agriculture

MDPI

**SUPPLEMENTARY MATERIAL**

# Microplastics in Agricultural Systems: Analytical Methodologies and Effects on Soil Quality and Crop Yield

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**Table S1.** Analyzed effects of MPs in the consulted research articles.

| Author (s) | Year | Country | Analyzed effects |
|---|---|---|---|
| (Zubris and Richards 2005) | 2005 | USA | Qu |
| (Kiyama, Miyahara, and Ohshima 2012) | 2012 | (-) | Fa |
| (Käppler et al. 2015) | 2015 | Germany | Me |
| (Sforzini et al. 2016) | 2016 | Italy | Fa; Ma; Ve |
| (D. Cao et al. 2017) | 2017 | China | Fa |
| (Dehghani, Moore, and Akhbarizadeh 2017) | 2017 | Iran | Qu |
| (Deng et al. 2017) | 2017 | (-) | Fa |
| (Geyer, Jambeck, and Law 2017) | 2017 | (-) | Tr |
| (Hongfei Liu et al. 2017) | 2017 | China | Ch; Ph |
| (Hodson et al. 2017) | 2017 | United Kingdom | Ch; Fa; Tr |
| (Horton et al. 2017) | 2017 | United Kingdom | Qu |
| (Huerta Lwanga, Gertsen, et al. 2017) | 2017 | (-) | Fa |
| (Huerta Lwanga, Mendoza Vega, et al. 2017) | 2017 | Mexico | Tr |
| (Maaß et al. 2017) | 2017 | Germany | Fa; Tr |
| (Rillig, Ziersch, and Hempel 2017) | 2017 | Germany | Fa; Tr |
| (Rodriguez-Seijo et al. 2017) | 2017 | (-) | Fa |
| (D. Zhu, Bi, et al. 2018) | 2018 | China | Ch; Fa; Ma; Tr |
| (D. Zhu, Chen, et al. 2018) | 2018 | China | Ch; Fa; Ma |
| (David et al. 2018) | 2018 | Germany | Me; Qu |
| (de Souza Machado et al. 2018) | 2018 | Germany | Ph; Ma |
| (G. S. Zhang and Liu 2018) | 2018 | China | Me; Qu; Tr |
| (Hurley et al. 2018) | 2018 | Norway | Me |
| (Lei et al. 2018) | 2018 | China | Fa |
| (M. Liu et al. 2018) | 2018 | China | Qu |
| (Piehl et al. 2018) | 2018 | Germany | Qu |
| (Qi et al. 2018) | 2018 | (-) | Ag; Fa |
| (Rodríguez-Seijo et al. 2018) | 2018 | (-) | Fa |
| (Scheurer and Bigalke 2018) | 2018 | Switzerland | Me |
| (Watteau et al. 2018) | 2018 | France | Me; Qu |
| (Weithmann et al. 2018) | 2018 | Germany | Qu; Tr |
| (Accinelli et al. 2019) | 2019 | (-) | Ch; Ma; Ph; Tr |
| (Allen et al. 2019) | 2019 | France | Qu; Tr |
| (Bergmann et al. 2019) | 2019 | (-) | Tr |
| (Boots, Russell, and Green 2019) | 2019 | United Kingdom | Ch; Fa; Ph; Tr; Ve |
| (Corradini et al. 2019) | 2019 | Chile | Me; Qu |
| (de Souza Machado et al. 2019) | 2019 | Germany | Ag; Ph |
| (Fueser et al. 2019) | 2019 | Germany | Fa |
| (G. S. Zhang, Zhang, and Li 2019) | 2019 | China | Ph |
| (Hüffer et al. 2019) | 2019 | Austria | Ch |
| (Ju, Zhu, and Qiao 2019) | 2019 | China | Fa |
| (Judy et al. 2019) | 2019 | Australia | Ag; Fa; Ma |
| (Kim and An 2019) | 2019 | Korea | Fa; Tr |
| (Lahive et al. 2019) | 2019 | United Kingdom | Fa |
| (Lv et al. 2019) | 2019 | China | Qu |
| (M. Yu et al. 2019) | 2019 | (-) | Fa; T |
| (Mintenig et al. 2019) | 2019 | Germany | Qu |
| (O'Connor et al. 2019) | 2019 | (-) | Tr |
| (Rezaei et al. 2019) | 2019 | Iran | Tr |
| (Song et al. 2019) | 2019 | China | Fa |
| (Y. Huang et al. 2019) | 2019 | China | Ma |
| (Y. Zhou, Liu, and Wang 2019) | 2019 | China | Qu |
| (B. Zhou et al. 2020) | 2020 | China | Qu |
| (Barreto, Rillig, and Lindo 2020) | 2020 | Germany | Fa |
| (Bayo, López-Castellanos, and Olmos 2020) | 2020 | Spain | Tr |
| (Chai et al. 2020) | 2020 | China | Ch; Ma; Ph |
| (Crossman et al. 2020) | 2020 | Canada | Qu; Tr |
| (Du et al. 2020) | 2020 | China | Qu |

