CONSERVATION TILLAGE FOR A SUSTAINABLE SUGAR BEET PRODUCTION IN GERMANY – ENVIRONMENTAL AND PHYTOPATHOLOGICAL ASPECTS

DR. H.-J. KOCH[1], C. PRINGAS[1], DR. J. SCHERER[2]

[1] *Institute of Sugar Beet Research, D-37079 GÖTTINGEN;*
[2] *Südzucker AG, Agricultural Department, D-74254 OFFENAU*

ABSTRACT

Soil compaction and soil erosion can be severe environmental hazards which are closely related to agricultural land use. In arable cropping conservation tillage can be an effective measure to protect the environment against these hazards. In Germany, awareness of ecological and economical benefits has resulted in a substantial increase of the beet crop area cultivated with conservation tillage systems during the past years (about 25 % of the national beet crop in 2002). These tillage systems require less input in terms of energy (minus 8 %) and are characterized by plant residues remaining on the soil surface (10 to 50 % soil cover) to prevent soil erosion (soil losses reduced by 95 %). Additionally, stable soil structure generated by conservation tillage increases the machine bearing capacity and protects against subsoil compaction. On the other hand, the development of pests and diseases (slugs, DTR and *Fusarium sp.* in wheat) can be promoted by plant residues on the soil surface. These aspects are reviewed with reference to long term results from German field experiments.

KURZFASSUNG

Bodenerosion und -verdichtung stellen erhebliche Gefahren für die Umwelt dar, die eng an die Form der landwirtschaftlichen Bodennutzung gekoppelt sind. Pfluglose, konservierende Bodenbearbeitung ist eine wirkungsvolle ackerbauliche Maßnahme, um den Boden vor diesen Gefahren zu schützen. In Deutschland hat das Bewusstsein für die ökologischen, aber auch für mögliche ökonomische Vorteile konservierender Bodenbearbeitung zugenommen und zu einer Anwendung dieser Bearbeitungsysteme auf ca. 25 % der bundesweiten Zuckerrübenfläche (2002) geführt. Bezogen auf das gesamte Produktionsverfahren von Zuckerrüben ermöglichen Systeme pflugloser Bodenbearbeitung einen geringeren Primärenergieaufwand (minus 8 %). Sie sind charakterisiert durch den Verbleib von Pflanzenresten auf der Bodenoberfläche (10 bis 50 % Bodenbedeckung), die wesentlich zum Erosionsschutz beitragen. Zusätzlich wird durch konservierende Bodenbearbeitung ein stabiles Bodengefüge geschaffen, das die Tragfähigkeit für landwirtschaftliche Maschinen erhöht und die Gefahr der Verdichtung des Unterbodens senkt. Pflanzenreste auf der Bodenoberfläche können andererseits Infektionsquellen für Pilzkrankheiten (DTR und *Fusarium sp.* an Weizen) sein und die Ausbreitung von Schädlingen (Schnecken) fördern. Anhand von Ergebnissen aus langjährigen Feldversuchen in Deutschland werden die Wirkungen konservierender Bodenbearbeitung auf die genannten Aspekte diskutiert.

ABRÉGÉ

L'érosion et le compactage du sol exposent l'environnement à des risques considérables; leur survenance et leur ampleur sont étroitement associées à la forme d'exploitation agricole du sol. Un travail conservateur de ce dernier, sans charrue, constitue une mesure culturale efficace pour protéger le sol contre de tels risques. En Allemagne s'intensifie la prise de conscience des avantages écologiques mais aussi des avantages économiques pouvant accompagner un travail conservateur du sol, et a conduit à utiliser ces systèmes de travail sur env. 25 % des surfaces affectées, en 2002 et sur tout le territoire allemand, à la culture de la betterave sucrière. Comparés au procédé global de production des betteraves sucrières, les systèmes de traitement sans charrue permettent d'économiser de l'énergie primaire (moins 8 %). Ils se caractérisent par le fait que les déchets végétaux restent à la surface du sol (couverture de 10 à 50 % du sol) et lui offrent ainsi une protection essentielle contre l'érosion (la diminution de l'érosion peut atteindre 95 %). En outre, le travail conservateur du sol confère au sol une structure robuste qui accroît sa portance sous les roues des machines agricoles et réduit le risque de compactage du sous-sol. D'un autre côté, les déchets végétaux couvrant le sol peuvent favoriser la prolifération d'organismes nuisibles et de maladies (limaces, DTR et *Fusarium sp.* dans le froment). Ces aspects sont examinés sur la base des résultats provenant d'expériences à long terme effectuées dans les champs.

