J. Agrofor. Environ. 2(1): 1-6, 2008 ISSN 1995-6983

Phosphorus transformation and pH change in SSP and RP amended soils

L. Adhikary, K. M. Mohiuddin, M. S. Ali, P. Mallick and M. S. Alam
Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh-2202

Abstract: An experiment was conducted to determine the transformation of phosphorus (P) in SSP and RP amended alluvial and red soils during the period of January to April, 2007. The experiment was laid out in Complete Randomized Design (CRD) with three replications assigning P @ 0, 110 and 220 µg g^{-1} soil from SSP and RP as treatment along with basal dose of urea and muriate of potash. Transformation of P and change of pH were monitored over 0, 2, 8, 16, 28, 40, 52, 64 and 76 days after incubation period maintaining waterlogged condition at room temperature. Depending on soil types, fertilizer source and doses of fertilizer, transformation of P varied significantly with the progress of incubation period. After all, the P availability was maximum at day 40 in SSP amended soil but RP took 52 days to release maximum available P. The rate of P transformation in SSP amended alluvial soil was higher than red soil but in case of RP, the best performance was observed in red soil than alluvial soil. At the end of the incubation significant amounts of P remained in the soil due to residual effect of those fertilizers. About 15 to 25% of the applied P was mineralized during the whole period of incubation. The overall findings of this study suggest that the use of RP may be encouraged as a source of P instead of SSP in red soil due to its low availability over longer period of time but in alluvial soil, SSP could be more efficient if applied during land preparation for maximizing the profitability of fertilizer use.

Key words: P transformation, Soil pH, Single superphosphate, Rock phosphate, Soils.

Introduction

Phosphorus is the second most important nutrient needed in adequate quantity in available source for the growth, reproduction, yield and quantity of any crop (Ozanne, 1980). The phosphorus content of Bangladesh soils is relatively low. Application of phosphatic fertilizer is recommended for all soils and crops in Bangladesh to obtain better yield (BARC, 1997). Unfortunately, the farmers of this country do not always follow the fertilizer recommendation guide or do not make rational use of phosphatic fertilizers. Since water soluble phosphatic fertilizers like triple superphosphate (TSP) and single superphosphate (SSP) have been commonly used as the phosphatic fertilizer. The main problem concerning phosphatic fertilizer is its fixation with soil complex. The most important factors controlling the solubility and the availability of phosphate of soils are pH of the soil-solution, content of the cations Al^{3+}, Fe^{3+}, and Ca^{++}, content and quality of clay, and content of organic matter. The solubility of phosphate ions has its maximum in the pH-range 6-7 (Mandal and Khan, 1972). Rock phosphate (RP) is the cheapest and economic source per unit of phosphorus. It is considered as a promising source for crop use in acidic soil, especially red one. Rock phosphate is a source not only of phosphorus, but it also contains variable amount of other essential nutrients like calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), copper (Cu), and zinc (Zn) (Dev, 1990). Bangladesh, though a small country, have a wide diversity and complexity of soils. If chemical fertilizers like urea, TSP, SSP or DAP added to soil, they undergo a number of transformation reactions. It is imperative to know their transformation mechanism in different types of soil to have a complete understanding of their dynamics in soil.

Materials and Methods

The experiment was conducted in the laboratory of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh. Alluvial and red soils used in the experiment were collected from the Soil Science Field Laboratory, BAU and Madhupur Upazilla of Tangail district of Bangladesh, respectively. General properties of the soils are presented in Table 1.

Table 1. General properties of the initial soils

Soil type	pH	O.M (%)	Total N (%)	CEC (cmolkg^{-1})	EC(µS cm^{-1})	Available P (µg g^{-1})	Available S (µg g^{-1})	Available K (meq $100g^{-1}$)
Alluvial soil	6.9	1.69	0.08	12.46	93	17.4	9.7	0.13
Red soil	5	0.98	0.05	14.75	21	11.5	6.5	0.38

The experiment consisted of three treatments: control (T_0), 110 µg P g^{-1} soil (T_1) and 220 µg P g^{-1} soil (T_2). Single superphosphate and rock phosphate were used as source of P. The experiment was laid out in Completely Randomized Design (CRD) with three replications. An amount of 100 g soil was weighed into a triplicate series of 150 cm^3 plastic container. Phosphorus at the rate of 0, 110 and 220 µg g^{-1} soil were added as SSP or RP fertilizer and distilled water was added so as to reach the moisture content in waterlogged condition. All the treated soils were incubated for 76 days at room temperature. Soil pH and P contents were determined at 0, 2, 8, 16, 28, 40, 52, 64 and 76 days after incubation.

