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# Plastic granules and their polluting effect on plant growth

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## ABSTRACT

The cultivation of bean plants was carried out in greenhouse conditions using plastic trays with a capacity of 5 kilograms per tray. The results revealed a decrease in growth and some physiological traits of bean plants when the soil was treated with plastic particles at concentrations of 10, 15, 20, and 25 grams per kilogram. A noteworthy drop in the fresh weight of both parts above the soil and root parts was observed when treating the soil with plastic particles at a concentration of 25 grams per kilogram, measuring 2.59 grams and 3.2 grams, respectively. It was also observed that treating the soil with plastic particles at a concentration of 25 grams per kilogram caused a significant decrease in the concentrations of total chlorophyll, carotene, and Relative Water Content, reaching 0.788 milligrams per gram fresh weight, 0.268 milligrams per gram fresh weight, and 41.85%, respectively, collation to the domination treatment. Additionally, treating the soil with plastic particles resulted in an increase in proline concentration in the leaf tissues of bean plants. The highest increase was observed when treating the soil with plastic particles at a concentration of 25 grams per kilogram, with a magnitude of 0.703 milligrams per gram of fresh weight compared to the control treatment.

**Keywords:** bean plants, carotene, chlorophyll, plastic particles, pollution.

## INTRODUCTION

Alongside the continuous evolution of the plastic industrialised, plastic processing has become broadly used in several fields such as agriculture, industry, and daily life (Xu et al., 2020). Moreover, most human activities today depend on or are influenced by plastic and plastic manufactured (Geyer et al., 2017). Generally, the sizes of microplastic particles can range from 100 nanometres to 5 millimetres, and nano-plastics are defined as particles smaller than 100 nanometres (Laura et al., 2019). The use of plastic reached 367 million tons in 2020 after it did not exceed one and a half million tons in 1950 (Plastic Europe, 2019), with agriculture and horticulture industries being major consumers of plastic materials in the form of thin sheets, pipes, and other materials. Plastic materials are also used in the transportation of fertilisers and herbicides, pest control, disease and pest management, crop storage, preservation, and construction and facilities (Andrady, 2003). Plastic membranes are used in crops and grains because of their diverse benefits in crop yield and quality (Gao et al., 2019). However, the presence of plastic residues in the soil has caused a serious natural environmental problem affecting plant growth, soil quality, and surrounding ecosystems (Wan et al., 2019; Rasheed et al., 2024). Plastic particles can enter agricultural soil in significant quantities through agrarian use, slow-release fertilisers based on polymers, sewage irrigation, fertiliser application, bio-solid materials, airborne deposits, and surface runoff, constituting common pollution of organic and inorganic pollutants in the soil (Bolan et al., 2020; Weithmann et al., 2018). Therefore, in the past 15 years, scientists worldwide have increasingly focused on plastic pollution and its impact on the environment, revealing that large and small plastic particles in aquatic ecosystems and atmospheric envelopes pose a threat to aquatic organisms, marine ecosystems, and human health (Enyoh et al., 2019; Verla et al., 2019).

The effects of airborne microplastic particles have expanded to impact human life, particularly health effects, including the respiratory system, with micro-sized particles of 250 micrometres affecting the lungs and other areas of the human body (Enyoh et al., 2019; Prata, 2018). As for its impact on plants, plant growth, regardless of its highly complicated and dynamic nature, depends on environmental states, especially soil type for terrestrial plants and water sort for aquatic plants. Microplastics in the environment can affect plant growth in several pathways, relying on the contents of the growth medium. However, the increasing prevalence of microplastics poses a danger due to their widespread use. Poor plastic waste management has led to significant environmental problems (De Silva et al., 2021). The accumulation of microplastics causes many impacts on soil quality and nutrient transfer, in addition to its impact on the microbial community (Heba et al., 2022). Plastic compounds can also alter a range of major soil biochemical processes by changing their properties, leading to multiple effects on microbial activity through the direct toxicity of plastic compound (Jie et al., 2021). Microplastics can interact with microorganisms in the soil, affecting the decomposition of organic matter, which are essential processes for maintaining soil fertility (Harpreet and Anjana, 2022). In addition, plastic waste discourages the growth of microorganisms important for soil activities (Udochukwu et al., 2017).

