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Effect of different K-supply on sugar beet production and soil fertility in a long-term fertilizer experiment

In a long-term field experiment with a duration of 19 years the impact of different rates of potassium (0–100–200–300 kg K_2O/ha/year) with and without farmyard manure (FYM) (30 t/ha every 3 years before sugar beet) on yields, crop quality, K-content in the soil and the economic effects in a sugar beet — wheat — barley crop-rotation was studied. K-rates below crops K-uptake led to a distinct decline in soil fertility. Sugar beet as well as wheat showed an average yield decrease of 35% and 12%, resp. during the whole trial period. FYM increased the yield level especially of sugar beet, but did not affect the optimum K-rate. With negative K-balances and a falling K-content in the soil, sugar yields decreased over the whole trial period combined with a lower sugar content in the roots. For that reason the efficiency of K-fertilization increased with the duration of the experiment. At the described site an extractable K-content of about 250 ppm K_2O was optimum. In order to maintain this soil-K-value a K-application rate exceed the K-removal by 45 kg K_2O/ha/year was necessary.

Key words: crop rotation, K balance, K rates, sugar beet, sugar yield

W długoterminowym (19-letnim) doświadczeniu polowym badano wpływ różnych poziomów nawożenia potasowego (0–100–200–300 kg K_2O/ha/rok) bez i łącznie z nawożeniem obornikiem (30 t co 3 lata pod buraki cukrowe) na plonowanie, jakość plonu, zawartość K w glebie i efekty ekonomiczne w następującym zmianowaniu buraki cukrowe — pszenica — jęczmień. Nawożenie potasem poniżej ilości pobranej przez rośliny prowadziło do wyraźnego obniżenia żyzności gleby. Buraki cukrowe oraz pszenica plonowały niżej o 35% i 12% odpowiednio, średnio za cały okres trwania doświadczenia. Nawożenie obornikiem powodowało podwyższenie poziomu plonowania szczególnie buraków cukrowych, lecz nie miało wpływu na optymalną K dawkę. Wraz z ujemnym bilansem potasu i obniżającą się zawartością K w glebie malał plon cukru i równocześnie obniżała się jego zawartość w korzeniach w okresie trwania doświadczenia. Dlatego też efektywność nawożenia potasem wzrastała wraz czasem trwania doświadczenia. Dla omawianej miejscowości optymalna zawartość potasu wynosiła 250 ppm K_2O. Aby utrzymać ten poziom potasu w glebie konieczna była dawka nawożenia potasowego, przekraczająca jego pobranie przez rośliny o 45 kg K_2O/ha/rok .

Słowa kluczowe: bilans potasu, buraki cukrowe, dawki potasu, plony cukru, zmianowanie

INTRODUCTION

In arable farming systems the nutrient supply is an important factor for sustainable plant production and soil fertility. The nutrient supply in the soil is influenced by the nutrient balance, an often discussed slogan in recent years. In times of decreasing profits farmers try to take advantage of the potash reserves in the soil and potash soil mining is widespread, particularly in some developing countries. But also in many European countries the K-consumption has decreased considerably in the past 10 years, for example in Germany, for example. The following results of a K-fertilizer experiment show that a mid or long-term exploitation of soil-potash leads to lower soil fertility combined with reduced plant production and product quality, even on a site with a high K-content in the soil before starting the experiment.

METHODS

In the long-term K-fertilizer experiment at Niestetal near Kassel/Germany the impact of different K-rates applied with and without farmyard manure (FYM) (30 t/ha every 3 years, corresponding to 80 kg K_2O/ha/year) was examined regarding the development of yield, crop-quality, K-content in the soil and economic effects (Table 1). The field-experiment with a crop rotation of sugar beet — winter wheat — winter barley was carried out for 19 years. Crop residues were removed. The soil type was an Orthic Luvisol from loess deposits with an exchangeable K-content in the soil of 260 ppm K_2O before starting the experiment. The annual averages of precipitation and temperature were about 647 mm and 8,7° C, respectively. The clay and silt contents amounted to 13% and 80%, respectively.

