Madras Agric. J. 90 (4-6) : 207-210 April-June 2003

ransfer factor of Caesium - 137 from soil to plant

MEENA AND A. RAJARAJAN
)pt. of Soil Science and Agrl. Chemistry, Tamil Nadu Agrl. Univ., Coimbatore-641 003, Tamil Nadu.

Abstract: The transfer of caesium - 137 (^{137}Cs) from soil to plant system was studied using two forage crops *viz.* sorghum (*Sorghum bicolor* L.) and lucerne (*Medicago sativa* L.) as the test crops. The soil-plant transfer factor is defined as the ratio of the radio activity per unit dry weight of the plant (or individual organs) and the activity per unit dry weight of the soil in the root zone. Of the three different soil series studied in the experiment, the highest transfer factor in both the crops was recorded by Madukkur series (Udic Haplustalf). An inverse relationship was observed with the levels of ^{137}Cs applied and of the two crops studied, sorghum recorded higher transfer factor values than lucerne.

Key words : Caesium-137, Transfer factor, Sorghum, Lucerne.

roduction

Radioactive materials have always been turally occuring as one of the components the environment and thus all living systems ve been subject to radiation exposure from s source. In addition, release of radioactive terials to the environment from weapon testing, l reprocessing and reactor accidents (such s the one that occurred at Chernobyl in Ukraine) las focused attention on these materials.

Strontium-90, Caesium-137 and Iodine-31 are by far the serious pollutants in the eneral environment from the fallout and as tomic wastes. The ^{137}Cs has received significant ttention in radioecology because of its persistence n the environment, high-energy emissions, rominence in nuclear fallout and nuclear fuel ycle and contribution to radiological dose Auerbach, 1987). Interest in the uptake of adionuclides from soil into vegetation originated vith the concern that deposited radioactivity rom nuclear testing/accident could enter into ood chain, thereby causing radiological hazards. Absorption of radionucleides from soil to plant s usually quantified in terms of concentration r transfer factor. The observed variability of he experimentally determined concentration/ ansfer factors for radionuclides in different ood and forage plants complicates the use f generalized values to be employed in the rediction of the transfer of radionuclides from oil to all kinds of plants. Thus rather than using a single soil to plant concentration factor specific values for each crop are to be employed.

Keeping this in view a study was undertaken to study the transfer factor of caseium-137 in three prominent soil series of Tamil Nadu in two forage crops (sorghum and lucerne) under four levels of caesium-137 *viz.* 20,40,60 and 80 K Bq kg^{-1} soil.

Materials and Methods

The experiment was conducted in the Radio isotope tracer laboratory of Tamil Nadu Agricultural University, Coimbatore during 1995-1996. The processed samples representing three major soil series of Tamil Nadu (Palathurai, Irugur and Madukkur) were filled in glazed ceramic pots, having an inner diameter of 28 cm, and height of 28 cm at the rate of 10 kg soil per pot. There were 48 pots in total comprising three soils, four leves of ^{137}Cs, two crops and three replications.

To all the 48 pots, common basal application of N (at 60 kg ha^{-1} for sorghum, 25 kg ha^{-1} for lucerne, as urea) P (40 kg P_2O_5 ha^{-1} for sorghum, 20 kg P_2O_5 ha^{-1} for lucerne as single superphosphate) and K (20 kg K_2O ha^{-1} for sorghum, 40 kg K_2O ha^{-1} for lucerne as muriate of potash) were given. From the stock solution of carrier free ^{137}Cs (obtained as carrier free ^{137}Cs as caesium nitrate in dilute nitric acid

Table 1. Characteristics of initial soil samples

S.No.	Properties	Palathurai soil	Irugur soil	Madukkur s
1.	*Physical properties*			
	Bulk density (Mg m^{-3})	1.39	1.30	1.28
	Particle density (Mg m^{-3})	2.40	2.36	2.04
	Total porosity (%)	54.05	46.69	14.96
	Capillary porosity (%)	40.81	34.81	29.86
	Non-capillary porosity (%)	13.24	11.88	15.1(
	Volume expansion on wetting (%)	15.72	6.69	7.35
2.	*Electro-chemical properties*			
	Soil reaction (pH)	8.1	7.5	7.4
	Electrical conductivity (dSm^{-1})	0.13	0.39	0.26
	CEC [cmol (p+) kg^{-1})]	20.00	14.20	8.55
3.	*Chemical properties*			
	Organic carbon (g kg^{-1})	11.1	4.3	2.6
	Total nitrogen (g kg^{-1})	0.32	0.20	0.30
	Total phosphorus (g kg^{-1})	2.0	0.2	0.1
	Total potassium (g kg^{-1})	3.7	2.3	1.8
	Available nitrogen (kg ha^{-1})	280	224	148
	Available phosphorus (kg ha^{-1})	18.14	13.05	3.50
	Available potassium (kg ha^{-1})	402	207	145

