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The effect of soil amendments on phosphorus mobilization in P saturated soils of Flanders, Belgium

Promoter(s) :

Prof. Dr. ir. Stefaan De Neve

Tutor(s):

ir. Stany Vandemoere

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by Niranjan Phuyal (Nepal)

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Gent,

The Promoter(s),	The Author,
Prof. Dr. ir. Stefaan De Neve	***Niranjan Phuyal***

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List of Abbreviations

Al_{OX}	Oxalate extractable Aluminum
Al-P	$AlPO_4$
$CaCO_3$	Calcium carbonate
CFU	Colony forming unit
DRP	Dissolved reactive phosphorus
Fe_{ox}	Oxalate extractable iron
Fe-P	$FePO_4$
$HClO_4$	Perchloric acid H_2PO_4- Dihydrogen phosphate
HPO_4^{2-}	Phosphoric acid
H_2SO_4	Sulfuric acid ICP inductively coupled plasma
KCl	Potassium Chloride
$K_2Cr_2O_7$	Potassium dichromate
OC	Organic carbon
PE	polyethylene tubes
P-AL	Ammonium lactate extractable phosphorus
PO_4^{3-}	Phosphate
P_{ox}	Oxalate extractable phosphorus
PSD	Phosphate saturation degree
PSC	Phosphorus sorption capacity
PSD	Phosphorus saturation degree
SPSS	Statistical Package for Social Sciences
TDP	Total dissolved phosphorus
TC	Total carbon
TOC	Total organic carbon
TP	Total phosphorus
TPP	Total particulate phosphorus
TRP	Total reactive phosphorus
USDA	United States Department of Agriculture

Summary

Flanders (Belgium) is facing huge water quality issues related to nitrates and phosphates in surface waters caused mainly by agriculture. Because of this, Flemish government has been restricting the use of P Manure by Manure Action Programs since 1996. In relation to phosphorus, the focus in these programs is on P mining by reducing P fertilizer use, because soil P stocks in Flemish soils are huge. As the major part of these P stocks are not (immediately) plant available two possible problems might arise. First of all, P sensitive crops might be dealing with reduced yield and/or delayed harvest. Secondly, P mining might be reduced after a couple of years.

In order to solve these problems, a three-step research strategy was used to select soil amendments (Organic acids, sulphur, Silicates and Phosphates solubilizing bacteria) which could improve the plant availability of P in soils, which have a low or moderate P intensity (0 mg P/kg dry soil < P $CaCl_2$ < 1.5 mg P/kg dry soil) and rather high P quantity (P-AL > 30 mg P/100 g dry soil). Soil sampling on two sites, experimental plot E13.0130 and van Oeckel was done.

Shaking experiment is the first step of this experiment. The first step included the selection of the best amendments and their concentration. This was done by shaking 4 g of soil in 40 ml of 0.5, 1 and 2 mM of organic acids (lactic acid, oxalic acid, citric acid), sodium silicate and sodium sulphate. Out of these tests it could be concluded that 2mM citric acid, 2 mM sodium silicate performed better. Within the organic acids, citric acid produced highest amount of P, 39.05 mg/kg dry soil in E13.0130 and 39.25 mg/dry soil in van Oeckel. Within silicate 2 mM sodium silicate produced 28.62 mg/dry soil and 33.23 mg/dry soil in E13.0130 and Van oeckel respectively. There is no much effect of concentration on P extraction for lactic acid and Na_2SO_4. From shaking experiment organic acid have negative correlation with pH whereas sodium silicate has significant positive correlation.

In a second step, soils were amended with one of following amendments: citric acid (10 mM/kg dry soil), elemental Sulphur (20 mM/kg dry soil), sodium silicate (10 mM/kg dry soil) and PSB (126×10^{11} CFU/kg dry soil) and incubated in small PE cups at a density of 1.4 kg/dm³ and 50% WFPS at 20°C. After 3, 6, 12, 24 and 48 days P-$CaCl_2$ and pH-H_2O were determined. From incubation experiment, PSB gave the highest amount of P-$CaCl_2$ in day 12 ranging from 2.78 to 2.91 mg/kg dry soil for site E13.0130 and 2.99 to 3.06 mg/kg dry for van Oeckel.

Similarly, Na_2SiO_3 has extracted more P-$CaCl_2$ in day 24 ranging from 1.87 dry soil to 1.91 mg/kg dry soil in site E13.013 and 1.85 dry soil to 1.96 mg/kg dry soil in site van Oeckel. Negative correlation for P-$CaCl_2$ extraction and pH was found for PSB, sulphur and citric acid while for sodium silicate negative correlation was found.

In a final experiment grass was grown in soil supplemented with one of the amendments: citric acid (10mM/kg dry soil), elemental Sulphur (10 mM/kg dry soil), sodium silicate (10 mM/dry soil) and PSB (126 x 10^{11} CFU/kg dry soil). P-$CaCl_2$, pH-H_2O, dry matter yield and P-uptake by grass were determined 20, 40 and 60 days after germination. On harvested pots P-$CaCl_2$ decreased with time as plants were up taking them but still with PSB and sodium silicate P-$CaCl_2$ remained higher. Effect of amendments on P-$CaCl_2$ is higher in all pots throughout the experimental period. PSB produces highest amount of total dry weight of grass 5.98 g in site E13.0130 and 8.32 g in site Van Oeckel. After PSB, sodium silicate produced 4.04 g at site E13.130 and 3.74 g at site Van Oeckel. Similarly, total P-uptake by plants was highest for PSB on both sites followed by sodium silicate. On day 60 total P-uptake for grass grown on PSB is 12.33 mg in site E13.0130 and 22.17 mg in site Van Oeckel. Similarly, total P-uptake for sodium silicate in site E13.0130 is 9.12 mg and in site Van Oeckel is 11.0 mg. So, the three step experiment shows PSB and sodium silicate are best performing. There might be some fertilizer effect on inoculation of PSB but still it's effect is higher. In conclusion, PSB and sodium silicate are found to be effective amendments to increase P availability in acidic sandy soil with a high P status but further pot trials are needed.

Chapter 1 Introduction

Phosphorus (P) is an essential nutrient of life and plays an important role for plants as a building block for cell walls and in the energy management. When the amount of phosphorus available for plants is sub-optimal, this can lead to yield losses in crops ranging from 10% to 15% (Shenoy and Kalagudi, 2005). Therefore, the use of P fertilizers has become essential for agriculture.

The problem arising with this practice is that not all P supplied will stay available for plants. In soils only 0.1 to 1.0 % of total soil P is soluble and plant available (Pierzynski et al., 2005a). This unavailability is due to phosphate fixation which restrains P availability temporarily or permanently in the soil which depends upon chemical fixation reactions. In P-fixation, P is either adsorbed on the soil minerals or it gets precipitated by free Al^{+3} and Fe^{3+} in the soil solution (Havlin et al., 2005).

As a consequence, farmers have been applying P fertilizer at levels much higher than the amount of P removed by the crops. This has led to the accumulation of P in soils. The environmental threshold of P concentration is far less than the agricultural crop demand. According to Pierzynski et al. (2005a), the optimum concentration of P in soil solution for plant growth is >0.2 mgL^{-1} whereas the threshold concentration of P in surface water to prevent eutrophication should be < 0.03 mgL^{-1}. Due to erosion, run-off and drainage, short-circuiting the buffering capacity of the soil large amounts of P are lost to the environment, causing eutrophication. In Flanders, about 29.4% of agricultural land is at risk of P leaching (VLM, 1997). The estimated share of agriculture in the phosphorus load of surface water in Flanders is 44% (Van Steertegem, 2012). Therefore, agriculture is an important factor in surface water pollution in this region.

To tackle these environmental problems, European Union has formulated the Nitrates Directive and the Water Framework Directive (Amery and Vandecasteele, 2013). The Flemish government has been taking action with the development of Manure Action Programs since 1996 (VLM, 2007). But, even after several years of P nutrient mitigation not enough improvement in water quality has been observed (Jarvie et al., 2013). Legislation measures are restricting farmers more and more on the use of P fertilizers. The maximum P application standard for Flanders is approximately 5 kg P_2O_5 $ha^{-1}y^{-1}$ smaller than the amount of P exported by the crop. This to obtain P mining (Amery and Schoumans, 2014).

Further the natural abundance of P is limited. According to (Cooper et al., 2011), 70% of global production of rock phosphate (RP) is currently produced from reserves which will be depleted within 100 years and by 2070 there will be already severe food production deficit because of shortage of P. Therefore, there is an increasing uncertainty about the future of RP supplies in order to ensure the food security (Cooper et al., 2011).

As farmers can use less P fertilizer, due to limited resources and legislation two possible problems might arise in time. First of all, P sensitive crops might be dealing with reduced yield and/or delayed harvest. Secondly, P mining might be reduced after a couple of years. To cope with both of these problems, , it is important to increase the amount of plant available P in soils .. Several studies suggest that the application of soil amendments like organic acids (Gardner and Boundy, 1983; Gang et al., 2012; Strobel, 2001) silicates (Roy, 1969; Smyth & Sanchez, 1980; Carvalho et al., 2000; Sandim et al., 2014), sulphates (Krol et al., 1986; Jaggi et al., 2005; Skwierawska and Zawartka, 2009), and PSB (Illmer and Schinner, 1992; (De Bolle et al., 2013)) can increase the amount of plant available P. In this study we've undertaken a three-step research strategy to select which soil amendments (Organic acids, Sulphates, Silicates and Phosphates solubilizing bacteria) could improve the plant availability of P in soils with low P intensity and high P quantity. So, in particular, this study aims to:

- Select the most promising amendments and concentrations to increase plant available phosphorus (P intensity) in shaking experiments
- Test whether the selected amendments could increase P-$CaCl_2$ when incubated for different time intervals
- Test whether the use of amendments really increased crop yield and P uptake
- Determine which mode of action is responsible for the effect of the amendment

Chapter 2 Literature Review

2.1 Phosphorous

Phosphorus (P) is a crucial nutrient as it is a structural element in nucleic acids (DNA and RNA) and it serves a critical role in cellular regulation, carbon partitioning and energy transfer (ATP). Also P is essential for seed formation, strength of shoots, development of roots and maturation of crops (Stevenson and Cole, 1999). Deficiency of plant available P can cause stunted growth and delayed maturity, which is visually seen as yellowing of the lower leaves in plants. Up to now P deficiency still limits crop yields on more than 40% of the world's arable land (Sylvain and Thomas, 2013).

2.2 Soil phosphorus cycle

The P cycle is given in Figure 1. Unlike nitrogen, there is no atmospheric source of P. The major inputs of the P cycle are fertilizers (inorganic or organic), agricultural wastes, plant residues, and municipal or industrial by-products (Pierzynski et al., 2005a). Outputs are P uptake and losses due to erosion, runoff and leaching which flows to surface water. Soil P is divided into three major forms which are in dynamic equilibrium. In the center of the Figure 1 we can see the P in soil solution which is immediately available for plants. This form of P ($H_2PO_4^-$, HPO_4^{2-}) can also be defined as P intensity. Sorbed P, secondary P minerals and primary minerals are the occluded forms of P which can be converted to soluble form by dissolution process and are accumulated in insoluble form by sorption process. The occluded form is represented by inorganic P compounds and are resistant to microbial process like mineralization (De Schrijver et al., 2012). Organic P is the another form of P which is dominated by soil biomass, soil organic matter, soluble organic P and decaying plant residues. Organic P is converted to soil solution P by mineralization. Soil solution P can be uptake by plants or loosed by leaching or flow to surface water.

The P concentrations in soil solution is relatively low and varies in the range of <1 $kgha^{-1}$, or <1% of the total quantity of P in the soil (Pierzynski, 1991). Since, P concentration in soil solution is low it should be maintained optimal for optimum plant growth. Because of this P in the soil solution must be replenished several times during the life cycle of a plant to meet its P demand. Hence, effective P management is very important which involves management of the chemical and biological process like *dissolution-precipitation*, *mineralization-immobilization*, *sorption-desorption*, and *oxidation- reduction* as shown in fig. 1 (Pierzynski et al., 2005a). Soil P content varies with parent material, texture, and management factors, such as rate and type of P applied and soil cultivation (Sharpley, 1995). In soil, P can be divided into two broad classes as organic P and inorganic P (Pierzynski et al., 2005a). In most soils 50 to 75% of the P is inorganic, although this fraction can vary from 10 to 90% (Sharpley, 1995).

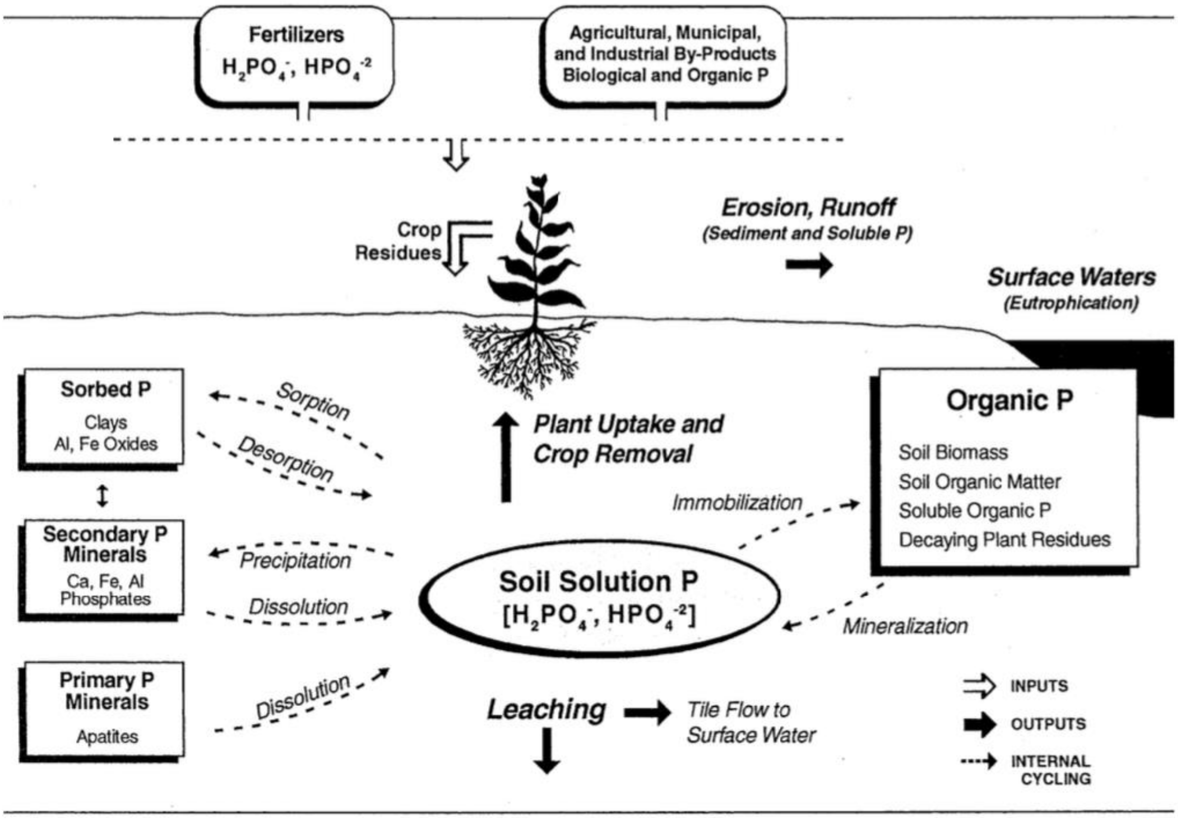


Figure 1 Phosphorous cycle in soil. Source : (Pierzynski et al., 2005a)

2.2.1 Inorganic soil phosphorous

Inorganic P is produced by weathering of different minerals (Pierzynski et al., 2005a) and can be present as hydrous sesquioxides, amorphous, and crystalline Al and Fe compounds in acidic, non-calcareous soils and as Ca compounds in alkaline, calcareous soils (Sharpley, 1995). In unweathered or moderately weathered soils, apatites (Ca phosphates) are the dominant minerals. P is plant available as primary (PO_4^{3-}) or secondary (HPO_4^{2-}, H_2PO^{4-}) orthophosphates in the soil solution when it gets dissolved or desorbed from soil minerals or colloids.

The amount of plant available P depends on the soil pH and the activities of Al^{3+}, Fe^{3+} and Ca^{2+}. As shown in fig. (2), at low pH, P is almost completely insoluble since it is fixed to Al^{3+} and Fe^{3+} and at high pH P is strongly held by Ca^{2+} (Tisdale et al., 1985). Similarly, the P is generally highly available at a pH of 6 to 7 (fig.5). Normally, the majority of the orthophosphate is present either as HPO_4^{-2} at pH > 7.2 or as $H_2PO_4^-$ at pH between 4.0 and 7.2. At the higher pH values soluble complexes like $CaHPO_4$ or $CaPO_4$ are present abundantly. But, in most cases these soluble complexes are rapidly converted into orthophosphate by chemical dissociation.

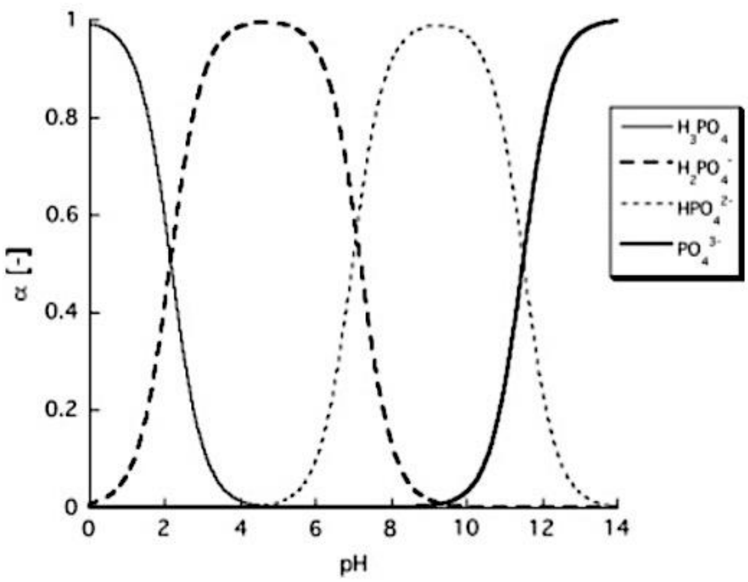


Figure 2 Changes in the form of soil P as affected by the pH for soluble P (alpha = mole fraction of the total P). Source: (Pierzynski et al., 2005a)

2.2.2 Organic soil phosphorus

Organic P forms include relatively labile phospholipids, inositols and fulvic acids, while more resistant forms are comprised of humic acids (Sharpley, 1995). Organic P varies between 3% and 90% of soil P (Pierzynski et al., 2005a), depending upon the nature and management of the soil. High proportions of organic P can be found in soils where significant quantities of organic P are continuously added to soil in plant, animal and microbial detritus (Condron et al., 2005). Microbial decomposition of organic P results in the release of soluble organic P that, with time, is converted into an inorganic form of P (Pierzynski et al., 2005a). Organic P transformations in soil are important in determining the overall biological availability of P, which in turn influences the ecosystem productivity (Condron et al., 2005). Based on the nature of the P bond, soil organic P is classified into phosphate esters, phosphonates and phosphoric acid anhydrides (Turner et al., 2005). Normally, ortho-P associated with humic compounds through metal bridges is not classified as organic P. The amount, forms and dynamics of organic P in the soil are determined by a combination of biological, chemical and physical conditions (e.g. pH, temperature and soil moisture), together with the history and the intensity of land use and associated levels of P input and removal from the system (Condron et al., 2005; Pierzynski et al., 2005a).

2.3 Major Reactions of Phosphorus in Soils

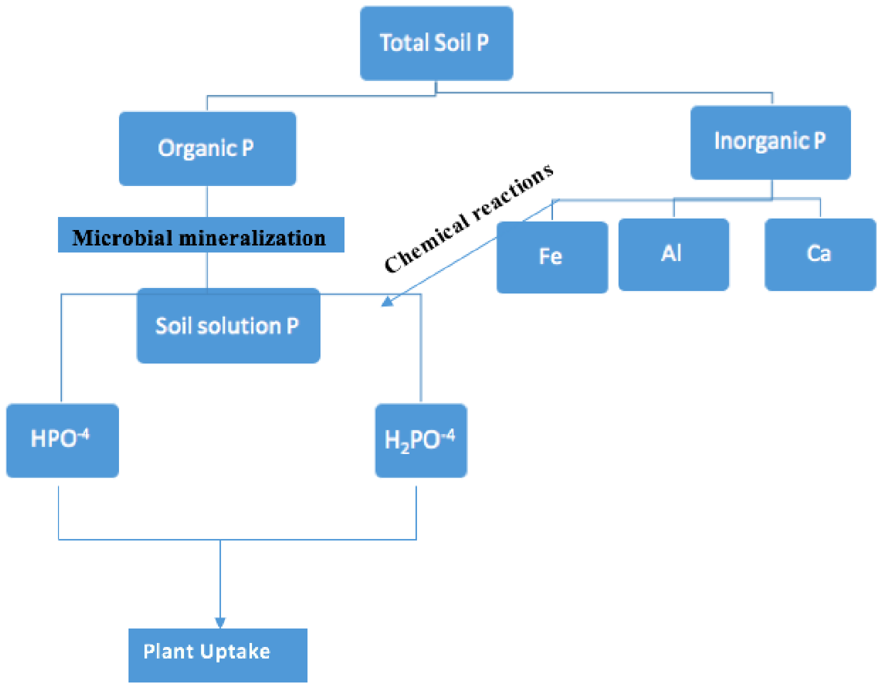


Figure 3 Scheme of the major forms of P in the soil. Source: (Minor and Stecker, 1993).

P is absorbed by plants, in the orthophosphate (H_2PO^{4-}) and HPO_4^{2-} forms (Pierzynski et al., 2005a). As concentrations of $H_2PO_4^-$ and HPO_4^{2-} in soils are low, it's important to understand and control the major reactions of P in soils. As shown in fig.2, Soil P chemistry is complicated (Figure 2). Generally, P is added to soil, in the form of soluble fertilizers, but is relatively quickly transformed in an insoluble P form, a process sometimes termed P retrogradation. This insoluble form can again be converted into soluble form. The main processes controlling soil P bioavailability are P sorption and desorption, immobilization and mineralization, dissolution and precipitation. However, other factors, such as pH, texture, fertilization, $CaCO_3$ and organic carbon may also influence these processes (Bastounopoulou et al., 2011).

2.3.1 P sorption and desorption

P sorption is the capacity of soil to sorb P. Due to the high sorption capacity only a small percentage of P is bioavailable in soil. Adsorption of orthophosphates (PO_4-P) on the surface of Fe (III) and aluminum (hydr)oxides is an important governing process of sorption and desorption (Gustafsson et al., 2012). Orthophosphates can adsorb to the surfaces and edges of hydrous oxides, clay minerals and carbonates by replacing H_2O or OH^- (Pierzynski et al., 2005a). Adsorption processes are expected to play a more important role at low pH, because PO_4–P adsorption increases with decreasing pH (Goldberg and Sposito, 1984).

Desorption of P mostly occurs through ligand exchange reactions, which means that a decrease in the concentration of P ions in the soil solution, through e.g. plant uptake, and an increase in the concentration of competing anions will both shift the adsorption–desorption equilibrium towards enhanced desorption (Pierzynski et al., 2005a). Desorption signifies the release of P from the solid phase into the solution phase (Stevenson and Cole, 1999).

2.3.2 Immobilization and mineralization

Immobilization is the process of temporarily "tying up" of water soluble P by soil microorganisms which are decomposing plant residues. Immobilized P will be plant unavailable for a while, but will eventually become available again as decomposition proceeds. P mineralization is very important to maintain soil fertility. Nutrients contained in soil organic matter (e.g., phosphorus, nitrogen, and sulfur) are converted to inorganic forms that are available to crops by the process of mineralization. Microorganisms can mineralize organic P inside and outside their cells (Spohn and Kuzyakov, 2013).

Mineralization and immobilization of phosphorus occur simultaneously in the soil. The C:P ratio determines whether there is net mineralization or net immobilization. If C:P ratio is less than 200:1 there will be net mineralization (White, 2013). Net mineralization indicates that there is enough phosphorus in the soil to sustain both plants and microorganisms. When the

C:P ration is between 200:1 and 300:1, immobilization and mineralization rates almost equal (White, 2013). If C:P ratio is greater than 300:1, net immobilization occurs (White, 2013).

2.3.3 Dissolution and Precipitation of P

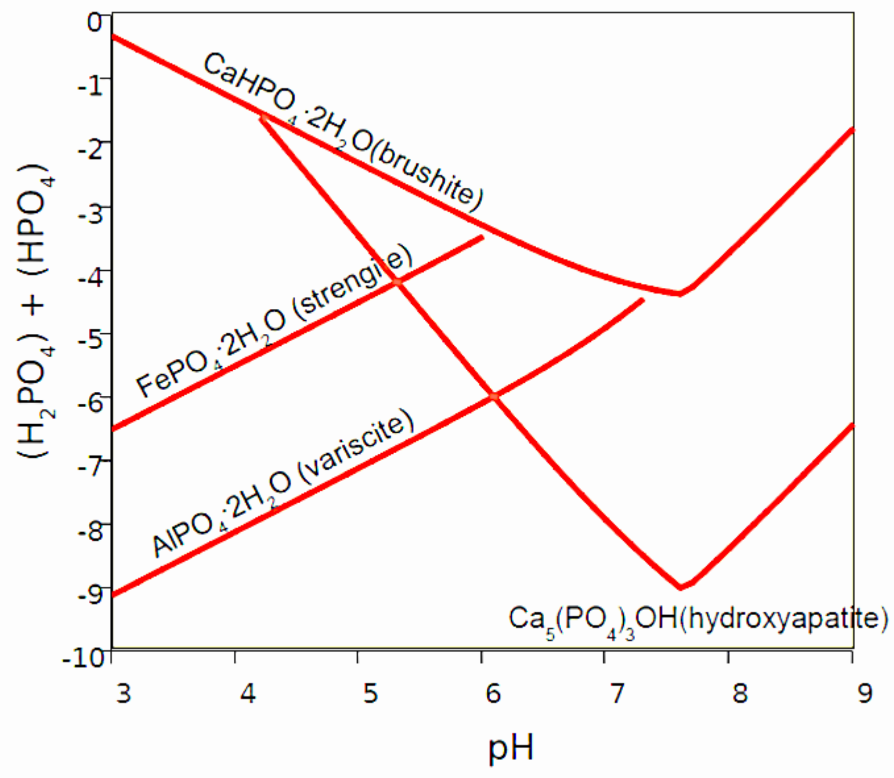


Figure 4 Soil pH and the solubility of some phosphate minerals. Source: (Lindsay, 1979)

Precipitation is the reverse process of dissolution that leads to the formation of insoluble compounds in soils which usually exceeds its solubility products (Pierzynski et al., 2005b). The availability of P is usually affected by precipitation reactions which is dependent on soil pH. At low pH, P in soil reacts with Fe and Al and form minerals such as strengite and varescite (Figure 4) and make it unavailable for plant uptake. Similarly, at high pH (>8), the precipitation of phosphates reacts with Ca forming a number of Ca-P minerals such as amorphous Ca phosphate, octa-Ca phosphate and apatite (hydroxyapatite) (Gustafsson et al., 2012). Normally, at the pH between 6.0 to 6.5 solubility of P is highest and is available for plants which can also be loosed by surface runoff, percolation or leaching (Pierzynski et al., 2005b) (Figure 4).

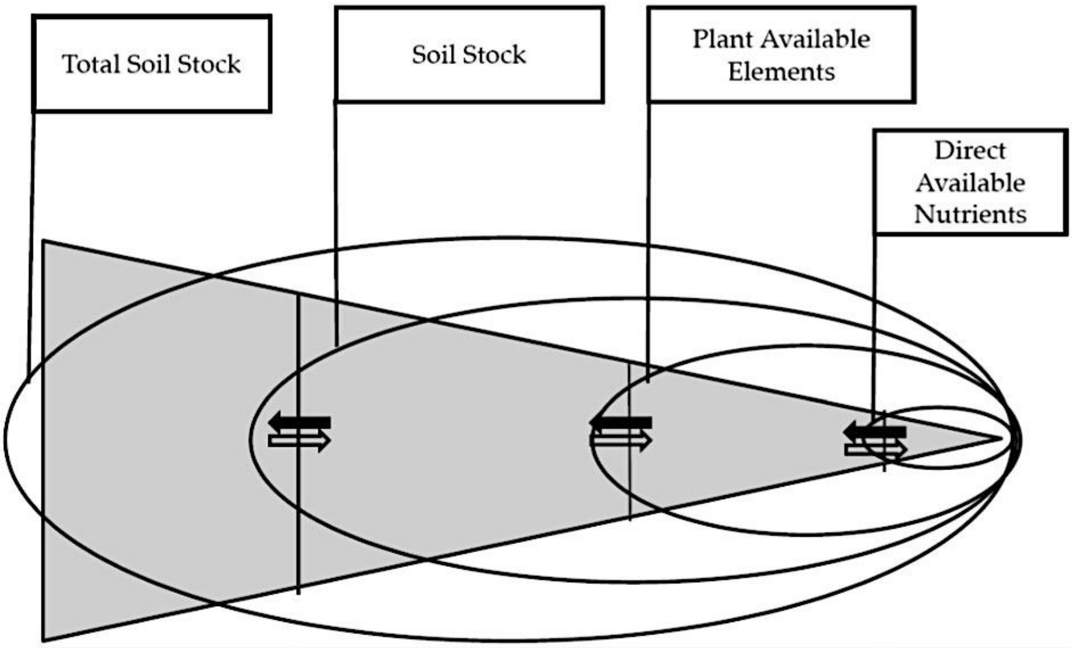
2.4 Measurement of plant available P

Fertilizer recommendation is done to supply essential amount of P required by plants. Fertilizer recommendation is a function of soil P status which is done with chemical extractions. Amount of P in soil is often determined by chemical different chemical extraction methods. A wide range of soil tests have been developed to determine the availability of phosphorus (P) in soils, based on the theoretical concepts of P intensity and P quantity (Van Raij, 1998). As only one test is used for the P estimation often P intensity of P quantity is determined. There are different soil test methods for P extraction, giving in insight in different pools of P present in soil: P total, P-oxalate, P-Al, P-CaL, P-Olsen, Pw and P-$CaCl_2$ (Van Rotterdam-Los et al., 2013). Though there are different P-test only one test is used for general fertilizer recommendation. According to Van Rotterdam-Los et al. (2013), in the Netherlands two soil tests, one for directly plant available P (P-intensity) and another one for P stock (P-quantity) were recommended for farmers since 1930 but they preferred to use only one test because of cost. For Dutch situation P-AL(ammonium lactate, Egner et al., 1960) and 0.01 P-CaCl2 (Huba et al., 2000) were used to approximate P-quantity and P-intensity respectively (Van Rotterdam-Los et al., 2013). Implementing new concept like the intensity, buffering capacity and quantity concept in fertilizer recommendation can provide more insight into the soil P status and its relationship with crop response to fertilizer (Van Rotterdam-Los et al., 2013).

P-intensity and P-quantity

The P intensity factor is considered to be the activity of orthophosphate in the soil solution, which is immediately available to plant roots (Pypers et al., 2006). But, generally amount of P available in soil solution is lower than crop demand. Therefore, deficient P is replenished form P adsorbed to soil particles. The capacity of soil to resist the change in the concentration of soil available form P is known as buffering capacity (Van Rotterdam-Los et al., 2013). P-Al and P-$CaCl_2$ ratio is used to predict the buffering capacity.

Figure 5 gives the visual representation of the soil quantity, buffering capacity, and intensity concept of P. The arrows indicate the buffering and binding process of P that is dependent on Fe, Al and Ca this can be estimated by P-Al/P-$CaCl_2$ ratio.



Method	← P-total →	← P-Al →	← P-$CaCl_2$# →	← P-$CaCl_2$^ →
Result	250 mg P_2O_5 100 g^{-1}	40 mg P_2O_5 100 g^{-1}	1.5 mg P kg^{-1}	0.5 mg L^{-1}
Kg ha^{-1}	3400 P	545 P	4.7 P	2.5 P
	Soil Quantity		Soil Intensity	

Figure 5 Visual representation of the concept of P-intensity (P-$CaCl_2$) and P-capacity (P-Al). Here, P-$CaCl_2$# is P extracted using 0.01 M 1:10 $CaCl_2$ in dried soils and P-$CaCl_2$^ is P extracted using 0.01 M 1:10 $CaCl_2$ in non-dried soils. Source: (Van Rotterdam-Los et al., 2013)

The soil P that is replenished when soluble P gets absorbed is called P-quantity that can be measured by P-Al. As shown in the figure plant available P can be derived either from P-quantity or direct available nutrients. Total soil stock represents the P that is accumulated in soil in immobilized form like with Fe, Al or Ca.

2.5 Phosphate saturation and losses to the environment

The Phosphate saturation degree (PSD) is a measure of potential P losses by leaching from acidic soils. PSD is a function of the portion of the soil exchangeable sites that are bound/saturated with P (P sorbed) in relation to the number of sites available for P binding capacity (PBC) (Hooda et al., 2000).

The P binding capacity (PBC) of the soil measures the maximum ability to adsorb/precipitate P (Van der Zee, 1990). It is the amount of P that can be bound by soil mainly with Fe and Al.

PBC = $(Fe_{ox} + Al_{ox}) * \alpha$

Al_{ox} and Fe_{ox} are oxalate-extractable Al and Fe and α is an affinity factor. The scaling factor α depends on soil type and experimental conditions (Renneson et al., 2010). The α value of 0.50 has been used for acidic Dutch soil (Van der Zee, 1990).

Concept of PSD was firstly introduced in the Netherlands where PSD of 25% is considered as the threshold of groundwater quality (Breeuwsma et al., 1995). The PSD of soil can be calculated by:

$$PSD = \frac{100P_{ox}}{\alpha(Al_{ox} + Fe_{ox})}$$

Here, P_{ox} is oxalate-extractable P.

PSD is a good indicator of the soil's potential to release P in soluble form and which can get loosed to water sources. PSD is an important soil test method to get an estimate of the risk of P leaching. PSD has already been used as an environmental indicator in some regions/countries all around the world, because it shows a strong relationship with P runoff or P leaching (Renneson et al., 2010). PSD is calculated as the ratio of acid ammonium oxalate P to [Al Fe] (Van der Zee and Van Riemsdijk, 1988).

In the Netherlands, a threshold of 25% was proposed (Breeuwsma et al., 1995) and 40% in Flanders (Chardon and Schoumans, 2007). Researchers like Schoumans and Groenendijk (2000) and Maguire and Sims (2002) have reported that when PSD is < 25% there is low potential for P leaching but if PSD exceed above 25% there is sharp increase in P leaching. Models Schoumans and Groenendijk (2000) have shown that in non-calcareous sandy Dutch soil P losses in subsurface water is higher because of higher PSD.

Generally, P is lost from soil by crop uptake & removal; runoff & erosion; and leaching (Mullins, 2009). By the process of erosion both soluble and deposited insoluble form for P is loosed with soil. By the process of runoff mainly dissolved P get away with water. Phosphorus loss by leaching is considered less important than surface runoff because P is held very tightly by soils mainly in P deficit subsoils (Mullins, 2009). But, in case of more build-up of soil P can increase the potential for P loss to surface waters via hydrological pathways such as over-land flow and subsurface drainage water which contribute to high P concentration in water

(Sharpley, 1995). In western Europe, P availability in agricultural soils is high due to application of huge amount of the livestock fertilizer (Sylvain and Thomas, 2013). In many soils P concentrations are now above the minimum value that is required for maximum yield (Sylvain and Thomas, 2013). Locally elevated concentrations of P in surface water, and the accumulated P are the long term source of P which cause environmental problem in this region (Chardon and Schoumans, 2007).

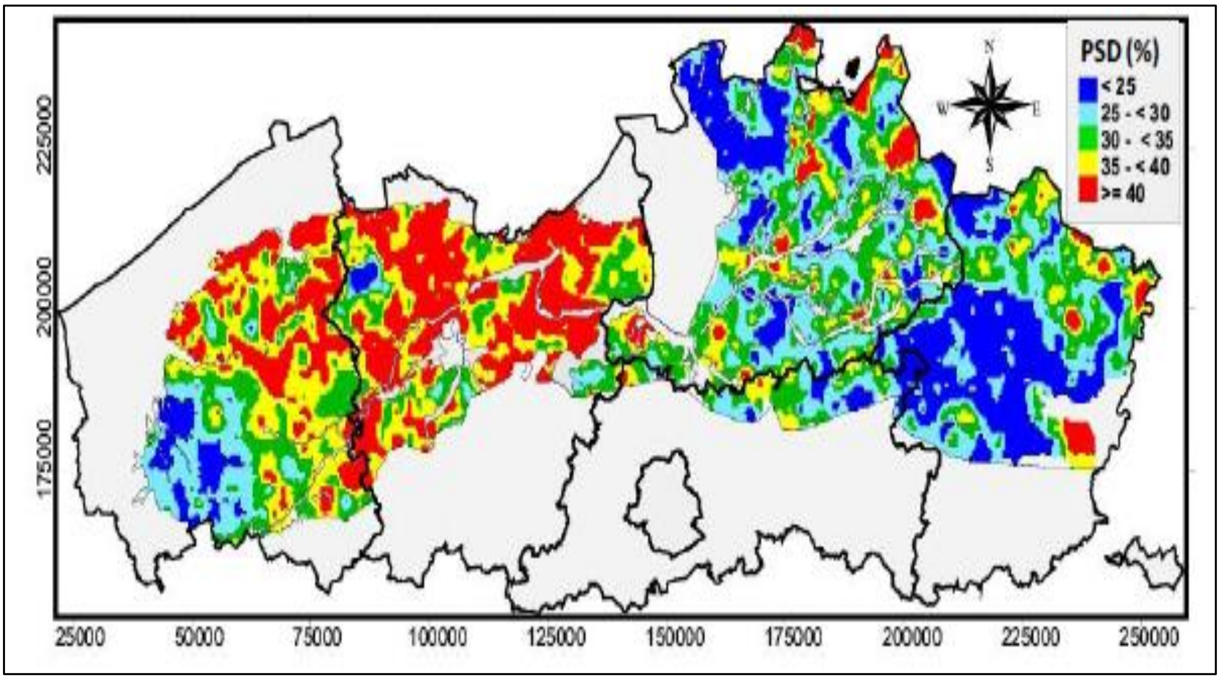


Figure 6 Classification of the PSD for soils in Flanders with a probability of 95%. Source: (Van Meirvenne et al., 2008)

Soils in Flanders are dominated by sandy texture. When sandy soil of this region are applied with more P fertilizer and it becomes more susceptible to P leaching (VLM, 1997). It can be seen in Figure 6 that large part of sandy areas for about 4404 km^2 used for agriculture is already P saturated with estimated PSD of more than 35 % (Van Meirvenne et al., 2008).

