**Soil health response to soil biological conditioner in Brazilian soybean fields**

Felipe Bonini da Luz, Gabriela Marques Cardoso, Andreia Mariana dos Santos Rodrigues, Rafael Braghieri Menillo, Mauricio Roberto Cherubin

**Supplementary Materials**

Table S1. Total amino acids analysis of soil biological conditioner.

|  |  |
| --- | --- |
| **Amino Acid** | **Concentration (%)** |
| Aspartic acid | 0.05 |
| Glutamic acid | 0.10 |
| Serina | <0.01\* |
| Glycine | 0.10 |
| Histidine | 0.19 |
| Taurine | <0.01\* |
| Alanine | <0.01\* |
| Valine | 0.09 |
| Methionine | <0.01\* |
| Cystine | 0.43 |
| Isoleucine | 0.09 |
| Leucine | 0.11 |
| Phenylalanine | 0.08 |
| Lysine | 0.15 |
| Hydroxyproline | <0.01\* |
| Arginine | <0.01\* |
| Threonine | 0.06 |
| Alanine | <0.01\* |
| Proline | 0.03 |
| Tyrosine | 0.10 |
| Tryptophan | <0.01\* |
| **Total**  | **1.58** |
| **Crude Protein** | **<1.50\*** |

\*Concentration lower than the detection limit.

Table S2. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in three consecutive years of the soil biological conditioner application (i.e., 2021 corresponds to one application, 2022 to two applications, and 2023 to three applications) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Sarandi-RS, South region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.37± 0.11 | 1.27 ± 0.28 | 1.38 ± 0.10 | 1.43 ± 0.00 |
| SOC (%) | 3.13 ± 0.40 | 2.61 ± 17.82 | 0.60 ± 23.78 | 1.74 ± 0.10 |
| ß-G (μ PNG g-1) | 64.35 ± 36.46 | 81.44 ± 36.0 | 24.2 ± 25.0 | 16.89 ± 15.78 |
| pH | 5.30 ± 0.34 | 5.46 ± 0.24 | 4.92 ± 0.15 | 5.13 ± 0.20 |
| P (mg dm-3) | 35.50 ± 14.96 | 46.93 ± 35.16 | 13.23 ± 9.19 | 11.20 ± 4.42 |
| K (mg dm-3) | 99.90 ± 54.03 | 121.50 ± 40.76 | 63.34 ± 49.64 | 63.93 ± 32.33 |
| Physical | 0.47 ± 0.13 | 0.55± 0.30 | 0.45 ± 0.14 | 0.36 ± 0.00 |
| Chemical | 0.88 ± 0.04 | 0.93 ± 0.07 | 0.72 ± 0.08 | 0.78 ± 0.09 |
| Biological | 0.69 ± 0.16 | 0.76 ± 0.10 | 0.76 ± 0.27 | 0.64 ± 0.23 |
| SMAF-SHI | 0.68 ± 0.10 | 0.74 ± 0.07 | 0.64 ± 0.11 | 0.59 ± 0.10 |
|  |  |  |  |  |
| **2022** |  |  |  |  |
| BD (Mg m-3) | - | - | - | - |
| SOC (%) | 2.15 ± 0.33 | 2.11 ± 0.52 | 2.07 ± 0.37 | 2.67 ± 0.32 |
| ß-G (μ PNG g-1) | 83.45 ± 34.25 | 78.89 ± 13.98 | 60.44 ± 36.54 | 53.55 ± 24.10 |
| pH | 5.10 ± 0.26 | 5.11 ± 0.08 | 5.20 ± 0.13 | 4.83 ± 0.54 |
| P (mg dm-3) | 54.48 ± 47.58 | 32.65 ± 16.26 | 35.53 ± 32.82 | 47.43 ± 17.47 |
| K (mg dm-3) | 74.68 ± 87.71 | 72.81 ± 33.77 | 44.77 ± 22.76 | 80.55 ± 37 |
| Physical | - | - | - | - |
| Chemical | 0.75 ± 0.16 | 0.81 ± 0.06 | 0.77 ± 0.08 | 0.78 ± 0.15 |
| Biological | 0.79 ± 0.19 | 0.89 ± 0.11 | 0.79 ± 0.12 | 0.91 ± 0.10 |
| SMAF-SHI  | - | - | - | - |
