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# Effect of inorganic and organic sources on nutrients availability in a Vertisol

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**Abstract :** The results of the experiments conducted during 2006-07 under the ongoing All India Coordinated Research Project on Long-Term Fertilizer Experiment with soybean-wheat-maize fodder cropping sequence that commenced from 1972 at J.N.K.V.V., Jabalpur (MP) showed that the distribution pattern of available N and P contents as well as the differences amongst different treatments were higher in 0-20 cm soil layer and continued to decrease with increasing soil depth in all the treatments. Further, the highest values were found associated with 100% NPK + FYM and 150% NPK treatments. Application of 100% N alone resulted in lower values of available N, P and K contents in the profile. Similar behaviour was also recorded for soil available K content as the values was higher in 0-20 cm depth and continued to decrease with increasing soil depth up to 60 cm, followed by an increasing trend in subsequent soil layers even beyond 100 cm in all the treatments. The highest values were found associated with 100% NPK + FYM treatment apparently because of contribution from fertilizer and FYM. The differences in the values of soil available S amongst various input treatments were significant. The values of soil available S content in most of the treatments were found to increase with soil depth upto 40 cm which subsequently declined.

**Additional key words :** *Soil, available nutrients, distribution pattern*

## Introduction

Fertilizers are the key inputs for increasing agricultural production. However, their cost and other constraints prevent farmers from using them in recommended quantities and balanced proportion. Further, the imbalanced use of chemical fertilizers also deteriorate soil health. Continuous use of high analysis chemical fertilizers increased the crop yield in the initial years and adversely affected the sustainability at the later stage, specially through reduction of organic carbon, secondary and micronutrients in soil. The nutrient imbalance causing decline in soil fertility and productivity has been recognized as one of the most important factors limiting crop yield. About 23% of the nutrients removed by crops are received from added fertilizers and 77% of the added fertilizers move to the soil and environment (Tandon 1992). Use of chemical fertilizers or organic manures alone cannot achieve and sustain the desired level of crop production under continuous cropping. A conjoint use of organic manures with chemical fertilizers is very essential as this not only sustains higher levels of productivity but also improves soil health and enhances the nutrient use efficiency (Verma *et al.* 2005). In view of this, the present investigation was undertaken at J. N. K. V. V., Jabalpur to study the effect and cofant application of inorganic and organic sources on nutrients availability in a Vertisol under long-term fertilizer experiment.

## Materials and Methods

The present study is a part of the ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment with soybean-wheat-maize fodder cropping sequence initiated during 1972 at the Research Farm of the Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (23°10" N latitude and 79°57" E longitude). The soils represent Kheri series (Typic Haplustert) with pH 7.6, electrical conductivity 0.18 dS $m^{-1}$ (1 : 2.5 soil : water ratio), organic carbon 5.7 g $kg^{-1}$ (Walkey and Black 1934), 193, 7.6, 370 and 15.6 kg $ha^{-1}$ of available N (Subbiah and Asiija 1956), P (Olsen *et al.*, 1954), K (Muhr *et al.* 1965) and S (Chesin and Yien 1951). The experiment included 10 treatments viz., sub optimal dose, *i.e.*, 50% NPK ($T_1$), optimal dose *i.e.*, 100% NPK ($T_2$), super optimal dose, *i.e.*, 150% NPK ($T_3$), 100% NPK + Hand Weeding ($T_4$), 100% NPK + Zn ($T_5$), 100% NP ($T_6$), 100% N ($T_7$), 100% NPK + FYM ($T_8$), 100% NPK-S ($T_9$) and Control ($T_{10}$) replicated four times in a randomized block design. An additional strip was also retained as No crop control (Fallow strip) by the side of the main experiment ($T_{11}$).

The crops (soybean-wheat-maize fodder), were grown in rotation and the recommended fertilizer applications (100% NPK) for these crops were as 20:80:20, 120:80:40 and 80:60:20 kg $ha^{-1}$ for the respective crops. The sources of N, P and K used were urea, single super phosphate (SSP) and muriate of potash. In sulphur free treatment, the diammonium phosphate (DAP) was used instead of SSP as a source of P. The application of FYM @ 15 t $ha^{-1}$ $year^{-1}$ is being practiced only to soybean crop during Kharif season. Irrigation was provided based on the needs of crops. Recommended chemical weed control measures were adopted in case of soybean and wheat in all the treatments except $T_4$ where hand weeding was practised.

