

Residual Effects of 20 Annual Applications of Ammonium Sulfate and Triple Superphosphate for Corn on Properties and Productivity of Oxic Paleustults

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ABSTRACT

The residual effects of 20 successive annual applications of N and P fertilizer for corn production on properties and productivity of an Oxic Paleustults were examined by field experiment. The experiment consisted of 4 application rates of N and P fertilizer, i.e., 0-0, 60-60, 120-120, and 180-180 kg N-P₂O₅/ha/year in the forms of ammonium sulfate and triple superphosphate.

The pH of the surface soil and sub-soil was decreased with increased rates of the fertilizers with more pronounced effects in the sub-soil. The EC of the surface soil was not affected by the fertilization while that of the sub-soil was increased with increased rates of the fertilizer. The CEC of the surface soil was not affected by the fertilizers while that of the sub-soil decreased with increased rates of the fertilizers. The OM and total-N contents of the surface soil tended to increase with increased rates of the fertilizer while those of the sub-soil were not affected by the fertilization. The available P of the surface soil was dramatically increased with increased rates of the fertilizers while that of the sub-soil was less affected. The exchangeable K, Ca and Mg either tended to decrease or significantly decreased with increased rates of the fertilizer, with more pronounced effect in the sub-soil. The DTPA-extractable Fe of the surface soil was increased with increased rates of the fertilizers while that of the sub-soil was not affected by the fertilization. The DTPA-extractable Mn and Zn of the top-layer soil was slightly increased with increased rates of the fertilizer whereas those of the middle-layer soil were similarly decreased by the three application rates of fertilizer and those of the bottom-layer soil were not affected. The DTPA-extractable Cu of soils of the top and middle layers was slightly increased with increased rates of the fertilizer whereas that of the bottom-layer soil was slightly decreased with increased rates of the fertilizer. The bulk density of the surface soils showed slight trends to decrease with increased rates of the fertilizers while that of the sub-soil showed no effect of the fertilizers. The aggregation of the soil was decreased with increased rates of the fertilizers. The hydraulic conductivity of the saturated soils was not affected by the fertilization. The infection on corn roots of arbuscular mycorrhizal fungi (AMF) showed consistent trends to decrease with increased rates of the fertilizer whereas AMF spore intensity in the soil was not affected by low rates of the fertilizer but decreased with increased rates of the fertilizer at high rates of fertilizer. The population of the free-living N₂-fixing bacteria in the soil showed consistent trends to increase with increased rates of the fertilizer. The productivity of the soil was increased with increased rates of the fertilizers.

Key words : ammonium, fertilizer, properties, long-term, phosphorus, productivity, soil

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INTRODUCTION

Though nitrogen and phosphorus fertilizers have been widely used to increase crop yields, data on a long-term basis on effects of these fertilizers on properties and productivity of soil are scarce and have been of continuing concern. Results of long-term application of fertilizers so far reported suggested that the length of successive application of the fertilizers and cropping conditions and/or cropping system were among factors influencing the conclusions. The results of study by Owensby *et al.* (1969), for example, led to a conclusion that annual application of N and P fertilizers at different rates for 20 year for bromgrass did not affect organic matter (OM) content of the soil whereas results of study by Schwab *et al.* (1990), who worked with the same plots as those of Owensby *et al.* (1969), led to a conclusion that, after 40 annual applications with the fertilizers, organic matter content of the soil increased with increased rates of the nitrogen fertilizer. Moreover, Hasathon (1982), working with lowland rice soils, reported that OM contents of the soils increased with increased rates of ammonium sulfate applied for rice in the previous 5 years.

This paper presents results of a study on effects of 20 annual applications of ammonium sulfate and triple superphosphate for corn grown on a Reddish Brown Lateritic soil in Thailand on chemical, physical and biological properties and productivity of the soil.

MATERIALS AND METHODS

Site and soil

The experiment was conducted on a Pakchong series soil, clayey kaolinitic, Oxic Paleustults at the National Corn and Sorghum Research Center, Nakhon Ratchasima Province, Thailand.

Design and treatments

A randomized complete block design with 6 treatments and 3 replications had been employed. However, only four of the treatments were accounted for in this study. Each plot measured 7.5m x 15.0m. Alleys of 175 cm and 75 cm had been inserted between the two adjacent plots along the shorter and the longer sides of the plots, respectively. The treatments studied were as follows.

F₀: without fertilizer application.

F₆₀: application of 60 and 60 kg N and P₂O₅/ha/year as ammonium sulfate and triple superphosphate in annual cropping with corn during the previous 20 years.