|  |  |  |  |  |
| **2023** |  |  |  |  |
| BD (Mg m-3) | 1.23 ± 0.16 | 1.12 ± 0.09 | 1.41 ± 0.09 | 1.41 ± 0.07 |
| SOC (%) | 2.46 ± 0.37 | 2.16 ± 0.07 | 1.85 ± 0.23 | 1.51 ± 0.09 |
| ß-G (μ PNG g-1) | 401.58 ± 221.06 | 426.46 ± 244.82 | 156.98 ± 56.83 | 309.59 ± 164.75 |
| pH | 5.17 ± 0.37 | 5.62 ± 0.35 | 4.77 ± 0.62 | 4.97 ± 0.19 |
| P (mg dm-3) | 40.63 ± 7.36 | 30.08 ± 7.05 | - | - |
| K (mg dm-3) | 107.64 ± 67.94 | 573.50 ± 404.35 | 64.06 ± 44.45 | 97.50 ± 56.78 |
| Physical | 0.69 ± 0.25 | 0.90 ± 0.11 | 0.41 ± 0.10 | 0.41 ± 0.09 |
| Chemical | 0.85 ± 0.13 | 0.97 ± 0.05 | 0.59 ± 0.25 | 0.71 ± 0.13 |
| Biological | 0.93 ± 0.14 | 0.93 ± 0.13 | 0.94 ± 0.07 | 0.97 ± 0.00 |
| SMAF-SHI  | 0.82 ± 0.08 | 0.93 ± 0.04 | 0.65 ± 0.12 | 0.70 ± 0.06 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S3. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in three consecutive years of the soil biological conditioner application (i.e., 2021 corresponds to one application, 2022 to two applications, and 2023 to three applications) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Quatro Irmãos-RS, South region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.32 ± 0.12 | 1.19 ± 0.08 | 1.35 ± 0.04 | 1.30 ± 0.07 |
| SOC (%) | 3.37 ± 0.43 | 3.45 ± 0.39 | 2.29 ± 0.12 | 2.37 ± 0.17 |
| ß-G (μ PNG g-1) | 99.53 ± 41.65 | 66.96 ± 20.00 | 10.66 ± 10.05 | 18.70 ± 24.12 |
| pH | 5.47 ± 0.40 | 5.30 ± 0.54 | 4.46 ± 0.32 | 4.32 ± 0.30 |
| P (mg dm-3) | 40.63 ± 7.36 | 30.08 ± 7.05 | 18.75 ± 13.82 | 29.85 ± 22.68 |
| K (mg dm-3) | 206.64 ± 116.14 | 109.58 ± 56.10 | 98.34 ± 64.12 | 65.59 ± 29.77 |
| Physical | 0.57 ± 0.21 | 0.81 ± 0.16 | 0.70 ± 0.05 | 0.66 ± 0.08 |
| Chemical | 0.94 ± 0.05 | 0.88 ± 0.09 | 5.55 ± 0.47 | 4.61 ± 0.31 |
| Biological | 0.82 ± 0.17 | 0.68 ± 0.11 | 0.64 ± 0.24 | 0.78 ± 0.25 |
| SMAF-SHI | 0.78 ± 0.06 | 0.79 ± 0.04 | 0.61 ± 0.10 | 0.67 ± 0.12 |
|  |  |  |  |  |
| **2022** |  |  |  |  |
| BD (Mg m-3) | - | - | - | - |
| SOC (%) | 2.49 ± 0.54 | 2.54 ± 0.42 | 2.23 ± 0.27 | 2.78 ± 0.58 |
| ß-G (μ PNG g-1) | 55.15 ± 34.57 | 53.83 ± 25.57 | 45.75 ± 37.51 | 51.90 ± 35.01 |
| pH | 5.27 ± 0.75 | 4.93 ± 0.68 | 4.92 ± 0.42 | 5.07 ± 0.72 |
| P (mg dm-3) | 71.98 ± 69.10 | 36.30 ± 33.10 | 25.90 ± 14.14 | 49.78 ± 44.71 |
| K (mg dm-3) | 108.60 ± 95.83 | 65.98 ± 41.78 | 119.45± 122.98 | 146.43 ± 57.66 |
| Physical | - | - | - | - |
| Chemical | 0.81 ± 0.24 | 0.75 ± 0.19 | 0.75 ± 0.19 | 0.85 ± 0.16 |
| Biological | 0.65 ± 0.15 | 0.63 ± 0.10 | 0.62 ± 0.17 | 0.64 ± 0.14 |
| SMAF-SHI | - | - | - | - |
|  |  |  |  |  |
| **2023** |  |  |  |  |
| BD (Mg m-3) | 1.30 ± 0.10 | 1.22 ± 0.11 | 1.30 ± 0.06 | 1.31 ± 0.05 |
| SOC (%) | 2.60 ± 0.15 | 2.30 ± 0.26 | 2.03 ± 0.15 | 1.91 ± 0.20 |