## MATERIALS AND METHODS

The soil for the study was selected from a farm in Nineveh Province to conduct experiments. Aboveground soil from a depth of 0–30 cm was collected in October 2023 and dried by exposure to air. After drying, the soil was filtered with a sieve that has holes of 2 mm in diameter. Greenhouse experiments were carried out to study the impact of different concentrations of residues from plastic sheet sawdust (in the form of small particles) Plastic particles were obtained from local laboratories for the manufacture of plastic doors and windows. in addition to the control treatment, with three replicates for each treatment.

Plastic particles were added at three concentrations (10, 15, 20, 25) grams per kilogram of soil. They were mixed with the soil in the pots and then placed in them to ensure thorough mixing. The experiments were carried out using plastic pots with a width of 25 cm and a 22 cm height, with each pot having a soil capacity of 6 kilograms.

### Agriculture and irrigation

Bean plant seeds were obtained from the Seed Testing and Certification Centre in Nineveh Governorate/Iraq. The seeds were sowed on 8/10/2023 at a rate of 10 seeds per pot, with equal spacing between the seeds. The pots were arranged methodically in a controlled greenhouse environment and watered with standard water at the soil's maximum water-holding capacity (75%). The quantity of water supplied to the pots was controlled regularly using a scale.

### Studied traits

#### *Estimation of fresh weight for root and shoot*

After lifting the plants from the pots, the root mass was washed to remove adhering soil. Subsequently, the water used for washing was discarded using specific drying sheets. Following this, the fresh weight of both the root and shoot masses was determined using a precision scale for weight measurement.

#### *Estimation of relative water content in leaf tissues*

Turner (1981) proposed a method to determine the relative water content. To obtain the result, the following procedure was used:

$$\begin{aligned}&\textit{Relative water content}\ (\%) = \\ &(\textit{Fresh weight} - \textit{Dry weight}) \times \\ &\times (\textit{Turger weight}) - (\textit{Dry weight})/100\end{aligned} \tag{1}$$

#### *Estimation of chlorophyll and carotenoid content in plant leaves*

Plant leaves from each plant in every treatment were collected and located in special bags until moved to the laboratory. Afterwards, 100 milligrams of each leaf were taken directly and crushed using a porcelain mortar with (10) millilitres of acetone at a concentration of (80%). The filtrate was separated from the remaining residue using a centrifuge, and the absorbance of the filtrate was read at wavelengths (480-645-663 nanometres) using a spectrophotometer. The chlorophyll content in the leaves was determined based on the method outlined in Jaleel et al. (2009).

*Estimation of proline in leaf tissues*

The amino acid proline concentration in the leaves of bean plants for each treatment was calculated using a spectrophotometer with a wavelength of 520 nanometres. This was done according to the method outlined by Bates *et al.* (1973).

## RESULTS AND DISCUSSION

### The fresh weight of the shoot parts

The data in Fig. 1 show that plastic particle injection into the soil results in decreasing fresh weight of bean plant shoots. The most intensive influence was recorded in the case of treatment with 25 grams of plastic particles per kilogram of soil. Shoots of bean plants had a fresh weight of 2.59 g, while shoots of the control plants had a fresh weight of 5.55 g. It was also observed that the stem weight of the plant decreased with increased plastic particle concentration in the soil. Minimal effect was seen when treated with a concentration of 10 g/kg soil, resulting in a fresh weight of plant shoot 5.4 as compared to that in the control treatment.

The writer can decide to Accept All or make manual modifications. The decrease in fresh weight of the aerial parts of bean plants may be a result of high soil concentration of carbon and nitrogen, possibly originating from presence plastic wastes. According to research by Lee et al. in 2019 and Ma et al. in 2018, this may cause a reduction in soil fertility. Microplastic particles will also have a damaging impact in the soil on different types of organisms if at the right digestive tract location. The physical and biological properties of the soil can be transformed by it, which includes the aggregation state and water-holding capacity, as stated by Huerta-Lwanga et al. (2017); Machado et al. (2018) and Wan et al. (2019). The above information has also been reinforced by other researchers.

