

EFFECTS OF LONG TERM CONSERVATION TILLAGE ON THE NITROGEN BALANCE OF A SUGAR BEET - WINTER WHEAT - WINTER BARLEY CROP ROTATION

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ABSTRACT

This study displays the effects of conservation tillage on N availability and the N balance of crops. Since 1992 mouldboard ploughing to each main crop and mulching (shallow tillage to a maximum depth of 10 cm) are compared in a sugar beet - winter wheat - winter barley - mustard (catch crop) crop rotation in the Harste tillage trial near Göttingen (North-West-Germany). Besides, N fertilization is varied in four levels respectively to the crop. All crops are grown each year on three neighbouring fields. The experimental fields are organized in split-plot designs with four replications each. N uptake of all three main crops increased with increasing N fertilization. In sugar beet N uptake was influenced by the tillage system. In average of all N-levels the sugar beets of the ploughed treatment took up more N (181 kg N ha^{-1}) than those of the mulched treatment (149 kg N ha^{-1}). N uptake of the cereals was not affected by tillage. Only 42 % of the total N incorporated by sugar beet plants was withdrawn from the field by the roots, i.e. more than half of the incorporated N remained in the field by tops and leaves. In cereals 77 % of the incorporated N (average N uptake: wheat 205 kg N ha^{-1} , barley 143 kg N ha^{-1}) was withdrawn from the field by the grain. The tillage effects on N uptake of sugar beet affected the N balance of the entire crop rotation. Almost settled balances were achieved in the high fertilization levels of the cereals (210 and 180 kg N ha^{-1}) whereas in high fertilization levels of sugar beet (170 kg N ha^{-1}) large balance surpluses occurred. Settled balances can be achieved without significant yield losses if N fertilization of sugar beets is reduced to an amount necessary for maximum white sugar yield (in this case 50 kg N ha^{-1}). During the course of the experiment the absolute height of the balances of the rotations decreased slightly which was due to an increasing yield level.

KURZFASSUNG

Diese Untersuchung zeigt den Einfluss konservierender Bodenbearbeitung auf die N-Verfügbarkeit und die N-Bilanzen der Feldfrüchte. Seit 1992 werden eine wendende Bodenbearbeitung mit dem Pflug zu jeder Hauptfrucht und eine flache Bodenbearbeitung bis maximal 10 cm Tiefe (konservierend, Festboden-Mulchwirtschaft) in einer Zuckerrüben-Winterweizen-Wintergerste-Zwischenfrucht (Senf) -Fruchtfolge im Systemversuch Bodenbearbeitung in Harste (Landkreis Göttingen) verglichen. Neben der Bodenbearbeitung wird die N-Düngung in vier fruchtartspezifischen Düngungsstufen variiert. Der Anbau der gesamten Fruchtfolge erfolgt jährlich auf drei benachbarten Teilschlägen. Die

Versuche sind jeweils als Spaltanlage angelegt. Mit zunehmender N-Düngung stieg die N-Aufnahme der Hauptfrüchte an. Bei Zuckerrüben beeinflusste die Bodenbearbeitung die N-Aufnahme. In der Pflugvariante nahmen Zuckerrüben im Mittel aller N-Stufen mehr N auf als die der Festboden-Mulchwirtschaftsvariante (181 bzw. 149 kg N ha⁻¹). Die N-Aufnahme des Getreides wurde von der Bodenbearbeitung nicht beeinflusst. Zuckerrüben entzogen nur etwa 42 % des aufgenommenen N mit dem Erntegut. 58 % verblieben in Form von Rübenköpfen und -blatt im Feld. Mit dem Korn des Getreides wurden dagegen 77 % des aufgenommenen N entzogen (mittlere N-Aufnahme: Weizen 205 kg N ha⁻¹, Gerste 143 kg N ha⁻¹). Bei Zuckerrüben traten in der höchsten N-Stufe (170 kg N ha⁻¹) deutliche Bilanzüberschüsse auf. Die bodenbearbeitungsbedingten Unterschiede in der N-Aufnahme von Zuckerrüben wirkten sich auf die N-Bilanz der Zuckerrüben sowie der gesamten Fruchtfolge aus. Die N-Bilanzen des Getreides waren dagegen in den höchsten N-Stufen (210 bzw. 180 kg N ha⁻¹) nahezu ausgeglichen. Ausgegliche N-Bilanzen können ohne signifikante Ertragsverluste erreicht werden, wenn die N-Düngung von Zuckerrüben auf das für den maximalen Bereinigten Zuckerertrag notwendige Minimum reduziert wird (in diesem Fall 50 kg N ha⁻¹).

