# EFFECT OF INORGANIC AND ORGANIC SOIL AMENDMENTS ON MAIZE BIOMASS PRODUCTIVITY

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## Introduction

In recent decades agriculture systems have tried to increase productivity at the same level of fertilization or even with reduced fertilization. It is very promising to use soil amendments alone or in a mixture with fertilizer. Changes in temperature and precipitation distribution affect soil microbial processes and above and below-ground biomass. Soil amendments are promising due to their ability to reduce SOM decomposition and possible carbon sequestration. Connecting inorganic and organic soil amendment features with mineral fertilizers is promising in modern agronomy systems. We hypothesize that mineral composites and organic amendments in combination with mineral fertilization might affect the biomass productivity of maize.

## The aim of research

This study aimed to determine the effect of different zeolite composites and mixtures with lignite or leonardite on the biomass production of maize. The objective of this study was to determine the effect of different mineral composites, organic amendments, and their doses on the biomass production of maize with the detailed characteristics of the root system.

## Materials and Methods

A pot experiment was conducted at the experimental station of the Faculty of Agriculture and Economics of the University of Agriculture, located in Kraków-Mydlniki in the period 2020-2021. The average annual temperature during the study period was 7.7 °C. The pots were arranged according to a completely randomized design with four replications. Three experimental factors were considered: inorganic composite (zeolite/vermiculite, zeolite/carbon), organic amendment (lignite, leonardite), and rate (low, high). The experiments consisted of 40 pots with the following treatments (Table 2). The root samples were prepared for analysis using a hydro-pneumatic washing system (Smucker et al., 1982) to separate soil particles from the roots. Its morphometric parameters were calculated by methods described by Głąb et al. (2020), i.e., root length density (RLD), mean root diameter (MRD), root surface area density (RSAD), specific root length (SRL), and root volume density (RVD). Statistical analyses were conducted with Statistica v. 13.0 statistical software package (StatSoft Inc., Tulsa, OK, USA).

***Table 2.** Summary of treatment in experimental design.*

| Treatment | Fertilizer | Composite | Organic amendment | Rate |
|---|---|---|---|---|
| CTR | - | - | - | - |
| MF | mineral NPK | - | - | - |
| MF+ZV3%+Lig3% | mineral NPK | zeolite/vermiculite | lignite | low |
| MF+ZV9%+Lig6% | mineral NPK | zeolite/vermiculite | lignite | high |
| MF+ZV3%+Leo3% | mineral NPK | zeolite/vermiculite | leonardite | low |
| MF+ZV9%+Leo6% | mineral NPK | zeolite/vermiculite | leonardite | high |
| MF+ZC3%+Lig3% | mineral NPK | zeolite/carbon | lignite | low |
| MF+ZC9%+Lig6% | mineral NPK | zeolite/carbon | lignite | high |
| MF+ZC3%+Leo3% | mineral NPK | zeolite/carbon | leonardite | low |
| MF+ZC9%+Leo6% | mineral NPK | zeolite/carbon | leonardite | high |

***Table 1.** Basic soil physical and chemical properties.*

| Parameter | Unit | Value |
|---|---|---|
| pH ($H_2O$) | | 5.24± 0.02 |
| pH (KCl) | | 5.03±0.01 |
| $C_{org}$ | g kg$^{-1}$ | 5.74± 0.07 |
| $N_{total}$ | g kg$^{-1}$ | 0.40± 0.01 |
| C:N | | 14.35 |
| P | g kg$^{-1}$ | 0.176±0.03 |
| K | g kg$^{-1}$ | 0.389±0.04 |
| Ca | g kg$^{-1}$ | 0.35±80.02 |
| Mg | g kg$^{-1}$ | 0.250±0.02 |
| S | g kg$^{-1}$ | 0.118±0.01 |
| Pb | mg kg$^{-1}$ | 188 ± 15 |
| Cd | mg kg$^{-1}$ | 1.15 ± 0.08 |
| Zn | mg kg$^{-1}$ | 267 ± 18 |
| Cr | mg kg$^{-1}$ | 5.32 ± 0.73 |
| Cu | mg kg$^{-1}$ | 5.14 ± 1.33 |
| Ni | mg kg$^{-1}$ | 2.22 ± 0.18 |
| EC | µS cm$^{-1}$ | 273 |
| Solid particle density | g cm$^{-3}$ | 2.65± 0.06 |
| Sand | g kg$^{-1}$ | 850 |
| Silt | g kg$^{-1}$ | 120 |
| Clay | g kg$^{-1}$ | 30 |