INTRODUCTION

In Germany, environmental aspects of agricultural land use are of great public concern at present and arable cropping systems must prove to be environmentally safe on a high level. Some of these aspects are closely related to the soil tillage system the farmer applies. 15 to 20 years ago, concern was restricted to the control of water erosion, but recently precautions against subsoil compaction and the reduction of the energy input in crop production (with respect to the global warming process) gained importance. The first part of the presented review is dedicated to these three environmental aspects of soil tilllage.

The second part will deal with some phytopathological problems which may arise from conservation tillage under German conditions concerning soils, climate and crop rotation. These problems may severly limit the area of arable land under conservation tillage and thus have to be taken into account seriously. Main topics are: Cercospora leaf spot disease in sugar beet and Fusarium ear disease in winter wheat.

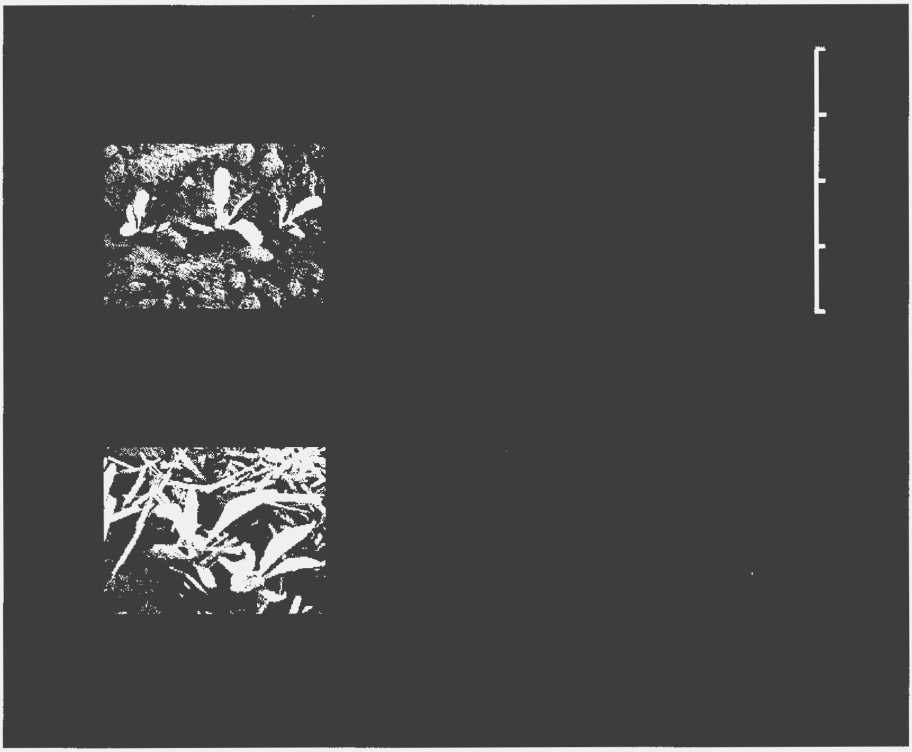
The results shown were mostly generated from a series of long term tillage trials which are jointly conducted with Südzucker AG on 9 farms in Southern and Eastern Germany (MILLER et al. 2003).

1. ENVIRONMENTAL ASPECTS

1.1. SOIL EROSION

In 1998, the German Federal Soil Conservation Act (BBODSCHG 1998) was released, which obliges farmers to avoid soil erosion as far as possible. In case of repeated severe erosion events on a distinct field resulting in soil deposition on public roads or ditches, the farmer can be forced to apply conservation tillage or even to abandon the cultivation of susceptible row crops like maize or sugar beet.

