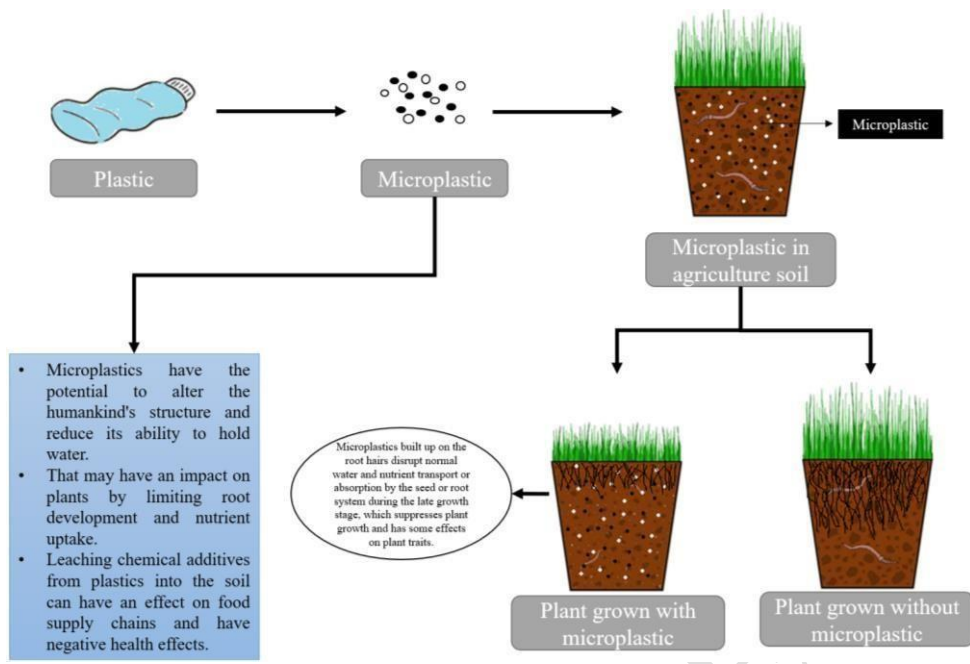


STUDY OF EFFECTS OF MICRO PLASTICS ON THE GROWTH OF PLANTS IN AGRICULTURAL SOIL

ABSTRACT

Plastics are a highly versatile material which are extensively used in majority of the industrial sectors in the world. Improper disposal of plastics have lead to accumulation in the environment and are broken down by natural degradation actions into finer minute particles known as micro plastics. These particles are causing a great threat to the environment by direct accumulation in water and soil and these leachates also contaminate agricultural soil thereby affecting the plant growth. The effects of artificially spiked Poly Vinyl Acetate (PVA) micro plastics soil at different concentrations (0%, 0.5 %, 1 %, 1.5%, 2%) on the growth parameters and nutrient contents of horse gram, green gram and chilli grown soil were analyzed. It was found that the Boron and the Sulphur concentrations showed drastic reduction at higher concentrations of PVA micro plastics in green gram, horse gram and chilli grown soil. The germination percentage, seedlings length and vigor index was also reduced due to the presence of PVA particles which may be suspected to hinder the growth of the seeds. The pH of the soil was found to be reduced to a very much lower extent due to the presence of PVA particles. The chlorophyll b got reduced at higher concentrations of micro plastics in horse gram and chilli. Whereas chlorophyll a only got reduced in horse gram at higher MP concentration. Hence this study can help to focus on future need of remediation of micro plastics contaminated soil.

Keywords: Micro plastics, leachates, density floatation, PVA micro plastics



- Microplastics have the potential to alter the humankind's structure and reduce its ability to hold water.
- That may have an impact on plants by limiting root development and nutrient uptake.
- Leaching chemical additives from plastics into the soil can have an effect on food supply chains and have negative health effects.

Graphical abstract

UNDER PEER REVIEW

INTRODUCTION:

Plastic is ambidextrous by nature, which makes it extremely advantageous to manufacture goods with economic value. The world's output of plastics has increased dramatically over the past 50 years, especially since the first large-scale manufacture of synthetic plastic (Bakelite) in the 1940s and 1950s [1, 2]. In actuality, 367 million metric tonnes (Mt) of plastics were created globally in 2020 [3]. Additionally, it has been calculated that between 1950 and 2020, more than 8000 Mt of plastic garbage were produced [1,4], and that 4900 Mt of the total amount of plastic ever manufactured will end up in landfills or the environment. Due to decades of plastic manufacture and use in almost every industry, micro plastics smaller than 5 mm, are becoming more and more common in the environment. These micro plastics can worsen human health when exposed to them, as they are capable of adsorbing hazardous substances. They are so light that they may be readily flung by themselves, and many aquatic creatures eat them because they mimic food. These micro plastics exist because they cannot be deteriorated by the action of microbes [17]. Microplastics are divided into two categories based on their source of production i.e primary micro plastics (made for industrial uses), and secondary micro plastics (produced by degradation of larger plastics overtime).

