Supplementary Material

**Influences of nitrogen input forms and levels on** **phosphorus availability in karst grassland soils**

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**This file Includes**: Comparisons of the concentrations (mg kg−1) of different soil P fractions and their proportions (%) in total P for the yellow soil and limestone soil (**Table S1**). Effects of different nitrogen fertilizers on soil properties and P fractions in soils **(Table S2-3)**.

**Table S1** Comparisons of the concentrations (mg kg−1) of different soil P fractions and their proportions (%) in total P for the yellow soil and limestone soil. The values are presented as mean ± standard error.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| P fraction | Concentrations | | |  | Proportions (%) | | |
| Yellow soil |  | Limestone soil |  | Yellow soil |  | Limestone soil |
| H2O-Pi | 0.68±0.06 |  | 1.22±0.02 |  | 0.07±0.01 |  | 0.23±0.00 |
| NaHCO3-Pi | 19.06±0.77 |  | 9.49±0.49 |  | 1.98±0.07 |  | 1.77±0.10 |
| NaHCO3-Po | 12.33±0.89 |  | 24.5±1.02 |  | 1.28±0.09 |  | 4.56±0.18 |
| NaOH-Pi | 274.54±4.87 |  | 71.28±0.88 |  | 28.51±0.28 |  | 13.27±0.22 |
| NaOH-Po | 127.81±1.68 |  | 115.06±4.36 |  | 13.30±0.22 |  | 21.34±0.67 |
| D.HCl-Pi | 2.20±0.26 |  | 0.55±0.02 |  | 0.23±0.03 |  | 0.10±0.00 |
| C.HCl-Pi | 225.76±1.36 |  | 58.23±1.92 |  | 23.48±0.21 |  | 10.81±0.29 |
| C.HCl-Po | 181.33±1.54 |  | 92.94±1.29 |  | 18.87±0.27 |  | 17.32±0.35 |
| Residual-Pt | 118.27±3.09 |  | 164.37±1.58 |  | 12.27±0.23 |  | 30.60±0.43 |
| Total Pi | 640.52±8.50 |  | 305.13±2.8 |  | 66.55±0.37 |  | 56.78±0.59 |
| Total Po | 321.47±1.37 |  | 232.49±4.34 |  | 33.45±0.37 |  | 43.22±0.59 |
| Total P | 961.99±7.64 |  | 537.63±4.11 |  | 100.00±0.00 |  | 100.00±0.00 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| variable |  |  | Yellow loam soil |  |  |  | Limestone soil | | | |
|  |  | Ca(NO3)2 | NH4Cl | NH4NO3 | Urea |  | Ca(NO3)2 | NH4Cl | NH4NO3 | Urea |
| NH4+ | N1 | 29.56±2.61a | 17.89±0.97b | 25.84±3.25a | 32.81±1.11a |  | 33.22±1.78a | 24.76±2.06b | 20.10±2.08b | 21.19±2.46b |
| N2 | 17.37±1.92ab\*\* | 20.71±1.04a | 15.67±1.74bc\* | 11.64±0.96c\*\*\* |  | 17.04±0.83ab\*\*\* | 18.76±1.53a | 11.58±1.19c\* | 14.43±1.1bc |
| NO3- | N1 | 1.90±0.10 | 1.89±0.04 | 2.08±0.07 | 1.95±0.03 |  | 3.63±0.14a | 2.88±0.21b | 3.02±0.06b | 3.14±0.11b |