### The fresh weight of the root

Fig. 2 indicates a dropping in the fresh weight of the root total for beans when treating the soil with different concentrations of plastic particles. The impact was most prominent when applying treatment to the soil with plastic particles at a concentration of 25 g/kg soil. The fresh weight of

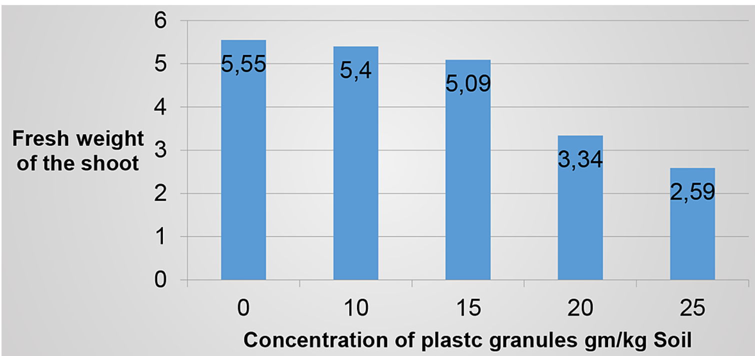


**Figure 1.** The effect of soil treatment with plastic granules on the fresh weight (gm) of bean plant shoots

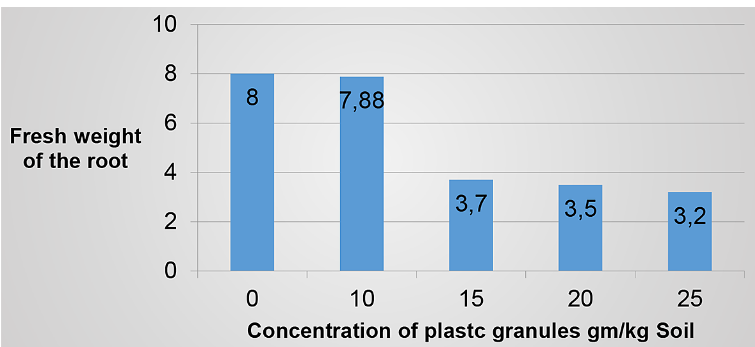


**Figure 2.** The effect of soil treatment with plastic granules on the fresh weight (gm) of bean plant roots

the root total for bean plants was 3.2 g compared to the control treatment, which was 8 g. It was also observed that the effect of treating the soil with plastic particles at concentrations of 15 and 20 g/kg soil on the fresh weight of the root total was similar, reaching 3.7 and 3.5 g, respectively.

When plastic enters the soil, it affects the physical properties of the soil-by-soil fragmentation. It also has a slow impact on ecosystems, either by the separation of large plastic particles into smaller plastic particles or by releasing poison such as (BPA) biphenyl A, additives, and absorbed composite (Sajiki and Yonekubo, 2003). This can, in turn, affect plant growth and soft weight. This is consistent with (Urbina et al., 2020), who confirmed that treatment with 100 mg/L of microplastics (PE) significantly reduced the height and biomass of corn plants and decreased nitrogen content in the roots and stems. They pointed out that the effects of microplastics on plants vary depending on the characteristics of microplastics (such as type, particle size, and shape) and plant species.

## Total chlorophyll concentration

From Fig. 3 it is evident that dealing the soil with different centralisation of plastic particles (10, 15, 20, 25 g/kg) soil resulted in a decrease in the total concentration of chlorophyll in the leaf of bean plants. Treating the soil with plastic particles at a concentration of 25 g/kg resulted in a significant decrease, reaching 0.788 mg/g fresh weight, compared to the control treatment, where the total concentration of chlorophyll in the leaf tissues was 1.975 mg/g fresh weight.

The effects of different types of plastics vary based on their concentration, exposure duration, plastic type, shape, and size (Liu et al., 2018). Both the topsoil and underground parts of the plant may be affected during vegetative growth and reproduction because of the plastic particles in the soil (Qi et al., 2018). The effects of plastic were seen through: First, the usage of microplastic particles into the plant, causing intoxication. Second, indirect shoot fresh weight parts impact on growth because it changes soil parameters. Other effects on the microbial community of the soil. Plant growth is sensitive to several factors as the works of Gu et al. (2017), Rillig et al. (2019), Qi et al. (2018) and Zang et al. (2020) showed. Besides, these factors can induce the malformation and damage problems in thylakoids and cell membranes as researched by Mao et al. (2018).

