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Study of bioaccumulation of selected heavy metals in *Phaseolus mungo* in agricultural fields in Sanganer, Jaipur

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Abstract
This paper contains a study carried out in agricultural fields of Sanganer, Jaipur. Results are based on samples collected from five selected sites. The crop plant selected was Phaseolus mungo. The edible part of the Phaseolus mungo (black gram) contained Zinc, Copper, Nickel, Cadmium, Chromium, Lead and Cobalt concentration which varied from 13.201 mg/gm to 13.445 mg/gm, 6.023 mg/gm to 6.253 mg/gm, 5.456 mg/gm to 5.701 mg/gm, 5.325 mg/gm to 5.445 mg/gm, 6.715 mg/gm to 6.852 mg/gm, 6.405 mg/gm to 6.557 mg/gm and 5.231 mg/gm to 5.701 mg/gm respectively.
The soil samples and water samples were also collected from the five selected sites and analysed for usual parameters with particular interest in heavy metals.

Keywords: *Phaseolus mungo*, Heavy metals, Bioaccumulation, Sanganer

Introduction
The aim of the present study was to find out the ill-effects of waste water on growth parameters phyico-chemical parameters and estimation of biologically accumulated metals. This waste water largely is a by-product and effluent from small, medium and large scale industries belonging to tie and dye, paper and pulp and blue potteries, categories. No. of studies have already been carried both in the country and at other parts of the world (Afrin et al., 2014, Jaishree and khan 2014, Joshi and Satnani 2012 and Marwari and Khan 2012). In general, wastewater contains substantial amounts of beneficial nutrients and toxic heavy metals, which are creating opportunities and problems for agricultural production, respectively (Chen et al., 2005; Singh et al., 2004). Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety (Muchuweti et al., 2006). Heavy metal contamination of vegetables cannot be underestimated as these foodstuffs are important components of human diet(Mayanka.2010 and Sharma et al.,2009). Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Khan et al., 2009; Radwan and Salama, 2006; Wang et al., 2005). Heavy metal accumulation in soils and plants is of increasing concern because of the potential human health risks. Vegetables take up metals by absorbing them from contaminated soils, as well as from deposits on different parts of the vegetables exposed to the air from polluted environments (Sobukola et al., 2010). This food chain contamination is one of the important pathways for the entry of these pollutants into the human body. Heavy metal accumulation in plants depends upon plant species, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil-to plant transfer factors of the metals (Rattan et al., 2005).
This study was undertaken with the object to find out adverse effects on the soil, water and selected crop plant and estimation of selected heavy metals (Zn,Cu,Ni,Cd,Cr,Pb and Co).

Study Area:- Sanganer, Jaipur was selected as study area. It is famous for Tie dye and printing, waste paper recycling and blue pottery industries. Sanganer is located between 26º 49' to 26º51'N latitude and 75º46' to 75º51'E longitude (Fig 1). These industries discharge untreated waste water in Amanishah Nala(Earstwhile Dravyawati river) in Sanganer. A large number of small, medium and large scale textile industrial units are located in Sanganer. The untreated waste water which conatins chemical like anelin, caustic soda, acids, bleaching powder and heavy metals is utilizing in irrigating agricultural fields for growing vegetables and other crop plants. Amanishah Nala is shown in Fig 1.

