Effect of High and Low-Input Nutrient Systems on Soil Properties and their Residual Effect on Sweet Corn.
I. Soil Properties

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1 Introduction

It is known that contemporary agriculture takes an active part in the changes of the environment and those environmental factors influence agricultural production. Under the intensive system of crop cultivation, some negative effects due to high input practices can not be avoided and its participants are obliged to develop such production methods that will be least hazardous to the environment and not significantly less productive. At the present circumstances of energy crises, it is common practice to make a precise balance of available resources and encourage their rational management. In this respect ecological systems are formed that are capable of using by-products of different production processes.

The reuse of organic wastes may be a useful contribution to the sustainable development in agriculture. Agriculture is predestined to accept organic residues. The pretext is not just the maintenance of nutrient cycles but also the prospects of economic utilisation that makes the employment of organic wastes in agriculture preferable to dumping them. The quantities of organic wastes applied to land world-wide steadily increased during the last two decades. The use of sewage sludge in agriculture as a partial substitute of fertilisers and an amendment for soil physical properties has been well recognised. Most sewage sludges contain nutrients that could be used to improve soil fertility. Further-more beneficial changes may be seen in soils with low organic matter content which are prone to soil structural degradation as well as loss of soil fertility. However, realisation of potential value has been accompanied by concerns regarding soil environmental problems (organic and inorganic xenobiotics) resulting from the use of contaminated sludge. Sludge contaminated with organic xenobiotics should be excluded from disposal on agricultural farm land as no objective risk assessment is possible. Incineration of such sludges proved to be a practical way to reutilise such products (HANEKLAUS et al. 1999).

The present study investigates the use of organo top (purified sewage sludge) as a potential fertiliser. The main objective of the study is to evaluate the fertility status of the soil after its fertilisation with conventional (inorganic) fertiliser and organo top.

2 Methods and Materials

To evaluate the agronomic effectiveness of organo top as a potential fertiliser, a green house experiment was conducted using fibre sorghum as a test crop. A bulk soil sample (0-30 cm) was collected from the experimental field of FAL, Braunschweig, Germany (E 10.451°, N 52.295 °). The main physico-chemical properties of the experimental soil were: Soil texture - sandy loam (61 % sand, 33.4 % silt and 5.6 % clay); pH - 7.23 (in 1:2.5, soil: $CaCl_2$, 0.025 N suspension); EC - 216 µS cm^{-1} (1:5 soil:water); N_{min} - 24.2 mg kg^{-1} soil; available P - 174.6 mg kg^{-1} soil; available K - 105.4 mg kg^{-1} soil; available S - 18.4 mg kg^{-1} soil; available Mg - 40 mg kg^{-1} soil. The nutrients were added according to the treatment plan outlined in **table 1**. Urea, KCl and $MgSO_4$ salts were used as source of N, K and S, respectively. The crop was harvested at full maturity after 6 months and soil samples were taken immediately after harvesting. Air dried samples (2 mm sieve) were analysed for: pH, EC, organic C, total N, available P (colorimetrically in

Table 1: Details of the treatments used in the study

Symbol	Fertiliser application rates (kg ha^{-1})	
T_1	$N_0K_0S_0$	(Control)
T_2	$N_{120}K_{200}S_{60}$	(N @ 120, K @ 200, S @ 60 kg ha^{-1}; recommended dose, reference treatment)
T_3	$N_{60}K_{200}S_{60}$	(N @ 50 % of recommended dose, full dose of K and S)
T_4	$N_{30}K_{200}S_{60}$	(N @ 25 % of recommended dose, full dose of K and S)
T_5	$N1_{120}K_{100}S_{60}$	(K @ 50 % of recommended dose, full dose of N and S)
T_6	$N_{120}K_{50}S_{60}$	(K @ 25 % of recommended dose, full dose of N and S)
T_7	$N_{120}K_{200}S_{30}$	(S @ 50 % of recommended dose, full dose of N and K)
T_8	$N_{120}K_{200}S_{15}$	(S @ 25 % of recommended dose, full dose of N and K)
T_9	OT_{160}	(60 g OT pot^{-1} equivalent to 120 kg N ha^{-1})
T_{10}	OT_{60}	(30 g OT pot^{-1} equivalent to 60 kg N ha^{-1})
T_{11}	OT_{30}	(15 g OT pot^{-1} equivalent to 30 kg N ha^{-1})
T_{12}	$OT_{60}F_{60}$	(60 kg N ha^{-1} from OT + 60 kg N ha^{-1} from fertiliser)
T_{13}	$OT_{90}F_{30}$	(90 kg N ha^{-1} from OT + 30 kg N ha^{-1} from fertiliser)
T_{14}	$OT_{200}F_{75}$	(1 packet of organo top supplying N equivalent to 200 kg ha^{-1} +1 pallet of ADK supplying N equivalent to 75 kg ha^{-1})

