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IMMOBILIZATION OF CHROMIUM BY POULTRY MANURE AND GYPSUM IN SOIL AND REDUCING ITS UPTAKE BY SPINACH GROWN WITH TEXTILE EFFLUENT IRRIGATION

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Chromium (Cr) is an ecological poison and its concentration is reaching to lethal intensities in soil and plants by irrigating the soil with raw industrial effluents, particularly in developing nations like Pakistan. Poultry manure and gypsum are recognized for their capability to immobilize heavy metals in soils for plant uptake and filtering to ground water. The current trial was conducted under controlled conditions to evaluate the viability of poultry manure (PM) and gypsum applications to mitigate Cr toxicity in spinach grown-up in soil watered with textile effluent. The trial was designed in a completely randomized design (CRD) with three repetitions. The treatments were: T1 (Control), T2 (Poultry Manure @ 0.5%), T3 (Poultry Manure @ 1%), T4 (Gypsum @ 0.3%) and T5 (Gypsum @ 0.6%). Chromium uptake by shoots and roots of spinach were enhanced in control plants where only textile effluent was applied. Chromium uptake in roots was higher than shoots. Application of poultry manure and gypsum reduced the Cr toxicity. The shoot length and dry weight of spinach was higher where PM was incorporated @ 1% as compared to gypsum and control. The extent of Cr toxicity mitigation by PM application @ 1% was higher when compared with control. The outcomes of this investigation demonstrated that application of PM @ 1% to the soil could be utilized as a viable approach for diminishing Cr concentration in spinach plants in Cr-contaminated soils irrigated with untreated textile effluents.
Keywords: Chromium, immobilization, poultry manure, gypsum, textile effluent, spinach.

INTRODUCTION

Anthropogenic activities, for example, excavating, refining, water system utilizing wastewater, use of sewage sludge and atmospheric deposition have triggered serious heavy metal pollution around the globe (Wong *et al.,* 2002). Soil is the main source of heavy metals as well as act as a sink for heavy metals. Collection of substantial metals in soils and their accumulation in the food chain is a potential risk to human wellbeing (Foucault *et al*., 2013; Bashir *et al*., 2018).
The compounds of chromium (Cr) are widely used in various industries and the effluent of these industries mostly released on agricultural soils. Metallurgical ventures, textile industries, chemical units and burning of coal and oil are the major sources of industrial effluent (Sharma *et al*., 2005). This industrial effluent usually discharged out into drains, from where it goes into water channels and used for irrigation of crops and turned into a major source of pollution for soils and plants with Cr and other heavy metals (Brar *et al*., 2000). Chromium is the risky metal released into natural surroundings by the industrial activities. Heavy metals are non-biodegradable unlike to other organic contaminants. Chromium exists in environment both in trivalent and hexavalent form. It is recognized that Cr (VI) is 500 times more harmful than the Cr (III). Industries like textile, paint and leather tanning mostly used hexavalent chromium. Abundance of chromium makes harm to liver, kidneys and nerves (Nagarajappa *et al*., 2017).
To lessen the plant available concentration of heavy metals in soil, distinctive remediation techniques are used during last decades and in this way limit the accumulation of heavy metals in the food chain (Clemente *et al*., 2012). Many amendments, for example, organic substances (Beesley *et al*., 2014), phosphate ores (Brown *et al*., 2004), lime (Geeblen *et al*., 2003), clay minerals (Sun *et al*., 2013; Liang *et al*., 2014) and industrial and agronomic by-products (Wang *et al*., 2014) have been created to bind heavy metals in soils. The plant available concentration is decreased by amendments application (Adams *et al*., 2004).
It is well known that organic amendments make stable complexes in soil and can bind the substantial quantities of metal (loid)s within these complexes (Shahid *et al*., 2014d; Sabir *et al*., 2015). Now a days fertilizer having low level of metals are utilized to bind metals in soils (Venegas *et al*., 2015). Khan *et al*. (2015) stated that the utilization of poultry manure (PM) was exceptionally viable in blocking plant uptake of metals. Organic amendments can increase the soil pH by anticipating sulfide oxidation and ultimately

binds the heavy metals in soil (Walker *et al*., 2004). Moreover organic amendments can lessen metal bioavailability by expanding in surface charge by making stable associations with metal particles (Gadd, 2000).

