Plant Archives Vol. 20, Supplement 2, 2020 pp. 3487-3492 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

BIOCHEMICAL ALTERATION OF MUSTARD GROWN UNDER TIN CONTAMINATED SOIL

Monika Sharma[1*], Prasann Kumar [1, 2*]
[1]Department of Agronomy, School of Agriculture, Lovely Professional University, Jalandhar, Punjab, 144411, India
[2]Climate Mitigation and Sustainable Agricultural Laboratory, Divisions of Research and Development
Lovely Professional University, Jalandhar, Punjab, 144411, India
Email: prasann0659@gmail.com

Abstract

Increasing demonstrative and man-induced behavior has made soils polluted all over the world leads to the health of the people. Nowadays, heavy metal stress influences a great decrease in the quality and quantity of the agricultural produce which ultimately leads to a great threat to the population health. An increase in bioavailable Tin (Sn) in the environment can contribute to its bioaccumulation in crops, which ultimately leads to the health of the people consuming the crops. The increasing concentration of heavy metals in soil affects the quality of the crops which can ultimately lead to the health of the people. Tin is one of these which affect the quality of the product but only when applied in higher concentration. Its concentration is toxic only when it is applied in a higher dose. The metal Tin (Sn) is produced using coal in a furnace to reduce the oxide ore and affect plant growth and quality to a greater extent. A pot experiment was conducted to check the effect of Tin (Sn) in a mustard plant. The main aim of this study is to mitigate the rhizosphere Tin (Sn) by mycorrhiza fungi with special reference to biochemical changes. In this study we perform the different biochemicals of plants viz; Total soluble sugar, Total soluble protein, Chlorophyll index, catalase activity to check the effects of Tin (Sn) on the plant growth and development. For this, Sn toxicity is created in the soil with stannous chloride (50ppm). 150 spores of Mycorrhiza fungi per kg of soil are also added to mitigate the effect of Sn in the plants. There is a significant increase in all the biochemical activities in treatment T1 (Mycorrhiza) as compared to the control (T0) and a slight decrease in treatment T2 in which metal (Sn) stress is there. Therefore, Mycorrhiza shows better results in the mitigation of Tin (Sn) stress.

Keywords**:** Agriculture, Biological, Chlorophyll, Environment, Growth, Injury, Membrane, Mitigation, Stability, Tin.