| ß-G (μ PNG g-1) | 276.09 ± 156.75 | 182.22 ± 134.01 | 91.50 ± 30.84 | 161.14 ± 160.76 |
| pH | 5.31 ± 0.47 | 5.22 ± 0.28 | 4.58 ± 0.17 | 4.16 ± 0.07 |
| P (mg dm-3) | 26.23 ± 9.54 | 27.23 ± 14.65 | 12.35 ± 12.59 | 14.13 ± 15.53 |
| K (mg dm-3) | 88.73 ± 16.65 | 127.04 ± 26.24 | 34.91 ± 7.27 | 41.63 ± 8.35 |
| Physical | 0.60 ± 0.19 | 0.74 ± 0.22 | 0.59 ± 0.13 | 0.57 ± 0.10 |
| Chemical | 0.88 ± 0.07 | 0.90 ± 0.06 | 0.56 ± 0.10 | 0.54 ± 0.07 |
| Biological | 0.90 ± 0.19 | 0.93 ± 0.09 | 0.81 ± 0.16 | 0.78 ± 0.25 |
| SMAF-SHI | 0.79 ± 0.11 | 0.86 ± 0.10 | 0.65 ± 0.08 | 0.63 ± 0.08 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S4. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Rio dos Índios-RS, South region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.59 ± 0.15 | 1.51 ± 0.06 | 1.67 ± 0.13 | 1.67 ± 0.05 |
| SOC (%) | 2.12 ± 0.35 | 2.02 ± 0.30 | 1.29 ± 0.11 | 1.31 ± 0.08 |
| ß-G (μ PNG g-1) | 30.77 ± 37.80 | 76.61 ± 28.62 | 20.31 ± 47.18 | 18.90 ± 12.06 |
| pH | 4.45 ± 0.13 | 4.37 ± 0.06 | 4.67 ± 0.19 | 4.62 ± 0.29 |
| P (mg dm-3) | 29.58 ± 5.01 | 50.45 ± 27.05 | 26.93 ± 21.71 | 35.88 ± 21.02 |
| K (mg dm-3) | 248.87 ± 109.93 | 270.28 ± 99.59 | 86.22 ± 27.75 | 91.98 ± 31.37 |
| Physical | 0.28 ± 0.07 | 0.30 ± 0.04 | 0.25 ± 0.05 | 0,24 ± 0.01 |
| Chemical | 0.77 ± 0.02 | 0.76 ± 0.01 | 0.75 ± 0.01 | 0,76 ± 0.05 |
| Biological | 0.71 ± 0.23 | 0.75 ± 0.13 | 0.58 ± 0.22 | 0,49 ± 0.02 |
| SMAF-SHI | 0.58 ± 0.08 | 0.60 ± 0.03 | 0.58 ± 0.08 | 0,49 ± 0.01 |
|  |  |  |  |  |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S5. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in two consecutive years of the soil biological conditioner application (i.e., 2021 corresponds to one application and 2022 to two applications) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Santa Barbara do Sul-RS, South region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | - | - | - | - |
| SOC (%) | 1.40 ± 0.29 | 1.15 ± 0.27 | 1.21 ± 0.36 | 1.44 ± 0.30 |
| ß-G (μ PNG g-1) | 17.09 ± 9.48 | 15.83 ± 10.90 | 12.68 ± 9.79 | 19.18 ± 12.30 |
| pH | 5.05 ± 0.56 | 5.44 ± 0.24 | 4.71 ± 0.46 | 5.66 ± 0.31 |
| P (mg dm-3) | 65.73 ± 42.36 | 51.00 ± 41.40 | 84.98 ± 90.55 | 58.95 ± 48.44 |
| K (mg dm-3) | 171.75 ± 44.85 | 181.42 ± 95.42 | 0.75 ± 0.17 | 0.96 ± 0.05 |
| Physical | - | - | - | - |
| Chemical | 0.88 ± 0.11 | 0.92 ± 0.07 | 84.98 ± 90.55 | 58.95 ± 48.44 |
| Biological | 0.47 ± 0.04 | 0.40 ± 0.10 | 0.40 ± 0.11 | 0.48 ± 0.06 |
| SMAF-SHI | - | - | - | - |
|  |  |  |  |  |
| **2022** |  |  |  |  |
| BD (Mg m-3) | 1.47 ± 0.09 | 1.42 ± 0.04 | 1.65 ± 0.03 | 1.60 ± 0.03 |
| SOC (%) | 1.79 ± 0.40 | 1.50 ± 0.73 | 0.95 ± 0.06 | 1.64 ± 0.34 |
