academicJournals

Vol. 8(29), pp. 4020-4024, 1 August, 2013
DOI: 10.5897/AJAR2013.1295
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Elevation and variability of acidic sandy soil pH: Amended with conditioner, activator, organic and inorganic fertilizers

Mohd Hadi-Akbar Basri[1], Nasima Junejo[2,3]*, Arifin Abdu[1,3], Hazandy Abdul Hamid[2,3] and Mohd Ashadie Kusno[2,3]

[1]Department of Forest Management, Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.
[2]Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.
[3]Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

Accepted 19 July, 2013

Availability of nutrients for plant uptake is directly related to soil pH and as an indicator of soil fertility status. Determination of effects of soil amendments on soil pH should be a necessary part of fertilizer and fertility research. A pot experiment was carried out to determine and compare the effects of biochar, chicken manure, urea and zeolite on soil pH variability and elevation in a sandy loam acidic soil. A modified method was used to determine the soil pH in the pots. Soil pH in pot was measured by a glass micro-electrode and spatial variability was interpolated and mapped by using geographic information system (GIS) + software. Kriged Maps clearly showed the presence of variability and elevation in pH within each treatment. Furthermore, the position of patches with maxima and minima values for pH changed between all treatments used in the experiment. The highest elevation was found in zeolite treated soil followed by urea and biochar. However, a significant decrease was measured in soil pH in chicken dung treated soil. These findings could be the first step towards temporal stability of the pattern of spatial distribution of soil pH affected by the soil amendments (biochar, urea, chicken manure and zeolite).

Key words: Biochar, soil pH, urea, zeolite, spatial variability.

INTRODUCTION

Soil pH is one of the fundamental soil properties, which influences nutrient availability and many soil chemical processes. A soil with neutral or higher pH, is poor in micronutrient and causes higher greenhouse-gas emissions such as high ammonia volatilization loss (Kissel, 1988). In contrast, the soil with acidic pH (3 - 5.5) has high concentration of heavy metals, Al and Fe toxicities and lower CEC (Zhao and Xing, 2009; Srinivasarao et al., 2011). Changes in soil pH with added fertilizer may have an effect on the reaction of fertilizer in soil; resulting in improvement of nutrient efficiency and reduction in N losses (Ayanaba and Kang, 1976; Antil et al., 1992; Ahmed et al., 2008a).

At present, fertilizer optimization for the improvement of soil fertility is a worldwide key concern. Mixing of organic and inorganic fertilizer with soil activator or conditioner may become a common practice which affects soil properties. Zeolite, biochar and chicken manure are

*Corresponding author. E-mail: nasimajunejo85@gmail.com.

Table 1. The properties of soil series used in a glass house study to measure the effects of selected agriculture in puts on soil pH.

Texture (%)			pH	Total C	Total N	Exchangeable cation ($cmol_c\ kg^{-1}$)			
Clay	Sand	Silt	H_2O	(%)	(%)	Ca	Mg	K	CEC
33	50	17	5.3	2	0.1	0.9	4.0	0.2	5.4

Table 2. pH of Soil amendments were used to determine their effects on soil pH at application site.

Soil amendments	pH	CEC cmol/kg	Rate of application g/pot
Urea	8.2	--	17.6
Chicken dung	4.5	--	17.6
Biochar	9.2	42.85	17.6
Zeolite	5.6	171.74	17.6

highly recommended soil amendments to improve soil properties and nutrient optimization in nutrient poor soils (Glaser et al., 2002; Duncan, 2005; Ahmed et al., 2008b). The value of chicken manure as fertilizer in agriculture is well documented. For example, chicken manure has been used as organic matter in poor soils to improve soil properties and fertility status (Perkins et al., 1964; Nichols and Daniel, 1994). Zeolite is a broad spectrum crystalline aluminosilicates. It has used in agricultural lands to increase the pH in acidic situations; a medium of free nutrients, trap of heavy metals and to improve soil cation exchange capacity (Ahmed et al., 2008b; Omar et al., 2010; Zhang et al., 2010; Ramesh and Reddy, 2011). Biochar is attractive approaches to reduce environmental pollution these days as it have an ability to reduce leaching of nutrient, improve crop yield and lead to a sustainable management of fertilizer (Glaser et al., 2001). It can be a source of organic carbon made by plant materials, highly considered as a carbon sequester, soil conditioner and retainer of ammonium to reduce nitrous oxide emission (Clough and Condron, 2011; Singh et al., 2011). These materials were evaluated as bio resources to improve soil fertility but their information on effects of soil pH are still lacking and not well documented. On the other hand, urea is an inorganic N fertilizer which is widely used but is volatilised in soil of high pH due to hydrolysis and urease enzyme activity (Cabrera et al., 1991; Freney et al., 1993; Chen et al., 2010).