2.6 Rules and Regulations related to Phosphorus

Nitrate directive (91/676/EEC) and water framework directive (2000/60/ICE) of European Union has restricted the amount of P in surface water to its member nations (Amery and Schoumans, 2014). In Europe, Belgium and The Netherlands have the largest national P surpluses because of intensive animal production in past (Chardon and Schoumans, 2007). The absence of regulations to prevent the overuse of manure P surplus was very high in Flanders before 1995 because manure directive was started from 1996 (Chardon and Schoumans, 2007). Flanders started legislation based on fertilizer applications allowing to use only the recommended dose (Clercq et al., 2001). There is special regulation for P-saturated areas and they have more restriction on the use of P fertilizer (Amery and Schoumans, 2014). Similarly, farmers are also not allowed to put surplus P and N animal manure. So, the current application standards for Flanders (2014) vary between 65 and 95 kg P_2O_5 /ha/y. The limits depend on the type of crop. Indicative limits for the next Manure Decree (2015-2018) are mentioned (5−10 kg P_2O_5 /ha/y) lower than the standards of 2014 (Amery and Schoumans, 2014). The maximum phosphorus application standards for Flanders are approximately 5 kg P_2O_5 /ha/y smaller than the general phosphorus export by the crop, resulting in a small negative phosphorus input into the soil (Amery and Schoumans, 2014). And, this regulation is same if farmer cultivate one crop per season or multiple crops in a season. So, it is very important to manage P in Flanders. So, all this regulation measures in Flanders are mainly concerned on increasing P mining. Increase in P mining would help to make use of already accumulated P in the soil which can help to reduce P losses to the environment.

Stricter P legislation in Flanders has restricted the amount of P used by farmers. This might have led over time in low P intensity and high P quantity. But, the main aim of P fertilizer restriction is to ultimately result in P mining (De Bolle et al., 2013). But, with usual crop rotation it takes several decades as P mining efficiency decrease with time (Sharma et al., 2007). So, with time P quantity can't replenish P intensity fast enough. This in result, can cause a reduced P mining.

2.7 Need for soil amendments to increase plant available P

P fertilizers are derived from phosphate-rich rocks which are located in a few places on Earth and are finite (Schoumans et al., 2015). Sign of scarcity of phosphate rock was shown up since 2008 after significant rise in the price by more than 900% (Heckenmüller et al., 2014). In one-way P scarcity is increasing and in other way there is already deposited P in the soil of Flanders but it may become less for plants under mining scenario. Legislations measure in Flanders on restricted use of P fertilizer has risk of reducing P mining. Reduced P mining ultimately lead to reduced amount of plant available P in soil which might ultimately cause impact on crop yield and its quality. So, for efficient long term P mining soil amendments is useful in order not to limit crop P uptake (De Bolle et al., 2013).

2.7.1 Effect of Organic acid amendments

Jones (1998) has reported the binding capacities of oxalic and citric acids on Fe and Al sites are the most efficient agents to mobilize soil P. Formic, acetic, citric, oxalic and malic acids are simple organic acids produced by plants and exuded by plant roots and commonly found in the soils (Strobel, 2001). According to Khademi et al. (2010) root exuded organic acids and anions may be a significant P acquisition mechanism operating in soils. Study of Gardner and Boundy (1983) have reported citrate exuded by root of *Lupinus albus* L., have improved P acquisition by the plant by freeing up fixed P in soil.

According to Earl et al. (1979), organic acids caused dissolution of the soil components and thereby decreased P adsorption. Dissolution of soil components such as Fe and A1 oxides is caused by chelation of metal ions with organic acids, and the ability to chelate depends on the stability constant of the organic acids for metal ions. Bolan et al. (1994) reported that organic acids increase the availability of P in soils mainly through both decreased adsorption of P and increased solubilization of P compounds.

Plants can mobilize organic and inorganic forms of phosphorus (P) in soils by exudation of low-molecular-weight organic acids and anions (Gang et al., 2012). According to Gang et al. (2012), organic acids are believed to be involved in several chemical reactions like sorption/desorption, and precipitation/dissolution of the poorly soluble P in the soils. Gang et al. (2012) reported the effectiveness of organic acids to mobilize P occurred in the order of tricarboxylic (tricarboxylate) > dicarboxylic (dicarboxylate) > monocarboxylic acid (monocarboxylate). Wei et al. (2009) investigated the effects of four major organic acids (citric, oxalic, maleic, and formic acids) on the available P determination with soil extract with soil and amendment solution ratio of (1:10) and found that 2 mM oxalic acid and 3 mM citric acid extracted higher amounts of P from soil when compared to other concentration.

2.7.2 Effect of Silicate amendments

The higher P availability with silicates can be attributed to the sum of two effects: the alkalizing power of Si and competition for the same site between Si and P (Sandim et al., 2014). The reaction of phosphate ion adsorption to soil colloids is directly related to the reaction conditions of soil, since with a rise of pH the solubility of iron and aluminum phosphates is increased with reduction of phosphate anion adsorption to the soil solid phase (Sandim et al., 2014).

Silicate increase the soil P availability because the silicate anion occupies sites of phosphate anion adsorption and saturates sites where P could be adsorbed (Sandim et al., 2014). The higher availability of P in the soil and for the plant uptake is because anions of silicates exert competition with P for the same adsorption sites (Smyth and Sanchez, 1980). According to Carvalho et al. (2000), use of Ca silicate ($CaSiO_3$) and/or Mg silicate ($MgSiO_3$) increases competition for the same adsorption site between Si and P which reduces P fixation.

Roy et al. (1971), who studied Si application prior to phosphate fertilization found increased P availability but they reported this was more influenced by pH increase than by competition for the same adsorption site between Si and P. In an experiment carried out by Castro et al. (2013) in acidic soil in Congo, they use slag (silicate of calcium and magnesium) in a rate that can reach the base saturation of soil up to 70%. After six months they found that the Si slag considerably increased the P level in soil. Castro et al. (2013) reported adsorption sites for phosphate are saturated or blocked by the silicate anion, which can improve P fertilization efficiency. In another experiment done by Pulz et al. (2008), used the Ca and Mg silicate concentration that raise the base saturation up to 60% in medium textured oxisol and they found greater availability of P and Si in soil and greater absorption of Si and P by the plants. So, the effect of silicates in plant available P can be either by completion for the binding sites or can also be by simple pH effect.

2.7.3 Effects of elemental S and sulphates amendments in P availability

Elemental Sulphur (S) and sulphate amendments increase P availability by different mode of action. Sulphates have mainly an effect of competition of binding sites whereas elemental S has both an effect of pH and competition for binding sites. Hence, elemental S can make P available in soluble form in soil by two mechanisms. The effect produced by elementary S depends on the rate of its oxygenation in soil and its dose (Germida and Janzen, 1993). This was also proved by Skwierawska and Zawartka (2009) because they found concentration of available P in soil increased during third year of their experiment only in the field fertilized with elemental S.

There are different interpretations of influence of Sulphur on the availability of P in soil. According to Jaggi et al. (2005) the change in soil pH causes mineralization of P into inorganic forms as well as liberation of Al and Fe ions, which reacts with sulphates and bind only few phosphate ions. They also reported addition of elemental S improves the availability of P in cultivated soils, irrespective of the initial soil pH. Krol et al. (1986) and Jaggi et al. (2005) have reported that the content of available phosphorus increases in the soil under the influence of sulphur. According to Gądor and Motowicka-Terelak (1986), presence of free sulphur acid in soils creates favorable condition for the release of P from compounds and make them soluble. (Motowicka-Terelak and Terelak, 1998) demonstrated that sulphur, by binding aluminum sulphate, reduced phosphorus fixation in soil, while excessive amounts of sulphates may result in incomplete utilization of phosphorus supplied with fertilizers, as they inhibit the growth of crops.

In an experiment conducted by (Skwierawska and Zawartka, 2009) in acid brown, heavy loamy sand soil with pH (KCl)= 5.30, in Poland; they applied 40, 80 and 120 $kgha^{-1}$ in the sulphate form and as elemental Sulphur. During their experiment they found that application of 120 $kg \cdot ha^{-1}$ of $S\text{-}SO_4$ caused significant increase in the content of available phosphorus in soil in the layers at 0-40 and 40-80 cm depth. They also reported the effect of sulphur on mobilization of phosphorus depends on the form of sulphur and duration of experiment.

2.7.4 Effect of Phosphate Solubilizing Bacteria (PSBs)

In addition to fertilization and enzymatic decomposition of organic compounds, microbial P-mobilization is another possible way to increase plant-available P (Illmer and Schinner, 1995). A number of microorganisms, including bacteria, have the capability of solubilizing mineral phosphates, there by affecting P cycle both in natural and agricultural ecosystems (Vazquez et al., 2000). Authors like (Parks et al., 1990); Yadav and Singh (1991) have attributed P-solubilization by PSB is caused due to the release of organic acids. Principal mechanism for mineral phosphate solubilization involves production of organic acids, and acid phosphatases in mineralization of organic phosphorous in soil (De Bolle et al., 2013). Illmer and Schinner

(1995) have found that the probable reason for solubilization is by the release of protons during respiration or NH^{4+} assimilation.

PSB in soil varies from 0.5 to 50% of total respective population (Vazquez et al., 2000). Among PSBs, *Pseudomans*, *Bacillus*, and *Rhizobium* species are dominating in soil environment (De Bolle et al., 2013). Trivedi and Sa (2008) reported *Pseudomonas* species solubilize P under a range of temperature condition. *Pseudomonas putida* is the most intensively studied species of genus Pseudomonas (Manna et al., 2001).

Phosphate solubilizing bacteria (PSB) transform unavailable P into plant available forms, and could thus proof to be very useful even in P saturated soils under severe fertilization restrictions, namely to increase the P mining efficiency (De Bolle et al., 2013). *Pseudomonas putida* and *Bacillus brevis* perform best as PSB in high P conditions where the P is fixed with Al or Fe, which is the case for the acid sandy soils in Flanders (De Bolle et al., 2013). Strains from genera *Pseudomonas*, *Bacillus*, *Rhizobium*, *Aspergillus* and *Cephalosporium* are among the phosphate solubilizers.

Table 1 Summary of P solubilizing amendments

Amendments	Mechanisms	Source
Organic Acids (lactic acid, oxalic acid, citric acid)	accelerate mineralization of stable P pools; chelation of metal ions with organic acids; change in pH	Gang et al. (2012) Khademi et al. (2010) Wei et al. (2009) Earl et al. (1979)
Silicates (Na_2SiO_3)	completion binding sites; acid correction	Sandim et al. (2014) Castro and Crusciol (2013) Pulz et al. (2008) Smyth and Sanchez (1980)
Sulphates/S	effect of competition of binding sites (SO_4^{2-}); effect of pH and competition for binding sites (S)	Skwierawska and Zawartka (2009) Jaggi et al. (2005) Lamers et al. (1998) Koerselman et al. (1993)
PSBs (*Pseudomonas*, *Bacillus*, *Rhizobium*, *Aspergillus*)	production of organic acids and acid phosphatases enzyme which mineralizes organic P in soil.	Igual et al. (2001) Yadav and Singh (1991) Parks et al. (1990) De Bolle et al. (2013)

Chapter 3 Material and Methods

3.1 Study Area and Soil Sampling

Study area is Flanders, Belgium. Soil sampling was done in two sites; experimental plot E13.0130 with geographical coordinate of 50° 56' 38.14" north and 3° 31' 13.98" east and Van Oeckel with geographical coordinate 51° 17' 2.19" north and 4° 57' 52.13" east. These both sites are acidic sandy soils known for their rather high P quantity and moderate to low P intensity. The plough layer (0-30 cm) was sampled randomly by following a cross pattern over the field. Sampled soils were air dried and sieved with 2 mm mesh sized sieve.

3.2 Physical and Chemical Characterization of the Soils

3.2.1 Texture

Soil texture was determined using the pipette method (Gee and Dani, 2002). 20 g of sieved air-dried soil sample was put into a 2 L beaker. Dispersion of the clay fraction was done by removing the cementing materials like $CaCO_3$ and organic matter. The fine fractions (silt and clay) were separated from the sand fraction by wet sieving on a 50 micrometer sieve. The clay (<2μm) and silt fraction (2-50 μm) were separated by pipetting with a Robinson-Köhn pipette after sedimentation at a constant temperature and fixed settling, according to Stokes' law. All fractions were weighed after drying at 105 °C, and the results were expressed as a percentage. Based on these percentages and the texture triangle, the texture of each of the soils was determined.

3.2.2 Organic carbon

The organic carbon content was determined using the method of Walkley and Black (1934). 1 g of air-dried soil was taken and put into an Erlenmeyer flask (500 ml). Next 10 ml $K_2Cr_2O_7$ (1 N) and 20 ml concentrated H_2SO_4 were added and shaken smoothly under a fume hood. Then, the solution was left for 30 minutes. After 30 minutes 150 ml H_2O was added. Before the titration 10 ml conc. H_3PO_4 followed by four drops of ferroine indicator were added. The solution was titrated with 1 N $FeSO_4$ till the color changed from green to reddish brown. By knowing the amount of oxidizing agent to oxidize the organic carbon, soil carbon was determined.

3.2.3 $CaCO_3$ content

$CaCO_3$ present was measured by titration using the method of Gee and Dani (2002). 1 g of soil was put into a 250 ml Erlenmeyer. After adding 25 ml H_2SO_4 (0.5 N) the solution was diluted with distilled water to a volume of 150 ml and placed on a hot plate at 80 °C for 1 hour. After cooling, 0.5 ml of an indicator was added. The solution was titrated with 0.5 N NaOH until the color changes from red to green. Based on the quantity of H_2SO_4 consumed, the amount of $CaCO_3$ present was calculated.

3.2.4 pH-KCl

The soil pH was measured potentiometrically in 1:2.5 ratio (soil: KCl extract). Soil samples were stirred thoroughly with a glass rod. Then the suspended samples were kept at room temperature for 10 minutes. Samples were stirred again with a glass rod before measuring with a pre-calibrated pH meter (Thermo Orion Model 420+).

3.3 P-status of soils

3.3.1 P intensity

P intensity is the P that is directly plant available. This can be determined by extraction with P-$CaCl_2$.

P-$CaCl_2$ was determined by shaking 5g of air dried and sieved soil for 2 hours in 50ml of 0.01M $CaCl_2$ solution. Afterwards the P concentration in the extract was determined using the method of Murphy and Riley (1962).

3.3.2 P quantity (P-AL)

P-quantity is a measure of P of the current P stock which can replenish soluble P when taken up by the plants. This quantity is determined by P-AL of the soil.

P quantity was determined based on the method of Egnér et al., (1960). 5g of air dried and sieved soil was shaken for 4 hours in a 100 ml ammonium lactate solution. After having filtered the samples over 589/3 whatman filter P content of the extract was determined using ICP-OES (ICAP 6000 series; Thermo Scientific).

3.3.3 Phosphorus saturation degree

The Phosphate saturation degree (PSD) is a function of the portion of the soil exchangeable sites that are bound with P (P sorbed) in relation to the number of sites available for P binding capacity (PBC) (Hooda et al., 2000). PSD is a good indicator of the soil's potential to release P in soluble form and which can get loosed to water sources.

$PSD = [P_{OX}/(Fe_{OX} + Al_{OX}) \text{ x } 0.5]) \text{ X } 100$

$PBC = (Fe_{OX} + Al_{OX}) \text{ X } 0.5$

PBC is expressed in mmol/kg.

P, Fe and Al oxalate determination (P_{OX}) was done by following the method of Egnér et al., (1960). 5 g air-dried and sieved soil was shaken in 100 ml ammonium oxalate solution for 2 hours. After shaking and filtering P, Fe and Al content of the samples was determined using ICP-OES).

3.4 Shaking experiment

Shaking experiment was done to identify the most promising amendment and their concentration to increase the P-intensity of soil. During this experiment, 4 grams of each soil type (E13.0130 and Van Oeckel) with 40 ml of a solution of Citric Acid, Lactic Acid, Oxalic Acid, Sodium Silicate and Sodium Sulphate at a concentration of 0.5 mM, 1 mM and 2 mM were shaken for 24 hours at 100 RPM in a shaker. After shaking, samples were filtered using 589/3 ashless Whatman filter paper and the filtrate was collected in a 100 ml dark polyethylene bottle. Finally, the P content and the pH of the extract were determined.

3.4.1 Amount of P in extract

P content in the extract of the solution from shaking experiment was determined colorimetric by the method of Murphy and Riley (1962).

3.4.2 pH of extract

In a 50 ml beaker, 10 ml of the extract from shaking experiment was put and pH was measured with a pre-calibrated pH meter (Thermo Orion Model 420+).

3.5 Incubation Experiment

Incubation experiment was done to see the effect of amendment on P-intensity under more realistic conditions and to verify the result of shaking experiment. On the basis of the results from the shaking experiment, the most promising combinations of additive and concentration were selected. Soil sample from sites E13.0130 and van Oeckel amended with four different amendments; citric acid (10 mmol/kg dry soil), sodium silicate (10 mmol/kg dry soil), elemental sulphur (20 mmol/kg dry soil), and PSB (*Pseudomonas putida*) (126 x 10^{11} CFU/kg dry soil) and incubated for 3, 6, 12, 24 and 48 days. Concentration of citric acid, sodium silicate and elemental Sulphur are analogous to 1mM citric acid, 1 mM sodium silicate and 2 mM sulphur in the shaking experiment and concentration of PSB is chosen according to De Bolle et al. (2013). Incubation was done at 18 °C at 50% water-filled pore space (WFPS) and density 1.4 kg/dm^3. After each incubation period, P-$CaCl_2$ and pH-H_2O were determined.

3.5.1 P-$CaCl_2$

P-$CaCl_2$ was determined by shaking incubated soil with 0.01 M $CaCl_2$ solution in the ratio 1:10. Afterwards the P concentration of the samples was determined using the method of Murphy and Riley (1962).

3.5.2 pH-H_2O

In a 100 ml beaker, 50 ml of distilled water was added to the beaker making soil: water ratio (1:5) and stirred with a glass rod. The soil suspension was left for 18 hours, and again the sample was stirred before measuring the pH. Then, the pH was measured with a pre-calibrated pH meter (Thermo Orion Model 420+).

3.6 Greenhouse experiment

Greenhouse experiment was conducted to check the effect of amendments on P intensity, P mining and crop yield. Soils from the site E13.130 and Van Oeckel were supplemented with citric acid (10 mmol/kg dry soil), sodium silicate (10 mmol/kg dry soil), elemental sulphur (20 mmol/kg dry soil), and PSB (*Pseudomonas putida*) (126 x 10^{11} CFU/kg dry soil) and filled in a grey plastic pots at 50% water-filled pore space (WFPS) and density 1.4 kg/dm^3. For control soil was treated with normal tap water. Concentration of amendments and soil samples were same as in incubation experiment. 0.25 g tetraplod Italian ryegrass was sown in each pot. Day temperature and night temperature in the greenhouse were maintained at 20 and 10°C respectively. Normal tap water was applied as an irrigation source. Harvesting was done 20, 40 and 60 days after germination. At each harvesting period P-$CaCl_2$ of the soils in each pot, dry matter yield (aboveground and below-ground) and P-uptake by grass in each pot was determined.

3.6.1 P-$CaCl_2$

P-$CaCl_2$ content of soils in each pot was determined by shaking an equivalent amount of 5 g dry soil in 50 ml 0.01M $CaCl_2$ for two hours in the mechanical shaker at the speed of 100 RPM. The P content of the extract was determined colorimetric (method of Murphy & Riley, 1962)

3.6.2 pH-H_2O

In a 100 ml beaker, 50 ml of distilled water was added to the beaker making soil: water ratio (1:5) and stirred with a glass rod. The soil suspension was left for 18 hours, and again the sample was stirred before measuring the pH. Then, the pH was measured with a pre-calibrated pH meter (Thermo Orion Model 420+).

3.6.3 Determination of dry matter yield

After 20, 40 and 60-day grass was harvested. Above ground and below ground biomass were collected by flushing all soil from each pot on a sieve with a 1 mm mesh size. collected biomass was dried at 50 °C for 24 hours in a hot air oven and the above ground, below ground and the total biomass weight were determined.

3.6.4 P content of biomass

The biomass was grinded in a mill. Replicates were bulked to have a large enough sample. One gram of each grinded sample was transferred to a crucible. Crucibles were placed in the muffle furnace for 4 hours 30 min at 580 °C temperature. After cooling the ashes were transferred to beakers with 20-30 ml 1 N HNO_3 and heated on a hot plate for 1 hour. After one-hour digestion, the digested samples were filtered with 589/3 filter paper and collected in a 100 ml conical flask. 1 N HNO_3 was added up to 100 ml. Then the P content was measured with ICP-OES

(ICAP 6000 series; Thermo Scientific). After measuring total P content in the dry matter P uptake by grass was also calculated by following formula:

Total P uptake (mg P) = P content (mg/g dry matter) x dry matter yield (g)

3.7 Statistical Analysis

For all statistical analysis the computer package SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp) was used. In shaking experiment Analysis of variance (ANOVA) was carried out in order to see the interaction between the soil, amendments and concentration. From ANOVA effect of concentrations on P extraction was seen. Tukey HSD post-hoc analysis was done to see the difference of mean with different concentration for different amendment. Similarly, in order to check effect of pH on P-extraction Pearson's correlation test was done.

For incubation experiment ANOVA was carried out in order to see the interaction between the soil, amendments and days of incubation. From ANOVA effect of amendments on P-$CaCl_2$ extraction was seen. Tukey HSD post hock analysis was done to see the difference of mean with different amendments on period of incubation. Similarly, in order to check effect of pH on P-$CaCl_2$ extraction Pearson's correlation test was done.

For greenhouse experiment ANOVA was carried out in order to see the interaction between the soil, amendments and harvesting days on P-$CaCl_2$ extraction from harvested pots. Similarly, ANOVA also done for the analysis effect of amendments on biomass weight and P-uptake form soil. Tukey HSD post hock analysis was done to see the difference of mean with different amendments on P-$CaCl_2$ extracted from the harvested pots, biomass weight of grass and P-uptake. Pearson's correlation calculation was done to check to see if there is pH effect on P-$CaCl_2$ extraction.

Levene's test was used to evaluate the assumption of homogeneity of variances for all the data and the differences were considered statistically significant when $P<0.05$.

Chapter 4 Results

4.1 General soil properties

In Table 2 the general characteristics of soils from E13.0130 and Van Oeckel are given. As soil E13.0130 consists of 87 % Sand, 7 % silt and 3 % clay; it can be classified as a sandy soil (according to the USDA classification). Soil coming from Van Oeckel consists of 87% of sand, 10.1% of silt and 2.9% of clay can also be classified as sandy soil. Further, both soils are acidic (pH-KCl = 5.26 and 5.30), which is typical for the Flemish region. Organic carbon content is 1.91% and 2.19% for the site E13.0130 and Van Oeckel respectively. Soils from both sites had almost no free $CaCO_3$.

Table 2 General properties of the soils

Sites	USDA text. class	% Clay (0-2µm)	% Silt (2-50µm)	% Sand (50-200µm)	pH (KCl)	% Org C	% $CaCO_3$
E13.0130	Sand	3	7	87	5.26	1.91	0.00
Van Oeckel	Sand	2.9	10.1	87	5.30	2.19	0.00

P status of the soils used in the study

P-intensity of site E13.0130 was 1.07 mg P/kg dry soil (Table 3) which is moderate and Van Oeckel was 0.51 mg/kg dry soil which is a rather low value. P-AL of the site E13.130 was 19.61 mg P/100 g whereas for the site Van Oeckel it was 21.25 mg P/100 dry soil which are both moderate to high values. PSD is an environmental indicator to estimate the potential of P leaching. PSD in both sites was higher than 40% but this value was measured for the upper 30 cm only while normally this is measured for the zone 0-90 cm.

Table 3 P status of the sampled soil

Sites	P-$CaCl_2$ (mg P/kg dry soil)	P-AL (mg P/kg dry soil)	Feox (mmol/kg dry soil)	Alox (mmol/kg dry soil)	PBC (mmol/kg dry soil)	Pox (mmol/kg dry soil)	PSD (%)
E13.0130	1.07	196.1	11.70	23.35	17.52	7.07	40.33
Van Oeckel	0.51	212.5	7.17	37.49	22.33	10.31	45.89

4.2 Shaking experiment

4.2.1 Amount of P-extracted

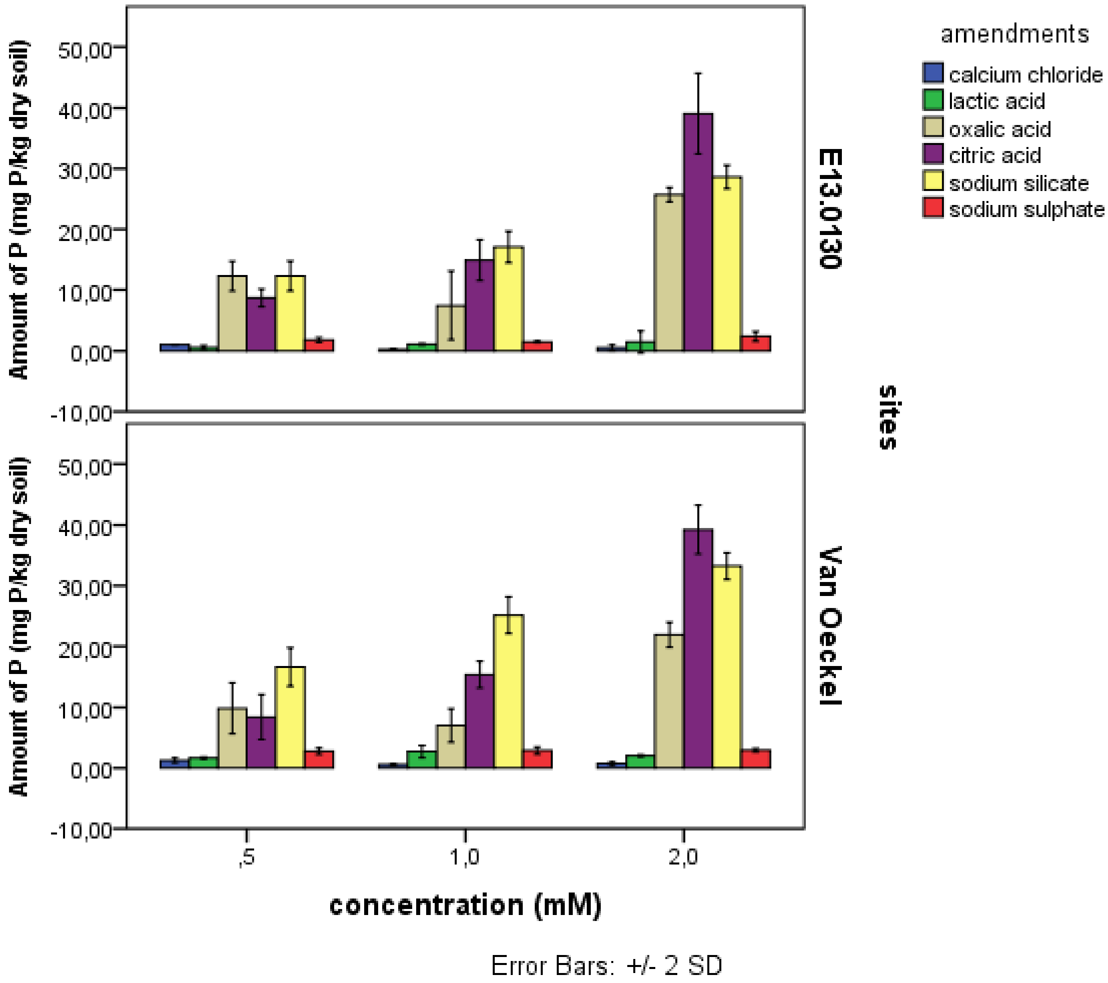


Figure 7 Amount of P extracted from soil after shaking with amendments (citric acid lactic acid, oxalic acid, sodium silicate and sodium sulphate) at concentrations (0.5, 1 & 2 mM), Calcium chloride (0.01 M) is control.

General trend on amounts of P extracted from soils after shaking experiment showed all the amendments had released more P in comparison to control i.e. 0.01 M $CaCl_2$ (Figure 7). For all three concentrations in both sites, oxalic acid, citric acid and sodium silicate had produced higher amount of P while sodium sulphate and lactic acid could extract least. At site E13.0130 citric acid extracted highest amount of P which ranges 8.71 to 38.62 mg/kg dry soil. Similarly, at site Van Oeckel also citric acid extracted highest amount of P ranging from 8.40 to 39.25

mg/kg dry soil whereas, sodium silicate had released P ranging from 16.59 to 33.23 mg/kg dry soil.

There was effect of concentration on amount of P extraction. There was increasing trend of concentration on amount of P-extraction for all amendments. But, the effect of concentration was more strong for oxalic acid, citric acid and sodium silicate whereas least effect was observed for lactic acid and sodium sulphate. In both sites for 0.5 mM and 1 mM concentrations, sodium silicate had extracted highest amount of P whereas for 2 mM concentration citric acid had extracted most. 2 mM citric acid had extracted highest amount of P for both sites which was 39.05 mg/kg dry soil for E13.0130 and 39.25 mg/kg dry soil for site Van Oeckel.

Three-way ANOVA was done to check the effect of the factors concentration, amendment and site. The three-way interaction was not significant ($p = 0.619$) and could be removed. Then, the two way interactions between soil and amendment; amendment and concentration; and soil and concentration were checked. All the two-way interactions between sites, amendments and concentration were found to be statistically significant. Therefore, data were splitted according to sites, and the interaction of amendments and concentration was tested. Statistically significant interaction ($p = 0.000$) between amendments and concentration for site E13.0130, were found. Therefore, all data were splitted according to amendment and concentration for each sites.

The ANOVA analysis of P (mg/kg dry soil) and concentration showed for E13.0130, lactic acid did not have significant effect. Similarly, for site van Oeckel concentration of Na_2SO_4 had no significant effect. Except these two there was significant interaction between P (mg/kg dry soil) and concentrations for all amendments for both sites.

Tukey HSD analysis of amount of P extracted by each amendment at 0.5, 1 and 2 mM concentrations at site E13.0130 showed oxalic acid, citric acid, sodium silicate had effect of concentration on amount of P extraction. For oxalic acid, citric acid and sodium silicate; increase in concentration had increased amount of P extracted. For Na_2SO_4 effect of concentration was seen only for 1 mM and 2 mM. For citric acid, 2 mM could produce 30.34 mg/kg dry soil higher than its concentration at 0.5 mM.

In site Van Oeckel, for all amendments there was positive mean differences of P extraction with increasing concentration. But oxalic acid at 1 mM concentration produced 2.80 mg less P than at 0.5 mM concentration. For sodium silicate mean difference of P for concentration 0.5 mM and 1 mM was 16.64 mg/kg dry soil.

The ANOVA analysis of amendments and amount of P (mg/kg dry soil) for both sites showed there was significant effect of amendments on P (mg/kg dry soil) extraction on both sites. Multiple mean comparisons of different amendments (0.5, 1 and 2 mM) and amount of extracted P (mg/kg dry soil) at site E13.0130 showed all amendments for all three concentration had positive mean difference with control (0.01 M $CaCl_2$) and sodium silicate and citric acid had highest significant mean difference. Lactic acid and sodium sulphate had positive mean difference with control but were not significant. For concentration 0.5 mM and 1 mM sodium silicate produced higher amount of P in comparison to other amendments. But, for 2 mM citric acid exceeded all other amendments and produced highest amount of P. 0.5 mM and 1 mM sodium silicate had produced 11.24 mg, and 16.81 mg more P than control. Similarly, 2 mM citric acid had produced 38.09 mg more P than control. Lactic acid and sodium sulphate could extract only 1.47 mg and 1.89 mg respectively higher than control at 2 mM concertation.

Multiple mean comparisons of different amendments (0.5, 1 and 2 mM) and amount of extracted P (mg/kg dry soil) at Van Oeckel showed all amendments for all three concentration had positive mean difference with control (0.01 M $CaCl_2$). Sodium silicate and citric acid had highest significant mean difference. 0.5 mM and 1 mM sodium silicate had produced 15.32 mg, and 23.08 mg more P than control. Similarly, 2 mM citric acid had produced 38.50 mg more P than control.

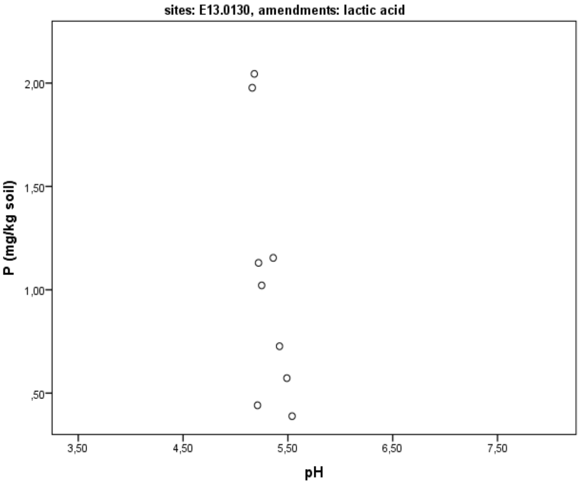
4.2.2 Effect of pH on amount of P extracted

pH-$CaCl_2$ of both soils showed both soils were really acidic. Effect of pH on amount of P extracted was checked to know whether the increase in P extracted was related to pH or also other modes of action are taking place (e.g. competition for binding sites). At both sites, sodium sulphate was more acidifying while carboxylic acids (lactic acid, oxalic acid and citric acid) had less acidifying effect (Table 4). Similarly, sodium silicate had slightly alkalizing effect. Increase in concentration had increased pH for extracts from sodium silicate and decreased for other amendments. For citric acid in both sites, increase in concentration from 1 mM to 2 mM had sharply decreased its pH.