Fig. 1: Long term tillage effect on soil losses due to water erosion in a sugar beet field (WEGENER 2001).



Calculated by the erosion model 2D/3D (SCHMIDT et al. 1997) for a distinct field in the hilly region of Saxony, Germany, with a silty loam soil texture and a mean annual rainfall of 550 mm. Calculation was done for the period from May to September of an average year.

Figure 1 illustrates the potential of long term conservation tillage to reduce soil water erosion in a sugar beet field with a silty loam soil located in a hilly region in Eastern Germany (WEGENER 2001, SCHMIDT et al. 1997). The greyish line in the background shows the course of the slope in the field. Based on the regional long term average rainfall, soil losses were calculated for each spot of the field for the time period from May to September. Added up for the total field, long term conservation tillage reduced soil losses almost to zero compared to losses of about 10 t per hectare and year with conventional tillage.

It is well documented, that this reduction is caused by plant residues remaining on the soil surface, mainly straw of the previous cereal crop or of a catch crop like mustard (SINGER et al. 1981). After sowing sugar beet until row closure at least 30 % of mulch cover is needed to protect the soil efficiently (FRIELINGHAUS et al. 2001). Additionally, increased numbers of deep burrowing earthworm species are observed on fields under long term conservation tillage. The burrows created by these earthworms are responsible for improved water infiltration and thus reduce erosion (EHLERS 1975).

1.2. SOIL COMPACTION

Along with the development of more efficient agricultural machinery during the last decades, the machine masses have increased (SCHULZE-LAMMERS & STRÄTZ 2002). Simultaneously, scientific and public concern about negative effects of heavy machines on soil structure and soil functions has grown (GYSI et al. 1999, ARVIDSSON 2001, KOCH et al. 2003). This discussion often focuses on 6-row self-propelled sugar beet harvesters, which harvest 70 to 80 % of the German sugar beet crop at present (MERKES et al. 2001).

Fig. 2: Soil pressure underneath the wheel of a 6-row self-propelled sugar beet harvester as affected by soil tillage. Measured with Bolling probes (redrawn from BRUNOTTE et al. 2000, SOMMER et al. 2002).

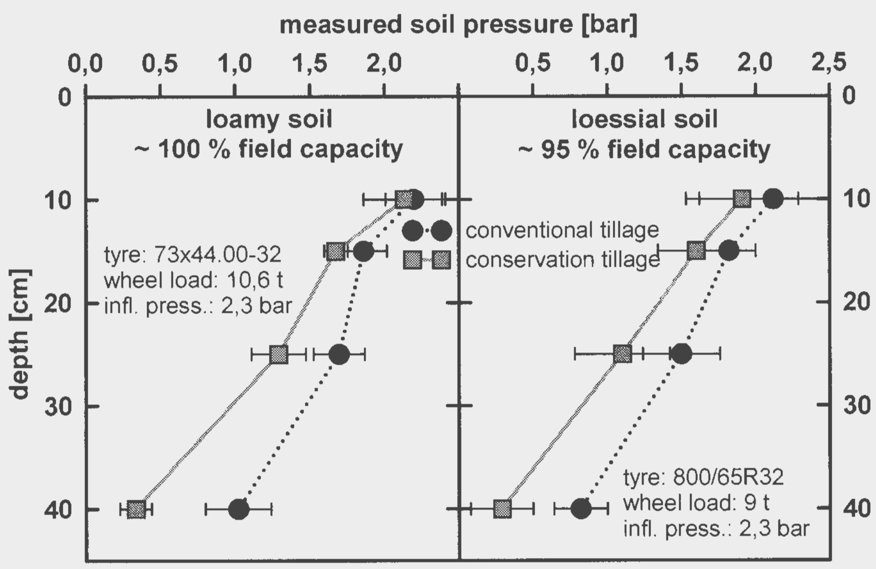
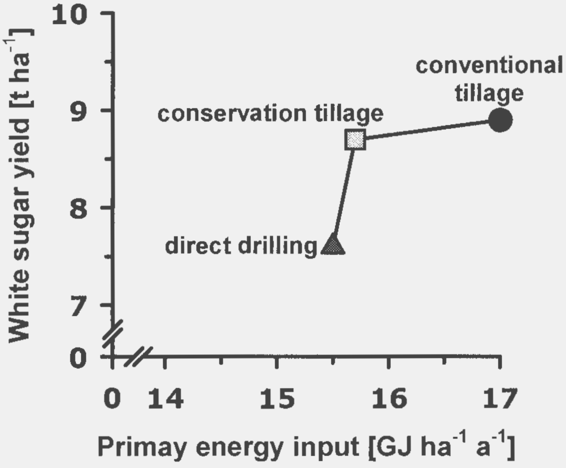