Inorganic amendments have been found to lessen the bioavailability of metals because of formation of binding sites (Puschenreiter *et al*., 2005). Gypsum could enhance the physical and synthetic properties of soils for crops and limit the transport of dissolved natural carbon and metal complexes in soils and is considered as a cheaper source of calcium (Ca) and sulfur. The alkaline amendments could increase soil pH that supports the advancement of oxides, metal carbonates, precipitates, and associations, prompting diminished bioavailability (Abbas *et al*., 2017). In perspective of the lack of information on critical toxic ranges of Cr in green vegetables, especially spinach, the goal of this study was to research the adequacy of poultry manure and gypsum to diminish Cr take-up in spinach grown on textile effluent irrigated soil.

MATERIALS AND METHODS

***Soil collection and textile effluent characteristics*:** A soil pot study was conducted in the wire house of institute of Soil and Environmental Sciences (ISES) Saline Agriculture Research Center (SARC), University of Agriculture, Faisalabad. Initially soil was assembled from soil science farm University of Agriculture, Faisalabad. Collected soil was stored in plastic containers for further analysis after air-drying, grinding and sieving through a 2 mm sieve. A sample of the prepared soil was analyzed for its different physicochemical properties, including pH, electrical conductivity (EC_e), organic matter (OM), cation exchange capacity (CEC), water soluble cations and anions (CO_3^{2-}, HCO^{3-}, Cl^-, Na^+, Ca^{2+}+Mg^{2+}) and soil texture following Richards (1954). The initial physic-chemical properties of the experimental soil are given in Table 1.

Table 1. Initial physicochemical properties of the experimental soil.

Parameters	Unit	Value
Textural class	-	Sandy clay loam (SCL)
Sand	%	49.10
Silt	"	24.50
Clay	"	26.40
pH_s	-	8.16
EC_e	dS m^{-1}	3.50
CO_3^{2-}	$mmol_c$ L^{-1}	-
HCO_3^-	"	4.70
Cl^-	"	13.80
Ca^{2+} + Mg^{2+}	"	4.80
Na^+	"	24.80
SAR	$(mmol_c\ L^{-1})^{1/2}$	16.00
OM	%	0.82

Soltanpour (1985) procedure was followed to determine the micronutrient in soil. The values are given in Table 2. Textile effluent collected from Dawood Textile Mill Faisalabad, Pakistan was used as irrigation water for growing spinach. The salient characteristics of the effluent are presented in Table 3.

Table 2. Total and available metals concentration in pre-sowing soil.

Metal concentrations	Unit	Total	[a]Available
Cr	mg kg^{-1}	2.86	0.14
Zn	"	36.16	3.37
Cu	"	11.87	3.75
Mn	"	44.87	4.01
Fe	"	154.60	31.5

[a] AB-DTPA extractable

Table 3. Characteristics of textile effluent used to irrigate plants.

Parameters	Unit	Value	Tolerable limit [a]
pH		11	6-10
EC	dS m^{-1}	10.45	< 1.25
Temperature	^{0}C	35	Upto 40
Total dissolved solids (TDS)	mg L^{-1}	6614.67	3500
Dissolved oxygen (DO)	mg L^{-1}	2.70	-
Biological oxygen demand $(BOD)_5$	mg L^{-1}	1150	80
Chromium (Cr)	mg L^{-1}	1.72	1.0
Copper (Cu)	mg L^{-1}	1.45	1.0
Cadmium (Cd)	mg L^{-1}	0.14	0.1
Interpretations	Not suitable for irrigation		

[a] Ayers and Westcot (1985).