F₁₂₀: as F₆₀ but the rates of fertilizers had been 120 and 120 kg N and P₂O₅/ha/year.

F₁₈₀: as F₆₀ but the rates of fertilizers had been 180 and 180 kg N and P₂O₅/ha/year.

Throughout the previous 20 years, all of the plots were planted to corn during the late rainy season (mid July to November) in each year. The N fertilizer was applied by balanced split application at planting and one month after planting whereas all of the P fertilizer was applied at planting. The fertilizers at planting were mixed and applied by banding under the soil surface on one side of each corn row. The fertilizer at one month after planting was applied by banding on the soil surface on one side of each corn row. In the present cropping, all of the plots were planted to corn and received no fertilizer.

Basal fertilizer and crop residue management

ZnSO₄ at the rate of 62.5 kg/ha was applied to all treatments in the second and third annual cropping to ensure adequate supply of Zn. During the 20 years prior to the present study, only corn ears were removed from the plots. The stubble from each cropping was left on the plots and then chopped and plowed into the soil when land was prepared at about one month before the following

cropping.

Soil sampling and sample preparation

Soil samples for chemical analysis were taken a few weeks before the crop residue incorporation into the soil. Within area of 25cm × 75cm across the direction of the corn rows, the soil was dug up in three separated layers, i.e., at 0-15cm, 15-30cm, and 30-60cm depths. The soil from each layer was crushed, well mixed and quartered. One quarter of the soil was then taken and proceeded with the preceding process. This process was repeated until a quarter of about 2 kg of soil was obtained. The soil sample obtained was then air-dried and crushed to pass a 2-mm sieve.

Soil samples for physical properties examination were taken from the central area of 3m × 3m of each plot before plowing for the present cropping. Undisturbed soil samples for bulk density and hydraulic conductivity examination were taken with steel cylindrical (63.71 cc) soil samplers. Samples from the centers of the surface (0-15cm depths) and sub-surface (15-30cm depths) layers were taken as representatives of the surface soil and sub-soil, respectively. From each plot, two kinds of samples were taken, one from the center between two adjacent hills of corn stumps and another from the center between two adjacent rows of corn stumps. Each kind of sample was taken from two sites in each plot. Soil clods for aggregate examination were also taken from the two kinds of sites but only one sample of each kind was taken.

One composite soil sample for examination of population of arbuscular mycorrhizal fungi (AMF) and free-living N₂-fixing bacteria was taken from the central area of 3m × 3m of each plot at one week before harvest of the present cropping. Surface soil (0-15 cm depth) from three squares, each measuring 50cm × 50cm and having two stumps of corn plants (grown 75 cm between rows and 25 cm between hills of one plant) in the central area, was

dug out, put together and well mixed. An aliquot of the soil was then taken for the examination.

Analyses of soil and plant samples

Chemical properties: pH of the soils were measured with pH meter according to Peech (1965). Saturation extracts of the soils for electrical conductivity (EC) measurement were obtained according to Bower and Wilcox (1965). The cation exchange capacity (CEC) was measured according to Chapman (1965), using neutral *N*NH₄OAc and 10% NaCl as saturating and replacing solutions, respectively. OM content of the soil was measured according to Walkley and Black (1934). Total N content of the soil was measured by Kjeldhal method (Jackson, 1958), using the H₂SO₄+Na₂SO₄+Se digestion mixture. The available P was measured by Bray II method (Olsen and Dean, 1965). Exchangeable K, Ca and Mg were measured as described by Pratt (1965), using neutral *N*NH₄OAc. Extractable Fe, Mn, Zn and Cu were measured using DTPA according to Lindsay and Norvell (1978).

Physical properties: The core soil samples were ovened at 105°C to constant weights for gravimetric bulk density determination. Aggregate analysis of the soils was done by wet sieving according to Kemper and Chepil (1965). The hydraulic conductivity of saturated soils was determined according to Klute (1965), respectively. The state of aggregation was the proportion of the total sample weight occurring in the aggregates of larger than 0.25mm. The degree of aggregations was the proportion $(m_1 - m_2)/(m_s - m_2)$, where m_1 was the weight of aggregates larger than 0.25mm, m_2 the weight of primary particles larger than 0.25mm and m_s the total sample weight. The mean weight-diameter was the sum of products of (1) the mean diameter of each size fraction and (2) the proportion of the total sample weight occurring in the corresponding size fraction.

Biological properties: Infection in corn root and spore intensity in the soil of AMF in the soil was determined according to Danial and Skipper (1987). Number of the free-living N_2 -fixing bacteria was determined by the Total Plate Count Technique.