| ß-G (μ PNG g-1) | 478.14 ± 277.43 | 272.05 ± 160.85 | 120.41 ± 101.86 | 91.24 ± 49.43 |
| pH | 5.56 ± 0.44 | 5.44 ± 0.20 | 4.40 ± 0.14 | 4.29 ± 0.10 |
| P (mg dm-3) | 90.53 ± 31.76 | 94.40 ± 14.62 | 25.78 ± 11.86 | 20.50 ± 11.64 |
| K (mg dm-3) | 487.31 ± 167.25 | 557.21 ± 196.79 | 110.27 ± 13.03 | 126.26 ± 16.74 |
| Physical | 0.35 ± 0.11 | 0.39 ± 0.04 | 0.24 ± 0.03 | 0.26 ± 0.01 |
| Chemical | 0.95 ± 0.06 | 0.95 ± 0.04 | 0.74 ± 90.55 | 0.73 ± 0.01 |
| Biological | 0.98 ± 0.02 | 0.89 ± 0.08 | 0.59 ± 0.22 | 0.85 ± 0.16 |
| SMAF-SHI | 0.76 ± 0.04 | 0.74 ± 0.03 | 0.52 ± 0.08 | 0.61 ± 0.05 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S6. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in two consecutive years of the soil biological conditioner application (i.e., 2021 corresponds to one application and 2022 to two applications) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Aurora-SC, South region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) |  |  |  |  |
| SOC (%) | 2.14 ± 0.23 | 2.00 ± 0.36 | 1.96 ± 0.23 | 2.93 ± 0.27 |
| ß-G (μ PNG g-1) | 67.97 ± 38.43 | 40.78 ± 16.46 | 45.16 ± 25.69 | 59.93 ± 17.28 |
| pH | 6.07 ± 0.44 | 6.33 ± 0.24 | 5.27 ± 0.62 | 5.52 ± 0.42 |
| P (mg dm-3) | 201.60 ± 102.12 | 221.33 ± 121.01 | 176.88 ± 89.98 | 96.28 ± 69.01 |
| K (mg dm-3) | 261.38 ± 103.55 | 202.93 ± 57.56 | 232.94 ± 93.73 | 141.44 ± 48.71 |
| Physical | - | - | - | - |
| Chemical | 0.82 ± 0.10 | 0.91 ± 0.02 | 0.90 ± 0.17 | 0.92 ± 0.09 |
| Biological | 0.71 ± 0.16 | 0.57 ± 0.06 | 0.60 ± 0.11 | 0.65 ± 0.07 |
| SMAF-SHI | - | - | - | - |
|  |  |  |  |  |
| **2022** |  |  |  |  |
| BD (Mg m-3) | 1.38 ± 0.03 | 1.25 ± 0.06 | 1.24 ± 0.06 | 1.21 ± 0.17 |
| SOC (%) | 2.30 ± 0.18 | 2.55 ± 0.33 | 2.04 ± 0.19 | 2.51 ± 0.34 |
| ß-G (μ PNG g-1) | 201.74 ± 45.03 | 248.03 ± 43.38 | 159.01 ± 97.81 | 221.84 ± 107.58 |
| pH | 5.44 ± 0.47 | 5.41 ± 0.50 | 5.21 ± 0.61 | 5.05 ± 0.67 |
| P (mg dm-3) | 128.0 ± 130.9 | 102.5 ± 84.9 | 66.0 ± 83.7 | 53.9 ± 58.7 |
| K (mg dm-3) | 232.5 ± 202.8 | 236.1 ± 244.5 | 118.5 ± 72.5 | 141.6 ± 110.9 |
| Physical | 0.43 ± 0.04 | 0.68± 0.15 | 0.70 ± 0.14 | 0.78 ± 0.30 |
| Chemical | 0.97 ± 0.04 | 0.99 ± 0.00 | 0.91 ± 0.07 | 0.95 ± 0.08 |
| Biological | 0.99 ± 0.01 | 1.00 ± 0.00 | 0.90 ± 0.15 | 0.99 ± 0.02 |
| SMAF-SHI | 0.80 ± 0.03 | 0.89 ± 0.05 | 0.84 ± 0.05 | 0.91 ± 0.09 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S7. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Lapa-PR, South region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | - | - | - | - |
| SOC (%) | 2.83 ± 0.45 | 2.92 ± 0.45 | 2.64 ± 0.29 | 2.76 ± 0.18 |
| ß-G (μ PNG g-1) | 25.98 ± 2.60 | 23.71 ± 2.46 | 17.81± 3.04 | 18.17 ± 5.25 |