CAL extract, 0.6 % calcium lactate, $C_6H_{10}CaO_6.5H_2O$, pH 3.6); available K (in CAL extract measured by flame emission spectrophotometry); available Mg (extracted with 0.025 N $CaCl_2$ and measured by flame emission spectrophotometry. N_{min} was determined in fresh soil samples using 0.0125 M $CaCl_2.2H_2O$ as exractant and determination by an autoanalyser.

2.1 Organo Top (OT) and ADK

The organo top produced by Recycling und Umweltschutz GmbH, Gerwisch, Germany is a multinutrient (N - 2 %; P - 0.83 %; K - 0.43 %; Mg - 1.28 %; Ca - 1.72 %; pH (1:5) - 12.80; EC (1:5) - 6.35 mS cm^{-1}; total C - 18.09 %; organic C - 13.37 % and C:N - 1:9) organic fertiliser which has been prepared from sewage sludge so that after its processing heavy metals were kept well below critical levels. Other unwanted properties like pathogens have been eliminated through the process of pasteurisation.

ADK (Ammonium-Depotkugeln) is a slow release N fertiliser and contains ammonium sulphate and urea (PROMINERAL GmbH, Essen, Germany) in the form of a large pellet (100 g) of 2.5 cm diameter. Each pellet contains 0.75 g N.

The experiment was carried out in a completely randomised block design (CRD) with four replications and data were statistical analysed using the General Linear Model in the SAS package.

3 Results and Discussion

3.1 Changes in Soil pH

It is evident in **table 2** that fertilisation affected the soil pH and higher significance is associated with application of organo top. In comparison with the control, the treatments T_2-T_4 did not bring any significant change in soil pH values; however, it increased significantly where K and S were applied at reduced rates (T_5-T_8). The application of organo top brought a significant increase in pH over control and inorganically fertilised soils (T_1-T_8). Both increases and decreases in soil pH, following the sludge application were reported (MORENO et al., 1999; AL-WABEL et al., 1998, NAVAS et al., 1998; PARKPAIN et al., 1998; SANGHANI, 1998; FEVARETTO et al., 1997; MOHAMMAD and BATTIKHI, 1997; ACOSTA et al., 1995; BEVACQUA and MELLANO, 1995; TSADILAS et al., 1995; CAVALLARO et al., 1993 and HUE, 1988) and found to reflect the nature (acidic or alkaline) of the added waste. Because the OT material used in the present study was highly alkaline (pH 12.80), its effect on soil pH was expected to increase soil pH. It is also apparent that pH values are controlled by the amount of material added. Highest values were recorded in treatment T_{14}, followed by T_9 where higher amounts (100 and 60 g organo top pot^{-1}, respectively) were added. It was followed by other treatments where organo top was applied in lesser amounts. The basic pH values as obtained are desirable which would reduce the heavy metal availability in the system (HECKMAN et al., 1987 and NARWAL et al., 1983) and are considered the safe key of sludge application. But it needs to be considered that on light soils this will lead to an immobilisation of essential nutrients such as Mn and thus may affect crop productivity negatively.

