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Impact of Plastic Mulching on Soil Properties and Heavy Metal Dynamics in Agricultural Systems: A Case Study from Manikganj, Bangladesh

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Abstract

This research study examines the impact of different types and sizes of plastics on various soil properties. Clay loam soil samples were collected from Paril village, Manikganj district, Bangladesh, and subjected to plastic incubation experiments. The plastics underwent 180 days of intense ultraviolet (UV) radiation to simulate natural sunlight degradation. The soil samples were mixed with three types of plastics (P1, P2, P3) and two sizes (1mm, 10mm) in individual pots, with and without the addition of zinc sulfate. The soil properties, including pH, total dissolved solids (TDS), available zinc, cation exchange capacity (CEC), nitrogen content, and total phosphorus, were analyzed using various techniques. The results indicate significant variations in pH and TDS values influenced by plastic size and type. The available zinc content differed among plastic types, and plastic size affected CEC values. Nitrogen content was influenced by plastic size, with smaller particles having a greater impact. Total phosphorus content varied with different plastic types. These findings contribute to our understanding of the potential effects of plastics on soil properties and highlight the need for further investigation into the underlying mechanisms.

Keywords: Plastic mulching, Soil properties, Heavy metal contamination, Microplastics, Zinc accumulation, Cation exchange capacity (CEC), Nitrogen content, Phosphorus availability, Soil pH, Agricultural soil health, Environmental pollution, Bangladesh.

Introduction

The term ‘mulch’ refers to a preventive layer covering the surface of the soil by organic or inorganic materials e.g. crop residues, plant leaves, straw, plastic paper etc. in order to improve the soil environment for better production of crops(Kader et al., 2019). Mulching has long been known to increase the growth and productivity of both annual and perennial crops (Magistad et al., 1935; Shonbeck). Mulching provide a physical barrier to prevent soil contamination, suppress weeds, and preserve a healthy soil structure. Based on the materials used, mulching can be classified into two broad types: (1) Organic mulching, in which organic materials like straw or wood chips, agricultural waste, plant leaves, animal manure etc. are used, and the other type is (2) Inorganic mulching, in which inorganic materials like plastic paper, biodegradable plastic foil, polypropylene non-woven fabric etc. are used.

There are many benefits of organic mulching like maintenance of soil organic matter and tilth (Tindall et al., 1991) and also providing food and shelter to the earthworm and other beneficial soil biota (Doran, 1980). However, one of the main issues with organic mulching is that organic materials are not always readily available in sufficient quantities and are of variable quality. Additionally, organic mulching is ineffective in controlling weeds because it may carry weed seeds and frequently prevents soil from warming up in the spring, which can delay the growth and maturity of warm-season vegetables (Hill et al., 1982). Therefore, it is obvious that we cannot use organic mulching for effective crop production throughout the entire year. As a result, plastic mulching has been introduced, which is a simple solution to many of the aforementioned issues.

Plastic mulching is nothing but a roll of polyethylene film that is placed on the surface of the cultivated soil. It is a recent advancement both in the world and in Bangladesh's agriculture. Generally the crops are grown through the slits and holes present in thin plastic mulch paper. At present, around 20% of world's vegetable cultivation area is covered with plastic film (FAO, 2021) and plastic mulching is now considering a promising contributor to vegetable yields (Gao et al., 2019). One of the key factors contributing to plastic mulch's increasing global popularity is its immediate economic advantages, including higher yields, earlier harvests, improved fruit quality, and increased water use efficiency. In their study of the microclimatic effects of different mulches (polyethylene film, straw, paper, and aluminum films), Waggoner et al. (1960) came to the conclusion that polyethylene film mulch was the most efficient type of mulching.

According to current definitions, heavy metals are now classified as metals with an atomic number greater than 20 and a density greater than 5 g/cm3 (such as Zn, Cd, Cr, Ni, and Co). The word is frequently linked to contamination and probable toxicity or ecotoxicity (Sanaei et al., 2020) (Duffus, 2003). Low amounts of naturally occurring heavy metals can be found in soil, and some of them, such as Fe, Zn, Ni, Cu, and Mn, are essential micronutrients for plants (Balseiro-Romero and Baveye, 2018). However, significant quantities of heavy metals may accumulate in soil as a result of numerous human activities, which can be hazardous to both plants and animals. Some heavy metals are persistent and non-biodegradable, and they can cause harm even at low quantities. Where they are bioavailable, they pose a major threat to the health of both people and the soil. Heavy metals that have accumulated in the soil can be absorbed by plants, which allows them to enter the food chain and the human body (Demkova, 2017). Additionally, they may be inhaled alongside soil particles or may be absorbed via the skin in specific situations or at high concentrations.

Generally, when a trace of toxic elements from soil or rock enters the environment, it follows normal biogeochemical cycles, being governed by air water and gravity until it reaches a geochemical sink (Thakur et al.). But due to the increased anthropogenic activity, this normal cycle is disturbed and as a consequence, concentrations of these toxic elements increases in the soil.

