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EFFECT OF ^{137}Cs ON THE TRANSFER OF NUTRIENT ELEMENTS AND ON GROWTH OF KALMI *(Ipomoea aquatica)*

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ABSTRACT

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A pot experiment was conducted during the month of March, 2006 to May, 2006 in the net house of the Department of Soil, Water and Environment, University of Dhaka to examine the effect of ^{137}Cs on the growth of different parts (root and shoot) of Kalmi (*Ipomoea aquatica*) grown in three representative soils of Bangladesh (Pabna, Gazipur and Munshigang) having different soil characteristics. The soils belonging to three different series (Gopalpur, Bhatpara and Pagla) were used to observe the effects of ^{137}Cs on the growth of roots and shoots of the Kalmi plant. Two treatments were used to see the effects of ^{137}Cs on the transfer of the different nutrient elements from soil to plant body and to observe the dry weights of roots and shoots of Kalmi. The average dry weight production of Kalmi (roots and shoots) in the three soil series was reduced about 8% due to the application of ^{137}Cs in soil and the dry weight reduction was as high as 25.70% in Gopalpur soil where 19.83% decrease in the shoot production was observed due to the application ^{137}Cs in soil. No significant effect was observed in the case of Pagla soil. Although the nitrogen and phosphorous uptake was not hampered but the average dry weight production of Kalmi was reduced due to the imposed radiation in soil.

Keywords: effect, cesium-137, nutrient element, growth, kalmi

INTRODUCTION

Radionuclides are unstable isotopes, which undergo radioactive decay; some occur naturally in air, rocks, soils and plants of concentrations that give measurable amounts of radiation and some are produced artificially as in nuclear weapon testing. Among all the radiations released from different kinds of nuclear and non-nuclear power installations, the most penetrating are neutrons and gamma-rays and they constitute the major external exposure hazards to occupational workers, the population at large and the immediate environment. Exposures to radiations are generally regarded undesirable at all levels although no harmful effects are known to occur in case of very low level of exposures (Anonymous, 1987).

Radioactivity in Bangladesh is due to natural deposition in Sylhet and Coastal areas of the Bay of Bengal and was detected in tertiary sandstones of Cox's Bazar, Teknaf and in exposed rocks of Sylhet. In these areas cereals (rice), vegetables (tomato, lettuce), tea and fruits (water melon, banana) are being grown continuously for many years and are taken up by the people specially the local inhabitants in their daily diet. The grasses grown in the field are also fed to grazed cows and goats. These radioactive elements may sometime reduce the growth of several plants. Radionuclides released into the environment reach the human body through several transfer processes (Anonymous, 1978).

The soil- to-plant transfer factor is one of the important parameters are widely used to estimate the internal radiation dose from radionuclides through food ingestion. These are also used as parameters for transfer models for predicting the concentration of radionuclides in foodstuffs and for estimating dose impacts to man (Ng *et al.*, 1979). The levels of radionuclides in the environment and food have been extensively compiled by United Nations Scientific Committee on the Effects of Atomic Radiation (Anonymous, 1982). Bangladesh is a densely populated country and all living beings here are in harmony with the nature. So, a minimum of pollution like radiation hazard, industrial pollution or waste disposal has a tremendous impact on us as well as on the environment. The distribution of radionuclides in nature and xenobiotic exposure of radiation due to misuse or mishandling of radioactive materials or installation, their concentration and movements can seriously affect human and animal lives by entering into the body through different metabolic path ways (Anonymous, 1990) and they may also reduce the production of roots and shoots of plants as well as the grain production. So an experiment was conducted to study the influence of ^{137}Cs on the dry weight production of roots and shoots of a vegetable plant Kalmi (*Ipomoea aquatica)* and on the transfer of some nutrient elements from soil to the different parts of the plant as influenced by ^{137}Cs.

METHODS AND MATERIALS

A pot experiment was conducted during the month of March, 2006 to May, 2006 in the net house of the Department of Soil, Water and Environment, University of Dhak**a** to study the effects ^{137}Cs on some nutrient element's transfer from soil to Kalmi (*Ipomoea aquatica*) and its dry weight production. The soil samples were collected at a depth of

0-15 cm from three different locations namely Gazipur Sadar Thana, district- Gazipur; Shirajdikhan Thana, district-Munshiganj and Chatmohar Thana, district- Pabna belong to Bhatpara, Pagla and Gopalpur series respectively and were processed for subsequent pot experiment and necessary analyses. The series thus selected from different locations had wide variations in their physical, chemical, minerialogical and physico-chemical properties. After harvesting the Kalmi, different parts of plants were processed for analyses. The dry weight production of roots and shoots of Kalmi, the uptake of several nutrient elements in the control (T0), treated sample (T1) was analyzed. The changes in the properties of soil due to the application of 137 Cs were also observed. The topsoil samples (0-15 cm) were collected from farmer's field. The collected soil samples were air dried ground and passed through a 2.0 mm sieve for physical, chemical and physico-chemical analysis as advised by Huq and Alam, 2005. Results of the physical and chemical analysis of the original soil samples are presented in the tables: 1, 2 & 3.