## Results and Discussion

The lowest biomass was produced at the CTR treatment (26.3 g) without fertilization and soil amendments, composites and organic amendments (Table 3). The highest aboveground biomass of maize straw was obtained at the MF treatment (138.8 g). Root dry matter was also affected by fertilisation and soil amendments, similarly to aboveground biomass (Table 4). The lowest RDMD was noticed at the CTR (0.23 mg cm$^{-3}$), whereas the highest was at the MF treatment (1.49 mg cm$^{-3}$). Linear regression models for the root:shoot ratios are presented in Figure 1. The most frequent root diameter fraction at every treatment was 0.1-0.2 mm (Figure 2). Zeolite/vermiculite and zeolite/carbon composites applied as inorganic soil amendment along with organic soil amendment affected the productivity of maize, both aboveground and root biomass.

### Highlights

- Mineral-organic fertilizer mixtures have a positive effect on the yield of maize.
- A higher rate of organic treatments resulted in a higher maize root diameter.
- The correlation between aboveground and root biomass was statistically significant.

***Table 3.** Above-ground biomass productivity for soil amendments treatment (g per pot). Treatments: control (C), mineral fertilization (MF), zeolite/vermiculite composite (ZV), zeolite/carbon composite (ZC), lignite (Lig), and leonardite (Leo). Different letters indicate significant differences by the Bonferroni test (P<0.05) (superscripts used only for significant differences according to ANOVA). Asterisks indicate significant differences between controls (CTR and MF) and the mean values of other treatments.*

| Composite | Organic amendment | Rate | Straw (g) | Cob (g) | Straw and cob (g) | RSR |
|---|---|---|---|---|---|---|
| CTR | | | 26.3* | 0.0 | 26.3* | 0.163* |
| MF | | | 138.8* | 39.8 | 168.7* | 0.116* |
| ZV | Leo | High | 92.7 | 47.3 | 122.2 | 0.093 |
| | | Low | 105.2 | 57.6 | 134.0 | 0.112 |
| | Lig | High | 111.3 | 33.8 | 136.7 | 0.103 |
| | | Low | 96.4 | 47.8 | 126.3 | 0.093 |
| ZC | Leo | High | 96.2 | 48.5 | 120.5 | 0.105 |
| | | Low | 87.6 | 49.1 | 112.1 | 0.067 |
| | Lig | High | 105.2 | 31.6 | 128.9 | 0.125 |
| | | Low | 100.4 | 42.5 | 127.0 | 0.112 |
| Means for Organic amendment and Rate interaction | | | | | | |
| | Leo | High | 94.4 | 47.9 | 121.3 | 0.099 |
| | | Low | 96.4 | 53.3 | 123.0 | 0.090 |
| | Lig | High | 108.3 | 32.7 | 132.8 | 0.114 |
| | | Low | 98.4 | 45.2 | 126.6 | 0.103 |
| Means for Composite and Rate interaction | | | | | | |
| | | High | 102.0 | 40.5 | 129.4 | 0.098 |
| | | Low | 100.8 | 52.7 | 130.1 | 0.103 |
| | | High | 100.7 | 40.1 | 124.7 | 0.115 |
| | | Low | 94.0 | 45.8 | 119.5 | 0.090 |
| Means for Composite | | | | | | |
| ZV | | | 101.4 | 46.6 | 129.8 | 0.101 |
| ZC | | | 97.3 | 42.9 | 122.1 | 0.102 |
| Means for Organic amendment | | | | | | |
| | Leo | | 95.4 | 50.6 | 122.2 | 0.094 |
| | Lig | | 103.3 | 38.9 | 129.7 | 0.109 |
| Means for Rate | | | | | | |
| | | High | 101.3 | 40.3 | 127.1 | 0.107 |
| | | Low | 97.4 | 49.2 | 124.8 | 0.096 |