| N2 | 2.04±0.07a | 1.6±0.02b\*\* | 1.72±0.08b\* | 1.90±0.02a\*\*\* |  | 3.02±0.18\* | 2.75±0.14 | 2.75±0.11 | 3.14±0.14\* |
| AN | N1 | 31.46±2.55a | 16.25±2.66b | 28.21±3.23a | 34.76±1.11a |  | 36.84±1.77a | 27.64±1.99b | 23.12±2.06b | 24.33±2.38b |
| N2 | 19.41±1.92ab\*\* | 22.81±1.51a | 17.39±1.78bc\* | 13.54±0.94c |  | 20.06±1.00ab\*\*\* | 21.51±1.46a\* | 14.07±1.03c\*\* | 17.56±1.15bc\* |
| pH | N1 | 5.42±0.03a | 5.21±0.01b | 5.43±0.01a | 5.46±0.02a |  | 6.04±0.02a | 5.85±0.03c | 5.97±0.03b | 5.92±0.01b |
| N2 | 5.46±0.01a | 5.05±0.02b\*\* | 5.48±0.03a | 5.45±0.01a |  | 6.06±0.02a | 5.66±0.03d\*\* | 5.86±0.01c | 5.98±0.01b\*\*\* |
| SM | N1 | 0.24±0.00 | 0.25±0.01 | 0.25±0.01 | 0.27±0.01 |  | 0.21±0.00 | 0.20±0.00 | 0.20±0.01 | 0.19±0.01 |
| N2 | 0.28±0.01a\*\* | 0.27±0.01a | 0.27±0.00a\*\* | 0.22±0.01b\*\* |  | 0.19±0.01b\* | 0.18±0.01b | 0.21±0.00a | 0.17±0.01b |
| ACP | N1 | 25264.15±1298.20 | 22907.84±5241.01 | 23331.79±3059.30 | 23712.64±4757.23 |  | 29607.31±2736.58ab | 33772.53±3255.10a | 31729.04±1560.64ab | 26030.07±282.74b |
| N2 | 23833.76±2531.83b | 32644.99±2104.5a | 15619.94±1953.49c | 27284.86±1910.64ab |  | 22030.22±3319.58b | 34216.53±2601.93a | 32425.51±1759.79a | 30433.2±3112.78ab |
| ALP | N1 | 1279.81±255.51c | 3291.19±1188.33c | 10261.18±1377.38b | 13945.71±1075.97a |  | 5632.92±1489.19c | 12541.34±1158.84b | 19548.20±1708.03a | 16522.62±1853.63ab |
| N2 | 1460.98±162.12b | 10812.5±1577.93a\*\* | 12520.35±1730.92a | 10920.57±112.57a\* |  | 6263.72±2157.19b | 16461.46±1074.71a\* | 13123.82±303.83a\* | 15304.65±659.59a |
| *phoC* | N1 | 639.28±81.58 | 608.89±93.92 | 599.34±19.26 | 477.39±20.33 |  | 16866.71±1226.81 | 21786.72±2657.70 | 16882.58±673.14 | 19859.90±1658.58 |
| N2 | 605.50±58.27b | 742.38±224.36b | 1032.79±162.31b\* | 6857.68±395.29a\*\*\* |  | 16399.83±1756.64c | 17898.45±1074.31c | 24158.30±2171.98b\* | 36163.94±2044.46a\*\* |
| *phoD* | N1 | 840.65±51.88 | 618.57±166.70 | 1211.40±28.63 | 1182.96±316.76 |  | 343721.33±32366.89 | 306689.83±30032.30 | 292568.65±38642.02 | 353283.58±32607.6 |
| N2 | 678.82±19.93b\* | 789.98±59.24b | 1679.87±334.74b | 9615.44±809.85a\*\*\* |  | 298024.39±15851.91ab | 243802.69±16504.46b | 352055.74±42502.31a | 325025.66±34866.81ab |
| RB | N1 | 1.50±0.19 | 1.58±0.45 | 1.31±0.34 | 1.78±0.31 |  | 3.35±1.04ab | 4.31±0.32a | 3.45±0.31b | 3.11±0.52b |
|  | N2 | 1.60±0.50c | 2.29±0.33ab | 1.73±0.29bc | 2.67±0.30a |  | 3.97±0.62b | 5.1±0.53b\* | 4.66±1.11b | 6.78±0.58a\*\* |