Table 1. Physical properties of three soil series

Name of the soil series	Moisture %	Particle size distribution			Textural Class
		Sand (%)	Silt (%)	Clay (%)	
Bhatpara	3.36	6.8	54.3	39	Silty clay
Pagla	6.42	1.3	40	59	Clay
Gopalpur	3.85	6.3	65	29	Silty clay loam

Table 2. Chemical and physico-chemical properties of three soil series

Name of the soil series	pH (1:2.5)	EC µS	Organic matter (%)	Total N (%)	C/N Ratio	CEC (Meq/100g)
Bhatpara	5.40	43	2.34	0.368	4	9
Pagla	5.85	189	1.98	0.178	6	30
Gopalpur	7.14	363	1.56	0.332	3	14

Table 3. Contents of available nutrients in the studied soils

Name of the soil series	Available (mg/kg)			Available (Meq/100g)				Available (mg/kg)			
	N	P	S	K	Na	Ca	Mg	Fe	Mn	Zn	Cu
Bhatpara	48	0.98	1.19	0.048	0.172	0.89	3.221	23	36	5.7	0.19
Pagla	54	1.49	3.56	0.107	0.448	5.63	3.245	33	22	17.5	0.72
Gopalpur	37	2.84	2.91	0.119	0.55	11.3	3.772	53	16	13.4	0.39

Table 4. Contents of total nutrients in the studied soils

Name of the soil series	Total (%)			Total (Meq/100g)				Total (mg/kg)			
	N	P	S	K	Na	Ca	Mg	Fe	Mn	Zn	Cu
Bhatpara	0.368	0.052	0.027	1.62	5.96	3.05	7.18	116	415	34	13
Pagla	0.178	0.115	0.055	7.12	29.12	4.17	45.85	188	179	108	47
Gopalpur	0.332	0.158	0.045	7.23	26.87	7.29	53.28	253	116	75	26

Total 9 pots were used for the experiment. Each pot was filled with 10 kg soils. The soils were previously pulverized and mixed well with doses of fertilizers as per recommendation of the Fertilizer Recommendation Guide (Anonymous, 1989). The experiments were arranged in a completely randomized design. In order to study the uptake of ^{137}Cs by Kalmi, $^{137}CsCl$ was taken as a basis of treatment and a source of radioactivity. Liquid solution of 73260 Bq $^{137}CsCl$ was mixed uniformly with 10 kg soil in each pot.

Treatments for the experiment were as follows:

To = Control (3 pots of each soil series where no ^{137}Cs was applied)

T_1 = 73260 Bq ^{137}Cs/ pot.

The seeds of Kalmi plants were brought from BRRI (Bangladesh Rice Research Institute). A seedbed was prepared in the field where seeds were sown during 25th March, 2006.

As Kalmi is a rain fed plant, for this reason water was applied for about 1-2 times in a day. Normal tap water was used for irrigation. The plant samples (root and shoot) were collected properly at the time of harvesting of the crop (60 days after sowing) up to the soil surface level. Roots and shoots were separated and were cut into small pieces, dried weighed, ground separately and stored properly for chemical analysis and radioactivity measurement.

The soil was analyzed for moisture percentage, particle size analysis, pH, EC, OM, the total nitrogen, the C/N ratio, the available nitrogen, total phosphorus, the available phosphorus, total and available sulfur, CEC, the exchangeable cations Ca^{++} , Mg^{++} Na^{+}, K^{+}, available Fe^{++}, Mn^{++}, Zn^{++} and Cu^{++},total Na, K, Ca, Mg, Fe, Zn, Cu and Mn contents. Several chemical and physical analyses were done according to the methods described by Huq and Alam (2005).

The radioactivity in soil and plant samples was measured by gamma ray spectrometry system. The measurement was carried out at the Health Physics Laboratory of Atomic Energy Centre, Bangladesh Atomic Energy Commission at Ramna, Dhaka. Transfer factors (TF) for plant samples (in case of root and shoot of both Kalmi and Lettuce) were calculated by the following equation:

$$TF = \frac{Activity\ concentration\ in\ plant(Bq/kgdry\ wt)}{Activity\ concentration\ in\ soil\ (Bq/kg\ dry\ wt)}$$

The Duncan's New Multiple Range Tests (DMRT) was performed and other statistical analysis was performed with the aid of SPSS (SPSS 12.0 for Windows, Release 12).

