Figure 1. Daily air temperatures (Top Panel) and precipitation (Bottom Panel) from the W.K. Kellogg Biological Station Long-term Ecological Research station (KBS 2013). Dark gray down-arrows indicate when spring, summer, and autumn samples were collected.
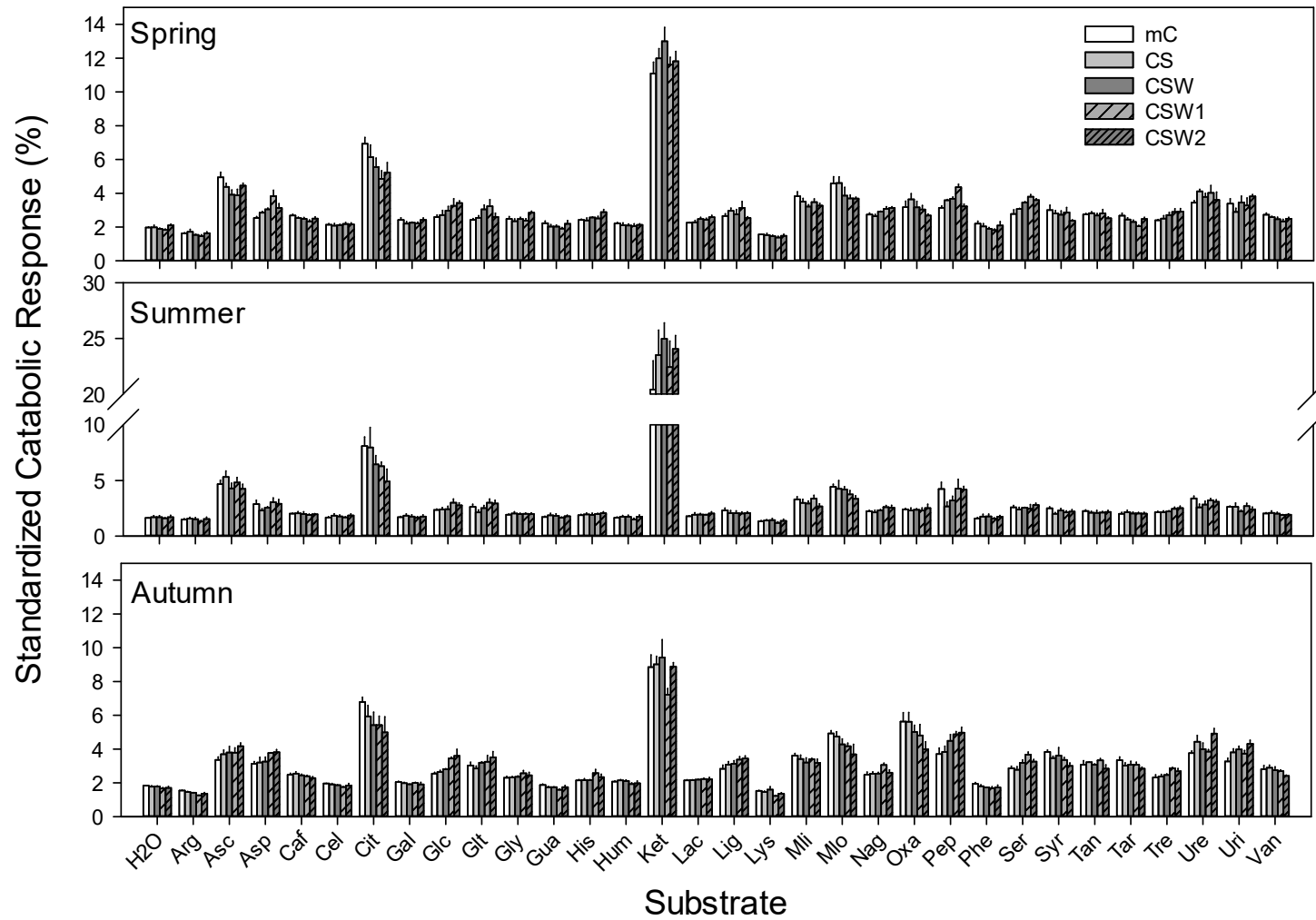
Figure S1. Standardized catabolic response (Respiration rate of Specific Substrate / Respiration rate of All Substrates * 100). Respiration rates were in units of $\mu g\ CO_2$-C per gram of dry soil. For substrate abbreviations see Table 1 in manuscript.
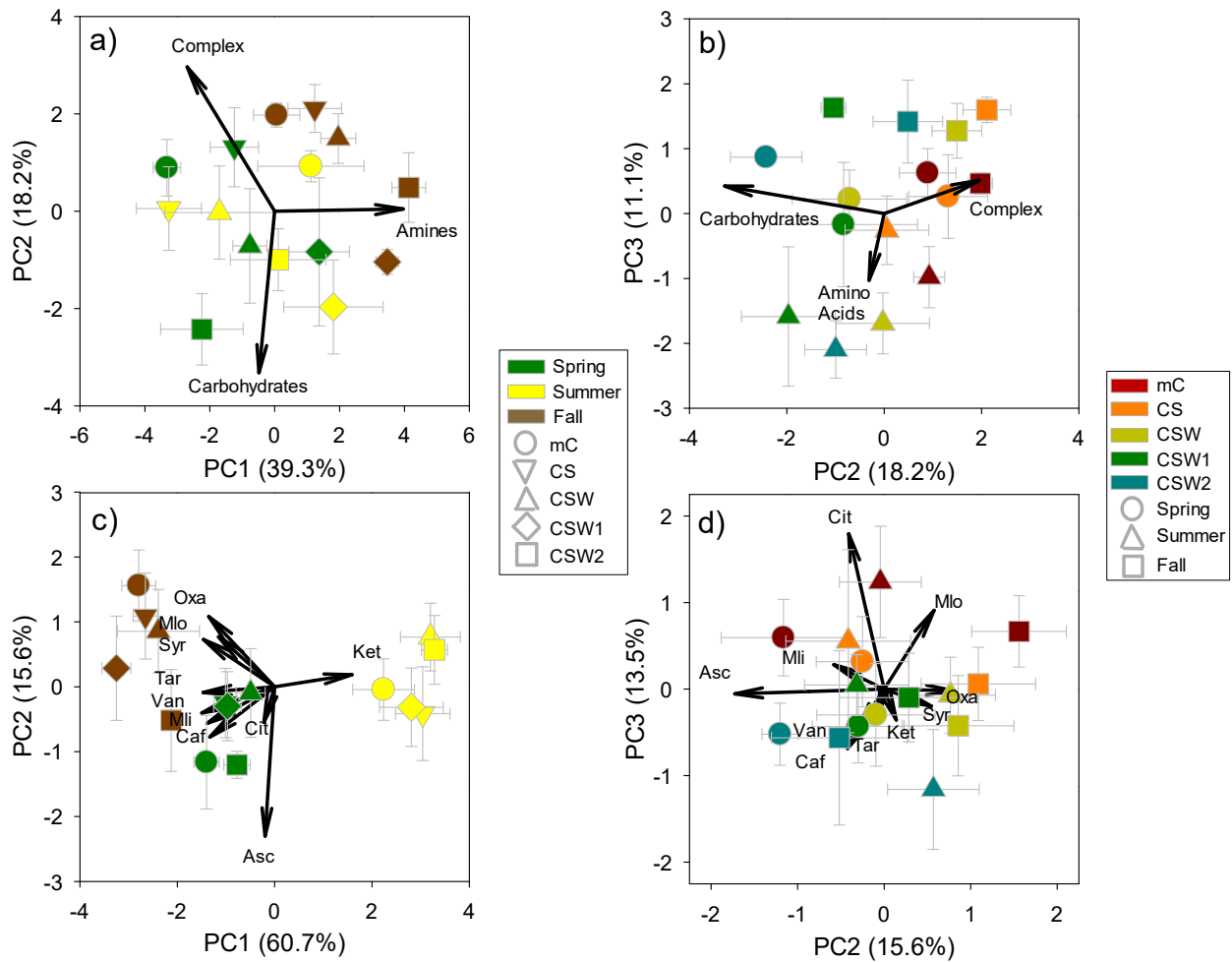
