The influence of soil conditions on soil microbiological activity and consequent rock dust fertilization effectiveness

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Abstract

Global demineralization of agricultural soils in particular due to intensive exploitation is an increasingly recognized and critical issue. Methods of remineralisation include the application of volcanic rock dust such as basalt on mineral-deficient fields. However rock dust application does not always lead to yield increase, depending on soil conditions and the activity of soil biota. In a research done in the north of the Netherlands one field (MH) showed higher grass yield as a result of rock dust application while another field (JH) did not show such an increase. This study examined if there were differences in abiotic soil factors between soils of the different fields that correlated with differences in soil microorganisms and their biological activity, influencing the availability of rock dust minerals and consequent higher grass yield. Soil samples were analysed for pH, degree of oxidation (derived from the redox-potential) and EC before and after incubation in order to determine microbial activity, and grass roots were analysed for the degree of mycorrhizal colonization. Differences were observed in measurements of O_2 levels and degree of mycorrhizal colonization, however the small sample size did not allow to draw secure conclusions.
The change in pH measured before and after two day incubation of soil samples was higher in samples of field JH than those of field MH ($P<0.05$), but this would not be correlatable with differences in microbial activity because the soil of field MH had a higher clay fraction which buffers pH, and other influent soil factors may also play an important role. Increase of the soil EC after incubation was significantly higher in MH samples ($P<0.05$), suggesting that mineralization by soil biota is greater in the soil of this field, which could explain why rock dust application is more effective. Although some differences between treatments with and without rock dust in strips of a same field were visible, none proved to be significant. More research would be necessary in order to draw definite conclusions with statistical significance.

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Introduction

As the world human population continues to exponentially increase, agricultural production will have to meet its nutritional demands in a fair and sustainable manner. Soils are the foundation of agriculture and are of utmost importance to maintain or augment food production, thus conservation of healthy and productive soils and prevention of soil degradation evidently must be a top priority of our global societies. The negative impact of agriculture on soil quality is commonly known and efforts must be made to mitigate and counter this effect. Especially conventional agriculture highly accelerates soil erosion. Soil fertility and the amount of arable land continue to be diminished by mismanagement of soil resources and bad agricultural practices (Pimentel et al. 1995).

A key parameter of soil fertility is the amount of humus and less decomposed organic matter present in the soil. This soil organic matter beneficially influences soil structure, water holding capacity and aeration, and confers pH buffering capacity and improved nutrient retention thanks to charge imparted by constituent organic ionisable functional groups (Parikh & James 2012). Another obvious function of soil organic matter is the provision of nutritional sources to soil dwelling organisms that recycle nutrients from residues and make them available to plants. The advent of chemical fertilizers in the second half of the 20th century greatly contributed to the degradation of soil fertility, partly due to the fact that application of notably inorganic nitrogen greatly accelerates decomposition rates of organic matter which becomes rapidly depleted (Khan 2007). Furthermore, most nitrogen fertilizers (ammonia-based) cause the soil to acidify, significantly affecting soil biota as well as plant nutrient availability (Parikh & James 2012). Also, fertilizer-induced soil acidification increases output fluxes of nutrients, releasing major cations from the soil system by processes of soil ion-exchange leaching as well as weathering of soil and rock (Pierson-Wickmann 2009).

Use of phytosanitary chemicals and other biocidal practices also greatly affect soil fertility. The role of soil organismal interactions in the maintenance of healthy soil through nutrient cycling and structure amelioration is often undermined (Kibblewhite et al. 2008), as are the mutualistic relations that benefit crop growth. For example, chemical fungicides can destroy beneficial soil fungi that aid plants in absorbing minerals, and pesticides greatly affect soil microbial populations that contribute to soil health (Ekundayo, 2003).