| | | | |
|---|---|---|---|
| (Edo et al. 2020) | 2020 | Spain | Qu; Tr |
| (Kleunen et al. 2020) | 2020 | China | Ve |
| (L. Ding et al. 2020) | 2020 | China | Qu |
| (Lozano and Rillig 2020) | 2020 | Germany | Ve |
| (Ma, Sheng, and O’Connor 2020) | 2020 | China | Ch; Ma; Fa |
| (Mueller et al. 2020) | 2020 | Germany | Fa |
| (Oliveri Conti et al. 2020) | 2020 | Italy | Qu |
| (Pignattelli, Broccoli, and Renzi 2020) | 2020 | Italy | Ag |
| (Shaoliang Zhang et al. 2020) | 2020 | China | Qu; Tr |
| (Seeley et al. 2020) | 2020 | USA | Ch; Ma; Ph |
| (van den Berg et al. 2020) | 2020 | Spain | Qu |
| (Wu et al. 2020) | 2020 | China | Ag |
| (Y. Chen et al. 2020) | 2020 | China | Qu |
| (Y. Huang et al. 2020) | 2020 | China | Qu |
| (Z. Li, Li, Li, Zhao, et al. 2020) | 2020 | China | Ag |
| (B. Huang et al. 2021) | 2021 | China | Qu |
| (Beriot et al. 2021) | 2021 | Spain | Fa; Tr |
| (Choi et al. 2021) | 2021 | Korea | Qu |
| (Corradini et al. 2021) | 2021 | Chile | Qu |
| (Fangli Wang, Wang, and Song 2021) | 2021 | China | Ag; Ch; Ma; Ph |
| (Fakour et al. 2021) | 2021 | Taiwan | Qu |
| (G. Xu, Liu, and Yu 2021) | 2021 | China | Ag |
| (G. Xu, Yang, and Yu 2021) | 2021 | China | Ch; Fa |
| (Gkoutselis et al. 2021) | 2021 | Germany | Ma |
| (H. Li et al. 2021) | 2021 | China | Tr |
| (Harms et al. 2021) | 2021 | Germany | Qu |
| (Hernández-Arenas et al. 2021) | 2021 | Spain | Ag |
| (J. Wang et al. 2021) | 2021 | China | Qu |
| (J. Yang, Li, Li, et al. 2021) | 2021 | China | Qu |
| (J. Yang, Li, Zhou, et al. 2021) | 2021 | China | Qu |
| (Katsumi et al. 2021) | 2021 | Japan | Tr |
| (L. Cao et al. 2021) | 2021 | China | Qu |
| (L. Yu et al. 2021) | 2021 | China | Tr |
| (Lian et al. 2021) | 2021 | China | Ag; Ch; Ma; Ph |
| (M. Yang, Huang, Tian, et al. 2021) | 2021 | China | Ag |
| (Meng et al. 2021) | 2021 | The Netherlands | Ag |
| (Pflugmacher et al. 2021) | 2021 | (-) | Ag |
| (Pignattelli et al. 2021) | 2021 | (-) | Ag |
| (Radford et al. 2021) | 2021 | United Kingdom | Me |
| (Ragoobur, Huerta-Lwanga, and Somaroo 2021) | 2021 | Mauritius | Qu |
| (Rehm et al. 2021) | 2021 | Germany | Tr |
| (Ren, Kong, and Ni 2021) | 2021 | China | Qu |
| (Rondoni et al. 2021) | 2021 | Italy | Fa; Ve |
| (S. Feng, Lu, and Liu 2021) | 2021 | China | Qu |
| (Shuxin Li et al. 2021) | 2021 | (-) | Ag |
| (S. Liu et al. 2021) | 2021 | China | Ag; Ch |
| (Selonen et al. 2021) | 2021 | (-) | Ch; Fa |
| (van Schothorst et al. 2021) | 2021 | Spain | Qu |
| (W. Yang, Cheng, Adams, et al. 2021) | 2021 | (-) | Ag; Ma; Ph |
| (X. Chen et al. 2021) | 2021 | China | Ch |
| (Xiao et al. 2021) | 2021 | China | Ch; Ph |
| (Yan et al. 2021) | 2021 | China | Ch; Ma |
| (Zhao, Lozano, and Rillig 2021) | 2021 | Germany | Ch; Ma; Ph |
| (Boughattas et al. 2022) | 2022 | Tunisia | Ch; Fa; Tr |
| (Chouchene et al. 2022) | 2022 | Tunisia | Qu |
| (Colzi et al. 2022) | 2022 | (-) | Ve |
| (Fang Wang et al. 2022) | 2022 | China | Ch; Ma; Ph |
| (F. Zhu et al. 2022) | 2022 | China | Ch; Ma |
| (Ferreira-Filipe et al. 2022) | 2022 | Portugal | Fa; Ma; Qu |
| (Gentili et al. 2022) | 2022 | Italy | Ve |