Uptake of N, P and K: Grain and stubble of corn were analyzed for N, P and K by wet digestion (Jackson, 1958). Total N in the digest was then measured with micro Kjeldhal distillation method (Bremner, 1965). P content of the digest was measured with the vanadomolybdophosphoric yellow calorimetric method (Jackson, 1958) using a Spectronic-20 colorimeter. K content of the digest was measured by flame photometry.

RESULTS AND DISCUSSION

pH, EC, CEC and OM

pH, EC, CEC and %OM of the soils are shown in Figure 1.

In all of the three soil layers, pH decreased with increased rates of the fertilizers with more pronounced changes in the lower soil layers. The effects of fertilizers on pH were presumably due primarily to oxidation of the applied NH_4 -ions which released H^+ ions. More pronounced effects in the lower layers were presumably results of lower buffering capacities of the soils due to lower OM contents. The results were slightly different from those obtained by Tattao (1987), who worked with the same experimental plots after fertilization for 10 years and found decreases in pH of the surface soil (at 0-30cm depths) with increased rates of the fertilizers but only trends of decreases in pH of the sub-soils (at 30-100cm depths) with increased rates of the fertilizers.

EC of the top-layer soil was not affected by the fertilizer application while those of the middle-layer and bottom-layer soils generally increased with increased rates of the fertilizers. The effects of

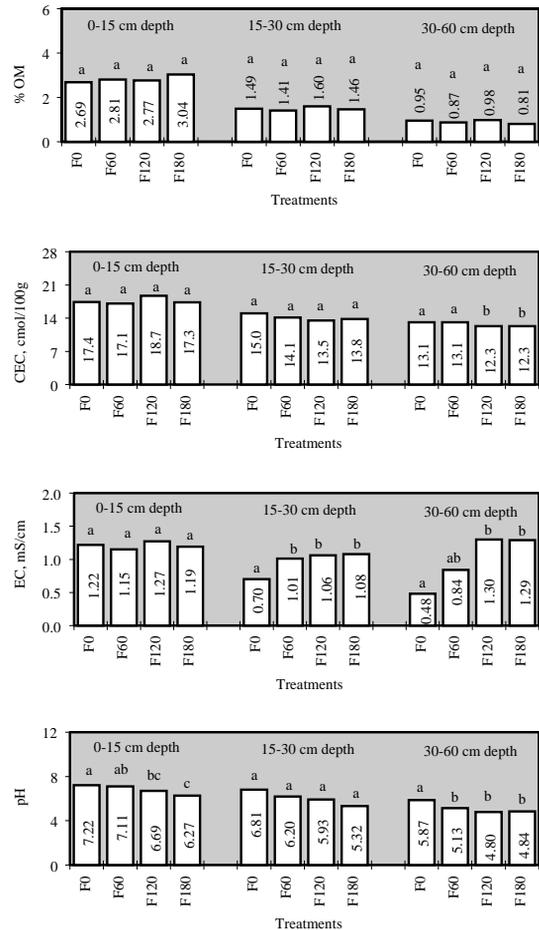


Figure 1 pH, EC, CEC and %OM of soils as affected by rates of N and P fertilizers applied in the previous 20 years. Within each group, bars with a common letter were not significantly different by DMRT_{.05}. % CV: 3.2%, 8.4% and 3.3%; 17.1%, 13.0% and 23.4%; 14.0%, 10.8% and 8.1%; 5.3%, 29.3% and 11.9% for pH, EC, CEC and %OM of soils, each at 0-15cm, 15-30cm and 30-60cm depths, respectively. F₀, F₆₀, F₁₂₀, and F₁₈₀: application with 0 and 0, 60 and 60, 120 and 120, 180 and 180 kg N and P₂O₅/ha/year in the previous 20 years.

fertilizers were more pronounced in the bottom layer. The results suggested that free salts from the fertilizers were mostly leached down to the lower layers.

CEC of the top-layer soil was not affected by the fertilization whereas those of soils of the middle and bottom layers either showed consistent trends to decrease or significantly increased with increased rates of the fertilizers. The effects of fertilizers on the lower-layer soils were presumably due to lower pH which resulted in more dissolution and leaching from the profile of sesquioxides which were sources of pH-dependent charges. However, the CEC of the top-layer soil was not affected by the fertilizers since the reduction in CEC as a result of reduction of sesquioxides content was compensated for by the CEC from the increased OM contents. The results were not in agreement with those of Tattao (1987) which showed trends of increases in CEC's of the surface soil and sub-soil with increased rates of the fertilizers.