| pH | 5.22 ± 0.30 | 5.13 ± 0.29 | 4.72 ± 0.56 | 4.57 ± 0.12 |
| P (mg dm-3) | 15.28 ± 5.38 | 17.65 ± 6.79 | 6.65 ± 2.06 | 7.93 ± 1.81 |
| K (mg dm-3) | 139.20 ± 47.78 | 101.76 ± 45.80 | 60.21 ± 19.78 | 49.46 ± 5.15 |
| Physical | - | - | - | - |
| Chemical | 0.80± 0.14 | 0.77 ± 0.13 | 0.79 ± 0.15 | 0.83 ± 0.13 |
| Biological | 0.53 ± 0.01 | 0.53 ± 0.01 | 0.53 ± 0.01 | 0.53 ± 0.01 |
| SMAF-SHI | - | - | - | - |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S8. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Guarapuava-PR, South region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | - | - | - | - |
| SOC (%) | 3.41 ± 0.33 | 3.63± 0.11 | 3.91 ± 0.37 | 3.31 ± 0.20 |
| ß-G (μ PNG g-1) | 21.86 ± 2.97 | 20.23 ± 2.84 | 20.04 ± 2.32 | 19.82 ± 0.25 |
| pH | 5.21 ± 0.04 | 5.32 ± 0.06 | 5.97 ± 0.41 | 5.79 ± 0.08 |
| P (mg dm-3) | 125.30 ± 77.93 | 140.85 ± 100.85 | 96.65 ± 73.14 | 166.65 ± 105.43 |
| K (mg dm-3) | 251.90 ± 86.40 | 297.16 ± 57.85 | 222.87 ± 60.76 | 309.67 ± 41.47 |
| Physical | - | - | - | - |
| Chemical | 0.85 ± 0.13 | 0.92 ± 0.03 | 0.94 ± 0.06 | 0.85 ± 0.20 |
| Biological | 0.52 ± 0.00 | 0.52 ± 0.00 | 0.52 ± 0.00 | 0.52 ± 0.00 |
| SMAF-SHI | - | - | - | - |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S9. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in two consecutive years of the soil biological conditioner application (i.e., 2021 corresponds to one application and 2022 to two applications) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Patrocínio-MG, Southeast region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | - | - | - | - |
| SOC (%) | 2.81 ± 0.17 | 2.77 ± 0.19 | 2.49 ± 0.32 | 2.42 ± 0.41 |
| ß-G (μ PNG g-1) | 73.76 ± 4.01 | 79.44 ± 20.66 | 47.03 ± 20.35 | 37.65 ± 10.98 |
| pH | 5.18 ± 0.34 | 5.81 ± 0.17 | 4.81 ± 0.21 | 5.67 ± 0.35 |
| P (mg dm-3) | 34.68 ± 8.77 | 49.98 ± 15.46 | 17.58 ± 8.61 | 41.75 ± 21.18 |
| K (mg dm-3) | 55.82 ± 15.60 | 55.42 ± 24.18 | 36.56 ± 5.80 | 44.67 ± 17.29 |
| Physical | - | - | - | - |
| Chemical | 0.86 ± 0.03 | 0.88 ± 0.05 | 0.80 ± 0.08 | 0.73 ± 0.15 |
| BiologicalSMAF-SHI  | 0.76 ± 0.17 | 0.70 ± 0.09 | 0.72 ± 0.15 | 0.70 ± 0.15 |
| **2022** |  |  |  |  |
| BD (Mg m-3) | 1.29 ± 0.06 | 1.27 ± 0.12 | 1.37 ± 0.08 | 1.28 ± 0.02 |
| SOC (%) | 2.89 ± 0.36 | 3.33 ± 0.48 | 2.65 ± 0.33 | 2.28 ± 0.20 |
| ß-G (μ PNG g-1) | 548.95 ± 93.35 | 561.05 ± 131.00 | 372.06 ± 57.08 | 268.13 ± 22.14 |
| pH | 5.41 ± 0.23 | 5.57 ± 0.22 | 5.49 ± 0.21 | 5.54 ± 0.13 |
| P (mg dm-3) | 63.83 ± 36.25 | 143.25 ± 23.07 | 34.50 ± 31.13 | 12.80 ± 5.61 |
| K (mg dm-3) | 135.72 ± 18.99 | 104.03 ± 12.75 | 142.74 ± 13.67 | 79.46 ± 9.15 |