3.2 Changes in Salt Content (EC)

Table 2 shows that inorganic fertilisation had a strong effect on the salt content of the soil. It is evident that EC values increased significantly over control with the addition of N K S fertilisers (except T_8). In most cases, the increase over control was > 50 per cent. Contrary to that organo top fertilisation had no impact on the electrical conductivity of the soil. This is really appreciable situation that avoids the fear of secondary salinisation, a major curse for soil health particularly in arid and semi-arid regions. In this study the distinctly highest EC values were obtained at treatment T_{14} (499.25 µS cm^{-1}). This could be due to SO_4^{2-}-ions as SO_4 is a constituent of ADK fertiliser and higher NO_3^{2-}-ions (20.42 mg kg^{-1} soil) present in the system after mineralisation of ADK. A high NH_4^+-N concentration resulting from the addition of ammonium containing nitrogen sources is supposed to increase osmotic suction (TISDALE et al., 1985). Contrarily, increase in salt concentration due to sludge application has been widely reported in literature (MORENO et al., 1999; MOHAMED and AWAD, 1998; NAVAS et al, 1998; SANGHANI, 1998; MOHAMMAD and BATTIKHI, 1997; ACOSTA et al., 1995; BEVACQUA and MELLANO, 1995; POLO et al., 1995; TSADILAS et al., 1995 and FLEMING and DAVIS, 1985).

Table 2: *Effect of N K S and Organo Top fertilisation on pH and EC (mS cm^{-1}) of the soil*

Treatments	pH	EC
T_1	7.5 fg	147.1 e
T_2	7.4 g	242.4 bc
T_3	7.5 ef	243.5 bc
T_4	7.4 g	285.9 b
T_5	7.6 de	209.3 cd
T_6	7.6 de	241.7 bc
T_7	7.6 de	256.1 bc
T_8	7.6 d	182.0 de
T_9	7.9 b	169.6 de
T_{10}	7.8 c	188.1 de
T_{11}	7.8 c	170.2 de
T_{12}	7.7 c	146.5 e
T_{13}	7.8 c	151.0 e
T_{14}	7.9 a	499.2 a

(Values within the column followed by the same letter are not significantly different at 0.05 level by Duncan's multiple range test).

3.3 Changes in Organic C

Intensive cultivation results in a slow but continuous decrease of the organic matter content in most agricultural soils. This makes soil inhospitable for micro-organisms and their diversity as well and expose them to a large array of stresses (ANDERSON and DOMSCH, 1990). Such a situation could have long lasting negative effects on soil fertility. Despite the differences in experimental conditions, it is possible to draw a general conclusion from the investigations that use of sewage sludge is a well established strategy to make up organic matter losses and to sustain its level in soil. The results presented strongly support this phenomenon. It is evident from **figure 1** that in organo top treated samples (T_9-T_{14}), the organic C content was significantly higher than in control (except in T_{11}). Conversely, with mineral fertilisation, differences in the organic C content were not different from the control (except T_2). The critical analysis of the data shows that mean organic C content of inorganic treatments (T_2-T_8) increased only to extent of 4 per cent over control where as in case of organo top treatments (T_9-T_{14}) it increased to the extent of 18 per cent. The highest amount of organic C was determined in the treatment T_{14} followed by T_{10}. Significant increase in soil organic C as a result of sewage addition has been widely reported (LINDSAY and LOGAN, 1998, NAVAS et al., 1998, EL-MAGHRABY and ABOU BAKR, 1997, HÄNI et al., 1996, ACOSTA et al., 1995. FORTUN and FORTUN, 1995, MEDIAVILLA et al., 1995, TSADILAS et al., 1995, GIUSQUIANI et al., 1988, and HUE,1988). But not all wastes may have this effect and opposite trends have been observed under condition of very high pH (LIEFFERING and MACLAY, 1996).