One very important and often overlooked aspect of soil degradation is that of soil demineralization. Agriculture effectively mines the soil of plant nutrients and minerals by intensive cultivation and harvesting of crops, altering the natural cycling of nutrients in the soil (Parikh & James 2012). The rate of demineralization of agricultural soils is alarming. The official report of the Rio Earth Summit of 1992 raised deep concerns on this issue, based on data showing that over the last 100 years average mineral levels have fallen by 72% in Europe, 76% in Asia, 85% in North America, 74% in Africa, 55% in Australia, and 76% in South America. Soil minerals are very important for adequate and healthy plant growth. For example, silicon plays a large role in plant growth, mineral nutrition, mechanical strength, and resistance against pathogens, herbivores, and adverse chemical conditions (Epstein 1994). Magnesium is essential for enzyme activation (Black et al. 2008), sodium is important for plant metabolism (Subbarao et al. 2003), iron has many catalytic roles in photosynthesis, respiration and nitrogen assimilation, and molybdenum is involved in NO_3 and (usually) N_2 reduction (Raven 2006). Mineral deficiencies in crops extends to mineral deficiencies in consumers of these crops, that is to say animals and, directly or indirectly, humans, which can have adverse health effects.

It is thus evident that measures need to be taken to decelerate and counter soil demineralization around the world. One such measure is the application of (volcanic) rock dust to mineral deficient crop fields and pastures. Rock dust contains many of the nutrients essential to plant growth, with the exception of nitrogen and generally only limited amounts of phosphorous. Grinded rock also improves soil structure and increases water holding capacity and cation exchange capacity (von Fragstein 1987). Moreover, the grinded rock is naturally alkaline which might constitute an effective alternative to traditional liming materials for correcting the pH (Silva 2012). Rock dust helps stabilise soil organic matter (Egli et al. 2010; Imaya et al. 2010), and its paramagnetic characteristics may aid plants in taking up water and nutrients (Electroculture, Good vibes for Agriculture, 2014; Yamaguchi & Krueger 1983). The release of nutrients from the rock dust is directly related to weathering, therefore

nutrient oversupply and leaching are limited (von Fragstein 1987). Soil biota (from microbes to vascular plants) obtain a significant proportion of their nutritional requirement from the weathering of soil minerals, predominantly secondary minerals (Killham 1994), and accelerate chemical weathering by producing organic acids (Schwartzman 1989). These biota thus play an essential role in liberating minerals from rock dust, making them available to plants. For example, mycorrhizal fungi have been shown to significantly dissolve soil minerals through their exo-enzymatic activity, as have other microorganisms mutualistically living in the rhizosphere (Balogh-Brunstad et al. 2007).

However, to date little empirical evidence exists proving the benefits of rock dust application in terms of yield. Specialists expect that the plant quality increases when rock dust is applied on the field, but it has not yet been significantly proved in field experiments. A field experiment on grasslands executed in the north of the Netherlands found that in some control fields plants had symptoms of nutrient deficiency whereas in experimental fields where rock dust was applied these symptoms were not visible (ARCADIS 2013; Vliex 2013). In some fields rock dust application resulted in higher grass biomass whereas this was not the case in other fields. It is thus presumed that soil characteristics, in particular regarding soil biota, are the prime determinant of the effectiveness of rock dust application in increasing yield.

The subject of the present research arises from these presumptions. The goal of this research is to examine if there are differences in abiotic soil factors such as pH and relative hydrogen score rH2 (derived from the redox-potential) between soils of the different fields that correlate with differences in soil microorganisms and their biological activity, influencing the availability of rock dust minerals and consequent higher grass yield. The corresponding sub-questions we aim to answer are then:

- Can differences in pH and redox-potential be observed between soils with and without yield increase resulting from rock dust application between fields?
- Are there differences in soil microorganism activity between the soils with or without yield increase resulting from rock dust application between fields?
- How do different conditions of pH and O_2 levels influence the capacity of soil microorganisms to make rock dust minerals available to crops?
- Can a correlation be observed between the influence of pH and O_2 on soil microbiological activity and differences in yield observed between fields?
- Are there differences in degree of mycorrhizal colonization between fields and do these correlate with differences in yield?