Soil and fertilizers evaluation for its effects on soil properties especially soil pH should be a part of research into fertilizers and amendments to avoid nutrient losses and failure of experiment (Cabrera et al., 1991; Christianson et al., 1993). Otherwise, the soil amended with a material of unknown soil pH may affect soil nutrient availability. The work reported here was done to study the effects of zeolite, biochar, chicken manure and urea on spatial variability and elevation of soil pH in a pot experiment. The information obtained by the presented research could be used to optimize soil nutrient management.

MATERIALS AND METHODS

Soil sampling and analysis

The experiment was conducted on a sandy loam soil under glass house conditions at Agricultural University Park, University Putra Malaysia. The average daily maximum temperature in the glasshouse is 35°C and the minimum temperature is 25°C. The soil (Typic Paleudult) was sampled from experimental area (bare) at the depth of 0 to 15 cm. The sampled soil was air dried, ground, sieved and analysed for its physical and chemical properties such as; soil pH measured in a 1 : 2 ratio (soil : distilled water) using a glass electrode; organic carbon was determined by the potassium dichromate and H_2SO_4 digestion method (Walkley and Black, 1934); CEC by leaching with 1 N ammonium acetate buffer (adjusted to pH 7.0); mineral-N (NH_4^+ -N and NO_3-N) by steam distillation techniques (Bremner, 1965) and total N by the salicylic acid digestion - Kjeldhal procedure (Bremner and Mulvaney, 1982). Mechanical analysis of the soils was done using pipette method and the USDA Textural Triangle was used to determine soil texture class (Table 1). The soil was filled in a plastic pot with measuring 32 cm (height) × 30 cm (diameter). Each pot was filled with 20 kg of soil (air-dried, crushed and sieved to pass a 2 mm sieve).

Soil amendments

Five agriculture inputs; control, chicken manure (pellet processed), zeolite, biochar (prepared from empty fruit bunches of oil palm) and urea were selected to evaluate their effects on soil pH elevation and variability. Before application to the pot, each amendment was analysed for their pH in water by pH meter (Table 2). The rate of agriculture inputs was same for all treatments which was 17.6 g for each of the material (Table 2). The amendments were mixed uniformly in the pot using a scoop.

Soil pH determination

The soil pH was measured at 150 points for each pot by glass microelectrode of digital pH meter (flat surface 3 mm Ag - AgCl model) using the method of Fan and Mackenzie (1993). A grid (15 × 10 cm) was placed on the surface area of the each pot and pH was measured at 1 cm intervals in both of the X and Y directions. The method was used previously for the determination of urea in petri dishes with 50 g of soil. In the present study, the quantities of

Table 3. Descriptive statistics of spatial variability of soil pH in a pot area (30 cm^2) influenced by application of selected agriculture inputs.

Variable	Mean	Min	Max	CV (%)
Control	5.37^c	4.6	5.7	10.11
Urea	5.79^b	5.3	6.8	12.21
Chicken dung	4.64^d	4.0	5.8	13.22
Biochar	5.84^b	5.1	6.5	10.23
Zeolite	6.51^a	5.9	7.4	11.22

Means with different letters indicated the significant differences in soil pH among various soil amendments application at $p < 0.05$.

amendments were modified and calculated to measure the variability in pot area at larger surface area than petri dish. The applied amount of agar solutions was used in this experiment was just 2 L for 20 kg soil which was evaluated in preliminary lab experiments. Furthermore, Fan and Mackenzie (1993) used only one granule to observe the hydrolysis or diffusion of urea on a microsite. But here in this experiment, 17.6 g of each fertilizer source and soil amendments were applied on surface. The purpose of modification of this method was to analyse the changes in soil pH on a pot surface area without any disturbance. Geostatistical mapping of a pot for soil pH could be novel approach to interprete clearly the possible variation and change in soil pH of a small experimental area.