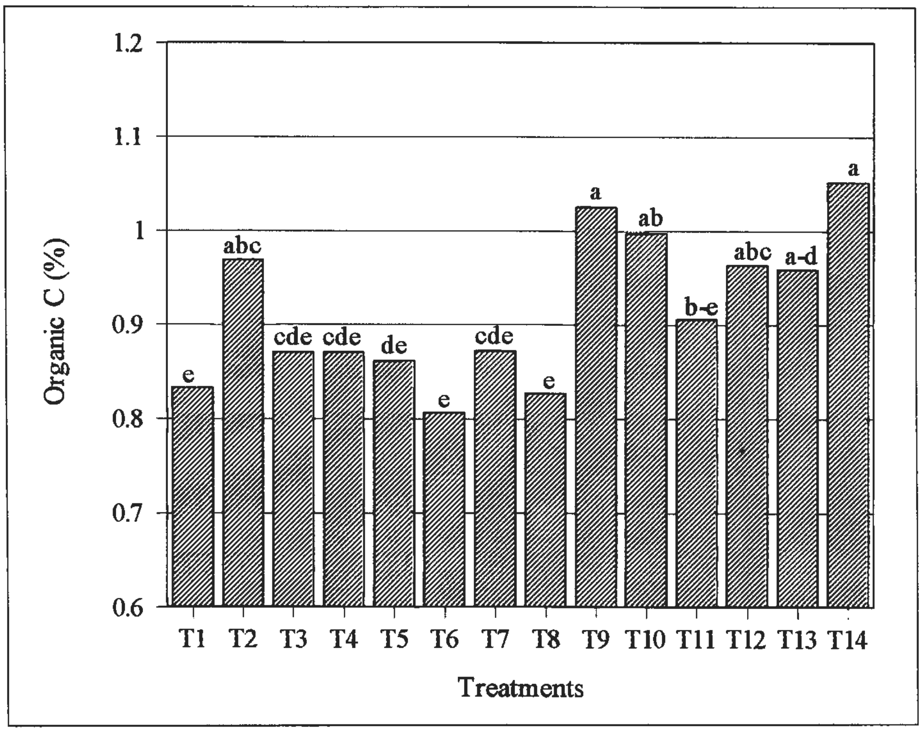

Figure 1: *Effect of N K S and organo top fertilisation on organic C content of soil (values having the same letters are not significantly different at the 0.05 level by Duncan's multiple range test)*

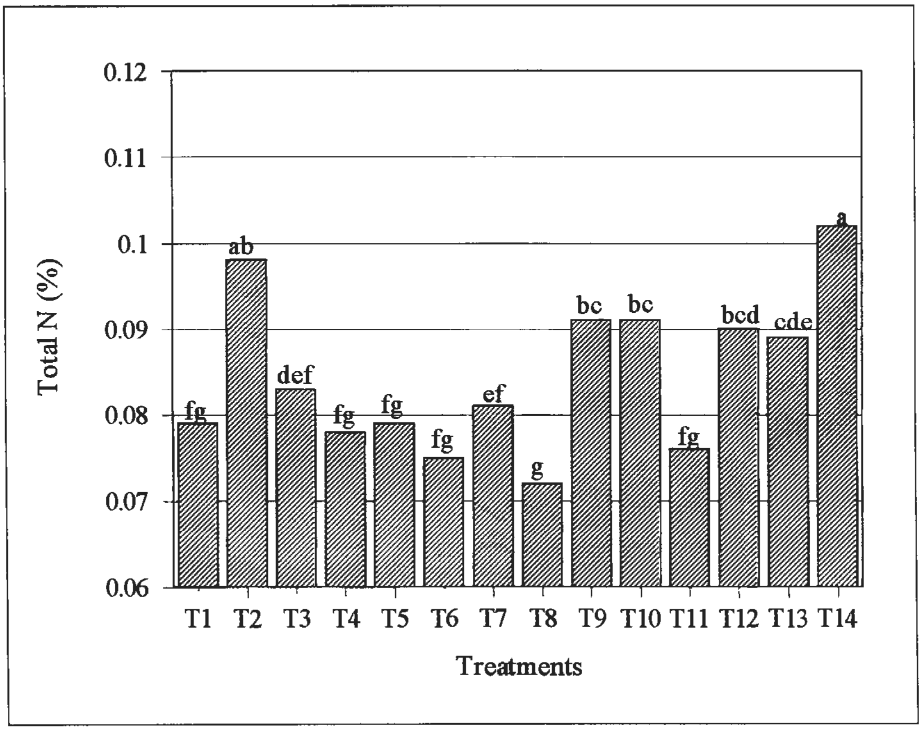

Figure 2: *Effect of N K S and organo top fertilisation on total N (%) content of soil (values having the same letters are not significantly different at the 0.05 level by Duncan's multiple range test).*

