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NUTRIENT UPTAKE BY PLANTS FROM DIFFERENT LAND TYPES OF MADHUPUR SOILS

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Abstract

Three different soil series such as Gerua, Kalma and Khilgaon were identified in three different land types (high, medium high and medium low land). Soil and plant samples were collected from each land type following a catena. Soil samples were collected from surface, subsurface and substratum in each soil series and plant samples were collected from each soil series to examine how the soil characteristics affect nutrient uptake by plants. The uptake of N, P, S and Zn increased from Gerua to Kalma soil and decreased to Khilgaon. K uptake increased from Gerua to Khilgaon soils. The concentration of Fe, Mn and Cu decreased at first and then increased that were opposite to the status of N, P, S and Zn. The uptake of P and Mn were positively correlated ($r^2 = 0.845^{**}$, $r^2 = 0.767^{*}$) and the uptake of K and Fe were negatively correlated ($r^2 = -0.951^{**}$, $r^2 = -0.676^{*}$) with the soil nutrients. This indicates the variation in nutrient concentration influenced by different factors in the catena. The uptake of nutrients by plants varied significantly within the catena. Macro and micronutrients were accumulated by the plants and the soils studied in the experiment did not show any nutrient deficiency or any metal contamination.

Key words: Nutrient, uptake, plants, land types, Madhupur soils

Introduction

Plant analysis is an important tool of evaluating soil fertility, which determines the nutrient supplying capacity of the soil. Soil plays a major role in determining the sustainable productivity of an agro-ecosystem and sustainable productivity of a soil mainly depends upon its ability to supply essential nutrients to the growing plants.

Intensive cropping often leads to nutrient imbalance/deficiency in soils and may affect nutritional status of plants (Kabata-Pendias and Pandias 2001). One of the major constraints for crop productivity in many countries of the world is the deficiency of micronutrients. About half of the world's population suffers from micronutrient shortage makes plant nutrition research indispensible (Cakmak 2002, Alloway 2008). A deficiency of one or more of the micronutrients can lead to severe depression in growth, yield and crop quality.

Some soils do not contain sufficient amounts of these nutrients to meet the plant's requirements for rapid growth and good production. In such cases, supplemental micronutrient applications in the form of commercial fertilizers or foliar sprays must be made.

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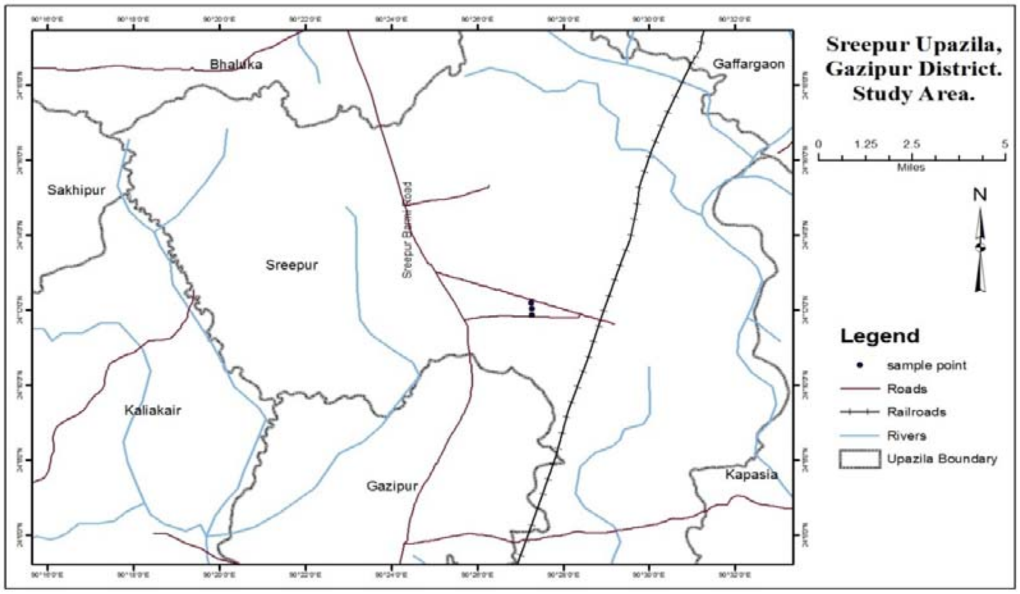
Soils are complex and multi-component systems, which can act as physical, chemical and biological reactors. Soils are the main source of nutrient elements for plants, and soil conditions play a crucial role in metal ion behavior. It is well known that the optimum plant growth and yield depend not only on the total amount of nutrients present in the soil at a particular time but also on their availability which in turn is controlled by physico-chemical properties like: soil texture, organic carbon and calcium carbonate, cation exchange capacity, pH and electrical conductivity of soil (Bell and Dell 2008). Soil properties, metal speciation, plant species, water regime, and especially soil-plant interactions determine the bioavailability of soil metal ions (Manouchehri *et al.* 2006, Kubová *et al.* 2008). The occurrence of nutrient deficiency or the toxicity of metal to plants and soil microorganisms or excessive transfer to food chain is related to metal bioavailability.