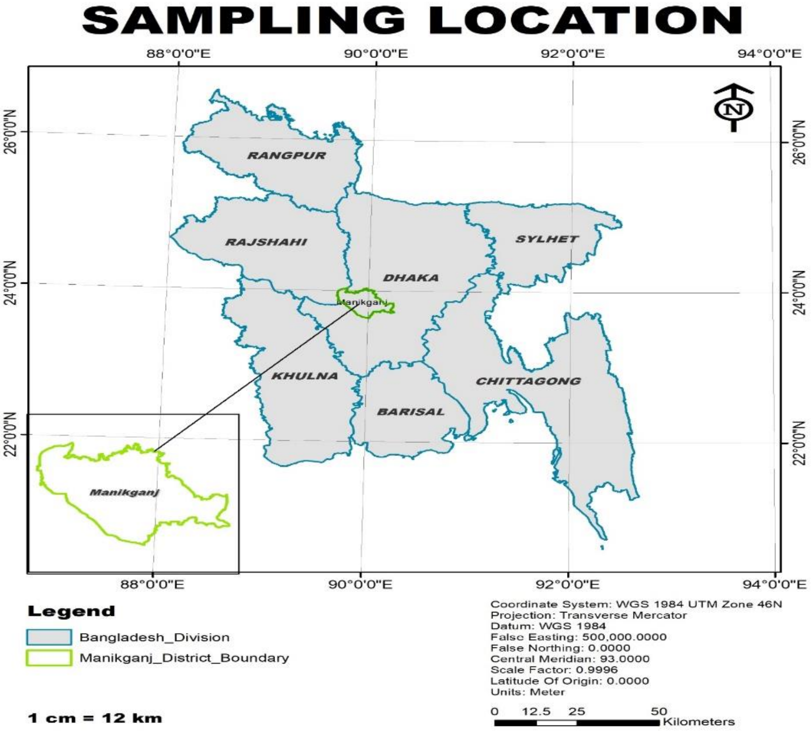
Even though plastic mulching has many benefits, it also has some drawbacks, the most noticeable of which is the plastic residues that are left in the environment after a crop season. Due to the fact that these plastic wastes are foreign substances to the soil, they may affect its natural biogeochemical processes and alter the concentration of harmful components therein. We suspect that plastic mulching residues could enhance the concentration of heavy metals in soil through a variety of mechanisms, including chemical reactions, physical processes, and biological interactions. This is why, we conducted this experiment, where we tried to find out the relationship between plastic mulching residues and heavy metals. Our main objectives were to see how plastic residues interact with the heavy metals in soil, and whether it exacerbates the heavy metal pollution or not. We carried out a pot experiment where we added various doses of heavy metals from outside and then incubated the samples under continuous UV radiation exposure for about 6 months. Then we conducted laboratory experiments to determine the heavy metals concentration of the samples.

Literature Review

In Bangladesh, research on the effects of plastic mulching residues on heavy metals is quite limited; even globally, not much has been done in this area. Most of the researches on plastic mulch mainly focused on soil water, soil temperature, and nutrient supply, which are the main controlling factors for vegetable yield (Farzi et al, 2017. Iqbal et al, 2020, Ni et al, 2016). To our knowledge, only few studies were conducted on plastic mulching residue and its impact on heavy metal. Li et al carried out an experiment where they investigated the effects of prothioconazole on degradation of the microplastics derived from plastic mulching and the adsorption and release characteristics of heavy metals (Cr, Cu, As, Pb, Ba, and Sn) by the microplastics during the degradation process. They worked on two types of plastic mulch paper, one is biodegradable plastic paper PBAT (polybutylene adipate-co-terephthalate) and the other one is polyethylene (PE). It was seen that PBAT degraded much faster and adsorbed more heavy metals than PE. It was found that the amount of heavy metals adsorbed or released from microplastic depended on the metal and its concentration. The study showed that prothioconazole inhibited the adsorption of Cr, As, Pb, and Ba by microplastics, but promoted the adsorption of Cu and had no significant effect on Sn. Another research was done by Xiu et al to find out the effect of plastic mulching on heavy metal migration from soil to vegetable. After conducting the experiments they concluded that plastic mulch can decrease the mobility of Cu, Pb, and Zn, while increasing Cd mobility through increasing soil temperature, organic matter, electrical conductivity and the abundance of related bacteria. Thus, it can be observed that using plastic mulch has a significant impact on the heavy metals in the soil. As heavy metals are potential environmental pollutants, knowing how they interacts with plastic mulching is essential in order to enrich our knowledge on heavy metals kinetics in soil.

Materials and Methods

The soil sample utilized in this study was obtained from the village of Paril, Union: Baldhara, Upazila: Singair, District: Manikganj, and consisted of clay loam soil (Fig 1). The soil samples were carefully collected and subsequently air-dried to facilitate soil incubation experiments. To simulate plastic degradation under natural sunlight, high-powered Ultraviolet (UV) rays were employed. This methodology involved subjecting the plastic samples to intense UV radiation for approximately 180 days, effectively replicating the effects of prolonged exposure to sunlight. The three types of plastics (P1, P2, P3) used for analysis were identified through ATR-FTIR (Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy) analysis, as illustrated in Figure 2.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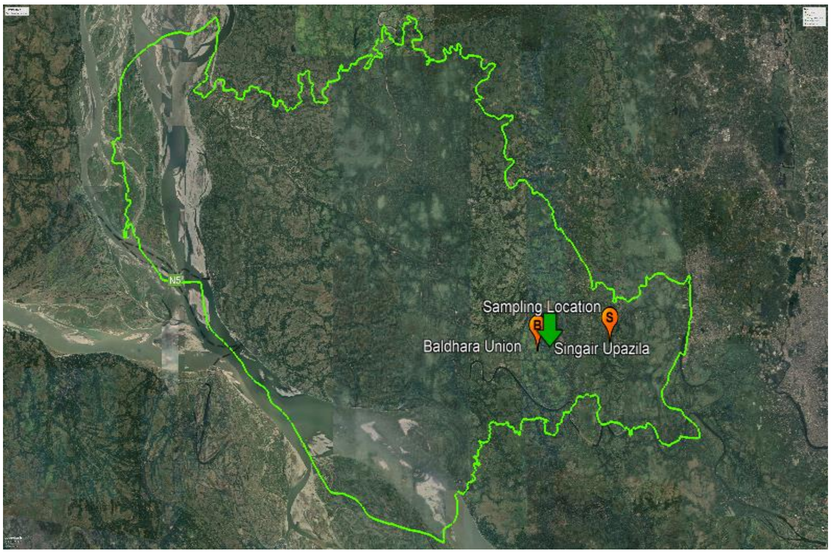