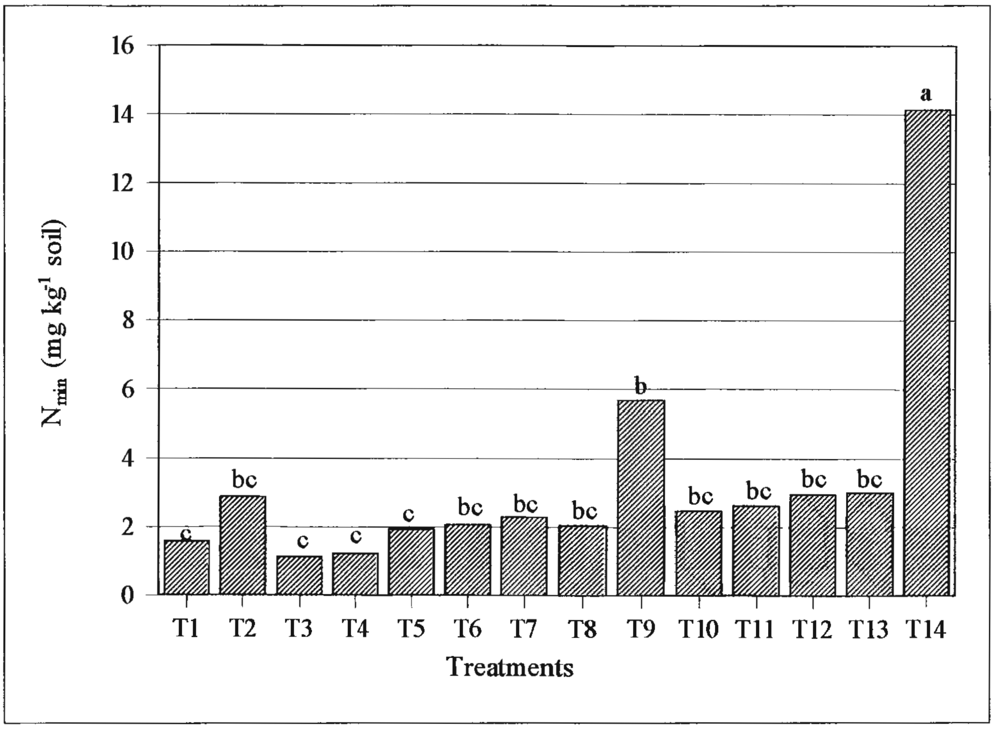

Figure 3: *Effect of N K S and organo top fertilisation on total N_{min} content of soil (values having the same letters are not significantly different at the 0.05 level by Duncan's multiple range test).*

have contributed to the understanding of N behaviour after sludge addition. It is evident from **figure 3** that N_{min} values of inorganically fertilised soils (T_2-T_8) did not vary statistically from the control. But on the other hand, addition of organo top handsomely contributed to the soil N pool particularly when it was applied @ 60 and 100 g pot^{-1} (T_9 and T_{14}, respectively). In treatment T_{14}, exceptionally higher amounts of N_{min} were determined. This could be due to additional contribution from ADK mineralisation, which has left higher concentrations of NO_3 in the system. Other organo top related treatments (T_{10}-T_{13}) are statistically at par with each other but considerably better than inorganic fertiliser treatments. These results are strongly supported by findings of NAVAS et al. (1998), PARTALA et al. (1998), KORENTAJER (1991), BOYLE and PAUL (1989), CAMPBELL and BECKET (1988) and SOMMER and MARSCHNER (1986) who suggested that a substantial labile N pool remain in the soil after sludge application.

3.4 Total and Mineralisable N (N_{min})

As a matter of fact the N and P content of sewage sludge is the most important nutrient for its use in agriculture. Therefore, the amount of sewage sludge applied to agricultural land is generally based upon the N content or the plant availability of N in the waste. One advantage of applying sewage sludge is slow release of N, which would match more closely, with N uptake of growing plants and thereby leaving a substantial amount of N in the system for future uses. The results of the present study also indicate this trend (**figure 2**). The amount of total N left in organo top treated soil is significantly higher than the control pot (except T_{11}) in comparison with inorganically fertilised soils where except T_2, other treatments were statistically at par with control. The mean increase over control in total N content in inorganically treated soil (T_2-T_8) was 2.3 per cent where as corresponding figure in case of organo top treated soil (T_9-T_{14}) was 14 per cent. This implies that organo top has promisingly left higher amounts of N in the system than inorganic fertiliser for subsequent mineralisation. The results are consistent with the findings of MOHAMED and AWAD, 1998, NAVAS et al., 1998, EL-MAGHRABY and ABOU BAKR, 1997, MUNTEAN et al., 1991 and GIUSQIANI et al., 1988.