Macro- and micronutrient contents of soil and their availability to plant are assessed by mineral presence and weathering process (Kumar and Babel 2011). Soil types and soil horizons influence the metal distribution factors. The soils of Madhupur Tract, having the problem of old soils with clay are characterized by heavy texture, more or less high organic carbon content, low pH, high CEC and acidic behavior. These soil conditions are favorable for adequate availability of micronutrients and also for the loss of macro- and micronutrients due to erosion. So, the present investigation was undertaken to assess the status of available micro- (Fe, Mn, Zn, Cu) and macronutrients (N, P, K, S) and their relationship with soil properties and plant uptake.

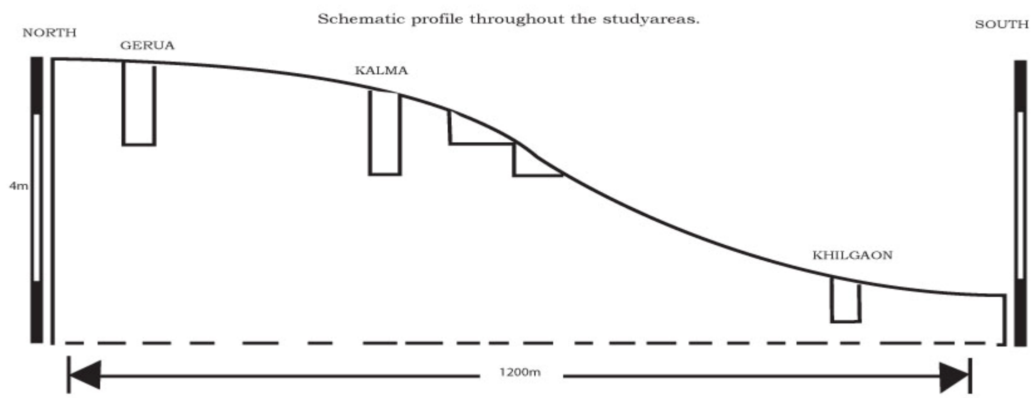
Materials and Methods

The study was designed to determine the status of macro and micronutrients in plants and soils from Gazipur district. In a catena nine soil samples and three composite plant samples were collected from three different land types under same parent material Madhupur Tract. The sampling site along with a soil catena is located about 24^{o} 01' and 24^{o} 21' North Latitude and 90^{o} 18' and 90^{o} 33' Longitude (Fig. 1).

Three land types were identified in a catena and each land type has individual soil series named as Gerua soil series (high land), Kalma soil series (medium high land) and Khilgaon soil series (medium low land). Composite soil samples were collected from three different land types from a depth of 0 - 15 cm, 15 - 40 cm and 40^{+}cm from surface, subsurface and substratum, respectively using Soil Survey Staff of the USDA (1951) manual. Soil samples were air-dried, ground by wooden hammer and screened to pass through a 2 mm stainless steel sieve. The sieved soils were then mixed thoroughly and used for various chemical analyses. Collected plant samples such as rice straw were washed out with distilled water in the laboratory. Then they were cut down into small pieces, covered with papers and were kept 72 hours in the oven for drying at 80^{o}C. After oven drying the plant samples were ground with mortar and were passed through a 0.2 mm stainless steel sieve and preserved in plastic containers.



a. Sampling site and location.



b. Schematic profile throughout the study areas, showing the topography and soil catena.

