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Nickel Fertilization as Plant's Foes or Friends?- Evaluation by Yield Attributes of Mash [*Vigna mungo* (L.) Hepper] Genotypes

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ABSTRACT

Background: Nickel can act as micronutrient essential for nitrogen fixation in legume crops or it can cause toxicity when present in high concentration. Rhizospheric supplement of Nickel be at a dose not beyond its beneficial level.

Methods: An experiment was conducted for mash bean genotypes to evaluate the toxic level of Nickel concentrations. Seeds of four genotypes were sown in earthen pots filled with homogenized loamy soil. Nickel was added as its chloride salt solutions at the age of twenty days @ 15.0, 30.0, 45.0, 60.0, 75.0 and 90.0 mg kg^{-1} soil. Yield $plant^{-1}$ and its contributing factors were recorded at physiological maturity of crop.

Result: At low concentration, Nickel appeared to be non toxic and high doses reduced yield attributes. The lowest significantly effective dose which affected the parameters was 45 mg kg^{-1} except for number of legumes $plant^{-1}$ for which same was true at 60 mg kg^{-1}. While, the most effective dose was 45 mg kg^{-1} for each attributes. The observations were excluded from the ongoing trend when 15 mg kg^{-1} Nickel reflected positive role. Of the genotypes, MASH 80 was the least productive while MASH 88 was the most productive. In terms of grain numbers, MASH 97 was the least sensitive.

Key words: Genotypes, Grain weight, Mash, Nickel, Yield.

INTRODUCTION

For a plant, soil is a source of heavy metals which acts as the sink of heavy metals resourced from geogenic and anthropogenic activities. The part of soil which is connected with plant roots termed as 'rhizosphere' is zone where the physical, chemical and biological characteristics are different from rest of soil zones (Seshadri *et al.*, 2015).

With the passage of time, environment is getting polluted with heavy metals imposing a serious threat for human and even for whole ecosystem (Asad *et al.* 2019; Maleki *et al.* 2017). Finally, after entering in the food chain, these metals become the sources of toxicity for ecosystem functioning (Budijono *et al.*, 2017; Ali and Khan, 2019). In addition to soil, air and water are also being contaminated by heavy metals which ultimately affect the various trophic levels of food chain (Aendo *et al.* 2020; Biswas *et al.* 2019). Nickel (Ni) is a heavy metal with non-biodegradable properties, posing threats of environmental pollution and damaging biosphere and human health worldwide (Das *et al.*, 2008). Anthropogenic activities like metal smelting, municipal sludge, industrial effluents, fertilizers and pesticides are the main sources of Ni (Fabiano *et al.*, 2015).

Nickel (Ni) was included in the list of essential nutrients to plants in 1983 (Eskew *et al.*, 1983). Ni fertilization can promote fixation, metabolism and assimilation of Nitrogen (Tan *et al.*, 2000; Malavolta and Moraes, 2007; Khoshgoftarmanesh *et al.*, 2011; Hosseini and Khoshgoftarmanesh, 2013; Dalir and Khoshgoftarmanesh, 2015; Uruç Parlak, 2016; Kutman *et al.*, 2013, 2014; González-Guerrero *et al.*, 2014; Macedo *et al.*, 2016).

Blackgram (Mash bean) is one of the important pulse crops belongs to the Papilionaceae family (Mohanlal *et al.* 2021). The crop has genetic diversity for its growth and yield (Kumar *et al.* 2021; Priya *et al.* 2021). Legume plants are efficient in biological nitrogen fixation (BNF). During nitrogen fixation in root nodules, ammonia formed is converted into ureides (Collier and Tegeder, 2012). Ureides are converted to urea which then is metabolized by urease in which Ni plays important role (Zrenner *et al.*, 2006). Also, when nitrogenase reduces Nitrogen to ammonia, molecular hydrogen is produced which is re-oxidized by the hydrogenase enzyme requiring Ni (González-Guerrero *et al.*, 2014).

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In plants, excess Ni leads to inhibition of cell division, compromises plant growth, alters photosynthesis and plant water status, inhibits of Calvin cycle enzyme activities, represses nitrogen metabolism and generates oxidative stress, as well as blocks absorption of other essential nutrients metals (Sreekanth *et al.*, 2013; Pietrini *et al.* 2015; Georgiadou, 2018).