Introduction

Tin is a chemical element with the symbol Sn and atomic no. 50 and atomic weight 118.710. The Discovery of Tin has been taking place around 3500 BC. Tin (Sn) is a naturally occurring heavy metal in the earth's crust. Its average concentration in the earth's crust is about 2 mg/kg. Due to the natural weathering of rocks, it becomes a part of many soils. Tin (Sn) is found in two oxidative states, stannous (+2) and stannic (+4) (Kumar and Dwivedi, 2018a; Kumar *et al*., 2018b; Kumar *et al*., 2018c; Kumar and Dwivedi, 2018dl Kumar *et al*., 2018e; Kumar and Pathak, (2019f); Kumar *et al*., 2019g; Siddique *et al*., 2018h; Siddique *et al*., 2018i; Pathak *et al*., 2017j; Prakash *et al*., 2017k; Kumar and Mandal, 2014L). The normal range of Tin (Sn) in unpolluted soils is less than or between 1 mg/kg to 200 mg/ kg (Shacklette & Boerngen, 1984). Usually, Tin is used in canned foodstuffs or Tin cans are used for various energy drinks. But a limited concentration of Tin is required in the cans. The blind use of the metal concentration can lead to the hazardous effects in population and environment both. The main source of heavy metal is excessive use of fertilizers, mining industries, and smelting industries, sewage, and sludge prone areas, etc. At present heavy metals are used in rechargeable batteries which leads to the environmental pollution (Kumar, 2018vii; Kumar, 2018viii; Kumar and Pathak, 2018ix; Kumar and Pathak, 2018x; Kumar and Pathak, 2018xi; Kumar *et al*., 2018xiii; Kumar and Pathak, 2018xiv). In the environment, the concentration of Tin is different in nature as well as man-induced conditions i.e. agriculture, mining and industrialization activities (Ashraf *et al*., 2011). In some areas, Tin concentration exceeds higher reaching up to 1000 mg/kg due to these increase in the agricultural and mining practices (Kumar *et al*., 2014m; Kumar *et al*., 2014n; Kumar, 2013o; Kumar and Dwivedi, 2015p; Gogia *et al*., 2014q; Kumar, 2014r; Kumar *et al*., 2012s; Mishra *et al*., 2012t; Kumar *et al*., 2011u; Kumar *et al*., 2011v; Kumar and Pathak, 2016w; Pathak *et al*., 2016x; Kumar *et al*., 2018y; Kumar *et al*., 2018z). Tin as lower concentration usually not affect plant growth but its higher concentration affects the plant and human health. Its toxicity causes the disease like fatigue, headaches, diarrhea, vomiting, muscular weakness and paralysis, anemia, excessive damage to the liver and kidneys, and affects the various levels of neurotransmitters in the brain (Kumar *et al*., 2018aa; Kumar *et al*., 2018bb; Kumar *et al*., 2018cc; Kumar and Dwivedi, 2018gg; Kumar *et al*., 2018ff; Kumar *et al*., 2018cd; Kumar and Pathak, 2018kk; Kumar and Pathak, 2018pq; Singh *et al.,* 2020a; Singh *et al*., 2020b; Sood *et al*., 2020; Bhadrecha *et al.,* 2020; Singh *et al*., 2020c; Sharma *et al*., 2020; Singh *et al*., 2020d; Bhati *et al*., 2020; Singh *et al*., 2019 and Sharma *et al*., 2019). Nowadays, Tin toxicity is going to be found in the crops which are incorporated in the plant tissues and affect the people who consume these crops. Therefore, it is important to understand the uptake of Tin (Sn) by different crops and its accumulation in different crops to save gourd our food products. 40-700 mg/kg Tin (Sn) concentration in sewage and sludge is used for the production of crops in some areas which are toxic to human health (Kumar, 2018i; Kumar, 2018ii; Kumar, 2018iii; Kumar, 2018iv; Kumar, 2018v; Kumar, 2018vi; Kumar, 2018vii; Kumar, 2018viii; Kumar and Pathak, 2018ix; Kumar and Pathak, 2018x; Kumar and Pathak, 2018xi; Kumar *et al*., 2018xiii; Kumar and Pathak, 2018xiv; Kumar and Pathak, 2018xv; Kumar and Pathak, 2018xvi; Kumar and Pathak, 2018xvii; Kumar and Pathak, 2018xviii).

Materials and Methods

Growing conditions and sample preparation:

A pot experimented was conducted at agriculture farm, School of agriculture, Lovely Professional University, Phagwara region, Punjab which is a North-Eastern state and comes under central plain zones. In Phagwara, the average annual temperature is 24.1 °C / 75.3 °F and the rainfall is 686 mm / 27.0 inch. The soil of central Punjab ranges from sandy loam to clayey with pH value ranges from 7.8 to 8.5. The temperature falls to 5°C in winters and maximum up to 40-45°C in summers. Mustard *(Brassica juncea, L.)* seeds variety PBR-357 were grown in 12 pots having dimensions 30×25 diameter and height respectively, in a completely randomized design. The seeds are collected from the Punjab Agriculture University Ludhiana. Four treatments (T, T_1, T_2, T_3) and three replications (R_1, R_2, R_3) were taken to check and analyze the results. Before 2 days of sowing, Tin (Sn) toxicity is created in the soil of the pots by the application of Stannous chloride ($SnCl_2.2H_2O$) 50 ppm per 10 kg of soil and Mycorrhiza 150 spores per kg of soil was also added as a treatment. Leaf samples of 15 days after sowing were taken for the estimation of different biochemical in the plant (Table 1).