Soil pH was measured using a glass electrode pH meter (WTW pH 522) at a soil-water ratio of 1:2.5 as described by Ghosh *et al.* (1983). Available P was extracted with 0.5 M $NaHCO_3$ at a pH 8.5. The P in the extract was determined by stannous chloride method. The intensity of blue colour of molybdophosphate complex was measured with the help of spectrophotometer (Spectronic 21D) set at 660nm (Olsen *et al.,* 1954; Jackson, 1973). The mean comparisons of the treatments were evaluated by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Phosphorus transformation

In alluvial and red soil amended with SSP showed significant increase in P content than that of control. Release pattern of available P was relatively slower showing increasing or decreasing pattern. The initial P content in alluvial soil was 17.4 µg g^{-1} soil. At the onset of the incubation, rate of available P was increased up to day 8, then decreased at 16 days and then the trend was gradually increasing up to day 40. At day 40, available P reached to maximum value. At day 40, SSP containing 220 µg P amended soil released 85.5 µg P g^{-1} soil, while in 110 µg P amendments it was 60.3 ppm µg P g^{-1} soil. After day 40, the availability of P was decreased up to 76 days (Fig.1). This could be due to microbial immobilization of P, which is known to be a limiting factor in the availability and supply of this nutrient in soil, particularly where the soil is low in P (Sauchelli, 1965). This true was acertain by Wiilliams and Simpson (1965) which is in agreement with the findings of this experiment indicating water logging for 1-2 days decreased phosphorus availability, due to the conversion of phosphorus under anaerobic conditions and then gradually increased at definite time of incubation afterwards, decrease gradually was observed.

In red soil, the initial P content was 11.5 µg g^{-1} soil. Red soil amended with SSP showed higher rate of available P release than the control treatment. At the onset of the incubation, P release pattern increased gradually. It reached to peak within 28 days in SSP containing 220 µg P amended soil, while it required 40 days in SSP containing 110 µg P amendments. At day 28, 220 µg P amended soil released 61.8 µg P and 110 µg P amendments it was 45.6 µg available P at 40 days after incubation. After peak, gradual decreasing trend continued until 76 days after incubation (Fig.1). Though 220 □g P g^{-1} soil amended always attributed higher amount of available P than 110 □g P g^{-1} soil amendments as expected, however, the relative performance of 110 □g P g^{-1} soil amended was significantly better than the 220 □g P g^{-1} soil amendments as this treatment 220 □g P g^{-1} soil did not show double the amount of available P. The red soil (Madhupur soil) was acidic in nature which had pH 5. On the other hand, the pH of alluvial soil (BAU soil) was 6.9. The results showed that the soils under study