Table 4 Mean pH of extract solution with citric acid, lactic acid, oxalic acid, sodium silicate and sodium sulphate at concentrations of 0.5, 1 and 2 mM. Here 0.01 M CaCl2 has been used as control.

			mean pH of extract					
			lactic acid	oxalic acid	citric acid	sodium silicate	sodium sulphate	control (0.01M $CaCl_2$)
concentration	,5	E13.0130	5.56	6,04	5,38	7,28	4,80	4.83
	1,0		5.35	6,48	6,79	7,37	4,75	4.98
	2,0		5.24	4,67	3,88	7,50	4,62	4.52
concentration	,5	van Oeckel	5.58	6,08	5,63	7,19	4,78	4.36
	1,0		5.65	6,75	6,69	7,37	4,69	4.98
	2,0		5.17	5,26	4,73	7,40	4,61	4.54

Pearson's correlation between amount of extracted P (mg P/kg dry soil) and the pH showed, for organic acids P extracted increases with decrease in pH. Similarly, for sodium silicate increasing pH caused increase in P content. But, for sodium sulphate change in P-extract could not be attributed to pH effect. Among the organic acid, lactic acid had strong negative correlation (r = -0.96) with pH but the pH range was rather small as seen in the scatter plot (Figure 8). Sodium silicate showed positive correlation (r = 0.72). Similarly, in Van Oeckel, among organic acids, oxalic acid (r = -0.83) and citric acid (r = -0.69) had significant negative correlation. There was no significant correlation for lactic acid (r = 0.25) but the range of pH change was narrow as seen in the scatter plot. Sodium silicate showed significant positive correlation (r = 0.74). In both sites, sodium sulphate didn't have correlation between the amount of P extracted and pH but the pH changes was not that big. This mean for sodium sulphate there was no pH effect but competition for sorption sites.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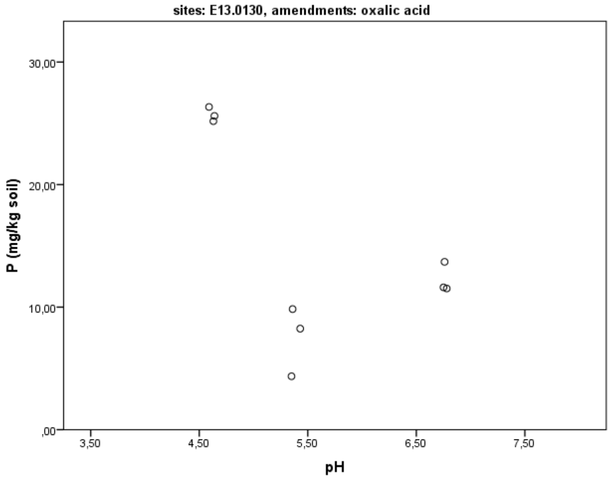
3,50
4,50
5,50
6,50
7,50
pH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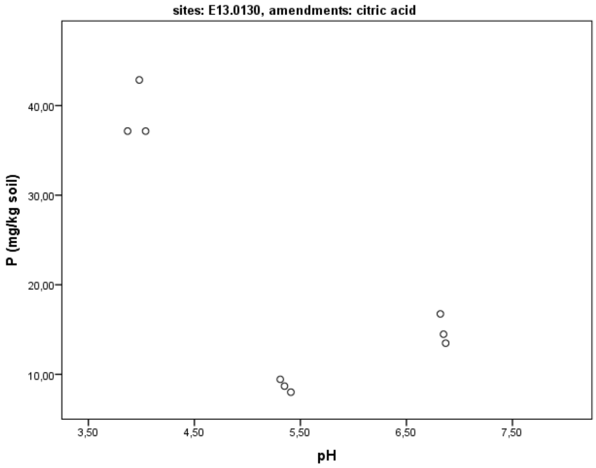
6,50
7,50
pH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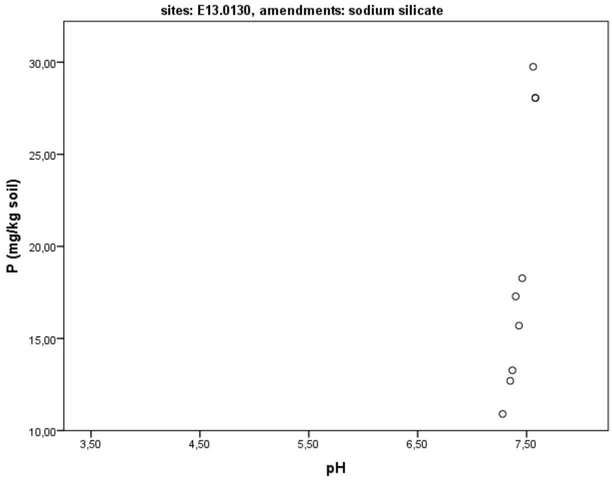
6,50
7,50
pH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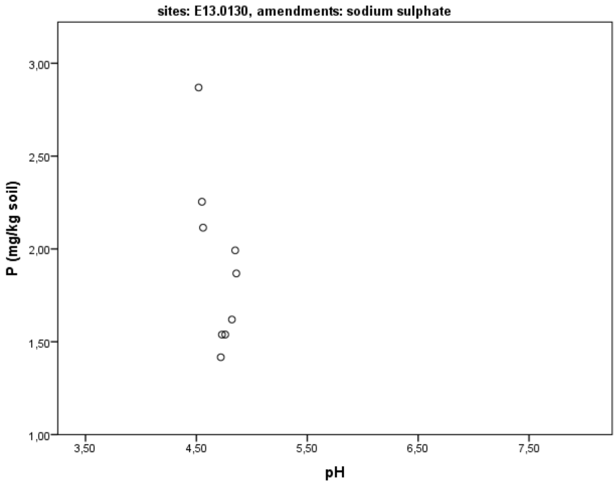
6,50
7,50
pH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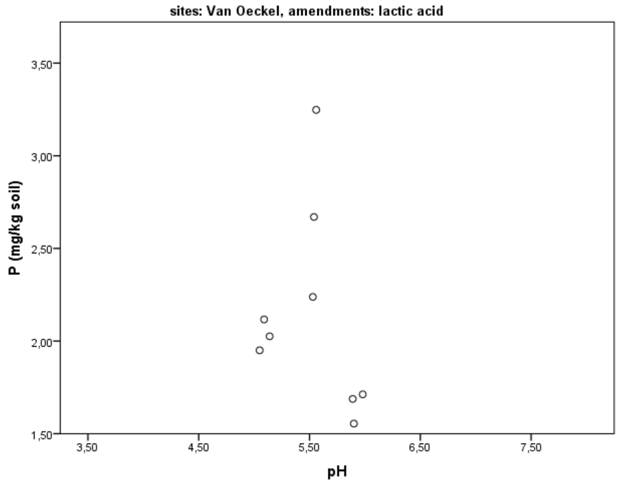
6,50
7,50
pH


sites: Van Oeckel, amendments: lactic acid
P (mg/kg soil)
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6,50
7,50
pH

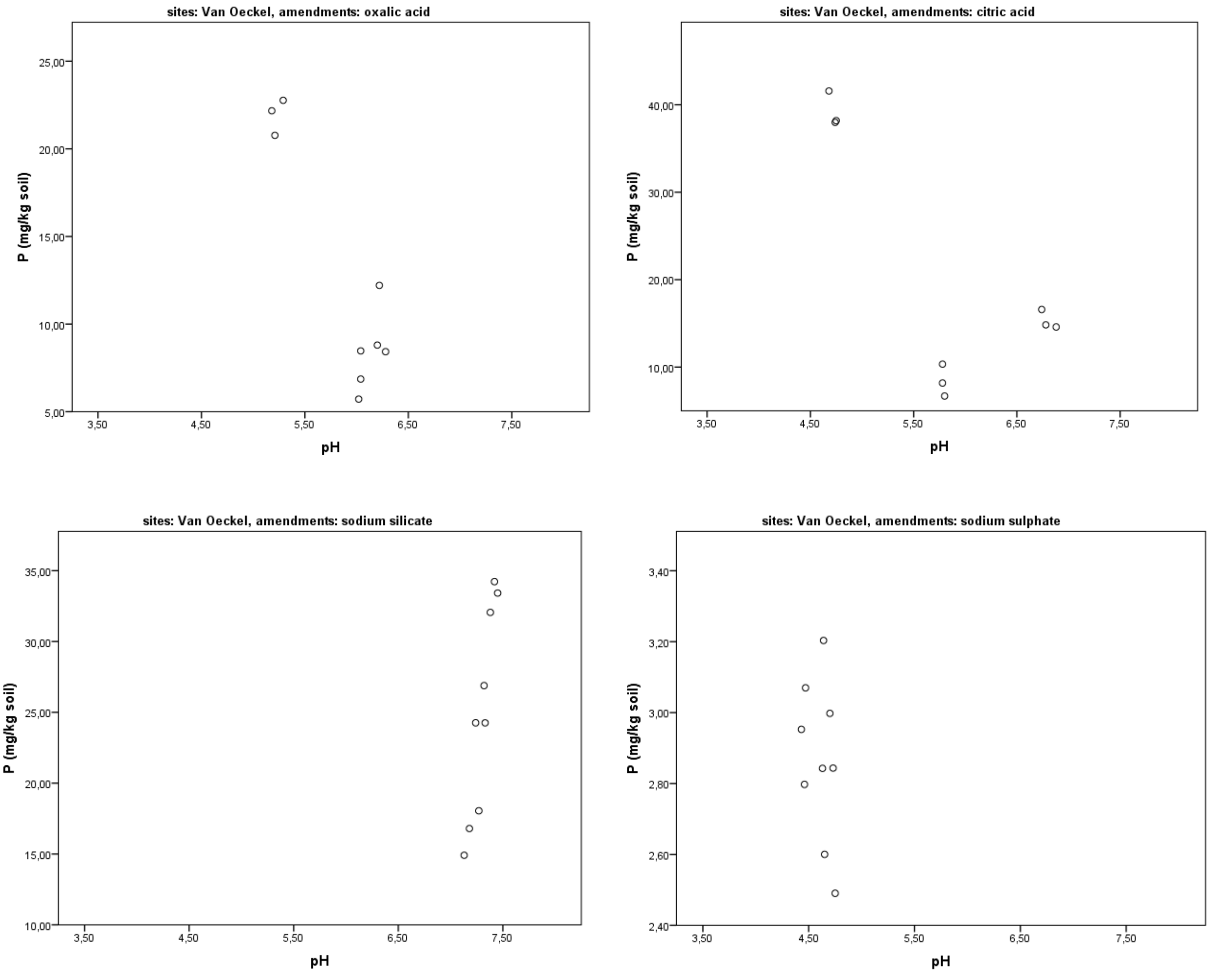


Figure 8 Scatter plot showing the relationship between pH and amount of P (mg/kg dry soil) extracted in sites E13.130 and Van Oeckel

4.3 Incubation experiment

4.3.1 P-$CaCl_2$ extraction

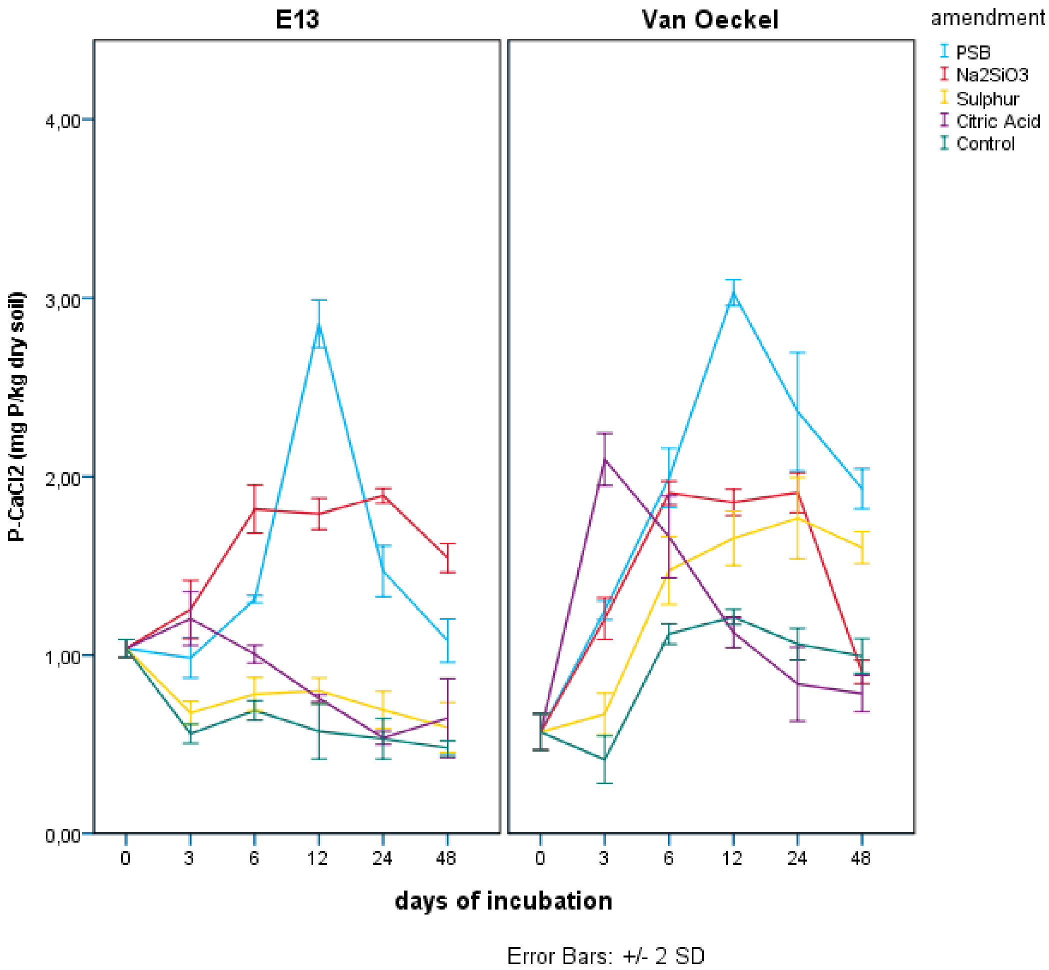


Figure 9 Evolution of P intensity (P-$CaCl_2$) in soil incubated with citric acid (10 mmol/kg dry soil), sodium silicate (10 mmol/kg dry soil), elemental sulphur (20 mmol/kg dry soil), and PSB (126 x 10^{11} CFU/kg dry soil) compared to control (incubated with demineralized water) for 3, 6, 12, 24 and 48 days.

General trend of P-$CaCl_2$ of soils incubated with amendments after 3, 6, 12, 24 and 48 days showed, P-$CaCl_2$ had increased initially and then decreased with time of incubation (Figure 9). P-$CaCl_2$ measured was higher for PSB and sodium silicate for all incubation time. P-$CaCl_2$ for PSB showed very high peak on day 12 for both sites and dropped down suddenly on 24 days. Citric acid had increased P-$CaCl_2$ during early days of incubation and then decreased. For both sites, sodium silicate had released higher amount of P-$CaCl_2$ for long duration of incubation.

Elemental sulphur had worked slowly in comparison to other amendments. Similarly, all the amendments had released more P-$CaCl_2$ than control in both sites.

At site E13.0130 the effects of citric acid, and elemental sulphur were rather small, while Na_2SiO_3 and PSB gave a rather high increase in P-$CaCl_2$. PSB had released highest amount of P-$CaCl_2$ ranging from 0.98 mg/kg dry soil to 2.91 mg/kg dry soil. Na_2SiO_3 produced higher P-$CaCl_2$ (241.91 mg/kg dry soil) on day 12. P-$CaCl_2$ extraction for the treatment elemental S varied from 0.59 to 0.68 mg/kg dry soil which was least among all other amendments.

At site van Oeckel also effects of citric acid, and elemental sulphur were quite small, while Na_2SiO_3 and PSB gave a rather high increase in P-$CaCl_2$. PSB had released highest amount of P-$CaCl_2$ ranging from 1.25 mg/kg dry soil to 3.03 mg/kg dry soil. Like on site E13.0130, PSB had peaked P-$CaCl_2$ by 3.06 mg/kg dry soil. After 24 days of incubation P-$CaCl_2$ extraction started to decrease for all amendments.

Three-way ANOVA showed statistically significant interaction ($p = 0.000$) between the factors site, amendment and days of incubation on P intensity. Therefore, data were splitted according to sites, and the interaction of amendments and days of incubation was tested. Statistically significant interaction between amendments and days of incubation for both sites with, ($p = 0.000$) for site E13.0130 and van Oeckel with, ($p = 0.000$) were found. Therefore, all data were splitted according to days of incubation for both sites. The ANOVA analysis of P (mg/kg dry soil) and amendments on days of incubation for each sites showed that there was statistically significant effect of amendments on P-$CaCl_2$ obtained.

For E13.0130, Na_2SiO_3 had significant highest mean difference on P-$CaCl_2$ extraction in comparison with other amendments during all period of incubation but on day 12 PSB exceeded Na_2SiO_3 by 1.06 mg P/kg dry soil. After Na_2SiO_3, PSB had higher significant mean difference with amendments ranging from 0.30 mg to 2.09 mg P/kg dry soil.

For the van Oeckel site PSB had significant highest mean difference on P-$CaCl_2$ ranging from 0.05 mg to 1.90 mg/kg dry soil in comparison with other amendments during all period of incubation except on day 3 when citric acid exceeds higher than 0.84 mg P/kg dry soil. Like on site E13.0130 all the amendments had produced more P-$CaCl_2$ in comparison to control.

4.3.2 Effect of pH on P-$CaCl_2$ extracted

Effect of pH on amount of P $CaCl_2$ was checked to know whether the change in P-$CaCl_2$ was an effect of pH or other modes of action are taking place. For E13.030 pH-H_2O when incubated with citric acid was almost similar to control while for Na_2SiO_3 was slightly alkaline which ranges from 7.04 to 7.16. For citric acid and Na_2SiO_3 pH was not changing and was almost similar for all time periods while for PSB and sulphur it was changing. Among four amendments elemental sulphur had more acidifying effect but it was seen after 12 days of incubation.

Table 5 pH-H_2O of soil incubated with amendments for 3, 6, 12, 24 and 48 days for site E13.0130

				Citric Acid	Control	Na_2SiO_3	PSB	Sulphur
days of incubation	3	pH	Mean	6,16	6,58	7,16	7,24	6,39
	6	pH	Mean	6,36	6,59	7,11	7,12	6,10
	12	pH	Mean	6,41	6,56	7,04	6,04	5,46
	24	pH	Mean	6,73	6,51	7,14	5,63	4,67
	48	pH	Mean	6,78	6,47	7,05	5,70	4,62

Like for soil from E13.0130, pH-H_2O for soil incubated with citric acid was almost similar to control in van Oeckel also. Similarly, for treatment Na_2SiO_3 pH ranges from 7.05 to 6.86. For PSB pH was decreasing from 7.17 at day 3 to pH = 5.68 on day 48. In this site also sulphur starts to show its more acidifying effect from day 12.

Table 6 pH-H_2O of soil incubated with amendments for 3, 6, 12, 24 and 48 days for site van Oeckel

				Citric Acid	Control	Na_2SiO_3	PSB	Sulphur
days of incubation	3	pH	Mean	6,04	6,81	7,05	7,17	6,48
	6	pH	Mean	6,16	6,58	7,02	6,97	6,20
	12	pH	Mean	6,28	6,40	6,82	5,83	5,34
	24	pH	Mean	6,67	6,48	6,95	5,66	4,84
	48	pH	Mean	6,71	6,59	6,86	5,68	4,69

The correlation coefficient showed there was significant positive correlation for sodium silicate and significant negative correlation for citric acid (Table 7).

At site E13.130, there was significant positive correlation between P and pH for Na_2SiO_3 (r = 0.72). Whereas citric acid had negative correlation (r = -0.58) with pH which means P-$CaCl_2$ increase with decrease in pH. There was strong negative correlation for control but from the scatter plot (Figure 10) very small pH range (6.40 to 6.81) was seen.

At site van Oeckel also there was significant positive correlation between P-$CaCl_2$ extracted and pH for Na_2SiO_3 (r = 0.72). Whereas citric acid had strong negative correlation (r = -0.94) with pH which means P-$CaCl_2$ increase with decrease in pH. There was no statically significant correlation between P-$CaCl_2$ and pH-H_2O for PSB and sulphur.

Table 7 Correlation analysis of extracted P-$CaCl_2$ (mg/kg dry soil) after incubation with the pH of the extracted solution at different sites

sites	Amendments				
	PSB	Na_2SiO_3	Elemental S	Citric acid	control
E13.0130	-0.03	0.72**	-0.08	-0.58*	-0.90**
Van Oeckel	0.10	0.69**	-0.36	-0.94**	0.31

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

4.4 Greenhouse experiment

4.4.1 P-$CaCl_2$

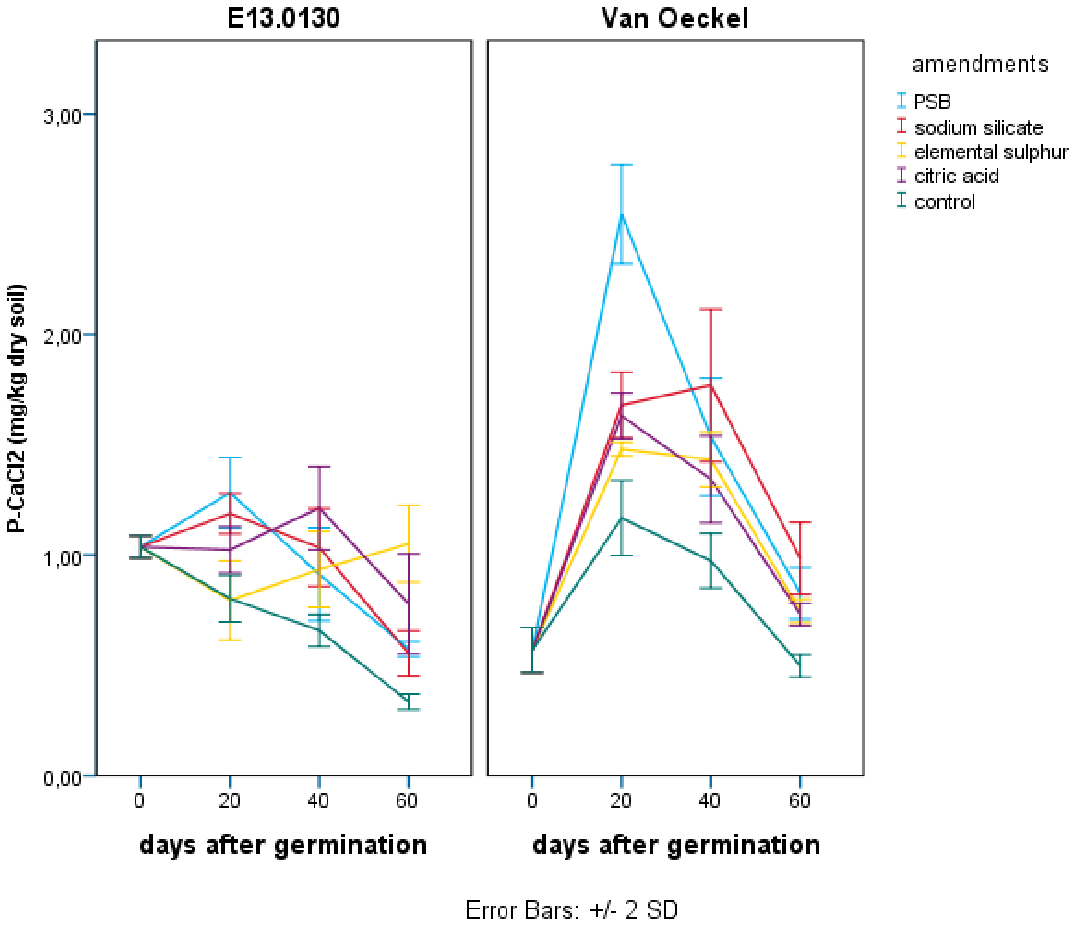


Figure 10 P intensity (P-CaCl2) of soils mixed with citric acid (10 mmol/kg dry soil), sodium silicate (10 mmol/kg dry soil), elemental sulphur (20 mmol/kg dry soil), and PSB (126 x 10^{11} CFU/kg dry soil) in the pot after growing grass for 20, 40 and 60 days.

Pots treated with PSB and sodium silicate measured higher amount of P-$CaCl_2$ for all harvesting time (Figure 10). P-$CaCl_2$ increased until day 20 and then decreased until last harvesting time but remained higher than control.

At site E13.130 P-$CaCl_2$ decreased with time as P had been taken up by the grass. P-$CaCl_2$ for pot treated with citric acid remain higher until day 60. PSB, citric acid and Na_2SiO_3 had shown an initial increase in P-$CaCl_2$. Pot treated with PSB measured highest P-$CaCl_2$ (1.28 mg/kg dry soil) on day 20 which steadily decreases up to (0.57 mg/kg dry soil) on day 60. P-$CaCl_2$ for sulphur remain higher on day 40 and 60. On day 20 sulphur had P-$CaCl_2$ similar as control (0.79 mg/kg dry soil) but it rose steadily on day 40 (0.93 mg/kg dry soil) and day 60 (1.05 mg/kg dry soil). Citric acid produced higher P-$CaCl_2$ on day 40. Effect of amendments on P-$CaCl_2$ was higher than control for all time.

For site Van Oeckel also first P-$CaCl_2$ for all amendments increases until day 20, and then decreases but remains higher than the control. Effect of sulphur increases up to day 20 then stays constant until day 40 and then starts to decrease. On day 20, PSB had more P-$CaCl_2$ (2.54 mg/kg dry soil) but on day 40 and 60 Na_2SiO_3 produce highest amount (1.77 mg/kg dry soil and 0.98 mg/kg dry soil respectively). On day 60, sulphur and citric acid produces same amount of P-$CaCl_2$ (0.75 mg/kg dry soil).

Three-way ANOVA was done to check the effect of the factors sites, amendments, and harvest time on P-$CaCl_2$ extraction. With, ($p = 0.000$) we could conclude that the three-way interaction was statistically significant. Therefore, data were splitted according to sites, and the interaction of amendments on harvesting days after germination were tested. Statistically significant interaction between amendments and harvesting days for both sites with, ($p = 0.000$) for site E13.0130 and van Oeckel with, ($p = 0.000$) were found. Therefore, all data were splitted according to harvesting days for both sites. The ANOVA analysis of P-$CaCl_2$ (mg/kg dry soil) and amendments on days of harvesting for each sites show that there was statistically significant effect of amendments and P-$CaCl_2$ obtained.

On day 20, Tukey HSD analysis of P-$CaCl_2$ (mg P/ kg dry soil) of the soils treated with PSB had significant highest mean difference on P-$CaCl_2$ in comparison with other amendments. On day 40 citric acid had significant highest mean difference on P-$CaCl_2$ in comparison with other amendments. Similarly, at day 60 sulphur had significant highest mean difference on P-$CaCl_2$ in comparison with other amendments. Multiple comparison of means clearly showed that all the amendments are making more P available for plant uptake than control throughout the incubation period.

Like in site E13.0130, PSB had significant highest mean difference on P-$CaCl_2$ in comparison with other amendments. But in 40 days harvesting time Na_2SiO_3 had significant highest mean difference on P-$CaCl_2$ extraction in comparison with other amendments. Multiple comparison of means clearly showed that P-$CaCl_2$ is significantly positive in comparison to control for all the amendments.

4.4.2 Effect of pH-H_2O on P-$CaCl_2$ extracted

For both sites, elemental sulphur was acidifying whereas citric acid and PSB had similar pH as control. Similarly, sodium silicate was slightly alkalizing. There was no much change in pH with time.

At site E13.0130, pH-H_2O for citric acid pH doesn't change compared to the control while for elemental sulphur pH ranges between 4.46 to 4.92 (Table 8). Similarly, for PSB pH was slightly acidifying ranging from 5.96 to 6.41 and for sodium silicate pH was slightly alkalizing which was between 7.15 to 7.33.

Table 8 Mean pH-H_2O in extracts of soil E13.0130 after harvesting grass grown in soil treated with different amendments for 20, 40 and 60 days.

sites = E13.0130			pH				
			citric acid	control	elemental sulphur	PSB	sodium silicate
days after germination	20	Mean	6,53	6,59	4,92	5,96	7,19
	40	Mean	6,45	6,66	4,46	6,41	7,15
	60	Mean	6,53	6,54	4,49	6,78	7,33

Table 9 shows at site Van Oeckel citric acid doesn't changes pH compared to control. Similarly, elemental sulphur had acidifying effect but it was more acidic with increase in growing time. This could be because we had applied elemental sulphur in powder form which takes time to oxidize. pH-H_2O for soil treated with PSB was slightly acidic (6.09 to 6.79) whereas sodium silicate had slightly alkalizing effect (7.12 to 7.24).

Table 9 Mean pH-H_2O in extracts of soil Van Oeckel after harvesting grass grown in soil treated with different amendments for 20, 40 and 60 days.

sites = Van Oeckel			pH				
			citric acid	control	elemental sulphur	PSB	sodium silicate
days after	20	Mean	6,37	6,59	5,06	6,09	7,19
germination	40	Mean	6,36	6,57	4,98	6,30	7,12
	60	Mean	6,50	6,53	4,94	6,79	7,24

Citric acid and elemental sulphur had negative correlation with pH in both sites (Table 10). In site E13.0130, there was statistically significant strong negative correlation PSB (r = - 0.99) for citric acid. Similarly, for Na_2SiO_3 there was positive correlation (r = 0.72). No correlation was observed for PSB.

In site Van Oeckel there was negative correlation for citric acid (r= - 0.89). Unlike in site E13.130, Sodium silicate was negatively correlated (r = - 0.67) in Van Oeckel. Similarly, elemental S had no significant correlation. Control at site van Oeckel showed significant positive correlation but from the scatter plot it could be seen that change in pH range was very small.

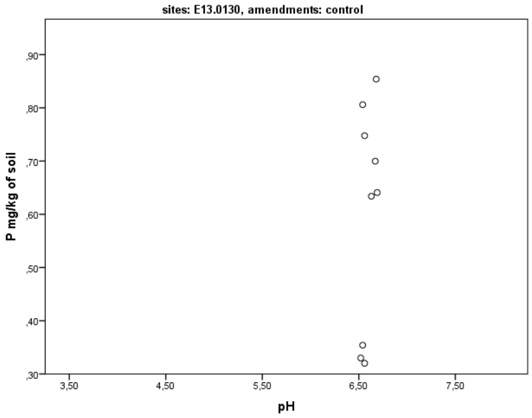
Table 10 Pearsons's Correlation analysis of extracted P-$CaCl_2$ (mg/kg dry soil) after incubation with the pH of the extracted solution at both sites

sites	Amendments				
	Citric acid	control	Elemental S	PSB	sodium silicate
E13.0130	-0.99**	0.54	-0.81**	-0.68*	0.72**
Van Oeckel	-0.89**	0.67*	-0.45	-0.57	-0.67*

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Scatter plots in figure 12 show the relation of P-$CaCl_2$ and pH-H_2O on 20, 40 and 60 days after germination in soils from site E13.130 and Van Oeckel treated with amendments.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P mg/kg of soil
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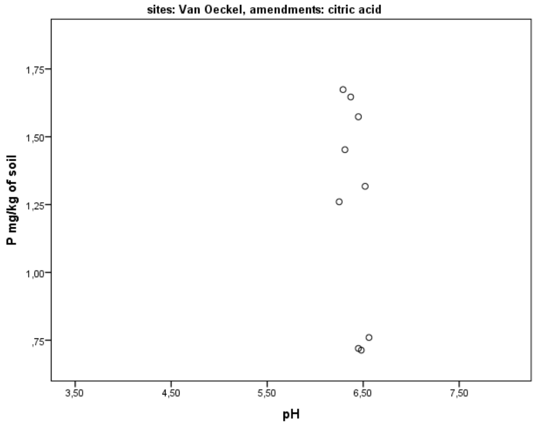
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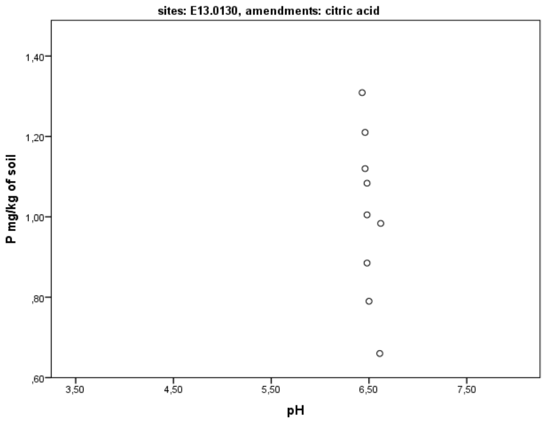
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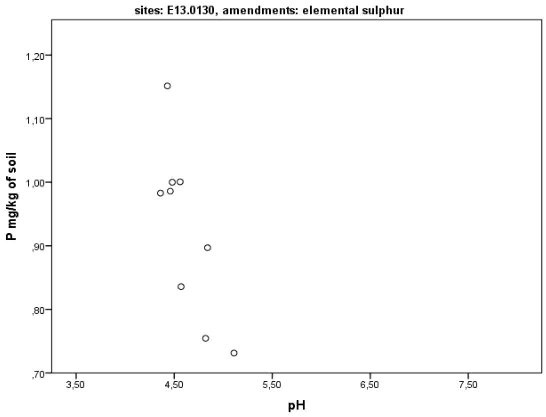
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P mg/kg of soil
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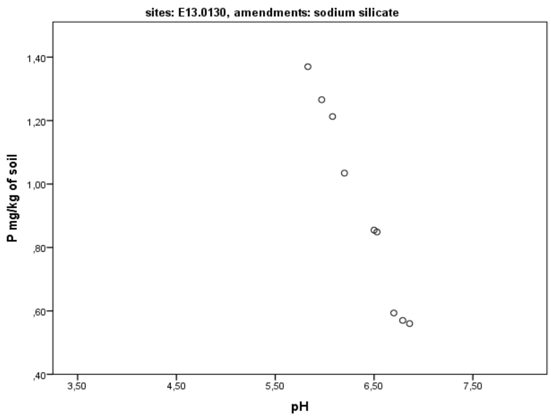
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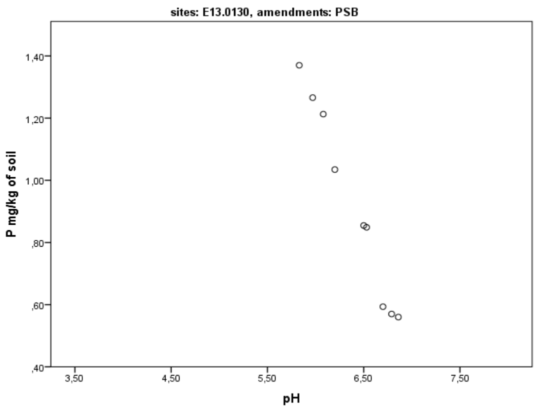
sites: E13.0130, amendments: PSB
P mg/kg of soil
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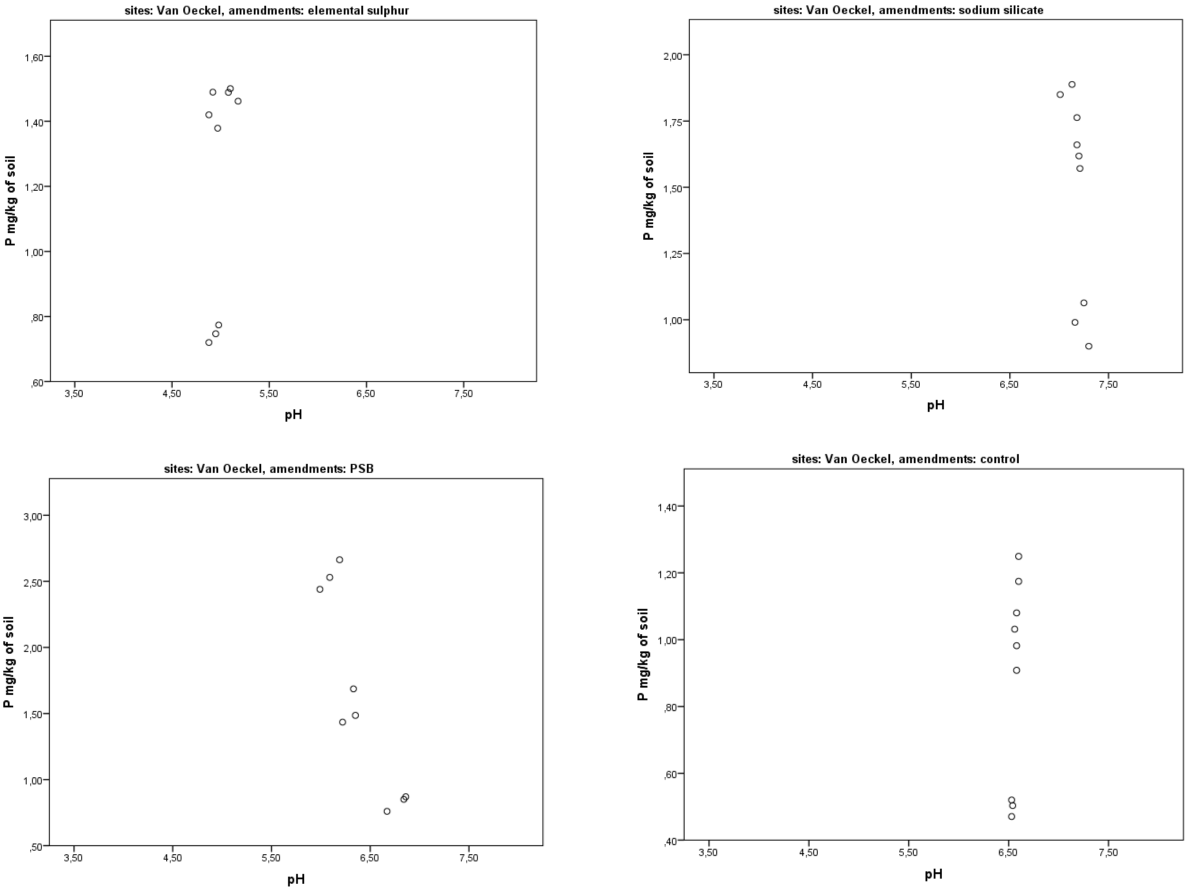

Figure 12 Relation of extracted P-$CaCl_2$ and pH-H_2O after harvesting on 20, 40 and 60 days after germination in soils soil from E13.130 and Van Oeckel treated with amendments, citric acid (10 mmol/kg dry soil), sodium silicate (10 mmol/kg dry soil), elemental sulphur (20 mmol/kg dry soil and PSB (126 x 10^{11} CFU/kg dry soil).

4.4.3 Determination of dry matter

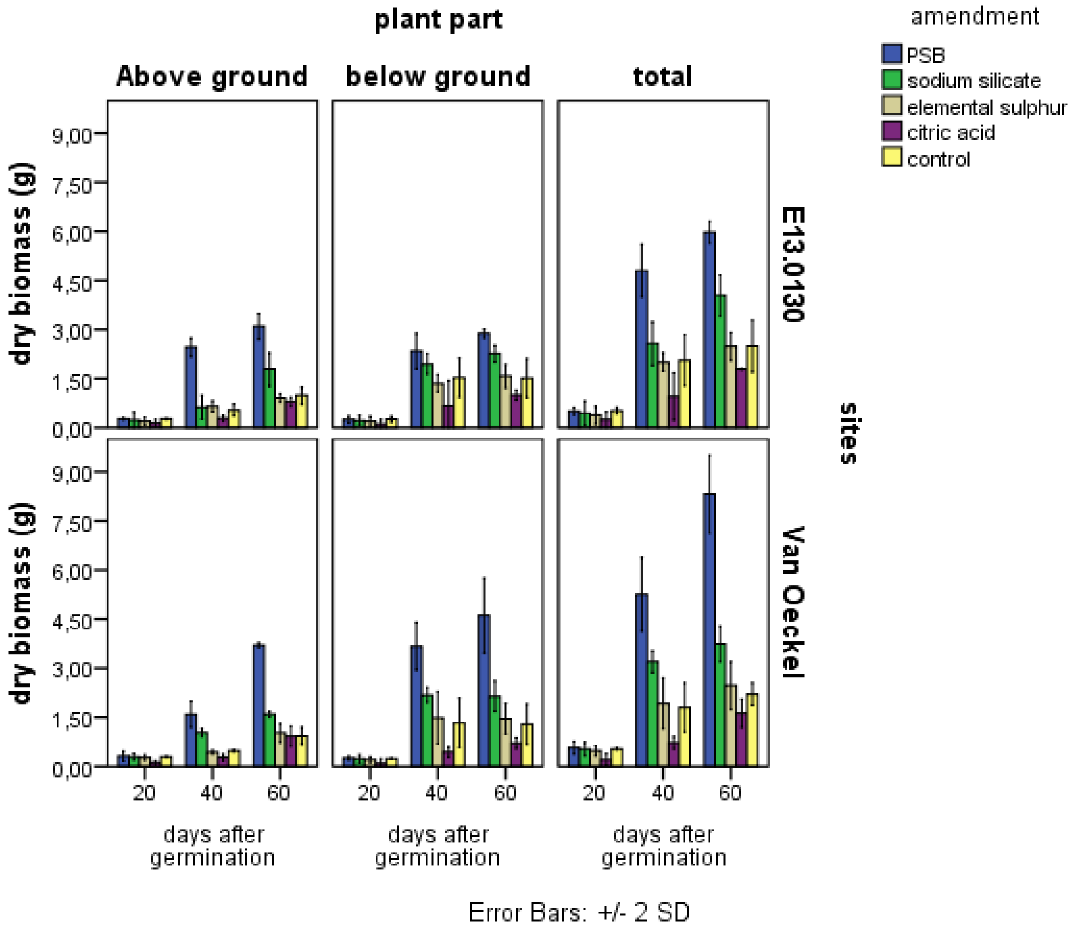

Figure 11 Dry biomass (above ground and below ground and total) weight (g) of grass grown in two types of soil treated with amendments, citric acid (10 mmol/kg dry soil), sodium silicate (10 mmol/kg dry soil), elemental sulphur (20 mmol/kg dry soil), and PSB (126 x 10^{11} CFU/kg dry soil) and harvested in 20, 40 and 60 days after germination.