Statistical and geostatistical analysis

Statistical analysis included investigation of mean values, coefficients of variation, maximum and minimum values. Spatial variability of soil pH was assessed by means of semi-variogram analysis. From models of spatial dependence between neighbouring data, the Kriging approximation was used for interpolation by using software (GS+ v. 9, Gamma design, Plainwell, MI) (Webster and Oliver, 2007; Balasudram et al., 2008; Dharejo et al., 2011; Junejo et al., 2012). The experimental design used was Completely Randomized Design (CRD) with four replications for each treatment. The differences among treatments were estimated by ANOVA followed by Tukey's mean test by using statistical analysis software (SAS version 9.5).

RESULTS AND DISCUSSION

The determination of soil properties showed that soil is sandy loam, strongly acidic, low in total N, moderate in total C, very low in K and Ca, high in Mg and low in CEC according to international soil interpretation values (Hazelton and Murphy, 2007). The soil pH is a considerable guide to understand nutrient deficiencies and toxicities such as; availability of phosphorus, nitrogen, potassium, calcium, sulphur reduced at < 5.0 (McKenzie et al., 2004).

Table 2 shows the pH of urea, chicken manure, biochar and Zeolite, which showed the basic pH of biochar, urea and the chicken manure were acidic; however, zeolite also has acidic pH with high CEC. The previous literature indicated that urea, biochar and chicken manure have higher pH which ranged from 7.5 to 9 (Ahmed et al., 2006; Steiner et al., 2010).

Soil pH observed were significantly different ($P = 0.001$) to each other in all the treatments. The soil pH of each treatment was ranged from 4.64 to 6.5. Mean pH was significantly higher in soil treated with zeolite and significantly lower in soil treated with chicken manure. Co-efficient of variation of soil pH treated with all the treatments had a narrow range from 10.11 to 13.22% (Table 3). Soil pH in all the treatment was modelled by exponential model. The range expressed as distance, and can be interpreted as the diameter of the zone of influence, which represents the average maximum distance over which a soil property of the two samples is related. Minimum range of 5.4 cm for control and maximum 6.5 cm was observed in the soil treated with zeolite. Co-efficient of determination indicating a good fit for models ranged from 0.46 to 0.56 for the soil pH treated with different treatments (Table 4).

Kriged maps showed variation in soil pH within 30 cm diameter pots. Soil pH in control ranged from 4.6 to 5.4, Urea ranged from 5.6 to 6.50, chicken manure ranged from 4.0 to 5.4, Biochar ranged from 5.6 to 6.5 and Zeolite ranged from 6.1 to 7.0 (Figure 1). The data in control (without any amendments) ranged from 5.3 to 5.7 showed a narrow range of variability in soil pH at soil surface of pot (Figure 1a). The urea treated pot show a soil pH which was ranged from 5.3 to 6.8 after 24 h of fertilizer applications (Figure 1b). These occur due to fast hydrolyses process of urea in soil which was resulted in an increase of soil pH. It is reported previously that the applied urea to the soil will rapidly hydrolyse to $(NH_4)_2CO_3$ facilitated by urease enzymes and subsequently to NH_4OH and CO_2 which results in pH increase at urea micro site and favours liberation of NH_3 (Ayanaba and Kang, 1976; Antil et al., 1992; Junejo et al., 2012). The addition of any type of organic matter always benefited buffer capacity of soils against the impact of acidity. However the addition of chicken manure reduced the soil pH which was ranged from 4.5 to 5.1 in this experiment (Figure 1c). Usually, the pH for the soil chicken manure mixtures were found to be neutral to slightly alkaline (Nichols and Daniel, 1994).

Table 4. Geostatistical statistics of spatial variability of soil pH in a pot area (30 cm^2) influenced by application of selected agriculture inputs.

