Results and Discussion

4. Results and Discussion

4.1 Soil solution chromium species as affected by chromium addition :

4.1.1 Trivalent chromium :

Remediation by reduction of hexavalent chromium [Cr(VI)] in soil is based on the concept that the trivalent chromium [Cr(III)] has negligible toxicity and minimal mobility compared with Cr(VI) and therefore, reduction of Cr(VI) to Cr(III) is a means of eliminating the hazard associated with Cr contamination in the soil without changing its total concentration **(James et al., 1997).**

Table (3) and Figs (4, 5, 6 and 7) show the values of Cr(III) in soil solution after different periods of Cr addition. These data reveal that [Cr(III)] significantly increased as the rate of Cr applied increased. This result is in accordance with those obtained by **Kozuh et al., (2000)** who reported that the reduction of hexavalent Cr [Cr(VI)] depends mostly on the concentration of the added Cr.

The concentration of soluble Cr(III) found in treatment supplied with 0, 10, 20, 40, 80 and 160 mg Cr(VI) kg^{-1} were 0.006, 0.526, 1.845, 1.978, 2.047 and 2.367 mg Cr L^{-1}, respectively. Conversion of Cr from one oxidation state to another in soils is dependent on several parameters including soil pH, organic matter content, Fe(II) and Mn(II) contents, soil structure, redox potential and indigenous Cr(VI)-reducing bacteria **(Turick et al., 1996; Golovatyj et al., 1999; Lee et al., 2000; Wielinga et al., 2001 and Loyaux-Lawniczak et al., 2001).**

The aforementioned results clearly show the effect of anaerobic (flooded) conditions on reducing the applied Cr(VI) and consequently its leachability from soils. This occurred in both soils, but this effect was more obvious in the sandy soil than in the clayey one. This finding could be explained on the basis that the anaerobic conditions in soils result in increases in Cr(III). The trivalent Cr yielded from the conversion of Cr(VI) is a cation, and thus it would be adsorbed on the negatively charged soils colloidal surfaces of soil. It follows that leachability of Cr(III) from the clayey soil is lower than from the sandy soil. On the other hand, **Taylor et al., (2000)** gave another explanation. They stated that clays containing Fe(II) would removed soluble Cr(VI) from their solution by reducing it to Cr(III) at the clay/water interface, and the capacity of clays to reduce Cr(VI) showed positive correlation with the ferrous ion content of the clays.

Chen-Nengehang (2000) reported that the rhizosphere exerted a positive effect on Cr(VI) reduction. Part of this reason was the decrease of pH in the rhizosphere due to the application of physiologically acid fertilizers.

Cresser et al., (1993) reported that under reduced conditions, since O_2-H_2O is a very strong redox couple, the availability of O_2 plays an import role in determining the soil redox potential. During irrigation, soil pores are filled with water instead of air and anaerobic conditions can quickly develop, because of slow diffusion of O_2 and then biological and chemical transformations processes would increase. Patterson and Fendorf (1997) stated that the reduction of Cr(VI) to Cr(III) occurred in the presence of FeS as a reductant.

James and Barlett (1984) found that in unplanted soil treated $(OH)_3$, soluble Cr(VI) levels were higher than in planted soil, but levels of soluble Cr(III) were higher in the rhizosphere soil. This indicates the influence of plant roots and its metabolites on the form of Cr and its subsequent availability to plants i.e., plant root exudates could influence the reduction of Cr(VI) to Cr(III) and the formation of Cr(III)-organic complexes, facilitating its uptake by the roots.

Data obtained clearly show that Cr(III) found in soil solution was very pronounced on the fifth day after Cr addition then it sharply decreased by prolonging the time after application. Increasing the time beyond 5 days showed progressive significant decrease which continued for 50 days in the sandy soil, but only 20 days in the clay one. The decrease beyond 20 days in the clay soil or 50 days in the sand one was most significant. **Lee et al., (2000)** reported that a time period of 2 days was considered the optimum time to obtain full reduction of Cr(VI).

Table (3) : Soil solution Cr(III) (mg L^{-1}) as affected by different rates of the applied chromium.

Soil (S)	Rate of applied Cr mg kg^{-1} (C)	Time of sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	**0**	0.007	0.001	0.003	0.001	0.013	**0.005**
	10	0.497	0.010	0.020	0.005	0.010	**0.108**
	20	0.870	0.020	0.017	0.010	0.007	**0.185**
	40	2.127	0.023	0.027	0.020	0.010	**0.441**
	80	3.283	0.120	0.047	0.030	0.010	**0.498**
	160	3.667	0.103	0.037	0.017	0.010	**0.772**
	Mean	**1.742**	**0.046**	**0.025**	**0.014**	**0.011**	**0.335**
Soil 2 (Sandy)	**0**	0.01	0.01	0.013	0.001	0.003	**0.004**
	10	4.580	0.077	0.033	0.013	0.013	**0.943**
	20	17.010	0.387	0.077	0.037	0.017	**3.505**
	40	16.773	0.573	0.110	0.070	0.043	**3.514**
	80	16.797	0.617	0.307	0.175	0.087	**3.597**
	160	16.797	1.540	0.947	0.173	0.130	**3.917**
	Mean	**11.994**	**0.534**	**0.248**	**0.400**	**0.049**	**2.465**
	General means of the two soils.						
	0	0.008	0.005	0.008	0.008	0.008	**0.006**
	10	2.538	0.045	0.027	0.008	0.012	**0.526**
	20	8.940	0.203	0.047	0.023	0.012	**1.845**
	40	9.450	0.298	0.068	0.045	0.027	**1.978**
	80	9.540	0.368	0.177	0.102	0.048	**2.047**
	160	10.232	0.822	0.492	0.218	0.073	**2.367**
	Mean	**6.785**	**0.290**	**0.136**	**0.066**	**0.030**	

L.S.D. 0.05 **S = 0.33** **T = 0.11** **C = 0.12**

ST = 0.15 **SC = 0.17** **TC = 0.27**

STC = 0.38

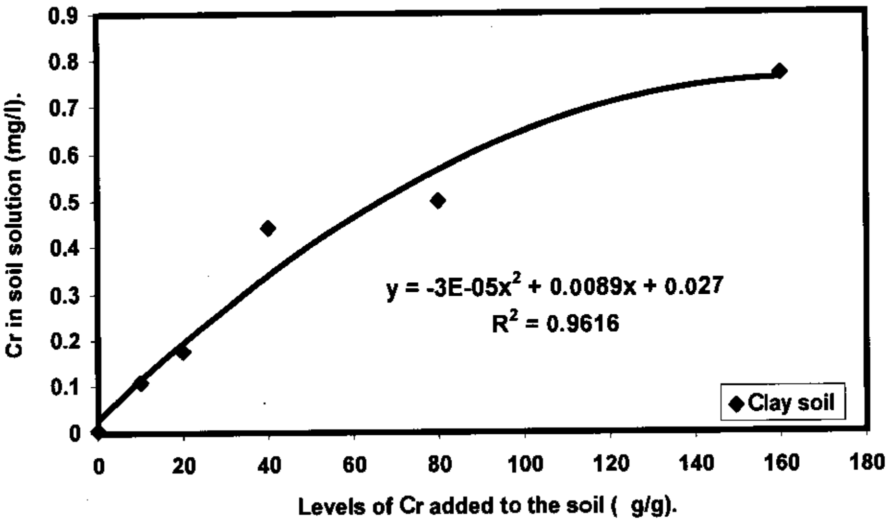

Fig. (4) Trivalent Cr in soil solution (mg/L) as affected by Cr addition.

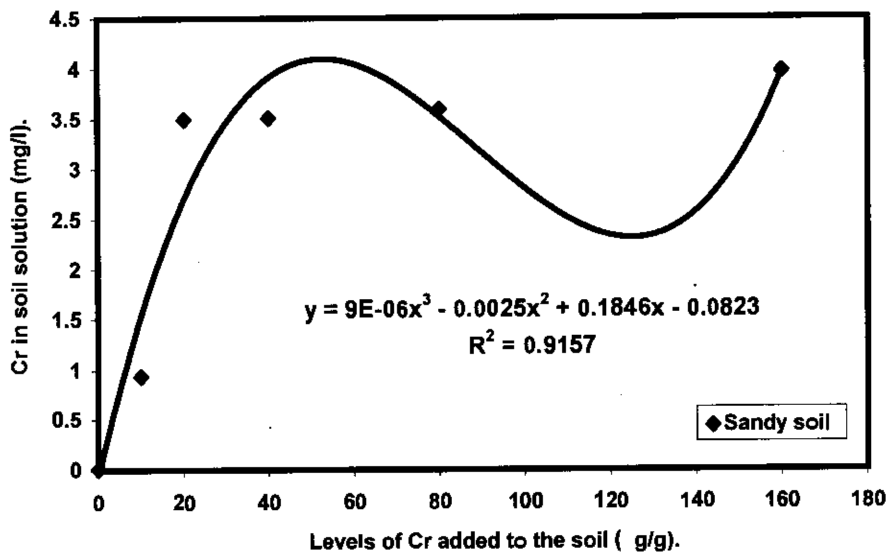

Fig. (5) Trivalent Cr in soil solution (mg/L) as affected by Cr addition .

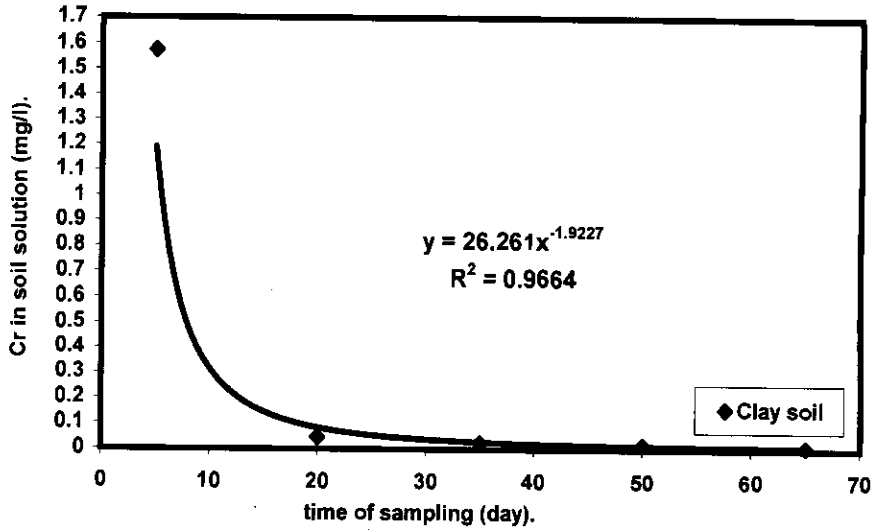

Fig. (6) trivalent Cr in soil solution (mg/L) as affected by tim of sampling after Cr addition.

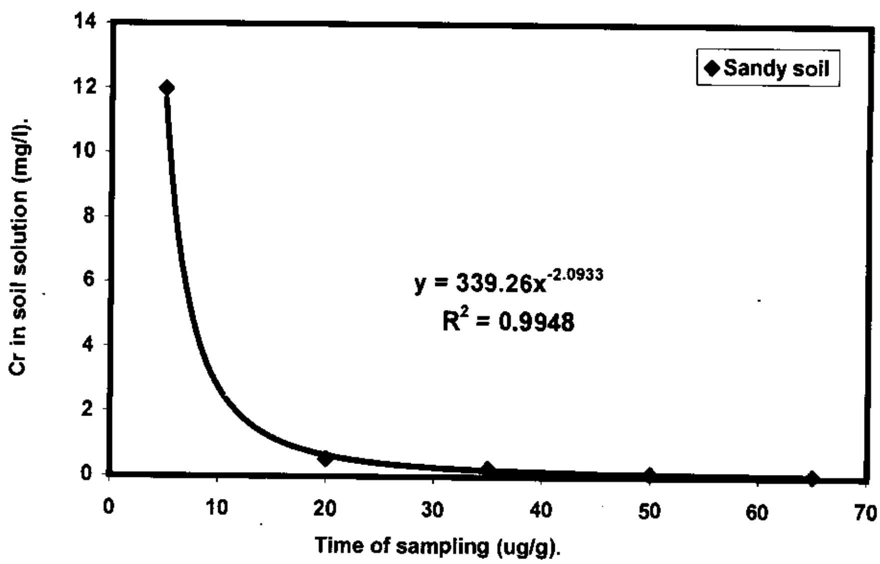

Fig. (7) Trivalent Cr In soil solution (mg/L) as affected by time of sampling after Cr addition .

The different trend obtained in the sandy soil, show that increasing the time of contact between soil and added Cr(VI) progressively decreased the amount of Cr(III) in the soil solution, except beyond the fiftieth day.

4.1.2 Hexavalent chromium :

Data listed in Table (4) and Figs (8, 9, 10 and 11) show the values of soil solution Cr(VI) in soil receiving different rates of applied Cr under flooding conditions for different periods of time.

It is obvious that, generally, Cr(VI) leached from the soil increased by increasing the rate of Cr(VI) added to the soil, but the increases were not significant, except beyond the rate of 40 mg Cr kg^{-1} were soluble Cr(VI) increased significantly. However, such a trend occurred in the sandy soil only and at all periods up to day 50. In the clay soil, in all periods, there was no significant differences among treatments receiving different Cr(VI) rates.

In the clayey soil, the no significant differences recorded between the different Cr treatments at all times of solution sampling may indicate that, the clayey soil has a considerable capacity to retain most of applied Cr(VI) on its colloidal surfaces.

On the other hand, in the sandy soil results may be attributed to its lower colloid contents (clay content as well as organic colloids). **Hale et al., (1978)** reported that the compounds with potentials for chelating Cr(III) or reducing Cr(VI) such as citric acid or gallic acid may be present in organic waste materials added to soils; and that they may form during organic matter decomposition or may be formed from plant root exudates.

Table (4) : Soil solution Cr(VI) mg L^{-1}) as affected by different rates of the applied chromium.