N5
Sampling Location
Baldhara Union
Singair Upazila

B

C

Fig.1. A) Map of Soil Sample collection area, Manikganj, Bangladesh, B) Location of the sample collection area generated from Google Earth pro, C) Sample Collection points are indicated by yellow spots.

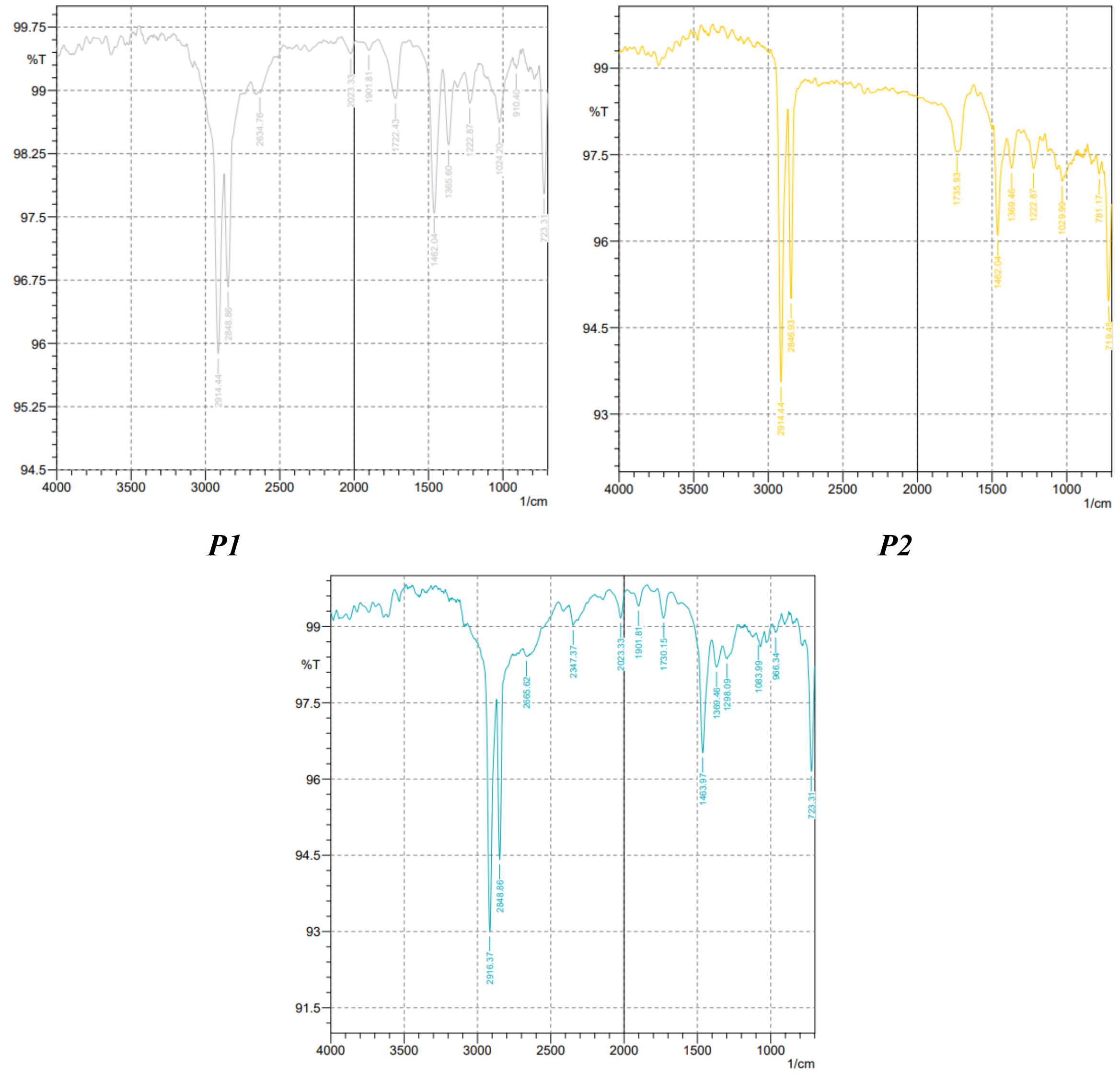
In the experiment, soil samples weighing 1kg were mixed thoroughly with each type of plastic material to ensure homogeneity. This mixture was then placed in individual pots. An additional 0.3g of Zinc Sulfate (Hepta Hydrate) was added in half of the pots (Zn1). Two different sizes of plastics, 1mm (S1), and 10mm (S10), were used, with respective doses of 80 and 15 pieces per pot. The moisture content of the soil was adjusted to match the field capacity. To ensure reliability and validity, three replicates were maintained for each sample. To minimize bias, all the pots were arranged using a randomized block design (Fig 3). Furthermore, a control treatment was included, which did not contain any microplastics, serving as a baseline for comparison in the subsequent analysis. This experimental setup allows for the examination of the potential effects of different plastic types, sizes, and zinc sulfate addition on the soil system.