| | | | |
|---|---|---|---|
| (Greenfield et al. 2022) | 2022 | United Kingdom | Ag; Ch; Ma; Ph |
| (Hao Liu et al. 2022) | 2022 | China | Qu |
| (Haixin et al. 2022) | 2022 | China | Qu |
| (Han et al. 2022) | 2022 | China | Tr |
| (J. Ding et al. 2022) | 2022 | China | Fa; Ma |
| (Xiangtao Jiang et al. 2022) | 2022 | China | Ch; Fa; Tr |
| (Xiaofeng Jiang et al. 2022) | 2022 | China | Fa |
| (K. Chen et al. 2022) | 2022 | China | Fa |
| (L. Xu et al. 2022) | 2022 | China | Qu; Tr |
| (Lang et al. 2022) | 2022 | China | Qu; Tr |
| (Perez et al. 2022) | 2022 | (-) | Me |
| (Pérez-Reverón et al. 2022) | 2022 | Spain | Qu |
| (Rezaei et al. 2022) | 2022 | Iran | Tr |
| (Shitong Li et al. 2022) | 2022 | China | Qu |
| (Shuwu Zhang et al. 2022) | 2022 | China | Ch; Fa |
| (Schell et al. 2022) | 2022 | Spain | Qu |
| (Scopetani et al. 2022) | 2022 | Finland | Qu |
| (X. Feng et al. 2022) | 2022 | China | Ch; Ph |
| (X. Liu et al. 2022) | 2022 | China | Qu |
| (Y. Yang et al. 2022) | 2022 | China | Tr |

(-): Unspecific or non-relevant; Ag: Agricultural interest crops; Ch: Chemical processes; Fa: Fauna; Ma: Microbial activity; Me: Methodology; MP: Microplastic; Ph: Physical processes; Qu: Quantification; Tr: Transport; Ve: Vegetation.