Above ground biomass

At E13.130 dry weight of biomass was higher for pots treated with PSB and sodium silicate and lowest for citric acid (Figure 11). On day 20, all pots produced almost similar above ground biomass but for citric acid it was even lower than control as there was very few germinations of seeds. PSB, sodium silicate and sulphur produced more dry matter than control on day 40 and 60. For all the time dry weight for pot treated with citric acid remained below control. For sodium silicate above ground dry matter yield was 1.78 g on day 60 which was almost twice as control (0.98 g). On day 60 sulphur had similar yield as control (0.90 g).

At Van Oeckel also PSB, sodium silicate and sulphur produced more above ground biomass than control whereas citric acid remained lowest for all the time. In this case also with citric acid germination was not so successful. On day 20 all the pots with different amendments produced similar amount of biomass but on day 40 and 60 yield was much higher for PSB and sodium silicate. On day 60, PSB and sodium silicate produced 3.71 g while citric acid could produce only 0.91g which was even lower than control (0.92 g).

Three-way ANOVA was done to check the three-way interaction between sites, amendments, and harvesting day with above ground dry biomass yield and the interaction was found significant ($p = 0.000$). Then, the interaction was splitted according to harvesting days, and the interaction of above ground biomass weight and amendments was tested. The ANOVA analysis of above ground dry biomass weight and amendments on days of harvesting showed that at site E13.0130 on day 40 and 60 there was significant interaction of amendments and dry biomass weight but on site Van Oeckel there was significant interaction for all harvesting days.

For site E13.0130, on day 20 no significant mean difference on aboveground dry matter yield was found for all amendments. But for harvesting day 40 and 60, PSB had significant positive mean difference followed by sodium silicate. Citric acid had significant negative mean difference with other amendments on day 40 and 60 suggesting its lowest yield. On day 60 PSB and sodium silicate could produce 2.11 g and 0.80 g more above ground dry mass than control.

For site Van Oeckel, on day 20 only PSB had significant positive mean difference with control. On day 40 and 60 sodium silicate and PSB had exceeded the yield of control. On day 60 PSB and sodium silicate could produce 2.78 g and 0.67 g more above ground dry mass than control.

Below ground biomass

At site E13.0130, PSB and sodium silicate produced much higher amount of below ground biomass while sulphur produced almost similar and citric acid remained lower than control. On day 20 PSB produced 0.24 g but on day 40 and 60 it produced 2.33 g and 2. 88 g respectively.

At site Van Oeckel PSB, sodium silicate and sulphur had produced higher biomass than control while citric acid was lower all the time. Like at site E13.0130 on day 20 yield was almost similar for all amendments except for citric acid which was much lower. On day 60 also PSB produced highest amount (4.61 g) followed by sodium silicate (2.14 g). Similarly, on day 60, sulphur could produce 1.45 g while control only 1.28 g.

Three-way ANOVA was done to check the three-way interaction between sites, amendments, and harvesting day with below ground dry biomass yield and significant ($p = 0.000$) interaction was found. Then, the data was splitted according to harvesting days, and the interaction of below ground biomass weight and amendments was tested. ANOVA analysis of below ground dry biomass weight and amendments on days of harvesting showed that at site E13.0130 on day 40 and 60 there was significant interaction of amendments and dry biomass weight but on site Van Oeckel there was significant interaction for all harvesting days.

The mean comparisons of below ground biomass weight for site E13.0130 showed that on day 20 no significant mean difference was found for all amendments. On day 40 PSB and sodium silicate had significant positive mean difference with control. On day 60 PSB, sodium silicate and sulphur could produce 1.37 g and 0.74 g and 0.07 g more below ground dry mass than control.

The mean comparisons of below ground biomass weight for Van Oeckel showed, on day 20 only PSB had significant positive mean difference with control. On day 40 and 60 sodium silicate and PSB had exceeded the yield of control. On day 60 PSB and sodium silicate could produce 3.33 g and 0.86 g more above ground dry mass than control.

Total biomass

For all time treatment PSB had higher total biomass followed by sodium silicate (Figure 12). At site E13.0130, for 20 days after germination not much difference on biomass yield was observed but starting from 40 days after germination differences were more. Citric acid led to poor germination resulting least total biomass for all harvesting time. On day 20 total biomass weight was almost similar for all amendments except citric acid. On day 60, total plant dry weight for PSB (5.98 g) and sodium silicate (4.04 g) had increased significantly in comparison to control (2.49 g).

At site Van Oeckel PSB had produced more total dry weight for all harvesting time. On day 20 sodium silicate produced similar total dry weight as control but on day 40 and 60 yield increased significantly. Total dry matter yield for sulphur remained slightly higher than control on 40 and 60. Total biomass produced by PSB on day 40 (5.25 g) and 60 (8.32 g) are much higher than other amendments. On day 40 and 60 sodium silicate produced 3.20 g and 3.74 g total dry weight respectively while sulphur could produce 1.92 g and 2.47 g respectively.

Three-way ANOVA was done to check the three-way interaction between sites, amendments, and harvesting day with total dry biomass yield and three-way interaction was found statistically significant ($p = 0.000$). Then, the interaction was splitted according to harvesting days, and the interaction of total dry biomass weight and amendments was tested. ANOVA analysis of total dry biomass weight and amendments on days of harvesting showed that at site E13.0130 on day 40 and 60 there was significant interaction of amendments and dry biomass weight but on site Van Oeckel there was significant interaction for all harvesting days.

The mean comparisons of total biomass weight with different amendments for different harvesting days for site E13.0130 showed, on day 20 no significant mean difference on total dry matter yield was found for all amendments. On day 40 PSB and sodium silicate had significant positive mean difference with control. On day 60 PSB, sodium silicate could produce 3.48 g and 1.54 g more below ground dry mass than control.

The mean comparisons of total biomass weight at site Van Oeckel showed, on day 29, only PSB had significant positive mean difference with control. While on day 40 and 60, PSB, Sodium silicate and sulphur had exceeded control. Citric acid had remained below control all the time. On day 60 PSB, sodium silicate and sulphur could produce 6.11 g and 1.53 g and 0.26 g more total dry biomass than control.

4.4.4 Determination of P uptake

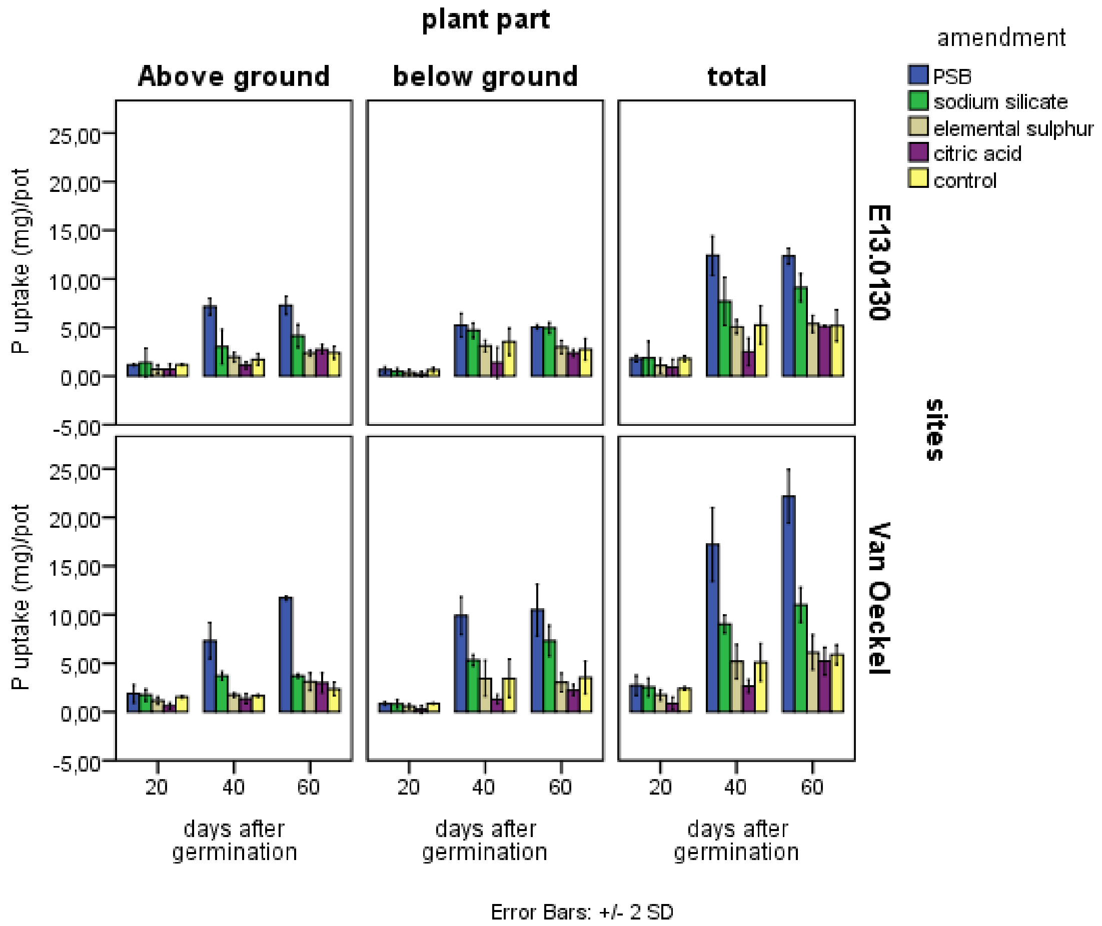

Figure 12 P uptake (mg/pot) by above ground, below ground and total plant parts of grass grown in two soil types treated with amendments, citric acid (10 mmol/kg dry soil), sodium silicate (10 mmol/kg dry soil), elemental sulphur (20 mmol/kg dry soil), and PSB (126 x 10^{11} CFU/kg dry soil) and harvested in 20, 40 and 60 days after germination.

P uptake (Above ground)

P uptake by grass on pot treated with PSB and Na_2SiO_3 was initially slightly higher than other amendments but later on increased considerably (Figure 12). At site, E13.130 P uptake per pot was higher for PSB and sodium silicate and lowest for citric acid. Pot with sulphur had higher P than control on day 40 only. Pot with citric acid had lower P than control for all harvesting time. On 20 day pots treated with sodium silicate took more P (2.39 mg) than other amendments. At Van Oeckel, pot with sulphur had more P on above ground plant parts than control on day 40 and 60.

Three-way ANOVA was done to check the three-way interaction between sites, amendments, and harvesting day with P-uptake by above ground biomass and three-way interaction was found significant (p = 0.000). Then, the interaction was splitted according to harvesting days, and the interaction of P-uptake and amendments was tested. ANOVA analysis of P-uptake by above ground biomass and amendments on days of harvesting showed that at site E13.0130 on day 40 and 60 there was significant interaction of amendments and P-uptake while on site Van Oeckel there was significant interaction for all harvesting days.

The mean comparisons of P-uptake by above ground plant parts on site E13.0130 showed that on day 20 there was no significant mean differences on P-uptake for any amendments though sodium silicate had positive mean difference with all amendments. On harvesting day 40 PSB had significant positive mean difference with other amendments followed by sodium silicate. On day 40, P uptake with PSB was 5.42 mg higher than that of control.

The mean comparisons of P-uptake by above ground at site Van Oeckel showed PSB had significant positive mean differences on P-uptake with all other amendments. Sodium silicate had positive mean difference on P-uptake with all amendments except PSB. P-uptake for citric acid was even lower than that of control.

P uptake (Below ground)

At site E13.0130, P content in below ground plant parts was almost similar for all amendments on day 20 (Figure 12). On day 40 and 60 PSB, sodium silicate had more P content in below ground plant parts than control. P uptake was similar for pot with PSB and sodium silicate in day 40 and 60. For PSB, P content on below ground plant part was 0.65 mg on day 20 while it raised to 5.25 mg on day 40 and decreased slightly lower to 5.05 mg P per pot on day 60.

At site Van Oeckel on day 20 P uptake by below ground plant parts were almost similar like in E13.0130 but on day 40 and 60 P uptake by plants grown with PSB was much higher. On day 40 PSB had highest P content of 9.88 mg per pot while for sodium silicate it was 5.30 mg/pot and for sulphur it was 3.0 mg/pot.

Three-way ANOVA was done to check the three-way interaction between sites, amendments, and harvesting day with P-uptake by below ground biomass and three-way interaction was found significant (p = 0.000). Then, the interaction was splitted according to harvesting days, and the interaction of P-uptake by below ground biomass and amendments was tested. ANOVA analysis of P-uptake by below ground biomass and amendments on days of harvesting showed that at site E13.0130 on day 40 and 60 there was significant interaction of amendments and P-uptake while on site Van Oeckel there was significant interaction for all harvesting days.

The mean comparisons of P-uptake by below ground biomass for site E13.0130 showed on day 20 there was no significant mean differences on P-uptake for any amendments though control had positive mean difference with all amendments. On harvesting day 40 PSB had significant positive mean difference with other amendments followed by sodium silicate. P uptake by belowground biomass on pot with PSB was 1.71 mg higher than that of control.

The mean comparisons of P-uptake by below ground plant parts at site Van Oeckel also showed, PSB had significant positive mean differences on P-uptake with all other amendments. Sodium silicate had positive mean difference on P-uptake with all amendments except PSB for all harvesting days. Elemental sulphur had positive mean difference on P-uptake with citric acid and control but differences are not statistically significant.

Total P uptake

Total P uptake for pot with PSB was significantly higher in both sites. After PSB total P was highest for sodium silicate. Pot with sulphur had almost similar P content as control while citric acid had significantly lower P uptake. In the shaking experiment and incubation experiment citric acid was performing well but in dry matter yield and P uptake citric acid is not favorable. The reason behind this could be the acidic nature of citric acid.

At site E13.0130 on day 20 total P uptake was almost similar for all pots but on day 40 and 60 it was higher for PSB and sodium silicate. On 60 days P-uptake on pots with PSB and sodium silicate had increased significantly in compared to other amendments and control. On 60-day average total P content for PSB, sodium silicate and sulphur was 12.61 mg, 9.10 mg and 5.74 mg respectively.

At site Van Oeckel also total P uptake on day 20 was almost similar but it increased much more for PSB. Like in site E13.130, pots with PSB and sodium silicate had more total P than other amendments. PSB had twice more total P content than sodium silicate on day 40 and 60. Pot treated with sulphur had more total P uptake per pot in day 40 and 60. Total P content for pot with PSB and sodium silicate on day 40 was 17.20 and 9.02 mg per pot. Similarly, on day 60 total P uptake for pot with PSB was 22.17 mg per pot and for sodium silicate was 11.00 mg per pot.

Three-way ANOVA was done to check the three-way interaction between sites, amendments, and harvesting day with total P uptake and three-way interaction was found significant ($p = 0.000$). Then, the interaction was splitted according to harvesting days, and the interaction of total P-uptake and amendments was tested. ANOVA analysis of total P-uptake by the grass and amendments on days of harvesting showed that at site E13.0130 on day 40 and 60 there was significant interaction of amendments and P-uptake while on site Van Oeckel there was significant interaction for all harvesting days.

The mean comparisons of P-uptake with different amendments for different harvesting time for site E13.0130 showed, on day 20 there was no significant mean differences on P-uptake for any amendments though sodium silicate had positive mean difference with all amendments. On harvesting day 40 PSB had significant positive mean difference with other amendments followed by sodium silicate. P uptake with PSB was 7.13 mg higher than that of control on day 40. Similarly, on day 40 P uptake with sodium silicate was 2.44 mg higher than control. On day 60 also P-uptake with PSB was higher in comparison to other amendments.

The mean comparisons of total P-uptake by grass at site Van Oeckel showed PSB had significant positive mean differences on P-uptake with all other amendments. Sodium silicate had positive mean difference on P-uptake with all amendments except PSB. Similarly, elemental sulphur had positive mean difference on P-uptake with citric acid and control but differences were not statistically significant.

Chapter 5 Discussion

Shaking experiment

Shaking experiment was done to select most promising amendments and concentration to increase plant available P. Both soils used for shaking experiment are acid sandy soil with no free $CaCO_3$. PSD in both sites were higher than 40% though this value was measured for the upper 30 cm only. According to Van der Zee (1990) risk of P leaching starts at a PSD of 25% in acidic sandy soils. Hence the risk of P leaching from the upper 30 cm to deeper soil layers in our studied sites is high. Similarly, both soil had rather high to moderate P-quantity but P-intensity was lower. The low P-intensity (P-$CaCl_2$) is due to the fact that much of the P was in unavailable forms and could be slowly available to the crop during the growing season or the next crop because of the residual effect. But for optimum plant growth P is essential (Van Rotterdam-Los et al., 2013). As Flanders legislation has set limits to the amount of P-fertilizer applied to field it is necessary to increase P-intensity of the soil.

P availability enhanced by amendments

P extraction on shaking experiment by amendments for all concentration remain higher. Among the amendments used lactic acid and sodium sulphate was found to be less effective than other amendments. Results from shaking experiment clearly shows that addition of organic acid has increased amount of P in extraction. According to Bolan et al. (1994), organic acids increase the availability of P in soils mainly through both decreased adsorption of P and increased solubilization of P compounds. Result shows the effectiveness of organic acids in amount of P-extraction followed the order lactic acid < oxalic acid < citric acid which is consistent with the previous study done by Bolan et al. (1994) and Gang et al. (2012). Mechanism of increase in P by organic acid is by mineralization of stable pools of P. Bolan et al. (1994) have reported that organic anions have chelation mechanism with the metal ions, such as Fe and A1, and thereby release anions bound to the metal ions and liberates phosphate in soluble form. In our experiment 2mM Citric acid has extracted highest amount of P i.e. around 39mg/kg dry soil in both sites. Wei et al. (2009) also have found 2 mM citric acid extracted higher amounts of P from soil when compared to other concentration.

Silicate is more efficient in correcting acidity due to its high solubility (Alcarde and Rodella, 2003). Castro et al. (2013) also have reported silicate is more efficient for P availability and reducing toxic aluminum. Increase in concentration of silicates have extracted increasing amount of P. Roy et al. (1971) have also reported that extractable P increased with increasing rates of silicate applied to the soil. Results shows in both sites for 0.5 mM and 1 mM concentrations, sodium silicate has extracted highest amount of P. Silicate has extracted highest amount of P in shaking experiment on both sites. Similarly, we also found increasing concentration for sodium silicate has increased the P-extraction is highest for 2 mM.

Sulphate increases the amount of P extraction by competition for the binding sites. In our experiment effect of sodium sulphate on P extraction was not that higher than other amendments. This could be because the soil was already acidic. Motowicka-Terelak and Terelak (1998) have demonstrated that sulphur reduce phosphorus fixation in soil by binding aluminum by sulphate. While comparing with other amendments sodium sulphate has produced less amount of P. 2 mM of sodium sulphate could produce only 2.41 mg/kg dry soil in site E13.0130 and 2.88 mg/kg dry soil for site Van Oeckel.

Most promising amendments chosen for shaking experiment were 1 mM citric acid, 1 mM sodium silicate and 2 mM elemental sulphur. Though the P-extraction was highest for 2 mM citric acid, increase in concentration form 1 mM to 2 mM has sharply decreased its pH. So, 1 mM citric acid was chosen for incubation experiment.

Effect of pH on amount of P extraction

There are different arguments about the pH dependence of phosphate solubilization because studies have reported different results from no effect or an increase or a decrease in solution phase of phosphate with decreasing pH, depending on the soil and pH range investigated (Jones et al., 2003).

Result shows at both sites, sodium sulphate is more acidifying while organic acids have less acidifying effect. Similarly, sodium silicate has slightly alkalizing effect. Negative Pearson's correlation has been found for pH and amount of P extracted with organic acids. Geelhoed et al. (1999) have also reported increase in P in solution with decrease in pH. Organic anions, the conjugate bases of organic acids, may play an important role in improving the availability of soil phosphate (Geelhoed et al., 1999). Positive significant correlation has found for amount of P extracted and pH for sodium silicate. Since the soil samples were acidic, alkalizing effect of sodium silicate might have effect on P availability. Roy et al. (1971) have reported that silicate decreased P sorption more effectively at low soil pH than at high soil pH. They have found that P sorption was greater at pH 5.5 than at 6.2 which was similar to our soil. This agree with most concept of P availability in soils.

Incubation experiment

Incubation experiment was done to test whether the selected amendments could increase P-$CaCl_2$ when incubated for different time intervals. Our results clearly demonstrate that addition of citric acid, elemental sulphur, PSB and sodium silicate significantly increased the amount of P-CaCl2 extraction in comparison to control. Generally, the effectiveness was highest for PSB and sodium silicate.

PSB releases organic acid and organic acids helps to enhances P-$CaCl_2$ in soil. Studies by Gang et al. (2012) indicated that organic acids accelerates the weathering of stable P pool, which would be significant for increasing P-intensity in soil. In our study on day 12, PSB has suddenly peaked P-$CaCl_2$ extraction. Similar result was also observed by De Bolle et al. (2013). Main reason behind this could be bacteria becoming more active during that time and they might have released more phosphates enzyme which helped in the weathering of stable P pool.

Na_2SiO_3 produced higher P-$CaCl_2$ after PSBs in the incubation experiment. For the acid sandy soil sodium silicate is effective in two ways. One is the competition for the binding site and another is alkalizing effect. According to Sandim et al. (2014), silicate increase the soil P availability because the silicate anion occupies sites of phosphate anion adsorption and saturates sites where P could be adsorbed. The higher competition for the same adsorption site between Si and P could reduce the P fixation. Similarly, the alkalizing power of Si also helps in solubilizing P because in acidic soil P in soil reacts with Fe and Al and make them insoluble but when pH increases phosphates are released from them.

After PSB and sodium silicate, citric acid extract higher amount of P-$CaCl_2$. For citric acid more effect has been observed on the initial stage of incubation. Result shows, on 3rd day of incubation (2.10 mg/Kg dry soil) which goes on decreasing afterwards and on day 12 P-$CaCl_2$

measured is even lower than control. According to Jones et al. (2003) addition of citric acid to soil release protons which can be involved in dissolution, complexation, hydroxylation and exchange reactions with the soil's solution and solid phases which release phosphates in soil solution.

In the shaking experiment sulphate was used but in incubation experiment and greenhouse experiment we decided to use elemental sulphur. As sulphur has both pH effect and competition for binding sites elemental sulphur was chosen. Elemental Sulphur has extracted more P-$CaCl_2$ in incubation experiment. Jaggi et al. (2005) have reported that the change in soil pH causes mineralization of P into inorganic forms as well as liberation of Al and Fe ions, which reacts with sulphates and bind only few phosphate ions. They also reported addition of elemental sulphur improves the availability of P in cultivated soils, irrespective of the initial soil pH. Results of Skwierawska and Zawartka (2009) also shows that elemental sulphur has pH effect on P availability in addition to binding effect. But, during incubation experiment, elemental Sulphur has worked slowly in comparison to other amendments. The reason behind this could be that the elemental sulphur was used in powder form and it might have taken time to oxidized. From incubation experiment citric acid, sodium silicate, elemental sulphur are found to be better performing.

Greenhouse experiment

In order to access the amount of P release by the soil as a result of P removal (P uptake by the crop) P-$CaCl_2$ is measured. P-$CaCl_2$ decreases to the end of the experiment it is because P-$CaCl_2$ is taken up by grass. PSB, Citric acid and Na_2SiO_3 show an initial increase in P-$CaCl_2$ indicating these amendments can make more P-$CaCl_2$ available. Pots treated with PSB and sodium silicate measured higher amount of P-$CaCl_2$ for all harvesting time. In site Van Oeckel there is initial increase in P-$CaCl_2$. That could be because of some mineralization, then P-$CaCl_2$ is normal as it is taken up by plants. For all amendments P-$CaCl_2$ remains higher than control which indicates that P-intensity has increased in pots by application of amendments. P-$CaCl_2$ for pot treated with citric acid remain higher until day 60 because very few seeds have been germinated in pots treated with citric. Effect of amendments on P-$CaCl_2$ is higher than control for all time. This proves that amendments are working better than control for all harvesting time. In case of Sulphur it has higher effect on day 40 and 60 for both soils because sulphur was used in powder form and it took time to oxidize which is similar result as seen in incubation experiment.

Effect of pH-H_2O on P-$CaCl_2$ extracted

Amendments are found to have different pH effects. In both sites, elemental sulphur is acidifying whereas citric acid and PSB has similar pH as control. The use of sodium silicate has also benefit in increasing pH in addition to increasing P-$CaCl_2$. Similarly, by using PSB as an amendment has not changed the pH of the soil. For sulphur change in pH has been observed with the time of incubation. This could be because of use of powder sulphur which might have taken time to oxidize. Similarly, the use of sulphur has further decreased the pH of the soil. So, we have to be careful while using elemental Sulphur because it is further adding acidity to the soil which is already acidic.

Determination of dry matter

Like in other results, PSB and sodium silicate produced much higher amount of both above and below ground biomass in both sites. The positive effect of increase in biomass on pot treated with PSB and sodium silicate can be attributed mainly to an increase in the availability of P to plants. Since, PSB and sodium silicate change the pH in opposite directions as compared to the control the amount to dry matter production can attributed to the pH effect caused by the amendments. PSB used in our experiment was grown in a Caesin soya bean digest medium. It contained nutrients like pancreatic digestion of casein (17 g/L), enzymatic digest of soya bean (3 g/L), dipotassium hydrogen phosphate (2.5 g/L). So, the effect of PSB on the dry matter yield can also be attributed to some of the nutrients effect.

On day 20 all amendments produced similar amount of below ground biomass except citric acid which produced much lower. As growing period was small on day 20 all treatment could have performed similar. But, on day 40 and 60 PSB have produced higher amount of dry matter in comparison to other amendments. Similarly, Citric acid has significant negative mean difference with other amendments on day 40 and 60 suggesting its lowest yield. Citric acid has extracted more P both in shaking experiment and incubation experiment. But, it’s performance on seed germination has been found really poor. Since, the sampled soil is acidic sandy soil pH effect might have cause Al toxicity which could have affected on seed germination.

In case of sulphur dry matter yield is not so high as compared to the control. As, the sulphur has added further acidity to soil it might have led to less dry matter yield. Motowicka-Terelak and Terelak (1998) demonstrated that sulphur, by binding aluminum sulphate, reduced phosphorus fixation in soil, while excessive amounts of sulphates may result in incomplete utilization of phosphorus, as they inhibit the growth of crops. So, in acidic soil sulphur might have growth inhibiting effects on crops.

P uptake by grass

Dry matter production on both above and below ground was found significantly influenced by treatments. P uptake by grass is directly related with the amount of P available on soil for plants. According to Mullins (2009), P concentrations in plant typically range from 0.1 to 0.5% on a dry weight which is similar to our findings. Results shows addition of sodium silicate and PSB increased P uptake in the grass during all three different harvesting period. Research by Roy et al. (1971) have also reported the effect of silicate has increased P nutrition in sugarcane plants. Similarly, Pulz et al. (2008) found higher P availability in soil in potato plants after silicate application. The reason for increase in P level because of sodium silicate could be due to release of P in soil by the competition for binding sites. Castro et al. (2013) have also reported that the P level of leaves were increased by silicate application and could be associated to competition between silicate ($H_3SiO_4^-$) and phosphate ($H_2PO_4^-$) for same absorption sites (Castro et al., 2013).

P content in grass is lowest for citric acid which is different than expected. Citric acid has increased the amount of P-$CaCl_2$ but it doesn't have good germination effect on grass. This effect could be because of acidic nature of citric acid. As the soil is already acidic, use of citric acid has further lowered the pH of soil affecting on germination as well as P uptake. Similar, effect is seen for elemental sulphur also though the effect is not that bad for sulphur as in the case of citric acid. For sulphur P uptake has been found to be higher on 40 days. This fact confirms that sulphur makes P available later than other amendments. Sodium silicate shows its effect from the beginning as P-uptake proving that sodium silicate has early action on P availability. Similarly, for PSB P uptake has remained higher in all growing period. PSB was grown in the nutrient medium and there could be some additional nutrient effect of growing medium on P-uptake.

Chapter 6 Conclusion and recommendations

Flanders legislation has restricted P fertilization on acid sandy soils with high PSD which ultimately should result in P mining. A way to bring phosphate saturated soils back to environmental safe P level is by P mining through plants. In this context soil amendments could be very useful for increasing mining efficiency over time.

Shaking experiment was done to select the most promising amendments and concentrations to increase plant available phosphorus (P intensity). P extracted by amendments at all concentration after shaking experiment remained higher than control but P extracted by lactic acid and sodium sulphate is considerably lower. P-extraction is highest for 2 mM citric acid, and sodium silicate.

Incubation experiment was done to selected amendments that increase P-$CaCl_2$ when incubated for different time intervals. During incubation experiment PSB gave higher amount of P-$CaCl_2$ on day 12 and sodium silicate produced highest amount of P-$CaCl_2$ on day 24. Elemental sulphur showed its effect slowly and citric acid didn't perform well. PSB and sodium silicate remain higher during all the incubation time.

Greenhouse experiment was done to test if the use of amendments really increased crop yield and P uptake. In greenhouse experiment PSB and sodium silicate was found to be best performing. For citric acid germination was very poor. PSB yield highest amount of dry matter and also the P-uptake was higher. Similarly, sodium silicate also significantly increased the dry matter yield and P-uptake was also higher for plants treated with PSB.

During this three step experiment mode of action of amendment was also studied. Mode of action for organic acid could be competition for binding sites. For sodium silicate both pH effect and competition for binding site could be responsible for liberating phosphates. Similarly, for PSB main mode of action could be because of release of organic acid and phosphatase enzyme. No, pH effect has been observed for PSB. For sulphur both competition for binding sites and pH effect is possible.

In conclusion, PSB and sodium silicate can be effective in acid sandy soil of Flanders for increasing P-intensity and increasing P-mining in soil. But, still more potting experiment for different crops is recommended. PSB grown only with physiological water can give real understanding on PSB effect but for this experiment we used Casein soya bean digest medium so this might have nutrients effect on dry matter yield and P uptake as well. Hence, we recommend to use PSB grown on physiological water in further potting experiment. In future this study could be replicated with different crops and also in agricultural farm to have a better understanding of the effect of amendments on P mobilization and availability to plants.

References

Alcarde, J., and Rodella, A. (2003). Quality and legislation of fertilizers and correctives. *Curi, N.; Marques, JJ*, 291-334.

Amery, F., and Schoumans, O. (2014). "Agricultural phosphorus legislation in Europe," Institute for Agricultural and Fisheries Research (ILVO).

Amery, F., and Vandecasteele, B. (2013). The phosphorus cycle in North-West European agricultural soils. *In* "NUTRIHORT: Nutrient management, nutrient legislation and innovative techniques in intensive horticulture" (B. V. Karoline D'Haene, Raf De Vis, Sara Crappé, Danny Callens, Els Mechant, Georges Hofman, Stefaan De Neve, ed.), pp. 124-129, Ghent, Belgium.

Bastounopoulou, M., Gasparatos, D., Haidouti, C., and Massas, I. (2011). Chemical fractionation and sorption of phosphorus in greek inceptisols. *Journal of Agricultural Science and Tehnology* **1**, 33-38.

Bolan, N. S., Naidu, R., Mahimairaja, S., and Baskaran, S. (1994). Influence of low-molecular-weight organic acids on the solubilization of phosphates. *Biology and Fertility of Soils* **18**, 311-319.

Breeuwsma, A., Reijerink, J., and Schoumans, O. (1995). Impact of manure on accumulation and leaching of phosphate in areas of intensive livestock farming.

Carvalho, R., Furtini Neto, A., Curi, N., Fernandes, L., and Oliveira Junior, A. (2000). Dessorção de fósforo por silício em solos cultivados com eucalipto. *Revista Brasileira de Ciência do Solo* **24**, 69-74.

Castro, G., Spadotti, A., Crusciol, C., and Alexandre, C. (2013). Yield and mineral nutrition of soybean, maize, and Congo signal grass as affected by limestone and slag. *Pesquisa Agropecuária Brasileira* **48**, 673-681.

Castro, G. S. A., and Crusciol, C. A. C. (2013). Yield and mineral nutrition of soybean, maize, and Congo signal grass as affected by limestone and slag. *Pesquisa Agropecuária Brasileira* **48**, 673-681.

Chardon, W. J., and Schoumans, O. F. (2007). Soil texture effects on the transport of phosphorus from agricultural land in river deltas of Northern Belgium, The Netherlands and North-West Germany. *Soil Use and Management* **23**, 16-24.

Clercq, P., Gertsis, A., Hofman, G., Jarvis, S., Neeteson, J., and Sinabell, F. (2001). Nutrient management legislation in European countries.

Condron, L. M., Turner, B. L., Cade-Menun, B. J., Sims, J., and Sharpley, A. (2005). Chemistry and dynamics of soil organic phosphorus. *Phosphorus: Agriculture and the environment*, 87-121.

Cooper, J., Lombardi, R., Boardman, D., and Carliell-Marquet, C. (2011). The future distribution and production of global phosphate rock reserves. *Resources, Conservation and Recycling* **57**, 78-86.

De Bolle, S., Gebremikael, M. T., Maervoet, V., and De Neve, S. (2013). Performance of phosphate-solubilizing bacteria in soil under high phosphorus conditions. *Biology and fertility of soils* **49**, 705-714.

De Schrijver, A., Vesterdal, L., Hansen, K., De Frenne, P., Augusto, L., Achat, D. L., Staelens, J., Baeten, L., De Keersmaeker, L., and De Neve, S. (2012). Four decades of post-agricultural forest development have caused major redistributions of soil phosphorus fractions. *Oecologia* **169**, 221-234.

Earl, K., Syers, J., and McLaughlin, J. (1979). Origin of the effects of citrate, tartrate, and acetate on phosphate sorption by soils and synthetic gels. *Soil Science Society of America Journal* **43**, 674-678.

Gądor, J., and Motowicka-Terelak, T. (1986). Wpływ zasiarczenia gleb na ich właœciwoœci oraz na plonowanie roœlin w doœwiadczeniu lizymetrycznym. *Cz. II. Wpływ zasiarczania gleb siarką elementarną na plonowanie i skład chemiczny roœlin uprawnych. Pam. Puł* **88**, 25-37.

Gang, X., Hongbo, S., Rongfu, X., Nie, Y., Pei, Y., Sun, Z., and Blackwell, M. (2012). The role of root-released organic acids and anions in phosphorus transformations in a sandy loam soil from Yantai, China. *Afr J Microbiol Res* **6**, 674-679.

Gardner, W., and Boundy, K. (1983). The acquisition of phosphorus by Lupinus albus L. IV. The effect of interplanting wheat and white lupin on the growth and mineral composition of the two species. *Plant and Soil*, 391-402.

Gee, G. W., and Dani, O. (2002). "Particle-size analysis," SSSA, Madison, WI.

Geelhoed, J., Van Riemsdijk, W., and Findenegg, G. (1999). Simulation of the effect of citrate exudation from roots on the plant availability of phosphate adsorbed on goethite. *European Journal of Soil Science* **50**, 379-390.

Germida, J., and Janzen, H. (1993). Factors affecting the oxidation of elemental sulfur in soils. *Fertilizer research* **35**, 101-114.

Goldberg, S., and Sposito, G. (1984). A Chemical Model of Phosphate Adsorption by Soils: I. Reference Oxide Minerals1. *Soil Science Society of America Journal* **48**, 772-778.

Gustafsson, J. P., Mwamila, L. B., and Kergoat, K. (2012). The pH dependence of phosphate sorption and desorption in Swedish agricultural soils. *Geoderma* **189–190**, 304-311.

Havlin, J. L., Beaton, J. D., Tisdale, S. L., and Nelson, W. L. (2005). "Soil fertility and fertilizers: An introduction to nutrient management," Pearson Prentice Hall Upper Saddle River, NJ.

Heckenmüller, M., Narita, D., and Klepper, G. (2014). "Global availability of phosphorus and its implications for global food supply: An economic overview." Kiel Working Paper.

Hooda, P., Rendell, A., Edwards, A., Withers, P., Aitken, M., and Truesdale, V. (2000). Relating soil phosphorus indices to potential phosphorus release to water. *Journal of Environmental Quality* **29**, 1166-1171.