MPs have been found to enter agricultural soils by major agricultural methods such irrigation and organic fertilisation using compost made from municipal solid wastes, manure, or sewage sludge [6,13,14]. In contrast to sewage sludge, which can contain MPs from laundry, personal care products, and urban runoff, home waste compost can contain both plastic debris from packaging materials and food waste that has been contaminated with MPs [8-10]. Films from coated seeds and plastic coatings from slow-release fertilisers have also been found to be possible sources of MPs in agricultural soils [11,12]. Plants have the ability to alter the distribution depth of MPs in the soil profile at the root level. MPs can change soil structure when they are incorporated into the soil matrix [25]. .Microplastics harm plants in a number of ways, including i) blocking cell wall pores or cell connections, which prevent plant nutrients from being absorbed and transported; (ii) reducing or delaying seed germination by preventing water absorption; (iii) altering root and shoot growth [15,16]; and (iv) disrupting the balance of plant chlorophyll a/b ratios [17].

Microplastics are more likely to encourage the phytotoxicity of other soil pollutants when they are present near plant roots. The shape, size, type, and concentration of microplastics [15,18–20], as well as the kind of soil [14,21], all affect how much of an impact they have on the soil-plant system.

The agricultural systems are high receivers of MPs is majorly owing to soil management practices, and also due to atmospheric deposition [7]. Ironically, a variety of agricultural techniques used to boost crop yields and preserve soil quality, moisture, and nutritional status may have a negative impact on soil health due to MP build up [5,7]. MPs have been found to enter agricultural soils by major agricultural methods such irrigation and organic fertilisation using compost made from municipal solid wastes, manure, or sewage sludge [6,13,14]. These MP particles increases the soil porosity and hence allowing less dense MPs to float when the pores are filled with water, plants with mostly primary and secondary roots push MPs closer to the soil surface, whereas plants with mostly tertiary roots keep MPs deeper in the soil layers [14,15]. There are a multitude of different toxins in plastics, according to regulatory authorities like the European Commission. They can ultimately accumulate in body, disrupt cellular signalling and metabolic activities, induce oxidative stress in cells and are also neuro toxic in nature. Plastics often serve as transporters of contaminants due to their great potential for sorption by transporting pathogenic microorganisms, heavy metal, and other substances, the soil MPs therefore serve as vectors. Micro plastics may encourage the adhesion and colonisation of bacteria that act as surface colonisers by producing biofilms [20]. Antibiotics have been adsorbing on micro plastics with a higher rate contrast to marine systems, those found in freshwater [21]. Chemical contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and polycyclic aromatic hydrocarbons (PAHs) can adsorb on plastics [22- 24]. Micro plastics also tend to accumulate in food chain leading to the process of bio magnification. It has been investigated that micro plastics have been accumulated in microscopic phytoplankton to top-level predators like killer whales. The bulk of plastics consumed by sea birds have been linked to PCB concentrations and other trace metal concentrations [18]. Thus, our following study focusses on examining the effects of micro plastics on the growth of plants and its effects on the nutrient content of the soil.

2. MATERIALS AND METHODS

2.1 Study Area and characterization of experimental soil

The experimental soil sample was collected from an agricultural land in Iledu village Chengalpettu district, India (12°.04'63.05"N, 79°.84'84.95"E). Soil samples were collected and dried for 2–3 days, ground, sieved (2 mm sieve), packed in polyethylene cover, and were used for further analysis. The soil was shade dried, sieved to get rid of plant residues, large rocks and gravel and digested using 30 % Hydrogen peroxide to remove the organic matter. pH was measured with a pH meter [26], EC with a conductivity meter [26], organic carbon with a wet digestion method [27]. NPK analysis was performed by using Diacid extract (5:2- H₂SO₄ : HClO₄)- semi automatic kjeldahl distillation method and (Piper 1966) Triacid extract (9:2:1- HNO₃: H₂SO₄ : HClO₄) Vanadomolybdate yellow colour method [26]. The estimation of Available Sulphur and Exchangeable Calcium and Magnesium was performed using the methods: 0.15 per cent CaCl₂-Turbidimetry method [28], Neutral normal ammonium extract- Versenate titration method respectively.

Experimental set up

The polyvinyl acetate microplastics (PVA-MPs) powder used in the study was obtained from online E commerce market. To reduce microbiological contamination, the microplastics were microwaved at 0.8 KW for 2 minutes [29]. Microplastics were added to the farm soil after 3

days of processing the soil at five different concentrations (T1- 0, T2 - 0.5, T3- 1.00, T4- 1.50 and T5- 2.00% on w/w basis). The concentrations were fixed based on the previous studies that quantified microplastics in different soils [30]. Mixing of microplastics with soil was done by stirring with ethanol sterilized glass rod in a glass beaker. The green gram, horse gram and chilli seeds were bought from the local market.