Analysis of various soil properties

In the study, the pH of the soil samples was determined using an electrochemical method with a digital pH meter. The ratio of soil to water used for the pH measurement was 1:2.5, following the recommendation by Jackson (1962). This ratio ensures an appropriate extraction of soil constituents into the water, allowing for an accurate assessment of the soil pH. The soil samples' electrical conductivity (EC) and total dissolved solids (TDS) were measured using a Hanna HI-98311 EC, TDS, and temperature tester.

The total zinc content of the soil samples was determined using AAS (Atomic Absorption Spectrophotometer (Jackson, 1962) after digestion with HNO_3:$HClO_4$ (3:1). The available zinc content was determined by AAS after extracting the soil with neutral ammonium acetate. The total phosphorus content of the sample was determined using a Shimadzu UV-VIS Spectrometer at a wavelength of 420 nm after developing the yellow color with vanadomolybdate, as described by Jackson (1962). In this method, the sample was digested with nitric acid and perchloric acid, and the resulting phosphorus was reacted with ammonium molybdate and vanadate to form a yellow complex. The absorbance of the complex was measured at 420 nm using the spectrometer, and the total phosphorus content of the sample was calculated from a calibration curve prepared using a series of standard solutions of known phosphorus concentration.

The cation exchange capacity (CEC) was assessed through a two-step process. Firstly, the soil was extracted with a neutral ammonium acetate (NH4OAc, Ph-7) solution. Subsequently, the ammonium ions in the soil's exchange complex were replaced with a 1M NaCl solution. The displaced ammonium was then distilled, employing a method similar to the detection of available ammoniacal nitrogen, as Black (1965) outlined.



P1

P2

P3

Fig.2. Absorbance Spectra of the Plastic Samples P1, P1, and P3.

Fig.3. Experimental Setup of Soil Sample Pots.

Statistical Analysis

The collected data were analyzed using descriptive statistics, and the results were presented as means accompanied by standard deviations (SD). Analysis of variance (ANOVA) was performed using the statistical software Minitab 19. Furthermore, a two-way ANOVA was conducted using Excel 2019 to assess the main effects of Plastic type and sizes and their potential interaction. Fisher's least significant difference (LSD) method was employed at a significance level of $P < 0.05$ to evaluate significant differences among the means. Graphical representations of the data were generated using Excel 2019.

Results

Effects on pH and TDS

The results of the two-way ANOVA revealed significant changes in pH and TDS (total dissolved solids) values. The analysis indicated that the pH values were significantly influenced by the different sizes of plastics used (F crit= 4.26, $p < 0.05$). Moreover, the TDS values showed a significant effect attributed to the different types of plastics employed (F crit= 2.62, $p < 0.05$). Under treatment size 1mm (S1), the pH ranges from 7.39 to 7.86; under treatment size 10 mm (S10), it ranges from 7.28 to 7.62. This suggests that the treatments may have influenced the pH levels in the soil samples. Comparing the samples within each treatment, it can be observed that the pH values tend to differ depending on the different types of plastic. For instance, within treatment S1, the pH increases gradually from P1Zn0 (7.78) to P3Zn0 (7.86). The pH value of the Control sample is recorded as 7.5, providing a reference point for comparison with the treated samples (Fig 4).

The TDS values of the soil samples treated with plastic size S1 ranged from 0.33 to 0.48 ppt, while the TDS values of samples treated with plastic size S10 ranged from 0.3 to 0.5 ppt. These results suggest that the plastic size had a minimal impact on the TDS of the soil, with no clear trend indicating a significant difference between the two plastic sizes. Comparing samples within the same plastic size, it can be observed that the TDS values varied with different zinc concentrations. For example, in the S1 plastic size group, the TDS values ranged from 0.38 to 0.48 ppt without zinc (P1Zn0) and increased to a range of 0.33 to 0.38 ppt with the addition of zinc (P1Zn1). Similarly, in the S10 plastic size group, the TDS values ranged from 0.35 to 0.41 ppt without zinc (P3Zn0) and increased to 0.34 to 0.5 ppt with zinc (P3Zn1). These findings suggest that higher zinc concentrations slightly increased the TDS values for both plastic size groups (Fig 5).

Effects on Available Zinc

The results of the two-way ANOVA revealed a significant effect of plastic type on the contents of available zinc in the soil samples. The zinc concentrations differed among the plastic types. For the S1 plastic size, the zinc concentrations ranged from 6.66 ppm (P1Zn0) to 55.9 ppm (P1Zn1) for Plastic Type P1, from 14.18 ppm (P2Zn0) to 39.7 ppm (P2Zn1) for Plastic Type P2, and from 9.65 ppm (P3Zn0) to 43.86 ppm (P3Zn1) for Plastic Type P3. These results demonstrate variations in zinc concentration across the different plastic types, indicating the influence of plastic-type on zinc availability in the soil. The control group exhibited a zinc concentration of 8.43 ppm, representing the baseline zinc level in the soil without any plastic or additional zinc treatments. Comparing the zinc concentrations of the treated samples with the control group, it is evident that specific treatments resulted in notable deviations from the baseline zinc levels (Fig 6).