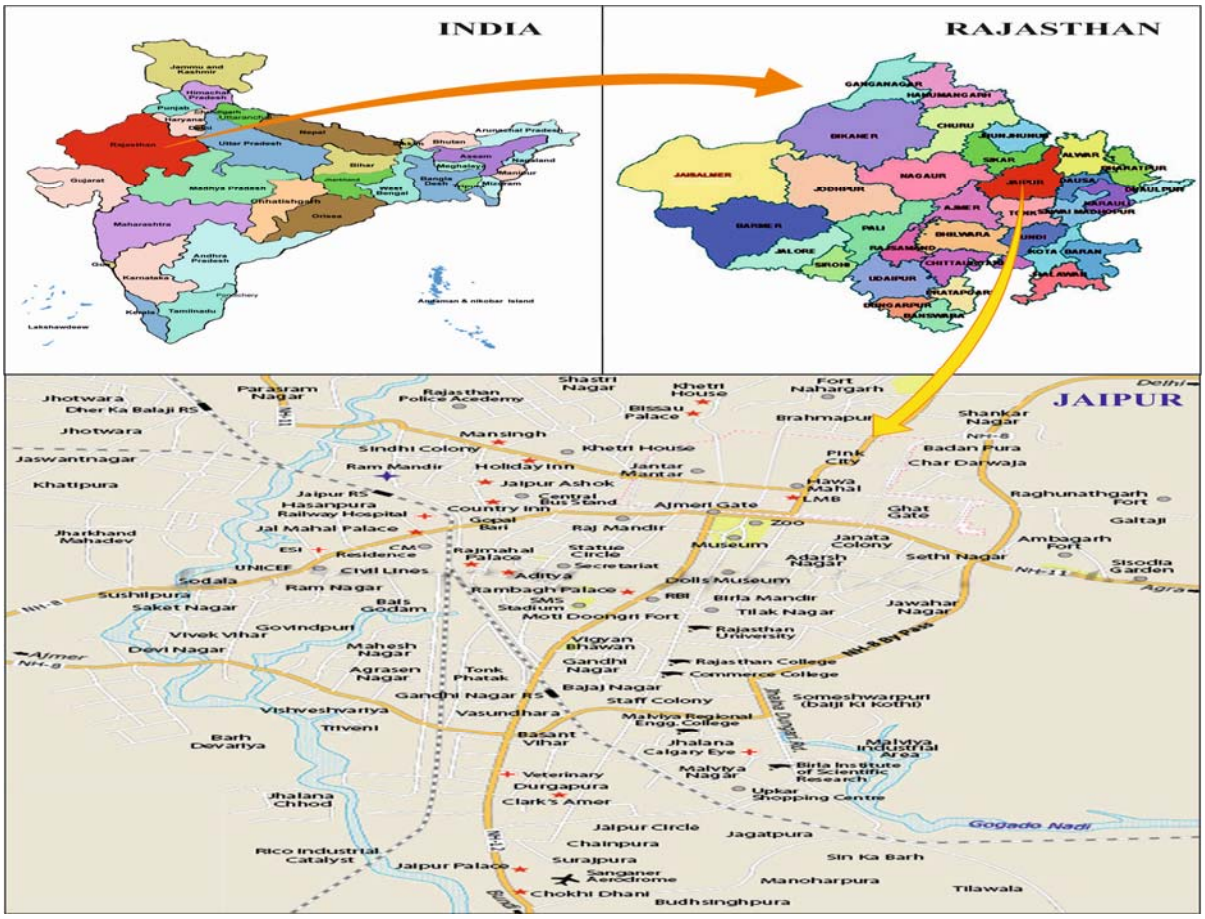

Fig: 1 Map showing the location of Study area, Sanganer, Jaipur, Rajasthan, India.

Fig: 2 Map showing sampling sites.

Material and methods

For this study *Phaseolus mungo* var. T-9 was selected as test crop plant. *Phaseolus mungo* (black gram) belongs to family *Fabaceae*. Green pods used as a vegetables and seeds are used as pulses. The plant sample were collected from five different agricultural fields in Sanganer (Fig. 2). Water sample were collected periodically from the study area where the waste water used is in agricultural fields. Soil samples from the agricultural fields of *Phaseolus mungo* were also collected periodically and analysed. The plants were harvested at pre-flowering, peak-flowering and post-flowering stages for studying different growth parameters (root and shoot length, dry weight of root and shoot and total dry weight). For dry weight determination roots and shoots were separated and dried in hot air oven at 80ºC for 72 hr. Chlorophyll a, b and total chlorophyll content in leaves were estimated by employing the method suggested by Arnon (1949). Carbohydrate content was estimated by emplying the Anthrone method. Protein content was determined by employing the method suggested by Lowry et al. (1951) while nitrogen content was estimated by microkjeldhal's method (Allen, 1931). Heavy metals (Zn,Cu,Ni,Cd,Cr,Pb and Co) in

the soil and crop plant samples were estimated using Atomic Absorption Spectrophotometer (AAS Model GBC 932 place).

Result and discussion

Heavy metals accumulation in the agricultural crop has been a matter of concerned. Various studies have been carried out at global and within the country. In the present study this water is used in the agricultural fields of Phaseolus mungo. The results of the analysis revealed that pH ranged from 7.38 to 9.64, E.C. from 0.741 to 1.852 mmhos/cm, T.D.S. from 679.23 to 1728 mg/L, Chloride from 342.2 to 491.2 mg/L, Total Hardness from 229.1 to 637.62 mg/L, Calcium Hardness from 169.2 to 528.4 mg/L and Magnesium Hardness from 58.4 to 109.22 mg/L in the waste water collected from the study area from different locations and times. (Table 1a).Heavy metal concentration was also determined. Zinc concentration varies from 3.002 mg/L to 3.258 mg/l, Copper 0.245 to 0.346 mg/L, Nickel from 0.943 mg/L to 0.985 mg/L, Cadmium from 2.055 mg/L to 2.120 mg/L, Chromium from 2.589 mg/L to 2.637 mg/L, Lead from 1.188 mg/L to 1.223 mg/L and Cobalt from 0.479 mg/L to 0.518 mg/L in the waste water collected from selected locations and different times (Table 1b).