**Table S2.** Overview of some reviewed classifications of MPs particles in agricultural soils.

| Shape | Size | Reference |
|---|---|---|
| Fiber, fragment, Ffilm, pellet | < 1 mm, 1–3 mm and 3–5mm | (M. Liu et al. 2018; Lv et al. 2019) |
| Membrane, alveolar structures, thick electro-dense particles | 0–2 μm, 2–20 μm and 20–50 μm | (Watteau et al. 2018) |
| Fiber, film, fragment | 0–5 mm | (B. Zhou et al. 2020) |
| Fiber, film, fragment, pellet | 0–150 μm (fiber width), 0–10 mm (fiber length) and 1.5 $mm^2$ (particle surface) | (Corradini et al. 2019) |
| Fiber, fragment, microbead, foam | 0.02–0.2 mm, 0.2–0.5 mm, 0.5–1 mm, 1–3 mm and 3–5 mm | (Y. Chen et al. 2020) |
| Fiber, film, fragment, string | 0.05 mm–0.25 mm, 0.25–1 mm and 1–10 mm | (G. S. Zhang and Liu 2018) |
| Fiber, fragment, sphere | 1–2 mm, 2–5 mm and > 5 mm | (Weithmann et al. 2018) |
| Fiber, film, fragment | 1–5 mm | (Piehl et al. 2018) |
| Fiber, film, fragment, pellet | 0–1 mm, 1–2 mm, 2–3 mm, 3–4 mm, 4–5 mm and > 5 mm | (L. Xu et al. 2022) |
| Fiber, film, fragment, pellet | 100–500 μm, 500 μm–1 mm, 1–2 mm and 2–5 mm | (Haixin et al. 2022) |
| Fiber, film, fragment, pellet, foam | 0–500 μm, 500–1000 μm and > 1–< 5 mm | (Xiaofeng Jiang et al. 2022) |

**Table S3.** Significant growth and biochemical effects observed in MPs exposed plants of agricultural interest compared to control plants.

| Specie | MP | Size (μm) | Dose [a] | Plant significant effects | Reference |
| --- | --- | --- | --- | --- | --- |
| Barley (*Hordeum vulgare* L. cv. L G Flynn) | PE, biodegradable PHBV | 40–48 and 1–15, respectively | 0.01 | ≈ 8 months field experiment. No differences in height, Chl content, grains per ear and straw, 1000 grain and ear dry weights. PE yield to $N_2O$ flux and soil moisture decrease. | (Greenfield et al. 2022) |
| Bean (*Phaseolus vulgaris* L.) | PE, biodegradable PLA+PBAT | 250–500 (60%) and 500–1000 (40%) | 0.5, 1, 1.5, 2, 2.5 | At the end of vegetative stage (46 days after seeding): dose-dependent decrease of dry shoots and roots biomass, dry leaf/root ratio and leaf area for PLA+PBAT; dose-dependent decrease of Chl content for PE and PLA+PBAT; increase of specific root length and nodule for PE and PLA+PBAT (dose-dependent for PE); leaf area increase at 1% and decrease at 0.5% for PE. After full maturation (105 days after seedling): dose-dependent decrease of fruit biomass for PLA+PBAT. | (Meng et al. 2021) |
| Chinese cabbage (*Brassica chinensis* L.) | PE, PS | < 25, 25–48, 48–150, 150–850 | 0.25, 0.5, 1, 2 | Measurements at 1 month. Decrease of aerial fresh weight with 1 and 2% of PS (< 25 and 48–150 μm). PS and PE (both 48–150 μm): decrease of Chl, dose-dependent decrease of starch contents, dose-dependent increase of soluble content. PS and PE (both 1%): decrease of Chl, increase of soluble sugar at 48–150 and 150–180 μm sizes but decrease at < 25 μm size. PE 1%: dose-dependent decrease of starch content. | (M. Yang, Huang, Tian, et al. 2021) |
| Cress (*Lepidium sativum* L.) | PC, aged PC (40, 80, 120, 160 days) | 3000 | 2 | Measurements at 7 days. Decrease of the germination rate. Aging-dependent decrease of root, shoot and seedling length, fresh and dry weights, and Chl content. Aging-dependent increase of CAT activity. | (Pflugmacher et al. 2021) |
| Cress (*Lepidium sativum* L.) | PET | 5–60, 61–499, 500–3000 | 0.02 | Measurements at 6 days. Increase of inhibition of germination percentage, and leaf $H_2O_2$, leaf and root GSH and root AsA concentrations; size-dependent decrease of shoots height; decrease of leaf number; size-dependent increase of root $H_2O_2$ and leaf AsA concentrations; no changes in plant total fresh biomass. Treatment x acid rain interactions were found. | (Pignattelli et al. 2021) |
| Cress (*Lepidium sativum* L.) | PP, PE, PVC, PE + PVC | < 125 | 0.02 | At 6 days: all MPs increase percentage of inhibition of germination and shoots fresh biomass (except PE for shoots biomass), and decrease shoots height and GSH content; PE and PE + PVC increase $H_2O_2$ content, and PE, PVC and PE + PVC decrease AsA content. At 21 days: PE and PP increase percentage of inhibition of germination; PE, PP and PVC decrease shoots biomass and increase GSH content; PE and PVC increase $H_2O_2$ content; PVC decrease AsA content; all MPs increase Chl a content; PE, PVC and PP increase Chl b and carotenoids contents; PVC and PP increases aminolaevulinic acid content; PVC increases proline content and PE + PVC decreases it. | (Pignattelli, Broccoli, and Renzi 2020) |
| Lettuce (*Lactuca sativa* L.) | PE | 8.68–500 | 0.1, 1, 10 | Dose-dependent shoot and root dry biomass decrease. Shoot and root Cd concentration and accumulation. | (Fangli Wang, Wang, and Song 2021) |