Table 1: Treatment details

Treatments	Details of the Treatments
T	Control
T_1	Mycorrhiza (150 spores per kg of soil)
T_2	Tin (Sn) 50ppm conc. per 10 kg of soil
T_3	Tin (Sn) (50 ppm) + Mycorrhiza (150 spores)

Overall detail and layout of the experiment

Table 2: Experimental Details

S. No.	Particulars	Details
1.	Design	CRD
2.	Genotype	PBR-357
3.	No. of Treatments	4
4.	No. of Replications	3
5.	Soil per pot	10 Kg
6.	Total number of pots	4*3= 12

Observations to be recorded are:

The leaf sample of 15 days after sowing (DAS) was taken for the estimation of biochemical changes in the plant. The standard procedure adopted for the estimation of biochemicals for different treatment are given below:

1. **Total Soluble Sugar:** It is estimated by the method proposed by Sadasuvam and Manickam (1992).
2. **Total Soluble Protein:** It is estimated by the method proposed by Bradford, (1976).
3. **Total Phenols:** For the estimation of total phenol the protocol of Mahadevan and Sridhar (1982) is followed.
4. **Chlorophyll Index:** SPAD meter is used for the measurement of the Chlorophyll index.
5. **Catalase Activity:** the activity of enzyme Catalase was measured according to the protocol given by Aebi *et al* (1983).

Results and Discussions

1. Total Soluble Proteins

For the estimation of Total Soluble Sugars, we follow the protocol given by Sadasuvam and Manickam (1992). For this, firstly we centrifuge our samples at 15000rpm for 15 min. and then observations were recorded by spectrophotometer at 595nm wavelength. The treatment T2 (Sn) (50 ppm) shows a 60% decrease in protein content and T3 (Mycorrhiza (150 spores per kg) + Sn (50 ppm) shows a 40% decrease as compared to T0 and T1. T1 (Mycorrhiza) shows a great increase in protein content i.e. 60%. The above study shows that there is a significant decrease in the protein content where there is Tin contaminated soil (Fig. 1).

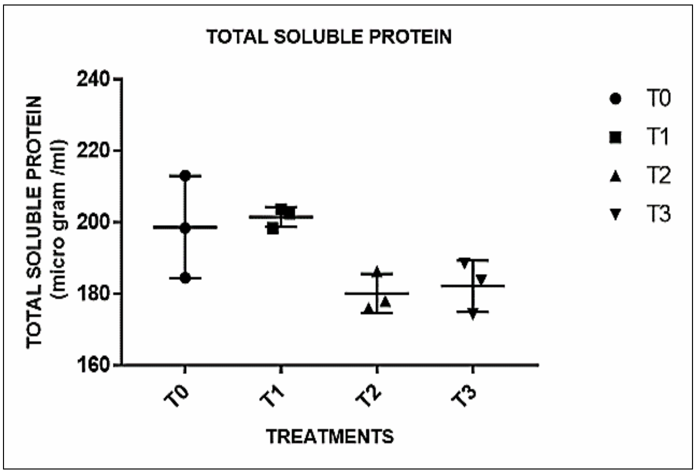

Fig. 1: Total Soluble Proteins (TSP)

2. Total Phenols

To estimate the Total Phenols, we follow the protocol given by Mahadevan and Sridhar (1982). For this, we make observations on a spectrophotometer at 650 nm wavelength. According to this study, treatment having mycorrhiza shows a great increase in the total phenol content i.e. 80% as compared to the control and treatment with heavy metal (Sn) shows a 63% decrease in total phenols as compare to the control. Treatment having Sn + Mycorrhiza shows a slight decrease i.e. 10% as compare to control (Fig. 2).

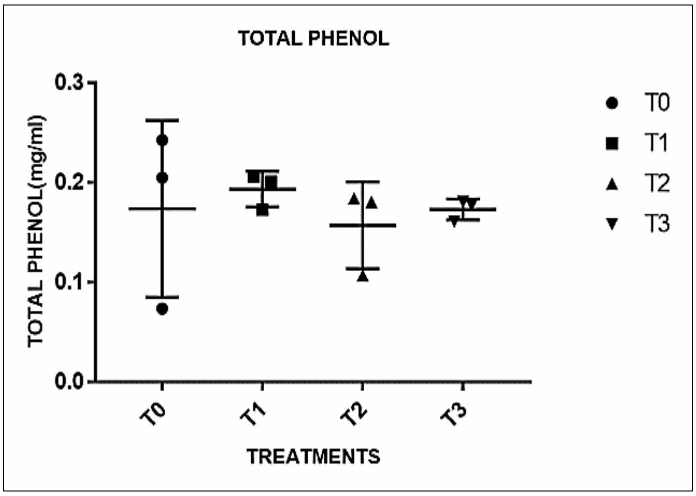

Fig. 2 : Total Phenols

3. Chlorophyll Index

We use the SPAD meter to determine the chlorophyll index of the mustard leaves. For this, we put the instrument on 4-5 leaves of the plant and take its average as an index. Treatment first having Mycorrhiza shows a higher chlorophyll index (75%) as compared to all three. There is a significant decrease in treatment having Tin and Tin + Mycorrhiza i.e. 65% and 63% respectively as compared to control (Fig. 3).