Table 1

Fertilizer treatments of the K-experiment at Niestetal

Plot	kg K_2O/ha/year	Plot	kg K_2O/ha/year
1	0	5	0
2	100	6	100
3	200	7	200
4	300	8	300
without FYM		with 30 t/ha FYM in autumn before sugar beets (corresponding 80 kg K2O/ha/year)	

RESULTS AND DISCUSSION

K-fertilization was highly efficient with regard to plant production (Table 2).
On plots without FYM sugar yield increased by 3.1 t/ha on the average, grain yield of wheat by 0.9 t/ha and of barley by 0.4 t/ha, with increasing K-rates. On the plots with FYM the same K-rate led to a yield increase of 1.5 t/ha and 0.4 t/ha for sugar beets and cereals, respectively. Hence, the yield increase obtained on the plots with FYM was only half of the increase observed on those without FYM.

Table 2

Impact of potassium fertilization and FYM on yield, economic efficiency and K-content in the soil in the long-term experiment at Niestetal 1978–1996

FYM t/ha	kg K_2O/ha/year	Sugar-/grain yield (t/ha)			K-balance 1978-96 kg K_2O/ha/year	K-content in the soil (CAL) Ø 1994–1996 ppm K_2O	Net profit against K-0 EUR/ha/year
		sb	ww	wb			
0	0	5.94	7.06	6.28	-188	65	—
	100	8.08	7.76	6.68	-127	107	241.33
	200	8.56	7.92	6.58	-33	177	268.94
	300	9.07	7.97	6.67	58	283	302.17
	LSD 5%	0.88	0.36	0.31			
30 every 3 years to sb	0	8.30	7.43	6.68	-149	143	—
	100	8.72	7.64	6.90	-58	190	35.28
	200	9.32	7.76	7.01	31	240	80.27
	300	9.81	7.83	7.05	125	330	110.44
	LSD 5%	0.70	0.44	0.35			
	LSD 5% (8 treatments)	0.93	0.47	0.39			

sb — Sugar beet ww — Winter wheat wb — Winter barley

The input/output ratios for K in the different treatments show that K-soil mining leads to lower soil-fertility as it is demonstrated in this case by lower K-content in the soil and a lower yield level on the plots with negative K-balances. This became especially evident in the development of sugar yields during the whole duration of the experiment. On the plots without K-fertilization the yield level of sugar declined from 7 t/ha at the beginning to 4.5 t/ha in the last year (Fig. 1) which is a tremendous loss fertility of (0.17 t/ha/year).

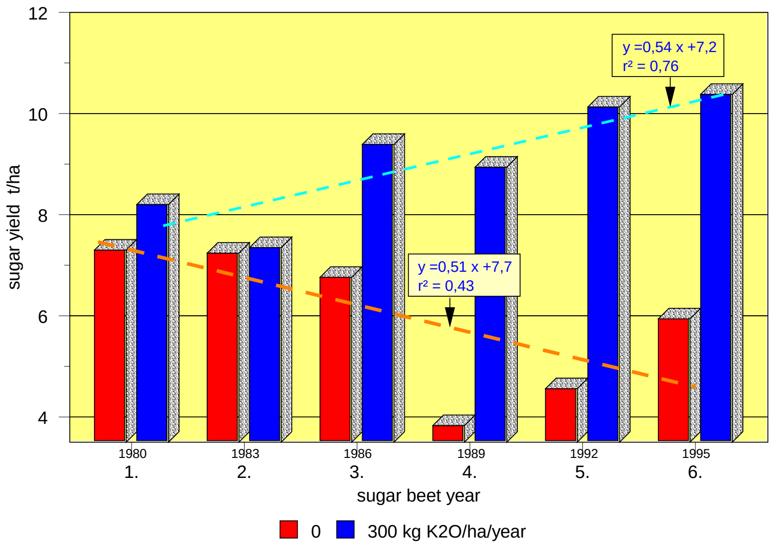

Fig. 1. Sugar yield trends at different K-supply in the K-experiment at Niestetal (1978–1996, without FYM)

In contrast, sugar yield on the plots with 300 kg K_2O/ha increased at a rate of 0.18 t/ha/year due to improved production system (varieties, soil cultivation, plant protection, N-fertilization, etc.). Hence, progress in plant production systems can only be fully utilized if the K-supply with fertilization and/or the K-content in the soil is adequate. In the plots with FYM a similar development could be observed but the differences between the mineral K-treatments were not as drastic as without FYM because of a higher K-content in the soil at the control plots.