Soil (S)	Rate of applied Cr mg kg^{-1} (C)	Time of sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	0	0.082	0.132	0.089	0.005	0.001	0.062
	10	0.326	0.273	0.089	0.013	0.001	0.142
	20	0.377	0.280	0.122	0.042	0.001	0.164
	40	0.685	0.356	0.172	0.024	0.001	0.247
	80	0.847	0.376	0.196	0.009	0.001	0.286
	160	1.0208	0.583	0.227	0.140	0.001	0.394
	Mean	0.556	0.333	0.150	0.039	0.001	0.216
Soil 2 (Sand)	0	0.062	0.161	0.064	0.070	0.003	0.072
	10	0.435	1.219	0.067	0.121	0.136	0.396
	20	6.427	3.343	1.650	0.824	0.256	2.509
	40	14.070	5.283	3.813	2.663	0.606	5.287
	80	374.333	43.090	38.820	22.927	1.486	96.167
	160	474.133	283.467	118.067	34.523	3.233	182.72
	Mean	144.918	56.094	27.080	10.217	0.967	47.858
	General means of the two soils						
	0	0.072	0.146	0.077	0.038	0.002	0.067
	10	0.381	0.746	0.078	0.067	0.068	0.268
	20	3.425	1.811	0.896	0.433	0.128	1.337
	40	7.378	2.820	1.994	1.344	0.304	2.768
	80	187.590	21.733	19.508	11.483	0.743	48.211
	160	237.671	142.671	59.147	172.687	1.698	91.721
	Mean	72.737	28.213	13.615	5.131	0.484	

L.S.D. 0.05 S = 2.10 T = 3.33 C = 3.64

ST = 4.70 SC = 5.15 TC = 8.15

STC = 11.52

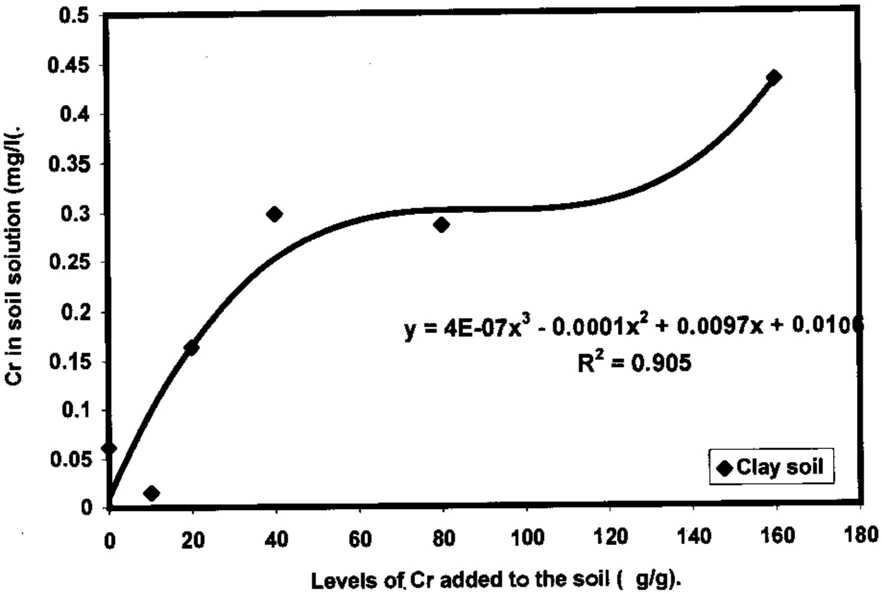

Fig. (8) Hexavalent Cr in sol solution (mg/L) as affected by Cr addition .

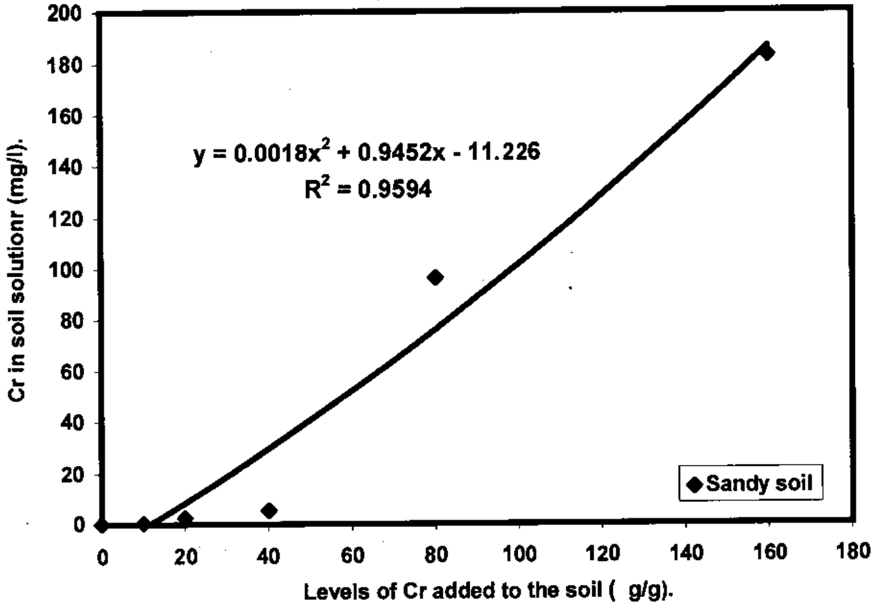

Fig.(9) Hexavalent Cr in soil solution (mg/L) as affected by Cr addition .

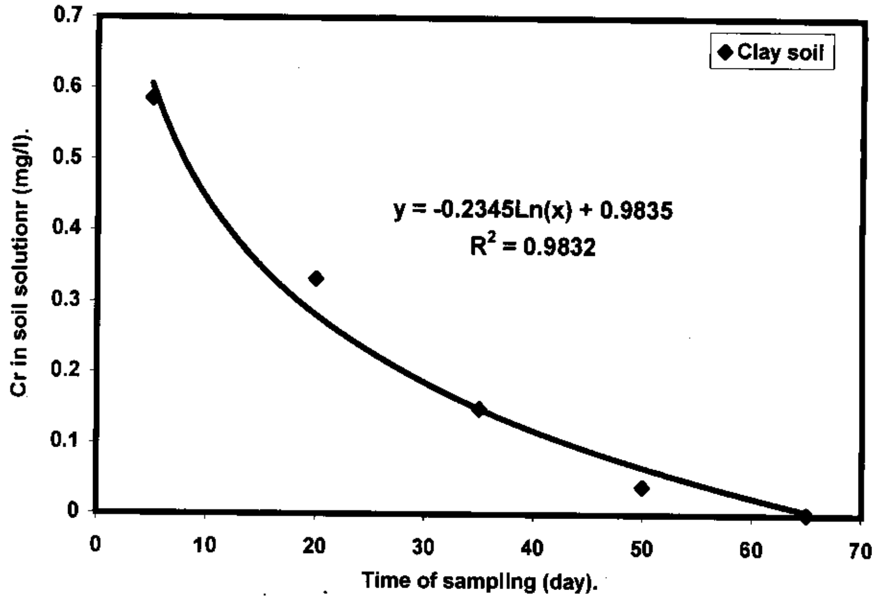

Fig. (10) Hexavalent Cr in soil solution (mg/L) as affected by time of sampling after Cr addition.

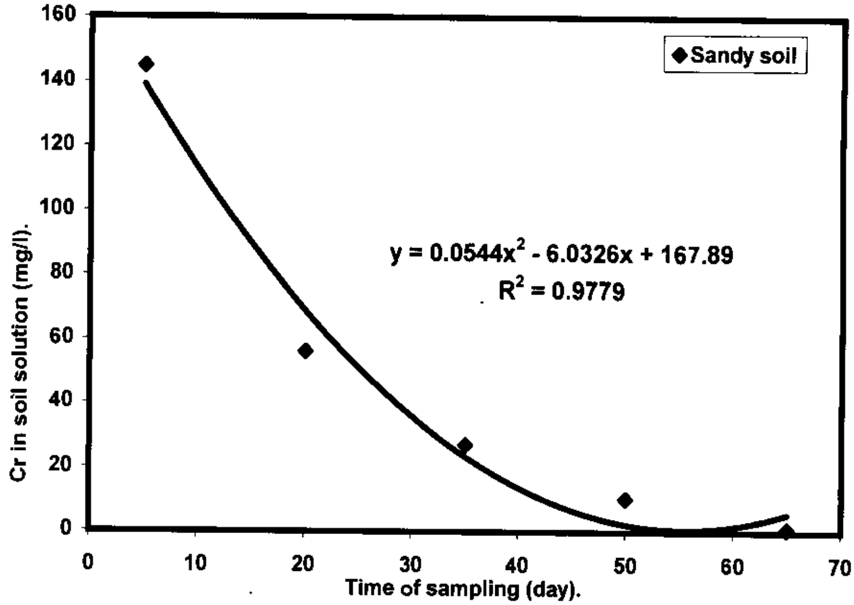

Fig. (11) Hexavelent Cr in soil solution (mg/L) as affected by time of sampling after Cr addition.

4.2 Effect of chromium addition on biological yield of rice plant :

4.2.1 Effect on dry matter yield :

Data presented in Table (5) and graphically illustrated in Figs. (12, 13, 14 and 15) show dry matter yield of rice shoots as affected by the application of Cr at different periods of plant sampling. Application of chromium at 10 mg Cr/kg soil caused a significant decrease in shoots yield. Yield decreased progressively with increased application of chromium. Mean values of yield were 72.7, 61.7, 56.3, 53.1, 48.6 and 45.2 g/pot with addition of 0, 10, 20, 40, 80 and 160 mg Cr/kg^{-1}, respectively. The magnitudes of yield decrease caused by adding 10, 20, 40, 80 and 160 mg Cr/kg^{-1} were all significant, being 15.1, 22.6, 27.0, 33.1 and 37.8 %, respectively. These results agree well with those obtained by **Ristovic (1995)** who reported that yields of lucerne and lettuce significantly decreased with increasing Cr rate. **Chino (1981)** stated that the Cr concentrations in plant tissues which are associated with toxicity symptoms are usually in the several hundreds mg kg^{-1} range. For the rice plants, 35 to 177 mg kg^{-1} of Cr in stem and leaf are associated with up to 10 % reduction in yield.

On the fifth day after start of experiment, the progressive retarding effect was slight and plant growth was retarded significantly only at 160 mg Cr kg^{-1}. The decreases in yield due to adding Cr amounted 5.2, 6.9, 8.4, 11.5 and 14.5% on day 5 due to application of 10, 20, 40, 80 and 160 mg Cr kg^{-1}. The decrease caused by up to 80 mg Cr kg^{-1} at this early growth stages was not statistically significant. On the twentieth and the thirty fifth day, the decrease were marked. On the thirty fifth day the percentages of decrease were 37.4, 41.0, 43.9, 47.0 and 54.5% as a result of adding 10, 20, 40, 80 and 160 mg Cr kg^{-1}, respectively. Therefore, the retarding effect of Cr was most active during the period between the 3rd and 5th weeks following Cr application.

The retarding effect of adding Cr on plant growth occurred in both the studied soils. However, in the sand soil each successive increments of Cr caused a progressive significant decrease, whereas, in the clayey soil some successive increments were of similar effects on plant growth. For example, the rates 20 and 40 mg Cr kg^{-1} were almost similar, and the rates 40 and 80 mg Cr kg^{-1} were similar; also the 80 and 160 mg Cr kg were similar in effect since the differences between each two successive treatments of those were not statistically significant.

Application of 10 mg Cr kg^{-1} soil caused a slight non significant decrease in plant yield. This occurred in both soils at the early stages during the first 5 days after Cr addition. However, with the progress of time, the retarding effect of this rate was acute and significant from day 20 onwards, particularly in the sand soil. In the clay soil, this rate caused a significant decrease only on day 35 and remained of non-significant effect with the progress of time.

Thus, addition of Cr caused a pronounced retarding effect on plant growth particularly in the sand soil. When it was applied at a rate of 20 mg Cr kg^{-1} or more in both, soils the decrease was 22.6 % or more. Such an adverse effect on plant growth was attributed by **Sharma and Sharma (1996)** to a decrease in chlorophyll contents and activities of catalase and pyroxidase as a result of applying Cr. Shahandeh and Hossner (2000) reported that most of the plant species that were treated with Cr(VI) hyper-accumulated Cr and died.

Khalil (1995) grew sorghum and carrots on alluvial, calcareous and sandy soils and found that their growth was inhibited by chromium rates exceeding 5 mg kg^{-1}. Similar results were obtained by **Foroughi et al., (1982)** with bush beans. **Eleiwa (1990)** showed that chromium concentration of between 0.05 to 52 mg Cr(III) stimulated growth (fresh and dry weight) of some bread and durum wheat varieties. **Khalil and Naguib (1988)** found that 10^{-5} m ML^{-1} of chromium suppressed the rate of germination of melon seeds.

On the other hand, **Neguib et al., (1986)** found that chromate and dichromate were more harmful than chromic ions particularly at the early stages of plant growth.

Table (5) : **Dry matter yield (g/pot) of rice plant (shoots) as affected by different rates of applied chromium.**

Soil (S)	Rate of applied Cr mg kg^{-1} (C)	Time of plant sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	0	75.9	53.7	63.3	101.0	106.0	80.0
	10	72.2	49.7	49.0	100.0	103.0	74.8
	20	71.5	46.0	48.3	85.0	98.7	69.7
	40	70.5	43.8	47.5	82.0	96.8	68.1
	80	67.2	39.0	45.8	80.5	95.7	65.6
	160	64.3	37.7	40.3	81.0	91.5	62.9
	Mean	70.3	45.0	49.1	88.4	98.6	70.3
Soil 2 (Sand)	0	57.5	53.2	57.0	74.0	85.5	65.4
	10	54.1	23.0	26.4	62.0	77.3	48.5
	20	52.7	23.8	22.7	42.8	71.6	42.7
	40	51.7	22.0	20.0	38.0	58.6	38.0
	80	50.7	21.8	17.5	20.8	46.7	31.4
	160	49.6	18.0	14.5	13.8	40.9	27.4
	Mean	52.7	27.0	26.3	41.9	63.5	42.3
General means of the two soils							
	0	66.7	53.5	60.2	87.7	95.8	72.7
	10	63.2	36.4	37.7	81.2	90.2	61.7
	20	62.1	34.9	35.5	63.9	85.2	56.3
	40	61.1	32.9	33.8	60.0	77.8	53.1
	80	59.0	30.4	31.9	50.7	71.2	48.5
	160	57.0	27.8	27.4	47.5	66.2	45.1
	Mean	61.5	36.0	38.0	65.2	81.0	

L.S.D. 0.05 S = 2.10 T = 3.33 C = 3.64

ST = 4.70 SC = 5.15 TC = 8.15

STC = 11.52

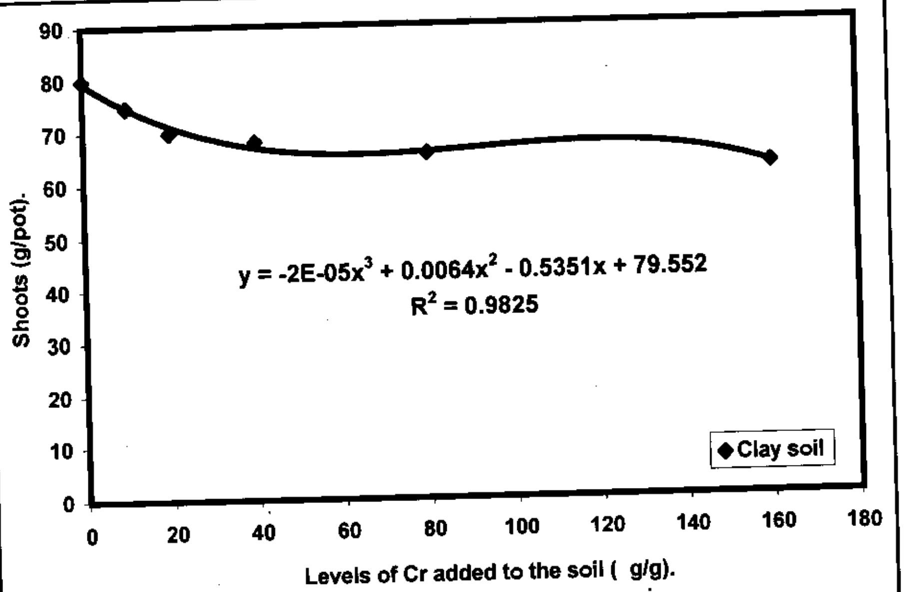

Fig. (12) Dry matter yield (g/pot) of rice shoots as affected by Cr addition .