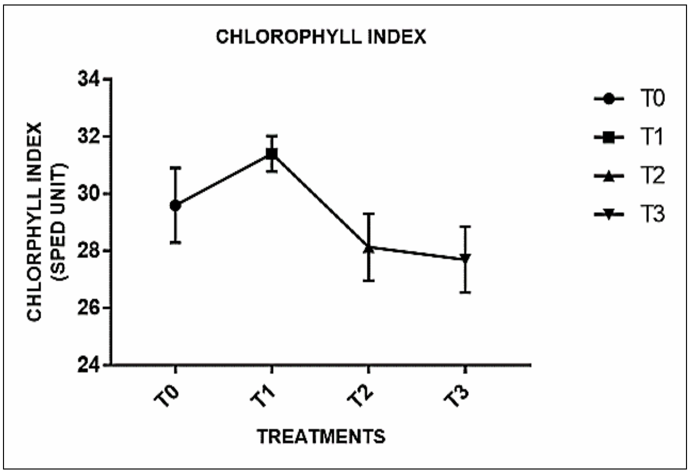

Fig. 3 : Chlorophyll Index

4. Catalase

To estimate the catalase activity, we perform the protocol of Aebi *et al.* (1983). For determining catalase activity, we take reading on a spectrophotometer at 240nm wavelength. My study shows that there is a slight increase in the treatment having Mycorrhiza and a slight decrease in the treatment having metal stress i.e. 9.50% and 10% respectively as compared to the control. Treatment having Tin + Mycorrhiza shows a 12% increase in catalase as compare to control. The treatment shows a slight decrease in catalase where there is Tin (Sn) contaminated soils. Whereas other results are close to each other. The above results show that Tin does not affect the catalase activity of the plants too much extent (Fig. 4).

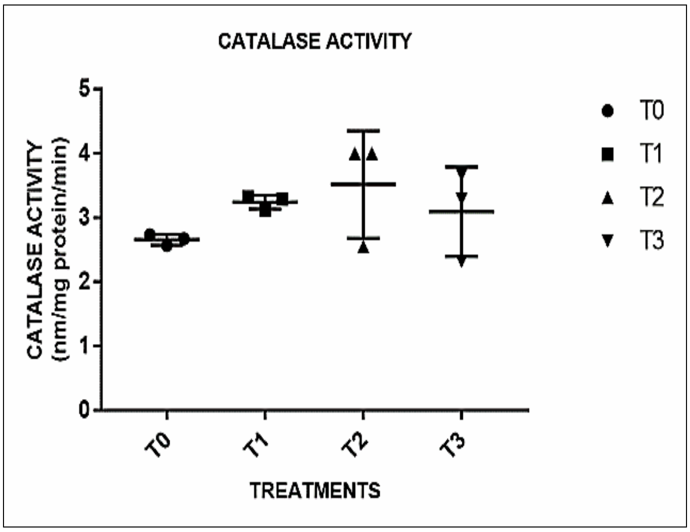

Fig. 4 : Catalase activity

5. Total Soluble Sugars

For the estimation of Total Soluble Sugars, we follow the protocol of Sadasuvam and Manickam (1992). To determine the sugar content observations are taken on a spectrophotometer at 620nm wavelength. According to my study, treatment having Mycorrhiza and Tin + Mycorrhiza shows a significant increase in Total Soluble Sugars i.e. 43% as compare to control. In the treatment of having mental stress, there is a 41% decrease in Sugar content as compare to treatments having Mycorrhiza in the soil. This shows that there is a visual increase in the Sugar level of the plants growing in the soils having Mycorrhiza (Figure 5).