Figure S2. Principal components analysis (PCA) on all substrates except for carboxylic acids [a) and b)] and only carboxylic acids [c) and d)]. Principal components 1 and 2 [a) and c)], where Season is dominant discriminating factor ($P < 0.001$) and Principal components 2 and 3 [b) and d)] where Rotation is highlighted as a dominant discriminating factor. See also Table 5 for PCA and ANOVA results. Crop rotation abbreviations are: monoculture corn (mC), corn-soy (CS), corn-soy-wheat (CSW), corn-soy-wheat with red clover cover crop (CSW1), and corn-soy-wheat with red clover + rye cover crops (CSW2). The carboxylic acid abbreviations are: ascorbic acid (Asc), caffeic acid (Caf), citric acid (Cit), ketobutyric acid (Ket), malic acid (Mli), malonic acid (Mlo), oxalic acid (Oxa), syringic acid (Syr), tartaric acid (Tar), and vanillic acid (Van).
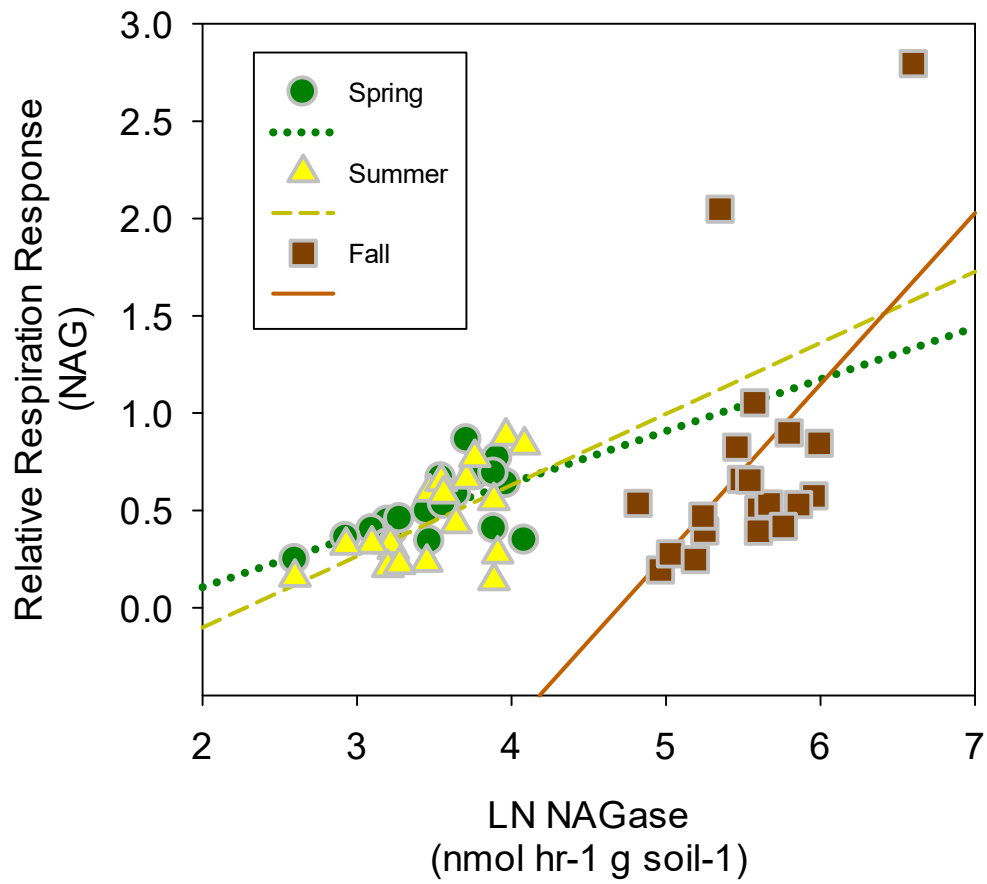
Figure S3.  LN N-acetyl glucosaminidase and the N-acetyl glucosamine Relative Respiration Response [$(R_{sub} - R_{H2O})/ R_{H2O}$ ].
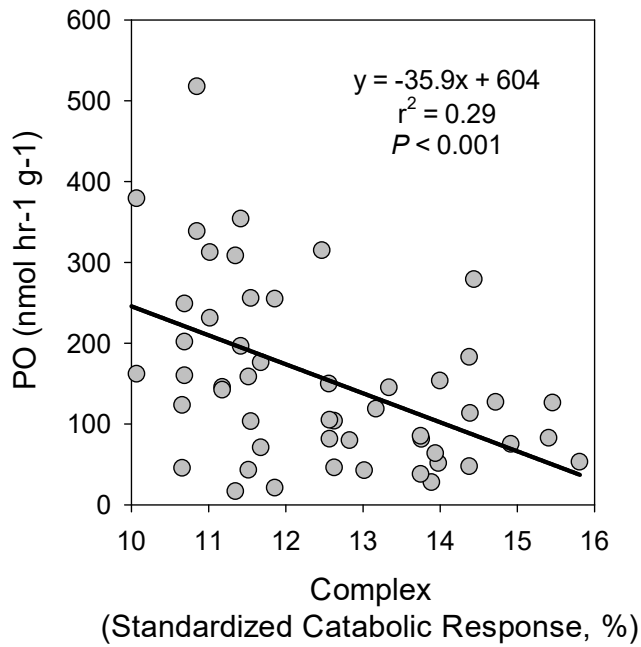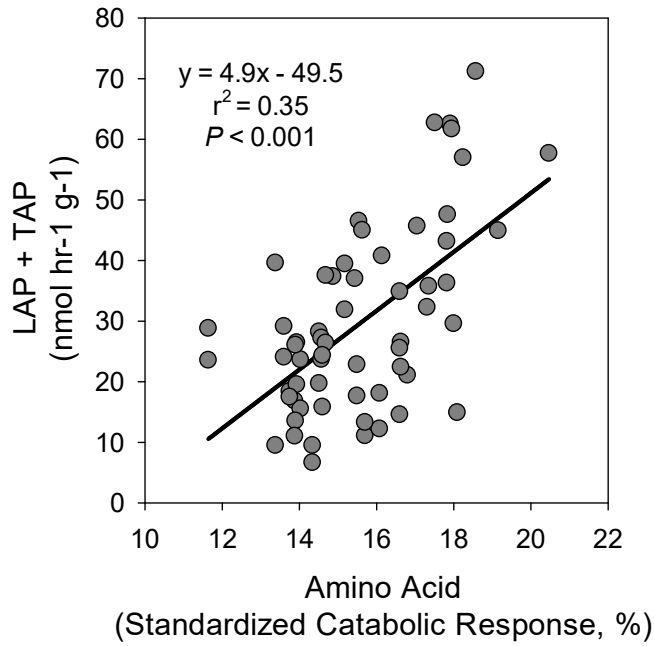
Figure S4. Relationships between substrate guild (Complex or Amino Acid) catabolic response and extracellular enzyme activities (EEA). EEA abbreviations are: Tyrosine aminopeptidase (TAP), Leucine aminopeptidase (LAP), and phenol oxidase (PO).
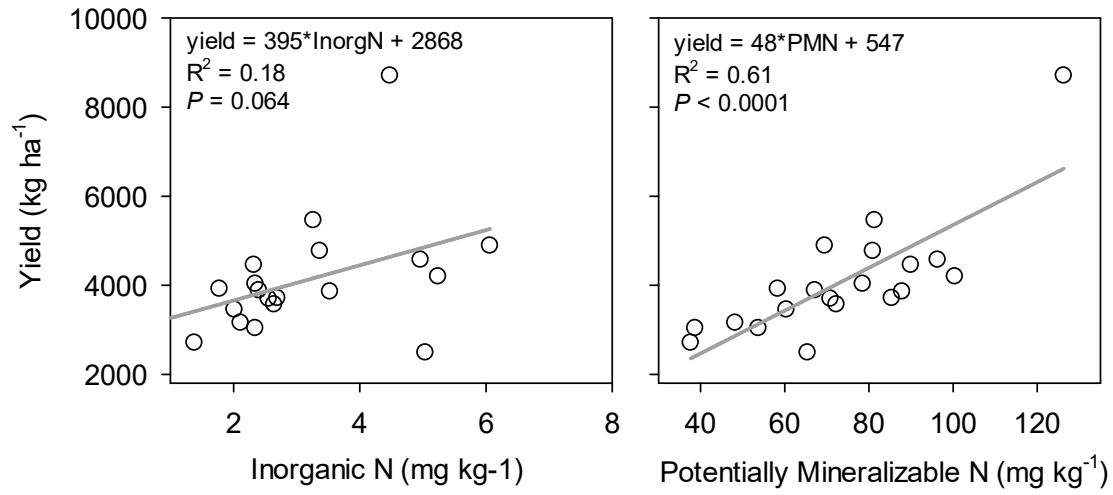
Figure S5. Relationships between spring soil nitrogen and 2012 yield in corn. *Note*: Inorganic N