Igual, J. M., Valverde, A., Cervantes, E., and Velázquez, E. (2001). Phosphate-solubilizing bacteria as inoculants for agriculture: use of updated molecular techniques in their study. *Agronomie* **21**, 561-568.

Illmer, P., and Schinner, F. (1995). Solubilization of inorganic calcium phosphates—Solubilization mechanisms. *Soil Biology and Biochemistry* **27**, 257-263.

Jaggi, R., Aulakh, M., and Sharma, R. (2005). Impacts of elemental S applied under various temperature and moisture regimes on pH and available P in acidic, neutral and alkaline soils. *Biology and Fertility of Soils* **41**, 52-58.

Jarvie, H. P., Sharpley, A. N., Spears, B., Buda, A. R., May, L., and Kleinman, P. J. A. (2013). Water Quality Remediation Faces Unprecedented Challenges from "Legacy Phosphorus". *Environmental Science & Technology* **47**, 8997-8998.

Jones, D. (1998). Organic acids in the rhizosphere – a critical review. *Plant and Soil* **205**, 25-44.

Jones, D., Dennis, P., Owen, A., and Van Hees, P. (2003). Organic acid behavior in soils–misconceptions and knowledge gaps. *Plant and Soil* **248**, 31-41.

Khademi, Z., Jones, D. L., Malakouti, M. J., and Asadi, F. (2010). Organic acids differ in enhancing phosphorus uptake by Triticum aestivum L.—effects of rhizosphere concentration and counterion. *Plant and Soil* **334**, 151-159.

Koerselman, W., Van Kerkhoven, M. B., and Verhoeven, J. T. (1993). Release of inorganic N, P and K in peat soils; effect of temperature, water chemistry and water level. *Biogeochemistry* **20**, 63-81.

Krol, M., Kobus, J., and Maziarczyk, B. (1986). Biological and chemical changes occurring in different soils under the influence of elementary sulphur application. *Pam. Pu³* **88**, 39-55.

Lamers, L. P., Tomassen, H. B., and Roelofs, J. G. (1998). Sulfate-induced eutrophication and phytotoxicity in freshwater wetlands. *Environmental Science & Technology* **32**, 199-205.

Lindsay, W. L. (1979). "Chemical equilibria in soils," John Wiley and Sons Ltd.

Maguire, R., and Sims, J. (2002). Measuring agronomic and environmental soil phosphorus saturation and predicting phosphorus leaching with Mehlich 3. *Soil Science Society of America Journal* **66**, 2033-2039.

Manna, M. C., Ghosh, P. K., Ghosh, B. N., and Singh, K. N. (2001). Comparative effectiveness of phosphate-enriched compost and single superphosphate on yield, uptake of nutrients and soil quality under soybean–wheat rotation. *The Journal of Agricultural Science* **137**, 45-54.

Motowicka-Terelak, T., and Terelak, H. (1998). "Siarka w glebach Polski: stan i zagrożenie," Państwowa Inspekcja Ochrony Środowiska.

Mullins, G. L. (2009). "Phosphorus, agriculture & the environment," Department of Crop and Soil Environmental Sciences, Virginia State University, Virginia.

Murphy, J., and Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* **27**, 31-36.

Parks, E. J., Olson, G. J., Brinckman, F. E., and Baldi, F. (1990). Characterization by high performance liquid chromatography (HPLC) of the solubilization of phosphorus in iron ore by a fungus. *Journal of industrial microbiology* **5**, 183-189.

Pierzynski, G. M. (1991). The chemistry and mineralogy of phosphorus in excessively fertilized soils. *Critical Reviews in Environmental Science and Technology* **21**, 265-295.

Pierzynski, G. M., McDowell, R. W., Sims, J., and Sharpley, A. (2005a). Chemistry, cycling, and potential movement of inorganic phosphorus in soils. *Phosphorus: Agriculture and the environment*, 53-86.

Pierzynski, G. M., Vance, G. F., and Sims, J. T. (2005b). "Soils and environmental quality," CRC press.

Pulz, A. L., Crusciol, C. A. C., Lemos, L. B., and Soratto, R. P. (2008). Influência de silicato e calcário na nutrição, produtividade e qualidade da batata sob deficiência hídrica. *Revista Brasileira de Ciência do Solo* **32**, 1651-1659.

Pypers, P., Delrue, J., Diels, J., Smolders, E., and Merckx, R. (2006). Phosphorus intensity determines short-term P uptake by pigeon pea (Cajanus cajan L.) grown in soils with differing P buffering capacity. *Plant and soil* **284**, 217-227.

Renneson, M., Vandenberghe, C., Marcoen, J. M., Bock, L., and Colinet, G. (2010). Study of the relevance of phosphorus saturation in Walloon Region (Southern Belgium). *In* "Proceedings of the 19th World Congress of Soil Science; Soil Solutions for a changing World". IUSS.

Roy, A. C., Ali, M. Y., Fox, R. L., and Silva, J. A. (1971). Influence of calcium silicate on phosphate solubility and availability in Hawaiian latosols. *In* "Symposium on soil fertility and evaluation", pp. 756-765.

Sandim, A. d. S., Büll, L. T., Furim, A. R., Lima, G. d. S., and Garcia, J. L. N. (2014). Phosphorus availability in oxidic soils treated with lime and silicate applications. *Revista Brasileira de Ciência do Solo* **38**, 1215-1222.

Schoumans, O., and Groenendijk, P. (2000). Modeling soil phosphorus levels and phosphorus leaching from agricultural land in the Netherlands. *Journal of Environmental Quality* **29**, 111-116.

Schoumans, O. F., Bouraoui, F., Kabbe, C., Oenema, O., and van Dijk, K. C. (2015). Phosphorus management in Europe in a changing world. *Ambio* **44**, 180-192.

Sharma, N. C., Starnes, D. L., and Sahi, S. V. (2007). Phytoextraction of excess soil phosphorus. *Environmental Pollution* **146**, 120-127.

Sharpley, A. N. (1995). Soil phosphorus dynamics: agronomic and environmental impacts. *Ecological Engineering* **5**, 261-279.

Shenoy, V. V., and Kalagudi, G. M. (2005). Enhancing plant phosphorus use efficiency for sustainable cropping. *Biotechnology Advances* **23**, 501-513.

Skwierawska, M., and Zawartka, L. (2009). Effect of different rates and forms of sulphur on content of available phosphorus in soil. *Journal of Elementology* **14**.

Smyth, T. J., and Sanchez, P. A. (1980). Effects of lime, silicate, and phosphorus applications to an Oxisol on phosphorus sorption and ion retention. *Soil Science Society of America Journal* **44**, 500-505.

Spohn, M., and Kuzyakov, Y. (2013). Phosphorus mineralization can be driven by microbial need for carbon. *Soil Biology and Biochemistry* **61**, 69-75.

Stevenson, F. J., and Cole, M. A. (1999). "Cycles of soils: carbon, nitrogen, phosphorus, sulfur, micronutrients," John Wiley & Sons.

Strobel, B. W. (2001). Influence of vegetation on low-molecular-weight carboxylic acids in soil solution—a review. *Geoderma* **99**, 169-198.

Sylvain, P., and Thomas, N. (2013). Why do we have to increase P use efficiency and recycling in cropping systems? *In* "NUTRIHORT: Nutrient management, innovative techniques and nutrient legislation in intensive horticulture for an improved water quality" (B. V. Karoline D'Haene, Raf De Vis, Sara Crappé, Danny Callens, Els Mechant, Georges Hofman, Stefaan De Neve, ed.), pp. 111-115, Ghent, Belgium.

Tisdale, S. L., Nelson, W. L., and Beaton, J. D. (1985). "Soil fertility and fertilizers," Collier Macmillan Publishers.

Trivedi, P., and Sa, T. (2008). Pseudomonas corrugata (NRRL B-30409) mutants increased phosphate solubilization, organic acid production, and plant growth at lower temperatures. *Current microbiology* **56**, 140-144.

Turner, B. L., Cade-Menun, B. J., Condron, L. M., and Newman, S. (2005). Extraction of soil organic phosphorus. *Talanta* **66**, 294-306.

Van der Zee, S. E., and Van Riemsdijk, W. H. (1988). Model for long-term phosphate reaction kinetics in soil. *Journal of Environmental Quality* **17**, 35-41.

Van der Zee, S. E. A. T. M., Van Riemsdijk, W.H. & De Haan, F.A.M. (1990). "The protocol of phosphate saturated soils Part I," Faculty of agriculture, Wageningen, The Netherlands.

Van Meirvenne, M., Tariku, M., De Neve, S., Hofman, G., Salomez, J., and De Bolle, S. (2008). Afbakening van de fosfaatverzadigde gebieden in Vlaanderen op basis van een kritische fosfaatverzadigingsgraad van 35%. *Ghent University, Ghent*.

Van Raij, B. (1998). Bioavailable tests: alternatives to standard soil extractions. *Communications in Soil Science & Plant Analysis* **29**, 1553-1570.
Van Rotterdam-Los, D., Reijneveld, A., van Oostrum, M., Abbink, G., and Bussink, W. (2013). A more turstworthy P recommendation by implementing the intesnity, buffering capacity, quantity concent into agricultural practice. *In* "NUTRIHORT: Nutrient management, innovative techniques and nutrient legislation in intensive horticulture for an improved water quality. " (B. V. Karoline D'Haene, Raf De Vis, Sara Crappé, Danny Callens, Els Mechant, Georges Hofman, Stefaan De Neve, ed.), pp. 136-141, Ghent, Belgium.
Van Steertegem, M. (2012). MIRA indicatorrapport 2011. *Milieurapport Vlaanderen, Vlaamse Milieumaatschappij, Aalst, Belgium*.
Vazquez, P., Holguín, G., Puente, M., Lopez-Cortes, A., and Bashan, Y. (2000). Phosphate-solubilizing microorganisms associated with the rhizosphere of mangroves in a semiarid coastal lagoon. *Biology and Fertility of Soils* **30**, 460-468.
VLM (1997). Phosphate saturation of sandy acid soil in Flanders. *Vlaamse Landmaatschappij, Brussels*.
VLM (2007). Afbakening van de fosfaatverzadigde gebieden in Vlaanderen op basis van een kritische fosfaatverzadigingsgraad van 35%. *Vlaamse Land Maatschappij*.
Walkley, A., and Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science* **37**, 29-38.
Wei, L. L., Chen, C. R., and Xu, Z. H. (2009). The effect of low-molecular-weight organic acids and inorganic phosphorus concentration on the determination of soil phosphorus by the molybdenum blue reaction. *Biology and Fertility of Soils* **45**, 775-779.
White, R. E. (2013). "Principles and practice of soil science: the soil as a natural resource," John Wiley & Sons.
Yadav, K., and Singh, T. (1991). Phosphorus solubilization of microbial isolate from a calcifluvent. *Journal of the Indian Society of Soil Science* **39**, 89-93.

Annex

ANOVA analysis of shaking experiment

Tests of Between-Subjects Effects

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14005,818[a]	35	400,166	278,570	,000
Intercept	11476,432	1	11476,432	7989,158	,000
sites	25,244	1	25,244	17,574	,000
amendments	8959,709	5	1791,942	1247,435	,000
concentration	2109,498	2	1054,749	734,249	,000
sites * amendments	150,917	5	30,183	21,012	,000
sites * concentration	11,709	2	5,854	4,076	,021
amendments * concentration	2737,099	10	273,710	190,539	,000
sites * amendments * concentration	11,643	10	1,164	,811	,619
Error	103,428	72	1,437		
Total	25585,679	108			
Corrected Total	14109,246	107			

a. R Squared = ,993 (Adjusted R Squared = ,989)

Tests of Between-Subjects Effects

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	13994,175[a]	25	559,767	398,891	,000
Intercept	11476,432	1	11476,432	8178,128	,000
sites * amendments	150,917	5	30,183	21,509	,000
amendments * concentration	2737,099	10	273,710	195,046	,000
sites * concentration	11,709	2	5,854	4,172	,019
sites	25,244	1	25,244	17,989	,000
amendments	8959,709	5	1791,942	1276,941	,000
concentration	2109,498	2	1054,749	751,616	,000
Error	115,071	82	1,403		
Total	25585,679	108			
Corrected Total	14109,246	107			

a. R Squared = ,992 (Adjusted R Squared = ,989)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6696,146[b]	17	393,891	242,283	,000
Intercept	5212,586	1	5212,586	3206,265	,000
amendments	4192,143	5	838,429	515,718	,000
concentration	1140,420	2	570,210	350,737	,000
amendments * concentration	1363,584	10	136,358	83,874	,000
Error	58,527	36	1,626		
Total	11967,259	54			
Corrected Total	6754,673	53			

a. sites = E13.0130

b. R Squared = ,991 (Adjusted R Squared = ,987)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7284,428[b]	17	428,496	343,552	,000
Intercept	6289,091	1	6289,091	5042,359	,000
amendments	4918,482	5	983,696	788,691	,000
concentration	980,787	2	490,393	393,179	,000
amendments * concentration	1385,158	10	138,516	111,057	,000
Error	44,901	36	1,247		
Total	13618,419	54			
Corrected Total	7329,329	53			

a. sites = Van Oeckel
b. R Squared = ,994 (Adjusted R Squared = ,991)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,928[b]	2	,464	23,221	,001
Intercept	3,330	1	3,330	166,572	,000
concentration	,928	2	,464	23,221	,001
Error	,120	6	,020		
Total	4,379	9			
Corrected Total	1,048	8			

a. sites = E13.0130, amendments = calcium chloride
b. R Squared = ,886 (Adjusted R Squared = ,847)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1542,154[b]	2	771,077	163,318	,000
Intercept	3927,702	1	3927,702	831,907	,000
concentration	1542,154	2	771,077	163,318	,000
Error	28,328	6	4,721		
Total	5498,184	9			
Corrected Total	1570,482	8			

a. sites = E13.0130, amendments = citric acid
b. R Squared = ,982 (Adjusted R Squared = ,976)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,295[b]	2	,648	2,269	,185
Intercept	9,938	1	9,938	34,814	,001
concentration	1,295	2	,648	2,269	,185
Error	1,713	6	,285		
Total	12,946	9			
Corrected Total	3,008	8			

a. sites = E13.0130, amendments = lactic acid
b. R Squared = ,431 (Adjusted R Squared = ,241)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	535,320[b]	2	267,660	81,845	,000
Intercept	2066,813	1	2066,813	631,987	,000
concentration	535,320	2	267,660	81,845	,000
Error	19,622	6	3,270		
Total	2621,754	9			
Corrected Total	554,942	8			

a. sites = E13.0130, amendments = oxalic acid

b. R Squared = ,965 (Adjusted R Squared = ,953)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	423,018[b]	2	211,509	152,167	,000
Intercept	3364,025	1	3364,025	2420,198	,000
concentration	423,018	2	211,509	152,167	,000
Error	8,340	6	1,390		
Total	3795,382	9			
Corrected Total	431,358	8			

a. sites = E13.0130, amendments = sodium silicate

b. R Squared = ,981 (Adjusted R Squared = ,974)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,288[b]	2	,644	9,557	,014
Intercept	32,921	1	32,921	488,399	,000
concentration	1,288	2	,644	9,557	,014
Error	,404	6	,067		
Total	34,614	9			
Corrected Total	1,693	8			

a. sites = E13.0130, amendments = sodium sulphate

b. R Squared = ,761 (Adjusted R Squared = ,681)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,782[b]	2	,391	21,658	,002
Intercept	6,652	1	6,652	368,353	,000
concentration	,782	2	,391	21,658	,002
Error	,108	6	,018		
Total	7,543	9			
Corrected Total	,891	8			

a. sites = Van Oeckel, amendments = calcium chloride

b. R Squared = ,878 (Adjusted R Squared = ,838)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1572,017[b]	2	786,009	273,051	,000
Intercept	3967,053	1	3967,053	1378,112	,000
concentration	1572,017	2	786,009	273,051	,000
Error	17,272	6	2,879		
Total	5556,342	9			
Corrected Total	1589,289	8			

a. sites = Van Oeckel, amendments = citric acid
b. R Squared = ,989 (Adjusted R Squared = ,986)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,756[b]	2	,878	9,724	,013
Intercept	40,973	1	40,973	453,918	,000
concentration	1,756	2	,878	9,724	,013
Error	,542	6	,090		
Total	43,270	9			
Corrected Total	2,297	8			

a. sites = Van Oeckel, amendments = lactic acid
b. R Squared = ,764 (Adjusted R Squared = ,686)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	375,614[b]	2	187,807	77,102	,000
Intercept	1500,083	1	1500,083	615,840	,000
concentration	375,614	2	187,807	77,102	,000
Error	14,615	6	2,436		
Total	1890,312	9			
Corrected Total	390,229	8			

a. sites = Van Oeckel, amendments = oxalic acid
b. R Squared = ,963 (Adjusted R Squared = ,950)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	415,736[b]	2	207,868	103,869	,000
Intercept	5618,868	1	5618,868	2807,692	,000
concentration	415,736	2	207,868	103,869	,000
Error	12,007	6	2,001		
Total	6046,611	9			
Corrected Total	427,743	8			

a. sites = Van Oeckel, amendments = sodium silicate
b. R Squared = ,972 (Adjusted R Squared = ,963)

Tests of Between-Subjects Effects[a]

Dependent Variable: P (mg/kg soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,041[b]	2	,020	,343	,722
Intercept	73,944	1	73,944	1242,820	,000
concentration	,041	2	,020	,343	,722
Error	,357	6	,059		
Total	74,342	9			
Corrected Total	,398	8			

a. sites = Van Oeckel, amendments = sodium sulphate

b. R Squared = ,103 (Adjusted R Squared = -,196)

Post hoc analysis of amount of P (mg p/kg dry soil) and concentration for each sites

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)

Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
,5	1,0	-6,1903*	1,77413	,030	-11,6339	-,7468
	2,0	-30,3410*	1,77413	,000	-35,7846	-24,8975
1,0	,5	6,1903*	1,77413	,030	,7468	11,6339
	2,0	-24,1507*	1,77413	,000	-29,5942	-18,7072
2,0	,5	30,3410*	1,77413	,000	24,8975	35,7846
	1,0	24,1507*	1,77413	,000	18,7072	29,5942

Based on observed means.

The error term is Mean Square(Error) = 4,721.

*. The mean difference is significant at the 0,05 level.

a. sites = E13.0130, amendments = citric acid

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)

Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
,5	1,0	-,5392	,43624	,477	-1,8777	,7993
	2,0	-,9251	,43624	,166	-2,2636	,4134
1,0	,5	,5392	,43624	,477	-,7993	1,8777
	2,0	-,3858	,43624	,669	-1,7243	,9527
2,0	,5	,9251	,43624	,166	-,4134	2,2636
	1,0	,3858	,43624	,669	-,9527	1,7243

Based on observed means.

The error term is Mean Square(Error) = ,285.

a. sites = E13.0130, amendments = lactic acid

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
,5	1,0	4,7951*	1,47656	,040	,2646	9,3256
	2,0	-13,4270*	1,47656	,000	-17,9575	-8,8965
1,0	,5	-4,7951*	1,47656	,040	-9,3256	-,2646
	2,0	-18,2221*	1,47656	,000	-22,7525	-13,6916
2,0	,5	13,4270*	1,47656	,000	8,8965	17,9575
	1,0	18,2221*	1,47656	,000	13,6916	22,7525

Based on observed means.
The error term is Mean Square(Error) = 3,270.
*. The mean difference is significant at the 0,05 level.
a. sites = E13.0130, amendments = oxalic acid

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
,5	1,0	-4,7928*	,96263	,006	-7,7464	-1,8392
	2,0	-16,3349*	,96263	,000	-19,2885	-13,3813
1,0	,5	4,7928*	,96263	,006	1,8392	7,7464
	2,0	-11,5421*	,96263	,000	-14,4957	-8,5885
2,0	,5	16,3349*	,96263	,000	13,3813	19,2885
	1,0	11,5421*	,96263	,000	8,5885	14,4957

Based on observed means.
The error term is Mean Square(Error) = 1,390.
*. The mean difference is significant at the 0,05 level.
a. sites = E13.0130, amendments = sodium silicate

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
,5	1,0	,3288	,21199	,335	-,3217	,9792
	2,0	-,5860	,21199	,073	-1,2364	,0644
1,0	,5	-,3288	,21199	,335	-,9792	,3217
	2,0	-,9148*	,21199	,012	-1,5652	-,2644
2,0	,5	,5860	,21199	,073	-,0644	1,2364
	1,0	,9148*	,21199	,012	,2644	1,5652

Based on observed means.
The error term is Mean Square(Error) = ,067.
*. The mean difference is significant at the 0,05 level.
a. sites = E13.0130, amendments = sodium sulphate

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
,5	1,0	-6,9320*	1,38531	,006	-11,1825	-2,6815
	2,0	-30,8516*	1,38531	,000	-35,1021	-26,6011
1,0	,5	6,9320*	1,38531	,006	2,6815	11,1825
	2,0	-23,9196*	1,38531	,000	-28,1701	-19,6691
2,0	,5	30,8516*	1,38531	,000	26,6011	35,1021
	1,0	23,9196*	1,38531	,000	19,6691	28,1701

Based on observed means.
The error term is Mean Square(Error) = 2,879.
*. The mean difference is significant at the 0,05 level.
a. sites = Van Oeckel, amendments = citric acid

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
,5	1,0	-1,0671*	,24531	,011	-1,8197	-,3144
	2,0	-,3793	,24531	,337	-1,1319	,3734
1,0	,5	1,0671*	,24531	,011	,3144	1,8197
	2,0	,6878	,24531	,069	-,0649	1,4405
2,0	,5	,3793	,24531	,337	-,3734	1,1319
	1,0	-,6878	,24531	,069	-1,4405	,0649

Based on observed means.
The error term is Mean Square(Error) = ,090.
*. The mean difference is significant at the 0,05 level.
a. sites = Van Oeckel, amendments = lactic acid

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
,5	1,0	2,7943	1,27432	,151	-1,1157	6,7043
	2,0	-12,0918*	1,27432	,000	-16,0017	-8,1818
1,0	,5	-2,7943	1,27432	,151	-6,7043	1,1157
	2,0	-14,8861*	1,27432	,000	-18,7960	-10,9761
2,0	,5	12,0918*	1,27432	,000	8,1818	16,0017
	1,0	14,8861*	1,27432	,000	10,9761	18,7960

Based on observed means.
The error term is Mean Square(Error) = 2,436.
*. The mean difference is significant at the 0,05 level.
a. sites = Van Oeckel, amendments = oxalic acid

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
,5	1,0	-8,5495*	1,15506	,001	-12,0936	-5,0055
	2,0	-16,6460*	1,15506	,000	-20,1900	-13,1019
1,0	,5	8,5495*	1,15506	,001	5,0055	12,0936
	2,0	-8,0965*	1,15506	,001	-11,6405	-4,5524
2,0	,5	16,6460*	1,15506	,000	13,1019	20,1900
	1,0	8,0965*	1,15506	,001	4,5524	11,6405

Based on observed means.
The error term is Mean Square(Error) = 2,001.
*. The mean difference is significant at the 0,05 level.
a. sites = Van Oeckel, amendments = sodium silicate

Multiple Comparisons[a]

Dependent Variable: P (mg/kg soil)
Tukey HSD

(I) concentration (mM)	(J) concentration (mM)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
,5	1,0	-,1049	,19916	,861	-,7160	,5062
	2,0	-,1628	,19916	,707	-,7739	,4483
1,0	,5	,1049	,19916	,861	-,5062	,7160
	2,0	-,0579	,19916	,955	-,6690	,5532
2,0	,5	,1628	,19916	,707	-,4483	,7739
	1,0	,0579	,19916	,955	-,5532	,6690

Based on observed means.
The error term is Mean Square(Error) = ,059.
a. sites = Van Oeckel, amendments = sodium sulphate

ANOVA analysis for data splitted according to sites and concentration

Tests of Between-Subjects Effects[a]

Dependent Variable: Amount of P (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	406,734[b]	5	81,347	27,293	,000
Intercept	620,123	1	620,123	208,057	,000
amendments	406,734	5	81,347	27,293	,000
Error	35,767	12	2,981		
Total	1062,624	18			
Corrected Total	442,501	17			

a. site = E13.0130, concentration = ,5
b. R Squared = ,919 (Adjusted R Squared = ,885)

Tests of Between-Subjects Effects[a]

Dependent Variable: Amount of P (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	762,600[b]	5	152,520	45,069	,000
Intercept	836,972	1	836,972	247,319	,000
amendments	762,600	5	152,520	45,069	,000
Error	40,610	12	3,384		
Total	1640,182	18			
Corrected Total	803,210	17			

a. site = E13.0130, concentration = 1,0

b. R Squared = ,949 (Adjusted R Squared = ,928)

Tests of Between-Subjects Effects[a]

Dependent Variable: Amount of P (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3989,852[b]	5	797,970	128,595	,000
Intercept	4556,279	1	4556,279	734,257	,000
amendments	3989,852	5	797,970	128,595	,000
Error	74,463	12	6,205		
Total	8620,594	18			
Corrected Total	4064,316	17			

a. site = E13.0130, concentration = 2,0

b. R Squared = ,982 (Adjusted R Squared = ,974)

Tests of Between-Subjects Effects[a]

Dependent Variable: Amount of P (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	542,266[b]	5	108,453	63,076	,000
Intercept	819,816	1	819,816	476,805	,000
amendments	542,266	5	108,453	63,076	,000
Error	20,633	12	1,719		
Total	1382,715	18			
Corrected Total	562,899	17			

a. site = Van Oeckel, concentration = ,5

b. R Squared = ,963 (Adjusted R Squared = ,948)

Tests of Between-Subjects Effects[a]

Dependent Variable: Amount of P (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1218,387[b]	5	243,677	89,767	,000
Intercept	1360,896	1	1360,896	501,332	,000
amendments	1218,387	5	243,677	89,767	,000
Error	32,575	12	2,715		
Total	2611,858	18			
Corrected Total	1250,962	17			

a. site = Van Oeckel, concentration = 1,0

b. R Squared = ,974 (Adjusted R Squared = ,963)

Tests of Between-Subjects Effects[a]

Dependent Variable: Amount of P (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4347,931[b]	5	869,586	186,719	,000
Intercept	4795,319	1	4795,319	1029,658	,000
amendments	4347,931	5	869,586	186,719	,000
Error	55,886	12	4,657		
Total	9199,136	18			
Corrected Total	4403,817	17			

a. site = Van Oeckel, concentration = 2,0

b. R Squared = ,987 (Adjusted R Squared = ,982)

Post Hoc analysis

Multiple Comparisons[a]

Dependent Variable: Amount of P (mg P/kg dry soil)

Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
calcium chloride	citric acid	-7,6764*	1,40962	,002	-12,4112	-2,9416
	lactic acid	,4743	1,40962	,999	-4,2606	5,2091
	oxalic acid	-9,4145*	1,40962	,000	-14,1493	-4,6797
	sodium silicate	-11,2539*	1,40962	,000	-15,9887	-6,5191
	sodium sulphate	-1,1248	1,40962	,962	-5,8596	3,6100
citric acid	calcium chloride	7,6764*	1,40962	,002	2,9416	12,4112
	lactic acid	8,1506*	1,40962	,001	3,4158	12,8854
	oxalic acid	-1,7381	1,40962	,813	-6,4729	2,9967
	sodium silicate	-3,5775	1,40962	,187	-8,3123	1,1573
	sodium sulphate	6,5516*	1,40962	,006	1,8168	11,2864
lactic acid	calcium chloride	-,4743	1,40962	,999	-5,2091	4,2606
	citric acid	-8,1506*	1,40962	,001	-12,8854	-3,4158
	oxalic acid	-9,8888*	1,40962	,000	-14,6236	-5,1540
	sodium silicate	-11,7281*	1,40962	,000	-16,4629	-6,9933
	sodium sulphate	-1,5991	1,40962	,858	-6,3339	3,1357
oxalic acid	calcium chloride	9,4145*	1,40962	,000	4,6797	14,1493
	citric acid	1,7381	1,40962	,813	-2,9967	6,4729
	lactic acid	9,8888*	1,40962	,000	5,1540	14,6236
	sodium silicate	-1,8394	1,40962	,777	-6,5742	2,8954
	sodium sulphate	8,2897*	1,40962	,001	3,5549	13,0245
sodium silicate	calcium chloride	11,2539*	1,40962	,000	6,5191	15,9887
	citric acid	3,5775	1,40962	,187	-1,1573	8,3123
	lactic acid	11,7281*	1,40962	,000	6,9933	16,4629
	oxalic acid	1,8394	1,40962	,777	-2,8954	6,5742
	sodium sulphate	10,1291*	1,40962	,000	5,3943	14,8639
sodium sulphate	calcium chloride	1,1248	1,40962	,962	-3,6100	5,8596
	citric acid	-6,5516*	1,40962	,006	-11,2864	-1,8168
	lactic acid	1,5991	1,40962	,858	-3,1357	6,3339
	oxalic acid	-8,2897*	1,40962	,001	-13,0245	-3,5549
	sodium silicate	-10,1291*	1,40962	,000	-14,8639	-5,3943

Based on observed means.

The error term is Mean Square(Error) = 2,981.

*. The mean difference is significant at the 0,05 level.

a. site = E13.0130, concentration = ,5

Multiple Comparisons[a]

Dependent Variable: Amount of P (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
calcium chloride	citric acid	-13,2208*	1,50204	,000	-18,2660	-8,1756
	lactic acid	-,8381	1,50204	,992	-5,8833	4,2071
	oxalic acid	-7,2178*	1,50204	,004	-12,2631	-2,1726
	sodium silicate	-16,8198*	1,50204	,000	-21,8650	-11,7746
	sodium sulphate	-1,2342	1,50204	,958	-6,2794	3,8110
citric acid	calcium chloride	13,2208*	1,50204	,000	8,1756	18,2660
	lactic acid	12,3827*	1,50204	,000	7,3375	17,4279
	oxalic acid	6,0030*	1,50204	,017	,9577	11,0482
	sodium silicate	-3,5990	1,50204	,231	-8,6442	1,4462
	sodium sulphate	11,9866*	1,50204	,000	6,9414	17,0318
lactic acid	calcium chloride	,8381	1,50204	,992	-4,2071	5,8833
	citric acid	-12,3827*	1,50204	,000	-17,4279	-7,3375
	oxalic acid	-6,3797*	1,50204	,011	-11,4250	-1,3345
	sodium silicate	-15,9817*	1,50204	,000	-21,0269	-10,9365
	sodium sulphate	-,3961	1,50204	1,000	-5,4413	4,6491
oxalic acid	calcium chloride	7,2178*	1,50204	,004	2,1726	12,2631
	citric acid	-6,0030*	1,50204	,017	-11,0482	-,9577
	lactic acid	6,3797*	1,50204	,011	1,3345	11,4250
	sodium silicate	-9,6020*	1,50204	,000	-14,6472	-4,5567
	sodium sulphate	5,9836*	1,50204	,017	,9384	11,0289
sodium silicate	calcium chloride	16,8198*	1,50204	,000	11,7746	21,8650
	citric acid	3,5990	1,50204	,231	-1,4462	8,6442
	lactic acid	15,9817*	1,50204	,000	10,9365	21,0269
	oxalic acid	9,6020*	1,50204	,000	4,5567	14,6472
	sodium sulphate	15,5856*	1,50204	,000	10,5404	20,6308
sodium sulphate	calcium chloride	1,2342	1,50204	,958	-3,8110	6,2794
	citric acid	-11,9866*	1,50204	,000	-17,0318	-6,9414
	lactic acid	,3961	1,50204	1,000	-4,6491	5,4413
	oxalic acid	-5,9836*	1,50204	,017	-11,0289	-,9384
	sodium silicate	-15,5856*	1,50204	,000	-20,6308	-10,5404

Based on observed means.
The error term is Mean Square(Error) = 3,384.
*. The mean difference is significant at the 0,05 level.
a. site = E13.0130, concentration = 1,0

Multiple Comparisons[a]

Dependent Variable: Amount of P (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
calcium chloride	citric acid	-38,0988*	2,03393	,000	-44,9306	-31,2670
	lactic acid	-1,4767	2,03393	,975	-8,3085	5,3551
	oxalic acid	-25,1797*	2,03393	,000	-32,0115	-18,3479
	sodium silicate	-25,6715*	2,03393	,000	-32,5033	-18,8397
	sodium sulphate	-1,8888	2,03393	,931	-8,7206	4,9430
citric acid	calcium chloride	38,0988*	2,03393	,000	31,2670	44,9306
	lactic acid	36,6221*	2,03393	,000	29,7903	43,4539
	oxalic acid	12,9191*	2,03393	,000	6,0873	19,7509

	sodium silicate	12,4272*	2,03393	,001	5,5954	19,2590
	sodium sulphate	36,2100*	2,03393	,000	29,3782	43,0418
lactic acid	calcium chloride	1,4767	2,03393	,975	-5,3551	8,3085
	citric acid	-36,6221*	2,03393	,000	-43,4539	-29,7903
	oxalic acid	-23,7030*	2,03393	,000	-30,5348	-16,8712
	sodium silicate	-24,1949*	2,03393	,000	-31,0267	-17,3631
	sodium sulphate	-,4121	2,03393	1,000	-7,2439	6,4197
oxalic acid	calcium chloride	25,1797*	2,03393	,000	18,3479	32,0115
	citric acid	-12,9191*	2,03393	,000	-19,7509	-6,0873
	lactic acid	23,7030*	2,03393	,000	16,8712	30,5348
	sodium silicate	-,4918	2,03393	1,000	-7,3236	6,3400
	sodium sulphate	23,2909*	2,03393	,000	16,4591	30,1227
sodium silicate	calcium chloride	25,6715*	2,03393	,000	18,8397	32,5033
	citric acid	-12,4272*	2,03393	,001	-19,2590	-5,5954
	lactic acid	24,1949*	2,03393	,000	17,3631	31,0267
	oxalic acid	,4918	2,03393	1,000	-6,3400	7,3236
	sodium sulphate	23,7827*	2,03393	,000	16,9509	30,6145
sodium sulphate	calcium chloride	1,8888	2,03393	,931	-4,9430	8,7206
	citric acid	-36,2100*	2,03393	,000	-43,0418	-29,3782
	lactic acid	,4121	2,03393	1,000	-6,4197	7,2439
	oxalic acid	-23,2909*	2,03393	,000	-30,1227	-16,4591
	sodium silicate	-23,7827*	2,03393	,000	-30,6145	-16,9509

Based on observed means.
The error term is Mean Square(Error) = 6,205.
*. The mean difference is significant at the 0,05 level.
a. site = E13.0130, concentration = 2,0

Multiple Comparisons[a]

Dependent Variable: Amount of P (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
calcium chloride	citric acid	-7,1370*	1,07064	,000	-10,7332	-3,5408
	lactic acid	-,3877	1,07064	,999	-3,9839	3,2084
	oxalic acid	-8,5473*	1,07064	,000	-12,1435	-4,9511
	sodium silicate	-15,3240*	1,07064	,000	-18,9202	-11,7279
	sodium sulphate	-1,5133	1,07064	,719	-5,1095	2,0829
citric acid	calcium chloride	7,1370*	1,07064	,000	3,5408	10,7332
	lactic acid	6,7493*	1,07064	,000	3,1531	10,3455
	oxalic acid	-1,4103	1,07064	,771	-5,0065	2,1859
	sodium silicate	-8,1870*	1,07064	,000	-11,7832	-4,5908
	sodium sulphate	5,6237*	1,07064	,002	2,0275	9,2199
lactic acid	calcium chloride	,3877	1,07064	,999	-3,2084	3,9839
	citric acid	-6,7493*	1,07064	,000	-10,3455	-3,1531
	oxalic acid	-8,1596*	1,07064	,000	-11,7558	-4,5634
	sodium silicate	-14,9363*	1,07064	,000	-18,5325	-11,3401
	sodium sulphate	-1,1256	1,07064	,891	-4,7217	2,4706
oxalic acid	calcium chloride	8,5473*	1,07064	,000	4,9511	12,1435
	citric acid	1,4103	1,07064	,771	-2,1859	5,0065
	lactic acid	8,1596*	1,07064	,000	4,5634	11,7558
	sodium silicate	-6,7767*	1,07064	,000	-10,3729	-3,1805
	sodium sulphate	7,0340*	1,07064	,000	3,4378	10,6302
sodium silicate	calcium chloride	15,3240*	1,07064	,000	11,7279	18,9202
	citric acid	8,1870*	1,07064	,000	4,5908	11,7832
	lactic acid	14,9363*	1,07064	,000	11,3401	18,5325
	oxalic acid	6,7767*	1,07064	,000	3,1805	10,3729
	sodium sulphate	13,8107*	1,07064	,000	10,2146	17,4069

sodium sulphate	calcium chloride	1,5133	1,07064	,719	-2,0829	5,1095
	citric acid	-5,6237*	1,07064	,002	-9,2199	-2,0275
	lactic acid	1,1256	1,07064	,891	-2,4706	4,7217
	oxalic acid	-7,0340*	1,07064	,000	-10,6302	-3,4378
	sodium silicate	-13,8107*	1,07064	,000	-17,4069	-10,2146

Based on observed means.
The error term is Mean Square(Error) = 1,719.
*. The mean difference is significant at the 0,05 level.
a. site = Van Oeckel, concentration = ,5

Multiple Comparisons[a]