***Amendments*:** In this study the binding agents like poultry manure and gypsum were used. Poultry manure was taken from poultry farm of University of Agriculture, Faisalabad. Poultry manure was air dried and ground to pass through 2mm sieve and was analyzed for various properties. Both EC and pH of poultry manure were determined with EC and pH meter. The samples were digested in di-acid (HNO_3:$HClO_4$) mixture and was run on atomic absorption spectrometer to determine the concentration of micronutrients (Soltanpour, 1985). Solubility of gypsum ($CaSO_4.2H_2O$) was 2.53 g L^{-1} in pure water and had 23.3% calcium (Ca) contents. pH and EC of poultry manure was 6.99 and 7.29 dS m^{-1}, respectively. Copper, Zinc and Manganese concentration in poultry manure was 407 mg kg^{-1}, 794 mg kg^{-1} 596 mg kg^{-1}, respectively.

***Experimental design*:** The experiment was arranged in a completely randomized design (CRD) with three replications. The treatment plan was T_1 (Control), T_2 (Poultry Manure @ 0.5%), T_3 (Poultry Manure @ 1%), T_4

(Gypsum @ 0.3%) and T_5 (Gypsum @ 0.6%). Twelve kg of soil was filled in each pot. The amendments were thoroughly mixed in soil at the time of pot filling. Basal dose of 35 mg N and 5.4 mg P per kg of soil was applied in each pot and almost fifteen seeds of spinach were sown in each pot. After germination five plants were maintained in each pot. The plants were watered with textile effluent collected from Dawood Textile Mill Faisalabad, Pakistan. Total eleven irrigations, each of 600 mL were applied to spinach plants throughout the study period.

***Determination of gas exchange and physiological parameters*:** Gas exchange parameters i.e. rate of photosynthesis, rate of transpiration and stomatal conductance was monitored and recorded by IRGA (Infra-Red Gas Analyzer LCA4). Chlorophyll contents were recorded by using chlorophyll meter. Physiological parameters i.e. relative water contents (RWC), leaf area and membrane stability index (MSI) were also determined by collecting the fresh leaves before final harvesting.

***Determination of growth parameters*:** First cutting of spinach was taken after 45 days of sowing and second cutting was taken after 90 days of first cutting. Plant height and fresh weights of shoots and roots were measured at the time of 2nd harvesting after 90 days. Plants were isolated into roots and shoots, and fresh weights were recorded promptly after harvest. The length of shoots and roots were also recorded at the time of harvesting. Subsequently, taking the fresh weight of shoots and roots the mockups were dried out in air and then kept in the oven at 70°C for 72 h and till steady dry weights were acquired.

***Determination of chromium (Cr)*:** The collected samples of shoots and roots were digested using diacid mixture (HNO_3:$HClO_4$) and filtered through filter paper and then fed to atomic absorption spectrometer for the determination of Cr metal following calibration of the equipment with standard solutions of Cr metal and readings were recorded.

***Statistical analysis*:** The results were analyzed using software Statistics 8.1. Results were equated using a general linear model. The data was analyzed statistically following Analysis of Variance technique (ANOVA) and means were separated by LSD test.

RESULTS

***Growth parameters*:** The effect of poultry manure and gypsum was observed on growth parameters of spinach. The results showed that amendments significantly ($P < 0.05$) increased the growth of spinach as compared to control plants where no amendment was applied (Table 4). A considerable increase in shoot length was recorded in all treatments as compared to control. The highest increase in shoot length (50%) was recorded with poultry manure application @ 1% (T_3). While the lowest increase (31%) in shoot length was observed in control (T_1). Overall, shoot length was improved in the following arrangement $T_3 > T_5 > T_4 > T_2 > T_1$ revealed better shoot length as compared to other treatments. Similarly, substantial ($P < 0.05$) increase in number of leaves pot^{-1} of spinach was observed by applying amendments except control plants (Table 4). The maximum increase in number of leaves pot^{-1} of spinach was recorded with poultry manure application @ 1% (T_3) that was 20% higher as compared to control plants without amendments where increase was only 8% (Table 4).