RESULT AND DISCUSSION

The values of soil properties like pH, organic matter, particle size distribution, clay mineral content, CEC, total and available contents of mineral nutrient were presented in the tables 1, 2, 3 and 4. The pH in water (1:2.5) of the soils of Bhatpara, Pagla and Gopalpur series was 5.40, 5.85 and 7.14 respectively, (Table 2). According to the classification by Anonymous (1989), Bhatpara series belongs to strongly acid, Pagla to moderately acid and Gopalpur to neutral. pH of the soils has been influenced mainly by parent material and vegetation, which are responsible for such variations. The organic matter contents of the soils were 2.34% for Bhatpara, 1.98% for Pagla and 1.56% for Gopalpur series (Table 2). Bhatpara and Pagla series fell in the medium and Gopalpur series fell in the low range (Anonymous, 1989). These variations in organic matter content might be due to the differences in natural vegetation, landscape, fertility status and intensity of cultivation in those areas. The Department of Soil Survey has analyzed about 11,000 samples from 2500 representative soil profiles covering agriculturally important areas of Bangladesh and found that the organic matter content of soils were generally low; it ranges from 0.3 to 1.5% in upland soils. 1.5 to 2% in the medium low land areas and 2.0 to 3.5% in the low land areas (Rahman, 1990). In Bil areas, this fraction is about 4% (Hossain, 1998). Haque *et. al.*, (1992) also reported that most agricultural soils of Bangladesh have low organic matter content. This was in well agreement with Gopalpur series.

The C/N ratio values in the studied soils ranged from 3 to 6. The highest value of C/N ratio (6) was obtained in Pagla series, followed by Bhatpara (4), and Gopalpur (3) soil series (table 2). The variations of C/N ratio values in the different soils were due to the difference in the degree of decomposition of organic matter. The cation exchange capacity (CEC) of the soils was 9, 30 and 14 meq/100g for Bhatpara, Pagla and Gopalpur soil series, respectively (table 2). Bhatpara and Gopalpur series fell in the medium range, while Pagla series fell in the very high range (Anonymous, 1989). The variation in CEC is associated with the type of clays and amount of organic matter content in soils.

Growth and yield characteristics of plants

Growth may be defined as an increase in mass, which is accompanied by change in form. It is usually desirable to give some quantitative expression to the amount of growth, which is accomplished by a plant during a given period of time. Various methods have been adapted to measure plant growth. The principal measures, which have been employed for this purpose, are increase in length of the stem and root and other organ of the plant, increase in the area of leaves and increase in dry and fresh weight of plant. The yield of a crop may be considered in biological as well as agricultural terms. "Biological yield" has been defined as the total production of plant material by a crop, whereas "the economic and commercial yield" takes into account only those plant organs, which for particular crops are cultivated, and harvested. Of the various growth and yield parameters fresh weight of roots/pot and shoots/pot of both lettuce and Kalmi plants were considered for the present investigation. The analysis of variance (ANOVA) of the data was computed to determine the F-value. The test of significance of treatments was calculated by Duncan's New Multiple Range Test (DMRT).

Dry matter production of Kalmi

Yield of root

The dry matter production of roots of Kalmi grown on three soil series treated with ^{137}Cs was presented in the table 4.1 and fig 4.1. The test of significance of root yield obtained in different soils was computed by Duncan's New Multiple Range Test (DMRT) at 5% level of significance. The results showed that soil properties generally influenced the dry matter production of roots and shoots of Kalmi. Gopalpur soil had significantly higher yields of roots than those Bhatpara and Pagla soil series; but there was no difference between Pagla and Bhatpara soil series. The root production grown at controlled condition was 5.72, 7.52 and 10.44 g/pot (table 5) was obtained in Bhatpara, Pagla and Gopalpur soil series, respectively. Root dry weight (g/pot) of Kalmi obtained under ^{137}Cs treatments grown on Pagla and Gopalpur soil series was significantly higher than those of Bhatpara soil series, the highest yield being found at Pagla (7.46 g/pot). This might be due to the hindrance of the uptake of potassium, ammonium and calcium (important nutrient elements for plants) due to application of Cs.

Yield of shoot

The average dry matter (g/pot) of shoot of Kalmi grown in three different soils was presented in the table 5 and fig 1. The results were significant (F-test) at 5% level (For T_1). The test of significance of different shoot yield was computed by Duncan's New Multiple Range Test (DMRT) at 5% level of significance. The mean dry matter production of shoot of Kalmi grown in the soils of Bhatpara and Pagla series differed significantly from that of the Gopalpur series; but there was no difference between the yield of Bhatpara and Pagla series. The results obtained from T_0 were significant (F-test) at 1% level. The test of significance of different shoot yield was computed by Duncan's New Multiple Range Test (DMRT) at 5% level of significance. Like root growth, dry matter production of shoots of Kalmi plants grown on three soil series was influenced by the soil properties (table 5 and fig. 1). The shoot growth at Pagla and Gopalpur soil series differed significantly than those of Bhatpara series at control treatment (T_0), but there was no significant difference in dry matter yields between Pagla and Gopalpur series. At control condition, the highest yield of shoot was obtained at Pagla series (13.37 g/pot) followed by Gopalpur soil series (13.06 g/pot) indicating that better growth conditions of Kalmi plants were prevailing in these two soil series. However, better yields of Kalmi were observed at Bhatpara and Pagla soil series (13.35 and 12.95 g/pot, respectively) instead of Gopalpur series. These differences in yield of shoot of Kalmi might be due to ion competition among Cs^+, K^+ and NH_4^+ ions, where Cs^+ probably reduced the uptake of the two ions affect shoot yields.