***Table 4.** Root morphometric characteristics for soil amendments treatment. Treatments: control (C), mineral fertilization (MF), zeolite/vermiculite composite (ZV), zeolite/carbon composite (ZC), lignite (Lig), and leonardite (Leo). Different letters indicate significant differences by the Bonferroni test (P<0.05) (superscripts used only for significant differences according to ANOVA). Asterisks indicate significant differences between controls (CTR and MF) and the mean values of other treatments.*

| Composite | Organic amendment | Rate | RDMD (mg cm$^{-3}$) | RLD (cm cm$^{-3}$) | SRL (cm mg$^{-1}$) | MRD (mm) | RSAD (cm$^2$ cm$^{-3}$) | RVD (cm$^3$ cm$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| CTR | | | 0.23* | 0.77* | 3.33 | 0.449 | 0.107* | 0.00214* |
| MF | | | 1.49* | 5.38* | 3.43 | 0.369 | 0.566* | 0.01420* |
| ZV | Leo | High | 0.66 | 1.75 | 3.12 | 0.395 | 0.219 | 0.00599 |
| | | Low | 0.79 | 2.48 | 3.13 | 0.408 | 0.311 | 0.00901 |
| | Lig | High | 0.70 | 2.98 | 4.07 | 0.345 | 0.298 | 0.00749 |
| | | Low | 0.57 | 1.83 | 3.21 | 0.418 | 0.235 | 0.00659 |
| ZC | Leo | High | 1.30 | 4.09 | 3.20 | 0.446 | 0.537 | 0.01583 |
| | | Low | 0.23 | 0.61 | 2.95 | 0.347 | 0.069 | 0.00157 |
| | Lig | High | 0.64 | 2.55 | 4.29 | 0.351 | 0.276 | 0.00633 |
| | | Low | 0.40 | 1.21 | 2.92 | 0.486 | 0.165 | 0.00420 |
| Means for Organic amendment and Rate interaction | | | | | | | | |
| | Leo | High | 0.981 | 2.92 | 3.16 | 0.420 a | 0.378 | 0.01091 |
| | | Low | 0.512 | 1.54 | 3.04 | 0.377 ab | 0.190 | 0.00529 |
| | Lig | High | 0.674 | 2.77 | 4.18 | 0.348 b | 0.287 | 0.00691 |
| | | Low | 0.484 | 1.52 | 3.07 | 0.452 a | 0.200 | 0.00539 |
| Means for Composite and Rate interaction | | | | | | | | |
| ZV | | High | 0.681 | 2.36 | 3.59 | 0.370 | 0.258 b | 0.00674 b |
| | | Low | 0.679 | 2.15 | 3.17 | 0.413 | 0.273 b | 0.00780 b |
| ZC | | High | 0.973 | 3.32 | 3.74 | 0.398 | 0.406 a | 0.01108 a |
| | | Low | 0.317 | 0.91 | 2.93 | 0.416 | 0.117 c | 0.00288 c |
| Means for Composite | | | | | | | | |
| ZV | | | 0.680 | 2.26 | 3.38 | 0.391 | 0.266 | 0.00727 |
| ZC | | | 0.645 | 2.11 | 3.34 | 0.407 | 0.262 | 0.00698 |
| Means for Organic amendment | | | | | | | | |
| | Leo | | 0.746 | 2.23 | 3.10 | 0.399 | 0.284 | 0.00810 |
| | Lig | | 0.579 | 2.14 | 3.62 | 0.400 | 0.243 | 0.00615 |
| Means for Rate | | | | | | | | |
| | | High | 0.827 | 2.84 a | 3.67 | 0.384 | 0.332 | 0.00891 |
| | | Low | 0.498 | 1.53 b | 3.05 | 0.415 | 0.195 | 0.00534 |

