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Glomus and putrescine based mitigation of cadmium induced toxicity in maize

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Abstract
Data of Intermodal length and node number were recorded at 30, 60 and 90 days after sowing of maize in *Rabi* season. The combination of putrescine and mycorrhiza showed the best combination for the mitigation of cadmium toxicity with reference to intermodal length and node number plants

Keywords: Agriculture, biotic, cadmium, density, energy, forage

Introduction
Maize (*Zea mays* L.) is known as queen of cereals because of its higher genetic yield potential among the cereals. In India, about 28% of maize produced is used for food purpose, about 11% as livestock feed, 48% as poultry feed, 12% in wet milling industry (for example starch and oil production) and 1% as seed (Abbasi *et al*., 2015) [15]. Heavy metal (s) are widespread pollutants of great concern as they are non-degradable and thus persistent. These metals are used in various industries from which effluents are consequently discharged into the environment. Heavy metals are metals with a density higher than 5 gcm^{-3}. Cadmium is a dangerous heavy metal having density 8.642 g cm^{-3} at 20^0 C. Cadmium (Cd) is a highly toxic trace element and has been ranked seventh among the top 20 toxic elements (Pinto *et al*., 2004) [2]. A polyamine is an organic compound having two or more primary amino groups –NH2 group Low-molecular-weight linear polyamines perform essential functions in all living cells.

Materials and Mehods
The present study was carried out to evaluate the compatibility of polyamines (putrescine) and mycorrhiza in the mitigation of induced toxic effect of cadmium at 30, 60 and 90 DAS of *Rabi* maize. The pot size for the experiment was in the diameter of 30 cm and 25 cm in height with capacity for 10 kg of soil, having a small hole at the bottom. Morphological observations were recorded at 30, 60 and 90 days after sowing with the help of standard scale and careful observation.

Results and Discussion
Average internodal length was significantly reduced by 17%, 43% and 35% when exposed to heavy metal stress (T6) as compared to control (T0) on dates of 30, 60 and 90 DAS of interval (Figure 1). Similarly, when plants were exposed to higher dose of heavy metal (T12) then its internodal length was significantly reduced by 53%, 44.85% and 44.14% as compared to control (T0) on the dates of proposed interval. Exogenous application of endo mycorrhiza in the soil (T7) showed the mitigation effect by increasing the internodal length by 1.68%, 9.17% and 7.92% as compared to T6 on the proposed dates of interval. Similarly when treatment T13 was compared to T12 the internodal length increased significantly by 3.50%, 3.37% and 1.24% on proposed dates of intervals. In comparison to T6, the exogenous application of putrescine (T8) showed mitigation of internodal length by 2.82%, 15.94% and 13.95%. The average internodal length significantly enhanced as compared to T6 by 6.54%, 21.18% and 17.57% when treated with higher dose of putrescine (T9) with respect to T8. Similarly, when treatment T14 was compared with T12 the internodal length increased significantly by 6.97%, 8.77% and 4.22% on. The average internodal length was significantly enhanced as compared to T12 by 10.91%, 14.00% and 6.67% when treated with higher dose of putrescine (T15) with respect to T14. The combination of putrescine and mycorrhiza showed the best mitigation effect by increasing the internodal length in treatment T10 by 12.16%, 29.84% and 23.64% with respect to treatment T6 on proposed dates of interval.
When treatment T11 was compared with treatment T6 then significant internodal length increased by 13.74%, 37.51% and 30.29%, respectively.