Amendments also showed significant ($P < 0.05$) effect on shoot fresh and dry weights of spinach plants as compared to control (Table 4). Maximum shoot fresh weight (57%) of spinach after 90 days was obtained with the soil application of poultry manure @ 1% (T_3), whereas the control (T_1)

Table 4. Shoot and root length (cm), number of leaves (pot^{-1}), shoot and root fresh and dry weights (g pot^{-1}) of spinach grown under different treatments.

Treatments	Shoot length (cm)		Number of leaves (pot^{-1})		Shoot Fresh Weight (g)		Shoot Dry Weight (g)		Root Length (cm)	Root fresh weight (g)	Root dry weight (g)
	After 45 days	After 90 days	After 45 days	After 90 days	After 45 days	After 90 days	After 45 days	After 90 days			
Control	15±1.20 b	22±2.03 (31) c	41±1.02 c	45±1.26 (8) d	45.67±0.67 c	80.67±2.60 (43) c	4.49±0.07 d	5.05±0.67 (11) c	18.33±1.20 b	8.00±0.58 c	1.05±0.05 c
Poultry manure@0.5%	21±0.33 ab	35±0.88 (40) b	59±2.65 ab	72±1.73 (18) b	61.33±1.76 b	117.67±5.36 (47) b	6.21±0.14 c	7.53±0.81 (17) bc	22.33±2.19 (17.9) ab	12.67±0.33 (36.8) b	1.72±0.13 (38.9) ab
Poultry manure@1%	23±0.88 a	46±1.45 (50) a	65±1.73 a	82±3.38 (20) a	70.00±0.88 a	163.00±10.82 (57) a	9.19±0.34 a	15.34±0.71 (40) a	26.00±1.53 (29.5) a	18.67±1.76 (57.1) a	2.08±0.03 (49.5) a
Gypsum@0.3%	21±0.58 ab	36±2.33 (41) b	49±2.04 bc	56±1.20 (12) c	52.33±1.76 c	108.67±10.17 (51) b	5.94±0.07 c	6.07±0.65 (15) c	19.00±1.00 (3.52) b	11.67±1.86 (31.4) bc	1.43±0.02 (26.5) bc
Gypsum@0.6%	21±1.20 ab	38±1.15 (44) b	49±2.85 bc	55±1.15 (10) c	51.33±2.91 c	112.33±4.10 (54) b	6.35±0.60 b	9.85±0.97 (35) b	21.33±1.67 (14.1) ab	14.67±1.45 (45.4) ab	1.49±0.27 (29.5) b
LSD values	2.62	5.23	3.21	5.56	7.36	23.41	0.54	2.42	4.94	4.25	0.43

Each value is average of three replicates ± S.E, and values in parenthesis mentioned with shoot length, number of leaves, shoot fresh and shoot dry weights are the percent increase with respect to days, while the values in parenthesis mentioned with root length, root fresh and dry weights are the percent increase with respect to control, the significant difference between treatments was determined by LSD test ($P \leq 0.05$)

showed minimum rise (43%). Overall, increasing trend of shoot fresh weight of spinach was observed as $T_3 > T_5 > T_4 > T_2 > T_1$. Following the same trend, application of poultry manure @ 1% (T_3) showed the highest progress in shoot dry weight of spinach (40%) with respect to days as compared to control (T_1) where increase was (11%). The increasing trend for all the treatments was $T_3 > T_5 > T_2 > T_4 > T_1$.

Application of amendments also increased the root length over control (Table 4). Maximum increase in root length (29.5%) was recorded with the application of poultry manure @ 1% (T_3) over control (T_1). Whereas the increase was minimum (3.5%) with the application of gypsum @ 0.3% with respect to control. The overall increasing trend in root length of spinach was noted as $T_3 > T_2 > T_5 > T_4 > T_1$. The root fresh and dry weights were also enhanced with the application of poultry manure @ 1% as compared to control (Table 4). The maximum increase in root fresh weight was (57.1%) while maximum increase in root dry weight was (49.5%) over control. The overall increasing trend for root fresh and dry weights were noted as $T_3 > T_5 > T_2 > T_4 > T_1$ and $T_3 > T_2 > T_5 > T_4 > T_1$ respectively.