OM contents of the top-layer soils showed consistent trends to increase with increased rates of the fertilizers whereas those of soils of the middle and bottom layers showed no effect of the fertilization. The increases in OM content of the top layer soil were presumably due to increased root growth in response to increased rates of the fertilizers of corn grown in the previous cropping. The results were similar to those of Tattao (1987) which showed trends of increases in %OM of the surface soil and sub-soil with increased rates of the fertilizers up to F₁₂₀ but only a slight trend of increase from F₁₈₀.

Total N, extractable P and exchangeable K, Ca and Mg in soils

Amounts of total N, extractable P and exchangeable K, Ca and Mg in the soils are shown in Figure 2.

Total-N contents of the top-layer soils

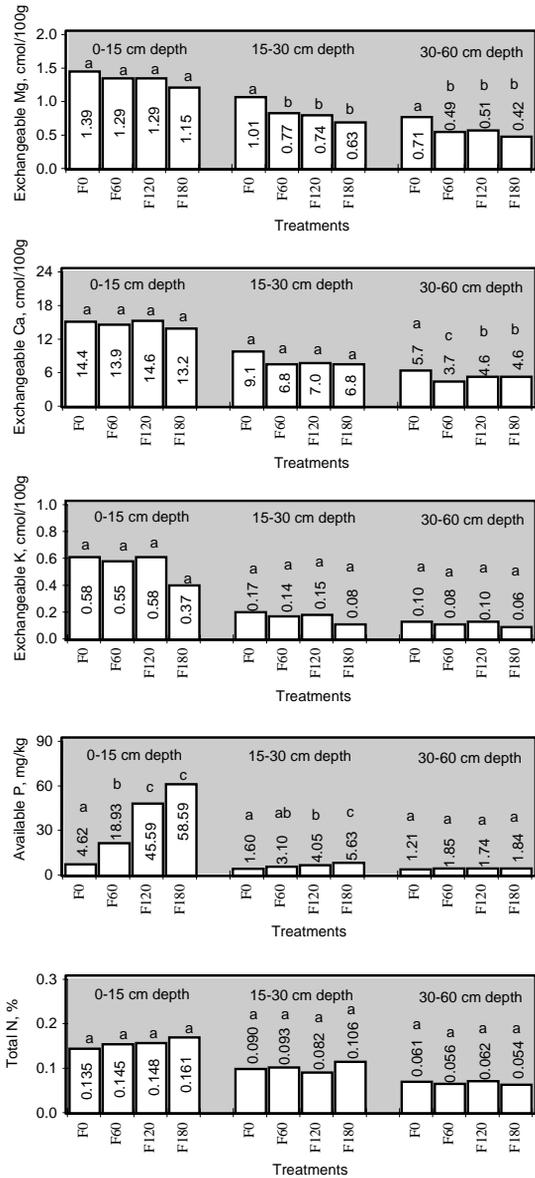


Figure 2 Amounts of total N, available P and exchangeable K, Ca and Mg of soils as affected by rates of N and P fertilizer applied in the previous 20 years. % CV: 6.2%, 24.3% and 11.2%; 21.0%, 21.9% and 19.1%; 14.0%, 35.5% and 17.0%; 5.5%, 18.6% and 6.7%; 6.3%, 14.3% and 15.5% for N, P, K, Ca and Mg of soils, each at 0-15cm, 15-30cm and 30-60cm depths, respectively. Refer to Figure 1 for captions.

showed consistent trends to increase with increased rates of the fertilizers whereas those of soils of the middle and bottom layers showed no effect of the fertilization. The increases in total-N content of the top-layer soil were presumably due to the trends to increase with increased rates of the fertilizers of OM content of the soil. The results were similar to those of Tattao (1987) which showed trends of increases in total-N content with increased rates of the fertilizer up to F_{120} but only a slight trend of increase from F_{180} in the case of surface soil and trends to increase with increased rates of the fertilizers in the case of sub-soil.

Extractable P of the top-layer soils increased markedly with increased rates of the fertilizers whereas those of the middle-layer soils slightly increased with increased rates of the fertilizers and those of the bottom-layer soils were not affected by the fertilization. The results showed that very little of the fertilizer P was moved down to the middle and bottom layers. The results were in good agreement with those of Tattao (1987) who worked with the same experimental plots after fertilization for 10 years.

Exchangeable K of soils in the three layers were not affected by F_{60} and F_{120} but showed trends to be decreased by F_{180} . This effect of fertilization was presumably due to the increase in soil acidity as a result of the fertilization which was largest in the case of F_{180} . The results were slightly different from those of Tattao (1987) which showed trends of increases in exchangeable K by the fertilization both in the cases of surface soil and sub-soil.