Effects on CEC

The results indicated that the plastic size factor significantly influenced the CEC values of the soil samples. The CEC values of the soil samples differed based on the plastic size. For the S1 plastic size, the CEC ranged from 26.9 meq/100g (P1Zn0) to 17.3 meq/100g (P1Zn1), while for the S10 plastic size, the CEC ranged from 15.1 meq/100g (P1Zn0) to 14.2 meq/100g (P1Zn1). These results indicate that the plastic size had an impact on the CEC of the soil, with variations observed between the two plastic sizes. The control group exhibited a CEC value of 17 meq/100g, representing the baseline CEC level in the soil without any plastic or additional zinc treatments. Comparing the CEC values of the treated samples with the control group, it is evident that certain treatments led to deviations from the baseline CEC levels (Fig 7).

Effects on Nitrogen

The two-way ANOVA analysis revealed a significant effect of plastic size variation on nitrogen content. Upon closer examination of the data, it can be observed that for most plastic types and zinc treatments, the nitrogen content tends to be higher in the S1 plastic size compared to the S10 plastic size. This implies that smaller plastic particles (1mm) may have a greater impact on soil nitrogen dynamics than larger particles (10mm). In the P1Zn0 treatment, the nitrogen content was 0.377% for S1 and 0.212% for S10. Similarly, in the P2Zn1 treatment, the nitrogen content was 0.353% for S1 and 0.183% for S10. These findings suggest that the size of the plastic particles influences the availability and uptake of nitrogen in the soil (Fig 8).

Effects on total Phosphorus

The phosphorus content exhibited significant variations among different plastic types. For instance, in the P1Zn1 treatment, the phosphorus content was 239.04 ppm for plastic-type S1 and 160.09 ppm for plastic-type S10. Similarly, in the P3Zn1 treatment, the phosphorus content was 205.2 ppm for plastic-type S1 and 103.69 ppm for plastic-type S10. These findings suggest that different plastic types have distinct effects on phosphorus availability and distribution in the soil (Fig 9).

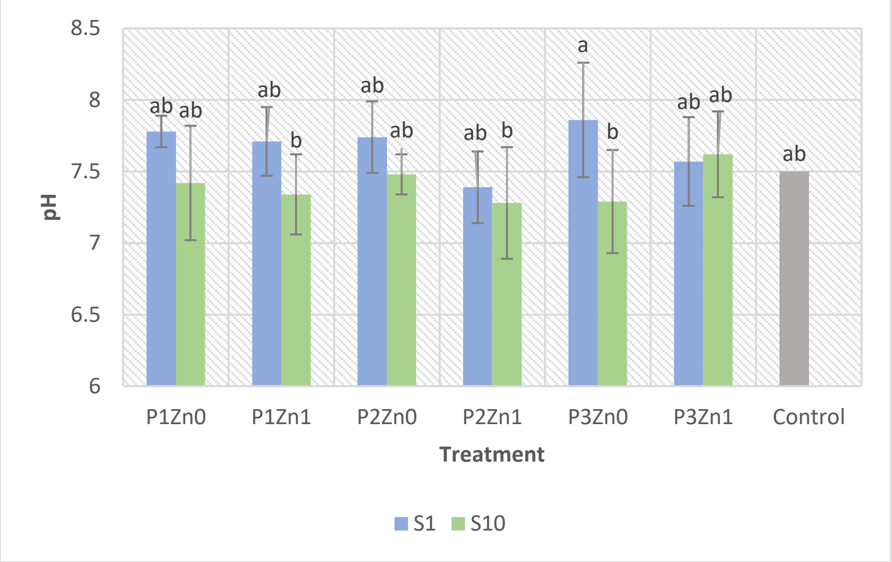


Fig.4. pH of the soil with different types and sizes of plastics. Different letters above the bars mean significant difference among all the treatments by Fisher's least significant difference (LSD) method at P < 0.05.

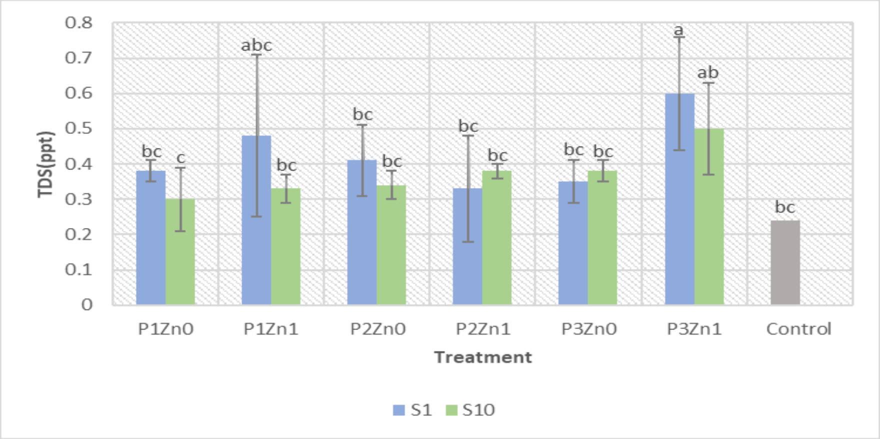


Fig.5. TDS of the soil with different types and sizes of plastics. Different letters above the bars mean significant difference among all the treatments by Fisher's least significant difference (LSD) method at P < 0.05.

