# Supplementary online material

## Supplementary Tables

### **Table S1**

**Table S1.** Nutrient types, rates and treatment combinations used in the trial

|  |  |  |
| --- | --- | --- |
|  | Rate |  |
| Nutrient | (kg ha-1) | Complete treatment combination |
| N  | 0 | 0 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 46 | 46 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 92 | 92 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 138 | 138 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 184 | 184 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 230 | 230 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
| P | 0 | 0 kg P ha-1 + 92 kg N ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 10 | 10 kg P ha-1 + 92 kg N ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 20 | 20 kg P ha-1 + 92 kg N ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 30 | 30 kg P ha-1 + 92 kg N ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 40 | 40 kg P ha-1 + 92 kg N ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 50 | 50 kg P ha-1 + 92 kg N ha-1 + 83 kg K ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
| K | 0 | 0 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 17 | 17 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 33 | 33 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 50 | 50 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 66 | 66 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 83 | 83 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 100 | 100 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 116 | 116 kg K ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 30 kg S ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
| S | 0 | 0 kg S ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 10 | 10 kg S ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 20 | 20 kg S ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 30 | 30 kg S ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 40 | 40 kg S ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |
|  | 50 | 50 kg S ha-1 + 92 kg N ha-1 + 30 kg P ha-1 + 83 kg K ha-1 + 2 kg Zn ha-1 + 0.5 kg B ha-1 |

### **Table S2**

**Table S2**. Response of maize grain yield (kg ha-1) to N, P, K, and S application rates on two soil types and agroecological zones

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Rate | Grain yield |  | % Increase over control |
| Nutrient | (kg ha-1) | Andosols (95% CL) | Nitisols (95% CL) |  | Andosols | Nitisols |
| N  | 0 | 2523 (1539–3538) | 2759 (1140–4135) |  |  |  |
|  | 46 | 3296 (2135–4135) | **5069 (3450–6445)** |  | 30.6 | **83.7** |