Variable	Model	Nugget	Sill	Effective range	r^2	Nug sill
Control	Exponential	0.03	0.12	5.40	0.48	0.26
Urea	Exponential	0.06	0.18	6.00	0.52	0.33
Chicken dung	Exponential	0.06	0.17	4.90	0.48	0.34
Biochar	Exponential	0.08	0.23	5.70	0.46	0.33
Zeolite	Exponential	0.05	0.14	6.50	0.56	0.38

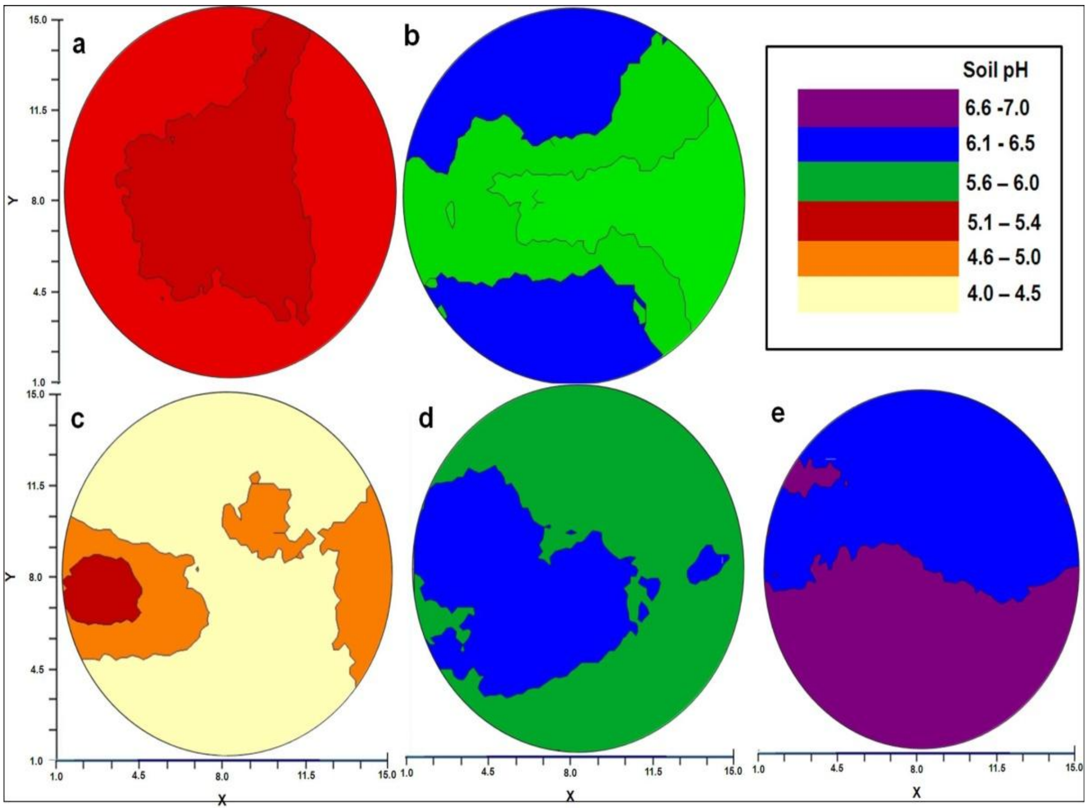

Figure 1. Spatial variability map of soil pH of a sandy loam soil affected by the application of a) control (b) urea (c) chicken dung (d) biochar (e) zeolite after 24 hours of application (the shades of same colour comes in the similar pH range).

Although, it was also documented that the addition of eight to ten years old chicken manure to soil can cause acidity or lower the soil pH (De Datta, 1995). The Figure 1d indicates the effect of biochar on micro-site soil pH variability on biochar treated soil surface. The EFB biochar pH is 8 as analysed and claimed by manufacturer. When EFB biochar added to the soil it will obviously expected to elevate the soil pH (Singh et al., 2011). The soil pH of biochar treated pot was increased from 5.2 to 6.2 which was less than the measured pH range of zeolite. Biochar have neutral to basic pH and many research studies revealed an elevation in soil pH after biochar application when the initial pH was low. On alkaline soils, this may be an adverse effect but for acidic soils it is a positive property. Increase in pH of an acidic soil reduced aluminium toxicities and enhance nutrient availability (Ayanaba and Kang, 1976; Bremner and Mulvaney, 1978; Ahmed et al., 2008a; Dawar et al., 2011). The highest elevation of soil pH were found in zeolite treated soil with a pH variability range from 6.3 to 6.7 (Figure 1e). Addition of zeolite increases the soil pH due to its catalytic ability and parental material structure. Zeolite has been used instead of lime to increase soil pH and to improve the nutrient availability and CEC of soil for a long time (Nibou et al., 2009; Ramesh and Reddy, 2011).