Soil samples were collected after the harvest of rabi (wheat) crop during 2006 with the help of tube augar and screw augar from each plot of the treatment. The samples were drawn from surface downwards up to 100 cm depth at an interval of 20 cm i. e., 0 – 20, 20 – 40, 40 – 60, 60 – 80 and 80 – 100 cm and were analysed for different available nutrients by the standard procedures.

## Results and Discussion

The basic soil properties of the profile are presented in table 1. The soil pH values (7.33 to 7.83) showed considerable variation with depth at different treatment levels. Electrical conductivity (0.13 to 0.32 $dSm^{-1}$) and $CaCO_3$ contents (4.21 to 8.63%) increased with soil depth, which indicates these soils have high clay content (40 to 60%), the dominant clay minerals are of smectite group and also titeniferous magnetite minerals present. The existing clays have the properties of churning within the pedon and the process of churning causes vertical mixing and leads to development of wide and deep cracks, and closely intersecting slickensides. The churning (argilli – pedoturbation) also results in non development of diagnostic horizons (Kulkarni et al. 1986). The organic carbon content of the soil (0.49 to 1.06%) has registered a decreasing trend with increasing soil depth.

### *Available N*

When the experiment was started in 1972, the initial available N value of the soil (0-20 cm) was 193 kg $ha^{-1}$. The available N values of different soil layers as influenced by continuous application of different treatments are presented in table 2. In general, the nitrogen content recorded from various soil layers were the highest in the surface layer and decreased with increasing soil depth. Thus, the minimum value was recorded from the lowest layer of each treatment. Further, the highest value in any soil layer was registered in $T_8$ (100% NPK+ FYM) followed by $T_3$ (150% NPK) treatments. A comparison of different treatments (Table 2) for the same soil layer indicated

**Table 1.** Selected properties of soils under different treatments

| Treatments | pH values | | | | | EC values (dS $m^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soil depth (cm) | | | | | Soil depth (cm) | | | | |
| | **0-20** | **20-40** | **40-60** | **60-80** | **80-100** | **0-20** | **20-40** | **40-60** | **60-80** | **80-100** |
| $T_1$ = 50% NPK | 7.53 | 7.71 | 7.74 | 7.78 | 7.78 | 0.13 | 0.14 | 0.17 | 0.20 | 0.26 |
| $T_2$ = 100% NPK | 7.42 | 7.70 | 7.76 | 7.72 | 7.74 | 0.15 | 0.17 | 0.20 | 0.20 | 0.28 |
| $T_3$ = 150% NPK | 7.43 | 7.69 | 7.73 | 7.75 | 7.71 | 0.18 | 0.19 | 0.24 | 0.22 | 0.32 |
| $T_4$ = 100% NPK + HW | 7.56 | 7.71 | 7.77 | 7.79 | 7.76 | 0.17 | 0.18 | 0.20 | 0.21 | 0.26 |
| $T_5$ = 100% NPK + Zn | 7.41 | 7.68 | 7.69 | 7.75 | 7.73 | 0.15 | 0.16 | 0.19 | 0.21 | 0.23 |
| $T_6$ = 100% NP | 7.44 | 7.68 | 7.67 | 7.74 | 7.71 | 0.20 | 0.22 | 0.18 | 0.23 | 0.28 |
| $T_7$ = 100% N | 7.64 | 7.76 | 7.89 | 7.80 | 7.79 | 0.19 | 0.18 | 0.21 | 0.22 | 0.25 |
| $T_8$ = 100% NPK + FYM | 7.51 | 7.64 | 7.71 | 7.81 | 7.72 | 0.19 | 0.19 | 0.18 | 0.21 | 0.26 |
| $T_9$ = 100% NPK – S | 7.42 | 7.71 | 7.76 | 7.81 | 7.82 | 0.19 | 0.18 | 0.21 | 0.20 | 0.20 |
| $T_{10}$ = Control | 7.72 | 7.75 | 7.83 | 7.74 | 7.75 | 0.13 | 0.16 | 0.19 | 0.21 | 0.25 |
| $T_{11}$ = Fallow | 7.33 | 7.58 | 7.63 | 7.71 | 7.69 | 0.22 | 0.25 | 0.27 | 0.28 | 0.31 |
| **SED** (Std error deviation) | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD at 5% | 0.06 | 0.05 | 0.04 | 0.03 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 |
| CV of Inorg. and Org. Sources | 0.50 | 0.42 | 0.31 | 0.23 | 0.33 | 6.50 | 6.73 | 3.55 | 4.45 | 5.24 |