Dependent Variable: Amount of P (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
calcium chloride	citric acid	-14,7635*	1,34525	,000	-19,2821	-10,2449
	lactic acid	-2,1498	1,34525	,615	-6,6684	2,3688
	oxalic acid	-6,4480*	1,34525	,005	-10,9666	-1,9294
	sodium silicate	-23,0833*	1,34525	,000	-27,6019	-18,5647
	sodium sulphate	-2,3132	1,34525	,545	-6,8318	2,2054
citric acid	calcium chloride	14,7635*	1,34525	,000	10,2449	19,2821
	lactic acid	12,6137*	1,34525	,000	8,0951	17,1323
	oxalic acid	8,3155*	1,34525	,001	3,7969	12,8341
	sodium silicate	-8,3198*	1,34525	,001	-12,8384	-3,8012
	sodium sulphate	12,4503*	1,34525	,000	7,9317	16,9689
lactic acid	calcium chloride	2,1498	1,34525	,615	-2,3688	6,6684
	citric acid	-12,6137*	1,34525	,000	-17,1323	-8,0951
	oxalic acid	-4,2982	1,34525	,066	-8,8168	,2204
	sodium silicate	-20,9335*	1,34525	,000	-25,4521	-16,4149
	sodium sulphate	-,1634	1,34525	1,000	-4,6820	4,3552
oxalic acid	calcium chloride	6,4480*	1,34525	,005	1,9294	10,9666
	citric acid	-8,3155*	1,34525	,001	-12,8341	-3,7969
	lactic acid	4,2982	1,34525	,066	-,2204	8,8168
	sodium silicate	-16,6353*	1,34525	,000	-21,1539	-12,1167
	sodium sulphate	4,1348	1,34525	,080	-,3838	8,6534
sodium silicate	calcium chloride	23,0833*	1,34525	,000	18,5647	27,6019
	citric acid	8,3198*	1,34525	,001	3,8012	12,8384
	lactic acid	20,9335*	1,34525	,000	16,4149	25,4521
	oxalic acid	16,6353*	1,34525	,000	12,1167	21,1539
	sodium sulphate	20,7701*	1,34525	,000	16,2515	25,2887
sodium sulphate	calcium chloride	2,3132	1,34525	,545	-2,2054	6,8318
	citric acid	-12,4503*	1,34525	,000	-16,9689	-7,9317
	lactic acid	,1634	1,34525	1,000	-4,3552	4,6820
	oxalic acid	-4,1348	1,34525	,080	-8,6534	,3838
	sodium silicate	-20,7701*	1,34525	,000	-25,2887	-16,2515

Based on observed means.
The error term is Mean Square(Error) = 2,715.
*. The mean difference is significant at the 0,05 level.
a. site = Van Oeckel, concentration = 1,0

Multiple Comparisons[a]

Dependent Variable: Amount of P (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
calcium chloride	citric acid	-38,5054*	1,76204	,000	-44,4239	-32,5868
	lactic acid	-1,2843	1,76204	,974	-7,2029	4,6343
	oxalic acid	-18,9823*	1,76204	,000	-24,9008	-13,0637
	sodium silicate	-32,4873*	1,76204	,000	-38,4059	-26,5688
	sodium sulphate	-2,1934	1,76204	,808	-8,1120	3,7252
citric acid	calcium chloride	38,5054*	1,76204	,000	32,5868	44,4239
	lactic acid	37,2211*	1,76204	,000	31,3025	43,1396
	oxalic acid	19,5231*	1,76204	,000	13,6045	25,4417
	sodium silicate	6,0180*	1,76204	,045	,0995	11,9366
	sodium sulphate	36,3120*	1,76204	,000	30,3934	42,2305
lactic acid	calcium chloride	1,2843	1,76204	,974	-4,6343	7,2029
	citric acid	-37,2211*	1,76204	,000	-43,1396	-31,3025
	oxalic acid	-17,6980*	1,76204	,000	-23,6166	-11,7794
	sodium silicate	-31,2030*	1,76204	,000	-37,1216	-25,2845
	sodium sulphate	-,9091	1,76204	,994	-6,8277	5,0095
oxalic acid	calcium chloride	18,9823*	1,76204	,000	13,0637	24,9008
	citric acid	-19,5231*	1,76204	,000	-25,4417	-13,6045
	lactic acid	17,6980*	1,76204	,000	11,7794	23,6166
	sodium silicate	-13,5050*	1,76204	,000	-19,4236	-7,5865
	sodium sulphate	16,7889*	1,76204	,000	10,8703	22,7074
sodium silicate	calcium chloride	32,4873*	1,76204	,000	26,5688	38,4059
	citric acid	-6,0180*	1,76204	,045	-11,9366	-,0995
	lactic acid	31,2030*	1,76204	,000	25,2845	37,1216
	oxalic acid	13,5050*	1,76204	,000	7,5865	19,4236
	sodium sulphate	30,2939*	1,76204	,000	24,3754	36,2125
sodium sulphate	calcium chloride	2,1934	1,76204	,808	-3,7252	8,1120
	citric acid	-36,3120*	1,76204	,000	-42,2305	-30,3934
	lactic acid	,9091	1,76204	,994	-5,0095	6,8277
	oxalic acid	-16,7889*	1,76204	,000	-22,7074	-10,8703
	sodium silicate	-30,2939*	1,76204	,000	-36,2125	-24,3754

Based on observed means.
The error term is Mean Square(Error) = 4,657.
*. The mean difference is significant at the 0,05 level.
a. site = Van Oeckel, concentration = 2,0

Annex II: Incubation experiment

Tests of Between-Subjects Effects

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	56,053[a]	49	1,144	285,768	,000
Intercept	240,888	1	240,888	60176,456	,000
Sites	6,361	1	6,361	1589,097	,000
Amendements	22,883	4	5,721	1429,098	,000
Days	6,073	4	1,518	379,277	,000
Sites * Amendements	2,953	4	,738	184,395	,000
Sites * Days	,620	4	,155	38,732	,000
Amendements * Days	14,305	16	,894	223,345	,000
Sites * Amendements * Days	2,858	16	,179	44,625	,000
Error	,400	100	,004		
Total	297,342	150			
Corrected Total	56,453	149			

a. R Squared = ,993 (Adjusted R Squared = ,989)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	23,943[b]	24	,998	338,560	,000
Intercept	84,480	1	84,480	28669,117	,000
Amendements	15,162	4	3,790	1286,311	,000
Days	2,159	4	,540	183,191	,000
Amendements * Days	6,623	16	,414	140,464	,000
Error	,147	50	,003		
Total	108,570	75			
Corrected Total	24,091	74			

a. site = E13.130
b. R Squared = ,994 (Adjusted R Squared = ,991)

Tests of Between-Subjects Effects[a]

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	25,748[b]	24	1,073	212,053	,000
Intercept	162,770	1	162,770	32172,076	,000
Amendements	10,674	4	2,668	527,435	,000
Days	4,534	4	1,133	224,039	,000
Amendements * Days	10,541	16	,659	130,211	,000
Error	,253	50	,005		
Total	188,771	75			
Corrected Total	26,001	74			

a. site = Van Oeckel
b. R Squared = ,990 (Adjusted R Squared = ,986)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,154[b]	4	,289	83,782	,000
Intercept	13,141	1	13,141	3816,193	,000
Amendements	1,154	4	,289	83,782	,000
Error	,034	10	,003		
Total	14,330	15			
Corrected Total	1,188	14			

a. site = E13, days of incubation = 3
b. R Squared = ,971 (Adjusted R Squared = ,959)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2,510[b]	4	,627	383,141	,000
Intercept	18,856	1	18,856	11513,632	,000
Amendements	2,510	4	,627	383,141	,000
Error	,016	10	,002		
Total	21,383	15			
Corrected Total	2,526	14			

a. site = E13, days of incubation = 6
b. R Squared = ,994 (Adjusted R Squared = ,991)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11,152[b]	4	2,788	1021,151	,000
Intercept	27,557	1	27,557	10093,177	,000
Amendements	11,152	4	2,788	1021,151	,000
Error	,027	10	,003		
Total	38,736	15			
Corrected Total	11,179	14			

a. site = E13, days of incubation = 12
b. R Squared = ,998 (Adjusted R Squared = ,997)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4,636[b]	4	1,159	493,065	,000
Intercept	15,747	1	15,747	6698,916	,000
Amendements	4,636	4	1,159	493,065	,000
Error	,024	10	,002		
Total	20,406	15			
Corrected Total	4,660	14			

a. site = E13, days of incubation = 24
b. R Squared = ,995 (Adjusted R Squared = ,993)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2,332[b]	4	,583	127,544	,000
Intercept	11,338	1	11,338	2480,240	,000
Amendements	2,332	4	,583	127,544	,000
Error	,046	10	,005		
Total	13,716	15			
Corrected Total	2,378	14			

a. site = E13, days of incubation = 48

b. R Squared = ,981 (Adjusted R Squared = ,973)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5,032[b]	4	1,258	360,140	,000
Intercept	19,060	1	19,060	5455,957	,000
Amendements	5,032	4	1,258	360,140	,000
Error	,035	10	,003		
Total	24,127	15			
Corrected Total	5,067	14			

a. site = Van Oeckel, days of incubation = 3

b. R Squared = ,993 (Adjusted R Squared = ,990)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,486[b]	4	,371	60,005	,000
Intercept	39,911	1	39,911	6446,692	,000
Amendements	1,486	4	,371	60,005	,000
Error	,062	10	,006		
Total	41,458	15			
Corrected Total	1,548	14			

a. site = Van Oeckel, days of incubation = 6

b. R Squared = ,960 (Adjusted R Squared = ,944)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6,992[b]	4	1,748	809,239	,000
Intercept	47,321	1	47,321	21906,743	,000
Amendements	6,992	4	1,748	809,239	,000
Error	,022	10	,002		
Total	54,335	15			
Corrected Total	7,014	14			

a. site = Van Oeckel, days of incubation = 12

b. R Squared = ,997 (Adjusted R Squared = ,996)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4,734[b]	4	1,183	105,363	,000
Intercept	37,814	1	37,814	3366,799	,000
Amendements	4,734	4	1,183	105,363	,000
Error	,112	10	,011		
Total	42,660	15			
Corrected Total	4,846	14			

a. site = Van Oeckel, days of incubation = 24

b. R Squared = ,977 (Adjusted R Squared = ,968)

Tests of Between-Subjects Effects[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2,970[b]	4	,743	334,362	,000
Intercept	23,198	1	23,198	10445,376	,000
Amendements	2,970	4	,743	334,362	,000
Error	,022	10	,002		
Total	26,191	15			
Corrected Total	2,993	14			

a. site = Van Oeckel, days of incubation = 48

b. R Squared = ,993 (Adjusted R Squared = ,990)

Post-hoc analysis for amendments on different days of incubation

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)

Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Citric Acid	Control	,6441*	,04791	,000	,4864	,8018
	Na2SiO3	-,0511	,04791	,819	-,2088	,1066
	PSB	,2200*	,04791	,007	,0623	,3777
	Sulphur	,5274*	,04791	,000	,3697	,6851
Control	Citric Acid	-,6441*	,04791	,000	-,8018	-,4864
	Na2SiO3	-,6952*	,04791	,000	-,8529	-,5375
	PSB	-,4241*	,04791	,000	-,5817	-,2664
	Sulphur	-,1167	,04791	,183	-,2744	,0410
Na2SiO3	Citric Acid	,0511	,04791	,819	-,1066	,2088
	Control	,6952*	,04791	,000	,5375	,8529
	PSB	,2711*	,04791	,002	,1134	,4288
	Sulphur	,5785*	,04791	,000	,4208	,7362
PSB	Citric Acid	-,2200*	,04791	,007	-,3777	-,0623
	Control	,4241*	,04791	,000	,2664	,5817
	Na2SiO3	-,2711*	,04791	,002	-,4288	-,1134
	Sulphur	,3074*	,04791	,001	,1497	,4651
Sulphur	Citric Acid	-,5274*	,04791	,000	-,6851	-,3697
	Control	,1167	,04791	,183	-,0410	,2744
	Na2SiO3	-,5785*	,04791	,000	-,7362	-,4208
	PSB	-,3074*	,04791	,001	-,4651	-,1497

Based on observed means.

The error term is Mean Square(Error) = ,003.

*. The mean difference is significant at the ,05 level.
a. site = E13, days of incubation = 3

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Citric Acid	Control	,3154*	,03304	,000	,2067	,4242
	Na2SiO3	-,8122*	,03304	,000	-,9209	-,7034
	PSB	-,3082*	,03304	,000	-,4169	-,1994
	Sulphur	,2239*	,03304	,000	,1151	,3326
Control	Citric Acid	-,3154*	,03304	,000	-,4242	-,2067
	Na2SiO3	-1,1276*	,03304	,000	-1,2363	-1,0188
	PSB	-,6236*	,03304	,000	-,7323	-,5148
	Sulphur	-,0915	,03304	,111	-,2003	,0172
Na2SiO3	Citric Acid	,8122*	,03304	,000	,7034	,9209
	Control	1,1276*	,03304	,000	1,0188	1,2363
	PSB	,5040*	,03304	,000	,3953	,6127
	Sulphur	1,0360*	,03304	,000	,9273	1,1448
PSB	Citric Acid	,3082*	,03304	,000	,1994	,4169
	Control	,6236*	,03304	,000	,5148	,7323
	Na2SiO3	-,5040*	,03304	,000	-,6127	-,3953
	Sulphur	,5320*	,03304	,000	,4233	,6408
Sulphur	Citric Acid	-,2239*	,03304	,000	-,3326	-,1151
	Control	,0915	,03304	,111	-,0172	,2003
	Na2SiO3	-1,0360*	,03304	,000	-1,1448	-,9273
	PSB	-,5320*	,03304	,000	-,6408	-,4233

Based on observed means.
The error term is Mean Square(Error) = ,002.
*. The mean difference is significant at the ,05 level.
a. site = E13, days of incubation = 6

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Citric Acid	Control	,1844*	,04266	,010	,0440	,3248
	Na2SiO3	-1,0334*	,04266	,000	-1,1739	-,8930
	PSB	-2,0979*	,04266	,000	-2,2383	-1,9575
	Sulphur	-,0429	,04266	,848	-,1833	,0975
Control	Citric Acid	-,1844*	,04266	,010	-,3248	-,0440
	Na2SiO3	-1,2178*	,04266	,000	-1,3582	-1,0774
	PSB	-2,2823*	,04266	,000	-2,4227	-2,1419
	Sulphur	-,2272*	,04266	,002	-,3676	-,0868
Na2SiO3	Citric Acid	1,0334*	,04266	,000	,8930	1,1739
	Control	1,2178*	,04266	,000	1,0774	1,3582
	PSB	-1,0645*	,04266	,000	-1,2049	-,9241
	Sulphur	,9906*	,04266	,000	,8502	1,1310
PSB	Citric Acid	2,0979*	,04266	,000	1,9575	2,2383
	Control	2,2823*	,04266	,000	2,1419	2,4227
	Na2SiO3	1,0645*	,04266	,000	,9241	1,2049
	Sulphur	2,0551*	,04266	,000	1,9147	2,1955
Sulphur	Citric Acid	,0429	,04266	,848	-,0975	,1833

	Control	,2272*	,04266	,002	,0868	,3676
	Na2SiO3	-,9906*	,04266	,000	-1,1310	-,8502
	PSB	-2,0551*	,04266	,000	-2,1955	-1,9147

Based on observed means.
The error term is Mean Square(Error) = ,003.
*. The mean difference is significant at the ,05 level.
a. site = E13, days of incubation = 12

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Citric Acid	Control	,0058	,03959	1,000	-,1244	,1361
	Na2SiO3	-1,3567*	,03959	,000	-1,4870	-1,2264
	PSB	-,9332*	,03959	,000	-1,0635	-,8029
	Sulphur	-,1556*	,03959	,019	-,2859	-,0254
Control	Citric Acid	-,0058	,03959	1,000	-,1361	,1244
	Na2SiO3	-1,3625*	,03959	,000	-1,4928	-1,2323
	PSB	-,9391*	,03959	,000	-1,0693	-,8088
	Sulphur	-,1615*	,03959	,015	-,2918	-,0312
Na2SiO3	Citric Acid	1,3567*	,03959	,000	1,2264	1,4870
	Control	1,3625*	,03959	,000	1,2323	1,4928
	PSB	,4235*	,03959	,000	,2932	,5538
	Sulphur	1,2011*	,03959	,000	1,0708	1,3313
PSB	Citric Acid	,9332*	,03959	,000	,8029	1,0635
	Control	,9391*	,03959	,000	,8088	1,0693
	Na2SiO3	-,4235*	,03959	,000	-,5538	-,2932
	Sulphur	,7776*	,03959	,000	,6473	,9079
Sulphur	Citric Acid	,1556*	,03959	,019	,0254	,2859
	Control	,1615*	,03959	,015	,0312	,2918
	Na2SiO3	-1,2011*	,03959	,000	-1,3313	-1,0708
	PSB	-,7776*	,03959	,000	-,9079	-,6473

Based on observed means.
The error term is Mean Square(Error) = ,002.
*. The mean difference is significant at the ,05 level.
a. site = E13, days of incubation = 24

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Citric Acid	Control	,1671	,05521	,075	-,0145	,3488
	Na2SiO3	-,8976*	,05521	,000	-1,0793	-,7160
	PSB	-,4336*	,05521	,000	-,6153	-,2519
	Sulphur	,0527	,05521	,869	-,1290	,2344
Control	Citric Acid	-,1671	,05521	,075	-,3488	,0145
	Na2SiO3	-1,0648*	,05521	,000	-1,2465	-,8831
	PSB	-,6007*	,05521	,000	-,7824	-,4190
	Sulphur	-,1145	,05521	,302	-,2961	,0672
Na2SiO3	Citric Acid	,8976*	,05521	,000	,7160	1,0793
	Control	1,0648*	,05521	,000	,8831	1,2465
	PSB	,4641*	,05521	,000	,2824	,6458
	Sulphur	,9503*	,05521	,000	,7686	1,1320
PSB	Citric Acid	,4336*	,05521	,000	,2519	,6153
	Control	,6007*	,05521	,000	,4190	,7824
	Na2SiO3	-,4641*	,05521	,000	-,6458	-,2824

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
	Sulphur	,4862*	,05521	,000	,3046	,6679
Sulphur	Citric Acid	-,0527	,05521	,869	-,2344	,1290
	Control	,1145	,05521	,302	-,0672	,2961
	Na2SiO3	-,9503*	,05521	,000	-1,1320	-,7686
	PSB	-,4862*	,05521	,000	-,6679	-,3046

Based on observed means.
The error term is Mean Square(Error) = ,005.
*. The mean difference is significant at the ,05 level.
a. site = E13, days of incubation = 48

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Citric Acid	Control	1,6816*	,04826	,000	1,5228	1,8404
	Na2SiO3	,8911*	,04826	,000	,7323	1,0499
	PSB	,8445*	,04826	,000	,6857	1,0034
	Sulphur	1,4264*	,04826	,000	1,2675	1,5852
Control	Citric Acid	-1,6816*	,04826	,000	-1,8404	-1,5228
	Na2SiO3	-,7905*	,04826	,000	-,9493	-,6317
	PSB	-,8371*	,04826	,000	-,9959	-,6782
	Sulphur	-,2552*	,04826	,003	-,4140	-,0964
Na2SiO3	Citric Acid	-,8911*	,04826	,000	-1,0499	-,7323
	Control	,7905*	,04826	,000	,6317	,9493
	PSB	-,0466	,04826	,865	-,2054	,1123
	Sulphur	,5353*	,04826	,000	,3764	,6941
PSB	Citric Acid	-,8445*	,04826	,000	-1,0034	-,6857
	Control	,8371*	,04826	,000	,6782	,9959
	Na2SiO3	,0466	,04826	,865	-,1123	,2054
	Sulphur	,5818*	,04826	,000	,4230	,7407
Sulphur	Citric Acid	-1,4264*	,04826	,000	-1,5852	-1,2675
	Control	,2552*	,04826	,003	,0964	,4140
	Na2SiO3	-,5353*	,04826	,000	-,6941	-,3764
	PSB	-,5818*	,04826	,000	-,7407	-,4230

Based on observed means.
The error term is Mean Square(Error) = ,003.
*. The mean difference is significant at the ,05 level.
a. site = Van Oeckel, days of incubation = 3

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Citric Acid	Control	,5434*	,06424	,000	,3319	,7548
	Na2SiO3	-,2450*	,06424	,022	-,4565	-,0336
	PSB	-,3312*	,06424	,003	-,5427	-,1198
	Sulphur	,1872	,06424	,089	-,0242	,3987
Control	Citric Acid	-,5434*	,06424	,000	-,7548	-,3319
	Na2SiO3	-,7884*	,06424	,000	-,9999	-,5770
	PSB	-,8746*	,06424	,000	-1,0860	-,6632
	Sulphur	-,3561*	,06424	,002	-,5676	-,1447
Na2SiO3	Citric Acid	,2450*	,06424	,022	,0336	,4565
	Control	,7884*	,06424	,000	,5770	,9999
	PSB	-,0862	,06424	,674	-,2976	,1252

	Sulphur	,4323*	,06424	,000	,2209	,6437
PSB	Citric Acid	,3312*	,06424	,003	,1198	,5427
	Control	,8746*	,06424	,000	,6632	1,0860
	Na2SiO3	,0862	,06424	,674	-,1252	,2976
	Sulphur	,5185*	,06424	,000	,3070	,7299
Sulphur	Citric Acid	-,1872	,06424	,089	-,3987	,0242
	Control	,3561*	,06424	,002	,1447	,5676
	Na2SiO3	-,4323*	,06424	,000	-,6437	-,2209
	PSB	-,5185*	,06424	,000	-,7299	-,3070

Based on observed means.
The error term is Mean Square(Error) = ,006.
*. The mean difference is significant at the ,05 level.
a. site = Van Oeckel, days of incubation = 6

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Citric Acid	Control	-,0876	,03795	,219	-,2125	,0373
	Na2SiO3	-,7289*	,03795	,000	-,8538	-,6041
	PSB	-1,9034*	,03795	,000	-2,0283	-1,7785
	Sulphur	-,5286*	,03795	,000	-,6535	-,4037
Control	Citric Acid	,0876	,03795	,219	-,0373	,2125
	Na2SiO3	-,6414*	,03795	,000	-,7663	-,5165
	PSB	-1,8158*	,03795	,000	-1,9407	-1,6909
	Sulphur	-,4410*	,03795	,000	-,5659	-,3161
Na2SiO3	Citric Acid	,7289*	,03795	,000	,6041	,8538
	Control	,6414*	,03795	,000	,5165	,7663
	PSB	-1,1744*	,03795	,000	-1,2993	-1,0495
	Sulphur	,2004*	,03795	,003	,0755	,3253
PSB	Citric Acid	1,9034*	,03795	,000	1,7785	2,0283
	Control	1,8158*	,03795	,000	1,6909	1,9407
	Na2SiO3	1,1744*	,03795	,000	1,0495	1,2993
	Sulphur	1,3748*	,03795	,000	1,2499	1,4997
Sulphur	Citric Acid	,5286*	,03795	,000	,4037	,6535
	Control	,4410*	,03795	,000	,3161	,5659
	Na2SiO3	-,2004*	,03795	,003	-,3253	-,0755
	PSB	-1,3748*	,03795	,000	-1,4997	-1,2499

Based on observed means.
The error term is Mean Square(Error) = ,002.
*. The mean difference is significant at the ,05 level.
a. site = Van Oeckel, days of incubation = 12

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Citric Acid	Control	-,2235	,08653	,147	-,5082	,0613
	Na2SiO3	-1,0725*	,08653	,000	-1,3572	-,7877
	PSB	-1,5259*	,08653	,000	-1,8107	-1,2411
	Sulphur	-,9292*	,08653	,000	-1,2140	-,6445
Control	Citric Acid	,2235	,08653	,147	-,0613	,5082
	Na2SiO3	-,8490*	,08653	,000	-1,1338	-,5642
	PSB	-1,3024*	,08653	,000	-1,5872	-1,0176

	Sulphur	-,7058*	,08653	,000	-,9906	-,4210
Na2SiO3	Citric Acid	1,0725*	,08653	,000	,7877	1,3572
	Control	,8490*	,08653	,000	,5642	1,1338
	PSB	-,4534*	,08653	,003	-,7382	-,1686
	Sulphur	,1432	,08653	,499	-,1416	,4280
PSB	Citric Acid	1,5259*	,08653	,000	1,2411	1,8107
	Control	1,3024*	,08653	,000	1,0176	1,5872
	Na2SiO3	,4534*	,08653	,003	,1686	,7382
	Sulphur	,5966*	,08653	,000	,3118	,8814
Sulphur	Citric Acid	,9292*	,08653	,000	,6445	1,2140
	Control	,7058*	,08653	,000	,4210	,9906
	Na2SiO3	-,1432	,08653	,499	-,4280	,1416
	PSB	-,5966*	,08653	,000	-,8814	-,3118

Based on observed means.
The error term is Mean Square(Error) = ,011.
*. The mean difference is significant at the ,05 level.
a. site = Van Oeckel, days of incubation = 24

Multiple Comparisons[a]

Dependent Variable: P-CaCl2 (mg P/kg dry soil)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Citric Acid	Control	-,2096*	,03848	,002	-,3362	-,0829
	Na2SiO3	-,1209	,03848	,063	-,2475	,0058
	PSB	-1,1475*	,03848	,000	-1,2741	-1,0208
	Sulphur	-,8180*	,03848	,000	-,9446	-,6914
Control	Citric Acid	,2096*	,03848	,002	,0829	,3362
	Na2SiO3	,0887	,03848	,220	-,0380	,2153
	PSB	-,9379*	,03848	,000	-1,0646	-,8113
	Sulphur	-,6084*	,03848	,000	-,7351	-,4818
Na2SiO3	Citric Acid	,1209	,03848	,063	-,0058	,2475
	Control	-,0887	,03848	,220	-,2153	,0380
	PSB	-1,0266*	,03848	,000	-1,1532	-,9000
	Sulphur	-,6971*	,03848	,000	-,8238	-,5705
PSB	Citric Acid	1,1475*	,03848	,000	1,0208	1,2741
	Control	,9379*	,03848	,000	,8113	1,0646
	Na2SiO3	1,0266*	,03848	,000	,9000	1,1532
	Sulphur	,3295*	,03848	,000	,2028	,4561
Sulphur	Citric Acid	,8180*	,03848	,000	,6914	,9446
	Control	,6084*	,03848	,000	,4818	,7351
	Na2SiO3	,6971*	,03848	,000	,5705	,8238
	PSB	-,3295*	,03848	,000	-,4561	-,2028

Based on observed means.
The error term is Mean Square(Error) = ,002.
*. The mean difference is significant at the ,05 level.
a. site = Van Oeckel, days of incubation = 48

Annex III: Greenhouse experiment

ANOVA of P-$CaCl_2$

Tests of Between-Subjects Effects

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	21,859[a]	39	,560	109,913	,000
Intercept	123,096	1	123,096	24139,815	,000
Site	1,123	1	1,123	220,199	,000
Amendment	2,328	4	,582	114,127	,000
days	8,564	3	2,855	559,832	,000
Site * Amendment	,588	4	,147	28,825	,000
Site * days	5,679	3	1,893	371,230	,000
Amendment * days	2,616	12	,218	42,759	,000
Site * Amendment * days	,960	12	,080	15,692	,000
Error	,408	80	,005		
Total	145,362	120			
Corrected Total	22,267	119			

a. R Squared = ,982 (Adjusted R Squared = ,973)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3,338[b]	19	,176	41,140	,000
Intercept	50,353	1	50,353	11792,363	,000
Amendment	,681	4	,170	39,894	,000
days	1,389	3	,463	108,438	,000
Amendment * days	1,267	12	,106	24,732	,000
Error	,171	40	,004		
Total	53,861	60			
Corrected Total	3,508	59			

a. sites = E13.0130
b. R Squared = ,951 (Adjusted R Squared = ,928)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17,398[b]	19	,916	154,452	,000
Intercept	73,866	1	73,866	12459,197	,000
Amendment	2,234	4	,559	94,222	,000
days	12,854	3	4,285	722,718	,000
Amendment * days	2,309	12	,192	32,462	,000
Error	,237	40	,006		
Total	91,501	60			
Corrected Total	17,635	59			

a. sites = Van Oeckel
b. R Squared = ,987 (Adjusted R Squared = ,980)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,586[b]	4	,147	33,119	,000
Intercept	15,553	1	15,553	3513,067	,000
Amendment	,586	4	,147	33,119	,000
Error	,044	10	,004		
Total	16,184	15			
Corrected Total	,631	14			

a. sites = E13.0130, days after germination = 20
b. R Squared = ,930 (Adjusted R Squared = ,902)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,489[b]	4	,122	16,730	,000
Intercept	13,555	1	13,555	1854,253	,000
Amendment	,489	4	,122	16,730	,000
Error	,073	10	,007		
Total	14,117	15			
Corrected Total	,562	14			

a. sites = E13.0130, days after germination = 40
b. R Squared = ,870 (Adjusted R Squared = ,818)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,873[b]	4	,218	46,272	,000
Intercept	6,504	1	6,504	1379,081	,000
Amendment	,873	4	,218	46,272	,000
Error	,047	10	,005		
Total	7,424	15			
Corrected Total	,920	14			

a. sites = E13.0130, days after germination = 60
b. R Squared = ,949 (Adjusted R Squared = ,928)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3,149[b]	4	,787	139,081	,000
Intercept	43,393	1	43,393	7666,644	,000
Amendment	3,149	4	,787	139,081	,000
Error	,057	10	,006		
Total	46,598	15			
Corrected Total	3,205	14			

a. sites = Van Oeckel, days after germination = 20

b. R Squared = ,982 (Adjusted R Squared = ,975)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,021[b]	4	,255	19,614	,000
Intercept	29,868	1	29,868	2294,149	,000
Amendment	1,021	4	,255	19,614	,000
Error	,130	10	,013		
Total	31,020	15			
Corrected Total	1,152	14			

a. sites = Van Oeckel, days after germination = 40
b. R Squared = ,887 (Adjusted R Squared = ,842)

Tests of Between-Subjects Effects[a]

Dependent Variable: P mg/kg of soil

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,374[b]	4	,093	38,445	,000
Intercept	8,605	1	8,605	3541,216	,000
Amendment	,374	4	,093	38,445	,000
Error	,024	10	,002		
Total	9,003	15			
Corrected Total	,398	14			

a. sites = Van Oeckel, days after germination = 60
b. R Squared = ,939 (Adjusted R Squared = ,915)

Post hoc for P-$CaCl_2$ with different amendments for different time

Multiple Comparisons[a]

Dependent Variable: P mg/kg of soil

Tukey HSD

(I) amendments	(J) amendments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	,2215*	,05433	,015	,0427	,4003
	elemental sulphur	,2298*	,05433	,012	,0510	,4086
	PSB	-,2588*	,05433	,005	-,4376	-,0800
	sodium silicate	-,1637	,05433	,077	-,3425	,0151
control	citric acid	-,2215*	,05433	,015	-,4003	-,0427
	elemental sulphur	,0083	,05433	1,000	-,1705	,1871
	PSB	-,4803*	,05433	,000	-,6591	-,3016
	sodium silicate	-,3852*	,05433	,000	-,5640	-,2064
elemental sulphur	citric acid	-,2298*	,05433	,012	-,4086	-,0510
	control	-,0083	,05433	1,000	-,1871	,1705
	PSB	-,4886*	,05433	,000	-,6674	-,3098
	sodium silicate	-,3935*	,05433	,000	-,5723	-,2147
PSB	citric acid	,2588*	,05433	,005	,0800	,4376
	control	,4803*	,05433	,000	,3016	,6591
	elemental sulphur	,4886*	,05433	,000	,3098	,6674

	sodium silicate	,0951	,05433	,448	-,0837	,2739
sodium silicate	citric acid	,1637	,05433	,077	-,0151	,3425
	control	,3852*	,05433	,000	,2064	,5640
	elemental sulphur	,3935*	,05433	,000	,2147	,5723
	PSB	-,0951	,05433	,448	-,2739	,0837

Based on observed means.
The error term is Mean Square(Error) = ,004.
*. The mean difference is significant at the 0,05 level.
a. sites = E13.0130, days after germination = 20

Multiple Comparisons[a]

Dependent Variable: P mg/kg of soil
Tukey HSD

(I) amendments	(J) amendments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
citric acid	control	,5548*	,06981	,000	,3251	,7846
	elemental sulphur	,2781*	,06981	,017	,0484	,5079
	PSB	,3003*	,06981	,011	,0706	,5301
	sodium silicate	,1786	,06981	,153	-,0511	,4084
control	citric acid	-,5548*	,06981	,000	-,7846	-,3251
	elemental sulphur	-,2767*	,06981	,018	-,5064	-,0469
	PSB	-,2545*	,06981	,029	-,4842	-,0247
	sodium silicate	-,3762*	,06981	,002	-,6060	-,1465
elemental sulphur	citric acid	-,2781*	,06981	,017	-,5079	-,0484
	control	,2767*	,06981	,018	,0469	,5064
	PSB	,0222	,06981	,997	-,2076	,2520
	sodium silicate	-,0995	,06981	,627	-,3293	,1302
PSB	citric acid	-,3003*	,06981	,011	-,5301	-,0706
	control	,2545*	,06981	,029	,0247	,4842
	elemental sulphur	-,0222	,06981	,997	-,2520	,2076
	sodium silicate	-,1217	,06981	,452	-,3515	,1080
sodium silicate	citric acid	-,1786	,06981	,153	-,4084	,0511
	control	,3762*	,06981	,002	,1465	,6060
	elemental sulphur	,0995	,06981	,627	-,1302	,3293
	PSB	,1217	,06981	,452	-,1080	,3515

Based on observed means.
The error term is Mean Square(Error) = ,007.
*. The mean difference is significant at the 0,05 level.
a. sites = E13.0130, days after germination = 40

Multiple Comparisons[a]

Dependent Variable: P mg/kg of soil
Tukey HSD

(I) amendments	(J) amendments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
citric acid	control	,4437*	,05607	,000	,2591	,6282
	elemental sulphur	-,2723*	,05607	,005	-,4569	-,0878
	PSB	,2039*	,05607	,029	,0193	,3884
	sodium silicate	,2242*	,05607	,017	,0396	,4087
control	citric acid	-,4437*	,05607	,000	-,6282	-,2591
	elemental sulphur	-,7160*	,05607	,000	-,9005	-,5315
	PSB	-,2398*	,05607	,011	-,4243	-,0552
	sodium silicate	-,2195*	,05607	,019	-,4040	-,0350
elemental sulphur	citric acid	,2723*	,05607	,005	,0878	,4569

	control	,7160*	,05607	,000	,5315	,9005
	PSB	,4762*	,05607	,000	,2917	,6608
	sodium silicate	,4965*	,05607	,000	,3120	,6810
PSB	citric acid	-,2039*	,05607	,029	-,3884	-,0193
	control	,2398*	,05607	,011	,0552	,4243
	elemental sulphur	-,4762*	,05607	,000	-,6608	-,2917
	sodium silicate	,0203	,05607	,996	-,1643	,2048
sodium silicate	citric acid	-,2242*	,05607	,017	-,4087	-,0396
	control	,2195*	,05607	,019	,0350	,4040
	elemental sulphur	-,4965*	,05607	,000	-,6810	-,3120
	PSB	-,0203	,05607	,996	-,2048	,1643

Based on observed means.
The error term is Mean Square(Error) = ,005.
*. The mean difference is significant at the 0,05 level.
a. sites = E13.0130, days after germination = 60

Multiple Comparisons[a]

Dependent Variable: P mg/kg of soil
Tukey HSD

(I) amendments	(J) amendments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	,4634*	,06143	,000	,2612	,6655
	elemental sulphur	,1511	,06143	,177	-,0511	,3532
	PSB	-,9132*	,06143	,000	-1,1153	-,7110
	sodium silicate	-,0492	,06143	,924	-,2514	,1530
control	citric acid	-,4634*	,06143	,000	-,6655	-,2612
	elemental sulphur	-,3123*	,06143	,003	-,5145	-,1101
	PSB	-1,3765*	,06143	,000	-1,5787	-1,1744
	sodium silicate	-,5126*	,06143	,000	-,7147	-,3104
elemental sulphur	citric acid	-,1511	,06143	,177	-,3532	,0511
	control	,3123*	,06143	,003	,1101	,5145
	PSB	-1,0642*	,06143	,000	-1,2664	-,8621
	sodium silicate	-,2003	,06143	,052	-,4024	,0019
PSB	citric acid	,9132*	,06143	,000	,7110	1,1153
	control	1,3765*	,06143	,000	1,1744	1,5787
	elemental sulphur	1,0642*	,06143	,000	,8621	1,2664
	sodium silicate	,8640*	,06143	,000	,6618	1,0661
sodium silicate	citric acid	,0492	,06143	,924	-,1530	,2514
	control	,5126*	,06143	,000	,3104	,7147
	elemental sulphur	,2003	,06143	,052	-,0019	,4024
	PSB	-,8640*	,06143	,000	-1,0661	-,6618

Based on observed means.
The error term is Mean Square(Error) = ,006.
*. The mean difference is significant at the 0,05 level.
a. sites = Van Oeckel, days after germination = 20

Multiple Comparisons[a]

Dependent Variable: P mg/kg of soil
Tukey HSD

(I) amendments	(J) amendments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	,3695*	,09316	,018	,0628	,6761
	elemental sulphur	-,0898	,09316	,865	-,3965	,2168
	PSB	-,1925	,09316	,304	-,4991	,1141