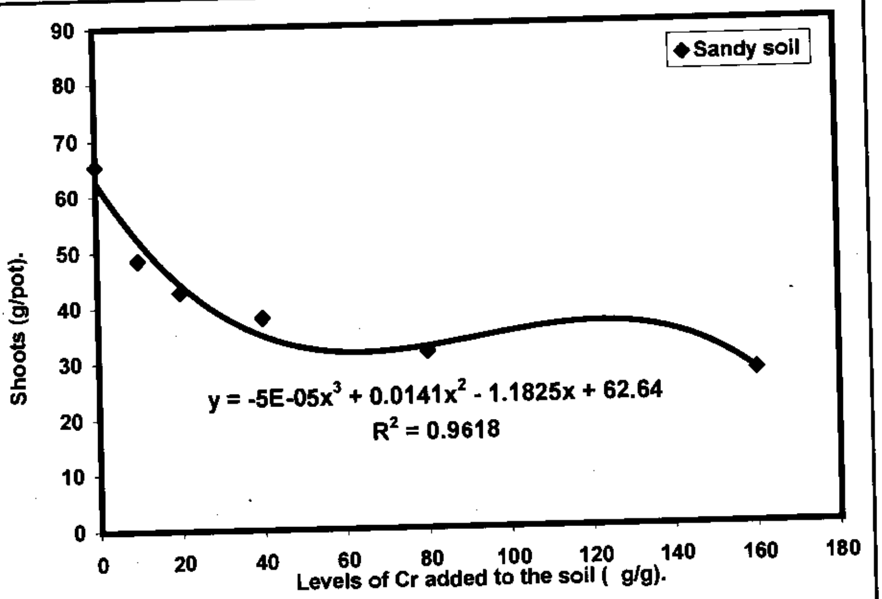

Fig. (13) Dry matter yield (g/pot) of rice shoots as affected by Cr addition.

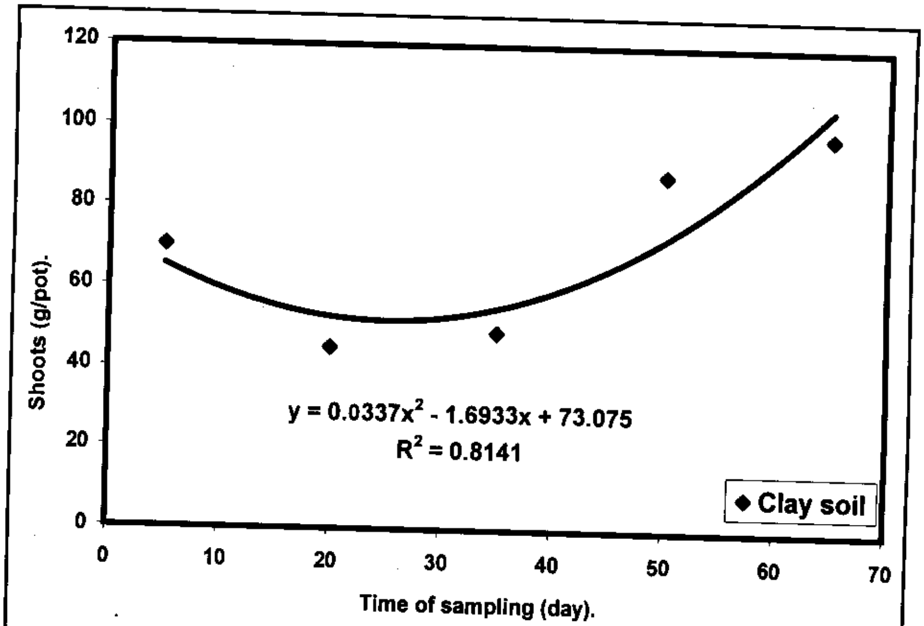

Fig. (14) Dry matter yield (g/pot) of rice shoots as affected by time of sampling.

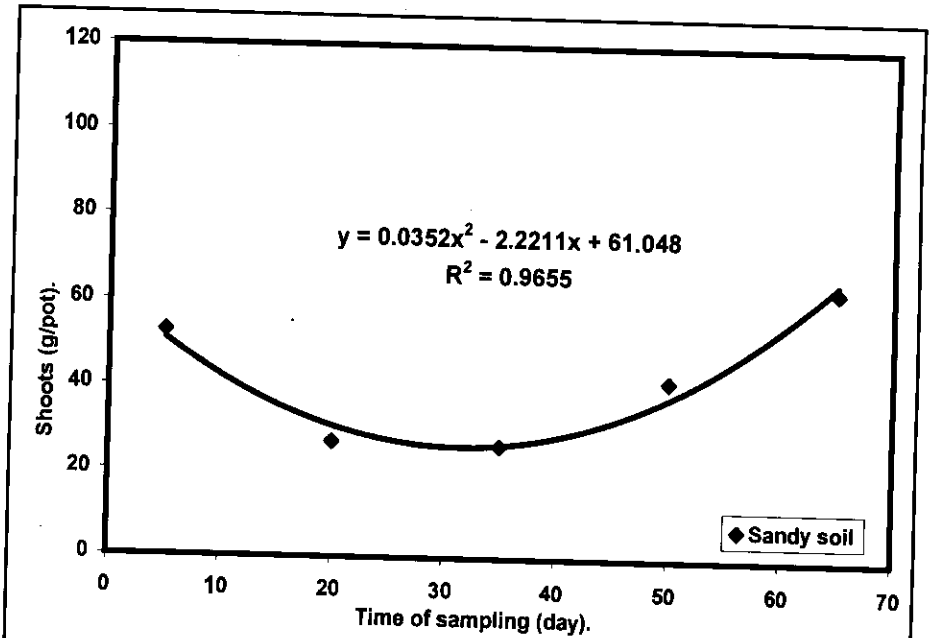

Fig. (15) Dry matter yield (g/pot) of rice shoots as affected by time of sampling after Cr addition

4.2.2 Effect of Chromium addition on dry matter yield of rice roots :

Regarding plant roots grown on the tested soils, data presented in Table (6) and graphically illustrated in Figs. (16, 17, 18 and 19), show that application of Cr significantly decreased the dry matter yield of roots and the decreases were more progressive with the increase in therate of applied Cr. Mean values of dry matter yield of roots, generally, decreased from 38.6 g pot^{-1} in soils with no applied Cr to 32.7, 28.4, 25.5, 23.0 and 19.8 g pot^{-1} in soil supplied with 10, 20, 40, 80 and 160 mg Cr kg^{-1}, respectively. **Golovatyj et al., (1999)** reported that the ability of Cr accumulation in the organs of a studied crop can be ranked in the following descending order : roots > leaves > stems. **Yamaguchi and Aso (1977)** reported decreased root elongation of rice and wheat growing in soils treated with 200 mg kg^{-1} Cr(III). **Bishnoi et al., (1993)** reported that the deleterious effect of Cr(VI) application to peas was pronounced on the growth of roots.

Such adverse effect on root growth could be attributed to Cr damage or toxicity. **Hauschild et al., (1993)** showed that resulting chromium contents of the roots were highly significantly positively correlated with most of the stress symptoms recorded for the plants, indicating that the basal cause of Cr phytotoxicity may be disturbance of the normal functions of roots. Accumulation of free putrescence in leaves were the most sensitive symptoms recorded.

The obtained data show that values of rice roots dry weight were drastically reduced upon application of Cr to each of the tested soils even at the lowest level of Cr addition (10 mg kg^{-1}). The values of the roots dry matter yield were 42.7 35.1, 32.1, 29.2 26.3 and 23.9 g pot^{-1} in the clayey soil upon treating it with Cr rates of 0, 10, 20, 40, 80 and 160 mg kg^{-1} , respectively. The corresponding values in the sandy soils were 34.5, 20.3 24.3 21.7, 19.7 and 15.7 g pot^{-1}, respectively. The percentages of yield decrease were, 15.3, 26.4, 33.9 40.4 and 48.7% as a result of adding 10, 20, 40, 80 and 160 µg Cr g^{-1}. The reduction in yield of roots was more pronounced in the sandy soil as compared with the clay one and this may be attributed to the buffering action of the clay soil.

The data obtained clearly show that the dry matter yield of plant roots grown in soil treated with different rates of chromium was significantly and progressively increased with time.

Thus, prolonging time of plant growth after Cr addition significantly increased the dry matter yield of plant roots. Mean values of dry matter yield obtained in the clay soil were 20.5, 28.4, 31.0 36.0 and 42.3 g pot^{-1} after 5, 20, 35, 50 and 65 days from Cr addition, respectively. The corresponding values in the sandy soil were, 21.0, 22.6, 26.6 and 27.8 g pot^{-1}, respectively. Increasing the duration time of plant growth from 5 days after Cr addition resulted in significant increases in roots yield which amounted to 23.2, 32.4, 51.2 and 69.1 % at days 20, 35, 50 , and 65 respectively compared with day 5. It is also clear that root dry matter yield of the clayey soil were higher as compared with the corresponding ones of the sandy soil and such trend could be explained on a basis of soil buffering effect, being much higher in the clay soil than the sandy one. **Pratt (1966)** reported that the visual symptoms of Cr toxicity which are commonly observed are : stunted growth, poorly developed root system and curled and discolored leaves.

Table (6) : Dry matter yield (g/pot) of rice plants (roots) as affected by different rates of applied chromium.

Soil (S)	Rate of applied Cr mg kg^{-1} (C)	Time of plant sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	0	28.7	41.7	44.8	46.6	56.5	42.7
	10	22.1	28.0	33.5	42.7	49.8	34.3
	20	20.4	27.3	30.3	38.6	45.9	32.1
	40	19.9	26.4	28.4	33.5	37.8	29.2
	80	19.0	25.0	25.8	28.0	33.4	26.3
	160	18.0	22.1	23.4	26.3	29.5	23.9
	Mean	20.5	28.4	31.0	36.0	42.3	31.6
Soil 2 (Sand)	0	25.3	28.4	33.8	34.8	50.3	34.5
	10	22.1	26.5	29.4	31.4	41.3	30.1
	20	21.2	23.5	24.3	28.7	24.0	24.3
	40	20.9	20.9	21.6	24.9	20.1	21.7
	80	19.8	19.9	19.4	22.6	16.7	19.7
	160	16.7	16.3	13.9	17.4	14.3	15.7
	Mean	21.0	22.6	23.7	26.6	27.8	24.3
General means of the two soils							
	0	24.5	35.0	39.3	40.8	53.4	38.6
	10	22.0	27.3	31.5	37.0	45.7	32.7
	20	20.8	25.4	27.3	33.7	35.0	28.4
	40	20.4	23.7	25.0	29.2	29.0	25.5
	80	19.4	22.5	22.6	25.2	25.0	23.0
	160	17.3	19.1	18.7	21.7	21.9	19.8
	Mean	20.7	25.5	27.4	31.3	35.0	

L.S.D. 0.05 S = 0.81 T = 1.28 C = 1.40
ST = 1.81 SC = 1.98 TC = 3.13
STC = 4.43

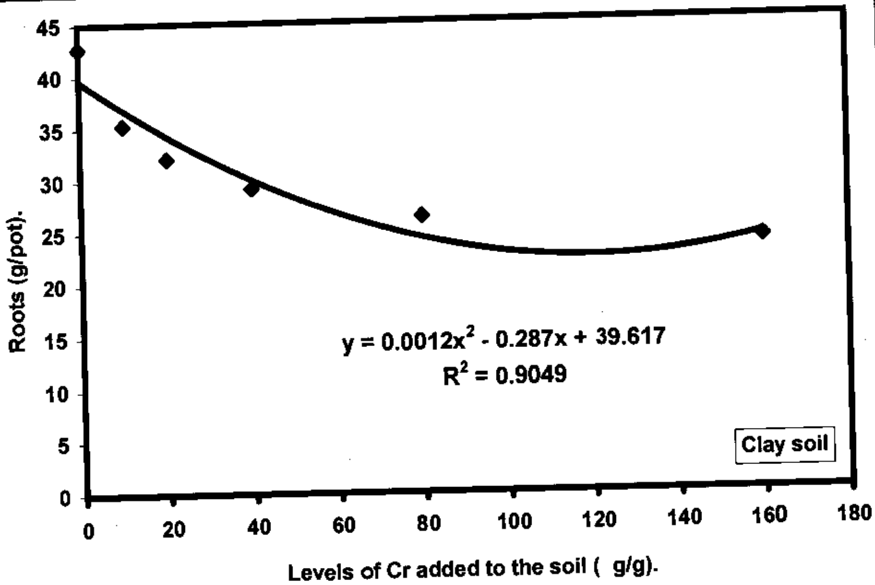

Fig. (16) Dry matter yield (g/pot) of rice roots as affected by Cr addition.

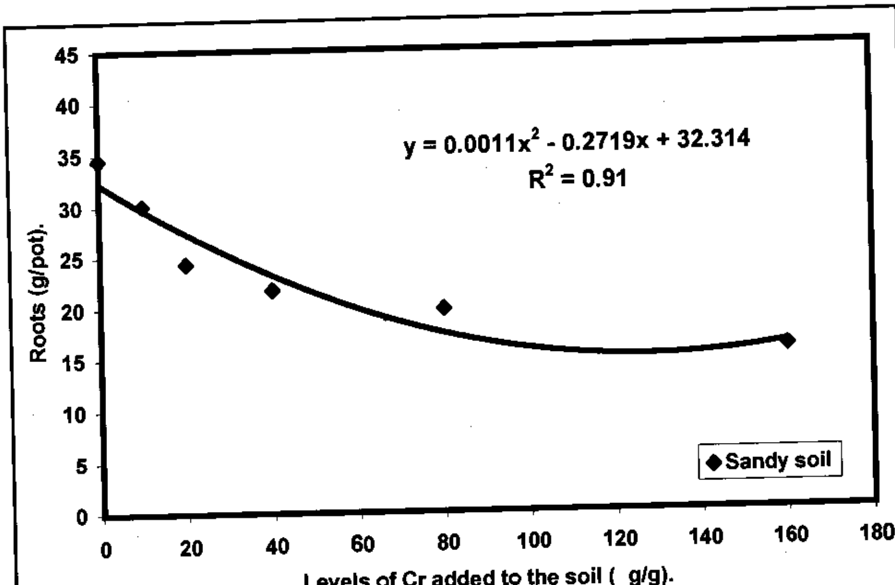

Fig. (17) Dry matter yield of rice roots as affected by Cr addition (g/pot).