Table 5. Differences in dry matter yield (g/pot) of roots and shoots of Kalmi grown on three investigated soils

Plant parts	Treatments	Name of the soil series		
		Bhatpara	Pagla	Gopalpur
		Dry weight (g/pot)		
Root	T_0	5.72b	7.52b	10.44a
	T_1	5.53b	7.46a	7.00a
Shoot	T_0	10.08b	13.37a	13.06a
	T_1	12.35a	12.95a	10.47b

Values in rows having same letter are not significantly different.

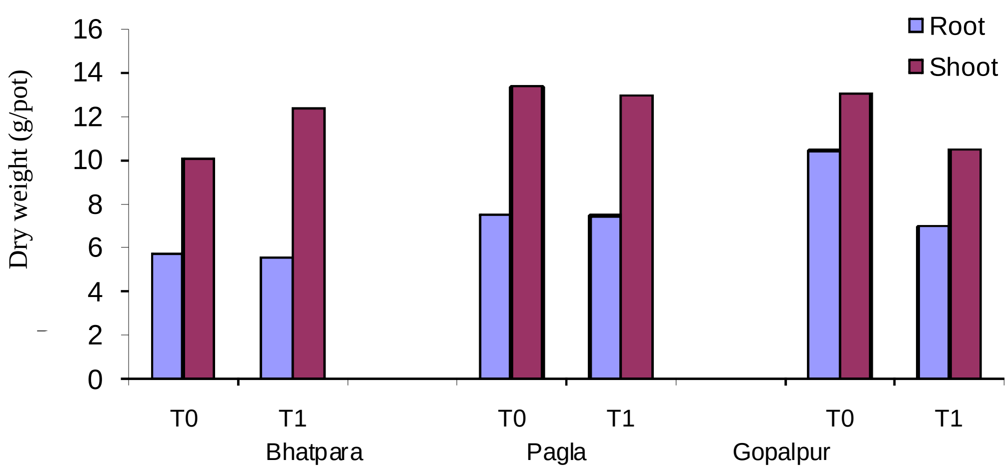

Figure 1. Differences in dry matter yield (g/pot) of roots and shoots of Kalmi grown on 3 investigated soils

Table 6 Comparison (between the plant parts and between treatments) of average dry matter (g/pot) production of Kalmi

Plant parts	Name of the soil series			Mean
	Bhatpara	Pagla	Gopalpur	
	Dry weight (g/pot)			
Root	5.62b	7.49b	8.72b	7.28b
Shoot	6.45a	13.16a	11.76a	10.46a
	Dry weight (g/pot)			
Treatments	Bhatpara	Pagla	Gopalpur	Mean
T_0	7.90b	10.44a	11.75a	10.03a
T_1	8.94a	10.20a	8.73b	9.29b

Values in columns having same letters are not significantly different.

Table 6 showed the comparison of average dry matter production (g/pot) between plant parts and between treatments of Kalmi plants grown on three soil series. The results were significant at 1% level of significance. Dry matter yield of shoot was significantly higher than of root of Kalmi was higher at control condition than that of ^{137}Cs treatment.

Mineral nutrition of Kalmi as affected by ^{137}Cs

^{137}Cs had pronounced influences on the nutrient availability as well as their transport in Kalmi plants. To evaluate the behavior of 137Cs in Kalmi plant, the contents of N, P, K, Na, Ca and Mg were determined in root and shoot of Kalmi (Tables 7 to 16 and figure 1 to 6).

Nitrogen concentration in Kalmi plant

The average nitrogen content of Kalmi root and shoot has been presented in Table 7 and Fig 2. Analysis of variance (ANOVA) of the results of three different soil series showed that there was no significant difference among three soil series in nitrogen content in Kalmi root (when ^{137}Cs was applied) and the results was significant at 1% level of significance. But nitrogen contents in shoot differed significantly at 5% level of significance (Table 7). The test of significance of nitrogen contents in different soils was computed by Duncan's New Multiple Range Test (DMRT) at 5% level of significance. Table 7 showed that Kalmi root of Gopalpur series accumulated more nitrogen than Bhatpara and Pagla series (4.38%). Concentration of nitrogen in Kalmi root of Bhatpara and Pagla series also differed significantly but there was only a slight difference of nitrogen concentration between Pagla and Gopalpur series. Table 7 also showed that the highest nitrogen content in shoot was observed in Gopalpur series (where no artificially ^{137}Cs was applied).

Table 7.Mean concentration of nitrogen in root and shoot of Kalmi

Plant parts	Treatments	Name of the soil series		
		Bhatpara	Pagla	Gopalpur
		Concentration (%) of nitrogen		
Root	T0	2.62b	3.96a	4.38a
	T1	3.15a	2.92a	3.92a
Shoot	T0	2.47b	3.78a	3.82a
	T1	2.97a	2.76b	3.27a

Values in rows having same letters are not significantly different.