Exchangeable Ca of the top-layer soils generally showed trends to decrease with increased rates of the fertilizers whereas those of the middle-layer soils showed similar trends of decreases by F_{60} , F_{120} and F_{180} . Exchangeable Ca of the bottom-layer soils were similarly decreased by F_{120} and F_{180} and was most markedly decreased by the F_{60} .

These effects of fertilization were presumably the net results of the effects of fertilization on soil acidity and the increased uptake of Ca. The ratio between the increased uptake of Ca by the previous corn crops in response to fertilization and the

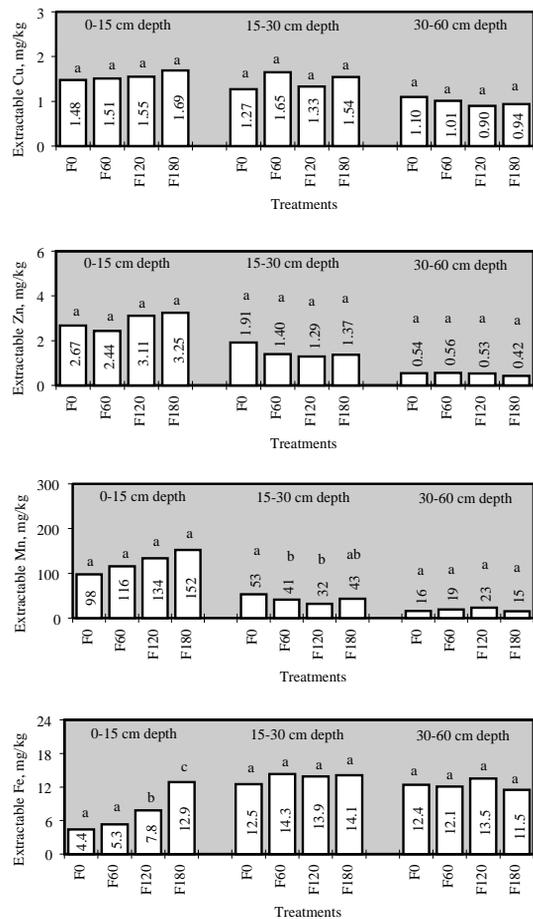


Figure 3 Amounts of extractable Fe, Mn, Zn and Cu of soils as affected by rates of N and P fertilizers applied in the previous 20 years. % CV: 14.0%, 10.8% and 8.1%; 18.3%, 13.9% and 22.1%; 11.0%, 22.8% and 12.7%; 7.2%, 12.5% and 19.3% for Fe, Mn, Zn and Cu of soils, each at 0-15cm, 15-30cm and 30-60cm depths, respectively. Refer to Figure 1 for captions.

amounts of Ca carried by the applied triple superphosphate for F₆₀ was presumably higher than those for F₁₂₀ and F₁₈₀ resulting in larger decrease in the amount of exchangeable Ca relative to rates of the fertilizers. The results for the top layer well agreed with those of Tattao (1987) who worked with the same experimental plots after fertilization for 10 years. However, Tattao (1987) found increases in exchangeable Ca with increased rates of the fertilizers in the case of sub-soil which was regarded as soil at the 30-100cm depths.

Exchangeable Mg of soils of the three layers showed effects of the fertilization that were similar to the effects on the exchangeable Ca but the effects

on Mg were more pronounced than those on Ca, presumably due to lower Mg content of the applied triple superphosphate. Tattao (1987) obtained results on exchangeable Mg similar to those mentioned above in the case of exchangeable Ca.

Extractable Fe, Mn, Zn and Cu in soils

Extractable Fe of the top-layer soils generally increased with increased rates of the fertilizers whereas those of the middle-layer soils showed similar trends to be increased by the three treatments and those of the bottom-layer soils showed no effect of the fertilization (Figure 3). The results suggested that the amount extractable Fe in the top-