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| Lettuce (*Lactuca sativa* L.) | PVC | 0.1–18, 18–150 | 0.5, 1, 2 | Measurements at 3 weeks. Roots: no significant effect on the root activity; size- and dose-dependent increase in roots length, surface area, volume and diameter. Leaves: no changes in MDA, Chl and carotenoids content; size- and dose-dependent increase of SOD. | (Z. Li, Li, Li, Zhao, et al. 2020) |
| Maize (*Zea mays* L. cv. ZNT 488 and cv. ZTN 182) | PU | 4280 | 0.01, 0.1, 1 | Measurements at 6 weeks. Increase of plant height, shoot dry biomass, Chl, carotenoids and Pn for cv. ZTN 182 at 1%. Tr increased for ZNT 488 at 0.1 and 1%, for ZTN 182 decreased at 1%. Gs increased for ZNT 488 at 0.1 and 1% and for ZTN 182 at 1%. | (Lian et al. 2021) |
| Maize (*Zea mays* L. var. Wannuoyihao) | PE, PLA | 100–154 | 0.1, 1, 10 | Measurements 1 month after seed sowing. PE increased and PLA decreased shoot and root dry biomass at 10%. PE and PLA generally increased root Zn content in plants exposed to ZnO, did not change shoot Zn content at 500 mg/kg ZnO, and decreased shoot Zn content at 50 mg/kg. MPs also changed Zn content in plants receiving without ZnO application: at 10%, both MPs decreased shoot Zn content, but PE decreased root Zn content and PLA increased it. | (W. Yang, Cheng, Adams, et al. 2021) |
| Rice (*Oryza O. sativa* L. II You. 900) | PS | 8.5–30.7 | 0.005, 0.025 | Farmland experiment for 142 days. No changes in root fresh biomass and length. Decrease of stem fresh biomass and length. Decrease of grain biomass. See original reference for metabolite analysis in leaves. | (Wu et al. 2020) |
| Soybean (*Glycine max* L.*Merrill*) | PS | 0.1, 1, 10, 100 | 0.001 | Measurements at 10, 20 and 30 days. Size- and date-dependent increase of MDA content and CAT and POD activity in roots and stems; increase of SOD activity in roots and stems; in leaves, increase of MDA content and size- and date-dependent increase of CAT, SOD and POD activities. PS decreased the uptake of PHE in leaves; size- and date-dependent decrease of PHE in roots and increase in stems. | (G. Xu, Liu, and Yu 2021) |
| Spring onion (*Allium fistulosum* L.) | PES (fiber); PA (bead); PE, PET, PP, PS (fragments) | 5000, 15–20, 643, 222–258, 647–754, and 547–555, respectively | PES at 0.2, the rest at 2.0 | Measurements at 40 days. PES, PS, PE, PET, PP: increase root dry biomass, root/leaf dry biomass ratio, onion bulbs dry biomass. PES and PS increase root tissue density. PES, PET and PP decrease bulb water content. PA decrease root/leaf dry biomass ratio, root tissue density, onion bulbs dry biomass, and increase onion bulb water content, leaves biomass and leaf nitrogen content. PES decrease leaf nitrogen content. PES, PET, PP decrease onion bulb water content. All MPs increase root length, and decrease root diameter. | (de Souza Machado et al. 2019) |
| Tomato (*Lycopersicon esculentum Mill.*) | PET | 310–2110 | 17 870 ± 2174, 27 821 ± 1357, 47 130 ± 3002 [b] | Measurements after three and a half months of cultivation. No changes in shoot and root length, stem diameter and root/shoot biomass. 27 821 ± 1357 dose led to root and shoot dry biomass increase; 17 870 ± 2174 dose led to shoot dry biomass increase. Decrease of number of mature tomatoes. | (Hernández-Arenas et al. 2021) |
| Wheat (*Triticum aestivum* L. cv. NAU 9918) | PE | 200–250 | 0.5, 1, 2, 5, 8 | Measurements at 15 days. Dose-dependent increase of root length, aerial and roots fresh weights. PHE concentration in leaves and roots decrease proportionally to increasing amounts of PE. Roots: dose-dependent increase of SOD, | (S. Liu et al. 2021) |