Studies on N mineralisation in soils that had recent applications of sewage sludge (SERNA and POMARES, 1992; LINDERMAN and CARDINAS, 1984 and EPSTEIN et al., 1978) as well as studies on land previously amended with sludge (GRIFFIN and LAINE, 1983 and STARK and CLAPP, 1980)

3.5 Available P

Application of organo top led to a considerable increase in plant available P in the soil. **Figure 4** shows that under inorganic fertilisation (T_2-T_8), there was absolutely no change in the P status in comparison to the control. But as a consequence of organo top application (T_9-T_{14}), available P content was improved significantly not only over control but over full dose treatment (T_2) as well. Treatment T_{14} registered the highest value of available P presumably because of the higher application rate.

Due to their relatively high P content, urban sewage sludges are used as a source of P for agricultural crops. Another advantage of adding sludge P is relatively high availability even in soils of high P fixing capacity (MC LAUGHLIN and CHAMPION, 1987). One reason for the relatively high availability of sludge P may be the effect of organic ligands on reducing P retention capacity of variable charge components largely responsible for P retention (FOX,1982). Other studies (PARKPAIN et al., 1998; PARTALA et al. 1998; FAVARETTO et al., 1997; MOHAMMAD and BATTIKHI, 1997; FROSSARD et al., 1996; TSADILAS et al., 1995; CAVALLARO et al., 1993; KORENTAJER, 1991; Coker and CARLTON-SMITH, 1986; MC COY et al., 1986 and SOMMER and MARSCHNER, 1986) also supported the fact that sewage sludge seems to be genuine source to maintain soil P content.

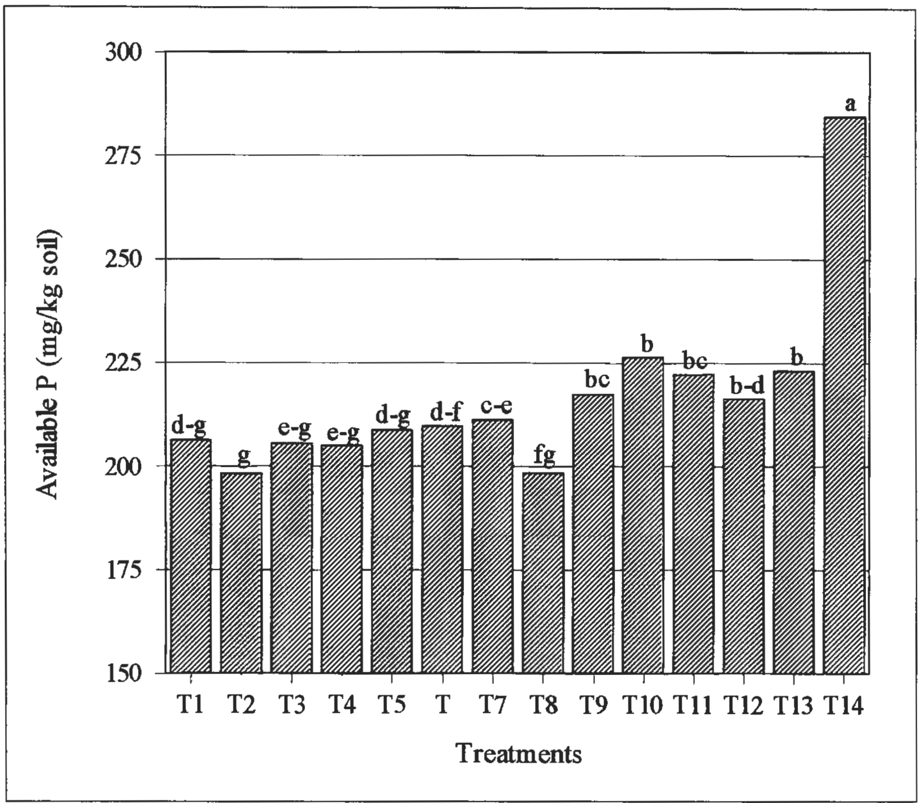

Figure 4: *Effect of N K S and organo top fertilisation on available P content of soil (values having the same letters are not significantly different at the 0.05 level by Duncan's multiple range test).*

3.6 Available K

Unlike N and P, addition of organo top did not influence the K status of the experimental soil. **Figure 5** shows those values of available K pertaining to organo top and its associated treatments (T_9-T_{14}) are statistically at par with that of the control. While comparing organo top treatments with inorganic fertiliser treatments, it emerges that inorganic treatments are statistically superior over organo top treatments except a few odds (T_5 and T_6). Low K content of organo top may be attributed to the poor K availability in the soil solution. This is verified by the fact that K concentration and its uptake in different plant parts of sorghum were considerably lower than inorganically fertilised plants (data not shown). The results are in agreement with those of FAVARETTO et al., 1997 and HUE (1988) who also did not observe any change in available K status of soil fertilised with sewage sludge but PARKPAIN et al. (1998) found increased concentrations of available K in soil due to sludge application.