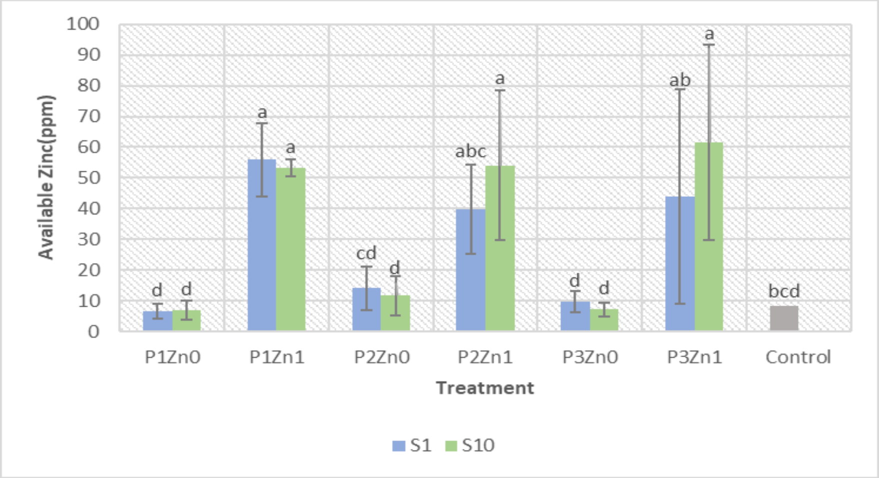


Fig.6. Available Zinc content in the soil with different types and sizes of plastics. Different letters above the bars mean significant difference among all the treatments by Fisher's least significant difference (LSD) method at P < 0.05.

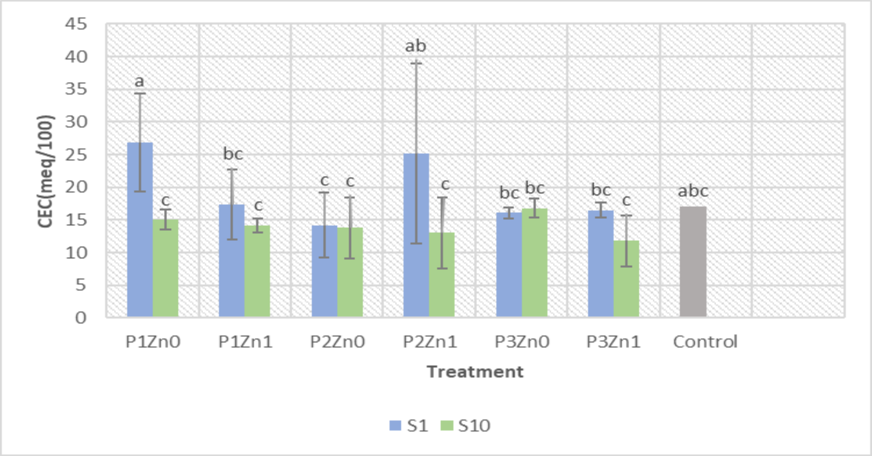


Fig.7. CEC of the soil with different types and sizes of plastics. Different letters above the bars mean significant difference among all the treatments by Fisher's least significant difference (LSD) method at P < 0.05.

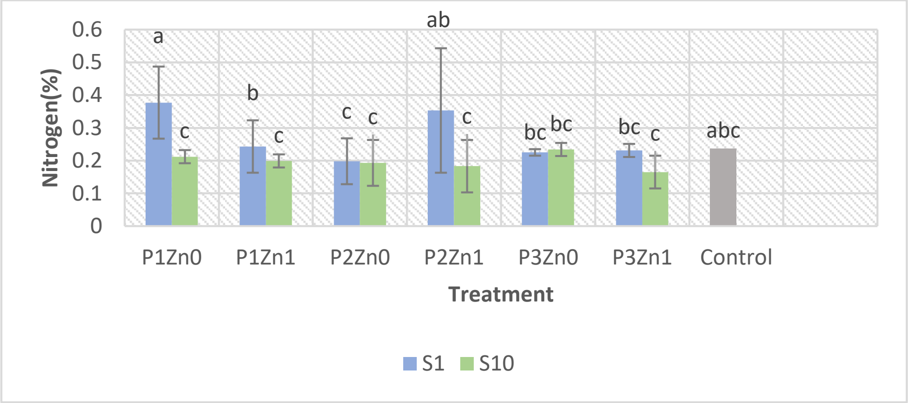


Fig.8. Nitrogen content in the soil with different types and sizes of plastics. Different letters above the bars mean significant difference among all the treatments by Fisher's least significant difference (LSD) method at P < 0.05.