$= NO_3^--N + NH_4-N$.

Table S1.  List of substrates used for the community-level physiological profile (CLPP).

| Substrate Name | Abbreviation | Molecular weight | C:N | Guild |
|---|---|---|---|---|
| L-arginine | Arg | 216.238 | 1.5 | amino acid |
| L-ascorbic acid | Asc | 176.124 | | carboxylic acid |
| L-asparagine | Asp | 189.169 | 2 | amino acid |
| caffeic acid | Caf | 180.175 | | carboxylic acid |
| cellulose | Cel | 342.296 | | complex |
| citric acid | Cit | 192.124 | | carboxylic acid |
| D-(+)-galactosamine | Gal | 215.623 | 6 | amine |
| D-(+)-glucose | Glc | 180.16 | | carbohydrate |
| L-glutamine | Glt | 146.145 | 2.5 | amino acid |
| glycine | Gly | 75.067 | 2 | amino acid |
| guaiacol | Gua | 94.112 | | complex |
| L-histidine | His | 169.181 | 2 | amino acid |
| humic acid | Hum | ??? | | complex |
| 2-ketobutyric acid | Ket | 102.089 | | carboxylic acid |
| lactose | Lac | 342.296 | | carbohydrate |
| lignin | Lig | 534.508 | | complex |
| L-(+)-lysine | Lys | 146.188 | 3 | amino acid |
| malic acid | Mli | 134.087 | | carboxylic acid |
| malonic acid | Mlo | 104.061 | | carboxylic acid |
| N-acetyl glucosamine | Nag | 221.208 | 8 | amine |
| oxalic acid | Oxa | 90.044 | | carboxylic acid |
| pepsin | Pep | 672 | 5.6 | amine |
| phenol | Phe | 94.112 | | complex |
| L-serine | Ser | 105.93 | 3 | amino acid |
| syringic acid | Syr | 198.173 | | carboxylic acid |
| tannic acid | Tan | 1701.2 | | complex |
| L-(+)-tartaric acid | Tar | 150.087 | | carboxylic acid |
| D-(+)-trehalose | Tre | 378.27 | | carbohydrate |
| urea | Ure | 60.055 | 0.5 | amine |
| uric acid | Uri | 170.126 | 1.25 | amine |
| vanillic acid | Van | 168.147 | | carboxylic acid |