Figure 2 is derived from field experimental data (BRUNOTTE et al. 2000, SOMMER et al. 2002). It shows, how soil pressure underneath the wheel of a sugar beet harvester declines with depth: The mechanical stress exerted by the wheel is data indicate as well, that this decrease of pressure with increasing depth is more pronounced with conservation tillage compared to conventional tillage. It is commonly accepted, that conservation tillage creates a more stable structure in the upper soil horizon, which helps to protect the subsoil against compaction (SOMMER et al. 2002).

1.3. PRIMARY ENERGY USE

Wegener (2001) calculated, that growing sugar beet with conservation tillage saves 1.3 GJ of primary energy per hectare and year compared to conventional tillage (Fig. 3). These savings are mainly due to a reduced input of fuel and lubricants. Yield is only slightly affected by conservation tillage, while direct drilling saves only little extra energy but goes along with marked yield losses.

Fig. 3: Primary energy input and white sugar yield as affected by soil tillage.
Mean of 9 sites 1994-1999, n=17. (Data from WEGENER 2001, modified by STOCKFISCH & MÄRLÄNDER 2002).



Added up for 100.000 hectares cultivated with sugar beet, 130.000 GJ in terms of primary energy or about 10.000 Mg of CO_2 released to the atmosphere can be saved by conservation tillage (calculation based on diesel as the most important primary energy source).

2. PHYTOPATHOLOGICAL ASPECTS

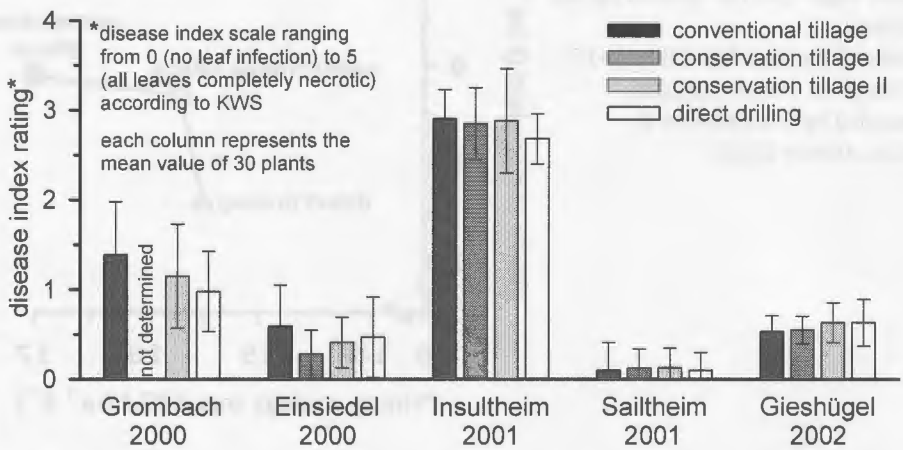
The environmental benefits of conservation tillage are closely linked to crop residues that are left on the soil surface when mouldboard ploughing is omitted. On the other hand, fungal disease attacks may become more severe, if beet tops and cereal straw remain on the soil surface, because conditions for survival of saprophytic fungi are more favourable and therefore the infection potential increases.

2.1. CERSOSPORA LEAF SPOT DISEASE

To test this hypothesis for Cercospora leaf spot disease (*Cercospora beticola*), the Südzucker long term tillage trial was used (PRINGAS 2003). On several sites subplots were artificially inoculated with a Cercospora spore and mycelium suspension to provoke heavily and uniformly infested areas in the field. After harvest leaves were ploughed under or left on the soil surface depending on the tillage treatment. In the following two years cereal crops were cultivated. Afterwards, in the third year sugar beet were grown again and Cercospora disease appearance was rated in this crop.