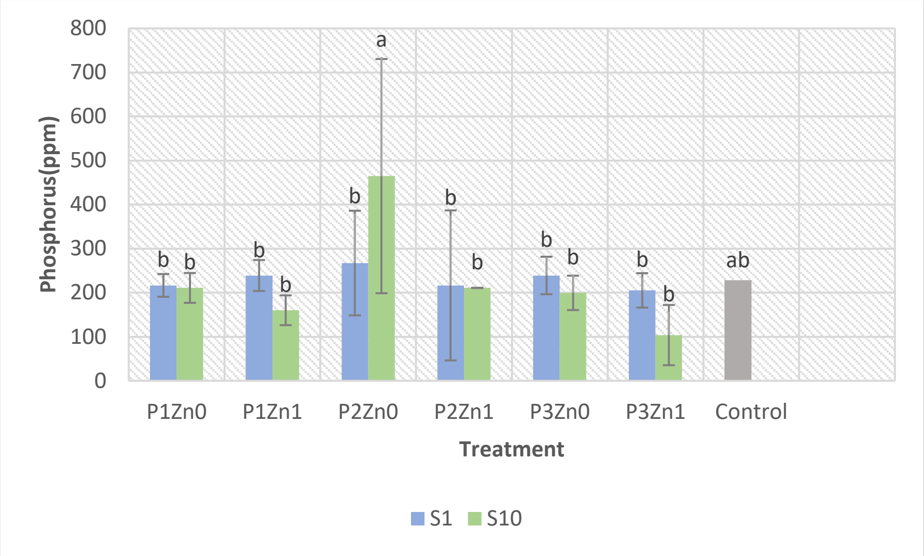


Fig.9. Phosphorus content in the soil with different types and sizes of plastics. Different letters above the bars mean significant difference among all the treatments by Fisher's least significant difference (LSD) method at P < 0.05.

The results of the analysis using analysis of variance (ANOVA) indicated no significant changes in the total zinc content and electrical conductivity (EC) of the soil due to different types or sizes of plastic. The comprehensive data depicting the various properties of the soil influenced by different types and sizes of plastic can be found in Table 1.

Table 1: Soil Properties Affected by Different Types and Sizes of Plastic

Treatment		pH	TDS(ppt)	Available Zn(ppm)	CEC(meq/100g)	Nitrogen(%)	Phosphorus(ppm)
Control		7.5 ± 0.00ab	0.24 ± 0.00bc	8.43 ± 0.00bcd	17 ± 0.00abc	0.237 ± 0.00abc	227.76 ± 0.00ab
P1Zn0	1mm	7.78 ± 0.11ab	0.38 ± 0.03bc	6.66 ± 2.40d	26.9 ± 7.5a	0.377 ± 0.11a	216.48 ± 25.84b
P1Zn0	10mm	7.42 ± 0.40ab	0.3 ± 0.09c	6.97 ± 3.14d	15.1 ± 1.51c	0.212 ± 0.02c	210.84 ± 33.84b
P1Zn1	1mm	7.71 ± 0.24ab	0.48 ± 0.23abc	55.9 ± 11.96a	17.3 ± 5.35bc	0.243 ± 0.08b	239.04 ± 35.22b
P1Zn1	10mm	7.34 ± 0.28b	0.33 ± 0.04bc	53.27 ± 2.71a	14.2 ± 1.08c	0.199 ± 0.02c	160.09 ± 33.84b
P2Zn0	1mm	7.74 ± 0.25ab	0.41 ± 0.10bc	14.18 ± 7.11cd	14.2 ± 5.03c	0.198 ± 0.07c	267.24 ± 118.83b
P2Zn0	10mm	7.48 ± 0.14ab	0.34 ± 0.04bc	11.64 ± 6.31d	13.8 ± 4.67c	0.193 ± 0.07c	464.62 ± 265.89a
P2Zn1	1mm	7.39 ± 0.25ab	0.33 ± 0.15bc	39.7 ± 14.56abc	25.2 ± 13.79ab	0.353 ± 0.19ab	216.48 ± 170.3b
P2Zn1	10mm	7.28 ± 0.39b	0.38 ± 0.02bc	54.07 ± 24.31a	13 ± 5.38c	0.183 ± 0.08c	210.84 ± 0.00b
P3Zn0	1mm	7.86 ± 0.40a	0.35 ± 0.06bc	9.65 ± 3.47d	16.1 ± 0.84bc	0.225 ± 0.01bc	239.04 ± 42.57b
P3Zn0	10mm	7.29 ± 0.36b	0.38 ± 0.03bc	7.18 ± 2.3d	16.8 ± 1.40bc	0.234 ± 0.02bc	199.57 ± 39.07b
P3Zn1	1mm	7.57 ± 0.31ab	0.6 ± 0.16a	43.86 ± 34.9ab	16.5 ± 1.21bc	0.231 ± 0.02bc	205.2 ± 39.07b
P3Zn1	10mm	7.62 ± 0.30ab	0.5 ± 0.13ab	61.5 ± 31.82a	11.8 ± 3.87c	0.165 ± 0.05c	103.69 ± 68.38b

Different letters following the mean values (±SD) within each column indicate significant differences among all the treatments, as determined by the Fisher LSD method at a significance level of $P < 0.05$. Means that share the same letter are not significantly different, while those with different letters indicate significant variations between treatments.

Discussion

The results of the study revealed significant variations in the nutrient dynamics, specifically nitrogen, phosphorus, and cation exchange capacity (CEC), available Zinc, and pH, influenced by the plastic type and size variations. These findings support the hypothesis that different types and sizes of plastics can affect soil nutrient availability and retention.

Soil pH is widely recognized as the "master variable" in soil chemistry, significantly influencing numerous chemical reactions that govern the availability and uptake of essential plant nutrients (Penn & Camberato, 2019). In our study, we observed significant variations in soil pH due to the different sizes of plastics used. These variations in pH can have important implications for nutrient availability, including nutrients such as phosphorus and nitrogen, which are crucial for plant growth and development. The pH-mediated changes induced by plastic sizes can potentially influence nutrient solubility, microbial activity, and nutrient uptake by plants (Barrow & Hartemink, 2023). Therefore, the observed variations in soil pH underscore the potential impact of plastic treatments on nutrient dynamics and highlight the need for further investigations into the specific mechanisms involved. Our findings revealed that the introduction of microplastics of 1mm size into the soil led to a significant increase in soil pH. This effect can be attributed to the enhanced soil aeration and increased porosity from these microplastics (De Souza Machado et al., 2019; Lozano et al., 2021).