The efficiency of K-fertilization increased with the duration of the experiment from the first beet year with 3 kg sugar/kg K_2O to the last year with 15–41 kg sugar/ kg K_2O (Fig. 2). This gives further evidence for the high K-demand of a crop rotation including root crops like sugar beets. Especially under middle and long-term aspects a soil-K-mining strategy leads to high risks of loosing yield and farm income.

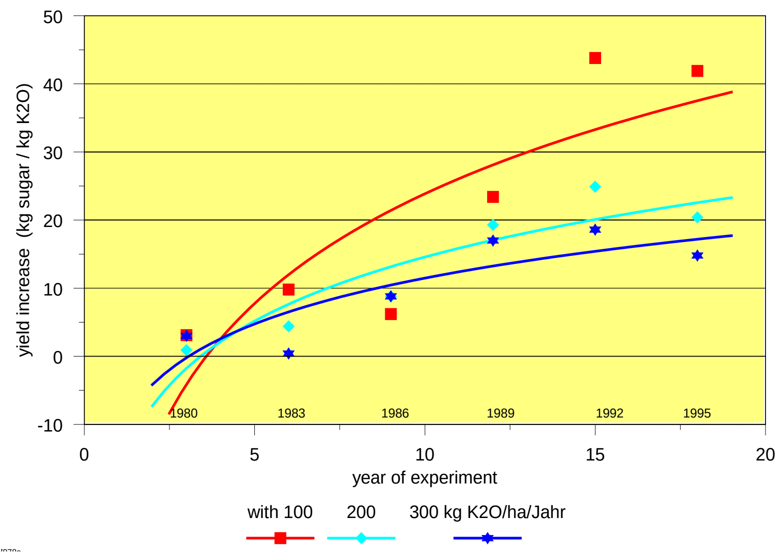

Fig. 2. Changes in the efficiency of K-fertilization (yield increase against control/kg K_2O) of sugar beet during the K-experiment at Niestetal

Of course the K-content of the organic manure has to be taken into account. The impact of FYM can be observed on the basis of yields, K-balance and K-content in the soil (Table 2). The application of FYM raised the general yield level, but especially that of sugar-beet. FYM increased sugar yields from 5.9 to 8.3 t/ha on the plots without mineral potassium. The main reason for this effect is probably due to the K-input through FYM. On the control plots K-deficiency symptoms were observed regularly because of a low K-content in the soil. In the treatment with FYM but without mineral potassium the K-content was twice the amount of the control plot without FYM.

On the plots with mineral K-fertilization the effect of FYM was less significant (0.7 t sugar/ha) and almost independent from the K-rate. Although FYM reduced the efficiency of K-fertilizer it did not affect the optimum K-rate, yields as such increased almost to the same extent through FYM-application on all plots with mineral potassium. Comparing the average yields of the whole crop rotation, highest yields were obtained by combined application of FYM and mineral fertilizer, an often observed result in long-term experiments (e.g. Körschens et al., 1994).

Beside the K-effect on yields also an impact on crop quality was observed. Decreasing K-contents in the soil led to a reduction of sugar formation and sugar translocation into the roots. Data from Peoples and Koch (1979) provide a clear illustration of a positive relationship between K-supply and photosynthesis as well as photorespiration, but a negative correlation to the dark respiration. K-values below 170 ppm K_2O led to an average loss (Fig. 3) of 0.5 % in the sugar content, in dry years even more than 1.5 %. The sugar content is an important part of the sugar beet payment-system in the European Community. This fact has therefore further-reaching influences on the economic of efficiency of K-supply and K-fertilization. A plus of 0.5 % sugar raises the beet price by about 0.20 EUR/dt, that means a yield level of 50 t/ha leads to an additional farm income of about 102.26 EUR/ha due to better crop quality.

