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Edaphic Diversity and Growth of Some Indian *Isoetes* L. Species

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ABSTRACT: In the present study an attempt has been made to correlate the different soil factors with the growth of four different species of *Isoetes* L. Soil collected from natural habitats of *Isoetes* have been analysed for colour, texture, pH and available plant nutrients. The present analysis revealed that the habit of the plant of different species is influenced by edaphic diversity. It has also been found that the genus *Isoetes* is one of the most edaphically diversified genera of the pteridophyta. There was certain sensitivity of plant length in relation to the various soil factors. The lower scale of acidity favored the growth of *Isoetes*. The length of the plant decreases with the altitude. The nutrients like, zinc, manganese, iron and copper present in the soil showed significant relationships with the growth of the plants.

KEY WORDS: Soil, *Isoetes*, Texture, Nutrients and Growth.

INTRODUCTION

The role of edaphic factors in controlling the growth and expansion of plant communities is well known. Soil is the main source of almost all the minerals for plant growth. The texture of the soil and the quantity and quality of its organic matter largely determine its productive potential. The influence of climate on soil is exerted partly through its partial determination of native vegetation under which the soil evolves (Lutz and Chandler, 1961; Jenny and Roychoudhury, 1967).

The plants of *Isoetes* L. grow in diverse environmental conditions. The soil and plant correlation may be of immense ecological and evolutionary significance for the genus. The ecological investigation of *Isoetes* can be traced back to the pioneering work of Engelmann (1882) who was the first to emphasize the relationship of *Isoetes* to water and had accordingly, subdivided the genus into submerged, amphibious and terrestrial forms. Dorris (1964) and Hall (1971) reported profound influence of microhabitat on morphological and population variability in *Isoetes*. Rury (1978) analysed the influence of microhabitat with a view to understand the marked polymorphism encountered within the genus *Isoetes*. Hickey *et al.* (1989) have studied different population aggregates of *I. storkii* occurring at different altitudes in Costa Rica and *I. melanopoda* complex endemic to granite outcrops in the USA to see the range of variations in a number of morphological characters such as the general plant length, leaf length, number of leaves, leaf arrangement and corm shape, etc.

The genus *Isoetes* has witnessed all the geological and environmental turmoil in the past. In India, it is distributed both in the hills the and the plains. The plant is so intimately related with its natural inhabitation that all efforts, thus far, to cultivate it have not been successful.

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The present study aims to investigate the soil plant interactions. This may help in understanding the reason of its intimate association with the habitat. In the present study was therefore, aimed to isolate, define and quantify the critical characteristics of soils of the various habitats of *Isoetes*. This was in reference to factors that apparently control the distribution and growth performance of plants (luxuriant growth or otherwise), and the net nutrient availability.

MATERIALS AND METHODS

The plants of *Isoetes* were growing along the margins of ponds, seasonal pools, marshy lands, wet open grass-covered surfaces and sometimes submerged in various water bodies. Soil samples were collected in all the habitats (fourteen different localities of India; table, 1 and 2) from the immediate surrounding of the roots. These samples were analysed for colour, texture, pH, electrical conductivity, organic carbon, nitrogen, phosphorus, potassium, manganese, iron, copper, and zinc using the methods described by Walkley and Black (1934), Piper (1942, 1950) and Jackson and Burton (1958).

Mechanical composition of soil: "International Pipette Method" described by Piper (1942) was used to determine the mechanical composition (i.e., percentage of sand, silt and clay including textural classes of soil samples.

Soil colour: The soil colour was compared with the Munsell colour chart and the values were recorded for each of the samples under dry and wet conditions (Piper, 1942).

Soil texture: The texture of the soil was determined by a rapid procedure by feel or rubbing. The soil is rubbed between thumb and fingers. Proficiency was gained by appropriate trial and errors and comparisons were made with samples of known textural class. Steps for this determination were as follows.

The texture of class of known soil sample taken for comparison was correctly ascertained from the percentage distribution of sand, silt and clay. It was determined according to the International pipette method (Piper, 1942) using standard triangular diagram.

Soil pH: It was measured by a pH meter. This meter is a direct current amplifier that measures the e.m.f. which appears across the electrode upon being immersed in a solution or soil suspension. The glass and calomel electrodes were immersed in the test solution and the e.m.f. was determined by an electrode tube voltmeter. The meter is graduated to read directly in pH units along with the e.m.f. (millivolts) scale. A standard buffer solution (of known pH) was used to calibrate the instrument before determining the pH of test solution. The measurements were registered in on suitably calibrated galvanometer.

Electrical conductivity: The Electrical conductivity was measured by an instrument consists of an A.C. salt bridge or electrical resistance bridge and conductivity cell having electrodes coated with platinum black.

Twenty grams of soil was shaken intermittently with 40ml of distilled water in a 150 ml Erlenmeyer flask for one hour and allowed to stand. Alternatively, the clear extract after pH determination could be used for electrical conductivity measurements. The conductivity of supernatant liquid was determined with the help of salt bridge. The measurements was adjusted for known temperature of the solution by setting the knob provided for this purpose.

Specific gravity: The specific gravity of soil is the mass of soil per unit volume and porosity of soil is the fraction of soil volume not occupied by soil particles.

Weigh a large weighing bottle of 50 ml capacity without the stopper. Fill it up with soil, flush up to the brim tapping the bottle about 20 times and weigh again. Remove the soil and now fill the bottle with water by means of burette and note the exact volume of water needed to fill the bottle. The specific gravity is obtained by the dividing the weight of the soil with volume of the soil. (J. S. Kanwar and S. L. Chopra, 1967).