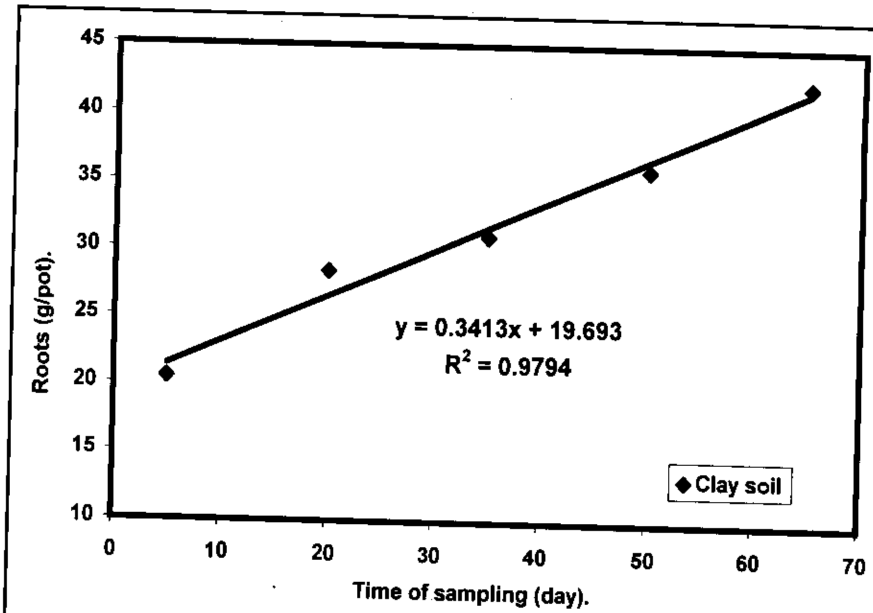

Fig. (18) Dry matter yield (g/pot) of rice roots as affected by time of sampling .

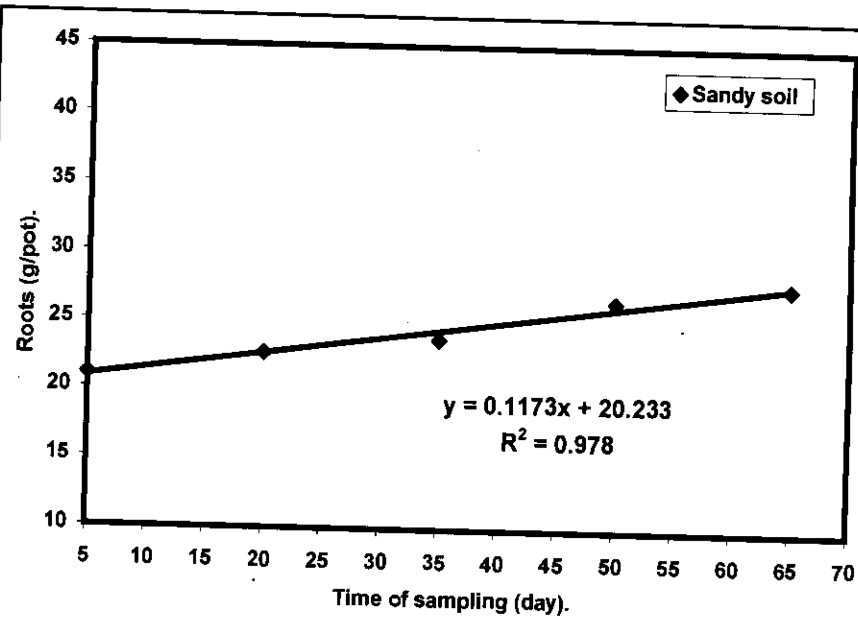

Fig. (19) Dry matter yield (g/pot) of rice roots as affected by time of sampling.

4.2.3 Effect of Chromium addition on dry matter yield of rice seeds :

Data presented in Table (7) and Figs. (20 and 21) show the dry matter yield of rice seeds as affected by Cr addition at different rates. The obtained values show that Cr application caused progressive and consistent decreases in seed yield with increased addition of Cr up to the highest rate. This occurred in the sandy soil. In the clay soil, however, a slight decrease occurred with Cr addition up to 20 mg kg^{-1}, then after a progressive increase occurred up to the highest Cr rate.

Comparing the results of the two tested soils, data show lower values of seeds yield of rice grown on the sandy soil as compared with the clayey one. In the sandy soil, the reduction in seeds yield occurred by adding 10, 20, 40, 80 and 160 mg Cr kg^{-1} amounted about 1, 52, 60, 67 and 72%, respectively. In the clay soil, the comparable reduction occurred by adding 10 and 20 mg Cr kg^{-1} were 7 and 18%, respectively.

Poomina-Vajpayee et al., (1999) attributed decreased yield due to Cr addition to a reduction in chlorophyll and protein contents and inhibition of <u>in vitro</u> nitrate reductase activity associated with an accumulation of Cr in plant tissues. **Panda and Patra (1997)** stated that Cr produces several physiological and biochemical lesions in plants which inhibits seed germination and affects mineral status and metabolism of plants thus reducing yield drastically. They added that the activity of several enzymes (including amylase, invertase and catalase) also decreases.

Wyszkowska et al., (2001) showed that hexavalent Cr applied at doses of 80 and 120 mg kg^{-1} of soil inhibited growth of oats; and adversely affected the activity of soil dehydrogenises, urease, acid and alkaline phosphatase and the numbers of Azotobacter bacteria and actinomycetes.

Table (7) : Dry matter yield (g/pot) of rice plants (seeds) affected by different rates of applied chromium.

Rate of applied Cr mg kg^{-1} (c)	Soils (S)		Mean
	Clay	Sandy	
0	99.26	50.33	74.81
10	91.83	41.33	66.58
20	81.67	24.00	52.83
40	125.0	20.17	72.58
80	126.67	16.67	71.67
160	144.67	14.32	79.49
Mean	111.52	27.80	69.66

L.S.D. 0.05 S = 20.94 C = 9.16 SC = 12.95

Bishnoi et al., (1993) reported that, in Cr-treated peas a larger proportion of pods failed to set seeds and the average number of seeds per pod was lower. The positive effect of Cr obtained in the clay soil at Cr rates of 40 mg kg^{-1} and over, could be attributed to adsorbing chromium by the clay soil and releasing species of other ions which were beneficial to plant growth.

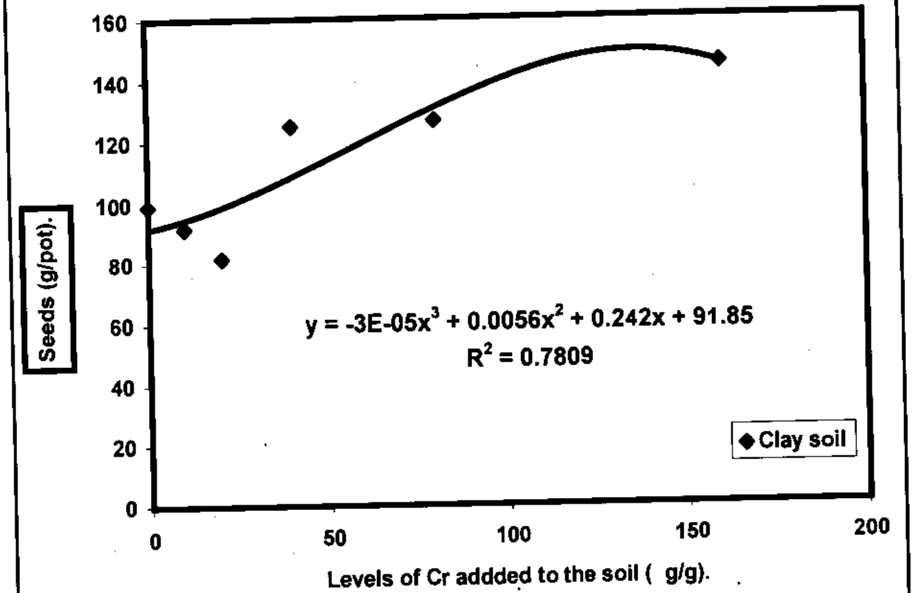

Fig. (20) Dry matter yield (g/pot) of rice plants (seeds) as affected by Cr addition.

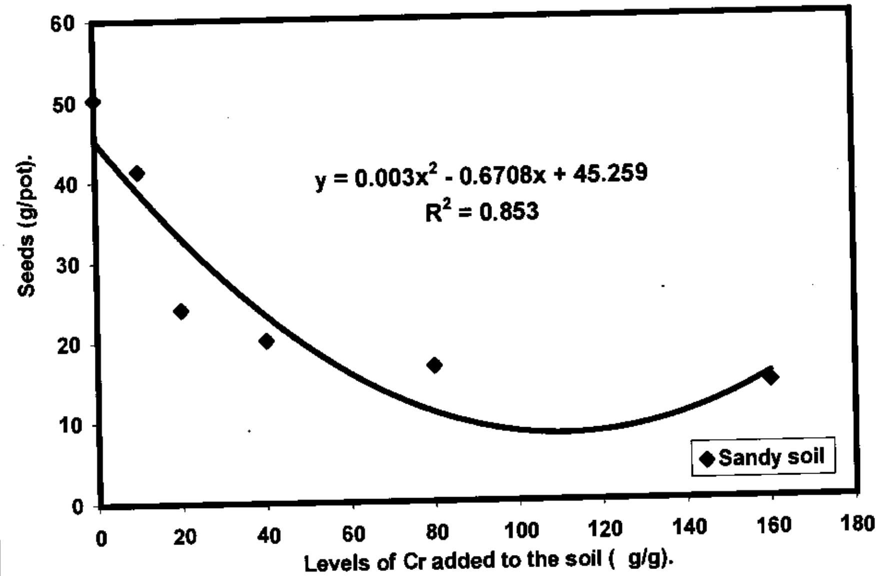

Fig. (21) Dry matter yield (g/pot) of rice plants (seeds) as affected by Cr addition.

4.3 Content and uptake of chromium by rice plant :

4.3.1 Effect of Chromium addition on Cr content in rice shoots:

Data in Table (8) and Figs (22, 23, 24 and 25) show that Cr content (concentration) in rice shoots were progressively increased with increasing the rate of applied Cr to reach levels more than control treatment by several times. Increased Cr concentration is reflection to decreased plant growth as well as increased presence of Cr in the rhizosphere. **Khalil (1995)** reported that the concentrations of Cr in sorghum and carrot plants were increased with increasing the amounts of applied Cr. It was reported that Cr was toxic to plants at 5 mg L^{-1} and above in nutrient solution in water culture and at 100 mg kg^{-1} and above in soil culture. **(Wallace et al., 1976)** and **Sarkuman et al., (1989)** reported that rice plants survived when given up to 200 mg kg^{-1} Cr(VI) in soil; and symptoms like leaf rolling and tip drying (which eventually led to the death of the plants) were observed in plants receiving 400 mg kg^{-1} Cr(VI) and above.

In the clay soil, mean values of Cr content in rice shoots were 5.4, 12.7, 21.5 31.4 84.8 and 198.8 µg g^{-1} due to Cr application at the rates of 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1}, respectively. The corresponding values of Cr concentrations in rice shoots grown in the sandy soil were 8.6, 43.1, 130.8, 402.3, 837.1 and 1484.4 µg g^{-1}, respectively.

Comparing the results of both tested soils, data show higher values of Cr content in rice shoots grown on the sandy soil compared to those grown on the clayey one. Such results reflect the abundance of soluble of Cr in the sandy soil as compared with the clay soil. The sand soil showed 7 times as much trivalent Cr as shown by the clay soil (see Tables 3 and 4). Growth reduction due to Cr application was 25.8 to as much as 58.1 % in the sand soil compared with 6.5 to 21.4 % in the clay soil (see Table 7).

Data in Table (8) reveal that the pattern of Cr effect under different periods of growth after Cr addition could be presented as follows :

In the clay soil, Cr content in rice shoots was severely and significantly decreased with increasing time of plant growth. The percentage of this reduction amounted to 45, 68, 92 and 94% for the periods of 20, 35, 50 and 65 days, respectively.

In the sandy soil different trend was obtained. Chromium content of rice shoots significantly and progressively increased with time up to day 35; then after a progressive decrease occurred. Percentages of increase at days 20 and 35 were 51.8 and 71.2 %, respectively; Percentage of decrease at days 50 and 65 were 81.5 and 89.0 %, respectively (all relative to content at day 5).

Such patterns are in line with the patterns of plant growth and the magnitude of soluble Cr in the root media. Increased contents of Cr in plant tissues reflect decreased output of biomass and increased percentage of Cr. Decreased content may be due to increased biomass (a dilution effect) and/or decreased presence of soluble Cr in soil solution (see Tables 3, 4 and 14).

Mean values of Cr content in rice shoots (means of the two soils) after different period of plant growth were 341.3, 446.3, 481.4, 55.5 and 34.2 $\mu g\ g^{-1}$ for the periods of 5, 20, 35, 50 and 65 days, respectively.

Table (8) : Chromium content (µg/g) in rice plants (shoots) as affected by different rates of applied chromium.