medium) obtained from Board of Radiation and Isotope Technology, Mumbai, volumes to supply 20,40,60 and 80 K Bq ^{137}Cs kg^{-1} of soil were applied to the soil as per the treatments. Routine cultural practices were adopted in raising the crops.

The crops were harvested 60 days after sowing. The chopped oven dry plant materials were ground in a Wiley mill to pass through 1 mm sieve and stored in wide mouth stoppered bottles. After proper sub sampling, one g plant material was transferred to a scintillation vial. The vial was then placed in a well type, Tl activated NaI crystal, gamma ray spectrometer (Type GRS 23 B of ECIL). The radioactivity of the sample was determined by differential counting, keeping the single channel analyser at optimal settings. The count rates were corrected for radioactive decay.

The count rates obtained by radioassay were converted into disintegration rates (dps) by using the following formula:

$$Bq = dps = \frac{\text{Corrected count rates / second}}{\text{Counter efficiency (\%)}} \times 10$$

The counting efficiency of gamma ra spectrometer for ^{137}Cs was 11.25 per cent

$$\text{Transfer factor from soil to plant} = \frac{\text{Radioactivity/unit dry weigh of the plant sample}}{\text{Radioactivity per unit dr weight of the soil}}$$

Results and Discussion

The transfer factor (TF) in respect o roots and clumps of lucerne and roots, sten and leaves of sorghum was significantly influence by the different soils studied (Table 2). Amon the soils, Madukkur soil recorded the highes TF values, followed by Irugur and Palathura soils. The TF values for roots, clumps an whole plant in lucerne were, respectively, 1.3 1.6 and 1.5 times greater in Madukkur soi than in Palathurai soil. In the case of sorghum

e corresponding increase was 3.7, 3.0, 2.5 nd 3.0 times, respectively for roots, stem, eaves and whole plant.

The higher TF for ^{137}Cs in both the rops in Madukkur soil, as compared to the ther two soils, could be attributed to a larger xtent to the inherent differences in the clay ontent among the soils. Increase in TF for ^{137}Cs with decrease in clay content has been eported by many workers (Abbazov *et al.* 978; Nielsen and Strandberg, 1988; Horak *t al.* 1989). When root absorption is dominant, F is related to the ability of the soil material release Cs into the soil solution. Soils with elatively coarse texture, as well as those with w amounts of exchangeable potassium, favour ss retention and more availability of ^{137}Cs nd, thereby, modify the TF (Antonopovlos *et al.* 1989). Relatively more root uptake and translocation due to less adsorption might be the reason for the high TF in Madukkur soil.

Also, on comparative terms, Madukkur soil is considered as a poor soil in respect of potassium (Table 1). The low potassium content of this soil might have caused the observed high TF because one of the important soil factors that contribute to the continually high availability of ^{137}Cs is low potassium content. The relationship between ^{137}Cs and potassium could be explained based on Michaelis-Menten competitive inhibition model which amply proved that in soils having low concentration of analogous stable element (K), the radionuclide (^{137}Cs) uptake by the plant was enhanced (Till and Meyer, 1983). A significant negative correlation obtained in the present investigation between the TF

able 2. Effect of levels of caesium-137 on the transfer factor of caesium-137 from soil to sorghum and lucerne