Similar effect was seen in the treatment (T16) with respect to treatment T12. Where internodal length was found to significantly increase by 14.17%, 19.63% and 9.67%, respectively. The treatment T17 was found to increase significantly by 15.67%, 21.93% and 10.89% with respect to T12. So, the combination of putrescine and mycorrhiza showed the best combination for the mitigation of cadmium toxicity for the internodal length. Cd does not have any beneficial physiological role in plants, but when accumulated, it affects all aspects of growth and development. In plants, Cd is one of the most readily absorbed and most rapidly translocated heavy metals, and can cause numerous morphological and physiological changes even at low concentrations (Auda *et al*., 2011) [3]. At the morphological level, an excessive amount of Cd causes inhibition of plant growth, photosynthesis, enzyme function and cell metabolism in addition to disturbances in plant-water relationships (Azizian *et al*., 2013 Courbot *et al*., 2004, Cheng *et al.*, 2006) [4, 5, 6] . These effects are strongly dependent upon the plant species and the level of Cd applied. Involvement of PAs in modulating plant physiology and biochemistry to improve growth performance under metal stress (Da-lin *et al*. 2011) [7]. Node number was significantly reduced by 3.84%, 36% and 20% when exposed to heavy metal stress (T6) as compared to control (T0) on dates of 30, 60 and 90 DAS of interval. Similarly, when plants were exposed to higher dose of heavy metal (T12) its average node number was significantly reduced by 38.46%, 63% and 45% as compared to control (T0). Exogenous application of endomycorrhiza in the soil (T7) showed ameliorative mitigation effect by increasing the average node number by 1.92%, 10.91% and 1.42% as compared to T6 on the proposed dates of interval. Similarly, when treatment T13 was compared to T12 the average node number increased significantly by 15.38%, 7.27% and 4.28% on the proposed dates of interval. In comparison to T6, the exogenous application of putrescine (T8) showed mitigation of average node number with 7.69%, 12.72% and 7.14% increase on proposed dates of interval. The average node number was significantly enhanced as compared to T6 by 13.46%, 13.69% and 8.57% when treated with higher dose of putrescine (T9) with respect to T8. Similarly, when treatment T14 was compared with T12 the average node number increased significantly by 17.30, 18.18% and 10.0% on proposed dates of interval. The average node number was significantly enhanced as compared to T12 with 23.07%, 25.45% and 10.71% increase when treated with higher dose of putrescine (T15) with respect to T14. The combination of putrescine and mycorrhiza showed the best mitigation effect by increasing the average node number in treatment T10 by 19.23%, 14.54% and 10.0% with respect to treatment T6. When treatment T11 was compared with treatment T6 significant average node number was increased by 23.07%, 15.45% and 11.42%, respectively. Similar effect was seen in the treatment (T16) with respect to treatment T12, and in this treatment, the average node number was found to incresase significantly by 28.84%, 32.72% and 11.42% respectively. The treatment T17 was found significant with 50.0%, 34.54% and 14.28% increase with respect to T12. So, the combination of putrescine and mycorrhiza showed the best combination for the mitigation of cadmium toxicity for the average number of node. Deng *et al*. (2016) reported that Cd in the nutrient solution produced growth inhibition in lettuce plants, the growth of lettuce shoots was significantly reduced after 14 days when compared to the control.

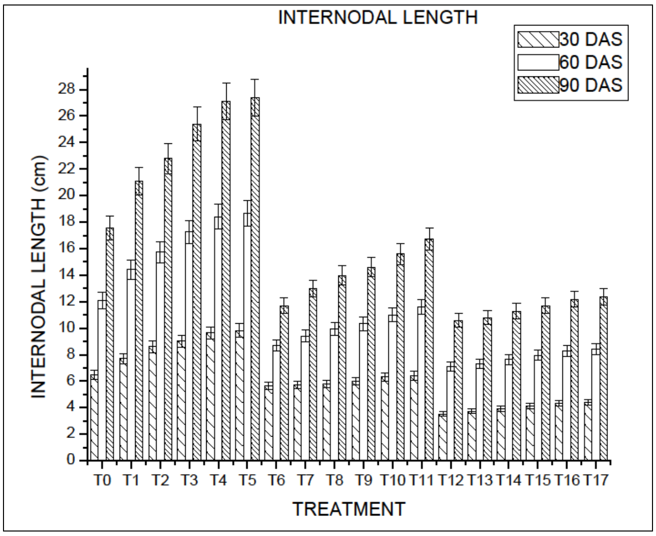

Fig 1: Effect of putrescine and mycorrhiza on Internodal length (cm) in maize under cadmium stress condition.