Mash bean [*Vigna mungo* (L.) Hepper], is an important pulse crops. In Pakistan, it is has high nutritive and economic value. While considering the dependence of mash bean on BNF and presence of Ni in soils, this study was hypothesized to find the dose of Ni for toxicity and fertilization mash bean genotypes

MATERIALS AND METHODS

The experiment was devised to evaluate the effects of various concentrations of Nickel on number of legumes plant^{-1}, number of grains fruit^{-1} and total yield plant^{-1}(g) of four mash bean [*Vigna mungo* (L.) Hepper]. The experiment was conducted in Botanic Garden of Bahauddin Zakariya University, Multan, Pakistan during 2020. Soil, free from contaminants and loamy in texture, was filled in pots which were lined with polyethylene sheet. Seeds of four mash genotypes *i.e.*, MASH 80, MASH 88, MASH 97 and MASH ES-1 were sown. The genotypes have their origin in Ayub Agricultural Research Institute (AARI), Faisalabad (Pakistan) and National Agricultural Research Centre (NARC) Islamabad (Pakistan). Five seeds sterilized with 0.1% (V/V) $HgCl_2$, similar in size and weights were germinated in each pot and thinning was performed after germination to maintain three seedlings in each pot to supply uniform nutrition in each pot. Normal irrigation and pesticide application were practiced for healthy growth of plants. For imposing metal pollution in soil, Nickel chloride of Sigma Aldrich, Japan was added to develop 15.0, 30.0, 45.0, 60.0, 75.0 and 90.0 mg kg^{-1} Nickel concentrations after twenty days of sowing. Pots without the addition of metals salts acted as control. Pots were placed with complete randomization of treatments and genotypes by design with four times replicated. Yield and its contributing factors were recorded at the maturity of crop (90 days age). Four plants per treatment in each replicate of all genotype were randomly selected and number of legumes plant^{-1}, number of grains fruit^{-1} and total yield plant^{-1} (g) was determined. The data collected were analyzed for analysis of variance using COSTAT computer package (CoHort Software, Berkeley, CA). Duncan's new multiple range test at 5% level of probability (Duncan, 1955) was used to compare means. Significant F values were tested for mean differences by LSD tests at 0.05% significance level, by using MSTAT-C Computer Statistical Programme.

RESULTS AND DISCUSSION

Number of legumes plant^{-1}

As revealed by Duncan's Multiple Range test (Table 1), Nickel adversely affected the frequency of legume differentiation and development to an extent according to the concentration and induced a substantial reduction in number of legumes. Concentrations ranges from 45 to 90 mg kg^{-1} have been found to alter legume number significantly while the lower level did not revealed statistically any clear cut differences from control. Documented data for mean

Table 1: Number of legumes plant^{-1} of [*Vigna mungo* (L.) Hepper] grown in Nickel supplemented soil (0, 15, 30, 45, 60 75 and 90 mg/kg soil).

Nickel	MASH 80	MASH 88	MASH 97	MASH ES-1	Treatments means
(mg kg^{-1} soil)	(LSD= ;n=4)				(LSD=1.348 ;n=16)
0 (Control)	23.000±1.678	25.500±1.568	23.500±3.502	22.000±2.978	23.500 a±2.626
15	23.000±2.070	24.670±2.112	23.000±1.582	23.164±0.642	23.458 a±1.690
	(0.00)	(3.254)	(2.127)	(-5.290)	(0.178)
30	22.000±1.218	24.670±0.942	21.000±1.678	21.670±2.526	22.334 a±2.096
	(4.347)	(3.254)	(10.638)	(1.500)	(4.961)
45	16.670±2.112	21.000±1.678	17.334±1.966	17.000±1.274	18.000 b±2.410
	(27.521)	(17.647)	(26.238)	(22.727)	(23.400)
60	12.000±1.218	18.164±2.398	14.164±0.898	13.164±2.204	14.372 c±3.136
	(47.826)	(28.768)	(39.727)	(40.163)	(38.842)
75	8.500±1.568	11.500±1.760	10.500±2.204	9.500±1.134	10.000 d±1.836
	(63.043)	(54.901)	(55.319)	(56.818)	(57.446)
90	4.334±1.272	8.330±1.760	8.500±1.266	6.500±1.988	6.916 e±2.254
	(81.156)	(67.333)	(63.829)	(70.454)	(70.570)
Genotypes	15.642 c±7.260	19.118 a±6.634	16.856 b±6.012	16.142 bc±6.452	
Means →		(-22.222)	(-7.761)	(-3.196)	

(LSD=1.018; n=28).