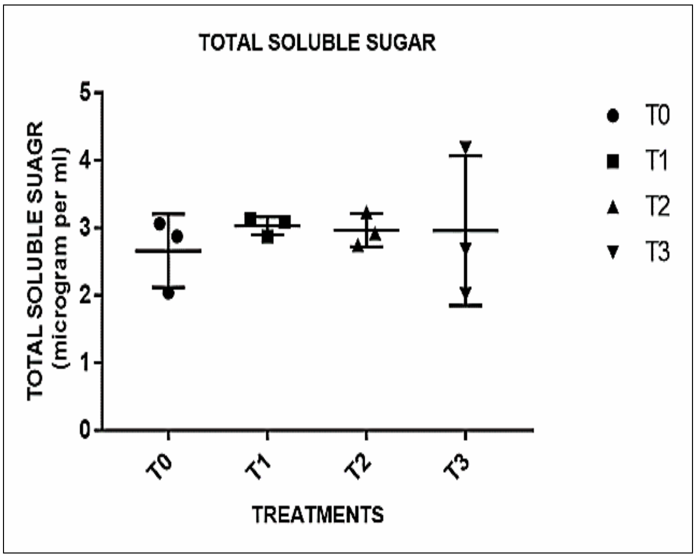

Fig. 5 : Total Soluble Sugars

Conclusion and Recommendations

Under natural conditions, Tin does not show any toxicity to the plants as well as humans. But a significant increase in the anthropogenic activities or industrialization of its concentration in the soil increases. Its higher concentration affects the growth and quality of the food products and ultimately human health. The above study gives results that treatment having high Sn concentration shows a decrease concerning biochemical and treatment having Mycorrhiza alone shows a comparatively good increase. On higher concentration, Sn affects the plant cell membrane first, enters the plant tissues and subsequently affects the quality of the produce. Tin stress slightly affects the catalase activity of the mustard plant while Mycorrhiza shows good results for all the biochemical. Mycorrhiza shows better results in the mitigation of Tin (Sn) stress therefore, this study recommends Mycorrhiza to mitigate Tin stress in the mustard plant.

Acknowledgments

I would like to express the depth of my appreciation to the honorable guide and 2* author of this paper for his suggestions and guidelines. The authors gratefully acknowledge the support provided by Lovely Professional University. The authors also want to thank the reviewers of this manuscript for their inputs and guidance. The opinions expressed and conclusions arrived at, are however those of the authors. I would also like to thank my friends who helped me during sample collection and performing by chemicals.

Author Contributions

The study was designed by P.K. and M.S. the biochemical protocolizations were established, the experiment was carried out and the data analyzed and interpreted were collected. The paper has been written by the author.

Conflict of Interest Statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

References

Bhadrecha, P.; Bala, M.; Khasa, Y.P.; Arshi, A.; Singh, J. and Kumar, M. (2020). Hippophae rhamnoides L. rhizobacteria exhibit diversified cellulase and pectinase activities. Physiology and Molecular Biology of Plants.

Bhati, S.; Kumar, V.; Singh, S. and Singh, J. (2020). Synthesis, Characterization, Antimicrobial, Anti-tubercular, Antioxidant Activities and Docking Simulations of Derivatives of 2-(pyridine-3-yl)-1H-benzo[d]imidazole and 1,3,4-Oxadiazole Analogy. Letters in Drug Design & Discovery.

Gogia, N.; Kumar, P.; Singh, J.; Rani, A. Sirohi, Kumar, P. (2014q). "Cloning and molecular characterization of an active gene from garlic (*Allium sativum* L.)" International Journal of Agriculture, Environment and Biotechnology, 7(1): 1-10.

Kumar P, Dwivedi, P. (2018d). "Putrescine and Glomus Mycorrhiza moderate cadmium actuated stress reaction in *Zea mays* L. utilizing extraordinary reference to sugar and protein" Vegetos. 31 (3): 74-77.

Kumar P. and Pathak S. (2018kk). Short-Term Response of Plants Grown under Heavy Metal Toxicity, Heavy Metals, Hosam El-Din M. Saleh and Refaat F. Aglan, Intech Open.