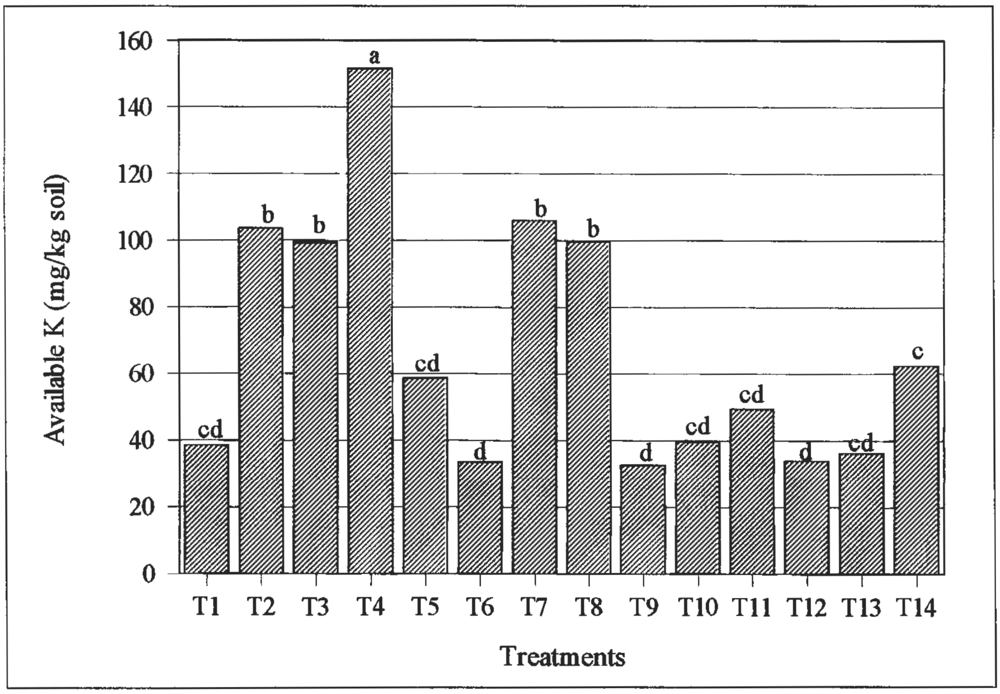

Figure 5: *Effect of N K S and organo top fertilisation on avalibale K content of soil (values having the same letters are not significantly different at the 0.05 level by Duncan's multiple range test).*

3.7 Available Mg

Figure 6 depicts that available Mg content in T_2 decreased significantly in comparison with the control. It could be due to a higher Mg uptake since highest yields were obtained at this treatment (data not shown). It remained unaffected at treatments T_3 and T_4 but decreased significantly in treatments where K and S have been applied at reduced rates (T_5-T_8). Like in K, in this case also, organo top fertilisation did not contribute towards soil Mg content possibly due to low Mg content of material added. In organo top treatments, it is also evident that significantly higher amount of available Mg in treatment T_{11} (where organo top has been applied in least amount i. e. 15 g pot^{-1}) is observed over T_9, T_{12}, T_{13} and T_{14}. It could be because of low uptake by plant due to lowest yield production (data not shown). CAVALLARO et al. (1993) and HUE (1988) also observed reduction while PARTALA et al. (1998) found increase in available Mg content of soil after fertilisation with sewage sludge.