(I) amendments	(J) amendments	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
	sodium silicate	-,4265*	,09316	,007	-,7331	-,1199
control	citric acid	-,3695*	,09316	,018	-,6761	-,0628
	elemental sulphur	-,4593*	,09316	,004	-,7659	-,1527
	PSB	-,5619*	,09316	,001	-,8685	-,2553
	sodium silicate	-,7959*	,09316	,000	-1,1026	-,4893
elemental sulphur	citric acid	,0898	,09316	,865	-,2168	,3965
	control	,4593*	,09316	,004	,1527	,7659
	PSB	-,1026	,09316	,802	-,4092	,2040
	sodium silicate	-,3367*	,09316	,030	-,6433	-,0300
PSB	citric acid	,1925	,09316	,304	-,1141	,4991
	control	,5619*	,09316	,001	,2553	,8685
	elemental sulphur	,1026	,09316	,802	-,2040	,4092
	sodium silicate	-,2340	,09316	,164	-,5406	,0726
sodium silicate	citric acid	,4265*	,09316	,007	,1199	,7331
	control	,7959*	,09316	,000	,4893	1,1026
	elemental sulphur	,3367*	,09316	,030	,0300	,6433
	PSB	,2340	,09316	,164	-,0726	,5406

Based on observed means.
The error term is Mean Square(Error) = ,013.
*. The mean difference is significant at the 0,05 level.
a. sites = Van Oeckel, days after germination = 40

Multiple Comparisons[a]

Dependent Variable: P mg/kg of soil
Tukey HSD

(I) amendments	(J) amendments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	,2333*	,04025	,001	,1008	,3657
	elemental sulphur	-,0157	,04025	,994	-,1482	,1168
	PSB	-,0957	,04025	,199	-,2281	,0368
	sodium silicate	-,2534*	,04025	,001	-,3859	-,1209
control	citric acid	-,2333*	,04025	,001	-,3657	-,1008
	elemental sulphur	-,2490*	,04025	,001	-,3814	-,1165
	PSB	-,3290*	,04025	,000	-,4614	-,1965
	sodium silicate	-,4867*	,04025	,000	-,6191	-,3542
elemental sulphur	citric acid	,0157	,04025	,994	-,1168	,1482
	control	,2490*	,04025	,001	,1165	,3814
	PSB	-,0800	,04025	,337	-,2125	,0525
	sodium silicate	-,2377*	,04025	,001	-,3702	-,1052
PSB	citric acid	,0957	,04025	,199	-,0368	,2281
	control	,3290*	,04025	,000	,1965	,4614
	elemental sulphur	,0800	,04025	,337	-,0525	,2125
	sodium silicate	-,1577*	,04025	,019	-,2902	-,0252
sodium silicate	citric acid	,2534*	,04025	,001	,1209	,3859
	control	,4867*	,04025	,000	,3542	,6191
	elemental sulphur	,2377*	,04025	,001	,1052	,3702
	PSB	,1577*	,04025	,019	,0252	,2902

Based on observed means.
The error term is Mean Square(Error) = ,002.
*. The mean difference is significant at the 0,05 level.
a. sites = Van Oeckel, days after germination = 60

ANOVA above ground biomass dry weight (g)

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	68,324[b]	29	2,356	202,610	,000
Intercept	69,714	1	69,714	5995,240	,000
Sites	,000	1	,000	,011	,918
Amendements	25,972	4	6,493	558,380	,000
Days	26,795	2	13,397	1152,140	,000
Sites * Amendements	,073	4	,018	1,559	,197
Sites * Days	,299	2	,150	12,857	,000
Amendements * Days	13,397	8	1,675	144,013	,000
Sites * Amendements * Days	1,789	8	,224	19,228	,000
Error	,698	60	,012		
Total	138,736	90			
Corrected Total	69,022	89			

a. plant part = Above ground
b. R Squared = ,990 (Adjusted R Squared = ,985)

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,036[b]	4	,009	2,068	,160
Intercept	,704	1	,704	160,640	,000
Amendements	,036	4	,009	2,068	,160
Error	,044	10	,004		
Total	,784	15			
Corrected Total	,080	14			

a. plant part = Above ground, sites = E13.0130, days after germination = 20
b. R Squared = ,453 (Adjusted R Squared = ,234)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,1297	,05406	,193	-,3076	,0483
	elemental sulphur	-,0547	,05406	,844	-,2326	,1232
	PSB	-,1291	,05406	,196	-,3070	,0489
	sodium silicate	-,0934	,05406	,460	-,2714	,0845
control	citric acid	,1297	,05406	,193	-,0483	,3076
	elemental sulphur	,0750	,05406	,649	-,1030	,2529
	PSB	,0006	,05406	1,000	-,1773	,1785
	sodium silicate	,0362	,05406	,959	-,1417	,2142
elemental sulphur	citric acid	,0547	,05406	,844	-,1232	,2326
	control	-,0750	,05406	,649	-,2529	,1030
	PSB	-,0744	,05406	,655	-,2523	,1036
	sodium silicate	-,0387	,05406	,948	-,2167	,1392
PSB	citric acid	,1291	,05406	,196	-,0489	,3070

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
	control	-,0006	,05406	1,000	-,1785	,1773
	elemental sulphur	,0744	,05406	,655	-,1036	,2523
	sodium silicate	,0356	,05406	,961	-,1423	,2136
sodium silicate	citric acid	,0934	,05406	,460	-,0845	,2714
	control	-,0362	,05406	,959	-,2142	,1417
	elemental sulphur	,0387	,05406	,948	-,1392	,2167
	PSB	-,0356	,05406	,961	-,2136	,1423

Based on observed means.
The error term is Mean Square(Error) = ,004.
a. plant part = Above ground, sites = E13.0130, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9,247[b]	4	2,312	160,367	,000
Intercept	12,431	1	12,431	862,303	,000
Amendements	9,247	4	2,312	160,367	,000
Error	,144	10	,014		
Total	21,822	15			
Corrected Total	9,391	14			

a. plant part = Above ground, sites = E13.0130, days after germination = 40
b. R Squared = ,985 (Adjusted R Squared = ,979)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,2532	,09803	,147	-,5759	,0694
	elemental sulphur	-,3730*	,09803	,023	-,6956	-,0504
	PSB	-2,1771*	,09803	,000	-2,4998	-1,8545
	sodium silicate	-,3403*	,09803	,038	-,6630	-,0177
control	citric acid	,2532	,09803	,147	-,0694	,5759
	elemental sulphur	-,1198	,09803	,740	-,4424	,2029
	PSB	-1,9239*	,09803	,000	-2,2465	-1,6013
	sodium silicate	-,0871	,09803	,895	-,4097	,2355
elemental sulphur	citric acid	,3730*	,09803	,023	,0504	,6956
	control	,1198	,09803	,740	-,2029	,4424
	PSB	-1,8041*	,09803	,000	-2,1268	-1,4815
	sodium silicate	,0327	,09803	,997	-,2900	,3553
PSB	citric acid	2,1771*	,09803	,000	1,8545	2,4998
	control	1,9239*	,09803	,000	1,6013	2,2465
	elemental sulphur	1,8041*	,09803	,000	1,4815	2,1268
	sodium silicate	1,8368*	,09803	,000	1,5142	2,1594
sodium silicate	citric acid	,3403*	,09803	,038	,0177	,6630
	control	,0871	,09803	,895	-,2355	,4097
	elemental sulphur	-,0327	,09803	,997	-,3553	,2900
	PSB	-1,8368*	,09803	,000	-2,1594	-1,5142

Based on observed means.
The error term is Mean Square(Error) = ,014.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = E13.0130, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11,270[b]	4	2,818	108,894	,000
Intercept	34,193	1	34,193	1321,500	,000
Amendements	11,270	4	2,818	108,894	,000
Error	,259	10	,026		
Total	45,722	15			
Corrected Total	11,529	14			

a. plant part = Above ground, sites = E13.0130, days after germination = 60
b. R Squared = ,978 (Adjusted R Squared = ,969)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,1903	,13134	,613	-,6226	,2419
	elemental sulphur	-,1117	,13134	,908	-,5440	,3205
	PSB	-2,3057*	,13134	,000	-2,7380	-1,8735
	sodium silicate	-,9905*	,13134	,000	-1,4228	-,5583
control	citric acid	,1903	,13134	,613	-,2419	,6226
	elemental sulphur	,0786	,13134	,972	-,3536	,5108
	PSB	-2,1154*	,13134	,000	-2,5477	-1,6832
	sodium silicate	-,8002*	,13134	,001	-1,2324	-,3680
elemental sulphur	citric acid	,1117	,13134	,908	-,3205	,5440
	control	-,0786	,13134	,972	-,5108	,3536
	PSB	-2,1940*	,13134	,000	-2,6263	-1,7618
	sodium silicate	-,8788*	,13134	,000	-1,3110	-,4466
PSB	citric acid	2,3057*	,13134	,000	1,8735	2,7380
	control	2,1154*	,13134	,000	1,6832	2,5477
	elemental sulphur	2,1940*	,13134	,000	1,7618	2,6263
	sodium silicate	1,3152*	,13134	,000	,8830	1,7475
sodium silicate	citric acid	,9905*	,13134	,000	,5583	1,4228
	control	,8002*	,13134	,001	,3680	1,2324
	elemental sulphur	,8788*	,13134	,000	,4466	1,3110
	PSB	-1,3152*	,13134	,000	-1,7475	-,8830

Based on observed means.
The error term is Mean Square(Error) = ,026.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = E13.0130, days after germination = 60

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,078[b]	4	,020	8,561	,003
Intercept	,984	1	,984	430,161	,000
Amendements	,078	4	,020	8,561	,003
Error	,023	10	,002		
Total	1,085	15			

Corrected Total	,101	14			

a. plant part = Above ground, sites = Van Oeckel, days after germination = 20
b. R Squared = ,774 (Adjusted R Squared = ,684)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-,1798*	,03904	,007	-,3083	-,0513
	elemental sulphur	-,1573*	,03904	,016	-,2858	-,0288
	PSB	-,1962*	,03904	,004	-,3247	-,0677
	sodium silicate	-,1785*	,03904	,007	-,3070	-,0500
control	citric acid	,1798*	,03904	,007	,0513	,3083
	elemental sulphur	,0225	,03904	,976	-,1060	,1510
	PSB	-,0164	,03904	,992	-,1449	,1121
	sodium silicate	,0014	,03904	1,000	-,1271	,1299
elemental sulphur	citric acid	,1573*	,03904	,016	,0288	,2858
	control	-,0225	,03904	,976	-,1510	,1060
	PSB	-,0389	,03904	,851	-,1674	,0896
	sodium silicate	-,0211	,03904	,981	-,1496	,1074
PSB	citric acid	,1962*	,03904	,004	,0677	,3247
	control	,0164	,03904	,992	-,1121	,1449
	elemental sulphur	,0389	,03904	,851	-,0896	,1674
	sodium silicate	,0178	,03904	,990	-,1107	,1463
sodium silicate	citric acid	,1785*	,03904	,007	,0500	,3070
	control	-,0014	,03904	1,000	-,1299	,1271
	elemental sulphur	,0211	,03904	,981	-,1074	,1496
	PSB	-,0178	,03904	,990	-,1463	,1107

Based on observed means.
The error term is Mean Square(Error) = ,002.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = Van Oeckel, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3,502[b]	4	,875	93,856	,000
Intercept	8,588	1	8,588	920,772	,000
Amendements	3,502	4	,875	93,856	,000
Error	,093	10	,009		
Total	12,183	15			
Corrected Total	3,595	14			

a. plant part = Above ground, sites = Van Oeckel, days after germination = 40
b. R Squared = ,974 (Adjusted R Squared = ,964)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-,1964	,07886	,169	-,4559	,0631

	elemental sulphur	-,1579	,07886	,331	-,4174	,1016
	PSB	-1,3050*	,07886	,000	-1,5645	-1,0455
	sodium silicate	-,7484*	,07886	,000	-1,0079	-,4889
control	citric acid	,1964	,07886	,169	-,0631	,4559
	elemental sulphur	,0385	,07886	,987	-,2210	,2980
	PSB	-1,1086*	,07886	,000	-1,3681	-,8491
	sodium silicate	-,5520*	,07886	,000	-,8115	-,2925
elemental sulphur	citric acid	,1579	,07886	,331	-,1016	,4174
	control	-,0385	,07886	,987	-,2980	,2210
	PSB	-1,1471*	,07886	,000	-1,4066	-,8876
	sodium silicate	-,5905*	,07886	,000	-,8500	-,3310
PSB	citric acid	1,3050*	,07886	,000	1,0455	1,5645
	control	1,1086*	,07886	,000	,8491	1,3681
	elemental sulphur	1,1471*	,07886	,000	,8876	1,4066
	sodium silicate	,5566*	,07886	,000	,2971	,8161
sodium silicate	citric acid	,7484*	,07886	,000	,4889	1,0079
	control	,5520*	,07886	,000	,2925	,8115
	elemental sulphur	,5905*	,07886	,000	,3310	,8500
	PSB	-,5566*	,07886	,000	-,8161	-,2971

Based on observed means.
The error term is Mean Square(Error) = ,009.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = Van Oeckel, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17,097[b]	4	4,274	317,024	,000
Intercept	39,909	1	39,909	2960,137	,000
Amendements	17,097	4	4,274	317,024	,000
Error	,135	10	,013		
Total	57,140	15			
Corrected Total	17,231	14			

a. plant part = Above ground, sites = Van Oeckel, days after germination = 60
b. R Squared = ,992 (Adjusted R Squared = ,989)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
citric acid	control	-,0078	,09481	1,000	-,3198	,3042
	elemental sulphur	-,1005	,09481	,822	-,4125	,2115
	PSB	-2,7907*	,09481	,000	-3,1027	-2,4787
	sodium silicate	-,6777*	,09481	,000	-,9897	-,3657
control	citric acid	,0078	,09481	1,000	-,3042	,3198
	elemental sulphur	-,0927	,09481	,859	-,4047	,2193
	PSB	-2,7829*	,09481	,000	-3,0949	-2,4709
	sodium silicate	-,6700*	,09481	,000	-,9820	-,3580
elemental sulphur	citric acid	,1005	,09481	,822	-,2115	,4125
	control	,0927	,09481	,859	-,2193	,4047
	PSB	-2,6902*	,09481	,000	-3,0022	-2,3782
	sodium silicate	-,5773*	,09481	,001	-,8893	-,2653

PSB	citric acid	2,7907*	,09481	,000	2,4787	3,1027
	control	2,7829*	,09481	,000	2,4709	3,0949
	elemental sulphur	2,6902*	,09481	,000	2,3782	3,0022
	sodium silicate	2,1129*	,09481	,000	1,8009	2,4249
sodium silicate	citric acid	,6777*	,09481	,000	,3657	,9897
	control	,6700*	,09481	,000	,3580	,9820
	elemental sulphur	,5773*	,09481	,001	,2653	,8893
	PSB	-2,1129*	,09481	,000	-2,4249	-1,8009

Based on observed means.
The error term is Mean Square(Error) = ,013.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = Van Oeckel, days after germination = 60

ANOVA below ground biomass dry weight (g)

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	110,697[b]	29	3,817	74,478	,000
Intercept	147,175	1	147,175	2871,606	,000
Sites	,501	1	,501	9,782	,003
Amendements	33,954	4	8,489	165,624	,000
Days	53,158	2	26,579	518,597	,000
Sites * Amendements	4,477	4	1,119	21,839	,000
Sites * Days	,257	2	,128	2,505	,090
Amendements * Days	15,945	8	1,993	38,889	,000
Sites * Amendements * Days	2,405	8	,301	5,865	,000
Error	3,075	60	,051		
Total	260,947	90			
Corrected Total	113,772	89			

a. plant part = below ground
b. R Squared = ,973 (Adjusted R Squared = ,960)

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,041[b]	4	,010	2,366	,123
Intercept	,602	1	,602	137,296	,000
Amendements	,041	4	,010	2,366	,123
Error	,044	10	,004		
Total	,687	15			
Corrected Total	,085	14			

a. plant part = below ground, sites = E13.0130, days after germination = 20
b. R Squared = ,486 (Adjusted R Squared = ,281)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,1492	,05406	,113	-,3271	,0287
	elemental sulphur	-,0833	,05406	,562	-,2612	,0946
	PSB	-,1348	,05406	,168	-,3127	,0432
	sodium silicate	-,1071	,05406	,339	-,2851	,0708
control	citric acid	,1492	,05406	,113	-,0287	,3271
	elemental sulphur	,0659	,05406	,742	-,1120	,2438
	PSB	,0144	,05406	,999	-,1635	,1924
	sodium silicate	,0421	,05406	,931	-,1359	,2200
elemental sulphur	citric acid	,0833	,05406	,562	-,0946	,2612
	control	-,0659	,05406	,742	-,2438	,1120
	PSB	-,0515	,05406	,870	-,2294	,1265
	sodium silicate	-,0238	,05406	,991	-,2018	,1541
PSB	citric acid	,1348	,05406	,168	-,0432	,3127
	control	-,0144	,05406	,999	-,1924	,1635
	elemental sulphur	,0515	,05406	,870	-,1265	,2294
	sodium silicate	,0276	,05406	,984	-,1503	,2056
sodium silicate	citric acid	,1071	,05406	,339	-,0708	,2851
	control	-,0421	,05406	,931	-,2200	,1359
	elemental sulphur	,0238	,05406	,991	-,1541	,2018
	PSB	-,0276	,05406	,984	-,2056	,1503

Based on observed means.
The error term is Mean Square(Error) = ,004.
a. plant part = below ground, sites = E13.0130, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4,790[b]	4	1,198	16,792	,000
Intercept	36,828	1	36,828	516,400	,000
Amendements	4,790	4	1,198	16,792	,000
Error	,713	10	,071		
Total	42,331	15			
Corrected Total	5,503	14			

a. plant part = below ground, sites = E13.0130, days after germination = 40
b. R Squared = ,870 (Adjusted R Squared = ,819)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,8586*	,21805	,018	-1,5762	-,1410
	elemental sulphur	-,6837	,21805	,064	-1,4013	,0339
	PSB	-1,6713*	,21805	,000	-2,3889	-,9537
	sodium silicate	-1,2786*	,21805	,001	-1,9962	-,5610
control	citric acid	,8586*	,21805	,018	,1410	1,5762
	elemental sulphur	,1749	,21805	,924	-,5427	,8925
	PSB	-,8127*	,21805	,025	-1,5303	-,0951
	sodium silicate	-,4200	,21805	,364	-1,1376	,2976
elemental sulphur	citric acid	,6837	,21805	,064	-,0339	1,4013

	control	-,1749	,21805	,924	-,8925	,5427
	PSB	-,9876*	,21805	,008	-1,7052	-,2700
	sodium silicate	-,5948	,21805	,119	-1,3124	,1228
PSB	citric acid	1,6713*	,21805	,000	,9537	2,3889
	control	,8127*	,21805	,025	,0951	1,5303
	elemental sulphur	,9876*	,21805	,008	,2700	1,7052
	sodium silicate	,3927	,21805	,423	-,3249	1,1103
sodium silicate	citric acid	1,2786*	,21805	,001	,5610	1,9962
	control	,4200	,21805	,364	-,2976	1,1376
	elemental sulphur	,5948	,21805	,119	-,1228	1,3124
	PSB	-,3927	,21805	,423	-1,1103	,3249

Based on observed means.
The error term is Mean Square(Error) = ,071.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = E13.0130, days after germination = 40

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,5168*	,14135	,028	-,9819	-,0516
	elemental sulphur	-,5834*	,14135	,014	-1,0486	-,1183
	PSB	-1,8873*	,14135	,000	-2,3525	-1,4221
	sodium silicate	-1,2659*	,14135	,000	-1,7310	-,8007
control	citric acid	,5168*	,14135	,028	,0516	,9819
	elemental sulphur	-,0667	,14135	,988	-,5318	,3985
	PSB	-1,3705*	,14135	,000	-1,8357	-,9054
	sodium silicate	-,7491*	,14135	,002	-1,2143	-,2839
elemental sulphur	citric acid	,5834*	,14135	,014	,1183	1,0486
	control	,0667	,14135	,988	-,3985	,5318
	PSB	-1,3039*	,14135	,000	-1,7690	-,8387
	sodium silicate	-,6824*	,14135	,005	-1,1476	-,2173
PSB	citric acid	1,8873*	,14135	,000	1,4221	2,3525
	control	1,3705*	,14135	,000	,9054	1,8357
	elemental sulphur	1,3039*	,14135	,000	,8387	1,7690
	sodium silicate	,6214*	,14135	,009	,1563	1,0866
sodium silicate	citric acid	1,2659*	,14135	,000	,8007	1,7310
	control	,7491*	,14135	,002	,2839	1,2143
	elemental sulphur	,6824*	,14135	,005	,2173	1,1476
	PSB	-,6214*	,14135	,009	-1,0866	-,1563

Based on observed means.
The error term is Mean Square(Error) = ,030.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = E13.0130, days after germination = 60

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,054[b]	4	,013	5,632	,012
Intercept	,615	1	,615	256,779	,000
Amendements	,054	4	,013	5,632	,012
Error	,024	10	,002		
Total	,693	15			

Corrected Total	,078	14			

a. plant part = below ground, sites = Van Oeckel, days after germination = 20
b. R Squared = ,693 (Adjusted R Squared = ,570)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-,1489*	,03996	,025	-,2804	-,0174
	elemental sulphur	-,1146	,03996	,096	-,2461	,0169
	PSB	-,1665*	,03996	,013	-,2980	-,0349
	sodium silicate	-,1461*	,03996	,028	-,2776	-,0146
control	citric acid	,1489*	,03996	,025	,0174	,2804
	elemental sulphur	,0343	,03996	,906	-,0972	,1658
	PSB	-,0176	,03996	,991	-,1491	,1140
	sodium silicate	,0028	,03996	1,000	-,1287	,1343
elemental sulphur	citric acid	,1146	,03996	,096	-,0169	,2461
	control	-,0343	,03996	,906	-,1658	,0972
	PSB	-,0519	,03996	,699	-,1834	,0797
	sodium silicate	-,0315	,03996	,928	-,1630	,1000
PSB	citric acid	,1665*	,03996	,013	,0349	,2980
	control	,0176	,03996	,991	-,1140	,1491
	elemental sulphur	,0519	,03996	,699	-,0797	,1834
	sodium silicate	,0204	,03996	,984	-,1111	,1519
sodium silicate	citric acid	,1461*	,03996	,028	,0146	,2776
	control	-,0028	,03996	1,000	-,1343	,1287
	elemental sulphur	,0315	,03996	,928	-,1000	,1630
	PSB	-,0204	,03996	,984	-,1519	,1111

Based on observed means.
The error term is Mean Square(Error) = ,002.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = Van Oeckel, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17,422[b]	4	4,355	48,067	,000
Intercept	49,665	1	49,665	548,100	,000
Amendements	17,422	4	4,355	48,067	,000
Error	,906	10	,091		
Total	67,993	15			
Corrected Total	18,328	14			

a. plant part = below ground, sites = Van Oeckel, days after germination = 40
b. R Squared = ,951 (Adjusted R Squared = ,931)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-,8846*	,24578	,031	-1,6935	-,0757

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
	elemental sulphur	-1,0413*	,24578	,012	-1,8502	-,2324
	PSB	-3,2283*	,24578	,000	-4,0372	-2,4194
	sodium silicate	-1,7355*	,24578	,000	-2,5444	-,9266
control	citric acid	,8846*	,24578	,031	,0757	1,6935
	elemental sulphur	-,1567	,24578	,965	-,9656	,6522
	PSB	-2,3438*	,24578	,000	-3,1527	-1,5349
	sodium silicate	-,8510*	,24578	,038	-1,6599	-,0421
elemental sulphur	citric acid	1,0413*	,24578	,012	,2324	1,8502
	control	,1567	,24578	,965	-,6522	,9656
	PSB	-2,1871*	,24578	,000	-2,9960	-1,3782
	sodium silicate	-,6943	,24578	,103	-1,5032	,1146
PSB	citric acid	3,2283*	,24578	,000	2,4194	4,0372
	control	2,3438*	,24578	,000	1,5349	3,1527
	elemental sulphur	2,1871*	,24578	,000	1,3782	2,9960
	sodium silicate	1,4928*	,24578	,001	,6839	2,3017
sodium silicate	citric acid	1,7355*	,24578	,000	,9266	2,5444
	control	,8510*	,24578	,038	,0421	1,6599
	elemental sulphur	,6943	,24578	,103	-,1146	1,5032
	PSB	-1,4928*	,24578	,001	-2,3017	-,6839

Based on observed means.
The error term is Mean Square(Error) = ,091.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = Van Oeckel, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	28,013[b]	4	7,003	64,347	,000
Intercept	62,309	1	62,309	572,519	,000
Amendements	28,013	4	7,003	64,347	,000
Error	1,088	10	,109		
Total	91,410	15			
Corrected Total	29,101	14			

a. plant part = below ground, sites = Van Oeckel, days after germination = 60
b. R Squared = ,963 (Adjusted R Squared = ,948)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
citric acid	control	-,5803	,26936	,271	-1,4668	,3062
	elemental sulphur	-,7504	,26936	,109	-1,6369	,1361
	PSB	-3,9103*	,26936	,000	-4,7968	-3,0238
	sodium silicate	-1,4429*	,26936	,002	-2,3294	-,5564
control	citric acid	,5803	,26936	,271	-,3062	1,4668
	elemental sulphur	-,1702	,26936	,966	-1,0567	,7163
	PSB	-3,3301*	,26936	,000	-4,2166	-2,4436
	sodium silicate	-,8627	,26936	,057	-1,7492	,0238
elemental sulphur	citric acid	,7504	,26936	,109	-,1361	1,6369
	control	,1702	,26936	,966	-,7163	1,0567
	PSB	-3,1599*	,26936	,000	-4,0464	-2,2734
	sodium silicate	-,6925	,26936	,150	-1,5790	,1940
PSB	citric acid	3,9103*	,26936	,000	3,0238	4,7968

	control	3,3301*	,26936	,000	2,4436	4,2166
	elemental sulphur	3,1599*	,26936	,000	2,2734	4,0464
	sodium silicate	2,4674*	,26936	,000	1,5809	3,3539
sodium silicate	citric acid	1,4429*	,26936	,002	,5564	2,3294
	control	,8627	,26936	,057	-,0238	1,7492
	elemental sulphur	,6925	,26936	,150	-,1940	1,5790
	PSB	-2,4674*	,26936	,000	-3,3539	-1,5809

Based on observed means.
The error term is Mean Square(Error) = ,109.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = Van Oeckel, days after germination = 60

ANOVA for total biomass dry weight (g)

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	331,815[b]	29	11,442	148,332	,000
Intercept	419,474	1	419,474	5438,024	,000
Sites	,517	1	,517	6,706	,012
Amendements	117,360	4	29,340	380,360	,000
Days	147,864	2	73,932	958,447	,000
Sites * Amendements	3,876	4	,969	12,561	,000
Sites * Days	,310	2	,155	2,009	,143
Amendements * Days	56,936	8	7,117	92,265	,000
Sites * Amendements * Days	4,952	8	,619	8,025	,000
Error	4,628	60	,077		
Total	755,917	90			
Corrected Total	336,443	89			

a. plant part = total
b. R Squared = ,986 (Adjusted R Squared = ,980)

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,154[b]	4	,038	2,588	,102
Intercept	2,608	1	2,608	175,343	,000
Amendements	,154	4	,038	2,588	,102
Error	,149	10	,015		
Total	2,911	15			
Corrected Total	,303	14			

a. plant part = total, sites = E13.0130, days after germination = 20
b. R Squared = ,509 (Adjusted R Squared = ,312)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,2789	,09958	,106	-,6066	,0489

	elemental sulphur	-,1380	,09958	,649	-,4657	,1897
	PSB	-,2638	,09958	,134	-,5916	,0639
	sodium silicate	-,2006	,09958	,326	-,5283	,1272
control	citric acid	,2789	,09958	,106	-,0489	,6066
	elemental sulphur	,1409	,09958	,633	-,1869	,4686
	PSB	,0150	,09958	1,000	-,3127	,3428
	sodium silicate	,0783	,09958	,929	-,2494	,4060
elemental sulphur	citric acid	,1380	,09958	,649	-,1897	,4657
	control	-,1409	,09958	,633	-,4686	,1869
	PSB	-,1258	,09958	,717	-,4536	,2019
	sodium silicate	-,0626	,09958	,967	-,3903	,2652
PSB	citric acid	,2638	,09958	,134	-,0639	,5916
	control	-,0150	,09958	1,000	-,3428	,3127
	elemental sulphur	,1258	,09958	,717	-,2019	,4536
	sodium silicate	,0633	,09958	,966	-,2645	,3910
sodium silicate	citric acid	,2006	,09958	,326	-,1272	,5283
	control	-,0783	,09958	,929	-,4060	,2494
	elemental sulphur	,0626	,09958	,967	-,2652	,3903
	PSB	-,0633	,09958	,966	-,3910	,2645

Based on observed means.
The error term is Mean Square(Error) = ,015.
a. plant part = total, sites = E13.0130, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	24,368[b]	4	6,092	52,492	,000
Intercept	92,051	1	92,051	793,163	,000
Amendements	24,368	4	6,092	52,492	,000
Error	1,161	10	,116		
Total	117,580	15			
Corrected Total	25,529	14			

a. plant part = total, sites = E13.0130, days after germination = 40
b. R Squared = ,955 (Adjusted R Squared = ,936)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-1,1118*	,27816	,017	-2,0273	-,1964
	elemental sulphur	-1,0567*	,27816	,023	-1,9722	-,1413
	PSB	-3,8484*	,27816	,000	-4,7639	-2,9330
	sodium silicate	-1,6189*	,27816	,001	-2,5343	-,7035
control	citric acid	1,1118*	,27816	,017	,1964	2,0273
	elemental sulphur	,0551	,27816	1,000	-,8603	,9705
	PSB	-2,7366*	,27816	,000	-3,6520	-1,8212
	sodium silicate	-,5071	,27816	,413	-1,4225	,4084
elemental sulphur	citric acid	1,0567*	,27816	,023	,1413	1,9722
	control	-,0551	,27816	1,000	-,9705	,8603
	PSB	-2,7917*	,27816	,000	-3,7071	-1,8763
	sodium silicate	-,5622	,27816	,323	-1,4776	,3533
PSB	citric acid	3,8484*	,27816	,000	2,9330	4,7639

	control	2,7366*	,27816	,000	1,8212	3,6520
	elemental sulphur	2,7917*	,27816	,000	1,8763	3,7071
	sodium silicate	2,2295*	,27816	,000	1,3141	3,1450
sodium silicate	citric acid	1,6189*	,27816	,001	,7035	2,5343
	control	,5071	,27816	,413	-,4084	1,4225
	elemental sulphur	,5622	,27816	,323	-,3533	1,4776
	PSB	-2,2295*	,27816	,000	-3,1450	-1,3141

Based on observed means.
The error term is Mean Square(Error) = ,116.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = E13.0130, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	33,979[b]	4	8,495	128,260	,000
Intercept	168,841	1	168,841	2549,278	,000
Amendements	33,979	4	8,495	128,260	,000
Error	,662	10	,066		
Total	203,483	15			
Corrected Total	34,641	14			

a. plant part = total, sites = E13.0130, days after germination = 60
b. R Squared = ,981 (Adjusted R Squared = ,973)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
citric acid	control	-,7071*	,21013	,045	-1,3987	-,0155
	elemental sulphur	-,6952*	,21013	,049	-1,3867	-,0036
	PSB	-4,1930*	,21013	,000	-4,8846	-3,5015
	sodium silicate	-2,2564*	,21013	,000	-2,9480	-1,5648
control	citric acid	,7071*	,21013	,045	,0155	1,3987
	elemental sulphur	,0119	,21013	1,000	-,6796	,7035
	PSB	-3,4859*	,21013	,000	-4,1775	-2,7944
	sodium silicate	-1,5493*	,21013	,000	-2,2409	-,8577
elemental sulphur	citric acid	,6952*	,21013	,049	,0036	1,3867
	control	-,0119	,21013	1,000	-,7035	,6796
	PSB	-3,4979*	,21013	,000	-4,1894	-2,8063
	sodium silicate	-1,5612*	,21013	,000	-2,2528	-,8697
PSB	citric acid	4,1930*	,21013	,000	3,5015	4,8846
	control	3,4859*	,21013	,000	2,7944	4,1775
	elemental sulphur	3,4979*	,21013	,000	2,8063	4,1894
	sodium silicate	1,9366*	,21013	,000	1,2451	2,6282
sodium silicate	citric acid	2,2564*	,21013	,000	1,5648	2,9480
	control	1,5493*	,21013	,000	,8577	2,2409
	elemental sulphur	1,5612*	,21013	,000	,8697	2,2528
	PSB	-1,9366*	,21013	,000	-2,6282	-1,2451

Based on observed means.
The error term is Mean Square(Error) = ,066.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = E13.0130, days after germination = 60

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,261[b]	4	,065	9,408	,002
Intercept	3,154	1	3,154	454,037	,000
Amendements	,261	4	,065	9,408	,002
Error	,069	10	,007		
Total	3,485	15			
Corrected Total	,331	14			

a. plant part = total, sites = Van Oeckel, days after germination = 20
b. R Squared = ,790 (Adjusted R Squared = ,706)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,3287*	,06806	,005	-,5527	-,1048
	elemental sulphur	-,2719*	,06806	,017	-,4959	-,0480
	PSB	-,3627*	,06806	,002	-,5867	-,1387
	sodium silicate	-,3246*	,06806	,005	-,5485	-,1006
control	citric acid	,3287*	,06806	,005	,1048	,5527
	elemental sulphur	,0568	,06806	,914	-,1672	,2808
	PSB	-,0340	,06806	,986	-,2579	,1900
	sodium silicate	,0042	,06806	1,000	-,2198	,2282
elemental sulphur	citric acid	,2719*	,06806	,017	,0480	,4959
	control	-,0568	,06806	,914	-,2808	,1672
	PSB	-,0908	,06806	,679	-,3147	,1332
	sodium silicate	-,0526	,06806	,933	-,2766	,1714
PSB	citric acid	,3627*	,06806	,002	,1387	,5867
	control	,0340	,06806	,986	-,1900	,2579
	elemental sulphur	,0908	,06806	,679	-,1332	,3147
	sodium silicate	,0381	,06806	,978	-,1858	,2621
sodium silicate	citric acid	,3246*	,06806	,005	,1006	,5485
	control	-,0042	,06806	1,000	-,2282	,2198
	elemental sulphur	,0526	,06806	,933	-,1714	,2766
	PSB	-,0381	,06806	,978	-,2621	,1858

Based on observed means.
The error term is Mean Square(Error) = ,007.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = Van Oeckel, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	36,118[b]	4	9,029	69,875	,000
Intercept	99,558	1	99,558	770,448	,000
Amendements	36,118	4	9,029	69,875	,000
Error	1,292	10	,129		
Total	136,968	15			
Corrected Total	37,410	14			

a. plant part = total, sites = Van Oeckel, days after germination = 40
b. R Squared = ,965 (Adjusted R Squared = ,952)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-1,0810*	,29351	,027	-2,0469	-,1150
	elemental sulphur	-1,1992*	,29351	,015	-2,1651	-,2332
	PSB	-4,5333*	,29351	,000	-5,4993	-3,5674
	sodium silicate	-2,4839*	,29351	,000	-3,4499	-1,5180
control	citric acid	1,0810*	,29351	,027	,1150	2,0469
	elemental sulphur	-,1182	,29351	,994	-1,0842	,8478
	PSB	-3,4524*	,29351	,000	-4,4183	-2,4864
	sodium silicate	-1,4030*	,29351	,005	-2,3689	-,4370
elemental sulphur	citric acid	1,1992*	,29351	,015	,2332	2,1651
	control	,1182	,29351	,994	-,8478	1,0842
	PSB	-3,3342*	,29351	,000	-4,3001	-2,3682
	sodium silicate	-1,2848*	,29351	,009	-2,2507	-,3188
PSB	citric acid	4,5333*	,29351	,000	3,5674	5,4993
	control	3,4524*	,29351	,000	2,4864	4,4183
	elemental sulphur	3,3342*	,29351	,000	2,3682	4,3001
	sodium silicate	2,0494*	,29351	,000	1,0834	3,0154
sodium silicate	citric acid	2,4839*	,29351	,000	1,5180	3,4499
	control	1,4030*	,29351	,005	,4370	2,3689
	elemental sulphur	1,2848*	,29351	,009	,3188	2,2507
	PSB	-2,0494*	,29351	,000	-3,0154	-1,0834

Based on observed means.
The error term is Mean Square(Error) = ,129.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = Van Oeckel, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	88,243[b]	4	22,061	170,364	,000
Intercept	201,951	1	201,951	1559,559	,000
Amendements	88,243	4	22,061	170,364	,000
Error	1,295	10	,129		
Total	291,490	15			
Corrected Total	89,538	14			

a. plant part = total, sites = Van Oeckel, days after germination = 60
b. R Squared = ,986 (Adjusted R Squared = ,980)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,5880	,29382	,331	-1,5550	,3789

	elemental sulphur	-,8509	,29382	,092	-1,8179	,1161
	PSB	-6,7010*	,29382	,000	-7,6680	-5,7340
	sodium silicate	-2,1207*	,29382	,000	-3,0876	-1,1537
control	citric acid	,5880	,29382	,331	-,3789	1,5550
	elemental sulphur	-,2629	,29382	,893	-1,2298	,7041
	PSB	-6,1130*	,29382	,000	-7,0799	-5,1460
	sodium silicate	-1,5326*	,29382	,003	-2,4996	-,5657
elemental sulphur	citric acid	,8509	,29382	,092	-,1161	1,8179
	control	,2629	,29382	,893	-,7041	1,2298
	PSB	-5,8501*	,29382	,000	-6,8171	-4,8831
	sodium silicate	-1,2698*	,29382	,010	-2,2367	-,3028
PSB	citric acid	6,7010*	,29382	,000	5,7340	7,6680
	control	6,1130*	,29382	,000	5,1460	7,0799
	elemental sulphur	5,8501*	,29382	,000	4,8831	6,8171
	sodium silicate	4,5803*	,29382	,000	3,6134	5,5473
sodium silicate	citric acid	2,1207*	,29382	,000	1,1537	3,0876
	control	1,5326*	,29382	,003	,5657	2,4996
	elemental sulphur	1,2698*	,29382	,010	,3028	2,2367
	PSB	-4,5803*	,29382	,000	-5,5473	-3,6134