ABRÉGÉ

Cette étude montre l'influence d'un travail conservateur du sol sur la disponibilité de l'azote et sur les bilans azotés des cultures. Depuis 1992, dans une étude systématique menée à Harste (arrondissement de Göttingen, Allemagne), les chercheurs comparent un travail du sol avec la charrue à versoir, à chaque culture principal, et un travail plus léger du sol avec pénétration jusqu'à 10 cm de profondeur maximum (travail conservateur, du sol ferme) dans des champs recevant la succession de cultures suivante : betterave sucrière, blé d'hiver, orge d'hiver, culture intercalaire (moutarde). Outre le travail du sol, ils font varier à quatre niveaux la fertilisation à l'azote, spécifiquement pour chaque culture. La culture de l'ensemble de ces plantes en rotation a lieu chaque année sur trois soles voisines. Les essais sont conçus chaque fois en parcelles partagées. L'absorption d'azote par les cultures principales croît comme l'augmentation de la fertilisation à l'azote. Avec la betterave sucrière, le travail du sol influe sur l'absorption d'azote. Dans la variante de travail à la charrue, ces betteraves absorbent, en moyenne de tous les niveaux de fertilisation azotée, plus d'azote que dans la variante à paillage sur sol ferme (181 et 149 kg de N par ha). Le travail du sol n'influence pas l'absorption d'azote par les céréales. Environ 42 % seulement de l'azote total absorbé par les betteraves est retiré du sol par les racines, c.-à-d. que plus de la moitié (58 %) de l'azote apporté au sol reste dans le champ sous la forme de têtes et de feuilles de betteraves. Par contre, les grains des céréales lui retirent 77 % de l'azote absorbé (absorption moyenne d'azote : 205 kg de N par ha pour le blé, 143 kg de N par ha pour l'orge). Avec les betteraves sucrières ayant reçu la plus forte fertilisation (170 kg de N par ha), de nets excédents du bilan se manifestent. Les différences d'absorption de l'azote par les betteraves sucrières, dues aux différences de traitement du sol, ont des effets sur le bilan azoté de ces dernières ainsi que de tout l'assolement. De leur côté, les bilans azotés des céréales ayant reçu les plus hauts niveaux de fertilisation (210 et 180 kg de N par ha) sont pratiquement équilibrés. Il est possible d'atteindre des bilans azotés équilibrés sans pertes significatives de

rendement à condition de réduire la fertilisation des betteraves sucrières au minimum nécessaire à l'obtention d'un rendement maximal corrigé en sucre (dans ce cas : 50 kg de N à l'hectare).

INTRODUCTION

Long term conservation tillage can be an effective means to improve trafficability, to prevent soil from erosion and to reduce energy costs (EHLERS, 1992). On the other hand, introducing conservation tillage on a field which has been ploughed annually for many years is sometimes reported to have a negative impact on the nutritional status of plants by immobilisation of nitrogen (BAEUMER & KÖPKE, 1989). In 1992 the Harste tillage trial was set up near Göttingen to compare mouldboard ploughing to each main crop with shallow mulching tillage. Within this trial yield losses caused by mulching tillage were observed (STOCKFISCH & KOCH, 2001). This study displays the effects of conservation tillage on N availability and the N balance of cereals and sugar beet. Therefore, simple N balances were calculated for the individual crops and the entire rotation.

