Comparative Changes in Growth and Seed Yield Characteristics of [Vigna Radiata (L.) Wilczek] Varieties under the Influence of Increased Levels of Cadmium (Cd^{+2})

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Summary: A net house experiment was conducted to determine the effects of different levels of Cadmium application on growth, yield and Cadmium (Cd^{+2}) in various Mungbean plant parts. The NM-98 variety produced higher biomass of different plant parts than NM-28. Significant differences in growth and yield of various plant parts were observed among the treatments. The significant interactions was found between Cadmium (Cd^{+2}) treatments and varieties for yield in all the parts of plant. The NM-98 had much greater yield than other varieties

Introduction

Soil cadmium affects plant growth adversely and is recognized as a contaminant in the environment. High Cadmium (Cd^{2+}) contents in soils lead to reduction in plant growth and dry matter yields [1, 2]. Plant species and even varieties differ greatly in their ability to take up, transport and accumulate Cadmium (Cd^{2+}) within the plant [3-5]. Identified Mungbean varieties tolerant to Cadmium (Cd^{2+}) toxicity could be potential value in cropping of (Cd^{2+}), contaminated soils and also may be used as parents for introducing this trait in improved varieties. But factors, such as species and cultivars also exert marked differences with regard to (Cd^{2+}), accumulation and tolerance by plants [6, 5]. The tolerance of crops to Cadmium (Cd^{2+}), toxicity depends on crops ability to absorb Cadmium (Cd^{2+}). It is important to know the difference of (Cd^{2+}), toxicity tolerance among varieties and the potential of Cadmium (Cd^{2+}) accumulation as well as their physiological responses to toxicity. Cadmium is easily taken up by plants and translocated to different plant parts. Generally, visual toxicity symptoms and impaired growth occur only at relatively high internal Cadmium (Cd^{2+}), concentrations [7]. Florijn & Van Beusichem [8] and Tudoreanu & Phillips [9] reported that internal distribution rather than uptake caused varietal differences in shoot Cadmium (Cd^{2+}) concentration of Maize inbred lines. Limited information is available about the effect of (Cd^{2+}) on the growth and possible tolerance mechanism among Mungbean varieties.

The objective of the study was to investigate the effect of (Cd^{2+}), on dry matter yield and seed characteristics of Mungbean varieties with the diverse genetic back ground. The experiment was performed for the screening of mungbean for optimum dose of cadmium. The research work was also aimed at to identify the tolerant and sensitive Mungbean varieties for Cadmium. The study would be useful for farmers in Pakistan and other Asian countries with similar ecological conditions and edaphic factors.

Results and Discussion

Mungbean variety NM-98 produced higher biomass of different plant parts at all the levels of (Cd^{2+}) additions than NM- 28. Among all the Mungbean varieties, NM-98 had a much greater yield than other varieties. Cadmium @ 9 and 12 mg kg^{-1} soil significantly decreased the root and shoot dry weight than the control (Table-1). Yield of Mungbean varieties in the control were not statistically different form those of 3 mg/ L treatment of Cd^{2+}. Significant differences in yield of various plant parts were noted between the treatments. Similarly interactions between varieties and (Cd^{2+}), levels in all the plant parts were significant. There were significant reduction in yields of about 42 % for seed, 32 % for roots and 14 % for shoots at 12 mg Cd^{2+}/ L soil than the control. Seed yield of Mungbean varieties decreased to a greater extent than that of other plant parts. The reduction in crop yields due to (Cd^{2+}), applications are in agreement with the finding [10]. Yield reduction in sunflower plants have been attributed to the direct effect of higher Cd^{2+} concentration in plant tissue [11] and not through

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Table-1: Comparative changes in shoot and root dry weight of Mungbean varieties under the influence of increased levels of Cadmium (Cd^{+2}) applied at reproductive stage.