| Treatments | OC content (%) | | | | | $CaCO_3$ Content (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soil depth (cm) | | | | | Soil depth (cm) | | | | |
| | **0-20** | **20-40** | **40-60** | **60-80** | **80-100** | **0-20** | **20-40** | **40-60** | **60-80** | **80-100** |
| $T_1$ = 50% NPK | 0.72 | 0.61 | 0.43 | 0.36 | 0.34 | 5.31 | 5.81 | 6.11 | 6.27 | 6.53 |
| $T_2$ = 100% NPK | 0.81 | 0.64 | 0.52 | 0.39 | 0.37 | 5.57 | 6.28 | 6.41 | 6.57 | 6.77 |
| $T_3$ = 150% NPK | 0.89 | 0.74 | 0.67 | 0.46 | 0.38 | 5.61 | 6.53 | 6.69 | 6.90 | 7.11 |
| $T_4$ = 100% NPK + HW | 0.71 | 0.45 | 0.36 | 0.35 | 0.34 | 5.84 | 6.72 | 6.78 | 7.05 | 7.43 |
| $T_5$ = 100% NPK + Zn | 0.64 | 0.46 | 0.38 | 0.33 | 0.33 | 5.51 | 6.83 | 7.01 | 7.16 | 7.56 |
| $T_6$ = 100% NP | 0.72 | 0.47 | 0.31 | 0.35 | 0.32 | 7.13 | 7.60 | 8.05 | 8.27 | 8.63 |
| $T_7$ = 100% N | 0.54 | 0.37 | 0.32 | 0.33 | 0.31 | 6.61 | 6.97 | 7.18 | 7.36 | 7.65 |
| $T_8$ = 100% NPK + FYM | 1.06 | 0.69 | 0.43 | 0.38 | 0.39 | 7.06 | 7.43 | 7.75 | 7.89 | 7.05 |
| $T_9$ = 100% NPK – S | 0.76 | 0.47 | 0.38 | 0.33 | 0.32 | 7.01 | 7.29 | 7.49 | 7.54 | 7.61 |
| $T_{10}$ = Control | 0.62 | 0.39 | 0.35 | 0.34 | 0.36 | 4.32 | 4.85 | 5.26 | 5.61 | 6.15 |
| $T_{11}$ = Fallow | 0.49 | 0.37 | 0.31 | 0.29 | 0.27 | 4.21 | 4.57 | 4.97 | 5.33 | 5.81 |
| **SED** | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.23 | 0.27 | 0.17 | 0.20 | 0.25 |
| CD at 5% | 0.05 | 0.04 | 0.02 | 0.02 | 0.02 | 0.47 | 0.55 | 0.35 | 0.41 | 0.44 |
| CV | 4.47 | 5.75 | 2.85 | 3.10 | 3.11 | 5.38 | 5.70 | 3.49 | 3.97 | 4.21 |

that the highest values of available N were found associated with treatments where recommended fertilizer + FYM @ 15 t $ha^{-1}$ ($T_8$) was applied. Further, by increasing the nutrient application rate, the amount of available nutrients also increased significantly as ($T_8$ and $T_3$). The difference in N contents of different soil layers among the sources is attributed to variable nutrient use efficiency, differential N conservation and fixation by the bio-inoculants, and the variable biochemical activities within the soil. In general, the lowest values of available N contents were found associated with low level inputs. Under all sets of inputs, the highest values were found associated with 100% NPK+FYM, the treatment in which all resources were integrated and the better proportions, consumption, utilization with maximum fixation of N from natural sources is expected.