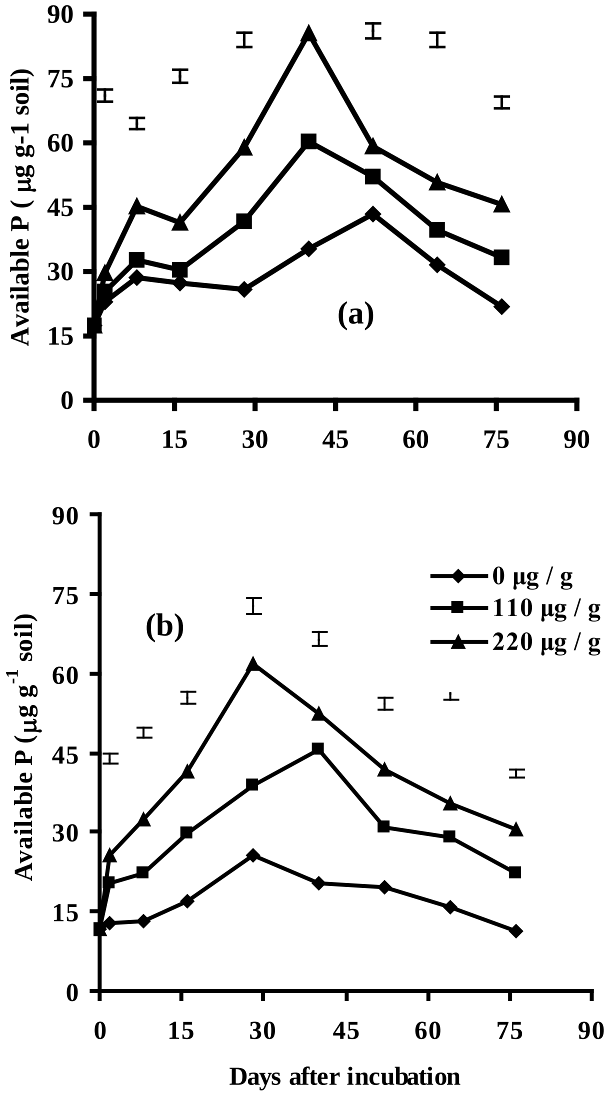

Fig. 1. Transformation of available P in (a) alluvial and (b) red soil amended with SSP

differed in their ability to transform P. Results indicate that the rate of P mineralization in alluvial soil was significantly higher than that of red soil amended with SSP. This finding is concomitant with Brady and Weil (2002). They stated that in acid soils reactions for fixation of P involve mostly Al, Fe or Mn; either as dissolved ions as oxides or as hydrous oxides. Moreover, P content is low in red soil. In acid soil, the availability of P was increased with increasing the pH value by the addition of water at the time of incubation. This finding is concomitant with Chiang (1963). He concluded that when acid soils are flooded, pH begins to rise and the amount of soluble P generally increase but decrease slightly later due to lowering of pH. In another experiment Lindsay and Moreno, (1960) stated that the solubility of phosphate from calcium, aluminum, and iron compounds are close to each other in the soil pH range between pH 6 and 7.

Available P transformation in alluvial and red soil amended with RP was noted from initial period of incubation to 76 days has been illustrated in Fig. 2. In alluvial soil, P availability showed significant increasing trend initially and became maximum at day 64. Initial soil contained 17.4 µg P but after 64 days of incubation it was 42.7, 54.3 µg P for RP containing 110 and 220 µg P amendments, respectively. Rate of available P release was lower in alluvial soil amended with RP than with SSP. From day 64, decreasing trend was found. The long time release of available P may be due to additional increase in inorganic P in soil solution with the addition of P fertilizer.

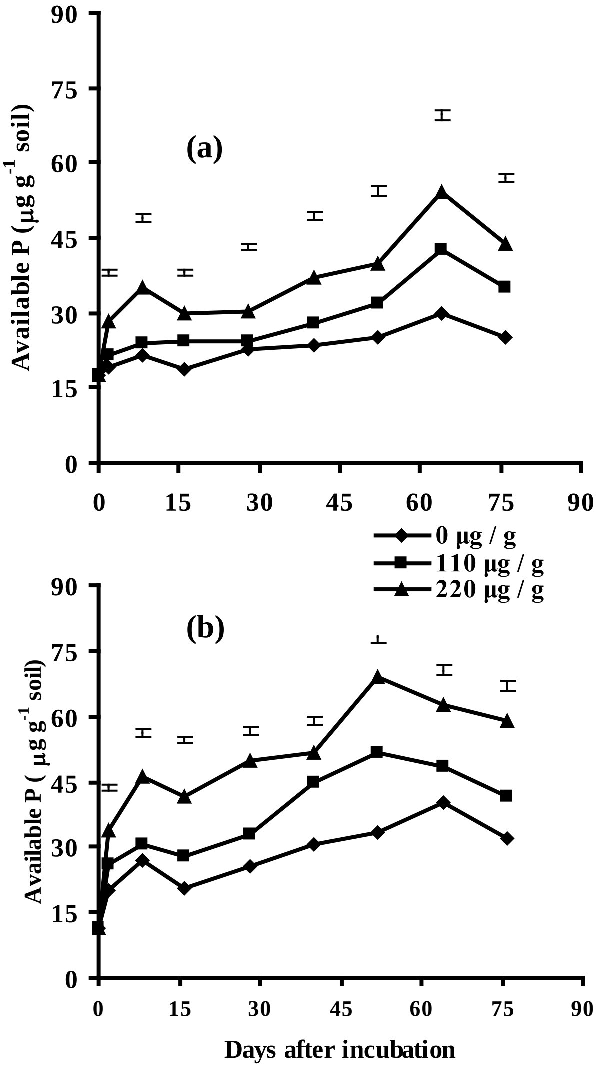

Fig. 2. Transformation of available P in (a) alluvial and (b) red soil amended with RP