oil	Sorghum				Lucerne		
	Leaves	Stem	Root	Total	Clumps	Root	Total
alathurai							
20	0.032	0.020	0.094	0.146	0.065	0.039	0.096
40	0.025	0.016	0.075	0.090	0.038	0.019	0.056
60	0.020	0.014	0.043	0.076	0.036	0.017	0.052
80	0.019	0.013	0.039	0.069	0.035	0.015	0.051
Mean	0.024	0.016	0.063	0.095	0.044	0.023	0.064
rugur							
20	0.069	0.038	0.182	0.289	0.093	0.034	0.126
40	0.050	0.034	0.098	0.182	0.060	0.019	0.078
60	0.036	0.024	0.093	0.153	0.054	0.019	0.074
80	0.034	0.020	0.089	0.142	0.051	0.016	0.067
Mean	0.047	0.029	0.116	0.192	0.065	0.022	0.086
Madukkur							
20	0.091	0.052	0.346	0.489	0.120	0.039	0.158
40	0.054	0.047	0.227	0.327	0.069	0.023	0.093
60	0.049	0.046	0.181	0.276	0.056	0.023	0.078
80	0.047	0.044	0.154	0.251	0.051	0.019	0.071
Mean	0.060	0.047	0.227	0.336	0.074	0.026	0.100
Source			CD (P=0.05)				
Soil (S)	0.002	0.002	0.020	0.080	0.018	0.002	0.006
Level (L)	0.004	0.003	0.003	0.093	0.020	0.002	0.007
S x L	0.007	0.004	0.004	NS	NS	NS	0.011

of ^{137}Cs (whole plant) and available K (r=-0.481* in lucerne and -0.701** in sorghum) further accentuates this contention and is in conformity with the findings of Bakunov (1989) and Seel *et al.* (1995) who observed similar relationship in several crops (beans, corn, okra, turnips, wheat and winter rye).

The factitious levels of ^{137}Cs applied greatly influenced the TF in both sorghum and lucerne. When the TF of the whole plant at the lowest level of 20 K Bq kg^{-1} soil was considered as 100 per cent, the TF was only 50 per cent at the highest level applied (80 K Bq kg^{-1}). This was so in case of both sorghum and lucerne.

The logarithmic decrease in TF with the increase in the quantity of ^{137}Cs added showed that plants could maintain a constant internal concentration as against the increasing external concentration (Ahamer, 1989). The decrease in TF with increase in levels of applied ^{137}Cs might also be due to the reduction of molar fraction of Cs in the alkali metal poor when increasing quantity was added to the soil. Of the two crops studied, lucerne recorded comparatively lesser transfer factor values than sorghum indicative of the strong manifestation of genetic attributes.

References

Abbazov, M.A, Dergunov, I.D. and Mikulin, R.G. (1978). Effect of soil properties on the accumulation of strontium-90 and caesium-137 in crops. *Soviet Soil Sci.* **10**: 52-56.

Ahamer, G. (1989). The uptake of radioactive caesium into the aquatic vegetation of Syria/Austria. In: Gerzabek, M.H. (Ed.). *After effects of Chernobyl.* Proc.19th ENSA Conf. Vienna.

Antonopovlos, D.M., Clovvas, A. and Gagianas, A. (1990). Derivation of soil-to-plant transfer factors of radiocaesium in Northern Greece after the Chernobyl accident with green house experiments. *Environ. Pollut.* **68**: 119-128.

Auerbach, S. (1987). Comparative behaviour of three long-lived radionuclides in the forest ecosystems. *Observations and Models,* **1**: 15-19.

Bakunov, N.A. (1989). Accumulation of ^{137}Cs in plants and characteristics of its behaviour in soils. *Soviet. Soil Sci.* **21**: 71-78.

Horak, O., Muck, K. and Gerzabek, M.H. (1989) Caesium-137 soil to plant transfer factors derived from pot experiments and field studies. In: International symposium on environmental contamination following a major nuclear accident. International atomic energy agency, Vienna, pp.29-36.

Nielsen, B. and Strandberg,M. (1988). A case study of the behaviour of caesium, strontium and plutonium in the soil-plant system. Risoe National Laboratory, DK-4000, Roskilde, Denmark, pp.1-71.

Seel, J.F., Whicker, F.W. and Adriano, D.C. (1995). Uptake of ^{137}Cs in vegetable crops grown on a contaminated lake bed. *Health Phys.* **68**: 793-799.

Till, J.E. and Meyer, H.R. (1983). Radiological assessment - A text book on environmental dose analysis. U.S. Regulatory Commission, Washington.

(Received : July 2002 ; Revised : April 2003)