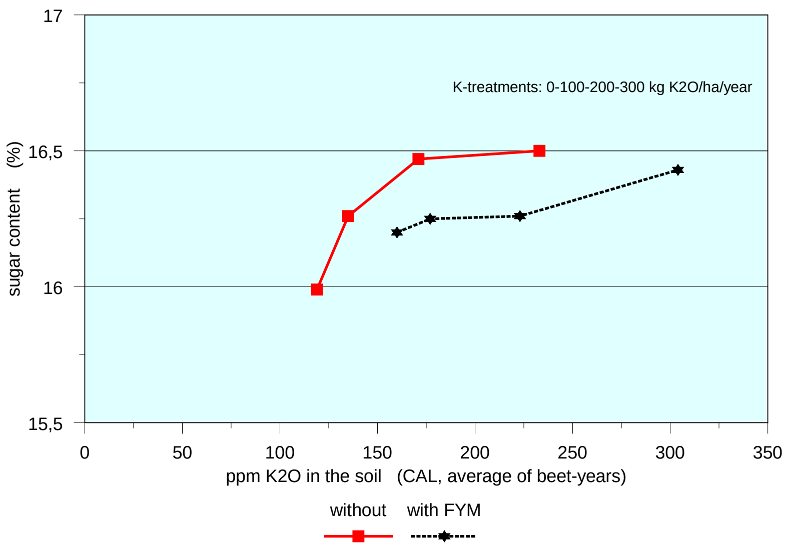

Fig. 3. Impact of different K-supply on sugar content of sugar beets in the K-experiment at Niestetal

The impact of the different K-rates and K-balances can be clearly observed by means of the K-content in the soil. Negative balances led to a decline of the exchangeable K-content in the soil, whereas K-supply to the soil increased the K-balances positively (Fig. 4). The relationship between K-balance and the change of K-content in the soil was almost independent from the application of FYM. However, K-fixation and K-sorption at the clay minerals led to a decrease of the K-content in the soil if K-rates were applied at the level of K-taken up by the crop. Similar results were obtained on other sites (Orlovius 1994, 1996).

On the base of the regression equation, a K-rate of about 45 kg $K_2O \cdot ha^{-1}$ $year^{-1}$ higher than the K-taken up by the crops was needed to maintain the soil K-value observed at the beginning of the experiment.

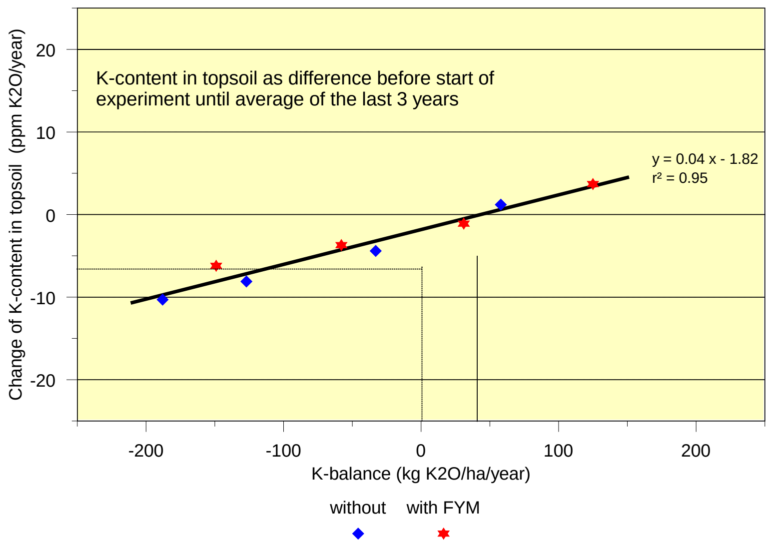

Fig. 4. Change of K-content in topsoil at different K-balance in the K-experiment at Niestetal (1978–1996)

CONCLUSIONS

Soil fertility can not be sustained with a decreasing K-content in the soil plant production. The optimum K-content in the soil is mainly determined by the K-demand of the broad leaved crops within a crop rotation. Plants with a high dry matter production like beets, potatoes, rape, maize, most vegetables have a higher K-demand than cereals, for example. With an insufficient K-supply the efficiency of other production factors (e. g. N-fertilization) is also reduced. Consequently adequate K-nutrition is a prerequisite for supporting the general progress of the whole production system (varieties, plant protection, soil cultivation, N-management, etc.). The required K-content in the soil for optimum exploitation of the yield potential at the presented site was about 250 ppm K_2O. In order to maintain this K-level in the soil a K-application rate which exceeded the K-removal from the field by 45 kg K_2O/ha/year was necessary. The K-content decline in the soil below 250 ppm K_2O reduces yield, crop quality, and income significantly.

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