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|---|---|---|---|---|---|
| | | | | CAT and POD activity. Leaves: dose-dependent increase of Chl; 1% PE increases carotenoids content, but 5 and 8% PE decreases it. PHE exacerbates toxic effects of PE. | |
| Wheat (*Triticum aestivum* L. var. Axe) | PE, PET, PVC | 370–2630, 510–2780 and 370–1940, respectively | 0.5 | For each MP, three kinds of soils (Kirby Sand, Kirby Clay and Warialda Loam) and three incubation periods (0, 3 and 9 months) were studied. No changes in dry shoot biomass. Germination rate decrease only in Kirby Sand soil after 3-months incubation with PE and after 9-months incubation with PVC. | (Judy et al. 2019) |
| Wheat (*Triticum aestivum* L.) | PE, starch-based biodegradable (Pullulan 37.1%, PET 44.6% and PBT 18.3%). | 50–250 (25%), 250–500 (62.5%) and 500–1000 (12.5%) | 1 | No changes: relative Chl content at 2 months, plant height at 2 and 4 months (61 days and 139 days, respectively) and number of fruits at 4 months (with and without earthworms). With bioplastic: decrease in shoot dry biomass number of leaves, leaf area and stem diameter at 2 months (with and without earthworms), shoot dry biomass at 4 months (with earthworms) and in number of tillers at 4 months (without earthworms). With bioplastic and PE: decrease in root dry biomass at 2 months (without earthworms). | (Qi et al. 2018) |
| Zucchini (*Cucurbita pepo* L. var. Faenza) | PP, PE, PVC, PET | 40–50 | 0.02, 0.1, 0.2 | Measurements at 28 days. No changes in leaf dry matter content and shoot water content. Shoot dry weight decrease with PVC and PP, dose-dependent decrease with PE and PET. Dose-dependent decrease of root and shoot fresh weight and root dry weight with PVC, PP and PET. Leaf area decrease with PVC and with 0.2% PE. Specific leaf area decreases with PE and with 0.1 and 0.2% PVC. Root water content decreases with 0.1 and 0.2% of PET. Chl content decreases with PE and PVC. See original reference for root, stem and leaf mineral content discussion. | (Colzi et al. 2022) |