Treatment details

The test soils (200g) with different microplastics concentrations were transferred to clean containers. Two replications were maintained for each treatment (3 seed types and 5 concentrations). The seedlings were maintained for duration of 15 days after sowing. To assess the influence of soil types in the presence of PVA-MPs in horse gram, green gram, chilli seedling growth, the critical parameters like germination rate, germination time, root length, shoot length, vigour index, and chlorophyll content were recorded after 15 days.

Evaluation of chlorophyll content

Leaves were collected separately from seedlings grown in control and micro plastics added soil. 0.1g leaf tissue was cleaned. The leaf tissues were placed in a glass beaker with 8ml of acetone and 2ml of ethanol for 18hours in darkness. After 18 hours the chlorophyll a and chlorophyll b was analysed at 665nm and 649nm respectively using UV spectrophotometer and absorbance values were noted as mentioned in [31] and the chlorophyll content was estimated as per the equation:

$$C_a = 13.95A_{665} - 6.88A_{649}$$

$$C_b = 24.96A_{649} - 7.32A_{665}$$

3. RESULTS AND DISCUSSION

3.1 Characteristics of the Initial Soil

The physico -chemical characterization was carried out as per the standard procedures and the results obtained were given in Table 1. The water holding capacity of the soil was found to be 51%. The pH and EC of the experimental soil was found to be 7.28, 0.42 mS/cm . The value of organic carbon was found to be 1.29 in the initial soil. The NPK concentrations were found to be

61.89 mg/kg, 28.9 mg/kg and 389 mg/kg in the initial soil. The other parameters such as Boron, Calcium and Zinc were found to be 0.4, 2201, 1.21.

3.2 Characteristics of growth parameters of the seeds

The presence of PVA-MPs influenced the germination of the green gram seedlings. The germination percentage of green gram reduced from 90% (Control T₁ – No presence of PVA-MPs) to 30% (T₅ – 2% PVA-MPs). The total seedling length decreased from 31cm (Control T₁ - 0% PVA-MPs) to 26.6cm (T₅– 2% PVA-MPs). The germination percentage of horse gram reduced from 100% (Control T₁ - 0% PVA-MPs) to 40% (T₅– 2% PVA-MPs). The total seedling length decreased from 18.2 cm (Control T₁ - 0% PVA-MPs) to 10.4 cm (T₅ – 2% PVA-MPs). The reduction of germination percentage of chilli was seen from 90% (Control T₁ - 0% PVA-MPs) to 10% (T₅ – 2% PVA-MPs). The total seedling length decreased from 11.9 cm (Control T₁ - 0% PVA-MPs) to 8.2 cm (T₅ – 2% PVA-MPs). Microplastics may physically or chemically interfere with seed imbibition or water uptake, which would reduce germination rates [32]. The influence on the growth parameters was also reported in cress [32,33,34], rye grass [35], soybean [36] and lettuce [37]. As the amount of microplastics in the soil increased, it was seen that the vigour index gradually declined. The vigour index of green gram, horse gram and chilli were found to be the lowest with the values of 798, 416, 82 (T₅ – 2% PVA-MPs). Previous studies have stated that the microplastics lead to lower biomass in maize [38], duckweed [39], plantain [40], broad bean [39], and cress [33].

3.3 Electrical conductivity and pH characteristics of the soil

The EC values of the green gram, horse gram and chilli grown in PVA micro plastics spiked soil were not much affected by the addition of PVA micro plastics. The pH values significantly reduced from 6.85 to 6.10 in green gram grown soil. The pH values significantly reduced from 6.83 to 6.52 in horse gram grown soil. The pH values drastically reduced from 6.87 to 5.72 in chilli. These results collectively indicated that the micro plastics decrease the pH values of soil up to a greater extent but do not have significant impact on the electric conductivity of the soil. The impact of PE on soil pH from a study by Wang et al. (2020) suggested that HDPE may also cause an increase in soil pH. As an example, low density polyethylene (LDPE) films may increase soil pH (Qi et al., 2020); whereas, high density polyethylene (HDPE), may have the opposite pattern.

3.2 Chlorophyll content of the seedlings

The chlorophyll content in the leaves of green gram didn't vary much significantly and more or less similar values were obtained as mentioned in table 4. The chlorophyll a and b values decreased at the concentration of 2% of PVA micro plastics where the concentrations were found to be 3.9121 and 1.6815 in horse gram leaves as mentioned in table 4. The chlorophyll a values remained similar in chilli leaves but the concentration of chlorophyll b decreased with the value of 1.9987 as mentioned in table. These results indicate that PVA did not have any impact on the chlorophyll content of green gram leaves and the chlorophyll content got reduced at higher concentration that is 2% of PVA in horse gram and the chlorophyll b value of chilli got reduced at 2% PVA concentration.