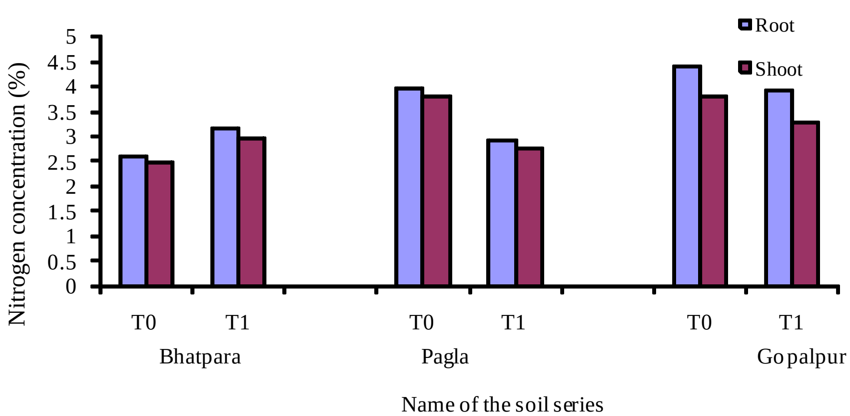

Figure 2. Mean concentration of nitrogen in root and shoot of Kalmi

But accumulation of nitrogen in Kalmi shoot of Pagla series did not differ significantly from Gopalpur series. Kalmi root of Bhatpara series accumulated the lowest amount of nitrogen (Table 7). Kalmi root of Pagla and Gopalpur series accumulated significantly different amount of nitrogen but there was no significant difference in nitrogen content in Kalmi shoot of Pagla and Gopalpur series.

Table 8. Comparison (among the plant parts and between treatments) of average nitrogen concentration of Kalmi

Plant parts	Name of the soil series		
	Bhatpara	Pagla	Gopalpur
	Concentration (%) of nitrogen		
Root	2.88a	3.44a	4.15a
Shoot	2.72b	3.27a	3.54a
	Concentration (%) of nitrogen		
Treatments	Bhatpara	Pagla	Gopalpur
T0	2.54b	3.87a	4.1a
T1	3.06a	2.84b	3.59a

Values in columns having same letters are not significantly different.

The nitrogen content in roots and shoot of Kalmi were presented in Table 8. The results showed that Kalmi roots generally accumulated more nitrogen than Kalmi shoot. However, there was no significant difference in nitrogen contents between the treatments (T0 and T1).

Phosphorus concentration in Kalmi plant:

Mean values of the phosphorus concentration in root and shoot of Kalmi has been presented in Table 9 and Figure 3.

Table 9.Mean concentration of phosphorus in root and shoot of Kalmi

Plant parts	Treatments	Name of the soil series		
		Bhatpara	Pagla	Gopalpur
		Concentration (%) of phosphorus		
Root	T0	0.148b	0.327a	0.206a
	T1	0.178b	0.416a	0.162b
Shoot	T0	0.2b	0.443a	0.345a
	T1	0.243b	0.244b	0.365a

Values in rows having same letters are not significantly different.

Results were statistically significant (F-test) at 1% level. The test of significance of different concentration means was calculated by Duncan's New Multiple Range Test (DMRT) at 5% level of significance. Table 9 showed that phosphorus concentration in Kalmi roots of Pagla series was the highest (For both T1 and T0) and differed significantly from Bhatpara and Pagla series (T0) but there was no difference in phosphorus concentration in Kalmi root between Pagla and Gopalpur series (T0). Kalmi root of Bhatpara series accumulated the lowest amount of phosphorus in both cases (For T1 and T0). Table 9 showed that Kalmi shoot of Bhatpara series also accumulated the lowest amount of phosphorus and differed significantly from others. The highest amount of phosphorus in Kalmi root was accumulated in Pagla series and significantly differed from that of Gopalpur and Bhatpara series and the highest amount of phosphorus in Kalmi shoot was accumulated in Gopalpur series and significantly differed from that of Pagla and Bhatpara series.

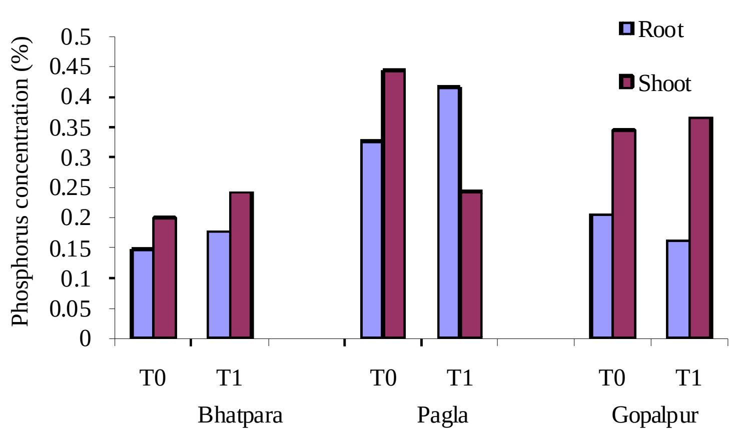

Figure 3. Mean concentration of phosphorus in root and shoot of Kalmi

Table 10. Comparison (among the plant parts and between treatments) of average phosphorus concentration of Kalmi