|  | 92 | 3387 (2207–4207) | 3757 (2138–5133) |  | 34.2 | 36.2 |
|  | 138 | 3253 (2114–4113) | 4816 (3197–6192) |  | 28.9 | 74.5 |
|  | 184 | **3640 (2500–4499)** | 4915 (3296–6291) |  | **44.2** | 78.1 |
|  | 230 | 3513 (2373–4372) | 4590 (2972–5967) |  | 39.2 | 66.4 |
|  | *Year* | *<0.001* |  |  |  |  |
|  | *Rate* | *<0.001* |  |  |  |  |
|  | *Soil* | *0.354* |  |  |  |  |
|  | *Rate x soil* | *0.156* |  |  |  |  |
|  | *Year x rate* | *0.233* |  |  |  |  |
|  | *Year x rate x soil* | *<0.001* |  |  |  |  |
| P | 0 | 2760 (2075–3884) | 2946 (1415–4247) |  |  |  |
|  | 10 | 3449 (2492–4300) | 4827 (3296–6128) |  | 25.0 | 63.8 |
|  | 20 | 3466 (2697–4506) | 4640 (3108–5940) |  | 25.6 | 57.5 |
|  | 30 | 3592 (2673–4486) | 4845 (3314–6146) |  | 30.2 | 64.4 |
|  | 40 | **3598 (2626–4435)** | 5124 (3593–6425) |  | **30.4** | 73.9 |
|  | 50 | 3187 (2230–4039) | **5159 (3629–6461)** |  | 15.5 | **75.1** |
|  | *Year* | *0.206* |  |  |  |  |
|  | *Rate* | *<0.001* |  |  |  |  |
|  | *Soil* | *0.117* |  |  |  |  |
|  | *Rate x soil* | *0.449* |  |  |  |  |
|  | *Year x rate* | *0.046* |  |  |  |  |
|  | *Year x rate x soil* | *<0.001* |  |  |  |  |
| K | 0 | 2672 (1235–3499) | 4133 (2465–5481) |  |  |  |
|  | 17 | 3153 (1716–3979) | **5934 (4265–7282)** |  | 18.0 | **43.6** |
|  | 33 | 3054 (1618–3881) | 5321 (3653–6669) |  | 14.3 | 28.7 |
|  | 50 | 3303 (1866–4130) | 5461 (3793–6810) |  | 23.6 | 32.1 |
|  | 66 | 3380 (1943–4207) | 5234 (3566–6582) |  | 26.5 | 26.6 |
|  | 83 | 3399 (1963–4226) | 5400 (3732–6749) |  | 27.2 | 30.7 |
|  | 100 | **3438 (2001–4265)** | 5906 (4140–7183) |  | **28.7** | 42.9 |
|  | 116 | 3321 (1884–4147) | 5817 (4051–7094) |  | 24.3 | 40.7 |
|  | *Year* | *0.012* |  |  |  |  |
|  | *Rate* | *<0.001* |  |  |  |  |
|  | *Soil* | *<0.001* |  |  |  |  |
|  | *Rate x soil* | *0.036* |  |  |  |  |
|  | *Year x rate* | *<0.001* |  |  |  |  |
|  | *Year x rate x soil* | *<0.001* |  |  |  |  |
| S | 0 | 3443 (2029–4689) | 4726 (2603–6239) |  |  |  |
|  | 10 | 3459 (1712–4372) | **6321 (4198–7834)** |  | 0.5 | **33.7** |
|  | 20 | 3649 (1902–4562) | 5883 (3760–7396) |  | 6.0 | 24.5 |
|  | 30 | 3617 (1870–4530) | 6134 (4011–7647) |  | 5.1 | 29.8 |
|  | 40 | 3554 (1807–4467) | 6007 (3884–7520) |  | 3.2 | 27.1 |
|  | 50 | **3654 (1908–4568)** | 6127 (4004–7640) |  | **6.2** | 29.6 |
|  | *Year* | *<0.001* |  |  |  |  |
|  | *Rate* | *0.152* |  |  |  |  |
|  | *Soil* | *0.37* |  |  |  |  |
|  | *Rate x soil* | *0.568* |  |  |  |  |
|  | *Year x rate* | *0.062* |  |  |  |  |
|  | *Year x rate x soil* | *<0.001* |  |  |  |  |