Organic carbon: Organic carbon was determined by wet digestion with in $K_2Cr_2O_7$ solution, concentrated H_2SO_4 and the titration was done with standard $FeSO_4$ solution; (Walkley and Black, 1934) as described by Jackson (1973). The percentage of organic matter was calculated, multiplying the percent organic carbon by the conventional Van Bemden Factor or 1.724.

Nitrogen: A sufficient amount of soil (10 g) was digested with conc. H_2SO_4 in the presence of a catalyst mixture in a Kjeldahl digestion flask. The digest was treated with conc. NaOH to extract NH_3 and was dissolved in the Boric acid solution. It was titrated with dilute H_2SO_4 (Piper, 1942).

Phosphorus: One gram of oven dried soil was taken in 500 ml. flask. It was titrated with 0.002N H_2SO_4 to extract phosphorus. The pH of the solution was maintained by Na_2CO_3 and H_2SO_4.

The reaction of sulphomolybdic acid forms yellow coloured heteropoly complex and is reduced to blue colour by the addition of stannous chloride solution. Concentration of the blue colour was read by the calorimeter in terms of optical density at 700 mμ (Jackson and Burton, 1958). Exchangeable phosphorus was estimated by Spectro-photometer. The optical density of the extract was compared with the standard curve (Piper, 1942).

Potassium: Five grams of soil was shaken with 25 ml of neutral ammonium acetate (pH=7) for 5 minutes and filtered immediately through the dry filter paper. First few ml of the filtrate was rejected. The potassium concentrate in the extract was determined with the Flame photometer after necessary setting and calibration of the instrument (Piper, 1942).

Four micronutrients, *viz.*, copper, iron, zinc and manganese were estimated in a single extraction with DTPA (Diethylene-Triamine Penta Acetic Acid) by setting the instrument (AAS) for each of them and using respective standard curve (Lindsay and Norvell, 1978).

Twenty ml DTPA reagent was added to 10 g of soil in 100 ml conical flask, and shaken for two hours. The extract was filtered and zinc was then estimated with the help of atomic absorption spectrophotometer. The same procedure was followed for the estimation of copper, iron and manganese.

Zinc: 1 g of pure zinc was dissolved completely in minimum amount of dill. HCl and made up to one litre with distilled water in already used volumetric flask and then transferred to a plastic bottle. This stock solution contains 1000 mg Zinc/ml. A working standard of 25 mg/ml was prepared diluting 2.5 ml of the stock solution to 100 ml. In six 100 ml volumetric flasks, required aliquots were taken and standard of 0, 0.5, 1.5, 2 and 2.5 ppm zinc solutions were made and the standard curve prepared against the reading of the atomic absorption spectrophotometer after necessary setting and calibration of the instrument.

Copper: A stock solution of 1000 ppm copper was obtained by dissolving exactly one gram of the pure (AR grade) metal in 50 ml of dill. HNO_3 and finally diluting to 1000 ml with distilled water. From this working solution (0.25, 0.5, 1.5, 2, 2.5, 3 ppm) were prepared by dilution in 100 ml volumetric flask.

Iron: To prepare a stock of solution of 1000 ppm iron, exactly 1g of AR grade Iron metal was dissolved in 50 ml of dill. HNO_3 and made upto one litre with distilled water. Working solution(1, 2, 3, 4, 6, 8, and 10 ppm) were made in 1000 ml volumetric flask by appropriate dilution.

Manganese: 1.583 g of MnO_2 (AR) or 1.0 g of pure metal dissolved in 50 ml of dill. HNO_3 and made upto 1 litre gave a stock dilution of 1000 ppm. In 100 ml volumetric flask requisite quantities of stock solution were diluted to obtain working concentration of 1, 2, 3, 4, 6 and 10 ppm. The standard curve for the above were prepared against the reading of the atomic absorption spectrophotometer after necessary setting and calibration of the instrument (Heintze, 1957).

RESULTS

The four species of *Isoetes* and their different localities and habitats selected in the present study are presented in table 1. Table 2 indicates the colour of the soil from various localities. Table 3 presents the textural classification of the soil and table 4-7 include mean values of concentration of mineral nutrients, electrical conductivity of soils and length of plants.

Table 1. Species of *Isoetes* and their localities.

Species	Locality
I. panchananii	Pologround, Rani Ki Bir, Jatashanker, Bhaisa Talya, Reechgarh, Banjarimata (M.P.)
I. panchganiensis	Panchgani, Khinger (Maharashtra) and Kamenegundi (Karnataka)
I. mahadevensis	Chotta Mahadev (M.P.)
I.coromandelina	Bari, Gyanpur, Phafamau, Sonebhadra (U. P.) Matculi, Halipad (M.P.)

Table 2. Soil colour of various localities.