***Gas exchange parameters*:** The amendments also showed positive response over gas exchange parameters of spinach plants. The maximum value of transpiration rate and stomatal conductance was noted in poultry manure @ 1% treated plants and control plants showed lowest value of these parameters (Fig. 1). Similarly, the mean maximum value of photosynthetic rate was also recorded in poultry manure (@ 1%) applied plants. Hence it was noted that application of poultry manure @ 1% considerably enhanced the transpiration and photosynthetic rate and stomatal conductance in contaminated soil (Fig. 1).

***Physiological parameters*:** All treatments described a remarkable ($P < 0.05$) increment in chlorophyll substance of spinach plants than control (Table 5). Poultry manure @ 1% (T3) showed maximum improvement in chlorophyll contents (66.7%) with respect to control. The amendments also improved the relative water contents in spinach plants as compared to control (Table 5). The most extreme increment in relative water contents of spinach was found in T3 treatment. The spinach plants also showed a noteworthy ($P < 0.05$) increment in membrane stability index (MSI) by applying amendments. Poultry manure @ 1% (T3) showed most elevated increment (44%) in MSI than control. Osmotic potential of spinach was also enhanced by using all amendments than control (Table 5). The highest increase (62.8%) was seen in T3 treatment with respect to control. Overall, the expansion in osmotic potential was noted with the expanding arrangement T3 > T5 > T2 > T4 > T1.

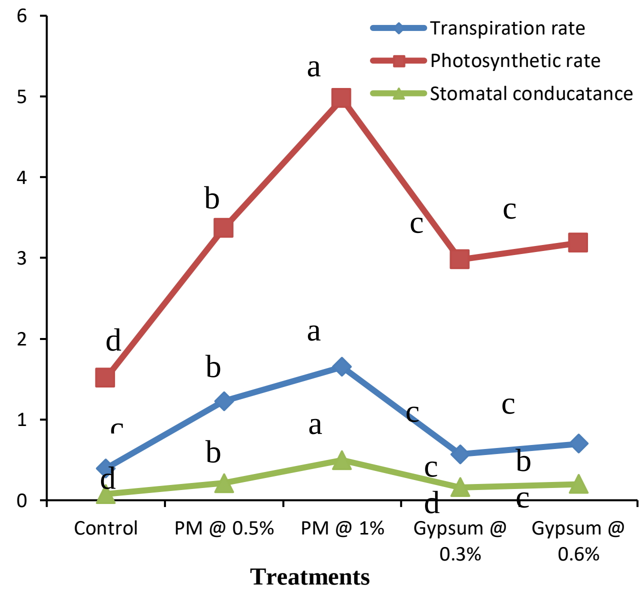

Figure 1. Photosynthetic rate (A) (μmol CO_2 m^{-2} s^{-1}), transpiration rate (E) (mmol H_2O m^{-2} s^{-1}) and

Table 5. Chlorophyll contents (SPAD values), relative water contents (%), membrane stability index (%) and osmotic potential (%) of spinach grown under different treatments.

Treatments	Chlorophyll contents (SPAD values)	Relative water contents (%)	Membrane stability index (%)	Osmotic potential (%)
Control	22.93±0.68 c	54.66±2.40 d	47.67±1.45 d	158.33±3.53 e
Poultry manure@0.5%	56.70±3.95 (59.5) b	85.27±2.73 (35.8) bc	73.67±2.60 (35.2) b	326.67±4.41 (51.5) c
Poultry manure@1%	68.93±1.46 (66.7) a	97.68±1.45 (44) a	84.67±1.76 (43.6) a	426.67±3.06 (62.8) a
Gypsum@0.3%	43.40±1.65 (47.1) bc	79.96±4.17 (31.6) c	65.00±1.15 (26.6) c	279.00±3.46 (43.2) d
Gypsum@0.6%	55.80±0.30 (58.9) b	89.26±1.69 (38.7) b	75.33±2.03 (36.7) b	384.00±2.08 (58.7) b
		LSD values		
	9.87	8.40	5.88	9.93