Plant parts	Name of the soil series		
	Bhatpara	Pagla	Gopalpur
	Concentration (%) of phosphorus		
Root	0.163b	0.371a	0.184b
Shoot	0.221b	0.343a	0.355a
	Concentration (%) of phosphorus		
Treatments	Bhatpara	Pagla	Gopalpur
T0	0.174b	0.385a	0.275a
T1	0.210b	0.33a	0.263a

Values in columns having same letters are not significantly different.

From Table 10 it was also found that there was no significant difference in phosphorus concentration in Kalmi shoot between Pagla and Gopalpur series (T0) but the concentration differed significantly between Bhatpara and Pagla series (T1). Table 10 showed that phosphorus contents in Kalmi root and shoot was significantly different, but there was no significant difference in phosphorus concentration in Kalmi plants due to application of ^{137}Cs, except in case of Bhatpara series. The differences of phosphorus concentration in root and shoot was mainly due to the variation in phosphorus contents in soils and differences in soil properties, which influenced phosphorus availability, absorption and its transfer into Kalmi plants.

Potassium concentration in Kalmi plant

The average concentration of potassium in root and shoot of Kalmi as affected by application of ^{137}Cs was shown in Table 11 and Fig 4. Analysis of variance (ANOVA) of the data obtained in three soil series showed that potassium content in Kalmi plant was enhanced significantly at 1% level (T0) and 5% level (T1). The test of significance of potassium content in different soil was computed by Duncan's New Multiple Range Test (DMRT) at 5% level of significance. Table 11 showed that potassium content in root of Pagla series differ significantly from Bhatpara and Gopalpur series at controlled condition and Bhatpara series differ significantly from Pagla and Gopalpur series at ^{137}Cs treatments. But there was no significant difference of potassium content of root in Bhatpara and Gopalpur series (T0) and also Pagla and Gopalpur series (T1).

Table 11. Mean concentration of potassium in root and shoot of Kalmi

Plant parts	Treatments	Name of the soil series		
		Bhatpara	Pagla	Gopalpur
		Concentration (%) of potassium		
Root	T0	1.425b	1.825a	1.3b
	T1	1.6a	1.481b	1.312b
Shoot	T0	1.45b	1.425b	1.7a
	T1	1.65a	1.925a	1.625a

Values in rows having same letters are not significantly different.

Table 11 also showed that the highest potassium content was recorded in roots of Pagla series (1.825%) and the lowest was recorded in roots of Gopalpur series (1.3%) when no ^{137}Cs was applied (T0). From Table 11, it was found that the potassium content in Kalmi shoot of Gopalpur series (when no artificially ^{137}Cs was applied, T0) differed significantly from Bhatpara and Pagla series but there was no significant difference in potassium content of shoot between Bhatpara and Pagla series. It was also evident from Table 11 that there was no significant difference in potassium content of three different soil series (when ^{137}Cs was applied). The highest

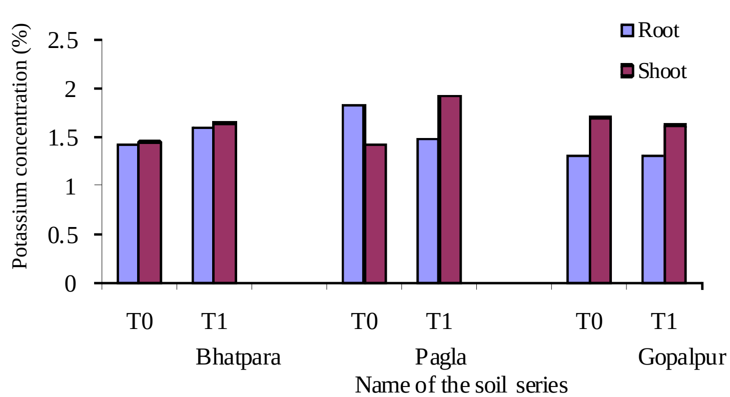

Figure 4. Mean concentration of potassium in root and shoot of Kalmi

potassium content was observed in Kalmi shoot of Pagla series (1.925%; T1) and the lowest was found in shoot of Gopalpur series (1.3%; T0).

Table 12. Comparison (among the plant parts and between treatments) of average potassium concentration of Kalmi

Plant parts	Name of the soil series		
	Bhatpara	Pagla	Gopalpur
	Concentration (%) of potassium		
Root	1.512a	1.653a	1.306b
Shoot	1.55a	1.675a	1.662a
	Concentration (%) of potassium		
Treatments	Bhatpara	Pagla	Gopalpur
T0	1.437b	1.453b	1.5a
T1 S. M Ullah, *et al.*	1.625a	1.875a	1.468b

Values in columns having same letters are not significantly different.