These findings might simply be explained by the fact that the effects of microplastics in the soil on plants are appropriate for their concentration. The small plastic granules' quality may delay the development of seeds and roots and also reduce the absorption of water by close-range mechanical blockage. Moreover, microplastics may tend to accumulate close to the root hairs, which reduces their growth rate (Bosker et al., 2019). The reduced water absorption, as specified from the citation, might result in a decrease in the water content of the leaves. This results in turn to closing the stomata on the surface of the plant leaves, hence concentration fall of plant pigments. Furthermore, the impact of microplastics on leaves was proved by a decrease in their capacity absorption, collection and transportation of electrons of light energy (Li et al., 2018).

## Carotenoid concentration

Carotenoids are hydrophobic tetraterpenoid compounds that function as pigments for capturing light. There are two types that these substances may be categorised into: carotenes, which lack oxygen, and xanthophylls, which contain oxygen

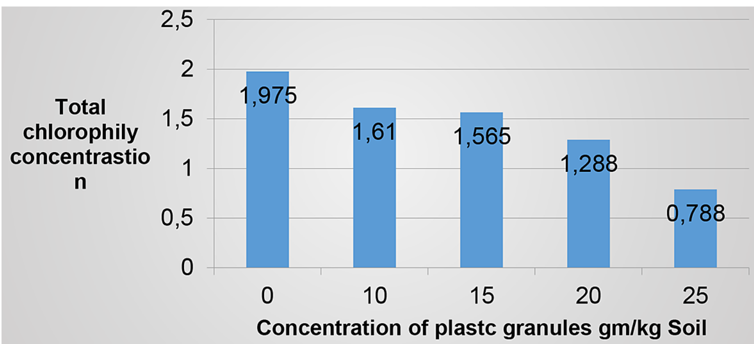


**Figure 3.** The effect of soil treatment with plastic granules on total chlorophyll concentration; (microgram/g fresh weight) of bean plant leaves

(Takaichi, 2011). Fig. 4 illustrates a decline in the concentration of carotenoids in plant leaves when the soil is altered with different amounts of plastic particles. There was an inverse relationship between the decrease in carotenoid content and the increase in particle concentration. Plastic particles at 25 g/kg soil resulted in the lowest level of carotenoids in the leaf tissues.

The carotenoid concentration in the treatment was 0.268 mg/g fresh weight, which is equivalent to the carotenoid concentration of 1.037 mg/g fresh weight in the control treatment. Furthermore, it is worthy to mention that the effects of treatments at concentrations of 15 and 20 g/kg soil exhibited a high degree of similarity in terms of their influence on carotenoid concentration.

The fact can be attributed to the suitable impact of microplastics in the soil on plants because of their concentration. Small plastics granules delay the development of seed and root growth, and inhibit water absorption through short-range mechanical blockage. Another possibility is that microplastics accumulate close to the root hairs, leading to a decrease in the growth rate (Bosker et al., 2019). The decrease in water uptake is not directly related to a decrease in leaf cellular water content, resulting in the closure of plant leaf surface stomata. This further reduces the plant pigment concentration. In addition, the effect on leaves was displayed by a reduced ability to absorb and capture light energy electrons to transfer them (Li et al., 2018).

## Water content

Transaction of the soil with different concentrations of plastic particles results in a clear decrease in the water content of bean plant leaves. This is evident in Figure 5, where an increase in soil treatment with plastic particles resulted in a reduction in the water content of plant leaves. The lowest water content appeared in plants treated with plastic particles at a concentration of 25 g/kg soil, reaching 41.85%, compared to the water content of bean plant leaves growing in untreated soil with plastic particles, which was 99.52%.

The effect of microplastics on the physicist and chemist properties of the soil and its impact on the soil pH may be a reason for the overall increase in soil volume, soil porosity, and ventilation when adding microplastics to the soil. Additionally, it affects the microorganisms in the soil (Nasrin and Rasool, 2022). This aligns with the findings of Anne et al. (2022) when studying *Arabidopsis thaliana* plants over a nine-week period. They discovered that the presence of plastic residues in the soil results in a decrease in soil water content. This effect becomes clearer when plastic residues are present at higher concentrations or big sizes. It was also observed that nano-sized plastic materials and microplastics of 50 nanometres in the soil delay water absorption or uptake, reducing germination and root growth (Li et al., 2018).