As it is obvious for all sites of this investigation, the tillage treatment did not influence Cercospora infestation (Fig. 4). Conclusively, conservation tillage seems not to improve the conditions for survival of the fungus over a three year period.

Fig. 4: Influence of soil tillage on Cercospora infestation level of sugar beet leaves. Rating was conducted late in September or October on subplots, which had been severly infested due to artificial inoculation 3 years before (PRINGAS 2003).



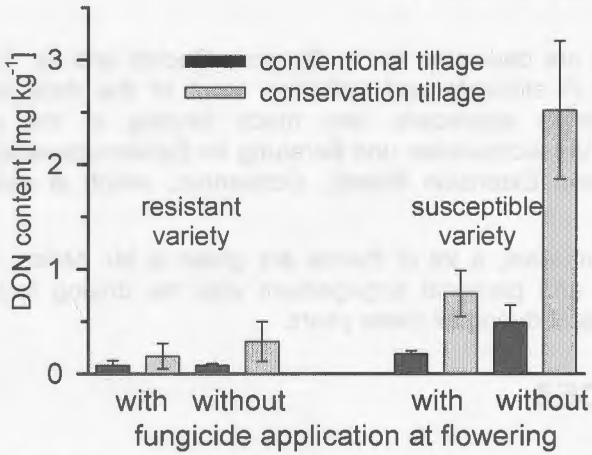
Beyond that, a second kind of „short cut pathway“ of infection might cause an increased Cercospora infestation due to conservation tillage: Cercospora spores originating from beet leaves decomposing on the surface of a distinct field may infect beet plants growing on an adjacent field. This could be the case, if a sugar beet field is neighboured by a wheat crop that is cultivated after sugar beet without being ploughed. Although field observations put some emphasis on Cercospora transmission by this pathway, clear evidence is still lacking.

2.2. FUSARIUM EAR DISEASE

It is well documented that Fusarium ear disease (*Fusarium sp.*) infestation level of wheat grown after wheat or maize may increase, when conservation tillage is applied. Some Fusarium species attacking wheat produce mycotoxins like Deoxynivalenol (DON) in amounts which may limit the use of grains for feed or food stuff. These saprophytic fungi can infect new plants very effectively from straw residues lying on the soil surface.

Furtheron, it is of interest to which extent Fusarium ear disease can be controlled by growing resistant wheat varieties and / or fungicide application during flowering in combination with varied soil tillage. Therefore, these measures were included into a short term tillage trial near Göttingen with wheat following wheat (Fig. 5, PRINGAS 2003).

Fig. 5: Influence of soil tillage on Deoxynivalenol (DON) content of winter wheat grain as affected by variety and fungicide application. (Wheat grown after wheat, means of years 2001 and 2002, PRINGAS 2003)



From the DON content of the grains it is obvious (Fig. 5), that with the susceptible variety only conventional ploughing in combination with fungicide application during flowering results in an acceptable DON content of less than 0.5 mg per kg of grain, a value being discussed as a threshold value at present. If a resistant variety is chosen, DON concentration did not exceed this value with any combination of tillage and fungicide application. Thus, growing a tolerant wheat variety is an effective means to avoid Fusarium mycotoxin problems even with conservation tillage.

CONCLUSION

In Germany, more than 100.000 ha or about 25 % of the sugar beet area were cultivated with conservation tillage techniques in 2002. Most of the German beet crop is grown on well drained, loamy soils that are suitable for conservation tillage. Thus it can be expected that the portion of sugar beet growing area under conservation tillage will increase in future.

Benefits of conservation tillage are:

- the production of high and stable yields,
- the control of soil erosion and of subsoil compaction and
- the lower energy input compared to conventional tillage.

On the other hand, plant residues remaining on the soil surface can promote the development of fungal diseases like Fusarium ear disease in wheat. These potential risks have to be taken into account very seriously and appropriate measures, like growing resistant varieties, have to be considered for control.

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