Fig. 1. Area of study (a. site and location, b. soil catena).

Bulk density, particle size analysis, moisture %, CEC and pH of soil samples were determined following the procedure described by Huq and Alam (2005). The organic carbon content of the soils was determined by wet oxidation method of Walkley and Black (1934). Total N of soil and plant samples were determined by Kjeldahl method. Total concentration of P, K, S, Fe, Mn, Zn and Cu in soil was analyzed by digesting soil with aqua-regia at a ratio of 1 : 10. Total concentration of the same elements in plant was determined by digesting them with nitric acid followed by perchloric acid (Jackson 1962). In case of available Fe, Mn, Zn and Cu in soil DTPA was used as an extracting agent (Huq and Alam 2005). Total phosphorus was estimated colorimetrically using a spectrophotometer by developing yellow color with vanadomolybdate, total potassium by flame photometer and total sulfur by turbidimetric method using spectrophotometer (Jackson 1962). Both total and available Fe, Mn, Zn and Cu were estimated by AAS (Atomic Absorption Spectrophotometer). Data were statistically analyzed using software Stata version 12.

Results and Discussion

The pH of the soils was acidic in nature and slightly increased from top soil of Gerua to the bottom soil of Khilgaon in the catena which may be due to fine clay accumulation. Similar trend also indicates in soil textures ranging from silt loam to silty clay loam (Table 1). Usually fertilizer application in spring and very dry summer conditions combine to temporarily depress soil pH. The soil pH increases due to continuous rain in fall and winter seasons. Seasonal fluctuation of soil pH makes year-to-year comparison difficult unless soil samples are collected at the same time each year. Use of most common nitrogenous fertilizers such as urea increases soil acidity and need lime. Therefore, lime applications are effective for several years if thoroughly mixed with the soil.

Table 1. Physical and chemical properties of the soils.

Soils	Layer	pH	Moisture %	Bulk density (g/cm^3)	CEC (meq/100g)	OM	Sand	Silt	Clay	Texture
						%				
Gerua	Surface	4.75	6.88	1.13	5.96	1.84	16	59	25	sil
	Subsurface	5.29	16.02	1.32	7.48	0.73	14	50	36	sicl
	Substratum	4.79	22.46	1.54	9.29	0.355	17	47	36	"
Kalma	Surface	5.54	35.63	1.28	3.97	2.39	11	69	20	sil
	Subsurface	5.28	21.69	1.71	3.975	0.605	9	64	27	sicl
	Substratum	5.34	34.33	1.19	6.31	0.355	8	57	35	"
Khilgaon	Surface	5.16	22.92	1.39	6.31	1.81	13	57	30	"
	Subsurface	5.14	23.91	1.35	5.03	0.85	13.5	54	32.5	"
	Substratum	5.88	26.75	1.53	11.12	0.48	11	42	47	sic

sil = Silt loam, sicl = Silty clay loam, sic = Silty clay.

Total N gradually decreased to the subsoil but available concentrations were higher. The total and available K concentrations increased from upper to lower layers, which clearly indicate that N and K are mobile nutrient elements (Table 2).

Both total and available Fe, Mn and Zn gradually decreased from top soil Gerua to the bottom soil Khilgaon of the catena because the solubility and availability of micronutrients are decreased if soil pH increases (Hart *et al.* 2003). In case of Cu, total concentrations gradually increased but the available Cu decreased in the lower layers (Table 3), in addition to pH, it may also be due to

Table 2. Total and available nutrient concentrations of N, P, K, S in different soils.