Soil samples from the selected agricultural fields were collected and analyzed. The results revealed that pH ranged from 7.99 to 9.31, E.C. from 1.59 to 2.89 mmhos/cm, Chloride from 12.26 mg/100gm to 17.53 mg/100gm, Organic carbon from 3.136 percent to 4.308 percent, Organic matter from 5.406 percent to 7.426 percent and Nitrogen from 0.029 percent to 0.144 percent in the soil collected from the study area from different location and times. (Table 2a). Heavy metal concentration was also determined. Zinc concentration varies from 11.652 mg/g to 16.481mg/g, Copper from 9.013 mg/g to 9.589 mg/g, Nickel from 4.023 mg/g to 5.096 mg/g, Cadmium from 4.056 mg/g to 5.139 mg/g, Chromium from 6.028 mg/g to 6.825mg/g, Lead from 5.235 mg/g to 5.402 mg/g and Cobalt from 3.259 mg/g to 3.623 mg/g in the soil collected from various locations and different times.(Table 2b).

The plant samples of Phaseolus mungo (black gram) collected from the selected five sites of Sanganer agricultural fields and analysed. The root length varied from 34.2 cm to 38.2 cm, 51.5cm to 56.3cm, and 52.6cm to 58.0cm and shoot length varied from 75.3cm to 81.2cm, 103.2cm to 109.1cm and 104.1cm to 110.7cm at pre, peak and post flowering stage respectively. Root weight varied from 1.641gm to 2.112gm, 2.685gm to 3.096gm and 3.641gm to 3.92gm and shoot weight varied from 4.412gm to 4.712gm, 6.888gm to 7.415gm and 8.001gm to 8.204gm at pre, peak and post flowering stage respectively.(Table 3a and 3b). The amount of total chlorophyll varied from 1.709mg/gm to 2.279 mg/gm, 2.119 mg/gm to 2.745 mg/gm and 2.465m g/gm to 2.906 mg/gm and carbohydrate varied from 57.322 mg/gm to 65.231 mg/gm, 81.023 mg/gm to 86.12 mg/gm and 86.13mg/gm to 92.054mg/gm and plant phosphorous varied from 3.42 mg/gm to 4.126mg/gm, 3.916 mg/gm to 4.342 mg/gm and 4.196 mg/gm to 5.003mg/gm at pre, peak and post flowering stage respectively. The nitrogen content varied from 2.036 percent to 2.19 percent, 2.866percent to 3.616percent and 4.209 percent to 4.405 percent at pre flowering respectively and protein content varied from 12.72 percent to 13.68 percent, 17.91 percent to 22.60 percent and 26.30 percent to 27.53 percent at pre, peak and post flowering stage respectively. (Table 3c,3d and 3e).

Heavy metals were estimated in different plant parts samples of *Phaseolus mungo* (black gram) at pre-flowering, peak-flowering and post-flowering stages. The heavy metals were estimated in mg/gm dry weight. The plants accumulated Zn concentration varied from 4.831 mg/gm to 6.215 mg/gm, 5.105mg/gm to 6.102 mg/gm and 6.215 mg/gm to 6.852 mg/gm in root, stem and leaves respectively at pre flowering stage. Cu concentration varied from 3.056 mg/gm to 3.448 mg/gm,3.185 mg/gm to 3.846 mg/gm and 3.339 mg/gm to 3.945 mg/gm, Ni was from 3.025 mg/gm to 3.206 mg/gm, 3.106 mg/gm to 3.302 mg/gm and 3.332 mg/gm to 3.568 mg/gm, Cd varied from 3.253 mg/gm to 3.485 mg/gm, 3.621mg/gm to 3.815 mg/gm and 3.763 mg/mg to 3.851 mg/gm, Cr varied from 4.105 mg/gm to 4.302 mg/gm, 4.207 mg/gm to 4.358 mg/gm and 4.312 mg/gm to 4.485 mg/gm, Pb varied from 3.284 mg/gm to 3.409 mg/gm, 3.361 mg/gm to 3.502 mg/gm and 3.507 mg/gm to 3.658 mg/gm, Co concentration varied from 2.247mg/gm to 2.409 mg/gm, 2.309 mg/gm to 2.509 mg/gm and 2.428 mg/gm to 2.603 mg/gm in root, stem and leaves respectively at pre flowering stage.(Table 3f). The Zn concentration was increased in peak-flowering stage. Zn concentration was accumulated and varied from 10.018 mg/gm to 10.632 mg/gm, 10.231 mg/gm to 10.693 mg/gm, 10.421 mg/gm to 10.728 mg/gm, Cu varied from 4.204 mg/gm to 4.506 mg/gm, 4.254 mg/gm to 4.523 mg/gm and 4.369 mg/gm to 4.589 mg/gm, Ni varied from 4.101 mg/gm to 4.448mg/gm, 4.359 mg/gm to 4.701 mg/gm and 5.025mg/gm to 5.342mg/gm, Cd concentration varied from 4.023 mg/gm to 4.623 mg/gm, 4.106 mg/gm to 4.623mg/gm and 4.258 mg/gm to 4.810 mg/gm, Cr was from 5.107 mg/gm to 5.529 mg/gm, 5.283 mg/gm to 5.721 mg/gm and 5.632 mg/gm to 5.986 mg/gm, Pb varied from 5.023 mg/gm to 5.582 mg/gm, 5.142 mg/gm to 5.751 mg/gm and 5.481 mg/gm to 5.812 mg/gm and Co concentration varied from 3.517 mg/gm to 3.881 mg/gm, 3.603 mg/gm to 3.902 mg/gm and 3.762 mg/gm to 3.949 g/gm in root, stem and leaves respectively at peak-flowering stage.(Table 3g)