Sulphur content present in soil

The concentration of sulphur decreased drastically from 22.8 mg/L to 9.4 mg/L in green gram grown soil especially from 1% concentration of micro plastics as mentioned in table 5 (a) and was significantly reduced from 29.2 mg/L to 20.0 mg/L in horse gram grown soil as mentioned in table 5 (a). The concentration of sulphur didn't vary at lower concentrations of PVA but reduced drastically at 1.5%, 2% of micro plastics. The concentration of sulphur didn't significantly vary in chilli grown soil as mentioned in table 5 and hence it can be concluded that micro plastics affected the concentration of sulphur in green and horse gram grown soil and it can be assumed that sulphur had got accumulated along with micro plastics making it unavailable to the seedlings as well as the soil. Similar results were reported in previous studies were 1% unplasticized PVC microplastics significantly reduced available Phosphorus content from 38.4 ± 2.5 mg/kg to 26.9 ± 1.3 mg/kg ($p < 0.05$) (Chen et al., 2021)

CONCLUSION

Research on plastic-related environmental pollution is the need of the hour due to wide spread micro plastic contamination. Depending on the kind, shape, size, and interaction of the microplastics with the plant's environment, different microplastics have different effects on plants. Therefore, it is important to research how each polymer behaves in various soil-plant systems. The study conducted by growing green gram, horse gram, chilli in PVA micro plastics spiked soil concludes that the nutrient concentration of the soil especially sulphur, varies significantly. Though the phosphorus content of the soil didn't vary significantly the sulphur concentration showed drastic reduction at higher concentrations of PVA micro plastics in green gram, horse gram and chilli. The seedlings length and vigour index was also reduced due to the presence of PVA particles which may be suspected to hinder the growth of the seeds. The electric conductivity of the soil didn't show much significant variation. The pH of the soil reduced to a very much lower extent due to the presence of PVA particles. The chlorophyll b got reduced at higher concentrations of micro plastics in horse gram and chilli. Whereas chlorophyll a only got reduced in horse gram at higher MP concentration. Hence the study has given an insight on the effects of microplastics on the growth on plants. Further studies and research activities can be conducted in order to develop remediation strategies for micro plastics contaminated soil.

REFERENCE

- Geyer, R.; Jambeck, J.R.; Law, K.L. Production, use, and fate of all plastics ever made. *Sci. Adv.* 2017, 3, e1700782. [CrossRef] [PubMed]
1. Rivas, M. L., Albion, I., Bernal, B., Handcock, R. N., Heatwole, S. J., Parrott, M. L., ... & Deschaseaux, E. (2022). The plastic pandemic: COVID-19 has accelerated plastic pollution, but there is a cure. *Science of The Total Environment*, 847, 157555.
 2. Zhao, J. R., Zheng, R., Tang, J., Sun, H. J., & Wang, J. (2022). A mini-review on building insulation materials from perspective of plastic pollution: Current issues and natural fibres as a possible solution. *Journal of Hazardous Materials*, 129449.
 3. Bläsing, M.; Amelung, W. Plastics in soil: Analytical methods and possible sources. *Sci. Total Environ.* 2018, 612, 422–435. [CrossRef]
 4. Tian, L.; Jinjin, C.; Ji, R.; Ma, Y.; Yu, X. Microplastics in agricultural soils: Sources, effects, and their fate. *Curr. Opin. Environ. Sci. Heal.* 2021, 25, 100311. [CrossRef]
 5. Rezaei, M.; Riksen, M.J.; Sirjani, E.; Sameni, A.; Geissen, V. Wind erosion as a driver for transport of light density microplastics. *Sci. Total Environ.* 2019, 669, 273–281. [CrossRef]
 6. Rezaei, M.; Abbasi, S.; Pourmahmood, H.; Oleszczuk, P.; Ritsema, C.; Turner, A. Microplastics in agricultural soils from a semi-arid region and their transport by wind erosion. *Environ. Res.* 2022, 212, 113213. [CrossRef]
 7. ,K.A.V.; Richards, B.K. Synthetic fibers as an indicator of land application of sludge. *Environ. Pollut.* 2005, 138, 201–211. [CrossRef]
 8. Weithmann, N.; Möller, J.N.; Löder, M.G.J.; Piehl, S.; Laforsch, C.; Freitag, R. Organic fertilizer as a vehicle for the entry of microplastic into the environment. *Sci. Adv.* 2018, 4, eaap8060. [CrossRef] [PubMed]
 9. Katsumi, N.; Kusube, T.; Nagao, S.; Okochi, H. The input–output balance of microplastics derived from coated fertilizer in paddy fields and the timing of their discharge during the irrigation season. *Chemosphere* 2021, 279, 130574. [CrossRef] [PubMed]
 10. Accinelli, C.; Abbas, H.K.; Shier, W.T.; Vicari, A.; Little, N.S.; Aloise, M.R.; Giacomini, S. Degradation of microplastic seed film-coating fragments in soil. *Chemosphere* 2019, 226, 645–650. [CrossRef]
 11. Yang, J.; Li, L.; Li, R.; Xu, L.; Shen, Y.; Li, S.; Tu, C.; Wu, L.; Christie, P.; Luo, Y.