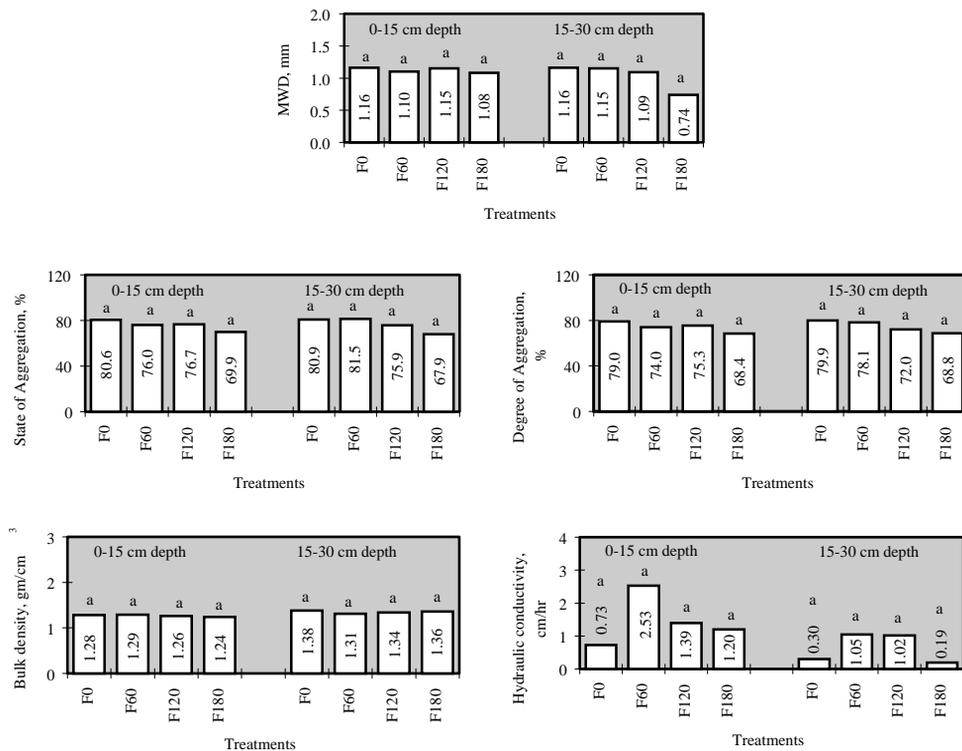


Figure 4 Mean weight diameter (MWD), state of aggregation, degree of aggregation, bulk density and hydraulic conductivity of soils as affected by rates of N and P fertilizers applied in the previous 20 years. % CV: 11.3% and 12.4%; 6.8% and 9.5%; 7.9% and 9.4%; 1.9% and 4.7%; and 29.2% and 14.1% for MWD, state of aggregation, degree of aggregation, bulk density and hydraulic conductivity at 0-15cm and 15-30cm depths, respectively. Refer to Figure 1 for captions.

layer soil depended primarily on soil acidity. Greater extractable Fe in soils of the middle and bottom layers, in the case of the unfertilized plots, than that of the top-layer soil suggested that amounts of extractable Fe of the middle and bottom layers were more dependent on soil aeration than on soil acidity and thus showed no effect of the fertilization. The results for the top layer well agreed with those of Tattao (1987) who worked with the same experimental plots after fertilization for 10 years. However, Tattao (1987) found trends of increases in extractable Fe with increased rates of the fertilizers in the sub-soil.

Extractable Mn and Zn of the top-layer soils showed consistent trends to increase with increased rates of the fertilizers whereas those of the middle-layer soils showed comparable decreases by the three fertilizer treatments and those of the bottom-layer soils showed no effect of the fertilization. The results suggested that the amounts of extractable Mn and Zn in the top-layer soil depended primarily on pH of the soil. Similar decreases in extractable Mn and Zn in the middle-layer soils by F_{60} , F_{120} and F_{180} were presumably net results of removal of Mn and Zn by the corn crops which increased with increased rates of the fertilizers and the solubility of Mn and Zn which were higher in the soils subjected to higher rates of fertilizers because of lower pH's. The results for the top layer well agreed with those of Tattao (1987). However, Tattao (1987) found trends of increases in extractable Fe with increased rates of the fertilizers in the sub-soil.

Amounts of extractable Cu of soils of the top and the middle layers showed trends of slight increases with increased rates of the fertilizers whereas those of the bottom-layer soils showed trends of decreases with increased rates of the fertilizers. The results suggested that the amounts of extractable Cu of soils of the top and middle layers depended primarily on soil acidity. The trends to decrease with increased rates of the ferti-

lizers of the extractable Cu in the bottom-layer soils suggested that acidity of the soil was not the main factor affecting it. The results of Schwab *et al.* (1990), which showed no effects of application with ammonium nitrate for 40 years on DTPA-extractable Cu in soil, supported this postulation.