Similarly the heavy metals concentration was estimated at post flowering stage also. Zn concentration varied from 10.996 mg/gm to 11.312 mg/gm, 10.463 mg/gm to 11.312 mg/gm and 11.023 mg/gm to 11.523 mg/gm, Cu varied from 5.025 mg/gm to 5.317 mg/gm, 5.739 mg/gm to 5.837 mg/gm and 5.624 mg/gm to 5.854 mg/gm, Ni varied from 5.022 mg/gm to 5.182 mg/gm, 5.111 mg/gm to 5.246 mg/gm and 5.162 mg/gm to 5.304 mg/gm, Cd varied from 5.023mg/gm to 5.251 mg/gm, 5.078 mg/gm to 5.229 mg/gm and 5.103 mg/gm to 5.246 mg/gm, Cr varied from 6.231 mg/gm to 6.445 mg/gm, 6.335 mg/gm to 6.498 mg/gm and 6.397 mg/gm to 6.536 mg/gm, Pb varied from 6.025 mg/gm to 6.191 mg/gm, 6.112 mg/gm to 6.269 mg/gm and 6.182 mg/gm to 6.352 mg/gm and Co concentration varied from 4.108 mg/gm to 4.501 mg/gm, 4.382 mg/gm to 4.702 mg/gm and 4.619 mg/gm to 4.823 mg/gm in root, stem and leaves respectively at post flowering stage.(Table 3h)

The heavy metal concentration in the edible parts was recorded at post flowering stage. Zinc, Copper, Nickel, Cadmium, Chromium, Lead and Cobalt concentration varied from 13.201 mg/gm to 13.445 mg/gm, 6.023 mg/gm to 6.253 mg/gm, 5.456 mg/gm to 5.701 mg/gm, 5.325 mg/gm to 5.445 mg/gm, 6.715 mg/gm to 6.852 mg/gm, 6.405 mg/gm to 6.557 mg/gm and 5.231 mg/gm to 5.701 mg/gm respectively.(Table 3h). Earlier studies by Khan and Marwari (2002, 2003) reported high concentration of heavy metal in vegetables grown in agricultural fields receiving textile waste water. Metal accumulation in vegetables may pose a direct threat to

human health. Heavy metals may enter the human body through inhalation of dust, direct ingestion of soil, and consumption of food plants grown in metal-contaminated soil. (Jaishree and Khan 2014).Crop plants growing on heavy metal contaminated medium can accumulate high concentrations of trace elements to cause serious health risk to consumers. Long et al., (2003) studied the effects of excess zinc on plant growth of three selected vegetables i.e. Chinese cabbage, celery and pakchoi. They found that excess Zn in growth media caused toxicity to all three vegetable crops and showed symptoms like chlorosis in young leaves, browning of coralloid roots, and serious inhibition on plant growth. Heavy metal concentration of the waste water used in irrigation gets gradually accumulated in the crop plants frown in the agricultural fields. These metals affect the growth of the plants and their higher concentration accumulated and consumed by the human which in turn become the cause of relevant diseases.

The authors suggest that the steps should be taken at the earliest to treat this waste water before its use in the agricultural fields as a precautionary measure.

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Table: 1a Physico-chemical analysis of Textile waste water collected from agricultural fields of Phaseolus mungo var T-9 (black gram) located in Amanishah nallah, Sanganer, at Pre, Peak and Post-Flowering Stages.