Based on observed means.
The error term is Mean Square(Error) = ,129.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = Van Oeckel, days after germination = 60

ANOVA of above ground biomass P (mg) content

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	537,983[b]	29	18,551	123,234	,000
Intercept	730,792	1	730,792	4854,619	,000
Days	144,301	2	72,150	479,292	,000
Sites	5,519	1	5,519	36,660	,000
Amendements	254,849	4	63,712	423,237	,000
Days * Sites	2,699	2	1,349	8,964	,000
Days * Amendements	105,890	8	13,236	87,928	,000
Sites * Amendements	9,300	4	2,325	15,446	,000
Days * Sites * Amendements	15,426	8	1,928	12,809	,000
Error	9,032	60	,151		
Total	1277,807	90			
Corrected Total	547,015	89			

a. plant part = Above ground
b. R Squared = ,983 (Adjusted R Squared = ,976)

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,178[b]	4	,295	2,141	,150
Intercept	15,728	1	15,728	114,309	,000
Amendements	1,178	4	,295	2,141	,150
Error	1,376	10	,138		
Total	18,283	15			
Corrected Total	2,554	14			

a. plant part = Above ground, sites = E13.0130, days after germination = 20
b. R Squared = ,461 (Adjusted R Squared = ,246)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-,4904	,30287	,518	-1,4872	,5064
	elemental sulphur	-,0092	,30287	1,000	-1,0059	,9876
	PSB	-,4681	,30287	,559	-1,4649	,5287
	sodium silicate	-,6990	,30287	,219	-1,6957	,2978
control	citric acid	,4904	,30287	,518	-,5064	1,4872
	elemental sulphur	,4812	,30287	,535	-,5155	1,4780
	PSB	,0223	,30287	1,000	-,9745	1,0191
	sodium silicate	-,2086	,30287	,955	-1,2053	,7882
elemental sulphur	citric acid	,0092	,30287	1,000	-,9876	1,0059
	control	-,4812	,30287	,535	-1,4780	,5155
	PSB	-,4589	,30287	,576	-1,4557	,5378
	sodium silicate	-,6898	,30287	,229	-1,6866	,3070
PSB	citric acid	,4681	,30287	,559	-,5287	1,4649
	control	-,0223	,30287	1,000	-1,0191	,9745
	elemental sulphur	,4589	,30287	,576	-,5378	1,4557
	sodium silicate	-,2309	,30287	,936	-1,2276	,7659
sodium silicate	citric acid	,6990	,30287	,219	-,2978	1,6957
	control	,2086	,30287	,955	-,7882	1,2053
	elemental sulphur	,6898	,30287	,229	-,3070	1,6866
	PSB	,2309	,30287	,936	-,7659	1,2276

Based on observed means.
The error term is Mean Square(Error) = ,138.
a. plant part = Above ground, sites = E13.0130, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	70,221[b]	4	17,555	77,038	,000
Intercept	134,071	1	134,071	588,351	,000
Amendements	70,221	4	17,555	77,038	,000
Error	2,279	10	,228		
Total	206,571	15			
Corrected Total	72,500	14			

a. plant part = Above ground, sites = E13.0130, days after germination = 40
b. R Squared = ,969 (Adjusted R Squared = ,956)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-,5996	,38977	,563	-1,8824	,6832
	elemental sulphur	-,8459	,38977	,265	-2,1287	,4368
	PSB	-6,0229*	,38977	,000	-7,3057	-4,7402

	sodium silicate	-1,8988*	,38977	,005	-3,1816	-,6161
control	citric acid	,5996	,38977	,563	-,6832	1,8824
	elemental sulphur	-,2463	,38977	,966	-1,5291	1,0364
	PSB	-5,4233*	,38977	,000	-6,7061	-4,1406
	sodium silicate	-1,2992*	,38977	,047	-2,5820	-,0165
elemental sulphur	citric acid	,8459	,38977	,265	-,4368	2,1287
	control	,2463	,38977	,966	-1,0364	1,5291
	PSB	-5,1770*	,38977	,000	-6,4597	-3,8942
	sodium silicate	-1,0529	,38977	,124	-2,3357	,2298
PSB	citric acid	6,0229*	,38977	,000	4,7402	7,3057
	control	5,4233*	,38977	,000	4,1406	6,7061
	elemental sulphur	5,1770*	,38977	,000	3,8942	6,4597
	sodium silicate	4,1241*	,38977	,000	2,8413	5,4068
sodium silicate	citric acid	1,8988*	,38977	,005	,6161	3,1816
	control	1,2992*	,38977	,047	,0165	2,5820
	elemental sulphur	1,0529	,38977	,124	-,2298	2,3357
	PSB	-4,1241*	,38977	,000	-5,4068	-2,8413

Based on observed means.
The error term is Mean Square(Error) = ,228.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = E13.0130, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	51,789[b]	4	12,947	86,010	,000
Intercept	215,701	1	215,701	1432,933	,000
Amendements	51,789	4	12,947	86,010	,000
Error	1,505	10	,151		
Total	268,995	15			
Corrected Total	53,294	14			

a. plant part = Above ground, sites = E13.0130, days after germination = 60
b. R Squared = ,972 (Adjusted R Squared = ,960)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	,3283	,31679	,833	-,7142	1,3709
	elemental sulphur	,3569	,31679	,790	-,6857	1,3994
	PSB	-4,5365*	,31679	,000	-5,5790	-3,4939
	sodium silicate	-1,4047*	,31679	,009	-2,4473	-,3622
control	citric acid	-,3283	,31679	,833	-1,3709	,7142
	elemental sulphur	,0285	,31679	1,000	-1,0140	1,0711
	PSB	-4,8648*	,31679	,000	-5,9074	-3,8222
	sodium silicate	-1,7331*	,31679	,002	-2,7756	-,6905
elemental sulphur	citric acid	-,3569	,31679	,790	-1,3994	,6857
	control	-,0285	,31679	1,000	-1,0711	1,0140
	PSB	-4,8933*	,31679	,000	-5,9359	-3,8508
	sodium silicate	-1,7616*	,31679	,002	-2,8042	-,7190
PSB	citric acid	4,5365*	,31679	,000	3,4939	5,5790
	control	4,8648*	,31679	,000	3,8222	5,9074
	elemental sulphur	4,8933*	,31679	,000	3,8508	5,9359

	sodium silicate	3,1317*	,31679	,000	2,0892	4,1743
sodium silicate	citric acid	1,4047*	,31679	,009	,3622	2,4473
	control	1,7331*	,31679	,002	,6905	2,7756
	elemental sulphur	1,7616*	,31679	,002	,7190	2,8042
	PSB	-3,1317*	,31679	,000	-4,1743	-2,0892

Based on observed means.
The error term is Mean Square(Error) = ,151.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = E13.0130, days after germination = 60

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3,064[b]	4	,766	10,413	,001
Intercept	28,424	1	28,424	386,399	,000
Amendements	3,064	4	,766	10,413	,001
Error	,736	10	,074		
Total	32,223	15			
Corrected Total	3,800	14			

a. plant part = Above ground, sites = Van Oeckel, days after germination = 20
b. R Squared = ,806 (Adjusted R Squared = ,729)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,9200*	,22145	,013	-1,6488	-,1912
	elemental sulphur	-,5428	,22145	,179	-1,2716	,1860
	PSB	-1,2538*	,22145	,002	-1,9826	-,5250
	sodium silicate	-1,1169*	,22145	,004	-1,8457	-,3881
control	citric acid	,9200*	,22145	,013	,1912	1,6488
	elemental sulphur	,3772	,22145	,473	-,3516	1,1060
	PSB	-,3338	,22145	,580	-1,0626	,3950
	sodium silicate	-,1969	,22145	,895	-,9258	,5319
elemental sulphur	citric acid	,5428	,22145	,179	-,1860	1,2716
	control	-,3772	,22145	,473	-1,1060	,3516
	PSB	-,7109	,22145	,057	-1,4398	,0179
	sodium silicate	-,5741	,22145	,145	-1,3029	,1547
PSB	citric acid	1,2538*	,22145	,002	,5250	1,9826
	control	,3338	,22145	,580	-,3950	1,0626
	elemental sulphur	,7109	,22145	,057	-,0179	1,4398
	sodium silicate	,1368	,22145	,969	-,5920	,8656
sodium silicate	citric acid	1,1169*	,22145	,004	,3881	1,8457
	control	,1969	,22145	,895	-,5319	,9258
	elemental sulphur	,5741	,22145	,145	-,1547	1,3029
	PSB	-,1368	,22145	,969	-,8656	,5920

Based on observed means.
The error term is Mean Square(Error) = ,074.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = Van Oeckel, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	75,614[b]	4	18,903	97,310	,000
Intercept	148,884	1	148,884	766,410	,000
Amendements	75,614	4	18,903	97,310	,000
Error	1,943	10	,194		
Total	226,440	15			
Corrected Total	77,556	14			

a. plant part = Above ground, sites = Van Oeckel, days after germination = 40
b. R Squared = ,975 (Adjusted R Squared = ,965)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,2960	,35987	,918	-1,4804	,8883
	elemental sulphur	-,3841	,35987	,819	-1,5685	,8002
	PSB	-5,9686*	,35987	,000	-7,1530	-4,7843
	sodium silicate	-2,3661*	,35987	,000	-3,5504	-1,1817
control	citric acid	,2960	,35987	,918	-,8883	1,4804
	elemental sulphur	-,0881	,35987	,999	-1,2724	1,0963
	PSB	-5,6726*	,35987	,000	-6,8570	-4,4882
	sodium silicate	-2,0700*	,35987	,001	-3,2544	-,8857
elemental sulphur	citric acid	,3841	,35987	,819	-,8002	1,5685
	control	,0881	,35987	,999	-1,0963	1,2724
	PSB	-5,5845*	,35987	,000	-6,7689	-4,4002
	sodium silicate	-1,9819*	,35987	,002	-3,1663	-,7976
PSB	citric acid	5,9686*	,35987	,000	4,7843	7,1530
	control	5,6726*	,35987	,000	4,4882	6,8570
	elemental sulphur	5,5845*	,35987	,000	4,4002	6,7689
	sodium silicate	3,6026*	,35987	,000	2,4182	4,7870
sodium silicate	citric acid	2,3661*	,35987	,000	1,1817	3,5504
	control	2,0700*	,35987	,001	,8857	3,2544
	elemental sulphur	1,9819*	,35987	,002	,7976	3,1663
	PSB	-3,6026*	,35987	,000	-4,7870	-2,4182

Based on observed means.
The error term is Mean Square(Error) = ,194.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = Van Oeckel, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	183,599[b]	4	45,900	384,463	,000
Intercept	340,502	1	340,502	2852,087	,000
Amendements	183,599	4	45,900	384,463	,000
Error	1,194	10	,119		
Total	525,295	15			

Corrected Total	184,793	14			

a. plant part = Above ground, sites = Van Oeckel, days after germination = 60
b. R Squared = ,994 (Adjusted R Squared = ,991)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	,6197	,28212	,256	-,3087	1,5482
	elemental sulphur	-,1320	,28212	,989	-1,0605	,7965
	PSB	-8,7426*	,28212	,000	-9,6711	-7,8142
	sodium silicate	-,7406	,28212	,138	-1,6691	,1879
control	citric acid	-,6197	,28212	,256	-1,5482	,3087
	elemental sulphur	-,7518	,28212	,130	-1,6802	,1767
	PSB	-9,3624*	,28212	,000	-10,2909	-8,4339
	sodium silicate	-1,3604*	,28212	,005	-2,2888	-,4319
elemental sulphur	citric acid	,1320	,28212	,989	-,7965	1,0605
	control	,7518	,28212	,130	-,1767	1,6802
	PSB	-8,6106*	,28212	,000	-9,5391	-7,6821
	sodium silicate	-,6086	,28212	,270	-1,5371	,3199
PSB	citric acid	8,7426*	,28212	,000	7,8142	9,6711
	control	9,3624*	,28212	,000	8,4339	10,2909
	elemental sulphur	8,6106*	,28212	,000	7,6821	9,5391
	sodium silicate	8,0020*	,28212	,000	7,0735	8,9305
sodium silicate	citric acid	,7406	,28212	,138	-,1879	1,6691
	control	1,3604*	,28212	,005	,4319	2,2888
	elemental sulphur	,6086	,28212	,270	-,3199	1,5371
	PSB	-8,0020*	,28212	,000	-8,9305	-7,0735

Based on observed means.
The error term is Mean Square(Error) = ,119.
*. The mean difference is significant at the 0,05 level.
a. plant part = Above ground, sites = Van Oeckel, days after germination = 60

ANOVA for Below Ground Biomass P (mg) content

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	629,812[b]	29	21,718	74,085	,000
Intercept	841,647	1	841,647	2871,079	,000
Days	280,694	2	140,347	478,760	,000
Sites	21,761	1	21,761	74,231	,000
Amendements	182,829	4	45,707	155,919	,000
Days * Sites	8,182	2	4,091	13,955	,000
Days * Amendements	80,096	8	10,012	34,154	,000
Sites * Amendements	36,565	4	9,141	31,183	,000
Days * Sites * Amendements	19,686	8	2,461	8,394	,000
Error	17,589	60	,293		
Total	1489,048	90			
Corrected Total	647,401	89			

a. plant part = below ground
b. R Squared = ,973 (Adjusted R Squared = ,960)

Tests of Between-Subjects Effects[a]

Dependent Variable: dry biomass wt (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,154[b]	4	,038	2,588	,102
Intercept	2,608	1	2,608	175,343	,000
Amendements	,154	4	,038	2,588	,102
Error	,149	10	,015		
Total	2,911	15			
Corrected Total	,303	14			

a. plant part = total, sites = E13.0130, days after germination = 20

b. R Squared = ,509 (Adjusted R Squared = ,312)

Multiple Comparisons[a]

Dependent Variable: dry biomass wt (g)

Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,2789	,09958	,106	-,6066	,0489
	elemental sulphur	-,1380	,09958	,649	-,4657	,1897
	PSB	-,2638	,09958	,134	-,5916	,0639
	sodium silicate	-,2006	,09958	,326	-,5283	,1272
control	citric acid	,2789	,09958	,106	-,0489	,6066
	elemental sulphur	,1409	,09958	,633	-,1869	,4686
	PSB	,0150	,09958	1,000	-,3127	,3428
	sodium silicate	,0783	,09958	,929	-,2494	,4060
elemental sulphur	citric acid	,1380	,09958	,649	-,1897	,4657
	control	-,1409	,09958	,633	-,4686	,1869
	PSB	-,1258	,09958	,717	-,4536	,2019
	sodium silicate	-,0626	,09958	,967	-,3903	,2652
PSB	citric acid	,2638	,09958	,134	-,0639	,5916
	control	-,0150	,09958	1,000	-,3428	,3127
	elemental sulphur	,1258	,09958	,717	-,2019	,4536
	sodium silicate	,0633	,09958	,966	-,2645	,3910
sodium silicate	citric acid	,2006	,09958	,326	-,1272	,5283
	control	-,0783	,09958	,929	-,4060	,2494
	elemental sulphur	,0626	,09958	,967	-,2652	,3903
	PSB	-,0633	,09958	,966	-,3910	,2645

Based on observed means.

The error term is Mean Square(Error) = ,015.

a. plant part = total, sites = E13.0130, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	27,254[b]	4	6,813	19,583	,000
Intercept	194,056	1	194,056	557,746	,000
Amendements	27,254	4	6,813	19,583	,000
Error	3,479	10	,348		
Total	224,789	15			

Corrected Total	30,733	14			

a. plant part = below ground, sites = E13.0130, days after germination = 40
b. R Squared = ,887 (Adjusted R Squared = ,842)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-2,1589*	,48161	,008	-3,7439	-,5738
	elemental sulphur	-1,7274*	,48161	,032	-3,3125	-,1424
	PSB	-3,8702*	,48161	,000	-5,4552	-2,2851
	sodium silicate	-3,3095*	,48161	,000	-4,8945	-1,7245
control	citric acid	2,1589*	,48161	,008	,5738	3,7439
	elemental sulphur	,4314	,48161	,892	-1,1536	2,0165
	PSB	-1,7113*	,48161	,033	-3,2963	-,1263
	sodium silicate	-1,1506	,48161	,195	-2,7357	,4344
elemental sulphur	citric acid	1,7274*	,48161	,032	,1424	3,3125
	control	-,4314	,48161	,892	-2,0165	1,1536
	PSB	-2,1427*	,48161	,008	-3,7278	-,5577
	sodium silicate	-1,5821	,48161	,050	-3,1671	,0030
PSB	citric acid	3,8702*	,48161	,000	2,2851	5,4552
	control	1,7113*	,48161	,033	,1263	3,2963
	elemental sulphur	2,1427*	,48161	,008	,5577	3,7278
	sodium silicate	,5607	,48161	,771	-1,0244	2,1457
sodium silicate	citric acid	3,3095*	,48161	,000	1,7245	4,8945
	control	1,1506	,48161	,195	-,4344	2,7357
	elemental sulphur	1,5821	,48161	,050	-,0030	3,1671
	PSB	-,5607	,48161	,771	-2,1457	1,0244

Based on observed means.
The error term is Mean Square(Error) = ,348.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = E13.0130, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	19,452[b]	4	4,863	44,232	,000
Intercept	198,215	1	198,215	1802,840	,000
Amendements	19,452	4	4,863	44,232	,000
Error	1,099	10	,110		
Total	218,767	15			
Corrected Total	20,552	14			

a. plant part = below ground, sites = E13.0130, days after germination = 60
b. R Squared = ,947 (Adjusted R Squared = ,925)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound

citric acid	control	-,4031	,27073	,591	-1,2941	,4879
	elemental sulphur	-,6225	,27073	,222	-1,5135	,2685
	PSB	-2,6762*	,27073	,000	-3,5672	-1,7852
	sodium silicate	-2,5830*	,27073	,000	-3,4740	-1,6920
control	citric acid	,4031	,27073	,591	-,4879	1,2941
	elemental sulphur	-,2193	,27073	,922	-1,1103	,6717
	PSB	-2,2731*	,27073	,000	-3,1641	-1,3821
	sodium silicate	-2,1798*	,27073	,000	-3,0708	-1,2888
elemental sulphur	citric acid	,6225	,27073	,222	-,2685	1,5135
	control	,2193	,27073	,922	-,6717	1,1103
	PSB	-2,0538*	,27073	,000	-2,9448	-1,1627
	sodium silicate	-1,9605*	,27073	,000	-2,8515	-1,0695
PSB	citric acid	2,6762*	,27073	,000	1,7852	3,5672
	control	2,2731*	,27073	,000	1,3821	3,1641
	elemental sulphur	2,0538*	,27073	,000	1,1627	2,9448
	sodium silicate	,0933	,27073	,996	-,7977	,9843
sodium silicate	citric acid	2,5830*	,27073	,000	1,6920	3,4740
	control	2,1798*	,27073	,000	1,2888	3,0708
	elemental sulphur	1,9605*	,27073	,000	1,0695	2,8515
	PSB	-,0933	,27073	,996	-,9843	,7977

Based on observed means.
The error term is Mean Square(Error) = ,110.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = E13.0130, days after germination = 60

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,834[b]	4	,208	9,005	,002
Intercept	6,712	1	6,712	289,879	,000
Amendements	,834	4	,208	9,005	,002
Error	,232	10	,023		
Total	7,777	15			
Corrected Total	1,065	14			

a. plant part = below ground, sites = Van Oeckel, days after germination = 20
b. R Squared = ,783 (Adjusted R Squared = ,696)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,6223*	,12424	,004	-1,0312	-,2135
	elemental sulphur	-,3194	,12424	,150	-,7282	,0895
	PSB	-,5961*	,12424	,005	-1,0049	-,1872
	sodium silicate	-,5597*	,12424	,008	-,9686	-,1509
control	citric acid	,6223*	,12424	,004	,2135	1,0312
	elemental sulphur	,3030	,12424	,182	-,1059	,7119
	PSB	,0263	,12424	,999	-,3826	,4352
	sodium silicate	,0626	,12424	,985	-,3463	,4715
elemental sulphur	citric acid	,3194	,12424	,150	-,0895	,7282
	control	-,3030	,12424	,182	-,7119	,1059
	PSB	-,2767	,12424	,245	-,6856	,1322

	sodium silicate	-,2404	,12424	,360	-,6493	,1685
PSB	citric acid	,5961*	,12424	,005	,1872	1,0049
	control	-,0263	,12424	,999	-,4352	,3826
	elemental sulphur	,2767	,12424	,245	-,1322	,6856
	sodium silicate	,0363	,12424	,998	-,3726	,4452
sodium silicate	citric acid	,5597*	,12424	,008	,1509	,9686
	control	-,0626	,12424	,985	-,4715	,3463
	elemental sulphur	,2404	,12424	,360	-,1685	,6493
	PSB	-,0363	,12424	,998	-,4452	,3726

Based on observed means.
The error term is Mean Square(Error) = ,023.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = Van Oeckel, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	126,017[b]	4	31,504	54,090	,000
Intercept	327,905	1	327,905	562,987	,000
Amendements	126,017	4	31,504	54,090	,000
Error	5,824	10	,582		
Total	459,747	15			
Corrected Total	131,842	14			

a. plant part = below ground, sites = Van Oeckel, days after germination = 40
b. R Squared = ,956 (Adjusted R Squared = ,938)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-2,1474*	,62313	,039	-4,1982	-,0966
	elemental sulphur	-2,1473*	,62313	,039	-4,1981	-,0965
	PSB	-8,5905*	,62313	,000	-10,6412	-6,5397
	sodium silicate	-4,0073*	,62313	,001	-6,0581	-1,9565
control	citric acid	2,1474*	,62313	,039	,0966	4,1982
	elemental sulphur	,0001	,62313	1,000	-2,0507	2,0509
	PSB	-6,4431*	,62313	,000	-8,4938	-4,3923
	sodium silicate	-1,8599	,62313	,080	-3,9107	,1909
elemental sulphur	citric acid	2,1473*	,62313	,039	,0965	4,1981
	control	-,0001	,62313	1,000	-2,0509	2,0507
	PSB	-6,4432*	,62313	,000	-8,4940	-4,3924
	sodium silicate	-1,8600	,62313	,080	-3,9108	,1908
PSB	citric acid	8,5905*	,62313	,000	6,5397	10,6412
	control	6,4431*	,62313	,000	4,3923	8,4938
	elemental sulphur	6,4432*	,62313	,000	4,3924	8,4940
	sodium silicate	4,5832*	,62313	,000	2,5324	6,6339
sodium silicate	citric acid	4,0073*	,62313	,001	1,9565	6,0581
	control	1,8599	,62313	,080	-,1909	3,9107
	elemental sulphur	1,8600	,62313	,080	-,1908	3,9108
	PSB	-4,5832*	,62313	,000	-6,6339	-2,5324

Based on observed means.
The error term is Mean Square(Error) = ,582.

*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = Van Oeckel, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	145,214[b]	4	36,304	53,870	,000
Intercept	422,125	1	422,125	626,381	,000
Amendements	145,214	4	36,304	53,870	,000
Error	6,739	10	,674		
Total	574,078	15			
Corrected Total	151,953	14			

a. plant part = below ground, sites = Van Oeckel, days after germination = 60
b. R Squared = ,956 (Adjusted R Squared = ,938)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-1,2917	,67028	,364	-3,4976	,9143
	elemental sulphur	-,7734	,67028	,776	-2,9793	1,4326
	PSB	-8,2235*	,67028	,000	-10,4295	-6,0176
	sodium silicate	-5,0660*	,67028	,000	-7,2720	-2,8601
control	citric acid	1,2917	,67028	,364	-,9143	3,4976
	elemental sulphur	,5183	,67028	,933	-1,6877	2,7242
	PSB	-6,9319*	,67028	,000	-9,1378	-4,7259
	sodium silicate	-3,7744*	,67028	,002	-5,9803	-1,5684
elemental sulphur	citric acid	,7734	,67028	,776	-1,4326	2,9793
	control	-,5183	,67028	,933	-2,7242	1,6877
	PSB	-7,4501*	,67028	,000	-9,6561	-5,2442
	sodium silicate	-4,2926*	,67028	,001	-6,4986	-2,0867
PSB	citric acid	8,2235*	,67028	,000	6,0176	10,4295
	control	6,9319*	,67028	,000	4,7259	9,1378
	elemental sulphur	7,4501*	,67028	,000	5,2442	9,6561
	sodium silicate	3,1575*	,67028	,006	,9516	5,3634
sodium silicate	citric acid	5,0660*	,67028	,000	2,8601	7,2720
	control	3,7744*	,67028	,002	1,5684	5,9803
	elemental sulphur	4,2926*	,67028	,001	2,0867	6,4986
	PSB	-3,1575*	,67028	,006	-5,3634	-,9516

Based on observed means.
The error term is Mean Square(Error) = ,674.
*. The mean difference is significant at the 0,05 level.
a. plant part = below ground, sites = Van Oeckel, days after germination = 60

ANOVA for total biomass (P content)

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2178,655[b]	29	75,126	129,262	,000
Intercept	3140,966	1	3140,966	5404,343	,000
Days	806,709	2	403,354	694,011	,000
Sites	49,196	1	49,196	84,647	,000
Amendements	840,477	4	210,119	361,531	,000
Days * Sites	16,987	2	8,493	14,614	,000
Days * Amendements	339,092	8	42,387	72,930	,000
Sites * Amendements	80,890	4	20,222	34,795	,000
Days * Sites * Amendements	45,304	8	5,663	9,744	,000
Error	34,872	60	,581		
Total	5354,493	90			
Corrected Total	2213,527	89			

a. plant part = total
b. R Squared = ,984 (Adjusted R Squared = ,977)

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2,589[b]	4	,647	2,876	,080
Intercept	33,347	1	33,347	148,179	,000
Amendements	2,589	4	,647	2,876	,080
Error	2,250	10	,225		
Total	38,186	15			
Corrected Total	4,839	14			

a. plant part = total, sites = E13.0130, days after germination = 20
b. R Squared = ,535 (Adjusted R Squared = ,349)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
citric acid	control	-,9108	,38734	,206	-2,1855	,3640
	elemental sulphur	-,1678	,38734	,992	-1,4426	1,1070
	PSB	-,9045	,38734	,211	-2,1793	,3702
	sodium silicate	-,9571	,38734	,174	-2,2319	,3176
control	citric acid	,9108	,38734	,206	-,3640	2,1855
	elemental sulphur	,7430	,38734	,368	-,5318	2,0177
	PSB	,0062	,38734	1,000	-1,2685	1,2810
	sodium silicate	-,0464	,38734	1,000	-1,3211	1,2284
elemental sulphur	citric acid	,1678	,38734	,992	-1,1070	1,4426
	control	-,7430	,38734	,368	-2,0177	,5318
	PSB	-,7367	,38734	,375	-2,0115	,5380
	sodium silicate	-,7893	,38734	,316	-2,0641	,4854
PSB	citric acid	,9045	,38734	,211	-,3702	2,1793
	control	-,0062	,38734	1,000	-1,2810	1,2685

	elemental sulphur	,7367	,38734	,375	-,5380	2,0115
	sodium silicate	-,0526	,38734	1,000	-1,3274	1,2222
sodium silicate	citric acid	,9571	,38734	,174	-,3176	2,2319
	control	,0464	,38734	1,000	-1,2284	1,3211
	elemental sulphur	,7893	,38734	,316	-,4854	2,0641
	PSB	,0526	,38734	1,000	-1,2222	1,3274

Based on observed means.
The error term is Mean Square(Error) = ,225.
a. plant part = total, sites = E13.0130, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	167,182[b]	4	41,796	50,344	,000
Intercept	650,725	1	650,725	783,814	,000
Amendements	167,182	4	41,796	50,344	,000
Error	8,302	10	,830		
Total	826,209	15			
Corrected Total	175,484	14			

a. plant part = total, sites = E13.0130, days after germination = 40
b. R Squared = ,953 (Adjusted R Squared = ,934)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-2,7585*	,74395	,026	-5,2069	-,3100
	elemental sulphur	-2,5733*	,74395	,039	-5,0218	-,1249
	PSB	-9,8931*	,74395	,000	-12,3415	-7,4446
	sodium silicate	-5,2083*	,74395	,000	-7,6567	-2,7599
control	citric acid	2,7585*	,74395	,026	,3100	5,2069
	elemental sulphur	,1851	,74395	,999	-2,2633	2,6335
	PSB	-7,1346*	,74395	,000	-9,5830	-4,6862
	sodium silicate	-2,4499*	,74395	,050	-4,8983	-,0014
elemental sulphur	citric acid	2,5733*	,74395	,039	,1249	5,0218
	control	-,1851	,74395	,999	-2,6335	2,2633
	PSB	-7,3197*	,74395	,000	-9,7681	-4,8713
	sodium silicate	-2,6350*	,74395	,034	-5,0834	-,1866
PSB	citric acid	9,8931*	,74395	,000	7,4446	12,3415
	control	7,1346*	,74395	,000	4,6862	9,5830
	elemental sulphur	7,3197*	,74395	,000	4,8713	9,7681
	sodium silicate	4,6847*	,74395	,001	2,2363	7,1332
sodium silicate	citric acid	5,2083*	,74395	,000	2,7599	7,6567
	control	2,4499*	,74395	,050	,0014	4,8983
	elemental sulphur	2,6350*	,74395	,034	,1866	5,0834
	PSB	-4,6847*	,74395	,001	-7,1332	-2,2363

Based on observed means.
The error term is Mean Square(Error) = ,830.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = E13.0130, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	124,089[b]	4	31,022	102,234	,000
Intercept	827,461	1	827,461	2726,905	,000
Amendements	124,089	4	31,022	102,234	,000
Error	3,034	10	,303		
Total	954,584	15			
Corrected Total	127,123	14			

a. plant part = total, sites = E13.0130, days after germination = 60

b. R Squared = ,976 (Adjusted R Squared = ,967)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot

Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-,0748	,44977	1,000	-1,5550	1,4054
	elemental sulphur	-,2656	,44977	,973	-1,7458	1,2146
	PSB	-7,2127*	,44977	,000	-8,6929	-5,7325
	sodium silicate	-3,9877*	,44977	,000	-5,4679	-2,5075
control	citric acid	,0748	,44977	1,000	-1,4054	1,5550
	elemental sulphur	-,1908	,44977	,992	-1,6710	1,2894
	PSB	-7,1379*	,44977	,000	-8,6181	-5,6576
	sodium silicate	-3,9129*	,44977	,000	-5,3931	-2,4326
elemental sulphur	citric acid	,2656	,44977	,973	-1,2146	1,7458
	control	,1908	,44977	,992	-1,2894	1,6710
	PSB	-6,9471*	,44977	,000	-8,4273	-5,4669
	sodium silicate	-3,7221*	,44977	,000	-5,2023	-2,2419
PSB	citric acid	7,2127*	,44977	,000	5,7325	8,6929
	control	7,1379*	,44977	,000	5,6576	8,6181
	elemental sulphur	6,9471*	,44977	,000	5,4669	8,4273
	sodium silicate	3,2250*	,44977	,000	1,7448	4,7052
sodium silicate	citric acid	3,9877*	,44977	,000	2,5075	5,4679
	control	3,9129*	,44977	,000	2,4326	5,3931
	elemental sulphur	3,7221*	,44977	,000	2,2419	5,2023
	PSB	-3,2250*	,44977	,000	-4,7052	-1,7448

Based on observed means.

The error term is Mean Square(Error) = ,303.

*. The mean difference is significant at the 0,05 level.

a. plant part = total, sites = E13.0130, days after germination = 60

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6,960[b]	4	1,740	12,723	,001
Intercept	62,759	1	62,759	458,938	,000
Amendements	6,960	4	1,740	12,723	,001
Error	1,367	10	,137		
Total	71,086	15			
Corrected Total	8,327	14			

a. plant part = total, sites = Van Oeckel, days after germination = 20

b. R Squared = ,836 (Adjusted R Squared = ,770)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-1,5423*	,30194	,003	-2,5360	-,5486
	elemental sulphur	-,8622	,30194	,098	-1,8559	,1315
	PSB	-1,8498*	,30194	,001	-2,8435	-,8561
	sodium silicate	-1,6767*	,30194	,002	-2,6704	-,6830
control	citric acid	1,5423*	,30194	,003	,5486	2,5360
	elemental sulphur	,6801	,30194	,237	-,3135	1,6738
	PSB	-,3075	,30194	,841	-1,3012	,6862
	sodium silicate	-,1343	,30194	,991	-1,1280	,8594
elemental sulphur	citric acid	,8622	,30194	,098	-,1315	1,8559
	control	-,6801	,30194	,237	-1,6738	,3135
	PSB	-,9877	,30194	,052	-1,9813	,0060
	sodium silicate	-,8145	,30194	,124	-1,8082	,1792
PSB	citric acid	1,8498*	,30194	,001	,8561	2,8435
	control	,3075	,30194	,841	-,6862	1,3012
	elemental sulphur	,9877	,30194	,052	-,0060	1,9813
	sodium silicate	,1732	,30194	,976	-,8205	1,1669
sodium silicate	citric acid	1,6767*	,30194	,002	,6830	2,6704
	control	,1343	,30194	,991	-,8594	1,1280
	elemental sulphur	,8145	,30194	,124	-,1792	1,8082
	PSB	-,1732	,30194	,976	-1,1669	,8205

Based on observed means.
The error term is Mean Square(Error) = ,137.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = Van Oeckel, days after germination = 20

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	392,185[b]	4	98,046	85,988	,000
Intercept	918,692	1	918,692	805,704	,000
Amendements	392,185	4	98,046	85,988	,000
Error	11,402	10	1,140		
Total	1322,279	15			
Corrected Total	403,587	14			

a. plant part = total, sites = Van Oeckel, days after germination = 40
b. R Squared = ,972 (Adjusted R Squared = ,960)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
citric acid	control	-2,4434	,87187	,106	-5,3128	,4260
	elemental sulphur	-2,5314	,87187	,091	-5,4008	,3380

	PSB	-14,5591*	,87187	,000	-17,4285	-11,6897
	sodium silicate	-6,3734*	,87187	,000	-9,2428	-3,5040
control	citric acid	2,4434	,87187	,106	-,4260	5,3128
	elemental sulphur	-,0880	,87187	1,000	-2,9574	2,7814
	PSB	-12,1157*	,87187	,000	-14,9851	-9,2463
	sodium silicate	-3,9299*	,87187	,008	-6,7993	-1,0605
elemental sulphur	citric acid	2,5314	,87187	,091	-,3380	5,4008
	control	,0880	,87187	1,000	-2,7814	2,9574
	PSB	-12,0277*	,87187	,000	-14,8971	-9,1583
	sodium silicate	-3,8420*	,87187	,009	-6,7114	-,9726
PSB	citric acid	14,5591*	,87187	,000	11,6897	17,4285
	control	12,1157*	,87187	,000	9,2463	14,9851
	elemental sulphur	12,0277*	,87187	,000	9,1583	14,8971
	sodium silicate	8,1857*	,87187	,000	5,3163	11,0551
sodium silicate	citric acid	6,3734*	,87187	,000	3,5040	9,2428
	control	3,9299*	,87187	,008	1,0605	6,7993
	elemental sulphur	3,8420*	,87187	,009	,9726	6,7114
	PSB	-8,1857*	,87187	,000	-11,0551	-5,3163

Based on observed means.
The error term is Mean Square(Error) = 1,140.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = Van Oeckel, days after germination = 40

Tests of Between-Subjects Effects[a]

Dependent Variable: P content (mg)/pot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	612,760[b]	4	153,190	179,910	,000
Intercept	1520,873	1	1520,873	1786,150	,000
Amendements	612,760	4	153,190	179,910	,000
Error	8,515	10	,851		
Total	2142,148	15			
Corrected Total	621,274	14			

a. plant part = total, sites = Van Oeckel, days after germination = 60
b. R Squared = ,986 (Adjusted R Squared = ,981)

Multiple Comparisons[a]

Dependent Variable: P content (mg)/pot
Tukey HSD

(I) amendment	(J) amendment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
citric acid	control	-,6719	,75343	,894	-3,1515	1,8077
	elemental sulphur	-,9054	,75343	,751	-3,3850	1,5742
	PSB	-16,9662*	,75343	,000	-19,4458	-14,4866
	sodium silicate	-5,8067*	,75343	,000	-8,2863	-3,3271
control	citric acid	,6719	,75343	,894	-1,8077	3,1515
	elemental sulphur	-,2335	,75343	,998	-2,7131	2,2461
	PSB	-16,2942*	,75343	,000	-18,7738	-13,8147
	sodium silicate	-5,1347*	,75343	,000	-7,6143	-2,6551
elemental sulphur	citric acid	,9054	,75343	,751	-1,5742	3,3850
	control	,2335	,75343	,998	-2,2461	2,7131
	PSB	-16,0607*	,75343	,000	-18,5403	-13,5812
	sodium silicate	-4,9012*	,75343	,001	-7,3808	-2,4216
PSB	citric acid	16,9662*	,75343	,000	14,4866	19,4458
	control	16,2942*	,75343	,000	13,8147	18,7738

	elemental sulphur	16,0607*	,75343	,000	13,5812	18,5403
	sodium silicate	11,1595*	,75343	,000	8,6799	13,6391
sodium silicate	citric acid	5,8067*	,75343	,000	3,3271	8,2863
	control	5,1347*	,75343	,000	2,6551	7,6143
	elemental sulphur	4,9012*	,75343	,001	2,4216	7,3808
	PSB	-11,1595*	,75343	,000	-13,6391	-8,6799

Based on observed means.
The error term is Mean Square(Error) = ,851.
*. The mean difference is significant at the 0,05 level.
a. plant part = total, sites = Van Oeckel, days after germination = 60