***Figure 1.** Relationship between root dry matter and aboveground biomass productivity of maize. The solid line is the fitted linear regression.*

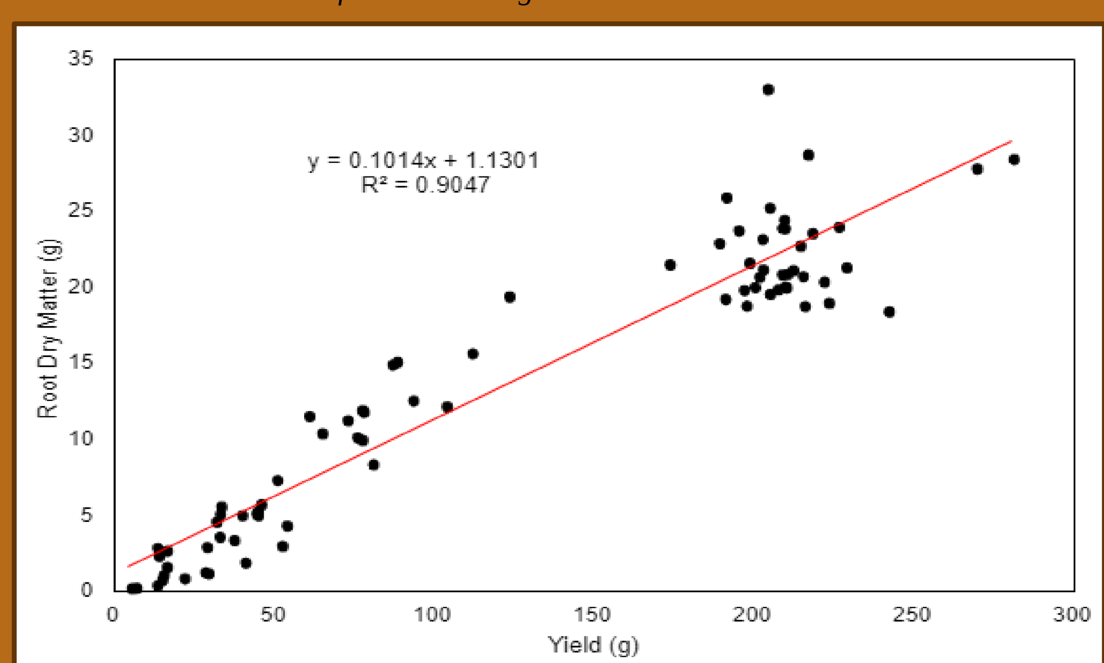


***Figure 2.** Root length density (RLD) distribution at the different root diameter values for treatments with different soil amendments. Treatments: control (C), mineral fertilization (MF), zeolite/vermiculite composite (ZV), zeolite/carbon composite (ZC), lignite (Lig), and leonardite (Leo).*