Kumar P.; Pathak S. (2018xii). Tobacco Cultivation: A crop of Economic Value. In: Cultivation Techniques in Modern Agriculture [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-03-0][p. 76]

Kumar P.; Pathak S. (2018xiv). Absorption of Water by Plants with Special Reference to the physiology of Cells. In: Plant Physiology: Stress, Disease, and Management [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-00-9][p. 9]

Kumar P.; Pathak S. (2018xv). Seed Dormancy with Special Reference to Crop Growth Physiology –Functional Relationship. In: Plant Physiology: Stress, Disease, and Management [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-00-9][p. 27]

Kumar P.; Pathak S. (2018xvi). Role of Polyamines and mycorrhiza for the mitigation of salinity stress in Sorghum. In: Plant Physiology: Stress, Disease, and Management [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-00-9][p. 51]

Kumar P.; Pathak S. (2018xvii). Crop Production: Concepts and Practices. In: Crop Plants: Issues and Management [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-02-3][p. 6]

Kumar P.; Pathak S. (2018xviii). Maize: the Queen of Cereals. In: Crop Plants: Issues and Management [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-02-3][p. 29].

Kumar P.; Pathak S. 2018xiii. Use of Robotics for Agricultural Innovation. In: Plant Physiology: Stress, Disease, and Management [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-03-0][p. 130]

Kumar P.; Siddique A.; *et al.* (2018ff). Cadmium Induced Changes in Total Starch, total Amylose and Amylopectin Content in Putrescine and Mycorrhiza Treated Sorghum Crop. Nature Environment and Pollution Technology. 18(2): 525-530 2019.

Kumar, P, Pathak, S, Kumar, M and Dwivedi, P. (2018cd). Role of secondary metabolites for the mitigation of cadmium toxicity in sorghum grown under mycorrhizal inoculated hazardous waste site. In: Biotechnological Approaches for Medicinal and Aromatic Plants. Springer, Singapore, pp.199-212.

Kumar, P. (2013o). "Cultivation of traditional crops: an overlooked answer. Agriculture Update, 8(3): 504-508.

Kumar, P. (2014r). "Studies on cadmium, lead, chromium, and nickel scavenging capacity by in-vivo grown Musa paradisiacal. using atomic absorption spectroscopy" Journal of Functional and Environmental Botany, 4(1): 22-25.

Kumar, P. (2018i). Role of Paclobutrazol for the mitigation of waterlogged stress in *Cicer arietinum* L. In: Stress Tolerance and Plant Productivity [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 1-14.

Kumar, P. (2018ii). Crop Adaptation and Their Distribution. In: Stress Tolerance and Plant Productivity [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 15-30.

Kumar, P. (2018iii). Herbicide selectivity and Resistance with special reference Agriculture crops. In: Stress Tolerance and Plant Productivity [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 58-70.

Kumar, P. (2018iv). Role of Rhizobium in Enhancing the yield and Yield attributes of crops with special references to chickpea [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 86-104.

Kumar, P. (2018v). Arsenic Induced toxicity in Plants with Special Reference to their Oxidative Damage. [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 86-104.

Kumar, P. (2018vi). Metals and Micronutrients-Food Safety Issue. [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 126-147.

Kumar, P. (2018vii). Role of Farming Practices on Environment. [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 148-158.

Kumar, P. (2018viii). Irrigation with Special Reference to Crop Production. [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 159-177.

Kumar, P. and Dwivedi, P. (2018gg). Ameliorative Effects of Polyamines for Combating Heavy Metal Toxicity in Plants Growing in Contaminated Sites with Special Reference to Cadmium. CRC Press, Taylor & Francis Group, UK. pp. 404.

Kumar, P. and Pathak, S. (2018ix). Cultivation of Fodder and Forage Crops: with Special Reference to Berseem, Oat, Lucern, and Maize. In: Cultivation Techniques in Modern Agriculture [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 6.

Kumar, P. and Pathak, S. (2018pq). Listeria monocytogenes: Potent Clinical Hazard, Listeria Monocytogenes, Monde Alfred Nyila, IntechOpen.

Kumar, P. and Pathak, S. (2018x). Sugarcane Cultivation: A Significance Way for Sustainability. In: Cultivation Techniques in Modern Agriculture [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi] 31.