| Physical | 0.61 ± 0.12 | 0.64± 0.23 | 0.46 ± 0.12 | 0.62 ± 0.05 |
| Chemical | 0.92 ± 0.04 | 0.89 ± 0.04 | 0.92 ± 0.03 | 0.86 ± 0.03 |
| Biological | 1.00 ± 0.00 | 1.00 ± 0.00 | 1.00 ± 0.00 | 1.00 ± 0.00 |
| SMAF-SHI | 0.84 ± 0.05 | 0.84 ± 0.09 | 0.79 ± 0.03 | 0.83 ± 0.02 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S10. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Rio Brilhante-MS, Midwest region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.59 ± 0.04 | 1.52 ± 0.09 | 1.68 ± 0.07 | 1.57 ± 0.09 |
| SOC (%) | 3.40 ± 0.23 | 3.80 ± 0.38 | 2.27 ± 0.48 | 2.91± 0.20 |
| ß-G (μ PNG g-1) | 60.22 ± 35.95 | 114.21 ± 50.78 | 39.11 ± 18.23 | 47.45 ± 10.58 |
| pH | 6.33 ± 0.15 | 6.17 ± 0.28 | 5.69 ± 0.13 | 5.60 ± 0.19 |
| P (mg dm-3) | 68.20 ± 28.88 | 122.35 ± 124.19 | 19.73 ± 20.72 | 31.35 ± 20.34 |
| K (mg dm-3) | 346.62 ± 60.30 | 357.08 ± 62.51 | 299.60 ± 37.17 | 344.76 ± 103.91 |
| Physical | 0.26 ± 0.02 | 0.30 ± 0.05 | 0.24 ± 0.02 | 0.28 ± 0.05 |
| Chemical | 0.98 ± 0.01 | 0.99 ± 0.02 | 0.95 ± 0.04 | 0.97 ± 0.02 |
| Biological | 0.66 ± 0.17 | 0.85 ± 0.12 | 0.57 ± 0.05 | 0.59 ± 0.04 |
| SMAF-SHI | 0.63 ± 0.06 | 0.71 ± 0.05 | 0.59 ± 0.03 | 0.61 ± 0.03 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S11. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Rio Brilhante-MS, Midwest region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.36 ± 0.11 | 1.29 ± 0.05 | 1.45 ± 0.04 | 1.42 ± 0.07 |
| SOC (%) | 2.21 ± 0.29 | 2.15 ± 0.47 | 1.46 ± 0.17 | 1.77 ± 0.49 |
| ß-G (μ PNG g-1) | 129.80 ± 27.95 | 87.87 ± 58.37 | 26.24 ± 2.75 | 61.03 ± 8.44 |
| pH | 6.14 ± 0.09 | 6.09 ± 0.10 | 5.55 ± 0.47 | 4.61 ± 0.31 |
| P (mg dm-3) | 67.78 ± 47.97 | 36.88 ± 11.93 | 47.23 ± 36.08 | 61.65 ± 58.83 |
| K (mg dm-3) | 214.07 ± 43.56 | 147.21 ± 44.12 | 99.51 ± 65.28 | 57.87 ± 27.56 |
| Physical | 0.49 ± 0.18 | 0.59 ± 0.10 | 0.35 ± 0.05 | 0.39 ± 0.08 |
| Chemical | 0.99 ± 0.01 | 0.98 ± 0.02 | 0.86 ± 0.11 | 0.66 ± 0.11 |
| Biological | 0.66 ± 0.06 | 0.59 ± 0.13 | 0.47 ± 0.03 | 0.52 ± 0.02 |
| SMAF-SHI | 0.71 ± 0.05 | 0.72 ± 0.04 | 0.56 ± 0.04 | 0.52 ± 0.06 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S12. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Primavera do Leste-MT, Midwest region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.57 ± 0.07 | 1.63 ± 0.01 | 1.64 ± 0.09 | 1.66 ± 0.04 |
| SOC (%) | 3.54 ± 0.10 | 3.15 ± 0.57 | 2.88 ± 0.35 | 2.45 ± 0.90 |
| ß-G (μ PNG g-1) | 62.74 ± 16.6 | 50.67 ± 32.19 | 29.66 ± 14.67 | 27.75 ± 8.14 |
| pH | 5.45 ± 0.20 | 5.11 ± 0.21 | 5.39 ± 0.32 | 5.05 ± 0.10 |
| P (mg dm-3) | 48.13 ± 12.08 | 38.83 ± 8.66 | 58.05 ± 26.49 | 60.10 ± 31.29 |
| K (mg dm-3) | 109.09 ± 41.43 | 123.17 ± 47.63 | 79.18 ± 23.52 | 74.88 ± 16.63 |