At the onset of the incubation in red soil amended with RP, the rate of available P was significantly increased up to day 8, then decreased at 16 days and then the trend was gradually increasing. At day 52, available P reached to maximum value. At day 52, RP containing 220 µg P amended soil released 68.9 µg available P and RP containing 110 µg P amendments it was 51.4 µg available P, while in control it was 40.3 µg available P. Then it was decreased. At day 76 after incubation the availability of P was higher in soils amended with RP than in soils amended with SSP. The mineralization of P from RP was relatively slow but it remained in soil for long time. The rate of mineralization in alluvial soil was significantly lower than that of red soil amended with RP. Foth and Ellis, (1988) reported that the solubility of rock is so limited that it is of little use under slightly acidic to neutral condition. The figure clearly indicates that only 15 to 25% of the applied P present in available form and remaining P seem unavailable for plants due to fixation with different minerals and clay particles. In general the availability of P gradually increased at definite time of incubation afterwards, decrease gradually was observed. Paul and Delong (1949) found the prolonged flooding reduced the amount of easily soluble phosphorus especially in the presence of easily decomposable organic matter. In other experiment Shapiro (1958) found that flooding increased the measured availability of native soil phosphorus and the applied synthetic iron and aluminium phosphate in acid soils. In acid soil the effectiveness of RP may be high compared to SSP due to the availability of P. Mitra *et al*. (1992) conducted field trial with RP alone, SSP alone or as a mixture of both on lateritic, red and alluvial soil. They stated that RP significantly increased rice yield in lateritic and red soils. A mixture of RP and SSP (1:1 ratio) gave grain yields as good as those with SSP. The yield response was red soil>lateritic soil>alluvial soil. Similar effect was also observed by Marwaha *et al*. (1989).

Changes in soil pH

Soil pH is very important parameter with respect to nutrient availability to plants. The initial pH of alluvial soil which was amended with SSP was 6.9. But after 2 days of incubation the pH was decreased. After 8 days pH was gradually increased due to the incubation time. At the day of 28, 7.7 pH was observed at both 220 µg P and 110 µg P treatment which was considered the highest pH while at the control treatment it was 7.6 pH. After that incubation time the pH was again gradually decreased and reaches to the days of 76. In red soil amended with SSP showed that the change of pH was increased progressively with the time of incubation and reached the peak 7.1 at the days of 40 for 110 µg P containing SSP, 7.0 for 220 µg P containing SSP and for the control treatment the peak 7.2 was also found at 40 days after incubation and thereafter declined fairly to a constant level (Fig. 3). In red soil the pH is lower in compare to alluvial soil. But when water is added to keep in incubation condition the pH in red soil become in neutral position. Soil pH influences the availability of nutrients specially phosphorus. When soil pH is increased the availability of P is increased in a definite range. The change of pH in alluvial soil amended with RP was found in gradually increased condition. Soil pH in initial condition was 6.9. After incubation the pH was increased gradually and the highest value was found in 28 days. The highest value for 220 µg P treatments was 7.9 and 7.8 for 110 µg P treatment while the control treatment showed 7.6. After 28 days of incubation the pH was decreased gradually.