Stages	S. No.	Physico-chemical parameters						
	Samples	pH	E.C. mmhos / cm	Total solids mg/L	Chloride mg/L	Total Hardness mg/L	Calcium Hardness mg/L	Magnesium Hardness Mg/L
Pre – flowering	Site 1	7.22 ± 0.342	1.985 ± 36.27	1321± 19.40	296.2 ± 25.41	348.32± 18.11	269.8 ±15.31	78.52±13.25
	Site 2	7.49 ± 0.311	1.952 ± 22.98	1396 ± 21.32	348.2 ±28.49	278.9±22.02	226.61 ±24.64	52.3±10.29
	Site 3	7.76 ± 0.338	0.989 ± 41.23	846 ± 24.32	423.1 ±18.27	543.1±21.32	448.7 ±17.12	94.4 ±18.96
	Site 4	8.28 ± 0.323	0.742 ± 59.61	592 ± 38.21	447±38.63	435.6±25.96	247.2 ±9.56	188.4±7.69
	Site 5	9.09 ± 0.401	0.638 ± 47.86	612 ± 41.13	279.6 ±58.62	317.2 ±22.36	229.2 ±9.28	88.0 ±8.21
Peak flowering	Site 1	8.65 ± 0.403	0.806 ± 27.39	722.1 ± 34.10	476.8 ±35.62	244.28 ±28.51	178.9 ±13.92	65.38 ±14.36
	Site 2	7.92 ± 0.379	1.087 ± 29.32	1052± 52.2	508.5 ±45.99	286.56 ±34.62	215.6 ±14.9	70.96 ±11.41
	Site 3	8.17 ± 0.398	0.945 ± 45.69	894.7± 44.88	381.5±31.2	567.9 ±47.31	467.1 ±18.4	100.8 ±7.86
	Site 4	9.24 ± 0.301	1.032 ± 28.9	1221 ±32.13	327.2±19.75	571.21 ±34.92	485.9 ±25.7	85.31 ±19.86
	Site 5	9.17 ± 0.332	0.964 ± 47.23	1513.1± 32.23	278.9 ±47.86	641.25 ±41.62	529.52 ±18.7	111.68 ±15.9
Post flowering	Site 1	7.38 ± 0.335	1.852 ± 75.23	1728 ± 28.20	359.3±42.1	229.13 ±18.36	169.2 ±18.2	59.93 ±22.1
	Site 2	9.64 ± 0.389	0.759 ± 13.9	679.23 ± 28.21	342.2 ±18.23	637.62 ±55.42	528.4 ±25.3	109.22 ±18.4
	Site 3	8.22 ± 0.396	1.786 ± 63.2	1559 ± 36.32	389.6 ±29.62	453.6 ±14.22	395.2 ±42.3	58.4±13.96
	Site 4	8.07 ± 0.321	0.753 ± 42.21	1041.2± 59.63	365.34 ±39.8	548.2 ±22.9	475.8 ±25.36	72.4 ±9.52
	Site 5	7.79 ± 0.312	0.741 ± 33.25	897.6 ± 25.23	491.2 ± 48.2	266.9 ±18.4	189.5 ±15.63	77.4 ±7.21

Table: 1b Heavy metals analysis of Textile waste water collected from agricultural fields of Phaseolus mungo var. T-9 (black gram) located in Amanishah nallah, Sanganer, at Pre, Peak and Post flowering stages.

Stages	S. No.	Heavy Metals						
	Samples	Zn	Cu	Ni	Cd	Cr	Pb	Co
Pre – flowering	Site 1	1.584	0.186	0.709	1.746	1.923	1.065	0.312
	Site 2	1.609	0.159	0.745	1.798	2.001	1.082	0.327
	Site 3	1.724	0.115	0.769	1.782	1.986	1.107	0.342
	Site 4	1.658	0.167	0.718	1.802	1.955	1.119	0.367
	Site 5	1.687	0.123	0.733	1.759	1.977	1.071	0.356
Peak flowering	Site 1	2.201	0.248	0.855	1.906	2.229	1.145	0.442
	Site 2	2.316	0.203	0.863	1.957	2.246	1.169	0.419
	Site 3	2.186	0.236	0.842	1.933	2.231	1.126	0.433
	Site 4	2.248	0.257	0.871	1.965	2.271	1.171	0.407
	Site 5	2.335	0.219	0.896	1.922	2.266	1.133	0.451

Post flowering	**Site 1**	3.002	0.309	0.985	2.120	2.612	1.202	0.496
	Site 2	3.196	0.276	0.971	2.101	2.637	1.196	0.507
	Site 3	3.152	0.251	0.965	2.088	2.589	1.223	0.479
	Site 4	3.209	0.245	0.943	2.055	2.622	1.215	0.518
	Site 5	3.258	0.346	0.955	2.063	2.604	1.188	0.488

Table: 2a Physico-chemical analysis of soil from agriculture fields of Phaseolus mungo var. T-9 (black gram) at Pre Flowering stages.

Stages	Sites	pH	E.C. mmhos/cm	Chlorides mg/100g	%Organic carbon	%Organic matter	% Nitrogen
Pre-Flowering	**Site 1**	7.21±0.06	0.88±0.07	5.86±0.45	2.510±0.011	4.324±0.006	0.080±0.009
	Site 2	7.46±0.04	1.26±0.08	6.23±0.45	2.206±0.009	3.802±0.007	0.091±0.01
	Site 3	7.31±0.05	0.93 ±0.06	8.63±0.351	2.301±0.002	3.966±0.08	0.075±0.012
	Site 4	8.16±0.05	1.26±0.06	9.03±0.402	2.612±0.008	4.503±0.011	0.112±0.007
	Site 5	8.02±0.06	1.39±0.05	10.03±0.603	3.065±0.01	5.284±0.11	0.123±0.008
Peak-Flowering	**Site 1**	8.22±0.06	2.38±0.07	14.02±0.25	3.245±0.051	5.594±0.16	0.145±0.009
	Site 2	8.09±0.04	1.56±0.08	11.73±0.451	3.257±0.009	5.615±0.07	0.091±0.01
	Site 3	7.29±0.05	1.65 ±0.06	10.26±0.351	3.272±0.09	5.640±0.08	0.042±0.012
	Site 4	9.16±0.05	2.69±0.06	13.93±0.305	4.132±0.09	7.123±0.11	0.168±0.007
	Site 5	8.69±0.06	2.21±0.05	17.22±0.503	4.034±0.011	6.954±0.11	0.132±0.008
Post-Flowering	**Site 1**	8.03±0.06	1.59±0.07	15.96±0.45	4.031±0.011	6.949±0.06	0.086±0.09
	Site 2	9.31±0.04	2.89±0.08	17.53±0.409	4.308±0.08	7.426±0.07	0.123±0.01
	Site 3	7.99±0.05	1.69 ±0.06	13.16±0.326	3.295±0.009	5.680±0.08	0.029±0.12
	Site 4	8.66±0.05	2.26±0.06	13.03±0.310	4.094±0.009	7.058±0.021	0.121±0.07
	Site 5	8.06±0.06	1.86±0.05	12.26±0.503	3.136±0.011	5.406±0.015	0.144±0.008