Physical properties

Bulk density of the surface soils showed slight trends to decrease with increased rates of the fertilizers while that of the sub-soil showed no effect of the fertilizers (Figure 4). The results were presumably due to the positive effects of the fertilization on OM contents of the soil. These results were similar to those of Tattao (1987) who worked with the same experimental plots after fertilization for 10 years. State of aggregation and degree of aggregation of both the surface soil and sub-soil decreased with increased rates of the fertilizers (Figure 4). The effects of fertilization on aggregation were presumably due primarily to the increased acidity as a result of the fertilization which in turn resulted in increased dispersion of soil particles. The aggregate-size distribution showed that proportion of the soil mass bound into smaller aggregates increased with increased rates of the fertilizers whereas that bound into larger aggregates decreased with increased rates of the fertilizers resulting in increased aggregate-size uniformity with increased rates of the fertilizers (Figure 5). Mean weight diameters of aggregates also either tended to decrease or significantly decreased with increased rates of the fertilizers (Figure 4). The results thus showed that the aggregation decreased with increased rates of the fertilizers and agreed well with results of Tattao (1987) who worked with the same experimental plots after fertilization for 10 years. Hydraulic conductivity of the saturated soils was not effected by the fertilization (Figure 4).

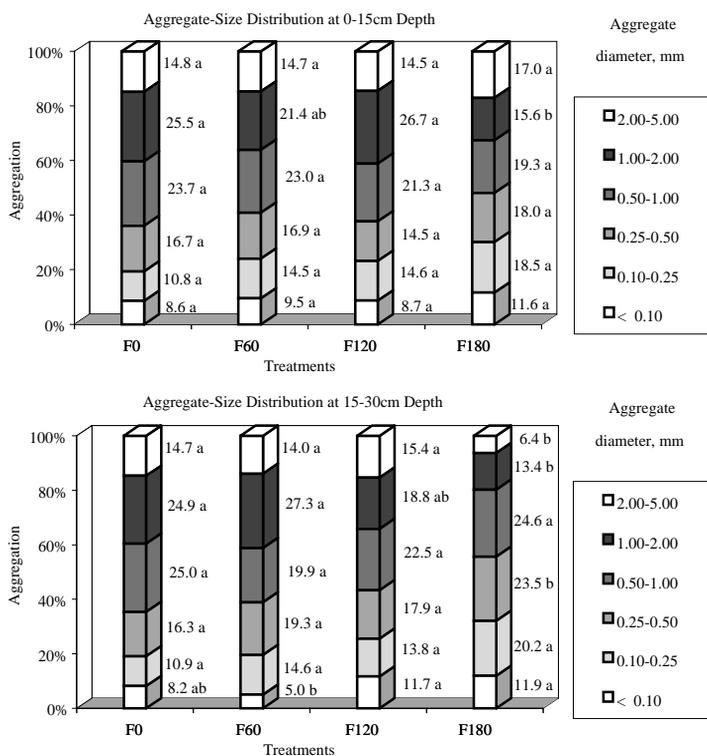


Figure 5 Aggregate size distribution of soils at 0-15cm and 15-30cm depths as affected by rate of NP fertilizer applied in the previous 20 years. % CV: in case of 0-15 cm depth, 20.3%, 14.6%, 10.3%, 15.6%, 23.9%; and 21.0% for aggregate sizes 2.00-5.00mm, 1.00-2.00mm, 0.50-1.00mm, 0.25-0.50mm, 0.10-0.25mm and 0.10mm, respectively, and 20.1%, 20.8%, 12.4%, 9.6%, 30.0% and 28.3% for aggregate sizes 2.00-5.00mm, 1.00-2.00mm, 0.50-1.00mm, 0.25-0.50mm, 0.10-0.25mm and 0.10mm, respectively, in the case of 15-30cm depth. Refer to Figure 1 for captions.

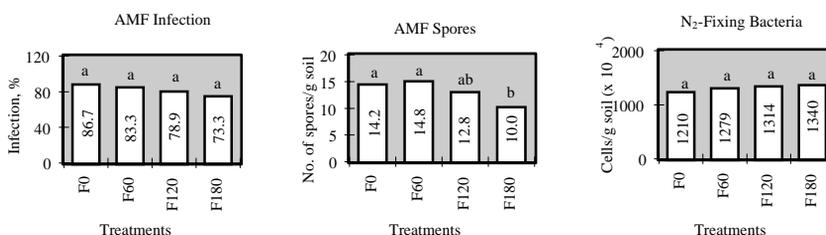


Figure 6 AMF infection of corn roots, intensity of AMF spores in the soils and intensity of free-living N₂-fixing bacteria in the soils as affected by rate of NP fertilizer applied in the previous 20 years. % CV: 5.9%, 12.3% and 13.3%, respectively. Refer to Figure 1 for captions.