Soil (S)	Rate of applied Cr mg kg^{-1} (C)	Time of plant sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	0	5.9	9.8	6.7	2.1	2.5	5.4
	10	7.9	32.7	8.6	8.2	6.0	12.7
	20	32.1	38.9	18.8	10.8	7.0	21.5
	40	53.1	54.4	27.9	12.7	8.6	31.4
	80	188.8	139.3	72.6	14.3	9.3	84.8
	160	596.5	207.1	145.5	21.7	23.2	198.8
	Mean	147.4	80.4	46.7	11.6	9.4	59.1
Soil 2 (Sand)	0	30.3	9.2	0.9	1.8	0.9	8.6
	10	75.6	36.0	93.4	3.6	7.0	43.1
	20	157.1	82.2	371.2	12.6	31.2	130.8
	40	415.2	928.8	557.5.	38.2	71.4	402.3
	80	971.9	1167.4	1710.5	288.7	96.9	837.1
	160	1560.8	2650.0	2763.5	300.6	145.8	1484.2
	Mean	535.2	812.3	916.2	99.3	58.9	484.4
General means of the two soils.							
	0	18.2	9.5	3.8	2.0	1.7	7.0
	10	41.8	34.4	51.0	5.9	6.5	27.9
	20	94.5	60.6	194.9	11.7	19.1	76.1
	40	234.2	491.6	292.7	25.4	40.2	216.8
	80	580.4	653.3	891.6	126.6	53.1	461.0
	160	1078.7	1428.6	1454.5	161.2	84.5	841.5
	Mean	341.3	446.3	481.4	55.5	34.2	

L.S.D. 0.05 S = 9.48 T = 14.99 C = 16.42

ST = 21.20 SC = 23.22 TC = 36.72

STC = 51.90

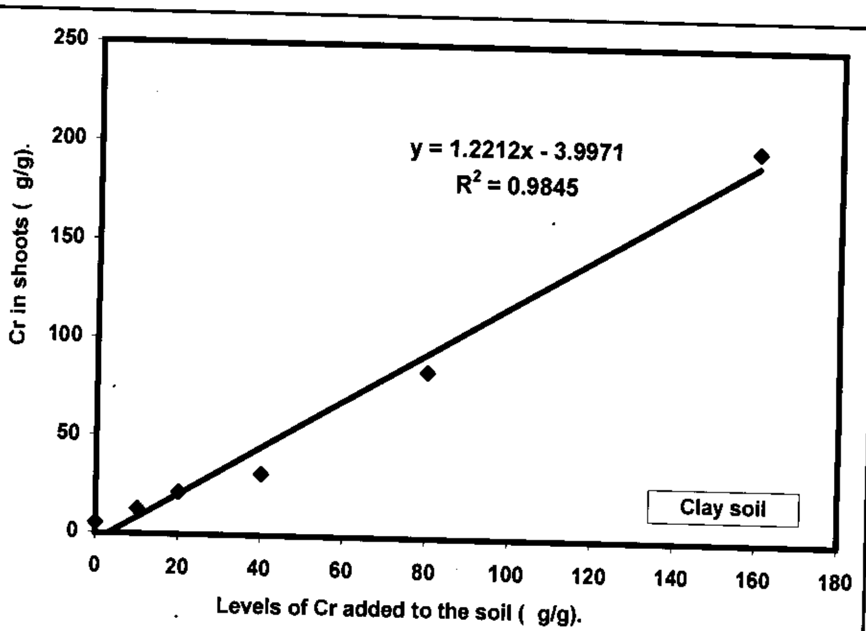

Fig. (22) Chromium content (g/g) in rice shoots as affected by Cr addition.

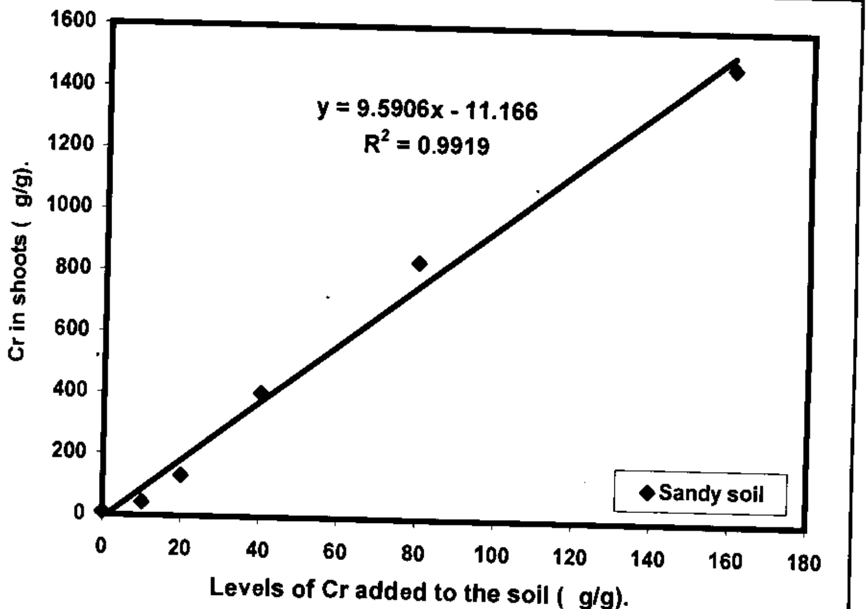

Fig. (23) Chromium Content (g/g) in rice shoots as affected by Cr addition.

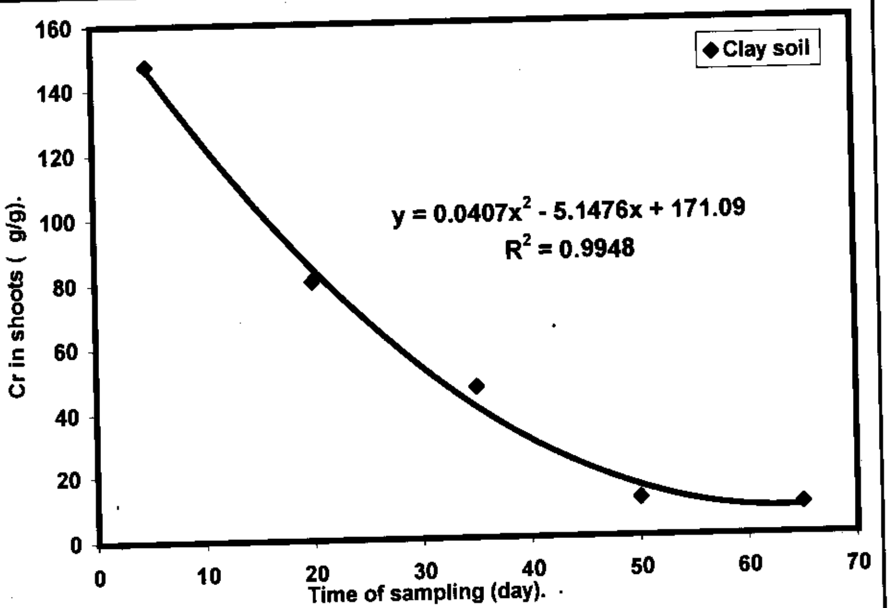

Fig.(24) Chromium content (g/g) rice shoots as affected by time of sampling after Cr addition.

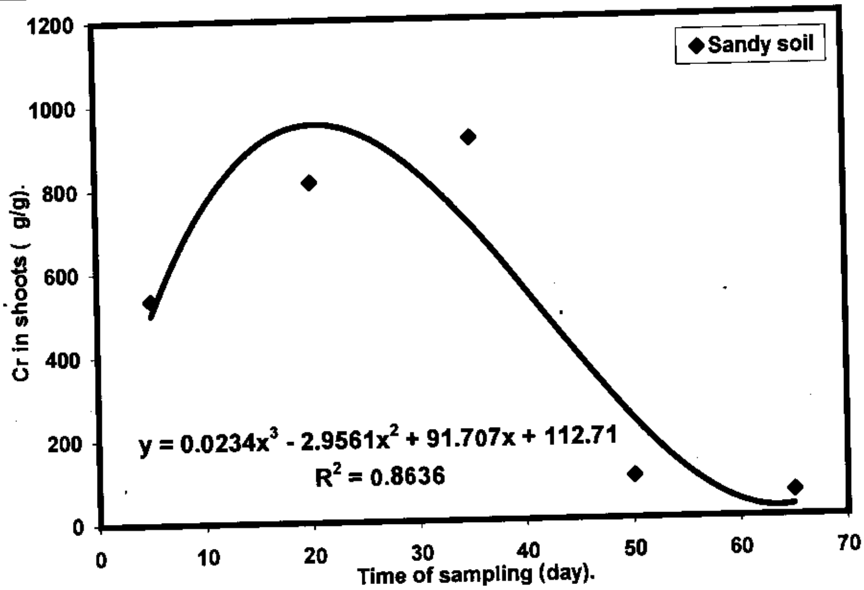

Fig. (25) Chromium content (g/g) in rice shoots as affected by time of sampling after Cr addition.

4.3.2 Effect of Chromium addition on Cr content in rice roots:

Data presented in Table (9) and Figs. (26, 27, 28 and 29) show Cr concentration (μg g^{-1}) in rice roots due to application of different rates of Cr.

Generally, results show that Cr content in rice roots was increased due to increasing rate of applied Cr. Mean values recorded as a result of applying 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1} were 135.4, 271.0, 379.5, 531.7, 828.6 and 1283.2 μg g^{-1}, respectively. In the clay soil, Cr content were 24.0, 62.7, 113.1, 142.7, 289.5 and 669.0 μg g^{-1} for treatments receiving 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1}, respectively. In the sandy soil corresponding contents were 246.9, 479.2, 645.8, 920.5, 1367.7 and 1897.4 μg g^{-1}, respectively.

Results obtained show also that the mean values of Cr content in rice roots in sandy soil were much higher than those recorded in the clayey one.

Comparing the results of Cr content in rice shoots with those of roots, data show that Cr concentration in plant roots was much higher than Cr concentration in plant shoots contents in roots were up to as much as 145 to 575 times those of shoots. This could be explained on the basis of absorbed being Cr not easily translocated from roots to shoots of plants. **Ramachandran et al., (1980)** found that > 90 % of Cr absorbed by plants remained in the roots. **Shewry and Peterson (1974)** suggested that most of the Cr retained in the roots is present in the soluble form in vacuoles of root cells, and more specifically in the protoplasmic fraction of the roots. **Moral et al., (1996)** stated that trivalent Cr ions were readily absorbed by plant roots of tomatoes but their transport to other plant parts was very slow and that Cr contents values in stems and leaves were much lower than roots. **Srivastava et al., (1994)** reported that only a small proportion of Cr taken up by plant translocated to the aerial parts, 70-90 % being incorporated in the roots. **Cary et al., (1977)** indicated that the barrier, believed to be the cell wall, to translocation of Cr from roots to tops was not circumvented by supplying Cr as organic acid-Cr- complexes. **James and Bartlett (1984)** found that bean shoots grown in soil receiving Cr-enriched tannery effluent and sewage sludge did not contain more Cr than those not receiving either material, but the roots did. **Zayed et al., (1998)** reported that translocation of the two Cr forms of chromic ions (Cr^{+3}) and chromate ions (CrO_4^{-2}) from roots to shoots of vegetable crops was extremely limited and accumulation of Cr by roots was 100-fold higher than that by shoots. In the current study there were cases exceeding such reported magnitude.

Data obtained also indicate that prolonging time of plant growth after Cr addition sharply decreased Cr content in rice roots and this reduction was more pronounced in the sandy soil as compared with the clayey one. The decrease in Cr content is associated with an increase in production of plant material, i.e., a dilution effect. The higher values of Cr content in rice roots grown in the sandy soil compared with those grown in the clayey one reflects the greater contents of soluble chromium in the sandy soil (see Tables 3 and 4).

Table (9) : Chromium content (µg/g) in rice plants (roots) as affected by different rates of applied chromium.

Soil (S)	Rate of applied mg kg^{-1} (C)	Time of plant sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	0	34.0	28.5	26.8	17.6	12.7	24.0
	10	69.9	110.5	61.2	36.1	36.8	62.7
	20	164.3	186.5	97.7	69.5	47.6	113.1
	40	181.1	215.5	135.8	122.7	43.0	142.7
	80	344.2	354.9	228.8	287.7	231.8	289.5
	160	1037.3	900.7	568.3	460.6	378.3	669.0
	Mean	305.0	299.5	186.5	165.7	127.6	216.8
Soil 2 (Sand)	0	113.7	224.8	574.6	286.4	34.7	246.9
	10	838.9	438.2	726.5	352.9	39.6	479.2
	20	884.0	515.3	1146.9	628.4	54.6	645.8
	40	1388.7	906.2	1404.1	844.7	64.3	920.6
	80	1895.8	1637.4	1720.7	1518.1	66.6	1367.7
	160	2126.3	2665.0	2488.3	2127.0	80.4	1897.4
	Mean	1207.0	1064.5	1343.5	959.6	56.7	926.3
General means of the two soils							
	0	73.9	126.6	300.7	152.0	23.8	135.4
	10	454.0	274.3	393.9	194.5	37.1	271.0
	20	524.1	351.0	622.3	348.9	51.2	379.5
	40	782.5	560.9	700.0	483.7	61.3	531.7
	80	1120.0	996.2	974.8	902.9	149.2	828.6
	160	1581.8	1782.9	1528.3	1293.8	229.3	1283.2
	Mean	756.0	682.0	765.0	562.7	92.2	

L.S.D. 0.05 S = 11.56 T = 18.28 C = 20.02
ST = 25.85 SC = 28.32 TC = 44.77
STC = 63.32

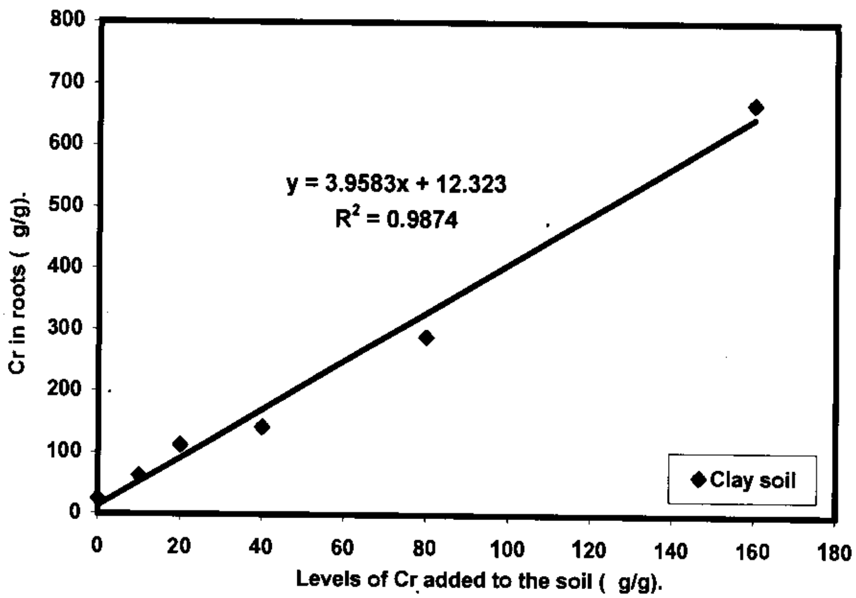

Fig. (26) Chromium content (g/g) in rice roots as affected by Cr addition .