**Table S2.** Effects of different nitrogen additions on soil properties in soil.

Notes: Values indicate mean ± standard error. Asterisk (\*) indicate significant difference between N addition levels in the same N addition forms (*P <*0.05). Different letters after the values indicate significant differences among N addition forms in the same N addition levels (*P <*0.05). AN: available nitrogen; ACP: acid phosphatase; ALP: alkaline phosphatase; RB: root biomass; SM: soil water contents.

**Table S3** Effects of different nitrogen additions on phosphorus fractions in soil.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| variable |  |  | Yellow loam soil |  |  |  | Limestone soil | | | |
|  |  | Ca(NO3)2 | NH4Cl | NH4NO3 | Urea |  | Ca(NO3)2 | NH4Cl | NH4NO3 | Urea |
| H2O-Pi | N1 | 0.84±0.14 | 0.69±0.04 | 1.00±0.14 | 0.96±0.11 |  | 1.47±0.19 | 1.15±0.10 | 1.31±0.07 | 1.51±0.12 |
| N2 | 0.79±0.03c | 1.26±0.14b\*\* | 1.99±0.13a\*\* | 1.74±0.06a\*\* |  | 1.91±0.40c | 2.03±0.11bc\*\* | 2.62±0.11b\*\*\* | 4.19±0.09a\*\*\* |
| NaHCO3-Pi | N1 | 18.21±0.66 | 16.90±0.51 | 17.99±0.80 | 18.07±1.00 |  | 6.87±1.01 | 4.25±0.51 | 6.23±1.14 | 7.00±1.02 |
| N2 | 14.82±1.42 | 10.88±1.48\*\* | 12.83±1.43\* | 10.85±0.83\*\* |  | 4.22±1.21 | 5.89±0.25\* | 4.30±0.14 | 4.78±1.32 |
| NaHCO3-Po | N1 | 13.71±3.64a | 9.53±2.05ab | 11.99±0.29ab | 6.53±1.08b |  | 26.78±3.3 | 26.48±1.55 | 21.69±0.81 | 25.52±0.95 |
| N2 | 13.04±2.54 | 14.15±1.50 | 8.87±2.90 | 15.12±1.30\*\* |  | 27.16±0.48b | 23.04±0.33c | 29.09±2.27ab\* | 31.32±1.00a\*\* |
| NaOH-Pi | N1 | 280.61±4.56a | 279.81±10.69a | 279.25±2.99a | 206.82±35.23b |  | 73.26±2.93 | 72.48±0.74 | 70.36±1.70 | 73.03±1.58 |
| N2 | 79.34±2.20\*\*\* | 282.60±5.19 | 273.67±2.93 | 287.10±6.43 |  | 73.68±3.20 | 75.19±2.22 | 72.94±0.45 | 73.69±3.76 |
| NaOH-Po | N1 | 43.44±4.75 | 54.62±3.09 | 45.64±3.08 | 60.58±8.73 |  | 109.93±9.98 | 108.05±9.48 | 89.80±7.57 | 118.77±8.93 |
| N2 | 120.82±4.33a\*\*\* | 71.28±7.51b | 48.16±14.45b | 43.46±8.75b |  | 83.78±5.06 | 94.39±12.88 | 90.18±16.08 | 119.66±10.35 |
| DHCl-Pi | N1 | 3.77±0.48 | 2.46±0.58 | 4.46±0.92 | 3.19±0.29 |  | 0.55±0.04c | 0.52±0.03c | 0.66±0.02b | 0.97±0.04a |
| N2 | 3.56±0.23b | 3.13±0.84b | 6.08±0.28a\* | 3.66±0.11b |  | 0.98±0.00ab | 1.20±0.09a\*\*\* | 0.85±0.08b | 1.06±0.06ab\* |
| CHCl-Pi | N1 | 200.89±8.84a | 205.28±0.98b | 228.69±7.30a | 216.27±7.40ab |  | 58.77±4.35b | 62.2±3.55b | 85.38±15.47ab | 99.90±15.36a |
| N2 | 155.81±17.05b | 173.20±1.16b\*\*\* | 191.15±11.12a | 201.73±14.96a |  | 63.00±6.65\*\*\* | 59.00±2.30 | 54.73±3.80 | 56.20±2.66 |
| CHCl-Po | N1 | 60.37±16.79b | 136.98±16.87a | 86.46±7.75ab | 70.37±26.61b |  | 100.82±6.6 | 101.42±4.87 | 97.38±5.15 | 89.00±3.60 |
| N2 | 60.99±11.54 | 74.33±2.78\* | 111.07±28.57 | 77.65±5.02 |  | 96.39±6.72 | 91.24±7.16 | 103.89±12.32 | 109.73±8.44 |
| Residue-Pt | N1 | 95.19±4.95ab | 94.38±2.70ab | 102.43±3.91a | 88.63±1.09b |  | 144.05±3.60ab | 143.98±3.38ab | 150.31±1.73a | 135.10±5.21b |
| N2 | 120.93±8.30ab | 119.64±2.55ab\*\*\* | 110.02±7.69b | 140.1±8.05a\*\* |  | 169.87±1.71\*\* | 166.86±7.50\* | 169.16±3.50\*\* | 163.20±6.32\* |

Notes: Values indicate mean ± standard error. Asterisk (\*) indicate significant difference between N addition levels in the same N addition forms (*P <*0.05). Different letters after the values indicate significant differences among N addition forms in the same N addition levels (*P <*0.05).