[a] % w/w MP/dry weight soil unless otherwise noted; [b] particles kg$^{-1}$ dry weight. AsA: Ascorbic acid; CAT: Catalase; Chl: Chl; cv.: Cultivar; DBP: di-*n*-butyl phthalate; DPPH: 2,2-Diphenyl-1-picrylhydrazyl; Gs: stomatal conductance; GSH: glutathione; $H_2O_2$: Hydrogen peroxide; MDA: Malondialdehyde; MP: Microplastic; PA: Polyamide; PBAT: poly-butylene-adipate-co-terephthalate; PBT: Polybutylene Terephthalate; PE: Polyethylene; PES: Polyester; PET: Polyethylene terephthalate; PHBV: poly(3-hydroxybutyrate-co-3-hydroxyvalerate); PHE: Phenanthrene; PLA: Polylactic acid; Pn: Photosynthetic rate; POD: peroxidase; PP: Polypropylene; PS: Polystyrene; PVC: Polyvinyl chloride; SOD: Superoxide dismutase; Tr: Transient transpiration rate; var.: variety.

**Table S4.** Significant growth and biochemical effects of selected experiments in which MPs were exposed to hydroponic or Petri dish grown plants of agricultural interest compared to control plants.

| Specie | MP | Size (µm) | Dose (mg mL$^{-1}$) | Plant significant effects | Reference |
|---|---|---|---|---|---|
| Barley (*Hordeum vulgare*) | PS | 5.64 | 2000 | Measurements at 14 days (hydroponic crop). Roots: increase of $O_2{\cdot}^-$ and $H_2O_2$ levels, and the activities of dehydroascorbate reductase, glutathione reductase, adenosine diphosphate-Glucose pyrophosphorylase, fructokinase and phosphofructokinase; decrease of activities of cell wall peroxidase, vacuolar invertase, sucrose synthase, phosphoglucomutase, glucose-6-phosphate dehydrogenase and phosphoglucoisomerase. Leaves: increase trans-zeatin and decrease indole-3-acetic acid, indole-3-butyric acid and dihydrozeatin. | (Shuxin Li et al. 2021) |
| Broad bean (*Vicia faba*) | PS | 0.1, 5 | 0.01, 0.05, 0.1 | Measurements at 2 days. Size- and dose-dependent decrease in root length, fresh and dry weight. With 0.1 µm MP, MDA decreased at 0.05 mg mL$^{-1}$ but increased at 0.1 mg mL$^{-1}$. Antioxidant enzymes: SOD increase; CAT dose-dependent decrease with 5 µm MP but increase with 0.1 µm MP; and POD increase except for 0.1 µm MP at mg mL$^{-1}$, which decreases. | (Xiaofeng Jiang et al. 2019) |
| Cress (*Lepidium sativum*) | PS | 0.5, 4.8 | $10^3$, $10^4$, $10^5$, $10^6$, $10^7$ | Reduction of seed germination rate (at 8 h after exposure but not at 24 h). Size-dependent changes of root and shoot length. No changes in Chl contents. | (Bosker et al. 2019) |
| Cucumber (*Cucumis sativus* L.) | PS | 0.1, 0.3, 0.5, 0.7 | 0.05 | Measurements at 65 days (hydroponic crop). Stem length, internode length of stem, fresh and dry aerial biomass decrease with 0.3 µm MP. $H_2O_2$ content increase and SOD activity decrease with 0.7 µm MP. MDA content increase and CAT activity decrease with 0.5 and 0.7 µm MP. Proline level decrease with 0.1 µm MP. POD activity increases and Chl and carotenoids levels decrease with 0.1 and 0.7 µm MP. Soluble proteins increase with 0.3, 0.5 and 0.7 µm MP. Soluble sugar decrease with 0.1, 0.3 and 0.7 µm MP. Vitamin C increase. In old leaves an exposure to 0.7 µm PS led to an Fe increase, whereas 0.5 µm PS conducted to a Zn decrease. In young leaves 0.5 µm PS decreased Fe content; 0.1, 0.3 and 0.7 µm PS increased zinc content; 0.3 and 0.5 µm PS yielded to lower Ca content; and K level decreased under the influence of the four evaluated sizes. | (Z. Li, Li, Li, Zhou, et al. 2020) |