[Values are means ± SE]. In parentheses %age increase (-)/decrease (+) over untreated of row#1 or over MASH 80 for genotypes means are given. Similar letters show non significant differences among means.

performance, reflecting the role Nickel played in checking legume setting, revealed that maximum (70.570%) effect was by 90 mg kg^{-1} and minimum (0.178%) by 25 mg kg^{-1} applied Nickel. This reduction accompanying the accelerated level of Nickel was expressed in all the genotypes reaching at the peak when 90 mg kg^{-1} Nickel was applied. Although not statistically justified, but to a considerable extent of 5.290% increase in legume number was found when 15 mg kg^{-1} Nickel was added to soil for plants of MASH ES-1. Among the genotypes, MASH 88 revealed maximum (9.559) and MASH 80 revealed minimum (7.821) values. MASH 97 differed statistically by a value of 7.761% less than MASH 80.

Number of grains fruit^{-1}

Increasing amount of Nickel appeared to be responsible for gradual reduction in grain development (Table 2). This inhibitory effect of Nickel was statistically clear at concentrations from 45 to 90 mg kg^{-1} while reduction in grain number lower than statistical approach was detected and documented by the effect of low concentration. All the genotypes responded in a similar fashion. Nickel concentration of 15 mg kg^{-1}, when supplied to plants of MASH ES-1, revealed an upset of 4.133% increase over the control plants. Among the genotypes, differences were of non significant extent and MASH 97 revealed maximum (5.864) and MASH 80 revealed minimum (5.649) values.

Total seed yield plant^{-1} (g)

Nickel supplement in the soil medium had a negative linear relation with yield plants^{-1} (Table 3). Detrimental effects of metal were statistically obvious by its concentrations from 45 to 90 mg kg^{-1} while the difference from untreated plants were barely detectable by imposition of lower concentration. Nickel rendered the plants less productive at all levels of its application and the effect was in a concentration dependent manner. Maximum effect for reduction (86.241%) was by 60 mg kg^{-1} and minimum (2.058%) by 15 mg kg^{-1} Nickel. As regard individual genotypic response, maximum effect in all the genotypes was by 60 mg kg^{-1} but in MASH 80 the same was conceived by 30 mg kg^{-1}. On applying 15 mg kg^{-1} Nickel to plants of MASH ES-1, the observations were excluded from the ongoing trend and an increase of 9.892% over control in yield was recorded. Among the genotypes, MASH 88 revealed maximum (3.002) value being most productive and MASH 80 revealed minimum (2.496) as the least productive

Increasing concentration of metal decreased yield attributes (Tables 1-3). Many reports revealed that Ni toxicity significantly decreases the seed numbers, seed weight and total seed yield per plant (Tripathy *et al.*, 1981). Stress mediated by Ni causes reductions in flowers and fruits density (Balaguer *et al.* 2002). As a whole, reductions in total yield of plant can be ascribed to poor plant growth, development and reduced supply of nutrients to the reproductive organs (Ahmad *et al.* 2007).

During the growth of plant differentiation of flower and fruit is accompanied by a set of physiological changes in plant. These changes are controlled by a set of internal and external environmental factors including supply of nutrients. Any change in these factors can influence directly the growth and finally the reproductive phase of plant (Arun *et al.*, 2005). Heavy metal stress creates an imbalance in micro and macronutrient availability to plant. Nutrients levels change

Table 2: Number of grains fruit^{-1} of [*Vigna mungo* (L.) Hepper] grown in Nickel supplemented soil (0, 15, 30, 45, 60 75 and 90 mg/kg soil).

Nickel	MASH 80	MASH 88	MASH 97	MASH ES-1	Treatments means
(mg kg^{-1} soil)		(LSD= ; n=4)			(LSD=0.521; n=16)
0 (Control)	7.657±0.717	7.345±0.421	7.795±1.098	7.015±0.903	7.453a±0.799
15	6.855±0.696	7.282±0.985	7.792±0.654	7.305±0.422	7.308ab±0.728
	(10.474)	(0.857)	(0.038)	(-4.133)	(1.945)
30	6.602±0.869	6.687±0.824	7.045±0.445	6.870±0.762	6.801b±0.688
	(13.778)	(8.958)	(9.621)	(2.066)	(8.748)
45	6.290±0.430	5.765±0.775	5.227±0.393	5.772±0.781	5.763c±0.679
	(17.852)	(21.511)	(32.944)	(17.719)	(22.675)
60	4.912±0.512	5.685±0.310	4.707±0.815	4.620±1.329	4.981d±0.863
	(35.849)	(22.600)	(39.615)	(34.141)	(33.167)
75	4.237±0.780	4.585±0.485	4.245±0.818	5.242±0.738	4.577d±0.768
	(44.665)	(37.576)	(45.542)	(25.274)	(38.588)
90	2.990±0.452	3.347±0.940	4.237±0.788	3.627±0.515	3.550e±0.785
	(60.950)	(52.756)	(45.644)	(48.296)	(52.368)
Genotypes	5.649±1.663	5.813±1.520	5.864±1.669	5.778±1.484	5.776±1.567
Means →		(-2.089)	(-3.009)	(-2.283)	

(LSD= 0.393; n=28).