Kumar, P. Pathak, S. (2019f). "Responsiveness index of sorghum (*Sorghum bicolor* (l.) Moench) grown under cadmium contaminated soil treated with putrescine and mycorrhiza" Bangladesh J. Bot. vol.48 (1).

Kumar, P. Purnima *et al*. (2018e). "Impact of Polyamines and Mycorrhiza on Chlorophyll Substance of Maize Grown under Cadmium Toxicity" International Journal of Current Microbiology and Applied Sciences, 7(10): 1635-1639.

Kumar, P. Siddique, A. *et al*.; (2019g). "Role of Polyamines and Endo-mycorrhiza on Leaf Morphology of Sorghum Grown under Cadmium Toxicity" Biological Forum – An International Journal. 11(1): 01-05.

Kumar, P.; Dwivedi, P. (2015p). "Role of polyamines for mitigation of cadmium toxicity in sorghum crop" Journal of Scientific Research, B.H.U.; 59: 121-148.

Kumar, P.; Dwivedi, P. (2018a). "Cadmium-induced alteration in leaf length, leaf width and their ratio of glomus treated sorghum seed" Journal of Pharmacognosy and Phytochemistry, (6): 138-141.

Kumar, P.; Dwivedi, P.; Singh, P. (2012s). "Role of polyamine in combating heavy metal stress in stevia rebaudiana Bertoni plants under in vitro condition" International Journal of Agriculture, Environment and Biotechnology, 5(3): 185-187.

Kumar, P.; Harsavardhn, M. *et al*. (2018y). "Effect of Chlorophyll a/b ratio in Cadmium Contaminated Maize Leaves Treated with Putrescine and mycorrhiza" Annals of Biology, 34(3): 281-283.

Kumar, P.; Krishna, V.; *et al*. (2018cc). "Assessment of Scavenging Competence for Cadmium, Lead, Chromium and Nickel Metals by in vivo Grown *Zea mays* L. using Atomic Absorption Spectrophotometer, Annals of Ari-Bio Research, 23(2): 166-168.

Kumar, P.; Kumar S. *et al*. (2018b). "Glomus and putrescine based mitigation of cadmium-induced toxicity in maize" Journal of Pharmacognosy and Phytochemistry. 7 (5): .2384-2386.

Kumar, P.; Kumar, P.K.; Singh, S. (2014n). "Heavy metal analysis in the root, shoot and the leaf of psidium guajava l. by using atomic absorption spectrophotometer" Pollution Research, 33(4): 135-138.

Kumar, P.; Kumar, S. *et al*. (2018bb). "Evaluation of Plant Height and Leaf Length of Sorghum Grown Under Different Sources of Nutrition" Annals of Biology, 34(3): 284-286.

Kumar, P.; Mandal, B. (2014L). "Combating heavy metals toxicity from hazardous waste sites by harnessing scavenging activity of some vegetable plants" vegetos, 26(2): 416-425.

Kumar, P.; Mandal, B.; Dwivedi P. (2014m). "Phytoremediation for defending heavy metal stress in weed flora" International Journal of Agriculture, Environment & Biotechnology, 6(4): 587-595.

Kumar, P.; Mandal, B.; Dwivedi, P. (2011u). "Heavy metal scavenging capacity of *Mentha spicata* and *Allium cepa*" Medicinal Plant-International Journal of Phytomedicines and Related Industries, 3(4): 315-318.

Kumar, P.; Mandal, B.; Dwivedi, P. (2011v). "Screening plant species for their capacity of scavenging heavy metals from soils and sludges. Journal of Applied Horticulture, 13(2): 144-146.

Kumar, P.; Misao, L.; *et al*. (2018c). "Polyamines and Mycorrhiza based mitigation of cadmium-induced toxicity for plant height and leaf number in maize" International Journal of Chemical Studies, 6(5): 2491-2494.

Kumar, P.; Pandey, A.K.; *et al*. (2018aa). "Phytoextraction of Lead, Chromium, Cadmium, and Nickel by Tagetes Plant Grown at Hazardous Waste site" Annals of Biology, 34(3): 287-289.

Kumar, P.; Pathak, S. (2016w). "Heavy metal contagion in seed: its delivery, distribution, and uptake" Journal of the Kalash Sciences, An International Journal, 4(2): 65-66.