S. No.	Localities and State	Soil Colour
1	Bari (Allahabad)U. P.	Dusky yellow
2	Phaphamau (Allahabad) U. P.	Dusky yellow
3	Gyanpur (Varanasi) U. P.	Gray
4	Pologround (Pachmarhi) M. P.	Dusky red
5	Bhaisa Talaya (Pachmarhi) M. P.	Brown
6	Chotta Mahadeve (Pachmarhi) M. P. {Ditch}	Very dusky red
7	Chotta Mahadeve (Pachmarhi) M. P. {Pedmontane}	Dusky red
8	Reechgarh (Pachmarhi) M. P.	Brownish red
9	Jatashanker (Pachmarhi) M. P.	Dark brown
10	Halipad (Pachmarhi) M. P.	reddish black
11	Panchgani (Satara) Maharashtra	Brown
12	Matculi (Hoshangabad) M. P.	Yellowish
13	Chickmanglore Karnataka	Very dusky red
14	Sonebhadra U. P.	Moderately Black

Isoetes panchananii Pant *et* Srivastava Fig. 1, Table 4

The size of the plants collected from different localities ranged from 18 to 23 cm. The concentrations of copper and nitrogen in the soil ranged between 0.65 and 1.82 kg/ha and 326.14 and 954.62 kg/ha, respectively. Plants occurring in copper and nitrogen rich habitat, e.g., Pologround, Rani Ki beer and Reechgarh were shorter in size. On the other hand, the Jata Shanker, Bhaisa Talaya and Banjarimata with the lower concentrations, supported plants of

Table 3. Textural classification of soils.

Localities	Soil Textural class	% of Sand	% of Silt	% of Clay	Feel of moist soil	Ball formation from slightly moist soil	Stickiness of wet soil	String formation from wet soil
Bari	Clay	22.0	28.5	60.6	Smooth	Firm balls are formed. They are slightly hard on drying.	It sticks to both fingers	There is no string formation
Phaphamau	Clay	12.5	15.6	60.3	Slightly gritty and fairly smooth	Fairly firm balls results. They are slightly hard on drying.	It sticks to only one finger	It shows slight tendency to form string
Pologround	Silt	13	66.2	20.5	Slightly gritty and fairly smooth	Fairly firm balls are formed. They are slightly hard on drying.	It sticks to only one finger	it shows slight tendency to form string
Panchgani	Clay	26.5	30.4	44.0	Very smooth	Very firm balls results. They are very hard on drying	It sticks to both hands	Long flexible strings are formed
Wilson point	Silty loam	18.3	15	66.3	Smooth	Very firm balls results. They are very hard on drying	It sticks to both fingers	short strings are formed
Reechgarh	Clay loam	33.5	32.6	33.5	Smooth	Very firm balls results. They are very hard on drying	It sticks to both fingers	Short strings are formed
Jatashanker	sand	87.5	8.5	4.2	Slightly gritty and fairly smooth	Very firm balls results. They are very hard on drying	It sticks to both fingers	Short strings are formed
Bhaisa Talaya	Clay loam	45.2	36.5	18.2	Slightly gritty and fairly smooth	Fairly firm balls results, which are slightly hard on drying.	It sticks to only one finger	It shows slight tendency to form string
Halipad	Clay	24.5	31.3	45.4	Smooth	Very firm balls results. They are slightly hard on drying	It sticks to both fingers	No string formation
Chotta Mahadev	Sandy loam	46.0	35.2	20.5	Moderately gritty	Balls formed are delicate but can bear careful handling.	It dirties finger slightly	No string formation
Chotta Mahadev (Pedmontane)	loam	85.0	12.0	3.5	Smooth	Very firm balls results. They are not hard on drying	It sticks to both fingers	Short strings are formed
Matculi	Silty loam	20.2	61.6	18.2	Smooth	Very firm balls results. They are slightly hard on drying	It sticks to both fingers	Short strings are formed
Gyanpur	Clay	22.6	20.0	61.5	Smooth	Very firm balls results. They are hard on drying	It sticks to both fingers	No string formation
Chickmanglore	Sandy clay loam	88.0	9.8	3.5	Slightly gritty and fairly smooth	Fairly firm balls results, which are slightly hard on drying.	It sticks to only one finger	It shows slight tendency to form string
Sonebhadra	Clay	17.5	21.94	61.01	Very smooth	Very firm balls results. They are very hard on drying	It sticks to both hands	Long flexible strings are formed.