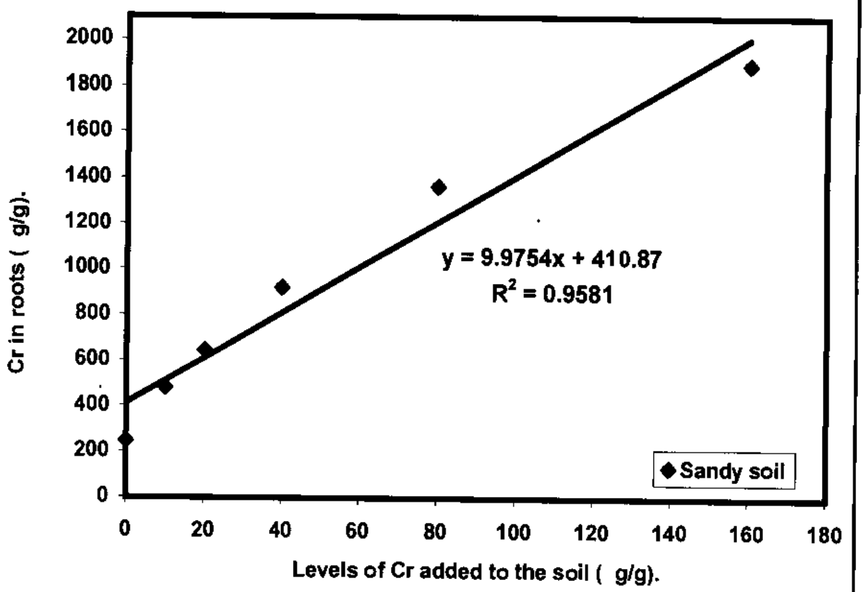

Fig. (27) Chromium content (g/g) in rice roots as affected by Cr addition.

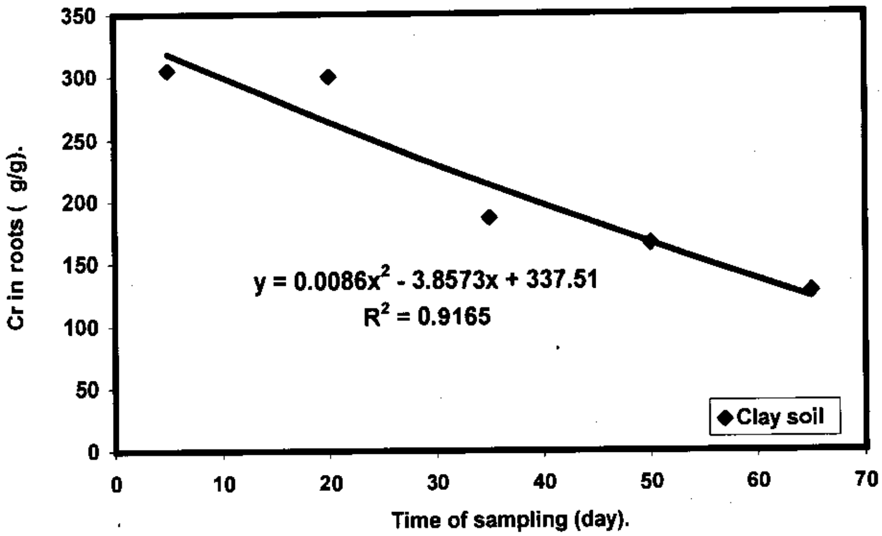

Fig. (28) Chromium content (g/g) in rice roots as affected by time of sampling after Cr addition .

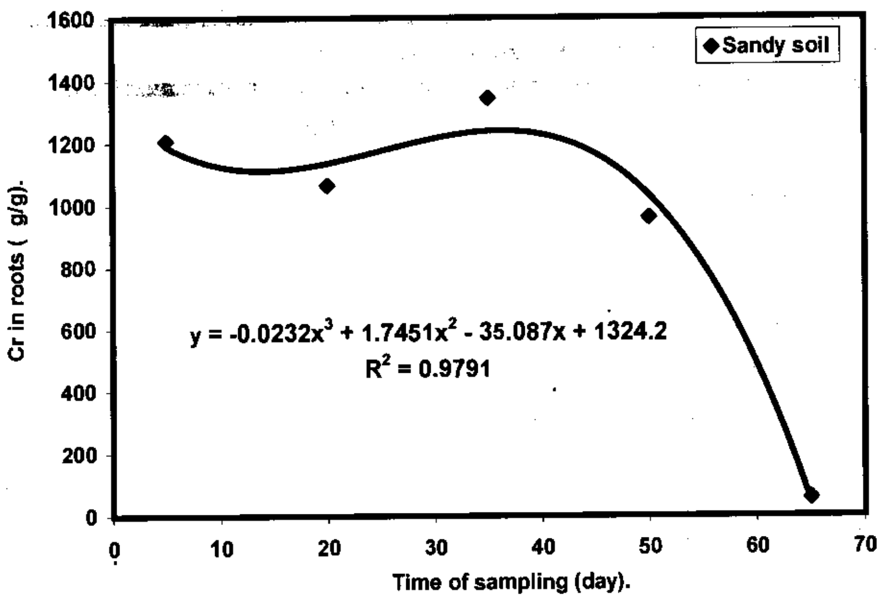

Fig. (29) Chromium content (g/g) in rice roots as affected by time of sampling after Cr addition.

4.3.3 Effect of Chromium addition on Cr uptake by rice shoots :

Values of Cr uptake by rice shoots due to application of different rates of Cr under flooded conditions are presented in Table (10) and graphically illustrated in Figs. (30, 31, 32 and 33).

Data obtained clearly show that Cr uptake by rice shoots was progressively increased upon increasing application rates of Cr to the soil. Mean values of Cr uptake were 0.44, 1.26, 2.81, 6.79, 13.75 and 23.15 mg pot^{-1} for treatments receiving 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1}, respectively. These results agree well with those obtained by **Flores-Tena et al., (1999)** who stated that Cr uptake by orchard grass and alfalfa is a function of the amount applied. **Aquino-Neto and Camargo (2000)** reported that Cr accumulation by lettuce grown in two latosol soils treated with $CrCl_3$ and tannery sludges was greater than in comparable soils not treated with either material.

Data also show that higher increase in Cr uptake occurred in plants grown on the sandy soil as compared with the clayey one due to greater soluble Cr in the farmer and greater adsorption and tight retention capacity for Cr in the latter.

Khalil (1995) applied up to 25 mg Cr kg^{-1} soil and found that Cr uptake in sorghum shoots and roots grown on alluvial, calcareous and sandy soils progressively increased with increasing the rate of Cr.

Mean values of Cr uptake in rice shoots grown in the sandy soil were 0.50, 1.70, 4.30, 11.72, 22.80 and 35.16 mg pot^{-1} in treatment receiving 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1}, respectively. The corresponding values obtained in the clay soil were 0.38, 0.81, 1.32, 1.86, 4.70 and 11.15 mg pot^{-1}, respectively.

The amount of Cr taken up by rice shoots significantly decreased by increasing plant age. Values of uptake were 18.37, 9.76, 8.66, 1.46 and 1.92 mg pot^{-1} at days 5, 20, 35, 50 and 65, respectively (means of the two soils). **Wallace (1989)** who reported that Cr translocation in plant gradually decreased as the rate of Cr application increased and the plant tend to accumulate the excessive amounts of absorbed Cr in roots rather than shoots.

The obtained results reveal that Cr taken up by rice shoots in sandy soil at 5 days was 27.05 mg pot^{-1} depressed by about 40, 43, 93 and 85 % at different growth stages of 20, 35, 50 and 65 days after Cr addition, respectively. However, in the clay soil, the Cr taken up by plants after 5 days was 9.68 mg pot^{-1} depressed by about 66, 79, 89 and 91 % at the same aforementioned successive periods, respectively.

The decrease in Cr concentration in shoots which occurred with increased age of plants was far more pronounced than concurrent increase in shoot growth with time. Therefore, the net result was a progressive decreased in Cr uptake with time (compare data of Tables 5 and 10.

Table (10): Chromium uptake (mg/pot) by rice plants (shoots) as affected by different rates of applied chromium.

Soil (S)	Rate of applied Cr mg kg^{-1} (C)	Time of plant sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	0	0.45	0.53	0.43	0.21	0.26	0.38
	10	0.57	1.62	0.43	0.82	0.62	0.81
	20	2.30	1.81	0.80	0.91	0.69	1.32
	40	3.73	2.39	1.30	1.04	0.83	1.86
	80	12.70	5.43	3.34	1.16	0.89	4.70
	160	38.30	7.77	5.74	1.77	2.13	11.15
	Mean	9.68	3.26	2.02	0.98	0.90	3.37
Soil 2 (Sand)	0	1.76	0.48	0.05	0.13	0.07	0.50
	10	4.09	0.85	2.48	0.22	0.55	1.70
	20	8.29	1.95	8.48	0.54	2.23	4.30
	40	21.46	20.47	11.06	1.46	4.18	11.72
	80	49.26	25.51	29.64	5.01	4.55	22.80
	160	77.43	48.02	40.12	4.22	5.99	35.16
	Mean	27.05	16.27	15.30	1.93	2.93	12.70
General means of the two soils							
	0	1.11	0.50	0.24	0.17	0.17	0.44
	10	2.33	1.40	1.45	0.52	0.58	1.26
	20	5.30	1.88	4.68	0.73	1.46	2.81
	40	12.60	11.43	6.18	1.25	2.51	6.79
	80	30.98	15.47	16.49	3.08	2.72	13.75
	160	57.88	27.89	22.93	3.00	4.06	23.15
	Mean	18.37	9.76	8.66	1.46	1.92	

L.S.D. 0.05 S = 0.54 T = 0.86 C = 0.94
ST = 1.21 SC = 1.33 TC = 2.10
STC = 2.97

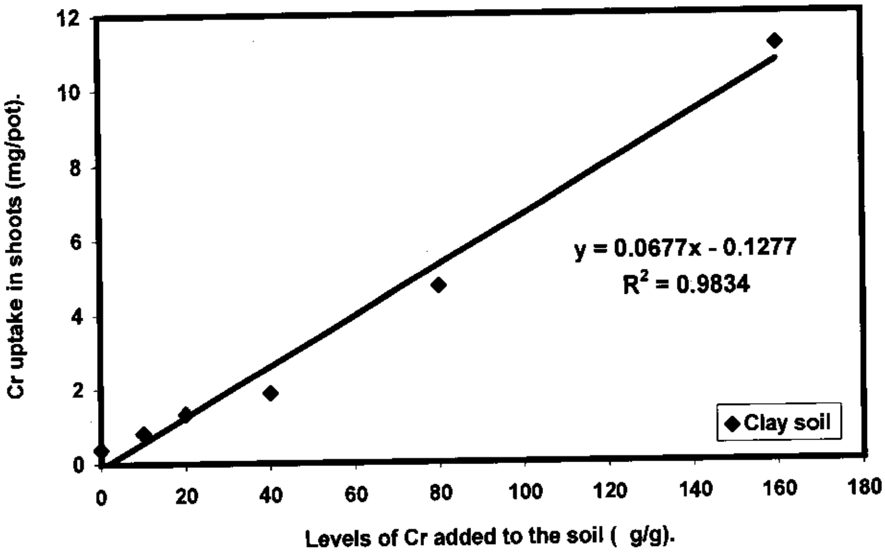

Fig. (30) Chromium uptake (mg/pot) by rice shoots as affected by Cr addition.

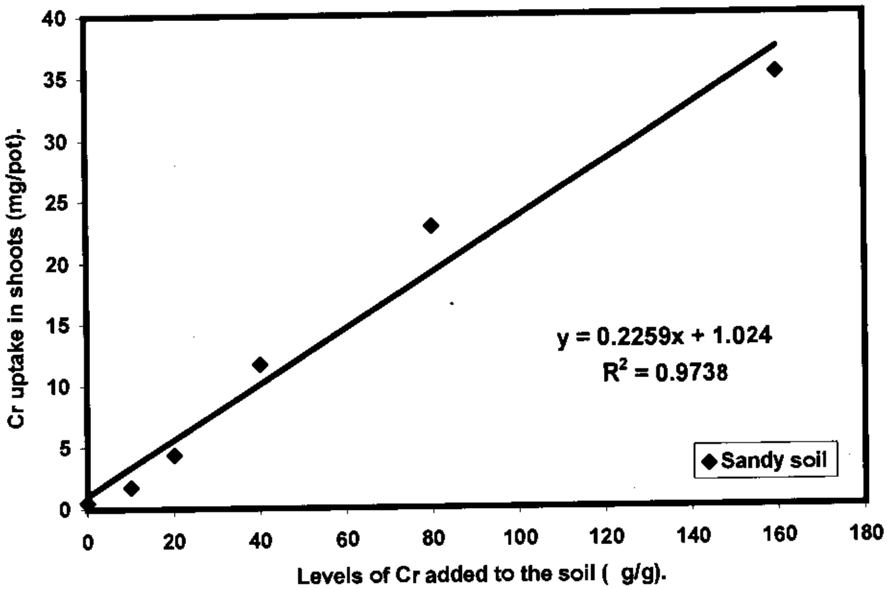

Fig. (31) Chromium uptake (mg/pot) by rice shoots as affected by Cr addition

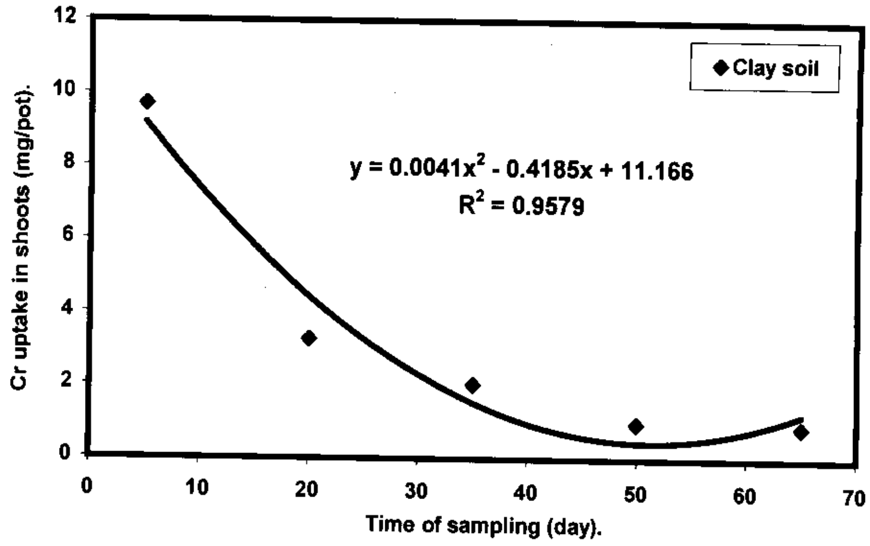

Fig. (32) Chromium uptake (mg/pot) by rice shoots as affected by Time of sampling after Cr addition.