Soils	Layer	N	P	K	S	N	P	K	S
		Total conc. (%)				Available conc. (µg/g)			
	Surface	0.056	0.043	0.069	0.015	9.82	24.81	9.83	10.23
Gerua	Subsurface	0.035	0.041	0.079	0.016	9.82	15.65	10.47	9.47
	Substratum	0.02	0.043	0.088	0.017	8.18	14.76	13.07	9.25
	Surface	0.08	0.039	0.06	0.012	9.82	32.23	9.78	10.88
Kalma	Subsurface	0.035	0.037	0.056	0.01	6.55	21.96	8.65	9.99
	Substratum	0.02	0.037	0.059	0.012	6.55	16.45	9	9.57
	Surface	0.066	0.039	0.062	0.013	4.91	26.77	9.09	11.17
Khilgaon	Subsurface	0.047	0.037	0.063	0.011	6.55	20.43	8.23	9.36
	Substratum	0.031	0.039	0.074	0.014	13.09	15.08	11.42	9.23

Table 3. Total and available nutrient concentrations of Fe, Mn, Zn and Cu in different soils.

Soil	Layer	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
		Total conc. (µg/g)				Available conc. (µg/g)			
	Surface	17100	587	33.04	20.12	8.85	88.06	2.07	0.32
Gerua	Subsurface	21300	799	29.04	15.01	6.61	9.80	0.70	0.11
	Substratum	48900	1055	36.11	26.92	8.41	15.48	1.23	0.19
	Surface	4500	55	20.98	12.56	8.52	12.78	1.94	0.39
Kalma	Subsurface	2200	40	14.99	10.44	5.43	11.7	0.86	0.22
	Substratum	2900	56	24.12	17.09	8.91	15.11	0.70	0.21
	Surface	9600	125	22.99	22.01	5.46	32.73	1.31	0.35
Khilgaon	Subsurface	5100	74	20.60	10.99	6.80	25.96	1.56	0.29
	Substratum	19000	95	25.96	25.71	6.68	12.41	0.90	0.25

the organic matter, because organic matter gradually decreased to the lower layers, and so, available Cu concentrations decreased. In case of Cu availability, Cu forms soluble complex with organic matter (Mengel and Kirkby 2001). Cation exchange capacity gradually increased from upper to the lower layers, suggesting that the increase in pH was partly responsible for the increase in effective CEC which is important as it may temporarily improve cation retention and reduce leaching of base cations. Soils dominated by clays are typically strongly weathered. The fertility of these soils decreases with decreasing pH which may have been induced by acidifying nitrogen fertilizer, nitrate leaching and by clearing and agricultural practices (McKenzie *et al.* 2004). Soil pH change can also be caused by natural processes such as decomposition of organic matter and leaching of cations. The lower the CEC of a soil, the faster the soil pH will decrease with time. Liming soils to pH higher than 5 will maintain exchangeable plant nutrient cations.

Table 4. Total nutrient concentrations of N, P, K, S, Fe, Mn, Zn and Cu in plant samples.

Source of samples	N	P	K	S	Fe	Mn	Zn	Cu
	Total concentration (%)						Total conc. (μg/g)	
Gerua	0.339	0.048	0.181	0.039	0.10	0.214	329	11.9
Kalma	0.473	0.049	0.20	0.042	0.099	0.159	387	9.60
Khilgaon	0.398	0.048	0.233	0.04	0.121	0.207	338	17.9

Table 5. Relationship between plant and soil nutrient concentrations.

Correlations between plant nutrients and available soil nutrients	
Plant N with available soil N	0.068
Plant P with available soil P	0.845**
Plant K with available soil K	–0.951**
Plant S with available soil S	0.518
Plant Fe with available soil Fe	–0.676*
Plant Mn with available soil Mn	0.767*
Plant Zn with available soil Zn	0.217
Plant Cu with available soil Cu	–0.384

The nutrient N, P, S and Zn concentrations showed maximum in Kalma soils. The research location dominates medium highland where farmers apply their available organic manures and chemical fertilizers due to intensive cultivation. On the other hand, Cu, Fe and Mn concentrations decreased in Kalma soils. The K concentrations increased from Gerua to Khilgaon soils because nutrients accumulation in plants is due to the available concentrations in the soils. The availability of plant nutrients is influenced by the soil properties. Soils with a low CEC are more likely to develop deficiencies in nutrients and other cations while high CEC soils are less susceptible to leaching of these cations (CUCE 2007). Several factors such as environmental conditions and crop characteristics have an important impact on nutrient uptake and may restrict the release of nutrients to plants.