| Physical | 0.35 ± 0.05 | 0.29 ± 0.01 | 0.30 ± 0.05 | 0.28 ± 0.02 |
| Chemical | 0.90 ± 0.06 | 0.85 ± 0.06 | 0.85 ± 0.04 | 0.79 ± 0.03 |
| Biological | 0.68 ± 0.08 | 0.64 ± 0.16 | 0.55 ± 0.03 | 0.54 ± 0.02 |
| SMAF-SHI | 0.64 ± 0.04 | 0.59 ± 0.07 | 0.57 ± 0.03 | 0.54± 0.01 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S13. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in three consecutive years of the soil biological conditioner application (i.e., 2021 corresponds to one application and 2023 to three applications) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Sorriso-MT, Midwest region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.25 ± 0.10 | 1.22 ± 0.04 | 1.40 ± 0.05 | 1.38 ± 0.04 |
| SOC (%) | 4.24 ± 0.31 | 4.62 ± 0.32 | 2.79 ± 0.42 | 2.76 ± 0.16 |
| ß-G (μ PNG g-1) | 54.89 ± 22.89 | 36.60 ± 11.38 | 26.74 ± 10.95 | 4.42 ± 4.48 |
| pH | 5.93 ± 0.32 | 5.80 ± 0.24 | 4.70 ± 0.20 | 4.74 ± 0.19 |
| P (mg dm-3) | 16.20± 4.03 | 16.98 ± 5.73 | 10.60 ± 8.04 | 13.73 ± 20.92 |
| K (mg dm-3) | 72.92 ± 13.49 | 78.69 ± 29.60 | 32.65 ± 9.75 | 45.65 ± 22.32 |
| Physical | 0.68 ± 0.20 | 0.75 ± 0.10 | 0.40 ± 0.06 | 0.43 ± 0.07 |
| Chemical | 0.89± 0.03 | 0.89± 0.03 | 0.54 ± 0.11 | 0.49 ± 0.09 |
| Biological | 0.64 ± 0.10 | 0.56 ± 0.03 | 0.54 ± 0.02 | 0.63 ± 0.24 |
| SMAF-SHI | 0.73 ± 0.06 | 0.73 ± 0.04 | 0.49 ± 0.05 | 0.52 ± 0.07 |
|  |  |  |  |  |
| **2023** |  |  |  |  |
| BD (Mg m-3) | 1.23 ± 0.03 | 1.27 ± 0.14 | 1.15 ± 0.13 | 1.27 ± 0.10 |
| SOC (%) | 4.11 ± 0.52 | 3.69 ± 0.43 | 2.81 ± 0.08 | 2.54 ± 0.15 |
| ß-G (μ PNG g-1) | 102.80 ± 58.60 | 189.99 ± 66.63 | 66.62 ± 28.86 | 81.90 ± 26.04 |
| pH | 5.80 ± 0.22 | 6.33 ± 0.53 | 5.04 ± 0.07 | 5.06 ± 0.05 |
| P (mg dm-3) | 13.87 ± 2.54 | 13.63 ± 4.65 | 4.47 ± 0.95 | 5.50 ± 2.72 |
| K (mg dm-3) | 70.72 ± 14.77 | 65.13 ± 10.38 | 54.99 ± 10.56 | 39.78 ± 4.68 |
| Physical | 0.74 ± 0.08 | 0.66 ± 0.28 | 0.85 ± 0.18 | 0.66 ± 0.22 |
| Chemical | 0.88 ± 0.03 | 0.84 ± 0.08 | 0.59 ± 0.09 | 0.58 ± 0.09 |
| Biological | 0.88 ± 0.20 | 0.97 ± 0.05 | 0.69 ± 0.16 | 0.84 ± 0.17 |
| SMAF-SHI | 0.83 ± 0.10 | 0.83 ± 0.11 | 0.71 ± 0.13 | 0.69 ± 0.05 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S14. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Rio Verde-GO, Midwest region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | - | - | - | - |
| SOC (%) | 1.98 ± 0.25 | 2.15 ± 0.44 | 1.84 ± 0.81 | 1.72 ± 0.41 |
| ß-G (μ PNG g-1) | 90.82± 23.74 | 43.95 ± 13.03 | 76.32 ± 17.67 | 36.86 ± 5.39 |
| pH | 6.1 ± 0.31 | 6.29 ± 0.09 | 5.57 ± 0.11 | 5.56 ± 0.43 |
| P (mg dm-3) | 100.08 ± 38.85 | 105.30 ± 19.41 | 27.68 ± 10.64 | 29.78 ± 18.88 |