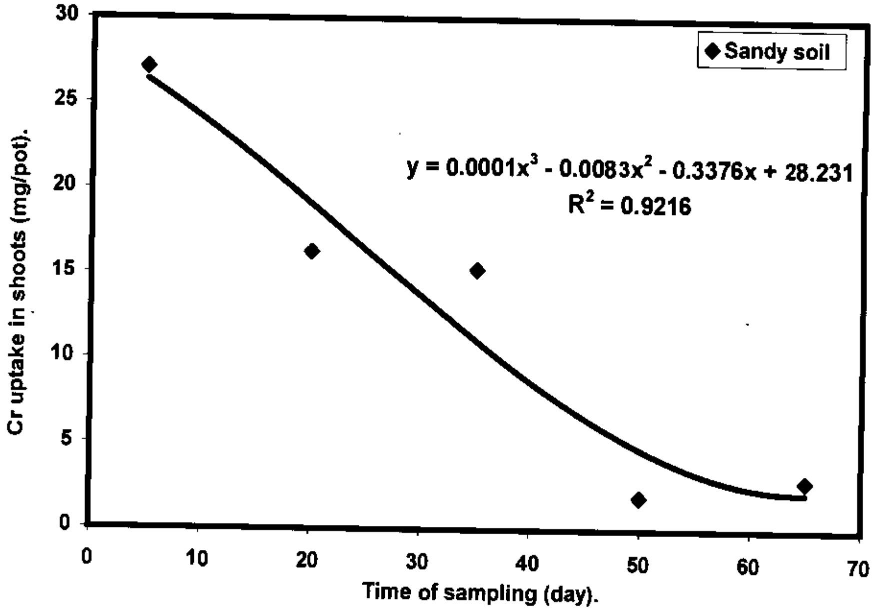

Fig. (33) Chromium uptake by rice shoots as affected by time of sampling after Cr addition .

4.3.4 Effect of Chromium addition on Cr uptake by rice roots:

The pattern was similar to that of the shoots data presented in Table (11) and graphically illustrated in Figs. (34, 35, 36 and 37) clearly show that the successive increments of Cr caused a progressive significant increases in Cr taken up by plant roots. This is true for both of the tested soils with the uptake in roots of plant grown in being the sandy soil was much higher than in those grown in the clay one.

Mean values of Cr uptake by rice roots grown in the sandy soil were 9.41, 14.32 17.95, 23.61, 33.71 and 35.07 mg pot^{-1} with addition of 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1}, respectively. The corresponding values obtained in the clay soil were 0.95, 1.98, 3.25, 7.38 and 15.04 mg pot^{-1}, respectively. Therefore, plants absorbed greater Cr since there were greater concentration of Cr in the root zone.s

This finding is in accordance with those obtained by Connell and Al-Hamadani (2001) who reported that Cr uptake by kudzu (*Paeraria montana* var. Lobata) was increased as Cr concentration increased in the growth media, and that most of it accumulated in the root. Working on paddy rice seedlings grown in soil supplied with 0.5, 1, 5 or 25 mg Cr L^{-1} as Cr(III) or Cr(VI), **Mishra et al., (1997)** found that the uptake of Cr for both the oxidation states and culture types increased rater linearly with the increase in Cr concentration. They added that the comparative rate of increase of uptake and concentration in water indicated that Cr absorption by roots is probably through a passive mechanism; with translocation to shoots and grains being low. There was a decrease in uptake with the increase in plant age, as the case with shoots. Uptake values were 17.72, 14.06, 16.33, 13.39 and 10.39 mg pot $^{-1}$ at days 5, 20, 35, 50 and 65 days, respectively (means of the two soils). However, their was a pattern of temporary increase followed by a progressive decrease with the passage of time. In the clay soil, the temporally increase occurred on day 20, after which a decrease occurred. In the sandy soil, it occurred on day 35 followed by a progressive decrease. As the case with uptake in shoots with time, such a change with time is an outcome of increased root growth associated with decreased Cr concentration with time.

Table (11) : Chromium uptake (mg/pot) by rice plants (roots) as affected by different rates of applied chromium.

Soil (S)	Rate of applied Cr mg kg^{-1} (C)	Time of plant sampling after Cr addition days (T)					Mean
		5	20	35	50	65	
Soil 1 (Clay)	0	0.81	1.19	1.20	0.82	0.72	0.95
	10	1.51	2.96	2.06	1.53	1.83	1.98
	20	3.36	5.12	2.92	2.65	2.19	3.25
	40	3.61	5.66	3.83	4.16	2.39	3.93
	80	4.49	8.70	5.90	8.01	7.76	7.38
	160	18.70	19.90	13.30	12.20	11.20	15.04
	Mean	5.74	7.27	4.86	4.90	4.34	5.42
Soil 2 (Sand)	0	2.92	6.35	19.33	10.00	8.44	9.41
	10	18.60	11.64	21.35	11.07	9.59	14.32
	20	18.78	12.09	27.86	17.97	13.05	17.95
	40	29.00	18.97	30.29	21.07	18.70	23.61
	80	37.53	32.64	33.26	34.25	30.26	33.71
	160	35.38	43.44	34.73	36.96	24.82	35.07
	Mean	23.70	20.86	27.81	21.89	17.47	22.34
General means of the two soils							
	0	1.87	3.77	10.27	5.42	4.57	5.18
	10	10.06	7.30	11.70	6.30	5.38	8.15
	20	11.07	8.61	15.39	10.31	7.62	10.60
	40	16.30	12.32	17.07	12.62	10.54	13.77
	80	22.01	20.67	19.58	21.13	19.31	20.54
	160	27.01	31.70	24.00	24.57	17.99	25.06
	Mean	14.72	14.06	16.33	13.39	10.90	

L.S.D. 0.05 S = 0.46 T = 0.73 C = 0.80
ST = 1.03 SC = 1.13 TC = 1.78
STC = 2.52

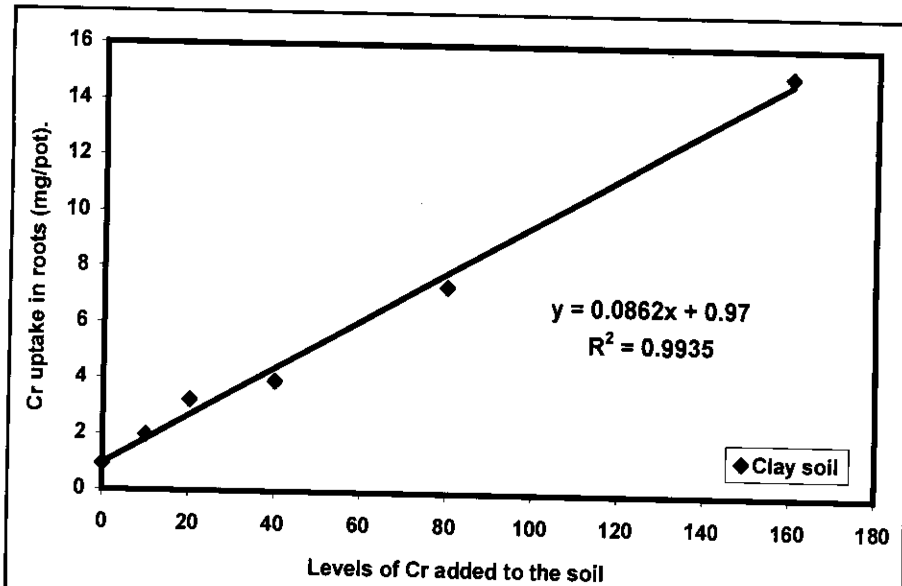

Fig. (34) Chromium uptake (mg/pot) by rice roots as affected by Cr addition.

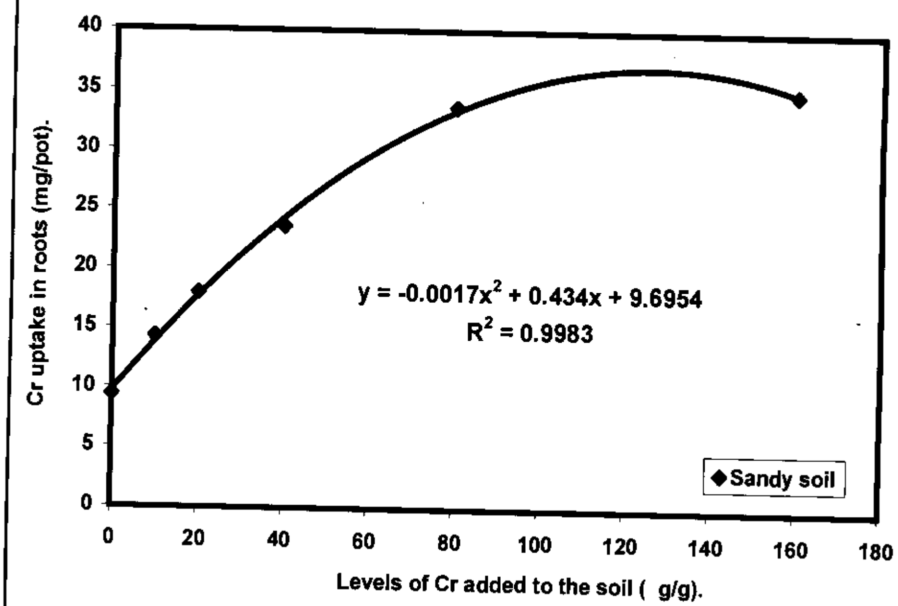

Fig. (35) Chromium uptake (mg/pot) by rice roots as affected by Cr addition.

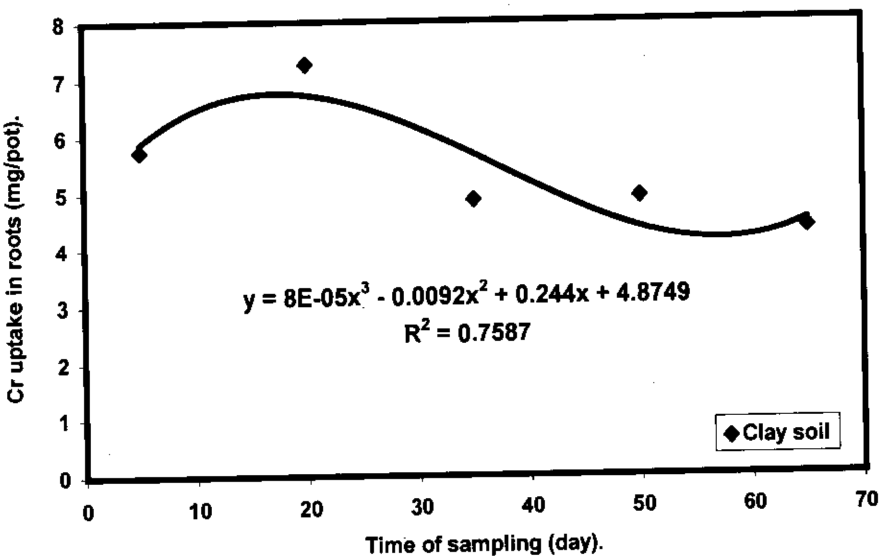

Fig. (36) Chromium uptake (mg/pot) by rice roots as affected by time of sampling

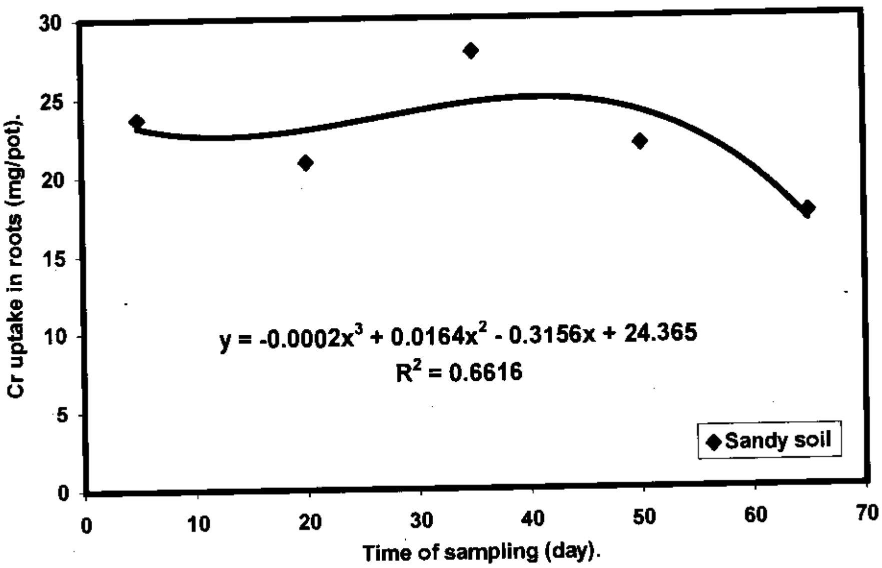

Fig. (37) Chromium uptake (mg/pot) by rice roots as affected by time of sampling after Cr addition.

4.3.5 Effect of chromium addition on Cr content in rice seeds :

Data concerning the content of Cr in rice seeds as affected by the different rates of Cr applied to the investigated soils are shown in Table (12) and Figs (38 and 39). It is quite clear that Cr content increased upon application of Cr. The increased was particularly significant at rates of 20 mg kg^{-1} and over but the differences between some successive Cr rates were not significant. However, such a pattern was true in the sandy soil; in the clay soil, there was no significant effect.

Mean values of Cr content in seeds of treatments 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1} were 20.94, 24.55, 32.84, 37.92, 39.37 and 46.68 g pot^{-1}, respectively.

The corresponding values for the clayey soil were 7.08, 9.40, 11.02, 11.47, 12.13 and 12.93 g pot^{-1}, respectively and for the sandy soil these values amounted to 34.80, 39.70, 54.67, 64.37, 66.60 and 80.43 g pot^{-1}, respectively. It is obvious that, in the sandy soil, increasing the addition rate of Cr was associated with a progressive and significant increases for Cr content in rice seeds. **Sharma et al., (1995)** reported that in response to Cr supply, grain yield of wheat was severely affected by Cr addition and no grain formation was observed for plants irrigated with water of 52 mg Cr(VI) L^{-1}. They concluded that Cr(VI) is inhibitory to metabolism and phytoxic to wheat. In pot experiment, **Barcelo et al., (1993)** found that supply of 25 t/h of tannery sludge (0.27% Cr) slightly increased dry matter of maize leaf but there was no significant effect on grain yield.

4.3.6 Effect of chromium addition on Cr uptake in rice seeds :

With respect to Cr uptake in rice seeds (Table 13) and Figs (40 and 41), data obtained show that in the sand soil Cr uptake was lower in seeds of plants receiving Cr than those not receiving Cr. In the clay soil, uptake was greater due to Cr application and the magnitude increased with the increase in Cr rate of application.