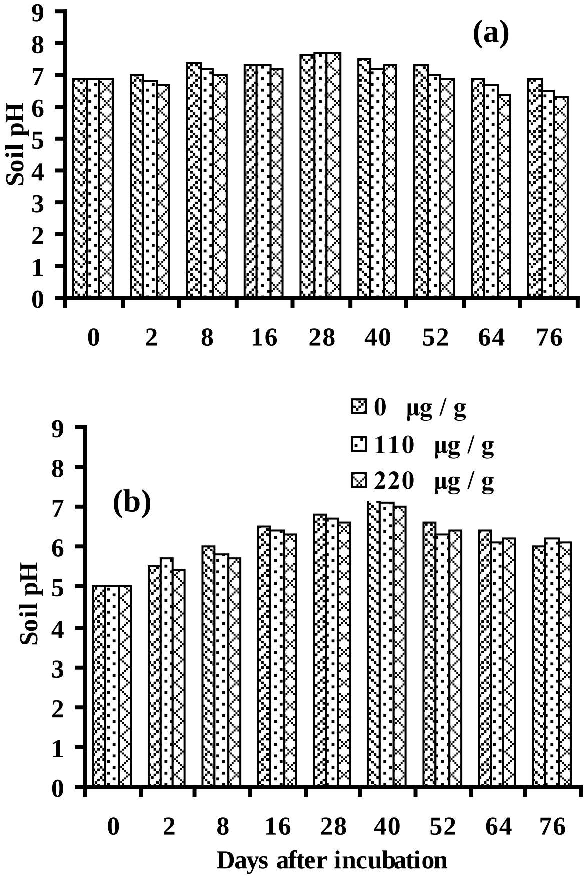

Fig. 3. Change of soil pH in (a) alluvial and (b) red soil amended with SSP

In red soil, pH in initial condition was 5.0. It was increased progressively with the time of incubation and reached to the peak 6.8 at the days of 40 for 110 µg P containing SSP, 6.9 for 220 µg P containing RP and for the control treatment the peak 6.8 was also found at 40 days after incubation and thereafter declined fairly to a constant level (Fig. 4). The change of pH was due to the effect of different factors such as temperature, incubation time, and microbial activity. Another reason which was responsible for the decreasing of pH was the decomposition of organic matter and production of organic acids (Amin, 1980). Mohiuddin *et al.* (2005) reported that the change in pH in alluvial soil amended with phosphatic fertilizer was increased at first and then decreased during 90 days of incubation. The pH change in alluvial soil amended with SSP and RP was almost same. The increased in pH due to water logging in acid soil may be attributed to the reduction of Fe, Mn and Al compounds (Pierre and Norman, 1953). Saraswathy and Arunachalam (2002) showed that the submergence increased the pH considerably in acid soils.

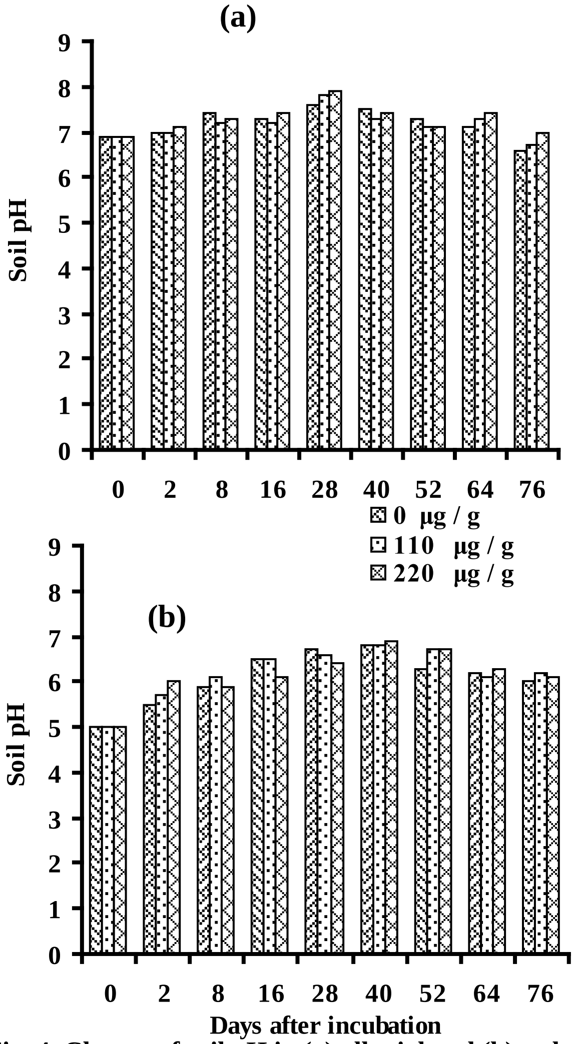

Fig. 4. Change of soil pH in (a) alluvial and (b) red soil amended with RP

References

Amin, M. S. 1980. Transformation and nitrification of urea in Bangladesh soils, Ph. D. Thesis. Dept. of Soil Science, BAU, Mymensingh.