| K (mg dm-3) | 60.90 ± 18.48 | 48.48 ± 27.44 | 48.97 ± 12.77 | 40.37 ± 13.52 |
| Physical | - | - | - | - |
| Chemical | 0.82 ± 0.04 | 0.80 ± 0.09 | 0.86± 0.02 | 0.83 ± 0.06 |
| Biological | 0.53 ± 0.03 | 0.55 ± 0.07 | 0.53 ± 0.05 | 0.51 ± 0.04 |
| SMAF-SHI | - | - | - | - |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S15. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Balsas-MA, Northeast region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.69 ± 0.06 | 1.59 ± 0.08 | 1.81 ± 0.04 | 1.77 ± 0.05 |
| SOC (%) | 1.02 ± 0.12 | 1.18 ± 0.06 | 0.71 ± 0.14 | 0.65 ± 0.03 |
| ß-G (μ PNG g-1) | 53.50 ± 18.75 | 65.83 ± 9.79 | 6.78 ± 1.80 | 8.95 ± 2.14 |
| pH | 5.72 ± 0.40 | 5.85 ± 0.21 | 5.39 ± 0.72 | 5.57 ± 0.17 |
| P (mg dm-3) | 34.70± 24.98 | 18.23 ± 6.87 | 57.05 ± 12.78 | 37.63 ± 13.70 |
| K (mg dm-3) | 59.14 ± 16.90 | 53.08 ± 18.50 | 35.68 ± 21.00 | 25.81 ± 5.68 |
| Physical | 0.32 ± 0.04 | 0.45 ± 0.14 | 0.26 ± 0.01 | 0.27 ± 0.03 |
| Chemical | 0.91 ± 0.04 | 0.91 ± 0.06 | 0.78 ± 0.14 | 0.79 ± 0.05 |
| Biological | 0.56 ± 0.09 | 0.66 ± 0.06 | 0.26 ± 0.09 | 0.23 ± 0.02 |
| SMAF-SHI | 0.60 ± 0.04 | 0.67 ± 0.06 | 0.43 ± 0.05 | 0.43 ± 0.01 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).

Table S16. Average of measured values of soil health indicators, SMAF scores of physical, chemical and biological components, and soil health index (SMAF-SHI) in one year of the soil biological conditioner application (i.e., 2021 corresponds to one application) for control and treatment strips at the 0-10 and 10-20 cm soil layers at farm located in Balsas-MA, Northeast region.

|  |  |  |
| --- | --- | --- |
| **2021** | **0-10 cm** | **10-20 cm** |
|  | **Control** | **Treatment** | **Control** | **Treatment** |
| BD (Mg m-3) | 1.53 ± 0.12 | 1.5 ± 0.09 | 1.73 ± 0.10 | 1.62 ± 0.14 |
| SOC (%) | 0.91 ± 0.26 | 1.39 ± 0.59 | 6.74 ± 2.15 | 9.71 ± 8.61 |
| ß-G (μ PNG g-1) | 43.76 ± 35.83 | 45.85 ± 21.79 | 24.2 ± 25.0 | 26.7 ± 20.6 |
| pH | 6.39 ± 0.31 | 5.94 ± 0.54 | 6.16 ± 0.40 | 5.35 ± 0.87 |
| P (mg dm-3) | 45.10 ± 14.58 | 48.58 ± 31.19 | 6.83 ± 3.54 | 5.88 ± 3.48 |
| K (mg dm-3) | 51.61 ± 44.81 | 38.32 ± 24.04 | 33.63 ± 27.42 | 34.99 ± 29.62 |
| Physical | 0.42 ± 0.19 | 0.34 ± 0.08 | 0.25 ± 0.03 | 0.33 ± 0.11 |
| Chemical | 0.81 ± 0.08 | 0.78 ± 0.07 | 0.67 ± 0.14 | 0.57 ± 0.27 |
| Biological | 0.42 ± 0.24 | 0.51 ± 0.18 | 0.16 ± 0.05 | 0.29 ± 0.18 |
| SMAF-SHI | 0.55 ± 0.15 | 0.55 ± 0.08 | 0.36 ± 0.04 | 0.40 ± 0.15 |

BD (bulk density), SOC (soil organic carbon), ß-G (ß-Glucosidase activity), pH (soil pH), P (test phosphorus), K (test potassium). Means represent all farms across the country. The plus-minus sign denotes the standard deviation of mean (n=4).