Our study, consistent with previous research (Kim et al., 2020; Waldman & Rillig, 2020), found that microplastic films led to a slight increase in soil pH. This aligns with studies demonstrating that plastic films can alter the diversity of nitrogen-fixing bacterial taxa in the soil (Zhao et al., 2021). These microbial changes can affect soil NH_4^+ levels and subsequently influence soil pH. The conversion of organic nitrogen to NH_4^+ consumes H^+ ions, resulting in an increase in soil pH (You et al., 2015; Zhao et al., 2021). Therefore, our findings suggest that the presence of microplastics may have implications for soil biota and nitrogen cycling processes, ultimately influencing soil pH. Therefore, the observed variations in soil pH underscore the potential impact of plastic treatments on nutrient dynamics and highlight the need for further investigations into the specific mechanisms involved.

In general, microplastics (MPs) have lower adsorption capacities for metals, such as zinc (Zn), lead (Pb), and cadmium (Cd), in comparison to pure soil. As a result, the presence of microplastics can reduce the adsorption of these metals by the soil. However, it can also lead to an increase in their desorption from the soil (Feng et al., 2022). The adsorption kinetics of cadmium (Cd) in a previous study by (Zhang et al., 2020) were observed to follow the pseudo-second order model. Additionally, the adsorption isotherm analysis revealed that the Langmuir model provided a more accurate fit than the Freundlich model. In general, the presence of microplastics (MPs) resulted in a decrease in Cd adsorption and an increase in Cd desorption from the soil. These effects were influenced by factors such as the dose and particle size of the microplastics, as well as the pH of the solution (Zhang et al., 2020). Relating these findings to our study on zinc, it is plausible that similar mechanisms may be at play, suggesting that the presence of microplastics could also impact the adsorption and desorption of zinc in the soil.

It is important to highlight that zinc is classified as a heavy metal. They have the potential to accumulate in the soil over time, posing potential risks to environmental and human health. The availability of heavy metals to biological systems is affected by several environmental factors, including soil pH, cation exchange capacity, oxidation-reduction potential, organic matter content, and the composition of the microbial community (Brown et al., 2004; Feng et al., 2022; Shahid et al., 2016). The variations in zinc concentrations observed in our study underscore the relevance of understanding the behavior and fate of heavy metals in soil systems. The presence of different plastic types can influence the mobility, bioavailability, and potential accumulation of zinc in the soil. It is crucial to consider the potential long-term effects of elevated zinc levels on soil quality, as well as the potential for zinc to leach into groundwater and impact surrounding ecosystems. Future research should continue to explore the interactions between microplastics, plastic types, and heavy metal dynamics in soil systems.

The presence of microplastic (MP) contamination in natural ecosystems poses an unpredictable risk to nutrient cycling processes. MPs in the soil can disrupt the activity of microorganisms involved in the nitrogen cycle (Wijesooriya et al., 2023). Our study further supports this notion, as we observed changes in nitrogen content associated with the presence of microplastics. The type, size, and concentration of MPs directly influence the transformation of nitrogen in the soil.

Additionally, the effects of microplastics extend beyond nitrogen cycling. The results of our study also revealed variations in cation exchange capacity (CEC) and phosphorus content due to the presence of microplastics. This suggests that microplastics can influence soil nutrient availability and potentially impact plant growth and ecosystem productivity. These findings highlight the importance of considering the potential consequences of microplastic contamination on soil nutrient dynamics and the overall functioning of natural ecosystems. Microplastics (MPs) have the potential to influence the biophysical characteristics of soil, such as bulk density and water-holding capacity, as well as the interactions among microbial activities (De Souza MacHado et al., 2018).

Conclusion

This research study investigated the effects of different types and sizes of plastics on various soil properties. The results revealed significant variations in pH, total dissolved solids (TDS), available zinc, cation exchange capacity (CEC), nitrogen content, and total phosphorus influenced by plastic type and size.

The pH and TDS values of the soil were notably affected by the size and type of plastic used. This suggests that plastics have the potential to alter the soil's acidity and mineral content, which can have implications for plant growth and nutrient availability. The available zinc content varied among plastic types, indicating that specific plastics may have a greater propensity to release zinc into the soil. This finding highlights the potential for plastic pollution to contribute to metal contamination in agricultural systems. Furthermore, the plastic size influenced the cation exchange capacity (CEC) of the soil, indicating that smaller plastic particles may have a more significant impact on the soil's ability to retain and exchange essential nutrients. The nitrogen content of the soil was also influenced by plastic size, with smaller particles having a more pronounced effect. This finding suggests that smaller plastic fragments may enhance nitrogen availability in the soil, potentially leading to nutrient imbalances or altered microbial activity. The total phosphorus content varied with different plastic types, indicating that certain plastics may have the potential to influence phosphorus cycling and availability in the soil.

Overall, this study provides valuable insights into the potential effects of plastics on soil properties. Further research is necessary to explore the mechanisms underlying the release of heavy metals from plastic mulching residue and its long-term effects on soil health. Developing environmentally friendly alternatives to plastic mulching and implementing proper waste management practices are crucial for mitigating the potential risks posed by plastic residues and ensuring sustainable agricultural systems.

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