Conclusion

The presented research experiments revealed and compare the effects of soil activator (zeolite), soil conditioner (biochar), organic matter (chicken manure), and inorganic fertilizer (urea) on soil pH, which is a fundamental property of soil. The outcomes of study revealed that the addition of these soil amendments having liming effects because of significant increase in soil pH except chicken manure application. The liming capacity of above mention materials can give better advantage to acidic soils that require liming, by being applied more frequently at lower application rates, reducing labour cost and time. In contrast, elevation in pH can cause nutrient losses in alkaline soils. Prior analysis of soil and agriculture inputs is highly recommended before proceeding to any amendment of soil.

ACKNOWLEDGEMENT

The authors are thankful to Universiti Putra Malaysia, for financial and technical support for the project Fundamental Research Grant Scheme 5524142.

REFERENCES

Ahmed OH, Aminuddin H, Husni MHA (2006). Reducing ammonia loss from urea and improving soil-exchangeable ammonium retention through mixing triple superphosphate, humic acid and zeolite. Soil Use Manage. 22:315-319.

Ahmed OH, Husin A, Hanif AHM (2008a). Ammonia volatilization and ammonium accumulation from urea mixed with zeolite and triple superphosphate. Acta Agric. Scand. Sec. B: Soil Plant Sci. 58:182-186.

Ahmed OH, Hussin A, Ahmad HMH, Rahim AA, Majid NMA (2008b). Enhancing the urea-N use efficiency in maize (Zea mays) cultivation on acid soils amended with zeolite and TSP. The Sci. World J. 8:394-399.

Antil RS, Narwal RP, Gupta AP (1992). Urease activity and urea hydrolysis in soils treated with sewage. Ecol. Eng. 1:229-237.

Ayanaba A, Kang BT (1976). Urea transformation in some tropical soils. Soil Biol. Biochem. 8:313-316.

Balasudram SK, Husni MHA, Ahmed OA (2008). Application of Geostatistical tools to quantify spatial variability of selected soil chemical properties from a cultivated Tropical peat. J. Agron. 7:82-87.

Bremner JM (1965). Total Nitrogen. In: Black CA, E.D., Ensminger LE, White JL, Clark FE, Dinauer RC (eds.) (Ed.), In, Method of soil analysis, Part 2. American Society of Agronomy, Madison, Wisconsin. pp. 1149-1178.

Bremner JM, Mulvaney CS (1982). Nitrogen-total. American Society of Agronomy and Soil Science Society of America Inc. Madison.

Bremner JM, Mulvaney RL (1978). Urease activity in soils. In: Burns, R.G. (Ed.), In "Soil Enzymes" Academic Press, London. pp. 149-196.

Cabrera ML, Kissel DE, Bock BR (1991). Urea hydrolysis in soil: Effects of urea concentration and soil pH. Soil Bio. Biochem. 23:1121-1124.

Chen D, Suter HC, Islam A, Edis R (2010). Influence of nitrification inhibitors on nitrification and nitrous oxide (N_2O) emission from a clay loam soil fertilized with urea. Soil Biol. Biochem. 42:660-664.

Christianson CB, Baethgen WE, Carmona G, Howard RG (1993). Microsite reactions of urea-nbtpt fertilizer on the soil surface. Soil Biol. Biochem. 25:1107-1117.

Clough TJ, Condron LM (2011). Biochar and the Nitrogen Cycle: Introduction. J. Envior. Qual. 39:1218-1223.

Dawar K, Zaman M, Rowarth JS, Blennerhassett J, Turnbull MH (2011). Urea hydrolysis and lateral and vertical movement in the soil: Effects of urease inhibitor and irrigation. Biol. Fert. Soils 47:139-146.