The high values of available N at lower soil depth in 100% NPK+FYM indicate more leaching of N with this level of application as urea. Singh (2002) also recorded similar observations for N profiles. According to his observations, the highest available N content was recorded in surface and sub surface layer with application of 100% NPK + FYM as compared to control and then progressively declined with increasing soil depth. Similarly, Nand Ram (1998) mentioned that the original status of organic carbon (available N) was maintained only by integrating NPK fertilizer and FYM.

*Available P*

The available phosphorous contents in different soil layers of the profile as influenced by imposition of

**Table 2.** Available plant nutrients (N, P, K and S) in soils

| Treatments | Soil available N (kg $ha^{-1}$) | | | | | Soil available P (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soil depth (cm) | | | | | Soil depth (cm) | | | | |
| | 0-20 | 20-40 | 40-60 | 60-80 | 80-100 | 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
| $T_1$ | 216.63 | 178.21 | 156.13 | 135.70 | 106.91 | 21.56 | 19.16 | 18.18 | 13.65 | 12.44 |
| $T_2$ | 299.75 | 241.11 | 213.63 | 181.08 | 150.97 | 31.10 | 28.48 | 27.03 | 24.15 | 21.76 |
| $T_3$ | 313.03 | 262.75 | 224.98 | 199.38 | 158.20 | 42.22 | 38.06 | 33.44 | 28.50 | 24.55 |
| $T_4$ | 302.48 | 242.11 | 216.69 | 184.40 | 154.46 | 32.64 | 27.04 | 22.51 | 19.25 | 17.68 |
| $T_5$ | 248.92 | 241.52 | 214.13 | 182.91 | 152.95 | 32.85 | 29.08 | 25.28 | 23.59 | 21.54 |
| $T_6$ | 261.55 | 229.59 | 203.02 | 170.47 | 138.74 | 30.20 | 30.10 | 26.27 | 23.87 | 19.33 |
| $T_7$ | 205.96 | 161.32 | 153.38 | 106.43 | 74.68 | 14.17 | 13.25 | 11.13 | 10.02 | 8.95 |
| $T_8$ | 324.66 | 288.16 | 260.07 | 226.22 | 182.69 | 42.60 | 38.50 | 34.78 | 31.93 | 29.11 |
| $T_9$ | 264.31 | 230.87 | 209.58 | 174.75 | 142.84 | 29.65 | 26.25 | 24.59 | 20.49 | 18.20 |
| $T_{10}$ | 197.08 | 160.46 | 127.71 | 96.27 | 61.56 | 12.81 | 9.89 | 8.86 | 8.38 | 7.52 |
| $T_{11}$ | 114.56 | 97.45 | 75.70 | 63.57 | 39.64 | 8.57 | 7.61 | 6.34 | 5.31 | 5.10 |
| SED | 7.91 | 4.94 | 7.95 | 3.30 | 3.71 | 0.93 | 0.86 | 0.71 | 0.63 | 0.48 |
| CD | 16.23 | 10.14 | 16.32 | 6.77 | 7.61 | 1.20 | 1.77 | 1.46 | 1.28 | 0.99 |
| CV | 4.25 | 3.13 | 5.68 | 2.81 | 3.96 | 4.51 | 4.71 | 4.33 | 4.34 | 3.75 |