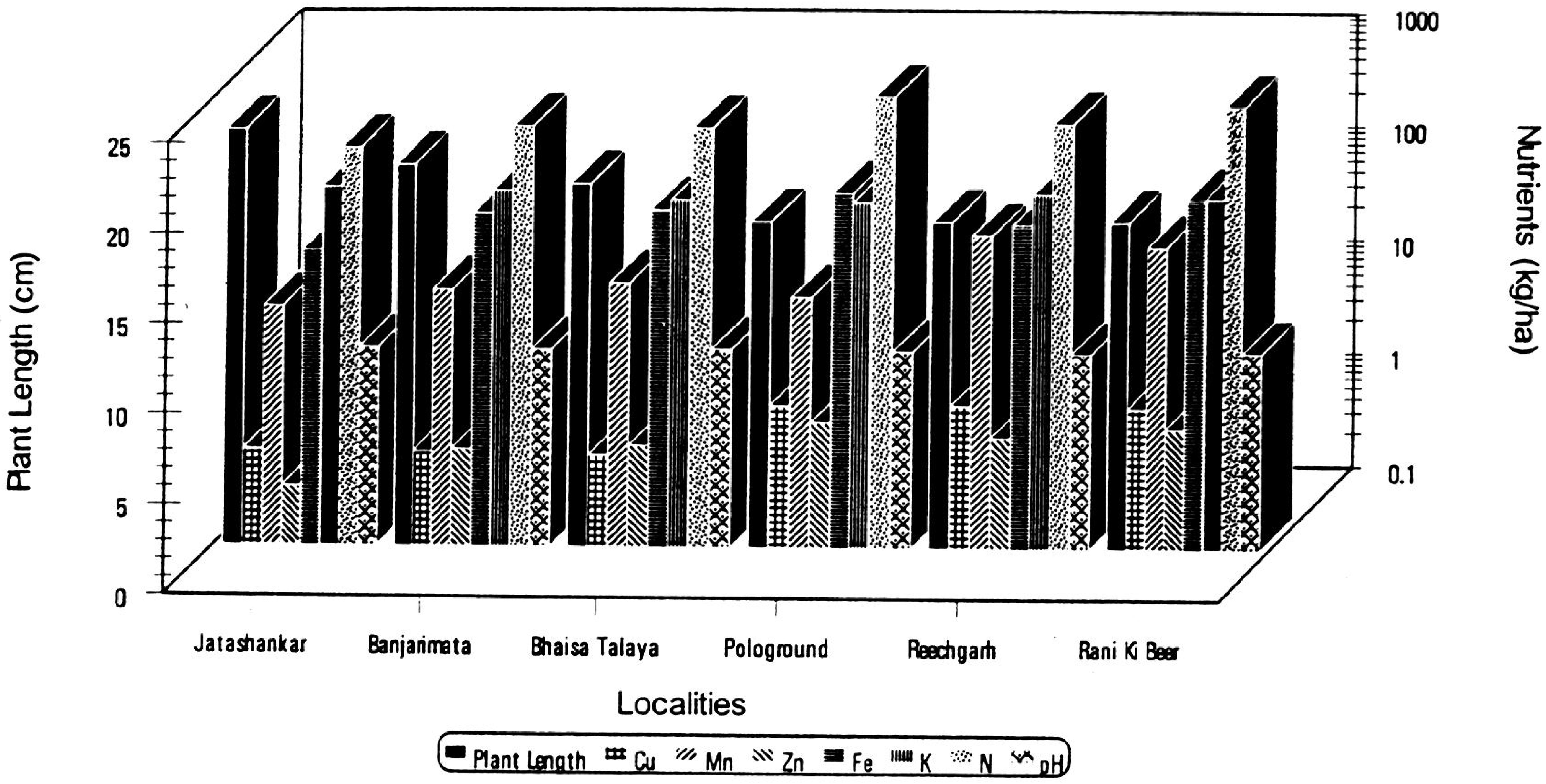

Fig. 1. Bar graph showing correlation between plant length and nutrient contents in the soil of various localities of *I. Panchananii.*

much greater size. The impact of potassium, was noted to be maximum at Jatashanker, i.e., 146 kg/ha where the length of the plant was also maximum. There was a positive relationship between plant length and potassium content of soil. The soil organic matter did not show any relation with the plant size.

The pH of the soil appeared to influence plant length, as relatively less acidity favoured greater height of plants and a positive relationship existed between pH and plant length.

Isoetes coromandelina L. f. Fig. 2, Table 5

The length of the plants varied from 21 to 51 cm and was significantly correlated with various nutrient elements present in the soil. The range of manganese, potassium, and