BARC. 1997. Fertilizer Recommendation Guide, 1997. Soils Publication No. 41, Bangladesh Agricultural Research Council. Farmgate, Dhaka, Bangladesh.

Brady, N. C and R. R. Weil. 2002. The Nature and Properties of Soils. (*13th ed.*). Pearson Education. Ltd., New Delhi 110092. India. pp: 402-544.

Chiang, C. T. 1963. A study on the availability and forms of phosphorus in paddy soils. In: The interrelationship between available phosphorus and soil pH, Eh. Soils Ferts. Taiwan 61. Cited from Soils and Fertilizers. 28(24): 324: 1965.

Dev, G., 1990. Effective Phosphate Management for Increasing Agricultural Production. *In***:** Fertilizer scene in the nineties: Proceedings Fertilizer Association of India Seminar. New Delhi, SVI-3/1-3/12.

Foth, H. D. and B. G. Ellis. 1988. Soil Fertility. John Wiley and Sons, Publishing Company. Inc. New York. pp. 101-137.

Ghosh, A. A.; J. C. Bajaj; R. Hasan and D. Singh. 1983. Soil and water testing methods. Soil Testing Laboratory, Division of Soil Science and Agricultural Chemistry. IARI, New Delhi, India. pp: 221-226.

Jackson, M. L., 1973. Soil Chemical Analysis. Constable and Co. Ltd. New Delhi. pp: 10-114.

Lindsay, W. L. and E. C. Moreno. 1960. *Soil Sci. Soc. Am*. Proc. 24: 177-182.

Mandal, L. N. and S. K. Khan. 1972. Release of Phosphorus from Insoluble Phosphate Materials in Acidic Lowland Rice Soils. *J. India Soc. Soil Sci*., 20(1) pp: 19-25.

Marwaha, B. C.; B. S. Kanwar and B. R. Tripathi. 1989. Direct and Residual Effectiveness of Mussoorie Rock Phosphate in Wheat-Maize Rotation. *Indian J. Agril. Sci.* 51: 870-874.

Mitra, G. N.; S. K Sahu; M. P. Panda and V. C. Panigrahi. 1992. Udaipur rock phosphate is good for the soils of Orissa. Indian Farming. 42(4): 27-28.

Mohiuddin, K. M.; M. S. Ali and M. A. H. Chowdhury. 2005. Change of pH and P transformation in diammonium phosphate amended three contrasting soils of Bangladesh. *Bangladesh J. Agril. Sci.* 33(1): 93-98.

Olsen, S. R.; C. V. Cole; F. S. Watanabe and L. A. Dean. 1954. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate, U. S. *Dept*. *Agron. Cire*. p: 929.

Ozanne, P. G. 1980. Phosphate Nutrition of Plants. A general treatise. *In*: The role of P in Agriculture F.E. Kansawneh *et al*. (ed.), *Ann. Soc. Agron., Madi. Wis.* pp.559-589.

Paul, H. and W. A. Delong. 1949. Phosphorus Studies. In: Effect of flooding on soil phosphorus. *Sci. Agric*. 29: 137-147.

Pierre, W. H. and A. G. Norman. 1953. Soil and Fertilizer Phosphorus. Academic Press. Inc. V. 4.

Saraswathy, R. and G. Arunachalam. 2002. Changes in Physicochemical Properties and Nitrogen Transformation in the Root Zone soil of Different Rice Cultivers in Problems Soils. *Indian. J. Agric. Res*. 36 (4)**:** pp: 282-285.

Sauchelli, V. 1965. Phosphates in Agriculture. Reinold Publishing Corporation. New York. Chapman & Hall, Ltd., London.

Shapiro, R. E. 1958. Effect of Flooding on Availability of Phosphorus and Nitrogen. *Soil Sci.* 85: 190-197.

Williams, C. H. and J. R. Simpson. 1965. Some Effects of Cultivation and Water- logging on the Availability of Phosphorus in Pasture Soil. *Australian*. *J. Agric. Res*.16**,** pp: 413- 427.