| Treatments | Soil available K (kg $ha^{-1}$) | | | | | Soil available S (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soil depth (cm) | | | | | Soil depth (cm) | | | | |
| | 0-20 | 20-40 | 40-60 | 60-80 | 80-100 | 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
| $T_1$ | 220.75 | 192.99 | 166.16 | 173.74 | 197.93 | 20.64 | 22.72 | 16.74 | 13.49 | 11.87 |
| $T_2$ | 269.78 | 236.01 | 204.01 | 212.73 | 240.49 | 31.57 | 34.56 | 27.09 | 21.24 | 17.12 |
| $T_3$ | 271.24 | 237.61 | 207.18 | 215.38 | 245.40 | 39.83 | 48.89 | 30.63 | 25.82 | 20.16 |
| $T_4$ | 272.45 | 239.16 | 210.28 | 217.20 | 247.39 | 30.78 | 34.92 | 24.52 | 17.67 | 14.28 |
| $T_5$ | 280.47 | 245.96 | 218.54 | 223.61 | 252.90 | 26.88 | 22.38 | 18.29 | 15.38 | 11.26 |
| $T_6$ | 232.00 | 197.54 | 166.01 | 173.29 | 205.37 | 24.23 | 27.37 | 20.45 | 15.86 | 10.72 |
| $T_7$ | 191.67 | 162.40 | 138.39 | 141.91 | 170.97 | 15.26 | 19.14 | 13.44 | 11.81 | 8.75 |
| $T_8$ | 307.72 | 269.89 | 241.76 | 247.06 | 276.63 | 44.12 | 52.74 | 36.70 | 25.58 | 20.12 |
| $T_9$ | 212.30 | 184.58 | 158.49 | 156.35 | 183.85 | 14.43 | 17.14 | 13.65 | 10.51 | 8.91 |
| $T_{10}$ | 186.71 | 156.88 | 128.25 | 134.72 | 164.45 | 13.35 | 16.72 | 12.16 | 8.52 | 7.66 |
| $T_{11}$ = | 171.53 | 144.72 | 118.24 | 122.75 | 151.80 | 16.58 | 23.51 | 14.56 | 12.84 | 10.45 |
| SED | 2.34 | 1.42 | 1.94 | 2.27 | 1.66 | 1.07 | 0.95 | 0.95 | 0.52 | 0.52 |
| CD | 4.81 | 2.91 | 3.98 | 4.67 | 3.40 | 2.19 | 1.95 | 1.94 | 1.07 | 1.07 |
| CV | 1.35 | 0.95 | 1.49 | 1.70 | 1.07 | 5.78 | 4.53 | 6.26 | 4.44 | 5.64 |

different treatments are given in table 2. The initial value of soil available P content recorded at the start of experiment in 1972 was 7.60 kg $ha^{-1}$. The illustration representing different treatments indicated that, in general, the differences in P content got reduced significantly with increasing soil depth. The P content of surface soil layer ranged between 8.57 to 42.60 kg $ha^{-1}$. The values of available P declined with increasing soil depth and got reduced to 3.47 to 13.49 kg $ha^{-1}$ at about one meter soil depth. It indicated that the P content decreased significantly with increasing soil depth. The differences in P contents of various soil layers increased significantly upto 60-80 cm soil layer due to application of inputs and the magnitude of the differences reduced in the subsequent lower layers.

Continuous use of balanced fertilizer is conducive for maintaining the soil available P. The results of the present study also revealed that in surface soil, maximum available P content was present as compared to that at lower depth in all the treatments. It was also observed that successive significant increase had occurred due to increasing levels of fertilizer application in surface soil. Similar results have also been reported by Singh *et al.* (1998a) from their long-term studies at Delhi. These authors found that exclusion of P in the fertilizer schedule had resulted in lowering the available P content in the surface soil. The results also support that increasing levels of fertilizer applications had resulted in substantially enhancing the available P content and so was the case with use of FYM along with balanced dose of fertilizer. Swarup and Yaduvanshi (2000) have also reported the beneficial effects of organic matter on available P in soils. The results also support that increasing levels of fertilizer applications had resulted in substantially enhancing the available P contents and so was the case with use of FYM along with balanced dose of fertilizer. These changes indicate strengthening of available P pool due to fertilizer use. Similar findings were reported by Singh *et al.* (1998 b) from their 25 years long-term continuous cropping experiments.