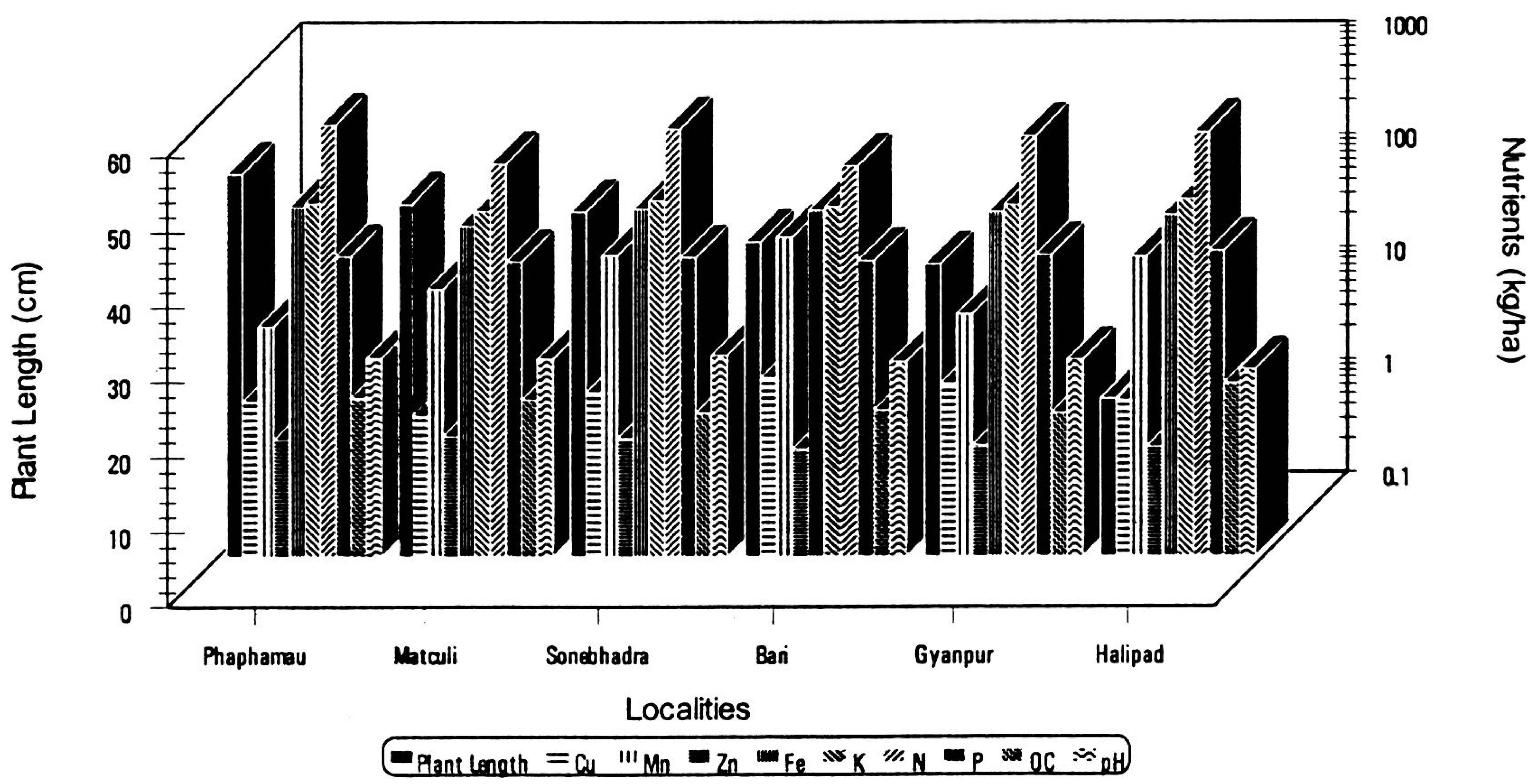

Fig. 2. Bar graph showing correlation between plant length and nutrient contents in the soil of various localities of *I. Coromandelina.*

Table 4. Mean values for plant length and mineral nutrients, pH and electrical conductivity, and r values for relationships between plant length and the physico-chemical characters of soil in various localities of *I. Panchananii.*

	Plant Length (cm)	Copper (kg/ha)	Manganese (kg/ha)	Zinc (kg/ha)	Iron (kg/ha)	Potassium (kg/ha)	Phosphorus (kg/ha)	Nitrogen (kg/ha)	Organic Carbon (kg/ha)	pH	Electrical Conductivity	Specific gravity (gm/cm^{-3})
Mean (x)	19.6700	1.2300	28.892	0.870	91.87	126.50	50.00	610.81	3.249	5.45	0.133	1.1095
Population S.D. (σn)	01.8856	0.5541	16.883	0.309	31.123	11.142	16.381	209.91	0.524	0.138	0.0234	0.096
Sample S.D. σ(n-1)	02.0656	0.6071	18.494	0.337	34.093	13.05	17.944	229.95	0.574	0.151	0.0259	0.105
Co-efficient of variation (CV)	09.5882	45.056	58.438	35.533	33.90	8.785	32.76	34.366	16.123	2.540	17.722	8.656
Co-efficient of correlation (r)	_	-0.8708	-0.6589	-0.9464	-0.7495	0.6900	-0.3291	-0.8181	-0.2879	0.766	-0.3125	0.5637

Table 5. Mean values for plant length and mineral nutrients, pH and electrical conductivity, and r values for relationships between plant length and the physico-chemical characters of soil in various localities of *I. Coromandelina.*

	Plant Length (cm)	Copper (kg/ha)	Manganese (kg/ha)	Zinc (kg/ha)	Iron (kg/ha)	Potassium (kg/ha)	Phosphorus (kg/ha)	Nitrogen (kg/ha)	Organic carbon (kg/ha)	pH	Electrical Conductivity	Specific gravity (gm/cm^{-3})
Mean (x)	41	2.783	35.53	1.0367	114.19	136.00	46.33	504.867	2.3743	5.55	0.1333	1.178
Population S.D. (σn)	9.713	0.70	20.830	0.098	13.49	10.52	3.30	149.38	0.5478	0.49	0.02357	0.09
Sample S.D. σ(n-1)	10.64	0.7671	22.82	0.108	14.78	11.52	3.615	163.64	0.600	0.54	0.258	0.099
Coefficient of variation (CV)	25.95	27.56	64.22	10.38	12.94	8.47	7.80	32.412	25.28	9.65	19.365	8.378
Coefficient of correlation (r)	_	-0.06	-0.3215	0.6496	0.1712	-0.5220	-0.7332	-0.0806	-0.6555	0.89	0.0364	-0.2601

phosphorus in the soil was 11.15-69.51 kg/ha, 118-150 kg/ha and 42 -52 kg/ha respectively. With an increase in the concentration of these elements the length of the plants decreased. However, in the case of zinc it was observed that at Phaphamau, Matculi and Sonebhadra sites where the amount of zinc was higher the length of plants was greater. Where the amount of Zinc was more than 1 kg/ha the length of the plants was maximum. This shows that higher zinc content in soil favors the growth of plants. However, the plant length was independent of concentrations other elements like copper, iron and manganese have insignificant correlation with the length of the plants. Soil organic matter was inversely related with the length of the plant, e.g., at Halipad where the concentration of organic matter was 3.4 kg/ha the length of the plant was minimum, i.e., 21 cm.

The pH of the soil (4.6-6.2) also had a positive correlation with the plant length, showing that acidity reduces the growth of plants.

Isoetes panchganiensis Srivastava, Pant *et* Shukla Fig. 3, Table 6

The impact of soil factors on the plants of *I. panchganiensis* was quite visible at Kamenegundi where it attained the maximum length of 16 cm. The present analysis shows that in this species copper, potassium, phosphorus, and nitrogen, had negative correlation with plant length. With an increase in the concentration of these elements the length of the plants decreased. For example, at Panchgani where the amount of copper was maximum the length of the plants was minimum (14 cm) and at Kamenegundi where the amount of copper was minimum the length of the plants was maximum (16 cm). In contrast, manganese in the soil had a positive relationship with the plant length. The amount of manganese and the length of plants were maximum at Kamenegundi whereas at Panchgani where the concentration of manganese was minimum the length was also minimum (17 cm). Soil organic carbon had negative correlation with the length of plants.