## Proline concentration

In Figure 6, it is observed that dealing soil with concentrations of 10, 15, 20, and 25 g/kg soil led to an increase in proline concentration in the leaf tissues of bean plants. The highest proline concentration was found in plants growing in soil treated with plastic particles at a concentration of 25 g/kg soil. The proline concentration reached 0.703 mg/g fresh weight compared to the control dealing, which was 0.286 mg/g. It is noteworthy that the increase was proportional to the proline concentration. As the concentration of plastic particles increased, the proline concentration in

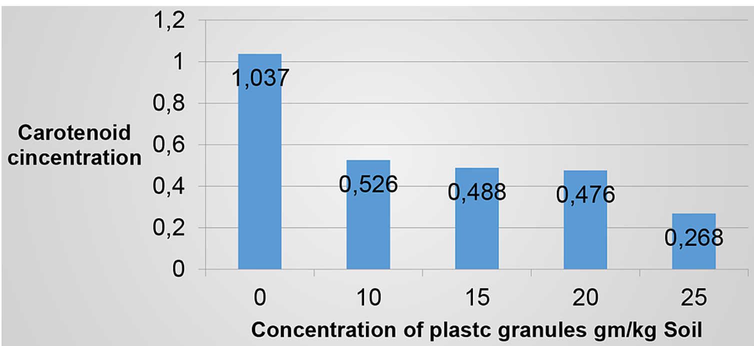


**Figure 4.** The effect of soil treatment with plastic granules on total carotenoid concentration, (mg/g fresh weight) of bean plant leaves

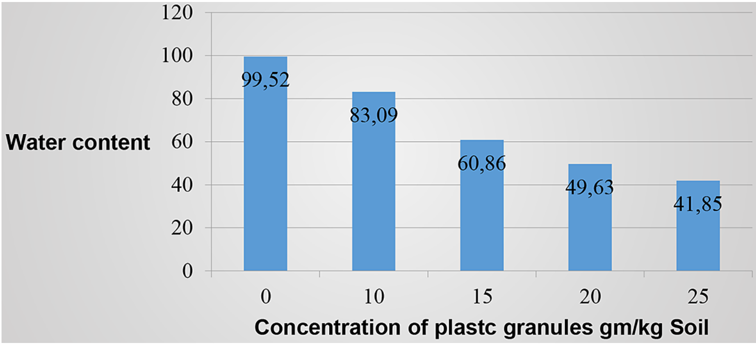


**Figure 5.** The effect of soil treatment with plastic granules on water Content (%) of bean plant leaves

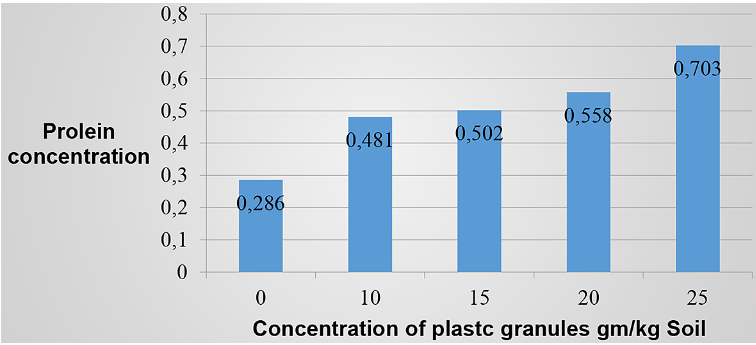


**Figure 6.** The effect of soil treatment with plastic granules on proline concentration (mg/g fresh weight) of bean plant leaves concentration (microgram/g fresh weight) of bean plant leaves

the leaf tissues of bean plants also increased. Microplastics can increase the possibility of absorbing heavy metals in the soil natural environment.

Studies conducted in aquatic environments to determine the rates of heavy metal adsorption, such as cadmium, zinc, nickel, and lead, on microplastics, have shown significant variations due to the different chemist and physicist properties of microplastics (Zhan et al., 2016) (Lambert et al., 2017). Proline concentration rises in plant leaf tissues as a result of increased heavy element concentration in the soil brought on by an increase in plastic particle concentration (Al-Rashedy, 2020).

## CONCLUSIONS

It was experimental from the research results that treating the soil with increasing concentrations of plastic particles of various sizes results in a significant lowering in the fresh weight of both the aerial and underground parts of the bean plants. Additionally, there was a decrease in water content, chlorophyll concentration, and carotene content in the leaf tissues of the plants. On the other hand, a significant increase was noted in the proline concentration compared to the control treatment. The results also clearly showed that the treatment with concentrations (20 and 25 gm/kg) soil had the greatest effect on all the studied traits compared to the control treatment and the other treatments.

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