Each value is an average of three replications ± S.E, and values in parenthesis are the percent increase with respect to control, the significant difference between treatments was determined by LSD test (P≤0.05)

Table 6. Chromium concentration (mg kg^{-1}) in shoots and roots of spinach grown under different treatments.

Treatments	Cr in shoots (mg kg^{-1})		Cr in roots (mg kg^{-1})
	After 45 days	After 90 days	
Control	0.22±0.02 a	0.14±0.01 (36) a	0.37±0.01 a
Poultry manure@0.5%	0.17±0.01 cd	0.08±0.01 (52) c	0.21±0.01 (43) b
Poultry manure@1%	0.14±0.01 d	0.04±0.01 (71) d	0.13±0.01 (64) c
Gypsum@0.3%	0.20±0.01 ab	0.11±0.01 (45) b	0.24±0.03 (35) b
Gypsum@0.6%	0.19±0.01 bc	0.10±0.01 (47) bc	0.21±0.01 (43) b
		LSD values	
	0.03	0.02	0.05

Each value is average of three replications ± S.E, and values in parenthesis mentioned with Cr in shoots are the percent decrease with respect to days, while the values in parenthesis mentioned with Cr in roots are the percent decrease with respect to control, the significant difference between treatments was determined by LSD test (P≤0.05)

stomatal conductance (gs) (mol m^{-2} s^{-1}) of spinach grown under different treatments.

***Chromium concentration in plants*:** Uptake of chromium was considerably changed by the use of organic and inorganic amendments in contaminated soil (Table 6). The amendments showed a substantial ($P < 0.05$) reduction in shoot Cr concentrations than control (Table 6). Poultry manure @ 1% revealed maximum reduction (71%) after 90 days in uptake of chromium in shoots of spinach plants compared to control plants where reduction was 36% after 90 days. In spinach shoots decrease in total Cr was noted with the ascending arrangement as $T_3 > T_2 > T_5 > T_4 > T_1$. Likewise, a substantial ($P < 0.05$) reduction in spinach roots Cr contents was noted by incorporating the amendments in soil than respective control plants (Table 6). Poultry manure @ 1% highly decreased (64%) the Cr concentration in spinach (T_3) than the control. Overall, increasing order was noted as $T_3 > T_2 = T_5 > T_4 > T_1$ (Table 6).

DISCUSSION

Chromium (VI) is the type of Cr normally found at polluted sites and its harmful levels are common in soils applied with sewage sludge. Soil organic matter proved to be effective in reducing Cr (III) from soil (Wuana *et al*., 2011). Chromium (Cr) is required for starch and lipid digestion, usage of amino acids and as pigments for paints, paper, concrete and rubber, metal plating to reduce corrosion, leather tanning and textile shading colors (Ahmet *et al*., 2010). Chromium is collected by plants and its accumulation is biomagnified at various trophic levels through food chain (Rai *et al.*, 2002). Chromium can also react with various metabolic processes and causes danger to the plants, as lessened development and phytomass, chlorosis, inhibit photosynthesis, stunting growth and ultimately death of the plants. Moreover, plants emerging on chromium contaminated soil face a potential hazard from reactive oxygen species (ROS). Their presence makes oxidative harm to biomolecules, for example, lipids and proteins (Vajpayee *et al.*, 2002).