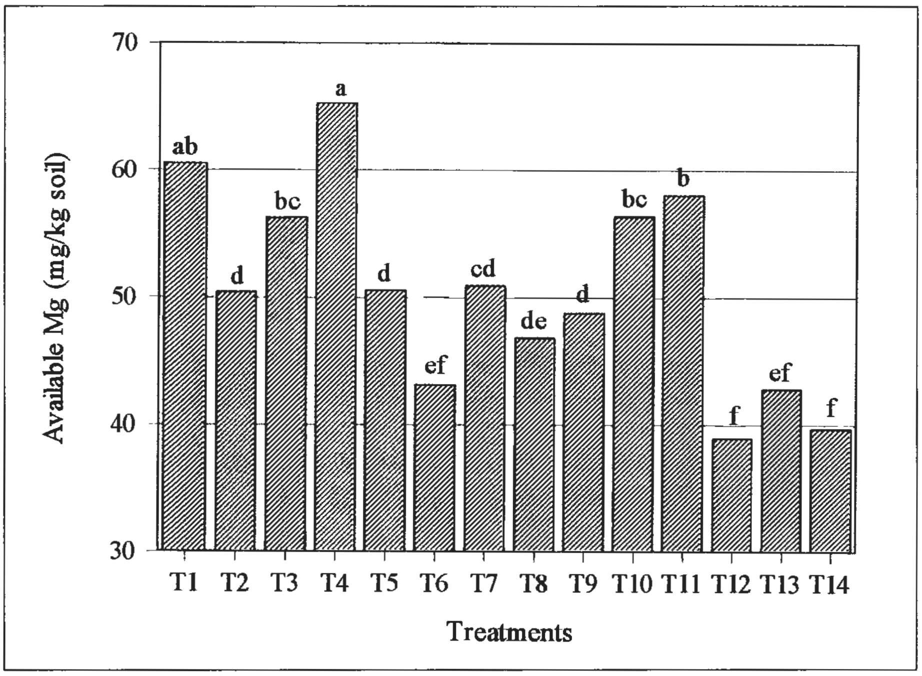

Figure 6: *Effect of N K S and organo top fertilisation on available Mg content of soil (values having the same letters are not significantly different at the 0.05 level by Duncan's multiple range test).*

Summary and Conclusion

The use of waste materials as an amendment to the soil has been a worldwide agricultural practice since years. It effectively disposes waste products while recycling valuable nutrients in the soil-plant system. However, the evaluation of the effects of these wastes on soil fertility is necessary and a preliminary task before establishing the real advantages of their use in agriculture. Therefore, the influence of purified sewage sludge (organo top) on soil fertility parameters was compared with conventional (mineral) fertilisers in a green house experiment. The study revealed that organo top fertilisation can promote the soil fertility stronger than conventional method of fertilisation. The application of organo top significantly increased soil pH and organic C while soil EC remained unaffected. Organo top fertilisation improved the soil fertility in terms of higher amounts of total N and available N (N_{min}) and P in soil solution. However, content of available K and Mg was higher under the influence of mineral fertilisation.

Einfluss von intensiven und extensiven Nährstoff-Systemen auf Bodenmerkmale und Ertragsparameter von Zuckermais:
I. Bodenmerkmale

Reststoffe werden seit langem weltweit auf landwirtschaftlichen Böden eingesetzt. Auf diese Weise ist es möglich, Nährstoffe im System Boden-Pflanze zu recyclisieren. Vor Einsatz von Reststoffen sollte jedoch deren Einfluß auf Parameter der Bodenfruchtbarkeit untersucht werden, um diesbezügliche Effekte abschätzen zu können. In einem Gewächshausversuch wurde der Einfluß von Organo Top, einem physikalisch-chemisch transformierten Klärschlamm, auf verschiedene Bodenmerkmale untersucht und dessen Wirkung mit mineralischen Düngemitteln verglichen. Die Ergebnisse zeigen, das Organo Top die Bodenfruchtbarkeit stärker förderte als mineralische Düngemittel. So stieg der Gehalt an organischem C und der pH-Wert im Boden signifikant durch die Zufuhr von Organo Top an, während die elektrische Leitfähigkeit nicht beeinflußt wurde. Des weiteren wurden die Gehalte an Gesamt- und verfügbarem (N_{min}) Stickstoff sowie der pflanzenverfügbare Phosphatgehalt im Boden signifikant erhöht. Bei mineralischer Düngung lagen die Gehalte an pflanzenverfügbarem K und Mg signifikant über denen der Organo Top Varianten.

Acknowledgement

The senior would like to acknowledge German Academic Exchange Service (DAAD) for providing him Post-Doctoral Fellowship. Sincere thanks are also to Mr. Bernd Arnemann for his technical assistance.

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