Table: 2b Heavy Metal analysis (mg/gm) in soil of Phaseolous mungo var T-9 (black gram) at Pre-Flowering stages collected from agricultural fields.

Stages	Sites	Heavy Metals (mg/gm)						
		Zn	Cu	Ni	Cd	Cr	Pb	Co
Pre-Flowering	**Site 1**	6.389	5.155	2.063	2.036	3.823	2.706	1.569
	Site 2	9.236	5.189	2.126	2.236	3.229	3.202	1.601
	Site 3	10.495	5.325	2.239	2.418	3.201	3.693	1.612
	Site 4	7.758	5.202	2.409	2.523	3.224	3.301	1.709
	Site 5	5.395	5.613	2.109	2.772	3.726	3.256	1.798
Peak-Flowering	**Site 1**	11.526	7.325	3.203	3.056	5.261	3.712	2.502
	Site 2	13.239	7.489	3.228	3.236	5.128	4.023	2.561
	Site 3	13.625	7.545	3.209	3.562	5.346	4.198	2.712
	Site 4	10.881	7.212	3.512	3.627	5.329	4.332	2.806
	Site 5	11.496	7.363	3.662	3.824	5.821	4.541	2.903
Post-Flowering	**Site 1**	13.281	9.105	4.023	4.056	6.028	5.235	3.459
	Site 2	15.212	9.589	4.381	4.129	6.112	5.292	3.623
	Site 3	16.481	9.445	4.852	4.887	6.205	5.306	3.369
	Site 4	11.652	9.512	5.096	5.003	6.446	5.369	3.562
	Site 5	14.425	9.013	4.812	5.139	6.825	5.402	3.259

Table: 3a Root and Shoot length (cm) of Phaseolus mungo var T-9 (black gram) at Pre, Peak and Post-Flowering stages collected from agricultural fields.

Sites	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	Root Length (cm)	Shoot Length (cm)	Root Length (cm)	Shoot Length (cm)	Root Length (cm)	Shoot Length (cm)
Site 1	34.28 ± 11.71	75.31 ± 4.53	52.41± 3.48	107.12 ± 3.39	53.10± 4.01	109.04 ± 3.19
Site 2	37.76 ± 13.04	80.12 ± 6.05	51.52 ± 9.22	106.6 ± 3.91	52.62 ± 7.22	107.76 ± 3.91
Site 3	36.02 ± 12.19	78.25 ± 5.11	55.15 ± 5.22	103.23 ± 4.5	56.4 ± 5.22	104.12 ± 3.86
Site 4	38.23 ± 7.68	81.28 ± 5.88	56.3 ± 5.06	109.12 ± 3.11	58.03 ± 5.86	110.71 ± 3.11
Site 5	35.18 ± 6.61	76.13 ± 1.04	52.78 ± 4.01	105.8 ± 2.21	53.81 ± 4.7	106.01 ± 2.01

Table: 3b Root and Shoot Weight (gm) of Phaseolus mungo var T-9 (black gram) at Pre, Peak and Post-Flowering stages collected from agricultural fields.

Sites	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	Root Weight (gm)	Shoot Weight (gm)	Root Weight (gm)	Shoot Weight (gm)	Root Weight (gm)	Shoot Weight (gm)
Site 1	1.641±0.149	4.672±0.36	2.685±0.228	7.415±0.251	3.641±0.224	8.162±0.23
Site 2	1.712 ±0.157	4.712±0.23	2.742±0.221	7.354±0.11	3.721±0.232	8.204±0.12
Site 3	1.891±0.19	4.412±0.182	2.816±0.206	6.922±0.18	3.679±0.236	8.001±0.151
Site 4	1.985±0.310	4.496±0.179	3.004±0.23	6.888±0.13	3.92±0.228	8.086±0.19
Site 5	2.112±0.201	4.509±0.181	3.096±0.21	7.012±0.17	3.852±0.23	8.123±0.16

Table: 3c Chlorophyll (mg/gm) in Phaseolus mungo var. T-9 (black gram) at Pre, Peak and Post-Flowering stages collected from agricultural fields.