Biological properties

The infection on corn roots of AMF showed consistent trends to decrease with increased rates of the fertilizers whereas AMF spore intensity in the soil was not affected by F₆₀ but decreased with increased rates of the fertilizers when the rates were higher than that of F₆₀ (Figure 6). The result on AMF spore intensity was slightly different from that of Tattao (1987) who found trends of increase in spore intensity with increased rates of the fertilizers up to F₁₂₀ but a trend of decrease by F₁₈₀.

The total plate counts of the free-living nitrogen-fixing bacteria in the soil showed consistent trends to increase with increased rates of the fertilizers. The results were different from those of Tattao (1987) which showed no significant effect of the fertilization on *Azotobacter* spp. population up to F₁₂₀ and a trend of decrease in the population by F₁₈₀.

Soil productivity

Grain yields of corn showed no effects of F₆₀, a trend to be increased by F₁₂₀ and was increased by F₁₈₀ whereas stubble yield showed consistent trends to increase with increased rates of the fertilizers (Figure 7). The uptake of N, P and K either showed trends to increase or significantly increased with increased rates of the fertilizers (Figure 7). The results therefore showed that pro-

ductivity of the soil increased with increased rates of the fertilizers.

CONCLUSIONS

pH of the surface soil and sub-soil decreased with increased rates of the fertilizers with more pronounced effects in the sub-soil. EC of the surface soil was not affected by the fertilization while that of the sub-soil increased with increased rates of the fertilizers. CEC of the surface soil was not affected by the fertilizers while that of the sub-soil decreased with increased rates of the fertilizers. OM and total N contents of the surface soil tended to increase with increased rates of the fertilizers while those of the sub-soil were not affected by the fertilization. Available P of the surface soil was dramatically increased with increased rates of the fertilizers while that of the sub-soil was less affected. Exchangeable K, Ca and Mg either tended to decrease or significantly decreased with increased rates of the fertilizers, with more pronounced effect in the sub-soil. DTPA-extractable Fe of the surface soil increased with increased rates of the fertilizers while that of the sub-soil was not affected by the fertilization. DTPA-extractable Mn and Zn of the surface soil slightly increased with increased rates of the fertilizers whereas those of the middle-layer soil were similarly decreased by

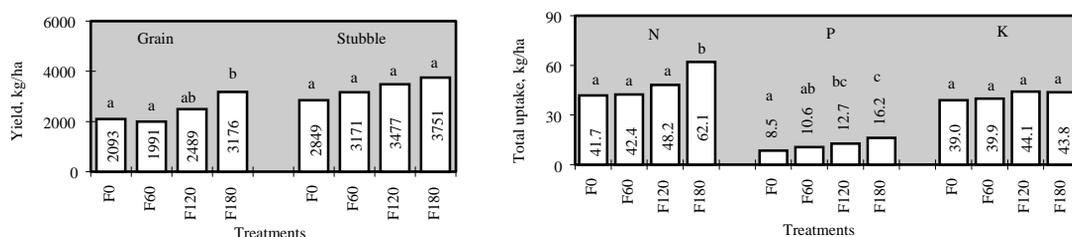


Figure 7 Grain (15% moisture) yields, dry stubble yields and total uptake of N, P and K of corn as affected by rates of NP fertilizer applied in the previous 20 years. % CV: 14.4%, 10.1%, 9.9%, 15.7% and 21.9% for grain, stubble, N, P and K, respectively. Refer to Figure 1 for captions.

the three rates of fertilizers and those of the bottom-layer soil were not affected. DTPA-extractable Cu of soils of the top and middle layers slightly increased with increased rates of the fertilizers whereas that of the bottom-layer soil slightly decreased with increased rates of the fertilizers.

Bulk density of the surface soils showed slight trends to decrease with increased rates of the fertilizers while that of the sub-soil showed no effect of the fertilizers. Aggregation of the soil decreased with increased rates of the fertilizers. Hydraulic conductivity of the saturated soils was not effected by the fertilization.

Infection on corn roots of AMF showed consistent trends to decrease with increased rates of the fertilizers whereas AMF spore intensity in the soil was not affected by low rates of the fertilizers but decreased with increased rates of the fertilizers at high rates of fertilizers. Population of the free-living nitrogen-fixing bacteria in the soils showed consistent trends to increase with increased rates of the fertilizers.

Productivity of the soil increased with increased rates of the fertilizers, with grain yield of plot with the highest fertilizer rate being about 151% relative to that of the non-fertilized plot.

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