Table S2. Soil chemical and biological parameters during the three seasons and ANOVA results.

| Season | Rotation | Permanganate Oxidizable C | $R_{Basal}$ | $R_{Total\ Sub.}$ |
|---|---|---|---|---|
| | | | $\mu g\ g\ soil^{-1}\ hr^{-1}$ | |
| Spring | | | | |
| | mC | 294 (30) | 14.8 (0.4) | 748 (36) |
| | CS | 258 (38) | 16.1 (0.4) | 826 (83) |
| | CSW | 268 (35) | 15.9 (0.3) | 845 (43) |
| | CSW1 | 330 (56) | 18.1 (0.4) | 998 (68) |
| | CSW2 | 289 (52) | 20.5 (1.9) | 968 (160) |
| Summer | | | | |
| | mC | 305 (18) | 12.5 (0.3) | 774 (51) |
| | CS | 453 (173) | 11.5 (0.1) | 682 (44) |
| | CSW | 430 (154) | 11.4 (0.3) | 676 (50) |
| | CSW1 | 479 (134) | 13.4 (0.9) | 842 (108) |
| | CSW2 | 424 (122) | 13.5 (0.3) | 827 (135) |
| Autumn | | | | |
| | mC | 232 (32) | 13.6 (1.9) | 807 (49) |
| | CS | 282 (14) | 12.5 (2.6) | 821 (123) |
| | CSW | 272 (31) | 13.0 (2.2) | 822 (88) |
| | CSW1 | 324 (7) | 12.0 (1.1) | 905 (161) |
| | CSW2 | 286 (35) | 11.0 (0.5) | 796 (132) |
| | ANOVA Factor | | | |
| | Season | 0.4519 | **< 0.0001** | 0.183 |
| | Treatment | 0.1022 | **0.0235** | 0.303 |
| | Season*Treatment | 0.9381 | 0.6253 | 0.945 |

Table S3.  Total MANOVA results for overall community-level physiological profile (and sub-sets of substrate additions).