Table 12 showed significant difference in potassium concentration among different plant parts and between two treatments (T0 and T1), which revealed that, application of ^{137}Cs had marked influences on the transfer of potassium into plants.

Calcium concentration in Kalmi plant

The average concentrations of calcium in Kalmi root and shoot as affected by soil properties and application of cesium have been evaluated and presented in the table 13 and fig 5. Analysis of variance (ANOVA) of the data obtained in three soil series showed that calcium content in Kalmi plant was enhanced significantly at 1% level (T_0) and 0.1% level (T_1). The test of significance of calcium content in different soil was computed by Duncan's New Multiple Range Test (DMRT) at 5% level of significance.

Table 13 and figure 5 showed that calcium content in roots of Bhatpara and Pagla series differed significantly from Gopalpur series at control condition and Pagla series differed significantly from Bhatpara and Gopalpur series at ^{137}Cs treatments. But there was no significant difference of calcium contents of roots in Bhatpara and Pagla series (T_0) and also Bhatpara and Gopalpur series (T_1). Table 4.9 also showed that the highest calcium content was recorded in roots of Pagla series (0.325%; T_1) and the lowest was recorded in roots of Gopalpur series (0.163%; T_0).

Table 13.Mean concentration of calcium in roots and shoots of Kalmi at control (T_0) and ^{137}Cs treatments (T_1)

Plant parts	Treatments	Name of the soil series		
		Bhatpara	Pagla	Gopalpur
		Concentration (%) of calcium		
Root	T_0	0.285a	0.282a	0.163b
	T_1	0.240b	0.325a	0.240b
Shoot	T_0	0.612b	0.737a	0.517c
	T_1	0.648b	0.787a	0.520c

Values in rows having same letter are not significantly different.

Table 13 also showed that the calcium content in Kalmi shoot of Pagla series differed significantly from Bhatpara and Gopalpur series both at controlled condition and ^{137}Cs treatments. There was also a significant difference in calcium content of shoot between Bhatpara and Gopalpur series both at control condition and ^{137}Cs treatments. The highest calcium content was observed in Kalmi shoot of Pagla series (0.787%; T_1) and the lowest was found in shoot of Gopalpur series (0.517%; T_0).

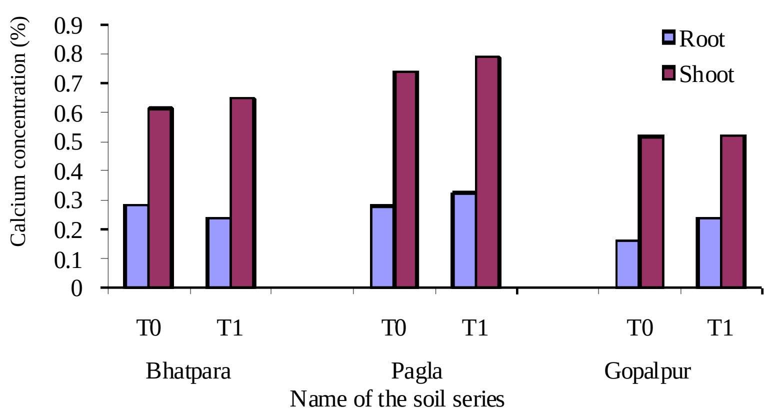

Figure 5. Mean concentration of calcium in roots and shoots of Kalmi

Table 14 showed significant difference in calcium concentration between roots and shoots and between two treatments (T_0 and T_1). The results also showed that application of ${}^{137}Cs$ had marked influences on the calcium concentration except in Gopalpur soil series. It was further observed that Kalmi shoot accumulated more calcium than Kalmi root which indicating that the roots did not restrict the transfer of Ca to shoots. It was also found that calcium concentration was high in ${}^{137}Cs$ treated soil, which showed that ${}^{137}Cs$ made Ca more available to Kalmi plants.

Table 14.Effects of plant parts and treatments on calcium contents of Kalmi grown on three soil series

Plant parts	Name of the soil series			Mean
	Bhatpara	Pagla	Gopalpur	
	Concentration (%) of calcium			
Root	0.262b	0.303b	0.201b	0.255b
Shoot	0.630a	0.762a	0.518a	0.637a
	Concentration (%) of calcium			
Treatments	Bhatpara	Pagla	Gopalpur	Mean
T_0	0.448a	0.509b	0.34a	0.432b
T_1	0.444a	0.556a	0.38a	0.460a

Values in columns having same letters are not significantly different

Magnesium concentration in Kalmi plant

The average concentrations of magnesium in Kalmi roots and shoots as affected by soil properties and application of cesium were evaluated and presented in the table 15 and fig 6. Analysis of variance (ANOVA) of the data obtained in three soil series showed that magnesium content in Kalmi plant was enhanced significantly at 0.1% level (T_0) and 5% level (T_1). The test of significance of magnesium content in different soil was computed by Duncan's New Multiple Range Test (DMRT) at 5% level of significance. Table 15 showed that magnesium content in Kalmi roots of Pagla series differed significantly from Bhatpara and Gopalpur series at control condition but there was no significant difference of magnesium contents of root in Bhatpara and Gopalpur series (T_0). On the other hand, Bhatpara and Pagla series differed significantly from Gopalpur series at ${}^{137}Cs$ treatments but there was no significant difference of magnesium contents of root in Bhatpara and Pagla series (T_1). Table 15 also showed that the highest magnesium content was observed in roots of Pagla series (0.277%; T_0) and the lowest was recorded in roots of Gopalpur series (0.144%; T_1).