In this investigation it was examined that control plants exhibited hindered development and yield when compared with other amendments. This was because of the reason that Cr danger timid the spinach growth. Moreover, its hazard lessened the plant biomass and promoted the take-up of Cr to aerial plant parts. In the present examination it was noted that control plants showed decreased growth due to Cr toxicity. Liu *et al*. (2004) found that toxicity of heavy metals cause reduction in the length of corn seedlings. The cause behind the damaging impact of heavy metal on plant development may be because of physical and chemical reactions between heavy metals and soil which changed the soil physical properties and eventually influenced the soil productivity. Chang and Wu (2005) found that the plant's capacity to assimilate phosphorus diminishes which influenced the plant development due to heavy metal contamination that can bind the phosphorous in soil.

The results of different experiments revealed the metal binding proficiency of various organic and inorganic amendments (Qayyum *et al*., 2017; Yang *et al*., 2017). Our current investigation indicated that the use of poultry manure and gypsum showed substantial outcomes for enhancing the development of spinach than control plants. The beneficial outcome of organic manure on shoot length could be because of the incorporation of organic compost that increases the richness status of the soil. The physicochemical properties of soil improve by the decomposition of manure. This could have prompted its high vegetative development (Awodun, 2007).

Spinach plants established on poultry manure performed better as far as the tallness of the plant than gypsum. This demonstrates that poultry manure was promptly accessible to plant roots in the best form for easy absorption, henceforth there was a lift in the morphological development of the plant. The consequences of this examination additionally authenticated the conclusion of Ajari *et al*. (2003) in vegetable growth in which they detailed that natural compost; particularly chicken manure could enhance the shoot length when compared with other manures. Chicken manure delivered primarily taller plants at 5, 10, and 15 t/ha than the control at all the examining dates. This finding is as a team with that of Okalebo *et al*. (2001) who reported that the consolidated utilization of maize with poultry manure gave a noteworthy increment in plant tallness.

The outcomes of the study demonstrated that poultry manure treated plants had most remarkable number of leaves pot^{-1} than gypsum treated plants. The expansion in number of leaf per plant with organic manure incorporation stressed its significance throughout the somatic development of plants (Fagwalawa and Yahaya, 2016).

In this study it was shown that poultry manure expanded the shoot fresh and dry weights of spinach. The expansion in fresh weight of spinach because of poultry manure application could be endorsed due to high solubility of released plant nutrients which prompts the supplement status of the soil. The outcomes obtained were supported with the discoveries of Sanwal *et al*. (2007) in okra and Premsekhar and Rajashree (2009) (A. esculentus) in turmeric (Curcuma longa) in which they stated that organic manure application give higher yield to crops that could be credited to enhanced physical and organic properties of the soil bringing about good provision of supplements to the plants. Most likely in light of the fact that as the manures expanded the water holding capacity of the soil and also increased the release of subsequent supplement in soil. Substitution of synthetic compost by natural fertilizers has been accounted to upgrade soil biological activity; productivity and the rate of microbial substrate utilize (Worthington, 2001). Recently higher yields of lettuce were accounted by using chicken manure and ultimately bounce back inorganic manure (Masarirambi *et al*., 2010). Expanded vegetable yield with the utilization of manure has also been accounted for (Ogunlela *et al*., 2005).

In this examination it was noted that use of poultry manure enhanced the physiological parameters of spinach plants. The control plants showed minimum increase in physiological parameters where no amendment was applied. This may be because of reason that Cr toxicity poses adverse impacts on the chloroplast and bringing down of other physical procedures that are compulsory for typical development and improvement of plants (Rizwan *et al*., 2016; Rehman *et al*., 2017). Usually, the most noteworthy increment in all the physical constraints was observed in T3 which may be because of strong part of high rate of poultry manure application for bringing down the damages of Cr destructiveness and establishment of appropriate nutrients (Abbas *et al*., 2017).

Conclusion**:** By comparing the effects of gypsum and poultry manure on yield and growth of spinach and reducing Cr uptake in shoots and roots of spinach plants, it is concluded that poultry manure (PM) @ 1% is effective in reducing the phytoavailability of Cr in spinach plants. It was additionally presumed that in calcareous soil, poultry manure can be utilized to diminish the phytotoxicity of heavy metals in polluted soil or utilizing textile wastewater for watering system.

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