| | MANOVA[§] | | |
| --- | --- | --- | --- |
| | Factors | F | *P* value |
| All Substrates | | | |
| | Season | **33.28** | **< 0.001** |
| | Rotation | **2.19** | **0.003** |
| | Season*Rot. | 0.65 | 0.949 |
| No Carboxylic Acids | | | |
| | Season | **17.98** | **< 0.001** |
| | Rotation | **1.96** | **0.012** |
| | Season*Rot. | 1.33 | 0.105 |
| Carboxylic Acids | | | |
| | Season | **21.37** | **< 0.001** |
| | Rotation | **1.72** | **0.035** |
| | Season*Rot. | 0.599 | 0.972 |
| Carboxylic Acids (no Ket[¥]) | | | |
| | Season | **11.93** | **< 0.001** |
| | Rotation | 1.27 | 0.207 |
| | Season*Rot. | 0.69 | 0.917 |

§ Degrees of freedom: Season = 2, Rotation = 4, Season*Rotation = 8.

¥ Ket = ketobutyric acid

Table S4. ANOVA and means comparisons of individual principal components.

| ANOVA[§] run | Parameter | PC1 | | PC2 | | PC3 | | PC4 | | PC5 | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **All Substrates** | | | | | | | | | | | | |
| | Proportion of variance | 38.7 | | 17.7 | | 14.5 | | 9 | | 3.8 | | 83.7 |
| | ANOVA Factor | F | *P* value | F | *P* value | F | *P* value | F | *P* value | F | *P* value | |
| | Season | **64.02** | **< 0.001** | **22.57** | **< 0.001** | **5.4** | **0.008** | 0.68 | 0.510 | **10.33** | **< 0.001** | |
| | Rotation | 0.69 | 0.605 | **3.03** | **0.028** | **12.82** | **< 0.001** | 0.36 | 0.834 | 1.81 | 0.146 | |
| | Season*Rot. | 0.16 | 0.995 | 1.22 | 0.311 | 0.55 | 0.81 | 0.88 | 0.544 | 0.27 | 0.973 | |
| | Significant comparisons | 1=3≠2 | | 1=2≠3, CS ≠ CSW1 | | 1=2≠3, mC=CS≠CSW=CSW2 | | | | 1≠2=3, | | |
| **No Carboxylic Acids** | | | | | | | | | | | | |
| | Proportion of variance | 39.3 | | 18.2 | | 11.1 | | 6.8 | | 4.4 | | 79.8 |
| | ANOVA Factor | F | *P* value | F | *P* value | F | *P* value | F | *P* value | F | *P* value | |
| | Season | **11.04** | **< 0.001** | **3.83** | **0.03** | **24.6** | **< 0.001** | 0.68 | 0.510 | **10.33** | **< 0.001** | |
| | Rotation | **4.06** | **0.007** | **5.6** | **0.001** | 0.58 | 0.678 | 0.36 | 0.834 | 1.81 | 0.146 | |
| | Season*Rot. | 1.97 | 0.075 | 0.7 | 0.691 | 1.05 | 0.419 | 0.88 | 0.544 | 0.27 | 0.973 | |
| | Significant comparisons | 1=2≠3, mC=CS≠CSW1 | | 2≠3, mC=CS≠CSW1=CSW2 | | 1≠2=3 | | | | 1≠2=3 | | |
| **Carboxylic Acids** | | | | | | | | | | | | |
| | Proportion of variance | 60.7 | | 15.6 | | 13.5 | | 4 | | 2.3 | | 96.1 |
| | ANOVA Factor | F | *P* value | F | *P* value | F | *P* value | F | *P* value | F | *P* value | |
| | Season | **200.2** | **< 0.001** | **5.19** | **0.01** | 0.18 | 0.84 | **12.33** | **< 0.001** | 0.36 | 0.699 | |
| | Rotation | 1.8 | 0.148 | 0.8 | 0.532 | **0.03** | **0.026** | 0.99 | 0.421 | **2.98** | **0.031** | |
| | Season*Rot. | 0.26 | 0.976 | 1.16 | 0.346 | 0.24 | 0.98 | 0.51 | 0.84 | 0.48 | 0.864 | |
| | Significant comparisons | 1≠2≠3 | | 1≠3 | | mC≠CSW2 | | 1≠2=3 | | CS≠CSW1 | | |