1. MATERIALS AND METHODS

The experimental site is located in Harste near Göttingen (North-West-Germany) on a silty loam soil which is typical for sugar beet cultivation. The annual temperature averages 8.8°C and the annual precipitation averages 602 mm. Since 1992 all crops of the sugar beet, winter wheat, winter barley and mustard (catch crop) crop rotation are cultivated annually on three neighbouring fields. On each field the tillage treatments (30 cm deep mouldboard ploughing to each main crop and shallow mulching tillage < 10 cm deep) and four crop specific N-fertilizer levels (Table 1) are organized in a split-plot-design with four replications on stationary plots. Crop and catch crop residues remained in the field. At harvest grain and root yields were determined and crop quality data such as N content, α -amino-N content or sugar content were collected. Besides, quantity and N content of the crop residues were recorded (for wheat and barley this data is missing for the first two experimental years). From this data N uptake and N removal by the crops were calculated. Additionally, simple N balances were calculated for the crops and the entire crop rotations by subtraction of N removal of the crops from N fertilizer application. Fertilizer N applied to the catch crop was included in the balances of the rotations. N inputs from the atmosphere and gaseous or leaching losses were not taken into account.

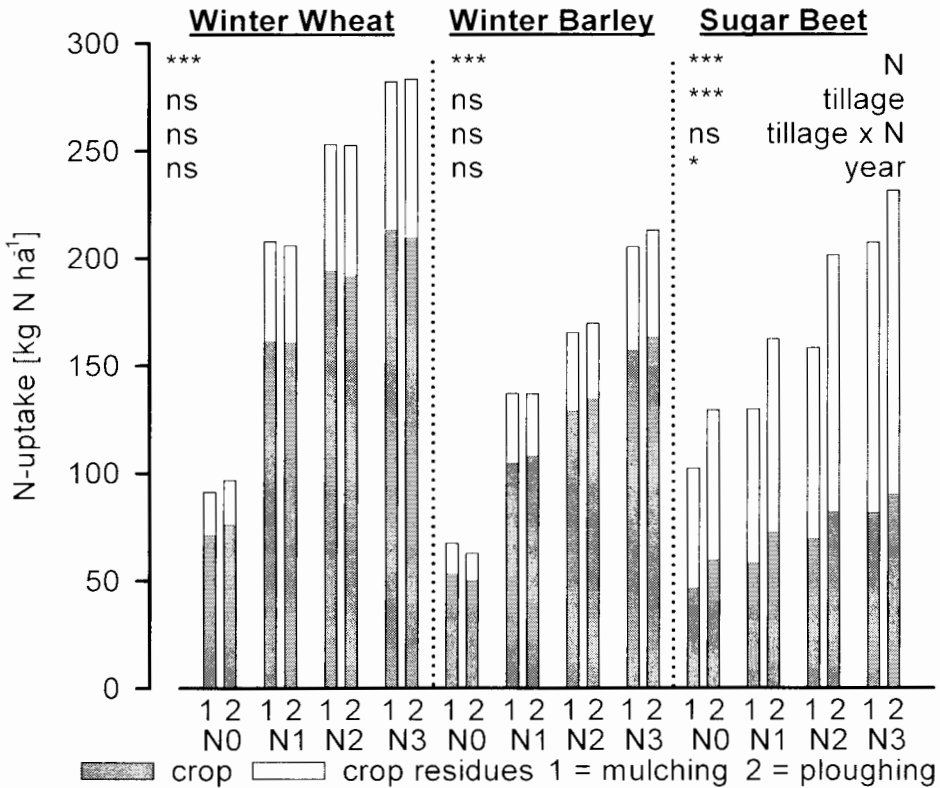
Table 1: Crop specific N-fertilizer levels of a sugar beet, winter wheat, winter barley, mustard (catch crop) crop rotation

N-level	Wheat	Barley	Mustard kg N ha ⁻¹	Sugar Beet	Total / rotation
N0	0	0	50	0	50
N1	110	80	50	50	290
N2	160	130	50	110	450
N3	210	180	50	170	610

2. RESULTS AND DISCUSSION

Fig. 1 shows the N uptake of the main crops which increased with increasing N fertilizer dose. Due to the close relation between N uptake of cereals and grain yield N fertilizer effect on grain yield is reflected by this data. This is contrasted by the sugar beet crop with highest white sugar yields in between fertilizer level N1 and N2 (data not displayed).