De Datta SK (1995). Nitrogen transformations in wetland rice ecosystems. Fertil. Res. 42:193-203.

Dharejo KA, Anuar AR, Khanif YM, Samsuri AW, Junejo N (2011). Spatial variability of Cu, Mn and Zn in marginal sandy beach ridges soil. Afr. J. Agric. Res. 6:3493-3498.

Fan MX, Mackenzie AF (1993). Urea and phosphate interactions in fertilizer microsite: Ammonia volatilization and pH changes. Soil Sci. Soc. Am. J. 57:839-845.

Freney JR, Keerthisinghe DG, Chaiwanakupt P, Phongpan S (1993). Use of urease inhibitors to reduce ammonia loss following application of urea to flooded rice fields. Plant Soil 155-156:371-373.

Glaser B, Haumier L, Guggnenberger G, Zech W (2001). The 'Terra Preta' Phenomenon; a model for sustainable agriculture in the humid tropics. Naturwissenschafen 88:37-41.

Glaser B, Lehmann J, Zech W (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal-A review. Biol. Fertil. Soils 35:219-230.

Hazelton P, Murphy B (2007). Interpreting soil tesr results; what do all the numbers mean? CSIRO, Collingwood.

Junejo N, Khanif MY, Dharejo KA, Hazandy AH, Abdu A (2012). Evaluation of coated urea for ammonia volatilization loss, nitrogen mineralization and microsite pH in selected soil series. Afr. J. Biotechnol. 11:366-378.

Kissel DE (1988). Management of urea fertilizers. North Central regional publication NCR-326.

McKenzie NJ, Jacquire D, Isbella R, Brown K (2004). Australian Soils and Landscapes- an illustrated compendium. CSIRO publishing: Melbourne.

Nibou D, Mekatel H, Amokrane S, Barkat M, Trari M (2009). Adsorption of Zn2+ ions onto NaA and NaX zeolites: Kinetic, equilibrium and thermodynamic studies. J. Hazard. Mater. 173:637-646.

Nichols DJ, Daniel TC (1994). Nutrient Runoff from Pasture after Incorporation of Poultry Litter or Inorganic Fertilizer. Soil Sci. Soc. Am. J. 58:1224-1228.

Omar L, Ahmed OH, Majid NMA (2010). Enhancing nutrient use efficiency of maize (*Zea mays* L.) from mixing urea with zeolite and peat soil water. Int. J. Phys. Sci. 6:3330-3335.

Perkins HF, Parker MB, Walker ML (1964). Chicken manure its production,composition and use as a fertilizer. Georgia Agricultural Experiment Station, Georgia.

Ramesh K, Reddy DD (2011). Zeolites and thier potential uses in agriculture. Adv. Agron. 113:219-240.

Singh BP, Hatton BJ, Singh B, Cowie AL, Kathuria A (2011). Influence of Biochars on Nitrous Oxide Emission and Nitrogen Leaching from Two Contrasting Soils. J. Envir. Qual. 39:1224-1235.

Srinivasarao C, Venkateswarlu B, Lal R, Singh AK, Vittal KPR, Kundu S, Singh SR, Singh SP (2011). Long-Term Effects of Soil Fertility Management on Carbon Sequestration in a Riceâ€“Lentil Cropping System of the Indo-Gangetic Plains. Soil Sci. Soc. Am. J. 76:168-178.

Steiner C, Das KC, Melear N, Lakly D (2010). Reducing Nitrogen Loss during Poultry Litter Composting Using Biochar. J. Environ. Qual. 39:1236-1242.

Walkley A, Black IA (1934). An examination of Degtjaref method for determination of soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. Soc. Am. J. 37:29-38.

Webster R, Oliver MA (2007). Geostatistics for Environmental Scientists. John Wiley and Sons, press, UK.

Zhang M, Zhang H, Xu D, Han L, Niu D, Tian B, Zhang J, Zhang L, Wu W (2010). Removal of ammonium from aqueous solutions using zeolite synthesized from fly ash by a fusion method. Desalination 271:111-121.

Zhao X, Xing GX (2009). Variation in the relationship between nitrification and acidification of subtropical soils as affected by the addition of urea or ammonium sulfate. *Soil* Biol. Biochem. 41:2584-2587.