Microplastics in an agricultural soil following repeated application of three types of sewage

UNDER PEER REVIEW

- sludge: A field study. *Environ. Pollut.* 2021, 289, 117943. [CrossRef]
12. Yang, J.; Li, R.; Zhou, Q.; Li, L.; Li, Y.; Tu, C.; Zhao, X.; Xiong, K.; Christie, P.; Luo, Y. Abundance and morphology of microplastics in an agricultural soil following long-term repeated application of pig manure. *Environ. Pollut.* 2020, 272, 116028. [CrossRef] [PubMed]
 13. Lwanga, E.H.; Beriot, N.; Corradini, F.; Silva, V.; Yang, X.; Baartman, J.; Rezaei, M.; van Schaik, L.; Riksen, M.; Geissen, V. Review of microplastic sources, transport pathways and correlations with other soil stressors: A journey from agricultural sites into the environment. *Chem. Biol. Technol. Agric.* 2022, 9, 20. [CrossRef]
 14. Li, H.; Lu, X.; Wang, S.; Zheng, B.; Xu, Y. Vertical migration of microplastics along soil profile under different crop root systems. *Environ. Pollut.* 2021, 278, 116833
 15. Avio, C.G., Gorbi, S., Milan, M., Benedetti, M., Fattorini, D., d'Errico, G., Pauletto, M., Bargelloni, L., Regoli, F., 2016. Pollutants bioavailability and toxicological risk from microplastics to mussels. *Environ. Pollut.* 198, 211–222.
 16. Yoshida, S., 2016. A bacterium that degrades and assimilates poly (ethylene terephthalate). *Science* 351 (6278),
 17. Cole, M., Lindeque, P., Halsband, C., Galloway, T.S., 2011. Microplastics as contaminants in the marine environment: a review. *Mar. Pollut. Bull.* 62, 2588–2597.
 18. Castañeda, R.A., Avlijas, S., Simard, M.A., Ricciardi, A., 2014. Microplastic pollution in St. Lawrence River sediments. *Can. J. Fish. Aquat. Sci.* 70:1767–1771.
 19. Lobelle, D. and Cunliffe, M., 2011. Early microbial biofilm formation on marine plastic debris. *Marine pollution bulletin*, 62(1), pp.197-200.
 20. Li, J., Zhang, K. and Zhang, H., 2018. Adsorption of antibiotics on microplastics. *Environmental Pollution*, 237, pp.460-467.
 21. Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C. and Kaminuma, T., 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental science & technology*, 35(2), pp.318-324.
 22. Rios, L.M., Moore, C. and Jones, P.R., 2007. Persistent organic pollutants carried by synthetic polymers in the ocean environment. *Marine pollution bulletin*, 54(8), pp.1230-1237.
 23. Teuten, E.L., Rowland, S.J., Galloway, T.S. and Thompson, R.C., 2007. Potential for plastics to transport hydrophobic contaminants. *Environmental science & technology*, 41(22), pp.7759-7764.

24. Guo, J.J., Huang, X.P., Xiang, L., Wang, Y.Z., Li, Y.W., Li, H., Cai, Q.Y., Mo, C.H., Wong, M.H., 2020. Source, migration and toxicology of microplastics in soil. *Environment*

UNDER PEER REVIEW

International 137, 105263.