The pH of the soil, in contrast to previous two species, tended to be negatively correlated with plant growth.

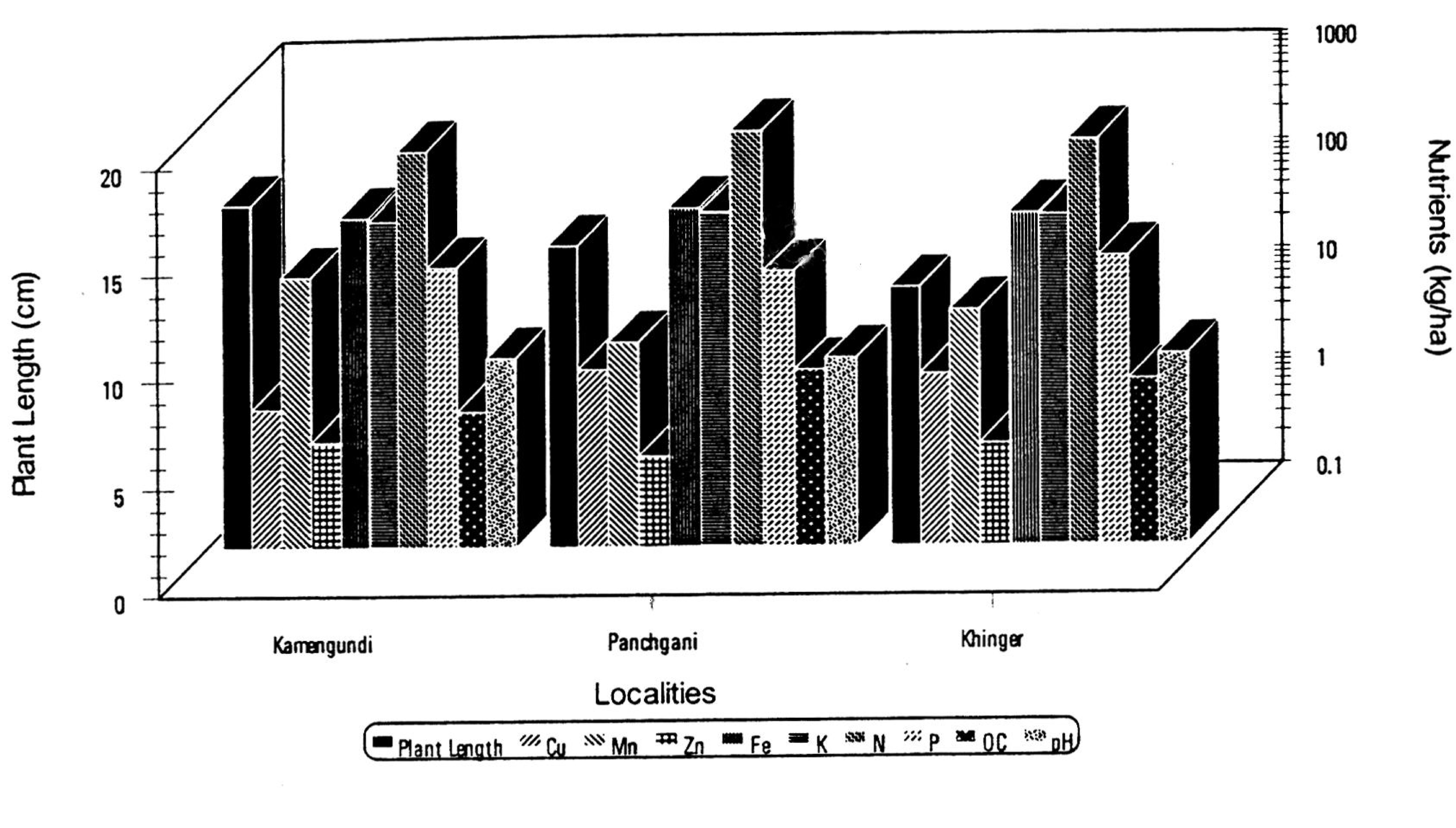

Fig. 3. Bar graph showing correlation between plant length and nutrient contents in the soil of various localities of *I. Panchganiensis.*

Isoetes mahadevensis Srivastava, Pant *et* Shukla Fig. 4, Table 7

In this case the plants were collected only from one locality, i.e., Chotta Mahadev that has two types of habitats. In one type of habitat (i.e., ditches) plants were larger in size as compared to those occurring on the other habitat (i.e., hill slope). The higher concentrations copper, manganese, zinc, iron, potassium and phosphorus at the hill slope site were associated with smaller size. The hill slope site also had lower soil N and more acidic soil. On the contrary the ditches had greater soil nitrogen, greater soil carbon and lower pH.