c Values in brackets represent 95% confidence limits.

### **Table S3**

**Table S3**. Percentage explained variation

|  |  |  |  |
| --- | --- | --- | --- |
|  | Explained variation (%) |  |  |
| Source | Nitrogen | Phosphorus | Potassium | Sulphur |
| Soil | 0.8 | 6.1 | 16.9 | 15.9 |
| Year | 9.4 | 2.8 | 1.6 | 8.1 |
| Rate | 9.8 | 8.2 | 3.2 | 1.2 |
| Soil\*Year | 11.8 | 21.1 | 12.8 | 25.9 |
| Soil\*Rate | 1.4 | 1.4 | 1.0 | 0.6 |
| Year\*Rate | 2.6 | 3.1 | 5.2 | 2.7 |
| Soil\*Year\*Rate | 5.0 | 2.1 | -- | 3.5 |
| Error  | 59.1 | 55.2 | 59.3 | 42.0 |

### **Table S4**

**Table S4.** Variations in harvest index with N, P, K, and S application rates on two soil types

|  |  |  |  |
| --- | --- | --- | --- |
| Nutrient | Rate (kg ha-1) | Andosols (95% CL) | Nitisols (95% CL) |
| N  | 0 | 0.39 (0.13 – 0.64) | 0.38 (0.12 – 0.64) |
|  | 46 | 0.42 (0.17 – 0.67) | 0.48 (0.22 – 0.74) |
|  | 92 | 0.45 (0.20 – 0.71) | 0.45 (0.19 – 0.70) |
|  | 138 | 0.46 (0.20 – 0.71) | 0.47 (0.21 – 0.72) |
|  | 184 | **0.49 (0.23 – 0.74)** | **0.49 (0.24 – 0.75)** |
|  | 230 | 0.44 (0.18 – 0.69) | 0.48 (0.22 – 0.73) |
|  | *Year* | *0.002* |  |
|  | *Rate* | *<0.001* |  |
|  | *Soil* | *0.925* |  |
|  | *Rate x soil* | *0.681* |  |
|  | *Year x rate* | *0.828* |  |
|  | *Year x rate x soil* | *<0.001* |  |
| P | 0 | 0.40 (0.21 – 0.60) | 0.41 (0.21 – 0.61) |
|  | 10 | **0.45 (0.25 – 0.65)** | 0.46 (0.26 – 0.66) |
|  | 20 | 0.45 (0.25 – 0.64) | 0.47 (0.27 – 0.67) |
|  | 30 | 0.44 (0.24 – 0.63) | 0.47 (0.27 – 0.67) |
|  | 40 | 0.44 (0.25 –0.64) | 0.47 (0.26 –0.67) |
|  | 50 | 0.43 (0.23 –0.63) | **0.48 (0.27 –0.68)** |
|  | *Year* | *<0.001* |  |
|  | *Rate* | *0.187* |  |
|  | *Soil* | *0.862* |  |
|  | *Rate x soil* | *0.963* |  |
|  | *Year x rate* | *0.834* |  |
|  | *Year x rate x soil* | *<0.001* |  |
| K | 0 | 0.52 (0.47 – 0.57) | 0.44 (0.39 – 0.49) |
|  | 17 | 0.55 (0.50 – 0.60) | 0.47 (0.41 – 0.52) |
|  | 33 | 0.55 (0.50 – 0.60) | **0.49 (0.44 – 0.54)** |
|  | 50 | **0.58 (0.53 – 0.63)** | 0.48 (0.43 – 0.53) |
|  | 66 | 0.57 (0.52 – 0.62) | 0.47 (0.41 – 0.52) |
|  | 83 | 0.55 (0.50 – 0.60) | 0.48 (0.43 – 0.53) |
|  | 100 | 0.58 (0.53 – 0.63) | NE |
|  | 116 | 0.56 (0.51 – 0.61) | NE |
|  | *Year* | *0.004* |  |
|  | *Rate* | *0.003* |  |
|  | *Soil* | *0.006* |  |
|  | *Rate x soil* | *0.067* |  |
|  | *Year x rate* | *<0.001* |  |
|  | *Year x rate x soil* | *<0.001* |  |
| S | 0 | 0.53 (0.45 – 0.61) | 0.43 (0.35 – 0.51) |
|  | 10 | 0.52 (0.43 – 0.61) | 0.43 (0.35 – 0.51) |
|  | 20 | 0.53 (0.44 – 0.62) | **0.45 (0.37 – 0.53)** |
|  | 30 | **0.55 (0.46 – 0.64)** | 0.44 (0.36 – 0.51) |
|  | 40 | 0.53 (0.44 – 0.62) | 0.44 (0.36 – 0.52) |
|  | 50 | 0.53 (0.44 – 0.61) | 0.45 (0.38 –0.53) |
|  | *Year* | *0.001* |  |
|  | *Rate* | *0.984* |  |
|  | *Soil* | *0.064* |  |
|  | *Rate x soil* | *0.958* |  |
|  | *Year x rate* | *0.946* |  |
|  | *Year x rate x soil* | *<0.001* |  |

d Values in brackets represent 95% confidence limits.

NE = not estimable

## Supplementary Figures

### **Figure S1**

|  |  |
| --- | --- |
|  |  |
|  |  |

Figure S1. Variations in aboveground biomass with nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) application rates on Andosols and Nitisols

### **Figure S2**

|  |  |
| --- | --- |
|  |  |
|  |  |

Figure S2. Variations in aboveground biomass with nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) application rates in agroecological zones M2 and SH3