Cd^{2+} level mg L^{-1}	NM-13-1	NM-1919	NM-2021	NM-28	NM-51	NM-54	NM-88	NM-92	NM-98	Chak-97	Mean
					Dry weight of shoot(g $plant^{-1}$)						
0	9.27	6.15	9.65	8.60	9.45	10.10	8.41	12.35t	12.60	10.95	9.75
3	5.85	6.15	5.10	6.75	6.15	10.35	5.85	7.05	8.55	9.15	6.09
6	5.25	9.00	5.85	6.00	9.45	4.50	9.30	5.85	9.30	5.40	6.99
9	5.25	9.00	5.70	4.65	5.40	5.60	6.45	8.25	9.15	5.25	6.47
12	4.35	7.35	5.10	4.65	6.70	4.90	5.10	7.10	6.45	5.25	5.69
Mean	5.94	7.53	6.28	6.13	7.43	7.09	7.02	8.12	9.21	7.19	7.19
Source of variance											
Treatments (T)						6.36*					
Varieties (V)						7.56**					
T × V						3.13ns					
Error						2.19					
					Dry weight of Root(g $plant^{-1}$)						
0	1.42	1.12	1.87	2.82	2.00	3.82	1.52	4.50	3.10t	3.32	2.54
3	1.50	1.22	1.80	2.71	1.42	2.17	1.52	2.30	2.32	1.97	1.89
6	1.45	1.22	1.37	1.22	3.25	1.32	2.00	1.12	2.40	1.81	1.66
9	1.03	1.80	1.62	2.30	2.37	4.50	1.32	3.30	2.20	1.35	2.17
12	0.95	1.75	1.22	1.02	1.90	2.32	1.14	1.60	2.45	1.52	1.58
Mean	1.27	1.42	1.57	1.01	2.18	2.82	1.5	2.56	2.49	1.99	1.93
Source of variance											
Treatments (T)						7.45**					
Varieties (V)						9.60**					
T × V						3.03**					
Error						0.75					

Significant at ** $P<0.01$; *$P<0.05$ and ns non-significant.

an indirectly induced deficiency of other nutrients. Highest dry matter yield of shoot was recorded followed by roots at all the levels of Cd^{2+} application. The growth determinations made at maturity stage revealed significant differences among the Cd^{2+} treatments and the varieties, however interaction of both these factors was not significant for shoot dry weight (Table-1). A comparison of varieties indicated that the root and shoot dry weight was greatest in NM-98, while the lowest in case of NM-28 among all the varieties.

The criteria for the determination of Mungbean response to (Cd^{2+}), stress was changed in various growth attributes and shoot and root dry weight and seed characteristics at maturity. Earlier study showed that Mungbean is sensitive to increased levels of (Cd^{2+}) stress [12, 13]. The toxicity of (Cd^{2+}) has primarily assigned to shoot or root growth. In this study it was noted that among the Mungbean varieties, NM-28 indicated sensitivity for (Cd^{2+}) root and shoot dry weight, while NM-98 followed by NM-92 and Chakwal-97 were tolerant to increased levels of Cadmium. This indicated existence of genetic variability for (Cd^{2+}) tolerance in Mungbean [5]. Changes in economic parameters of any crop species are important because it remains the sole purpose of growing it [14]. In view of this importance, the determinations were carried out at maturity, so that the variety showing tolerance at this particular stage may be chosen and recommended for commercial scale cultivation in the areas where (Cd^{2+}) stress is problem. It is noted frequently in case of many crop species that the tolerance to prevailing stress conditions changes with the advancing age of plant [15]. So any material capable of showing tolerance towards the prevailing stress is selected for commercial cultivation [16, 14]. In this study, it was investigated that with few differences, NM-98 is the highly (Cd^{2+}) tolerant variety amongst the varieties. On the other hand NM-28 indicated sensitivity to (Cd^{2+}) when compared with rest of the varieties. This variety was therefore declared as the most sensitive to (Cd^{2+}) stress.

Experimental

Cadmium (Cd^{+2}) is one of the most toxic non essential and mobile metallic elements found in soils which affect plant growth. A net house experiment was conducted to determine the effects of different levels of Cadmium application on growth, yield and Cadmium (Cd^{+2}) in various Mungbean plant parts.

Table-2: Comparative changes in 100-seed weight and seed yield per plant of Mungbean varieties under the influence of increased level of Cadmium (Cd^{+2}) applied at reproductive stage.