where, DAS=Days after sowing. Data are in the form of Mean ± SEM. S=Significance at $P\leq0.05$ and $P\leq0.01$, NS= Non-Significant at $P\leq0.05$ and $P\leq0.01$ using Origin 6.1. T0= Control, T1=Control + Mycorrhiza, T2=Control + 2.5mM Putrescine, T3=Control + 5mM Putrescine, T4= Control + 2.5mM Putrescine + Mycorrhiza, T5=Control + 5mM Putrescine + Mycorrhiza, T6=0.07% $Cd(NO_3)_2$, T7=0.07% $Cd(NO_3)_2$ + Mycorrhiza, T8=0.07% $Cd(NO_3)_2$ + 2.5mM Putrescine, T9=0.07% $Cd(NO_3)_2$ + 5mM Putrescine, T10=0.07% $Cd(NO_3)_2$ + 2.5mM Putrescine + Mycorrhiza, T11=0.07% $Cd(NO_3)_2$ + 5mM Putrescine + Mycorrhiza, T12=0.15% $Cd(NO_3)_2$, T13=0.15% $Cd(NO_3)_2$ + Mycorrhiza, T14=0.15% $Cd(NO_3)_2$ + 2.5mM Putrescine, T15=0.15% $Cd(NO_3)_2$ + 5mM Putrescine, T16=0.15% $Cd(NO_3)_2$ + 2.5mM Putrescine + Mycorrhiza, T17= 0.15% $Cd(NO_3)_2$ + 5mM Putrescine + Mycorrhiza.

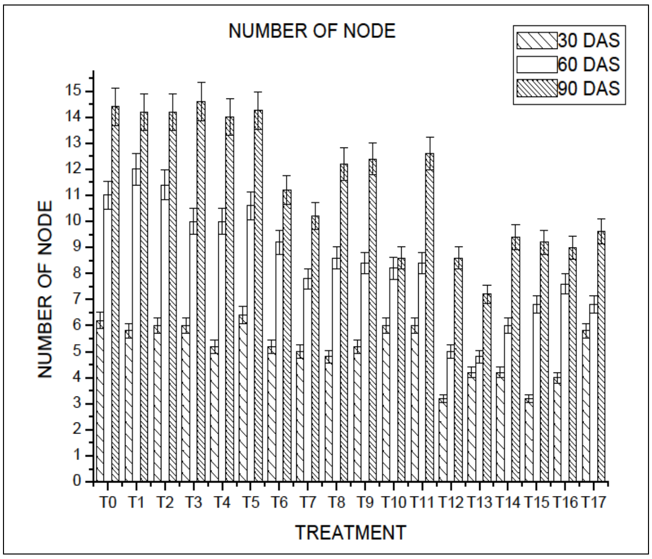

Fig 2: Effect of putrescine and mycorrhiza on Node number (plant^{-1}) in maize under cadmium stress condition

where, DAS=Days after sowing. Data are in the form of Mean ± SEM. S=Significance at $P\leq0.05$ and $P\leq0.01$, NS= Non-

Significant at $P \leq 0.05$ and $P \leq 0.01$ using Origin 6.1. T0= Control, T1=Control + Mycorrhiza, T2=Control + 2.5mM Putrescine, T3=Control + 5mM Putrescine, T4= Control + 2.5mM Putrescine + Mycorrhiza, T5=Control + 5mM Putrescine + Mycorrhiza, T6=0.07% $Cd(NO_3)_2$, T7=0.07% $Cd(NO_3)_2$ + Mycorrhiza, T8=0.07% $Cd(NO_3)_2$ + 2.5mM Putrescine, T9=0.07% $Cd(NO_3)_2$ + 5mM Putrescine, T10=0.07% $Cd(NO_3)_2$ + 2.5mM Putrescine + Mycorrhiza, T11=0.07% $Cd(NO_3)_2$ + 5mM Putrescine + Mycorrhiza, T12=0.15% $Cd(NO_3)_2$, T13=0.15% $Cd(NO_3)_2$ + Mycorrhiza, T14=0.15% $Cd(NO_3)_2$ + 2.5mM Putrescine, T15=0.15% $Cd(NO_3)_2$ + 5mM Putrescine, T16=0.15% $Cd(NO_3)_2$ + 2.5mM Putrescine + Mycorrhiza, T17= 0.15% $Cd(NO_3)_2$ + 5mM Putrescine + Mycorrhiza.

Conclusion

The decrease in internodal length was noticed in both the higher doses of heavy metal treatments (0.07% Cd $(NO_3)_2$) and (0.15% Cd $(NO_3)_2$) and the significant increase was noticed in the treatment of putrescine and mycorrhiza. The decrease in number of nodes was also noticed in both the higher doses of heavy metal treatment (0.07% Cd $(NO_3)_2$) and (0.15% Cd $(NO_3)_2$) and the significant increase in the treatment of putrescine and mycorrhiza in combination was recorded.

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