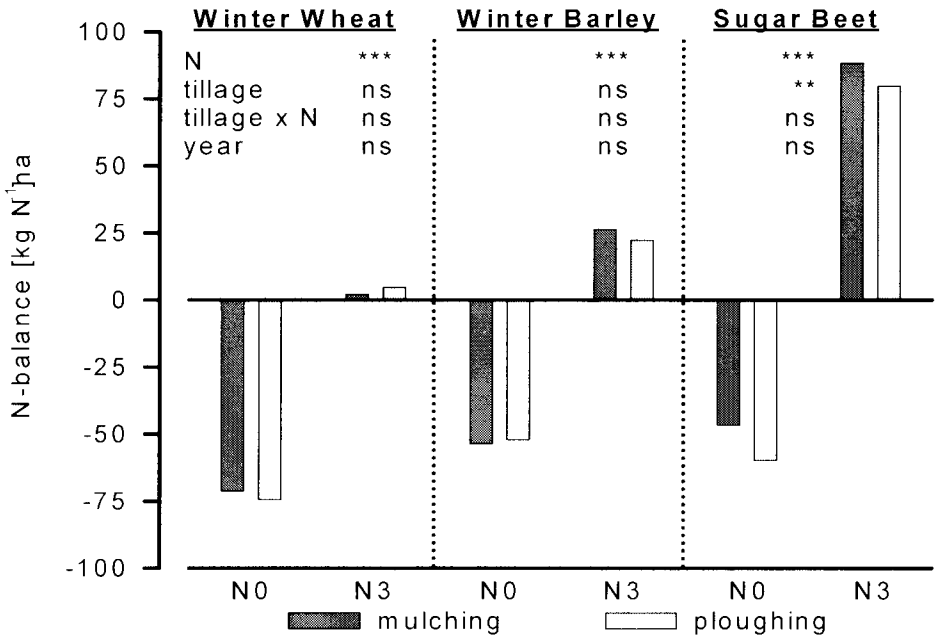
Fig. 1: N-uptake of winter wheat (1995-2001), winter barley (1995-2001) and sugar beet (1993-2001) at different fertilizer and tillage levels; ns = not significant at $\alpha = 0,05$



Obviously, N uptake of winter wheat and winter barley were not affected by soil tillage where as sugar beets of the mulching treatment were significantly lower in N uptake compared to ploughing (Fig. 1). This was due to a lower dry matter production but not to a lower N-concentration in leaves or roots. Thus, no evidence was found for a limited N availability during the first years after introducing conservation tillage on a field that has been formerly ploughed annually. Besides, crops differed in the crop N : crop residue N ratio. The cereals incorporated most of the N in the grain and about 77 % of the total N uptake was withdrawn from the field at harvested whereas in sugar beet only 42 % of the incorporated N was removed.

The N balances differed depending on the crop (Fig. 1). In fertilizer level N3 N balances of winter wheat were settled and those of winter barley were only slightly positive ($24 \text{ kg N ha}^{-1} \text{ year}^{-1}$).

Fig. 2: N balances of winter wheat, winter barley and sugar beet (1993-2001) at different fertilizer and tillage levels; ns = not significant at $\alpha = 0,05$