Sites	Pre-Flowering Stage			Peak-Flowering Stage			Post-Flowering Stage		
	Chl-a (mg/gm)	Chl-b (mg/gm)	Total Chl (a+b) (mg/gm)	Chl-a (mg/gm)	Chl-b (mg/gm)	Total Chl (a+b) (mg/gm)	Chl-a (mg/gm)	Chl-b (mg/gm)	Total Chl (a+b) (mg/gm)
Site 1	1.509±0.532	0.756±0.406	2.279±0.354	1.726±0.301	0.975±0.131	2.745±0.257	1.859±0.371	1.036±0.121	2.906±0.357
Site 2	1.327±0.602	0.712±0.325	2.046±0.361	1.51±0.256	0.923±0.127	2.463±0.356	1.679±0.231	0.994±0.127	2.682±0.316
Site 3	1.405±0.710	0.696±0.463	2.112±0.365	1.606±1.023	0.885±0.16	2.502±0.454	1.752±1.072	0.875±0.15	2.645±0.302
Site 4	1.209±0.202	0.645±0.165	1.869±0.407	1.439±0.12	0.812±0.108	2.269±0.323	1.609±0.197	0.832±0.108	2.465±0.396
Site 5	1.369±0.197	0.626±0.238	1.709±0.326	1.367±0.556	0.736±0.318	2.119±0.569	1.586±0.418	0.796±0.218	2.486±0.238

Table: 3d Carbohydrate and Phosphorous (mg/gm) in Phaseolus mungo var T-9 (black gram) at Pre, Peak and Post Flowering stages collected from agricultural fields.

Sites	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	Carbohydrate (mg/gm)	Phosphorous (mg/gm)	Carbohydrate (mg/gm)	Phosphorous (mg/gm)	Carbohydrate (mg/gm)	Phosphorous (mg/gm)
Site 1	63.148 ± 0.35	3.748 ± 0.172	85.548 ± 0.32	3.916 ± 0.11	86.13 ± 0.23	4.196 ± 0.16
Site 2	61.294 ± 0.32	4.015 ± 0.18	86.12 ± 0.21	4.212 ± 0.14	88.045 ± 0.14	4.37 ± 0.13
Site 3	65.231 ± 0.40	4.126 ± 0.21	82.536 ± 0.69	4.342 ± 0.18	90.198 ± 0.39	5.003 ± 0.14
Site 4	57.322 ± 0.29	3.624 ± 0.25	83.664 ± 0.74	4.258 ± 0.14	88.528 ± 0.25	4.678 ± 0.25
Site 5	62.132 ± 0.21	3.42 ± 0.19	81.023 ± 0.19	4.179 ± 0.17	92.054 ± 0.28	4.488 ± 0.16

Table 3e: Nitrogen and Protein in Phaseolus mungo var T-9 (black gram) at Pre, Peak and Post-Flowering stages collected from agricultural fields.

Sites	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	% Nitrogen	% Protein	% Nitrogen	% Protein	% Nitrogen	% Protein
Site 1	2.036 ± 0.021	12.725 ± 0.19	2.866 ± 0.11	17.91 ± 0.58	4.312 ± 0.33	26.95 ± 2.21
Site 2	2.112 ± 0.022	13.20 ± 0.15	2.906 ± 0.098	18.16 ± 0.61	4.209 ± 0.65	26.30 ± 2.42
Site 3	2.079 ± 0.026	12.99 ± 0.13	2.919 ± 0.087	18.24 ± 0.52	4.396 ± 0.29	27.47 ± 1.09
Site 4	2.19 ± 0.027	13.68 ± 0.19	2.934 ± 0.108	18.33 ± 0.62	4.405 ± 0.36	27.53 ± 2.39
Site 5	2.078 ± 0.029	12.98 ± 0.18	3.616 ± 0.099	22.60 ± 0.74	4.338 ± 0.38	27.11± 2.21

Table: 3f Heavy Metal analysis (mg/gm) of Phaseolus mungo var T-9 (black gram) at Pre Flowering stages collected from agricultural fields.

Heavy Metals (mg/g)	Plant Parts	Sites				
		Site 1	Site 2	Site 3	Site 4	Site 5
Zn	**Root**	4.831	5.206	5.328	6.107	6.215
	Stem	5.105	5.502	5.603	5.541	6.102
	Leaves	6.402	6.636	6.215	6.386	6.852
Cu	**Root**	3.124	3.056	3.320	3.216	3.448
	Stem	3.185	3.583	3.846	3.669	3.326
	Leaves	3.339	3.692	3.945	3.702	3.452
Ni	**Root**	3.025	3.121	3.058	3.159	3.206
	Stem	3.148	3.106	3.253	3.302	3.285
	Leaves	3.358	3.568	3.332	3.478	3.502
Cd	**Root**	3.421	3.253	3.425	3.356	3.485
	Stem	3.685	3.621	3.709	3.815	3.728
	Leaves	3.812	3.769	3.801	3.851	3.763
Cr	**Root**	4.105	4.183	4.206	4.302	4.285
	Stem	4.221	4.207	4.252	4.358	4.309
	Leaves	4.356	4.312	4.485	4.446	4.408
Pb	**Root**	3.259	3.332	3.284	3.357	3.409
	Stem	3.375	3.456	3.361	3.502	3.435
	Leaves	3.658	3.586	3.602	3.546	3.507
Co	**Root**	2.247	2.289	2.389	2.409	2.338
	Stem	2.309	2.367	2.405	2.486	2.509
	Leaves	2.428	2.489	2.451	2.557	2.603