In the clay soil, values of uptake for treatments receiving 0, 10, 20, 40, 80 and 160 mg Cr kg^{-1} were 0.707, 0.863, 0.910, 1.417, 1.517 and 1.863 mg Cr pot^{-1}, respectively. In the sand soil, comparable values were 1.750, 1.650, 1.313, 1.303, 1.127 and 1.153 mg Cr pot^{-1}, respectively. The pattern of Cr uptake relating each soil was in line with the pattern of yield of seeds. In the clay soils, increased seeds yield was obtained with increased Cr addition. In the sand soil, the reverse occurred, increased Cr addition caused decreased seeds yield. This indicates that the Cr concentration was not affected by Cr addition. **Golovatyi (1999)** reported data showing that even with high concentration of Cr in the root zone, concentration of Cr in reproductive organs or in sap of fruits was small and not very much different from that regarding plants growth under no-contamination conditions.

Table (12) : Chromium content (g/pot) of rice plants (seeds) as affected by the different rate of applied chromium.

Rate of Cr addition mg kg^{-1} (c)	Soils (S)		Mean
	Clay	Sand	
0	7.08	34.80	20.94
10	9.40	39.70	24.55
20	11.02	54.67	32.84
40	11.47	64.37	37.923
80	12.13	66.60	39.37
160	12.93	80.43	46.68
Mean	10.67	56.76	33.715

L.S.D. 0.05 S = 7.35 C = 7.75 SC = 10.96

Table (13) : Chromium uptake (g/pot) of rice plants (seeds) affected by the different rate of applied chromium.

Rate of Cr addition mg kg^{-1} (c)	Soils (S)		Mean
	Clay	Sand	
0	0.707	1.750	1.228
10	0.863	1.650	1.257
20	0.910	1.313	1.112
40	1.417	1.303	1.360
80	1.517	1.127	1.322
160	1.863	1.153	1.508
Mean	1.213	1.383	1.298

L.S.D. 0.05 S = 0.39 C = 0.28 SC = 0.39

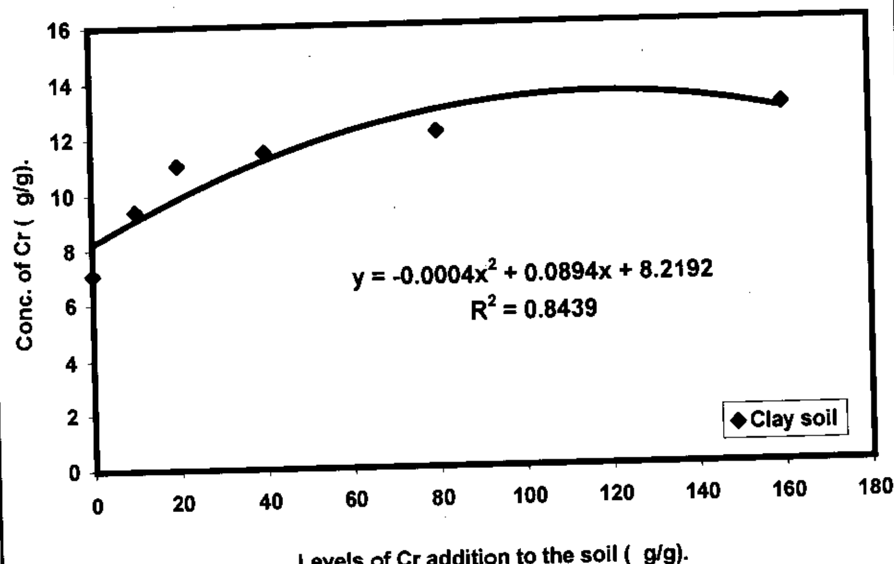

Fig. (38) Chromium content (g/g) of rice plant (seeds) as affected by Cr addition.

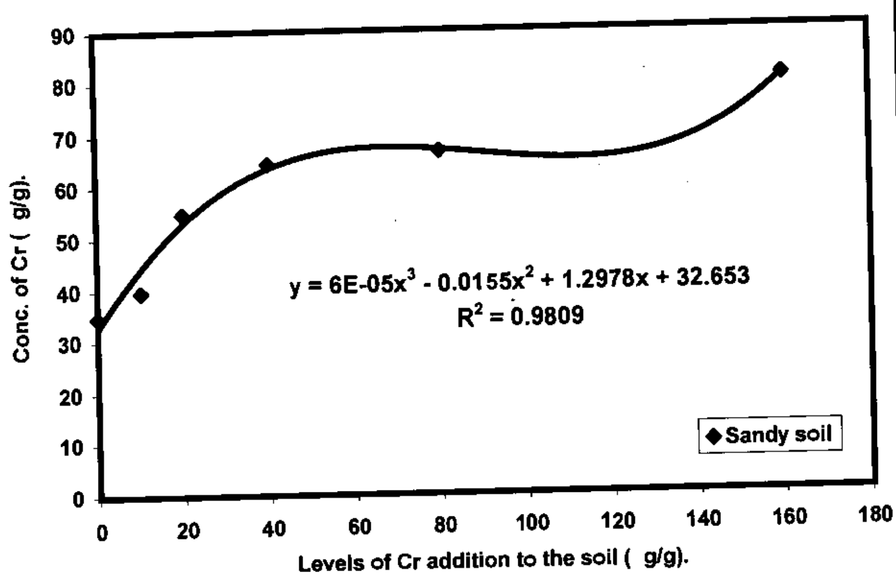

Fig. (39) Chromium content (g/g) of rice plant (seeds) as affected by Cr addition.

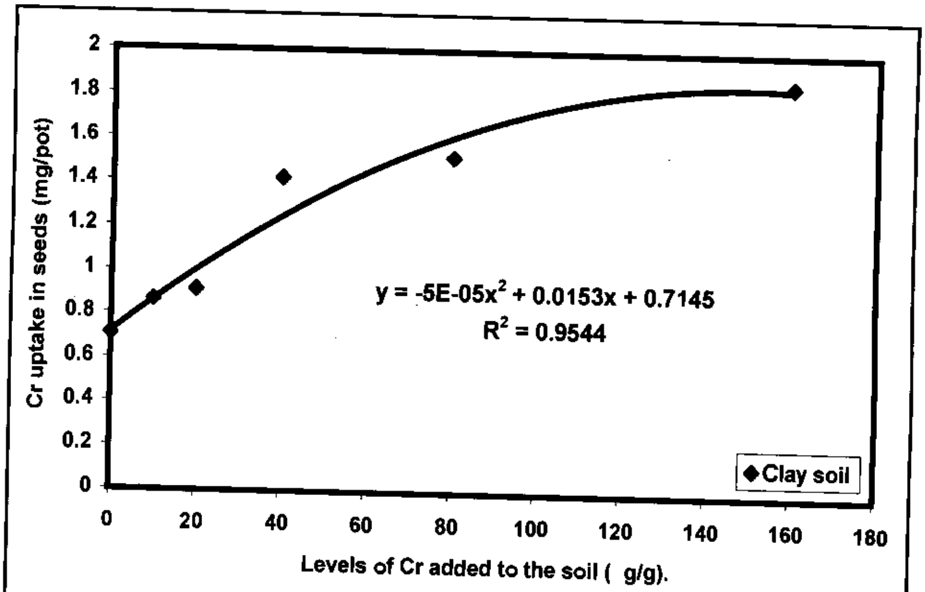

Fig. (40) Chromium uptake (mg/pot) of rice plant (seeds) as affected by Cr addition.

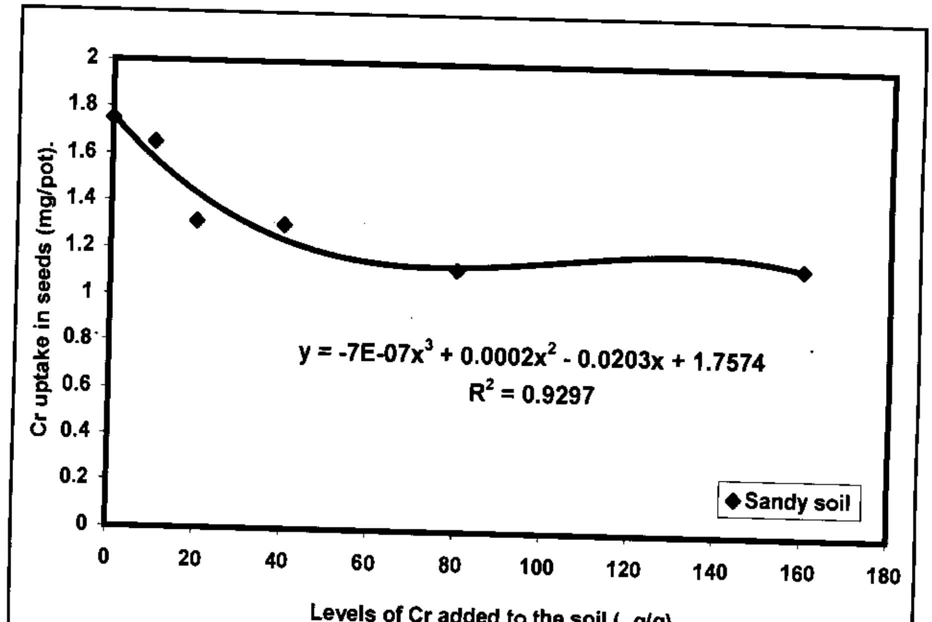

Fig. (41) Chromium uptake (mg/pot) of rice plant (seeds) as affected by Cr addition.

4.4. Total chromium in soil (mg kg^{-1}) as determined by INAA technique.

Data presented in Table (14) and graphically illustrated in Fig. (42 and 43) show that total chromium in soils determined by INAA after removal of plant roots sharply increased upon increasing the applied rate of Cr. Mean values of total Cr in clay soil were 27.58, 41.30, 48.12, 59.63, 76.87 and 103.41 mg kg^{-1} in soils treated with of 0, 10, 20, 40, 80 and 160 mg Cr Kg^{-1}, respectively. The corresponding increases in total Cr were 50, 75, 115, 179 and 275 %, respectively. It is obvious that increasing rates of Cr addition yielded progressive increases in Cr remained in the clay soil although part of it could be leached from the soil profile by drainage water either in cation form [Cr(III)] or in anion one [Cr(VI)]. The amount of total Cr recorded in the sandy soil were 14.85, 21.82, 30.22, 41.77, 48.57 and 48.35 µg g^{-1} by adding 0, 10, 20, 40 and 80 mg Cr kg^{-1}, respectively. Comparison the data of both soils show that total Cr in the clay soil was much higher than in the sand one. The clay soil had greater indigenous Cr than the sand soil. Functional groups on the clay surfaces may adsorb both forms of Cr and thus Crleachability from the soil would be low. On the other hand, retention of Cr species in the sand soil would be low since the surface of particles of the sand soil would be inert and thus the leachability of Cr from such soil would be high. Total Cr recorded in the clay soil was almost twice that recorded in the sand at all rates of the applied Cr.

Table (14) : Total chromium in soil ($\mu g\ g^{-1}$) as determined by INAA technique.

Soil	Cr rate ($\mu g\ g^{-1}$)					
	0	10	20	40	80	160
Clayey	27.58	41.30	48.12	59.63	76.87	103.41
Sandy	14.85	21.82	30.22	41.77	48.57	48.35

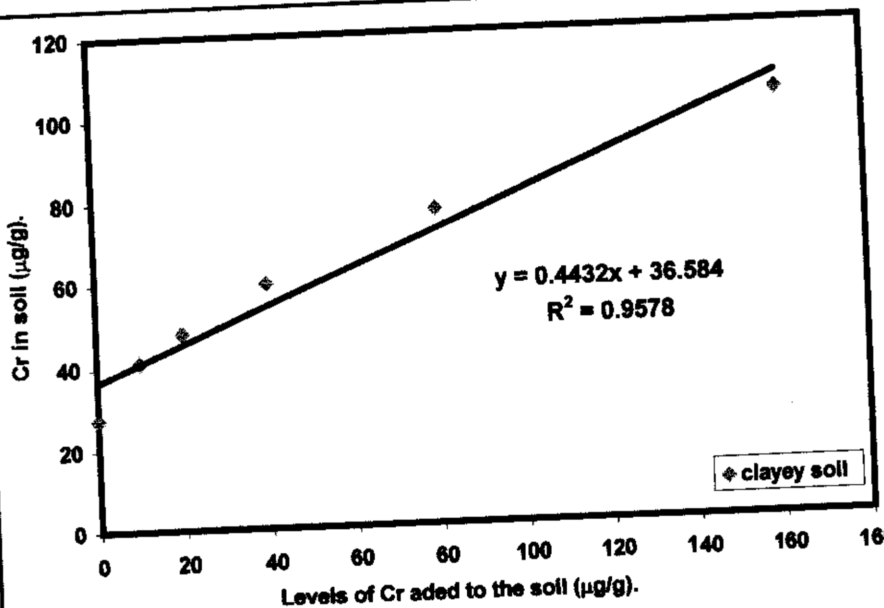

Fig. (42) Total chromium in clay soil (µg/g) as determined by INAA technique.

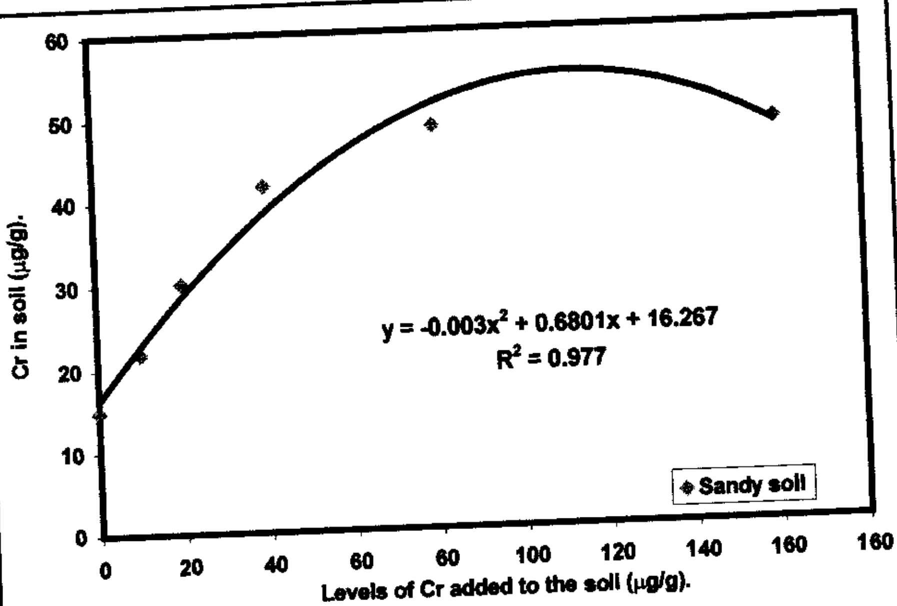

Fig. (43) Total chromium in sandy soil (µg/g) as determined by INAA technique.