Plant P ($p < 0.01\%$) and Mn ($p < 0.05\%$) levels showed significant positive relationship with their available concentrations (Table 5). Results also indicate higher P and Mn accumulation in plants in Kalma (0.049%) and Gerua (0.214%) soils (Table 4), as the available concentrations of these nutrients were higher in the surface soils (Tables 2 and 3), except Kalma soil Mn.

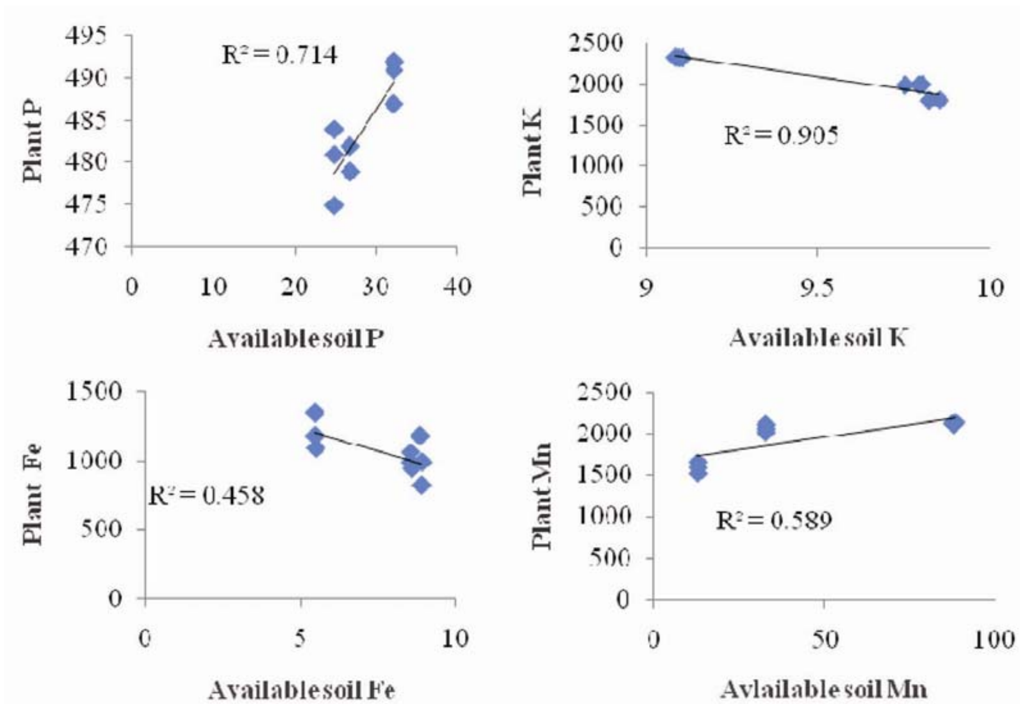


Fig. 2. Relationship between available soil and plant nutrients.

Plant K and Fe showed significant negative relationship at $p < 0.01\%$ and $p < 0.05\%$ levels (Table 5 and Fig. 2) because accumulation in plants were higher in Khilgaon soils at 0.233 and 0.121%, respectively (Table 4) but their availability is lower in the surface of Khilgaon soils (9.09 and 5.46 µg/g, respectively). Available Fe concentrations were high in the Gerua soils (Table 3), but plant uptake was less. In substratum soils, the organic matter content is decreasing and increasing CEC because it's governed by clay content, hence CEC trends increased downwards. Furthermore, microelements status has become a subject of scientific interest in the two states of affairs: one is when any of the essential elements start to limit plant growth and the other is when soil has been subjected to pollution with heavy metals. In soil system, plants take the microelements mainly by their root system, as a natural requirement for their growth. Any factor that restricts root growth and activity has the potential to restrict nutrient availability.

Conclusion

The uptake of nutrients by plants varied significantly within the catena because both physical and chemical soil properties are responsible for the difference in nutrient status. The results showed no contamination or deficiency in soils. The findings may suggest the evaluation of soil management techniques to limit mobility and plant availability of microelements and to ultimately minimize their transfer into the food chain.

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