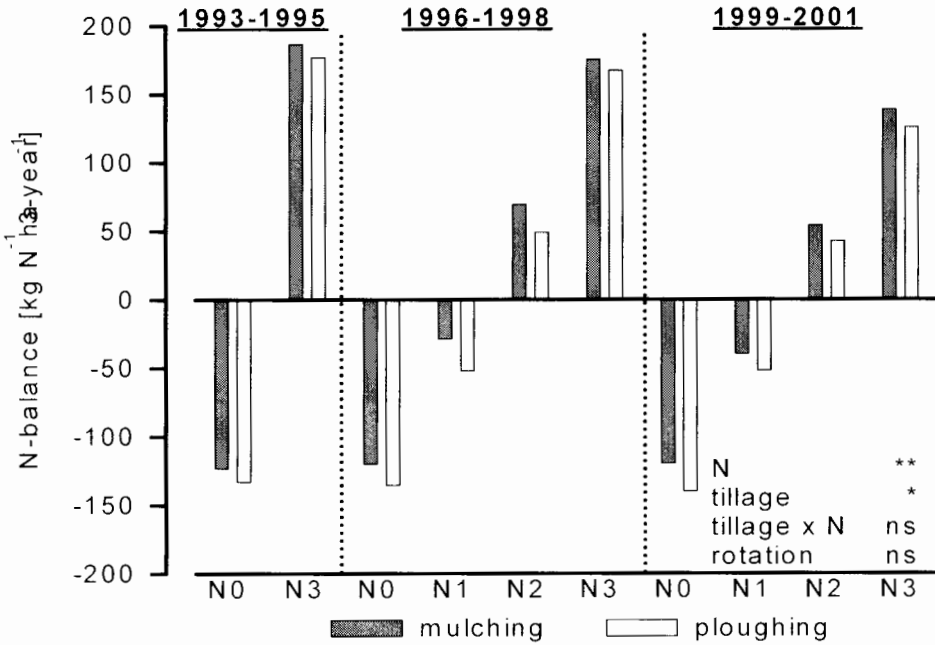


Similar to the N uptake the N balances of wheat and barley (Fig. 2) were not affected by soil tillage. In sugar beet mulching led to less negative and more positive N balances respectively. Highest surpluses occurred in level N3 when mulching was applied (mulching $88 \text{ kg N ha}^{-1} \text{ year}^{-1}$, ploughing $80 \text{ kg N ha}^{-1} \text{ year}^{-1}$). Additionally, the fertilizer level N3 exceeded the fertilization necessary for maximum white sugar yield by far.

Fig. 3 displays the effect of an increasing N application on the balances of the entire crop rotation. It indicates that the optimum N fertilization for settled balances could be achieved in between level N1 and N2 (entire rotation). Surpluses in N3 were ranging from $186 \text{ kg N ha}^{-1} \text{ 3-years}^{-1}$ in the mulching treatment after the first rotation to $125 \text{ kg N ha}^{-1} \text{ 3-years}^{-1}$ in the ploughing treatment after the third rotation. Within these three rotations (1993-1995; 1996-1998; 1999-2001) a slight decline in N surpluses mainly in N3 occurred. This decline was not statistically significant but corresponds with an increasing yielding level in all main crops as already reported by STOCKFISCH et al. (1999).

The N balances of the crop rotations were affected by soil tillage as well. These differences originate from those observed for sugar beet (Fig. 2). If the N surpluses of fertilizer level N3 of sugar beet solely and of the entire crop rotations are compared it is obvious that not only the sugar beet crop causes these surpluses: The sugar beets took up more N than fertilizer N was applied. This was enabled by the mustard receiving 50 kg N ha^{-1} which remained in the field completely; i.e. this N was at least partly available to the following sugar

Fig. 3: N balances of entire crop rotations including the catch crop at different fertilizer and tillage levels; ns = not significant at $\alpha = 0,05$



beet crop by mineralization. Comparably, N derived from sugar beet leaves was available to the following winter wheat. This is approved by the N uptake of wheat exceeding the fertilizer N application.

CONCLUSION

The negative impact of conservation tillage (mulching) on sugar beet N uptake was due to a diminished dry matter production but not to a limited N supply.

Sugar beet and mustard catch crop are mainly accountable for the observed N surpluses because these crops leave residues containing high amounts of N behind. On the other hand, this N contributes to the N nutrition of the following crops.

To achieve more settled balances for the entire crop rotation a reduction in fertilizer application seems to be necessary: without severe yield and quality losses this can be obtained by saving fertilizer N in mustard and sugar beet to an extend of up to $120 \text{ kg N ha}^{-1} \text{ rotation}^{-1}$.

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