*Available K*

The available K content at different depths of soil profile as influenced by imposition of different treatments is given in table 2. The initial value of soil available K content recorded at the start of experiment in 1972 was 370 kg $ha^{-1}$. In general, the values of soil available K were the highest in $T_8$ (100% NPK +FYM), significantly superior to that of $T_3$ (150% NPK). Further, the values found in $T_6$ (100% NP) in surface and subsurface layers were significantly superior to $T_1$ (50% NPK). However, the values of available K in the surface soil layer ranged between 171.53 to 307.72 kg $ha^{-1}$ and the values continued to drop in all treatments with increasing depth, thus the values of 40-60 cm soil layer approached the lowest values, which ranged between 118.24 to 241.76 kg $ha^{-1}$. A subsequent increase of available K content was recorded with increasing soil depth below 60 cm depth and thus the values of soil available K recorded from 80-100 cm soil layer ranged between 151.80 to 276.63 kg $ha^{-1}$.

The highest value of available K in $T_8$ (100% NPK+FYM) from all soil layers was attributed to better conservation and use efficiency of this nutrient in the presence of organic manures. Further, a significant reduction in available K content from all soil layers in treatments receiving imbalance inputs was attributed to the relatively poor biological activities in these plots and inefficient use of nutrients. The treatment $T_9$ (100% NPK – S), with sufficient application of K and without sulphur has attained merely the same level of K as those recorded in treatments not receiving any K.

The difference in the values of available K content among different treatments for the given soil depths were attributed to the differences in the soil environment created by the applied nutrient muriate of potash. Based on the result of a long-term fertilizer experiment, Sharma *et al.* (1998) concluded that there could be mining of native reserve of K even under its optimum application rates, and it may affect the productivity of land in years to come. The available K gradually decreased in soil up to 60 cm depth and then increased in subsequent layers. A typical behaviour of K distribution within the soil profile, irrespective of the treatments applied was attributed to the movement of K in the profile, from the applied pool, luxury consumption of K by the growing crops as per its availability and the prevailing soil moisture situations of the profiles (Kauraw 1982; Sahu 2004).

*Available S*

The available S content values as influenced by imposition of different treatments at depths are given in table 2. The status of available S in the surface soil (0-20 cm depth) was 15.6 kg $ha^{-1}$, when experiment was started in 1972. The illustrations representing the profiles under various treatments also indicated that the differences amongst treatments were maximum upto 40 cm soil depth and subsequently declined and approached minimum value at a depth of 100 cm or below. The highest values were found associated with $T_8$ (100% NPK+FYM) and $T_3$ (150% NPK) treatments and the lowest with the treatments exclusive of S ($T_7$, $T_9$ & $T_{10}$). Available S content in surface soil, which was initially 15.60 kg $ha^{-1}$, had decreased to 13.65 kg $ha^{-1}$, 14.43 kg $ha^{-1}$ and 15.26 kg $ha^{-1}$ in surface soil in treatments not receiving S application (through super phosphate) i.e. 100% N, 100% NPK – S or control plots, respectively. In all other treatments, there was a buildup of S within upper half-meter profile and the magnitude of buildup depended on the level of nutrient inputs. Thus maximum buildup was recorded in plots receiving 150% NPK or 100% NPK + FYM. The highest value was found associated with FYM plot due to better nutrient use efficiency in presence of FYM. The values of soil available S was also higher than any other soil layer of all the treatments at 20-40 cm soil layer. It was attributed to the movement of S from the surface layer and accumulation in subsurface soil due to insufficient microbial activity as compared to the surface layer. Similar findings have been reported by Singh *et al.* (1998 b). In the treatment, where only N alone was applied, the content of available S in surface soil was also low. In other treatments, available S content increased with increasing levels of fertilizer application reaching a peak value (44.12 kg $ha^{-1}$) in treatments where 100% NPK + FYM was applied. Aggarwal and Nayyar (1998) have also noticed a decline in the available S content in the soil with increasing depth.

Continuous use of N alone or NP had deleterious effect on long term fertility and sustainability. Use of balanced fertilizers (100% NPK) along with organic manure (@ 15 t FYM $ha^{-1}$ $year^{-1}$) was found to be quite promising since it improved organic carbon, available N, P, K and S status of the Vertisols. There was no perceptible change in pH and EC as a result of continuous use of fertilizers and intensive cropping over a long period. The available N and P content decreased in the soil with depth, whereas available K decreased up to half meter and then gradually increased.

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