| Lentil (*Lens culinaris*) | PE | 0.74–4.99 | 0.01, 0.05, 0.1 | Dose-dependent decrease in germination viability at 2 days and germination rate at 7 days. Decrease in root and shoot lengths, roots and shoots fresh weights, shoots dry weight and dose-dependent roots dry weight at 7 days. Dose-dependent increase of antioxidant enzymes (SOD, CAT), $H_2O_2$, and MDA content at 7 days. | (De Silva et al. 2022) |
| Lettuce (*Lactuca sativa* L. var. *ramosa* Hort) | PE | ≈23 | 0.25, 0.5, 1 | At 14 and 28 days: reduction of growth (fresh and dry weight of leaves and roots, plant height, number of leaves and roots lenght), photosynthetic parameters (Pn, Gs, Tr, Fv/Fm and ETR, except increase of Ci), Chl content, and Rubisco enzyme activity; increase of $H_2O_2$ and $O_2{\cdot}^-$ levels, antioxidant enzymes SOD, CAT, GSH-Px, APX, GR, DHAR, and MDHAR contents, and AsA, GSH and MDA enzyme activity indicators levels. All the effects are strengthened by adding DBP. | (Gao, Liu, and Song 2019) |
| Lettuce (*Lactuca sativa* L. var. *ramosa* Hort) | PS | 0.1–1, > 10 | 0.25, 0.5, 1 | Seedlings collected at 28 days. Decrease in shoots and roots dry biomass. Increase of oxidative stress (increase of $O_2{\cdot}^-$, $H_2O_2$ and MDA contents in leaves and roots) and antioxidant enzyme activities (increase of activities of SOD, CAT, and GSH-Px in the leaves and roots). All the effects are strengthened by adding DBP. | (Gao et al. 2021) |
| Onion (*Allium cepa*) | PS | 0.1 | 0.025, 0.05, 0.1, 0.2, 0.4 | At 3 days. Decrease of root length and mitotic index. Increase of the hydroxyl and $O_2{\cdot}^-$ content, DPPH scavenging activity and lipid peroxidation. Induction of cytogenotoxicity. | (Maity et al. 2020) |
| Rice (*Oryza sativa* L.) | PS | 0.2 | 0.0001, 0.01, 1 | Dose-dependent increase of root length, reduction of antioxidant enzyme activity, induction of expression of genes related to antioxidant enzyme activity in plant roots. No changes in seed germination, bud length and lateral root number. | (Q. Zhang et al. 2021) |

AsA: Ascorbic acid; APX: ascorbate oxidase; CAT: Catalase; Chl: Chl; Ci: intercellular $CO_2$ concentration; DBP: di-*n*-butyl phthalate; DHAR: dehydroascorbate reductase; DPPH: 2,2-Diphenyl-1-

picrylhydrazyl; ETR: Photosynthetic electron transport rate; $F_v/F_m$: maximum quantum yield of photosystem II; GR: glutathione reductase; Gs: stomatal conductance; GSH: glutathione; GSH-Px: Glutathione peroxidase; $H_2O_2$: Hydrogen peroxide; MDA: Malondialdehyde; MDHAR: monodehydroxyascorbate reductase; MP: Microplastic; $O_2^{\cdot-}$: Superoxide radicals; PE: Polyethylene; Pn: Photosynthetic rate; POD: peroxidase; PS: Polystyrene; SOD: Superoxide dismutase; Tr: Transient transpiration rate; var.: variety.

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