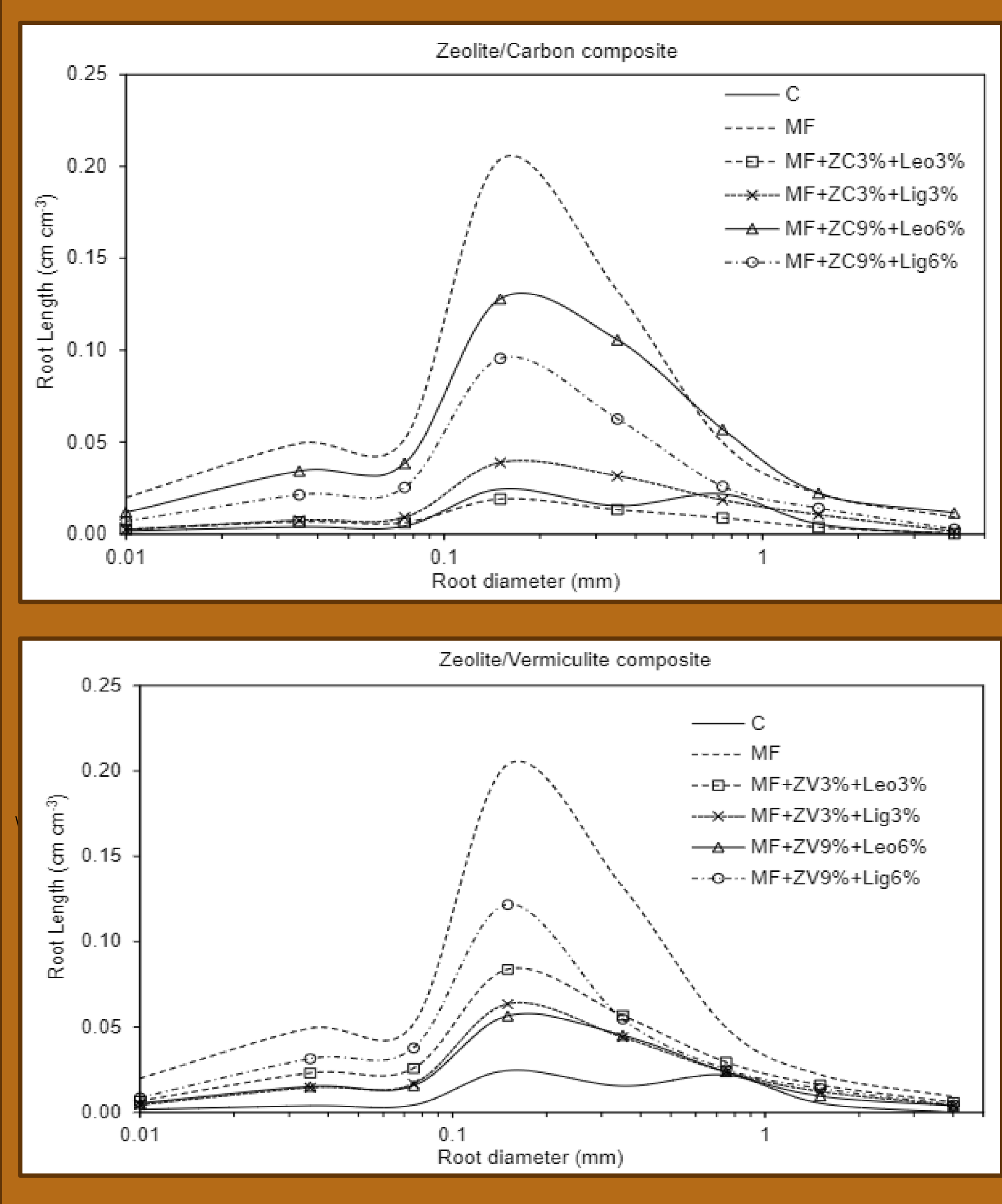


***Figure 3.** The pot experiment in vegetation hall.*

## Conclusions

1. Our investigation shows that zeolite composites with organic amendments affect maize biomass production, both aboveground and root systems.
2. The highest aboveground biomass of maize straw was obtained when mineral fertilization was applied.
3. Both aboveground and root biomass were at the same level, notwithstanding the soil amendments, zeolite composites, or organic amendments.
4. Zeolite/vermiculite composite application increased root surface area and root volume.

## References

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