Table: 3g Heavy Metal analysis (mg/gm) of Phaseolus mungo var T-9 (black gram) at Peak Flowering stages collected from agricultural fields.

Heavy Metals	Plant Parts	Sites				
		Site 1	Site 2	Site 3	Site 4	Site 5
Zn	Root	10.113	10.553	10.632	10.018	10.359
	Stem	10.359	10.456	10.693	10.231	10.426
	Leaves	10.569	10.630	10.728	10.421	10.602
Cu	Root	4.326	4.204	4.452	4.418	4.506
	Stem	4.345	4.254	4.491	4.402	4.523
	Leaves	4.459	4.369	4.572	4.589	4.575
Ni	Root	4.236	4.101	4.169	4.348	4.448
	Stem	4.359	4.462	4.621	4.359	4.701
	Leaves	5.025	5.153	5.291	5.209	5.342
Cd	Root	4.526	4.623	4.023	4.281	4.392
	Stem	4.581	4.640	4.106	4.415	4.623
	Leaves	4.741	4.806	4.258	4.603	4.810
Cr	Root	5.269	5.316	5.107	5.423	5.529
	Stem	5.359	5.402	5.283	5.617	5.721
	Leaves	5.856	5.742	5.632	5.902	5.986
Pb	Root	5.023	5.128	5.345	5.486	5.582
	Stem	5.142	5.358	5.542	5.751	5.693
	Leaves	5.481	5.583	5.681	5.786	5.812
Co	Root	3.517	3.716	3.881	3.605	3.582
	Stem	3.603	3.774	3.902	3.714	3.687
	Leaves	3.812	3.885	3.949	3.906	3.762

Table: 3h Heavy Metal analysis (mg/gm) of Phaseolus mungo var T-9 (black gram) at Post Flowering stages collected from agricultural fields.

Heavy Metals	Plant parts	Sites				
		Site 1	Site 2	Site 3	Site 4	Site 5
Zn	Root	10.996	11.108	11.230	11.176	11.312
	Stem	10.463	10.984	11.086	11.222	11.312
	Leaves	11.023	11.149	11.212	11.312	11.523
	Fruit	13.201	13.410	13.286	13.326	13.445
Cu	Root	5.232	5.121	5.025	5.156	5.317
	Stem	5.739	5.746	5.837	5.780	5.754
	Leaves	5.797	5.823	5.811	5.854	5.624
	Fruit	6.023	6.125	6.222	6.184	6.253
Ni	Root	5.063	5.022	5.126	5.115	5.182
	Stem	5.111	5.145	5.201	5.189	5.246
	Leaves	5.162	5.202	5.265	5.304	5.297
	Fruit	5.456	5.552	5.669	5.605	5.701
Cd	Root	5.023	5.096	5.251	5.153	5.214
	Stem	5.078	5.113	5.205	5.187	5.229
	Leaves	5.103	5.159	5.227	5.201	5.246
	Fruit	5.325	5.406	5.376	5.445	5.419
Cr	Root	6.231	6.445	6.337	6.372	6.406
	Stem	6.335	6.498	6.381	6.419	6.439
	Leaves	6.397	6.536	6.445	6.522	6.512
	Fruit	6.852	6.715	6.804	6.823	6.756
Pb	Root	6.025	6.158	6.117	6.083	6.191
	Stem	6.112	6.156	6.269	6.187	6.241
	Leaves	6.182	6.212	6.306	6.253	6.352
	Fruit	6.405	6.496	6.529	6.503	6.557
Co	Root	4.225	4.108	4.327	4.501	4.385
	Stem	4.403	4.382	4.512	4.623	4.702
	Leaves	4.619	4.725	4.791	4.742	4.823
	Fruit	5.231	5.436	5.509	5.642	5.701

Safe limit of irrigation water for heavy metals

Heavy Metal	*Concentration (mg/L)*
Pb	*0.5*
Cu	*0.2*
Cr	*0.1*
Zn	*5*
Ni	*0.2*
Co	*0.6*
Cd	*0.01*

Source: Pescod, M.B. (1992)

Safe limit of heavy metals for human consumption in food stuff

Heavy Metal	*Concentration (mg/L)*
Pb	*0.0025*
Cu	*0.03*
Cr	*0.02*
Zn	*0.05*
Ni	*0.07*
Co	*0.04*
Cd	*0.0015*

Source: Awashthi, S. K. (2000).

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