25. OURRY, A., BOUCAUD, J. and SALETTE, J., 1988. Nitrogen mobilization from stubble and roots during re-growth of defoliated perennial ryegrass. *Journal of Experimental Botany*, 39(6), pp.803-809.
26. Walkley, A. and Black, I.A., 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, 37(1), pp.29-38.
27. Williams, C.H. and Steinbergs, A., 1959. Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research*, 10(3), pp.340-352.
28. de Souza Machado AA, Lau CW, Kloas W, Bergmann J, Bachelier JB, Faltin E, et al. Microplastics can change soil properties and affect plant performance. *Environ. Sci. Technol.* 2019;53(10):6044-52.
29. Lian J, Liu W, Meng L, Wu J, Zeb A, Cheng L, et al. Effects of microplastics derived from polymer-coated fertilizer on maize growth, rhizosphere, and soil properties. *J. Clean. Prod.* 2021;318: 128571.
30. Zhao, J., Zhou, J., Gu, J., Qian, F. and Xie, X., 2012. Phytochrome B positively regulates chlorophyll biosynthesis and chloroplast development in rice. *Chinese Journal of Rice Science*, 26(6), pp.637-642.
31. Bosker T, Bouwman LJ, Brun NR, Behrens P, Vijver MG. Microplastics accumulate on pores in seed capsule and delay germination and root growth of the terrestrial vascular plant *Lepidium sativum*. *Chemosphere.* 2019;226:774-81.
32. Pignattelli S, Broccoli A, Piccardo M, Felling S, Terlizzi A, Renzi M. Short-term physiological and biometrical responses of *Lepidium sativum* seedlings exposed to PET-made microplastics and acid rain. *Ecotoxicol. Environ. Saf.* 2021;208: 111718.
33. Pignattelli S, Broccoli A, Piccardo M, Terlizzi A, Renzi M. Effects of polyethylene terephthalate (PET) microplastics and acid rain on physiology and growth of *Lepidium sativum*. *Environ. Pollut.* 2021;282: 116997.
34. Boots B, Russell CW, Green DS. Effects of microplastics in soil ecosystems: above and below ground. *Environ. Sci. Technol.* 2019;53(19):11496-506.
35. Wang L, Liu Y, Kaur M, Yao Z, Chen T, Xu M. Phytotoxic Effects of Polyethylene Microplastics on the Growth of Food Crops Soybean (*Glycine max*) and Mung Bean (*Vigna radiata*). *Int. J. Environ. Res. Public Health.* 2021;18(20):10629

36. Ren X, Tang J, Wang L, Liu Q. Microplastics in soil-plant system: Effects of nano/microplastics on plant photosynthesis, rhizosphere microbes and soil properties in soil

UNDER PEER REVIEW

with different residues. *Plant Soil*. 2021;462(1):561-76.

37. Lian J, Liu W, Meng L, Wu J, Zeb A, Cheng L, et al. Effects of microplastics derived from polymer-coated fertilizer on maize growth, rhizosphere, and soil properties. *J. Clean. Prod.* 2021;318: 128571
38. Jiang X, Chen H, Liao Y, Ye Z, Li M, Klobučar G. Ecotoxicity and genotoxicity of polystyrene microplastics on higher plant *Vicia faba*. *Environ. Pollut.* 2019;250:831- 8
39. van Kleunen M, Brumer A, Gutbrod L, Zhang Z. A microplastic used as infill material in artificial sport turfs reduces plant growth. *Plants, people, planet.* 2020; 2(2):157-66.
40. Mateos-Cárdenas A, Scott DT, Seitmaganbetova G, van Pelt Frank N, AK JM. Polyethylene microplastics adhere to *Lemna minor* (L.), yet have no effects on plant growth or feeding by *Gammarus duebeni* (Lillj.). *Sci. Total Environ.* 2019;689:413-21.
41. Yan, Y., Chen, Z., Zhu, F., Zhu, C., Wang, C., & Gu, C. (2021). Effect of polyvinyl chloride microplastics on bacterial community and nutrient status in two agricultural soils. *Bulletin of Environmental Contamination and Toxicology*, 107, 602-609.

Table 1: Initial characteristics of the soil

Parameters	Unit	Value
pH	-	7.28
EC	mS/cm	0.42
Organic Carbon	%	1.29
Boron	mg/kg	0.4
Available phosphorus	mg/kg	28.9
Available sulphur	mg/kg	38.01
Exchangeable potassium	mg/kg	389
Exchangeable calcium	mg/kg	2201
Exchangeable magnesium	mg/kg	621
Available Iron	mg/kg	3.89
Available copper	mg/kg	3.12
Nitrate	mg/kg	61.89
Available Zinc	mg/kg	1.21

Table 2: Growth parameters of seedlings

	Spiked Concentration Of MPs	Total seedling Length (In cm)	Germination Percentage (In %)	Vigour index
Green gram	Control	31	90	2790
	0.5%	30.5	70	2135
	1%	29.7	60	1782
	1.5%	26.8	50	1340
	2%	26.6	30	798
Horse gram	Control	18.2	100	1820
	0.5%	18.0	80	1440
	1%	17.2	80	1376
	1.5%	15.5	50	775
	2%	10.4	40	416
Chilli	Control	11.9	90	1071
	0.5%	10.6	50	530
	1%	11.7	30	351
	1.5%	7.9	20	158
	2%	8.2	10	82

Table 3: electrical conductivity and pH of soil

	Spiked Concentration Of MPs	EC	pH
Green gram	Control	0.108	6.85
	0.5%	0.103	6.72
	1%	0.097	6.65
	1.5%	0.090	6.64
	2%	0.083	6.10
Horse gram	Control	0.068	6.83
	0.5%	0.057	6.72
	1%	0.057	6.62
	1.5%	0.053	6.58
	2%	0.051	6.52
Chilli	Control	0.072	6.87
	0.5%	0.061	6.72
	1%	0.057	6.48
	1.5%	0.051	6.40
	2%	0.050	5.72