Cd^{2+} level mg L^{-1}	Varieties										Mean
	NM-13-1	NM-1919	NM-2021	NM- 28	NM-51	NM-54	NM-88	NM-92	NM-98	Chak-97	
					Seed yield (g $plant^{-1}$)						
0	3.24	3.6	3.6	3.24	3.24	3.26	3.34	3.24	3.25t	3.27	3.32
3	2.64	2.76	2.76	2.68	2.68	2.78	2.66	2.68	2.88	2.88	2.74
6	2.49	2.59	2.58	2.00	2.49	2.09	2.04	2.09	2.45	2.35	2.31
9	2.39	2.39	2.39	1.78	2.35	1.83	1.86	1.80	2.18	2.04	2.10
12	1.88	1.78	1.8	1.48	1.91	1.64	1.56	1.54	2.02	1.92	1.75
Mean	2.52	2.62	2.62	1.23	2.53	2.32	2.29	2.27	2.55	2.49	2.44
Source of variance											
Treatments (T)						14.80**					
Varieties (V)						0.458**					
T × V						0.075*					
Error						0.047					
					100 Seed weight (g $plant^{-1}$)						
0	6.03	6.54	6.55	5.85	6.05	6.17	5.55	5.55	5.26t	5.01t	5.85ss
3	4.16	4.06	4.26	3.91	4.16	4.04	4.07	3.91	3.99	3.74	4.03
6	3.30	3.30	3.11	3.09	3.30	3.25	3.25	3.09	3.67	3.42	3.27
9	3.08	3.13	2.95	2.82	3.08	3.07	2.90	2.70	3.44	3.19	3.03
12	2.11	1.78	1.68	1.51	2.26	1.52	1.61	1.60	2.86	2.48	1.94
Mean	3.73	3.76	3.71	1.43	3.77	3.61	3.47	3.37	3.84	3.56	3.62
Source of variance											
Treatments (T)						83.20**					
Varieties (V)						0.590**					
T × V						0.44**					
Error						0.21					

Significant at ** P<0.01; *P < 0.05 and ns non-significant.

For this purpose, ten varieties of Mungbean were obtained from National Institute of Agriculture and Biology (NIAB), Faisalabad. The experiment was conducted in the net house of Botanical Garden, University of Agriculture, Faisalabad. The air dried soil was sieved (<2mm) and 8 kg soil was placed in polythene-lined earthen ware pots. Basal recommended fertilizers (NPK) were applied in solution form along with (Cd^{2+}) in the form of $CdCl_2$. $6H_2O$ @ 0, 3, 6, 9 and 12 mg Cd Kg^{-1} of soil.

Each treatment was replicated four times, mixed thoroughly with the soil and imposed 15 days after germination. Eight seeds each of ten varieties of Mungbean were sown. Sub soil water was pumped out and used for irrigating the crop, as and when required. After germination, the seedlings were thinned to five plants per pot and grown to maturity.

After harvest, plants were partitioned in to seed, shoot and root, washed and dried at 70 °C. The oven dried weights were recorded for root, shoot and 100-seed weights and the seeds were counted per plant of each treatment.

Determination of Cd^{2+} from Plant Samples

For the determination of Cadmium (Cd^{2+}), 0.5 g of dried milled (using Foss Tecator AB, Hoganas, Sweden high-speed mill) plant tissue was digested in a 5 ml mixture of nitric acid and perchloric acid (3: 1) on a heating block in a fume hood by gradually raising the temperature to 250°C for 2 to 3 h or till the time the sample became clear. The digested sample was diluted to 50 ml with distilled water and filtered. The samples were stored in a freezer until analyzed on atomic absorption spectrophotometer (Perkin Elmer, Model 3100 EDS, USA) using a fuel rich air–acetylene flame; 10 cm burner head, 357.9 nm wavelength, 0.7 nm slit and 20 mA lamp current. The sample values were compared with the standard series prepared by dissolving 1.17 g $CdCl_2$. $2.5H_2O$ in water to obtain 1000 mg L^{-1} stock followed by preparation of Cadmium (Cd^{2+}) standard series ranging from 0 to 80 mg/ L.

Statistical Analysis

The data regarding to all these parameters were analyzed statistically by using COSTAT computer package (CoHort software, Berkeley, CA). Duncan's new multiple range test at 5 % level of probability was used to compare the means [17].

Conclusion

Based on these findings, it can be concluded that the variety NM-98 showed higher productivity compared to NM-28 in relation to different treatments. It was also found that toxicity of cadmium has more pronounced effects on root than shoot system.

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