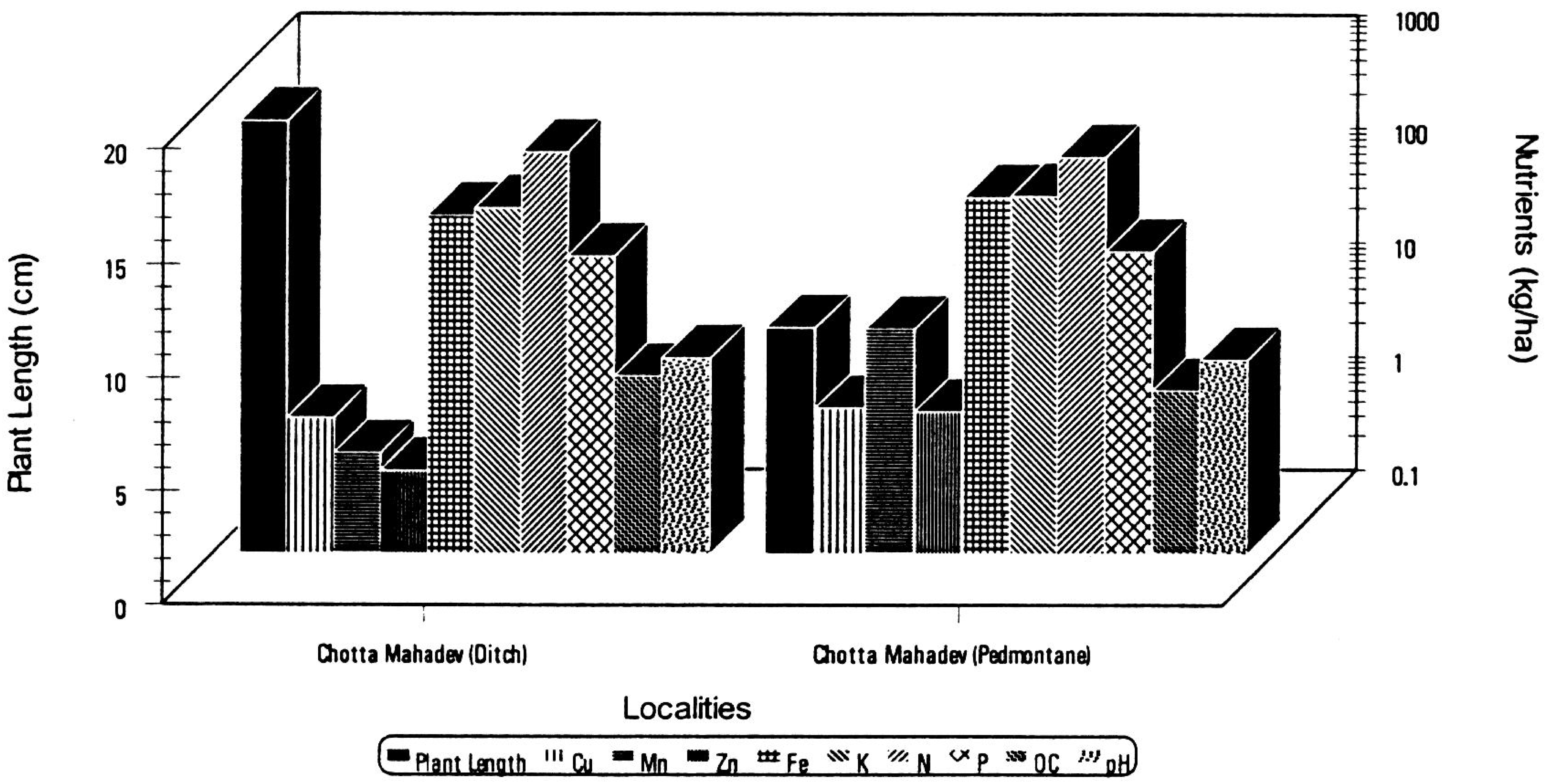

Fig. 4. Bar graph showing correlation between plant length and nutrient contents in the soil of various localities of *I. Mahadevensis*.

DISCUSSION

"Vegetation" and "Soil" are the two sub-systems of any ecosystem in which the living and non-living components interact and bring about circulation, transformation and accumulation of energy and matter. The development of soil and production of vegetation are so intimately related with one another that it is difficult to understand their intricate interrelationship. The soil factors like changes in pH, available mineral nutrients, organic matter, water holding capacity and ionic exchange capacity influence the biological population in any area.

An evaluation of physical properties of soil supporting *Isoetes* clearly showed differences among habitats. The highest percentage of sand was noticed around *I. panchananii* at Jatashanker (Pachmarhi). The sandy soil with low absolute surface naturally has low water holding capacity and the water percolates readily through it carrying much of the valuable nutrients and materials. As a result, the pH of such soil is reduces and the soil becomes acidic. The highest percentage of clay was noticed around *I. coromandelina* at Gyanpur followed by Sonebhadra soil. The clay soil has contrasting characteristics i.e., it has higher absolute particle surface and higher water holding capacity, higher availability of many plant nutrients, with pH being only moderately acidic Wild (1993). Etherington (1976) reported that clay was the main source of many plant nutrients and has certain exchange capacity. The sandy soil is inherently nutrient deficient because of its higher porosity and loss of nutrients by leaching in humid climates.

Table 6. Mean values for plant length and mineral nutrients, pH and electrical conductivity, and r values for relationships between plant length and the physico-chemical characters of soil in various localities of *I. Panchganiensis.*

	Plant Length (cm)	Copper (kg/ha)	Manganese (kg/ha)	Zinc (kg/ha)	Iron (kg/ha)	Potassium (kg/ha)	Phosphorus (kg/ha)	Nitrogen (kg/ha)	Organic Carbon (kg/ha)	pH	Electrical Conductivity	Specific gravity (gm/cm^{-3})
Mean (x)	14.0	3.42	18.806	0.85	125.8	117.67	41.33	590.153	3.188	5.733	0.1166	1.207
Population S.D. (σn)	1.63	1.074	10.565	0.1098	9.835	8.179	4.989	95.698	1.042	0.1247	0.0235	0.06
Sample. S.D. σ(n-1)	2.00	1.315	12.939	0.1345	12.045	10.016	6.110	117.206	1.276	0.157	0.029	0.076
Coeff. of variation (CV)	11.66	34.203	56.18	12.92	7.818	6.951	12.069	16.22	32.68	2.175	20.204	5.15
Coeff. of correlation (r)	-	-0.7527	0.6863	0.2602	-0.1245	-0.4493	-0.6547	-0.3859	-0.6344	-0.655	-0.866	0.0985