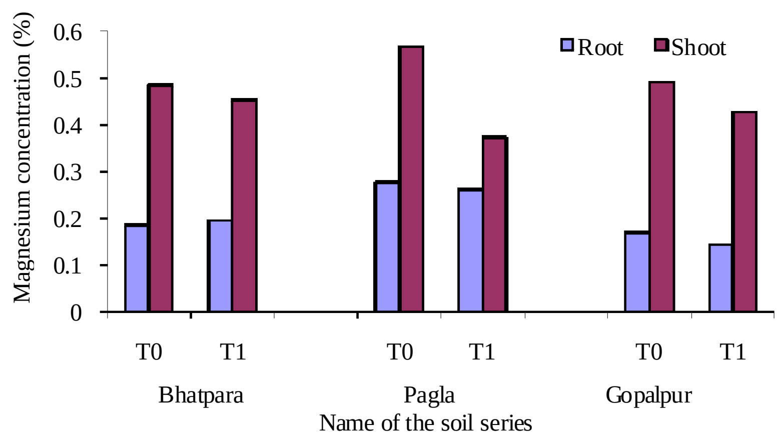

Figure 6. Mean concentration of magnesium in root and shoot of Kalmi

Magnesium content in Kalmi shoot of Pagla series differed significantly from Bhatpara and Gopalpur series, when no ${}^{137}Cs$ was applied (T_0; table 15). From analysis of variance it was also revealed that there was no significant difference in magnesium content of shoot between Bhatpara and Gopalpur series at control condition. From the table 15 and fig 6, it was also seen that Bhatpara and Gopalpur series differed significantly from Pagla series at ${}^{137}Cs$ treatments but there was no significant difference in magnesium content of shoot between Bhatpara and Gopalpur series. The highest magnesium content was observed in Kalmi shoot of Pagla series (0.566%; T_0) and the lowest in shoot of Pagla series (0.372%; T_1).

Table 15. Mean concentration of magnesium in root and shoot of Kalmi

Plant parts	Treatments	Name of the soil series		
		Bhatpara	Pagla	Gopalpur
		Concentration (%) of magnesium		
Root	T_0	0.185b	0.277a	0.170b
	T_1	0.195a	0.262a	0.144b
Shoot	T_0	0.485b	0.566a	0.490b
	T_1	0.453a	0.372b	0.428a

Values in rows having same letter are not significantly different

Table 16 showed significant difference in magnesium concentration among different plant parts and between two treatments (T_0 and T_1). From the comparison it was observed that Kalmi shoot accumulated more magnesium than Kalmi root. It was also found that magnesium concentration was high at control condition.

Table 16. Effects of plant parts and treatments on magnesium concentrations of Kalmi grown on three investigated soils

Plant parts	Name of the soil series			Mean
	Bhatpara	Pagla	Gopalpur	
	Concentration (%) of magnesium			
Root	0.190b	0.269b	0.157b	0.205b
Shoot	0.469a	0.469a	0.459a	0.466a
	Concentration (%) of magnesium			
Treatments	Bhatpara	Pagla	Gopalpur	Mean
T_0	0.340a	0.421a	0.330a	0.364a
T_1	0.319b	0.317b	0.286b	0.307b

Values in columns having same letters are not significantly different.

CONCLUSION

In the experiment it has been observed that the average dry weight production of Kalmi decreased due to the application of Cesium-137 in soil. The imposed radiation might have some bad influence for which this growth reduction took place. In the case of Bhatpara soil the average dry wt. production of roots of Kalmi was reduced due to the application of ^{137}Cs (T_1) and more root production was there when there was no ^{137}Cs treatment (T_0). In the case of Bhatpara and Gopalpur soil no difference was observed. Similar result was observed in the case of shoots of Gopalpur soil i.e. ^{137}Cs application in soil decreased the dry wt. production of shoots although opposite result was observed in the case of Bhatpara soil where positive correlation with the application of ^{137}Cs were found. No significant effect was observed in the case of Pagla soil. Calcium and potassium uptake was increased but magnesium uptake was decreased. Although the nitrogen and phosphorous uptake was not hampered but the average dry weight production of Kalmi was reduced due to the imposed radiation in soil. The nutrient transfer change might also have the influences for which the growth reduction took place.

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