[Values are means ± SE]. In parentheses %age increase (-)/decrease (+) over untreated of row#1 or over MASH 80 for genotypes means are given. Similar letters show non significant differences among means.

Table 3: Total yield plant^{-1}(g) of [*Vigna mungo* (L.) Hepper] grown in Nickel supplemented soil (0, 15, 30, 45, 60 75 and 90mg/kg soil).

Nickel (mg kg^{-1} soil)	MASH 80	MASH 88 (LSD= ;n=4)	MASH 97	MASH ES-1	Treatments means (LSD=0.335 ;n=16)
0 (Control)	8.980±1.122	9.530±0.588	9.410±2.328	7.844±1.316	8.540a±1.490
15	8.070±1.372	9.200±1.754	9.140±1.038	8.620±0.482	8.756a±1.214
	(10.133)	(21.739)	(2.869)	(-9.892)	(2.058)
30	7.284±1.318	8.244±1.152	7.904±0.964	7.374±0.540	7.702b±1.010
	(18.886)	(13.494)	(16.004)	(5.991)	(13.847)
45	5.234±0.794	6.010±0.666	4.504±0.418	4.904±0.744	5.162c±0.830
	(41.714)	(36.935)	(52.136)	(37.480)	(42.259)
60	2.944±0.508	5.140±0.616	3.330±0.900	3.060±1.068	3.618d±1.166
	(67.216)	(46.065)	(64.612)	(60.989)	(59.530)
75	1.790±0.656	2.560±0.240	2.154±0.528	2.454±0.548	2.240e±0.556
	(111.731)	(73.137)	(77.109)	(68.714)	(74.944)
90	0.644±0.270	1.350±0.416	1.774±0.454	1.154±0.456	1.230f±0.562
	(92.828)	(85.834)	(81.147)	(85.288)	(86.241)
Genotypes	4.992b±3.19095	6.004a±3.134	5.460b±3.260	5.058b±2.858	5.378±3.098
Means →		(-20.272)	(-9.375)	(-1.322)	

(LSD=0.253; n=28)

[Values are means ± SE]. In parentheses %age increase (-)/decrease (+) over untreated of row#1 or over MASH 80 for genotypes means are given. Similar letters show non significant differences among means.

may influence the development of floral buds, flowers and fruit (Hayati *et al.*, 1995).

The reduction in growth and ultimately in yield might also be due to decreased photosynthesis as a consequence of reduction in photosynthetic pigments under metal stress (Fargasova, 2001; Jose *et al.* 2017) and sink limitations (Brun and Betts, 1984). Metal toxicity induced senescence of flower and pod may reduce number of viable pods and seeds (Sharma and Dubey, 2005).

Reduction of cytokinin contents by metal might be responsible for growth and finally the yield reduction by inhibition of cell division and cell elongation. This also may cause a decline in nitrate reductase activity (Bueno *et al.*, 1994). This reduction in nitrate reductase activity might be also due to nutrients limitations (Andrews *et al.*, 1999; Pilipovic *et al.* 2019).

Heavy metals accumulations in floral organs effectively alter plant reproductive potential of a floral organ like anther, pistil and nectarines. Heavy metal can negatively affect pollen viability, pollen senescence, pollen germination and pollen tube growth (Xun *et al.*, 2017; Tuna *et al.*, 2002).

Whenever, in the experiment the absence of decline in yield was found, could be attributed to the fact that low level of metal may just be accumulated in roots than in the shoot and the effect is restricted to the root only (Selvam and Wong, 2008).

CONCLUSION

The studies revealed that the application of low doses of Nickel acted as fertilizer and high doses created toxicity.

Conflict of interest

Authors have no conflict of interest and there was no funding body for research and manuscript.

Authors contribution

Ghulam Yasin designed and conducted experiment. Adeela Altaf and Ikram ul Haq participated in manuscript drafting. Aleem A. Khan and Shahzadi Saima participated in proof reading and correction of final version of manuscript.

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