Table 4 Effect of PVA-MPs at concentrations 1.5% and 2 % on chlorophyll content of leaves

Concentration of PVA micro plastics						
	Control		1.5%		2%	
	Chlorophyll a	Chlorophyll b	Chlorophyll a	Chlorophyll b	Chlorophyll a	Chlorophyll b
Green gram	4.2321	2.2678	4.2034	2.1976	4.1983	2.1956
Horse gram	4.1863	2.2798	4.1862	2.1743	3.9121	1.6815
Chilli	4.2567	2.3765	4.2489	2.264	4.2287	1.9987

Table 5. Sulphur content present in soil after the addition of microplastics

	Green gram	Horse gram	Chilli
Control	22.8	29.2	29.2
0.5%	18.5	26.8	29.0
1%	14.6	22.8	28.1
1.5%	14.5	20.9	28.0
2%	9.4	20.0	28.0

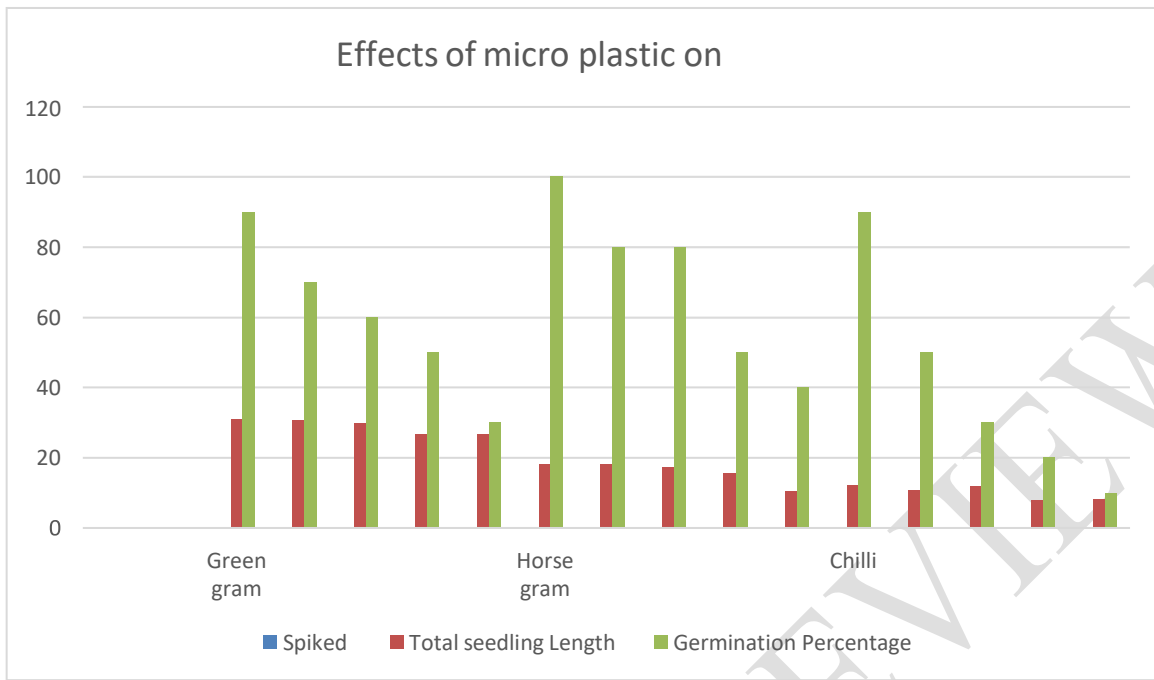


Figure 1: Effects of microplastics on growth of seedling

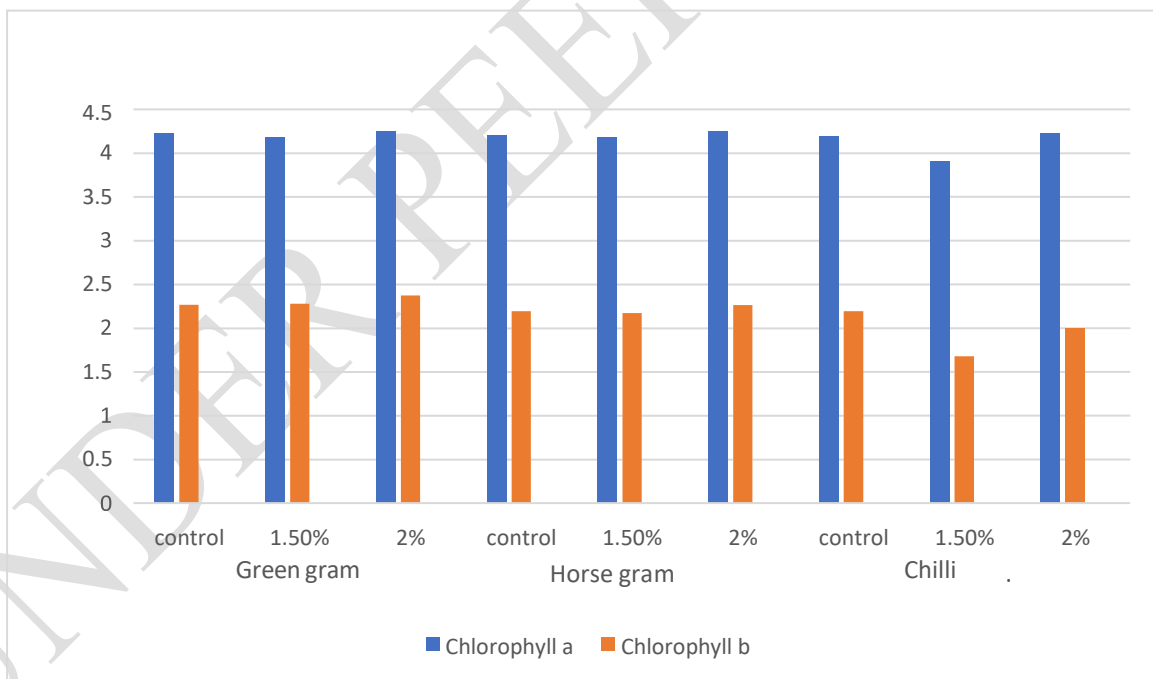


Figure 2: Graphical representation of PVA MPs affecting the chlorophyll content in leaves

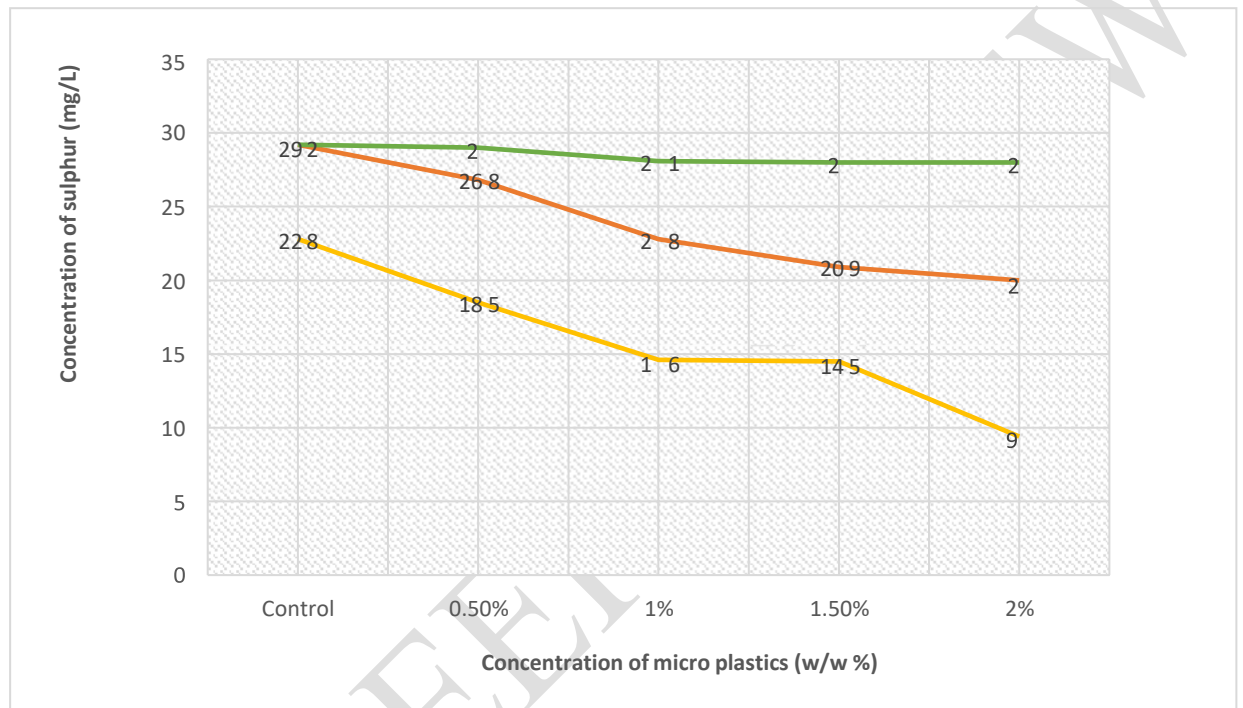


Figure 3: Graphical representation of PVA MPs affecting the sulphur content in soil [yellow-green gram, orange-horse gram, green- chilli]