Table 7. Mean values for plant length and mineral nutrients, pH and electrical conductivity, and r values for relationships between plant length and the physico-chemical characters of soil in various localities of *I. Mahadevensis.*

	Plant Length (cm)	Copper (kg/ha)	Manganese (kg/ha)	Zinc (kg/ha)	Iron (kg/ha)	Potassium (kg/ha)	Phosphorus (kg/ha)	Nitrogen (kg/ha)	Organic Carbon (kg/ha)	pH	Electrical Conductivity	Specific gravity (gm/cm^{-3})
Mean (x)	14.5	1.76	5.24	1.17	115.75	125	44	323	3.246	5.3	0.125	1.22535
Coeff. of variation (CV)	31.034	10.227	85.305	53.846	18.43	12.00	4.545	4.85	14.54	1.9	20.00	2.4523
Coeff. of correlation (r)	-	-1	-1	-1	-1	-1	-1	+1	1	1	1	1

The soil organic carbon content was highest in *I. panchananii* soil (3.2 kg/ha) the differences in the amount of organic carbon in such situations can be attributed to the differences in vegetation type and the species composition (Prasad *et al.* 1985). The higher content of organic matter confirms the higher return of exchangeable cations by phytocycling of nutrients under *I. panchganiensis*. When the uptake significantly exceeds the nutrient return, the nutrient status of the soil declines as observed in the case of *I. panchananii* soil.

The average pH values observed under *I. panchganiensis*, *I. coromandelina*, *I. panchananii* and *I. mahadevensis* were 5.7, 5.55, 5.45 and 5.3, respectively. The pH, an indication of hydrogen ion concentration, expresses the quantity of an acid/alkali depending upon its dissociation and its total amount present in the soil (Peech, 1941). The present analysis reveals that the lower scale of acidity favours the growth of *Isoetes*. It has a positive significant correlation except in the case of *I. panchganiensis* where the correlation was negative. In India, *Isoetes* grows well in habitats ranging between medium acid soils (pH 5.2) and less acid soils (pH 6.3). The acidic nature of these soils may be attributed to the excessive rains which lead to the leaching and cation exchanges in which hydrogen replaces the bases.

The adverse impact of developmental activities and other anthropogenic factors has influenced the balance of nutrients particularly the component of trace elements in the soil. The present studies have clearly revealed the fact that the sites located near the mining and stone-quarrying areas have suffered a lot due to leaching of essential elements in rain water run off. In such places the density and population of the plant has been altered tremendously. Such regions were having plant species in abundance in earlier times.

The abundance of trace elements not only reduces the propagation of plants but also adversely affects their morphological features. The luxuriance and the size of the *Isoetes* plants vary from habitat to habitat, a fact which may be attributed to a combination of many factors. The present analysis, however, shows that there is certain sensitivity of plant length in relation to the amount of copper content in the soil. Calculated coefficient of correlation reveals a negative but significant relationship between the abundance of copper element in the soil and the general length the of plants of *I. panchananii, I. panchganiensis* and *I. mahadevensis*. The role of copper in the growth of *I. coromandelina* does not appear to be significant. The result of this analysis indicates that whenever copper content in the soil increases the plant lengths consequently shows a marked decrease. A positive and significant correlation exists between the height of the plants of *I. panchganiensis* in relation to manganese content in the soil. However, in *I. coromandelina* its role appears to be insignificant.

The preceding analysis shows that the zinc content in the soil has a positive significant correlation with the length of the plants of *Isoetes* except for *I. panchananii* where the zinc probably plays a negative but significant role. zinc is supposed to be a very important trace element. Its deficiency in the soil reduces the photosynthetic efficiency of plants due to occurrence of chlorosis (Ernst, 1965; 1968). The present investigation also reveals that the soils of Pachmarhi and Western Ghats possess substantial proportion of iron. This may firstly be because they are derived from basalt, an iron-rich rock, and secondly because of the relative stability and immobility of iron as compared to other base elements such as calcium, magnesium, and nitrogen. A calculated correlation between plant length and the Iron content in soil showed the a negative significant relationship between the two factors. The study area of Chotta Mahadev has a high percentage of ferric elements, due to which the pH of the soil decreases showing a high degree of acidity. At slopes the plants of *I. mahadevensis* remained dwarf. They could attain a height of 10 cm only whereas plants growing in nearby ditches where the percentage of iron is lower and the pH of the soil is comparatively high the plant attains almost double the height, i.e., approximately 19 cm.

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土壤多樣性與一些印度水韭植物的生長

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摘　　要

本研究是探討部同土壤因子對四種不同品種水韭植物的生長影響。由水韭自然生長區收集土壤樣品，以分析土壤顏色、構造、酸鹼值及植物可利用的養分。本研究發現水韭植物的生長受到土壤變異所影響，同時也發現水韭是蕨類植物中因土壤不同屬也成多樣化的現象。有些植物其長度與不同土壤因素有相關，酸鹼值較低的土壤會促進水韭生長，但是隨著海拔高度的增加，其長度反而隨著減少。另外土壤中的養分如鋅鎂及銅對植物的生長有顯著的影響作用。

關鍵詞：土壤，水韭，土壤結構，養分與生長。

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