field experiments concerning the influence of lime, soil conditioners and different methods of seedbed-preparation)
d. soil crusts (e.g. preventing of soil crusts by careful seedbed-preparation, influence of genetical soil properties, hampering of germination by crusts, but also protection of water and structure by crusts)
e. local differences in soil structure (e.g. influence of tillage tools on local differences in soil structure, demonstrated by thin-sections, importance of micromorphological studies for a better knowledge of soil structure and the choice or the development of suitable methods to measure the various physical soil properties).

All these examples could not be much more than spotlights on the very complicated system of the soil from the viewpoint of tillage problems and could by far not give a complete picture. Their only purpose was to incite the discussion about new ways and better methods to solve the numerous questions we are up against.