Kumar, P.; Pathak, S. (2018xi). Potato and Sugar beet Cultivation: A Sugar Crop with Poor Man's Friends. In: Cultivation Techniques in Modern Agriculture [Ed. Kumar P and Bharti P.K, Discovery Publication, New Delhi][ISBN: 978-93-88854-03-0][p. 55]

Kumar, P.; Yumnam, J. *et al*. (2018z). "Cadmium Induced Changes in Germination of Maize Seed Treated with Mycorrhiza" Annals of Agri-Bio Research, 23(2): 169-170.

Mishra, P.K.; Maurya, B.R.; Kumar, P. (2012t). "Studies on the biochemical composition of *Parthenium hysterophorus* L. in different season" Journal of Functional and Environmental Botany, 2(2): 1-6.

Pathak, S.; Kumar, P.; Mishra, P.K. and Kumar, M. (2017j). "Mycorrhiza assisted approach for bioremediation with special reference to biosorption", Pollution Research, Vol. 36(2).

Pathak, S.; Kumar, P.; Mishra, P.K.; Kumar, M. (2016x). "Plant-based remediation of arsenic-contaminated soil with special reference to sorghum- a sustainable approach for a cure". Journal of the Kalash Sciences, An International Journal, 4(2): 61-65.

Prakash, A. and Kumar, P. (2017k). "Evaluation of heavy metal scavenging competence by in-vivo grown *Ricinus communis* L. using atomic absorption spectrophotometer" Pollution Research, 37(2): 148-151.

Sharma, M.; Singh, J.; Chinnappan, P.; and Kumar, A. (2019). A comprehensive review of renewable energy production from biomass-derived bio-oil. Biotechnologia 100(2): 179-194.

Sharma, R.; Jasrotia, K.; Singh, N.; Ghosh, P.; Sharma, N.R.; Singh, J.; Kanwar, R. and Kumar, A. (2020). A Comprehensive Review on Hydrothermal Carbonization of Biomass and its Applications. Chemistry Africa, 3(1): 1-19.

Siddique, A. and Kumar, P. (2018h). "Physiological and Biochemical basis of Pre-sowing soaking seed treatments-An overview" Plant Archive, 18(2): 1933-1937.

Siddique, A.; Kandpal, G.; Kumar P. (2018i). "Proline accumulation and its defensive role under Diverse Stress condition in Plants: An Overview" Journal of Pure and Applied Microbiology, 12(3): 1655-1659.

Singh, S.; Kumar, V. and Singh, J. (2019). The effects of Fe(II): Cu(II) and Humic Acid on biodegradation of atrazine. Journal of Environmental Chemical Engineering, 8: 103539.

Singh, S.; Kumar, V.; Datta, S.; Dhanjal, D.S.; Sharma, K.; Samuel, J. and Singh, J. (2020). Current advancement and future prospect of biosorbents for bioremediation. Science of the Total Environment, 709: 135895.

Singh, S.; Kumar, V.; Datta, S.; Wani, A.B.; Dhanjal, D.S.; Romero, R. and Singh, J. (2020). Glyphosate uptake, translocation, resistance emergence in crops, analytical monitoring, toxicity, and degradation: a review. Environmental Chemistry

Singh, S.; Kumar, V.; Kapoor, D.; Kumar, S.; Singh, S.; Dhanjal, D.S.; Datta, S.; Samuel, J.; Dey, P.; Wang, S.; Prasad, R. and Singh, J. (2020). Revealing on hydrogen sulfide and nitric oxide signals co-ordination for plant growth under stress conditions. Physiologia Plantarum, 168(2): 301-317.

Singh, S.; Kumar, V.; Singla, S.; Sharma, M.; Singh, D.P.; Prasad, R.; Thakur, V.K. and Singh, J. (2020). Kinetic Study of the Biodegradation of Acephate by Indigenous Soil Bacterial Isolates in the Presence of Humic Acid and Metal Ions. Biomolecules, 10: 433.

Sood, M.; Sharma, S.S.; Singh, J, Prasad, R.; and Kapoor, D. (2020). Stress Ameliorative Effects of Indole Acetic Acid on Hordeum vulgare L. Seedlings Subjected to Zinc Toxicity. Phyton – International Journal of Experimental Botany, 89(1): 71-89.