We hypothesize that abiotic soil factors determining the activity of soil biota, namely soil pH and redox-potential, are the main driving force determining if application of rock dust results in an increase of yield.
This hypothesis can then be divided into the following sub-hypotheses in correspondence with the sub-questions:

- The soil pH and O_2 levels within fields where rock dust application resulted in higher yield are more suitable for soil biota.
- The soil microorganism activity will be higher in the fields where rock dust application resulted in higher yield.
- The amount of minerals from rock dust made available to the crop by microorganisms will be higher in the fields where higher yield resulted from application.
- The fields with higher yield as a result of rock dust application have a higher degree of mycorrhizal colonization.

Research setup and execution/materials and methods

An experiment is a research method consisting of a trial or operation for the purpose of discovering something unknown or of testing a principle or supposition. In an experiment a control group is compared to one or more experimental groups where ideally only one factor is changed.

For this research an experiment was chosen as research strategy because it can give us empirical insight in processes and conditions which can explain why no yield increase is observed in some fields with added grinded rock while in others adding grinded rock to the field results in an increase in yield.

In the experiment the practical part of adding rock dust to an experimental field and harvesting the final product was already done beforehand. The grinded rock or rock dust used in this experiment was BasaBox, which is finely ground basalt and is originally used as bedding for cattle. Also data about soil pH, redox-potential, and grass yield were made available by the project manager.

This research involved taking soil samples at the different fields where the experiment takes place in the north of the Netherlands (Friesland). Samples were taken from the fields of dairy farmers Minne Hiemstra (MH) and Jan Hania (JH) in order to make comparisons between a field that did and a field that did not show increased yield as a result of rock dust application, respectively. Both are clay soil fields, which limits deviations of conditions caused by different soil types. Every field consists of 3 strips with rock dust and 3 control strips. Two soil samples were taken per strip in an attempt to obtain reliable averages. This added up to 12 samples per field, and 24 samples in total. The samples were taken using a Dutch auger up to a depth of about 10cm and stored in a refrigerated room. This provided us with an adequate amount of soil for analysis with limited very localised variations of conditions. The pH of the soil samples were measured in a 50% dilution with demineralized water using a pH-meter (Consort C5020). The redox-potential of the samples were measured using a redox-meter (Consort C5020), and the soil EC with an EC-meter (Consort C5030). This was done a first time after sampling. Then the samples were left to incubate for 48 hours at 27ºC with 0.5% added sugars (0.25% glucose, 0.25% lactose) to activate the soil biota. Afterwards the pH, EC and redox-potential were measured a second time and the resulting measured change was used to determine the activity of the biota as well as the released nutrients as a result of this activity. The pH-specific oxidation levels, an indirect measure of O_2 concentration, were calculated using the pH and redox values according to a derivation of the Nernst equation: $rH_2 = (redox * 10.083)/(25+273.15) + 2 * pH$ (Lower, 2014; Bohn, 1971).

As for the root samples destined for mycorrhiza analysis, because it is labour intensive, only one sample per strip was taken by digging out a small portion of roots, amounting to 12 samples in total. Sample size was about 1 gram of roots. They were analysed using trypan blue to stain fungal structures, and following the density count method in which the microscopic preparation of the root sample is divided into 100 visual frames which score positive or negative for presence of mycorrhizal features (Vierheilig et al. 2005). This way relative comparisons of the degree of colonization could be made between samples.

Statistical analysis of the data was done with a two-tailed t-test.

The timetable of the study can be found in the appendix.

Results

Soil structure

The soil of field JH was a relatively loose and well aerated clay soil, with dark-coloured crumbly aggregates and relatively deep root penetration. On the other hand, the soil of field MH was much more compact and clumped together, and showed signs of waterlogging with the formation of small pools of water on the surface. Root penetration was substantially shallower compared to that of field JH.

pH

For field JH the average soil pH on the 5th of June was significantly lower than the average soil pH on the 3rd of June for both the strips with and without rock dust ($P<0.05$) as a result of the microbial incubation (Figure 1). This was also the case for the strips without rock dust of field MH ($P<0.05$),

however the decrease of pH for the rock-dust treated strips, though evident, was not statistically significant.
More importantly, the change in pH after incubation in samples from field JH was significantly higher than in those from field MH for samples with and without rock dust ($P<0.05$). No significant differences in pH could be observed between treated and untreated strips within a same field.

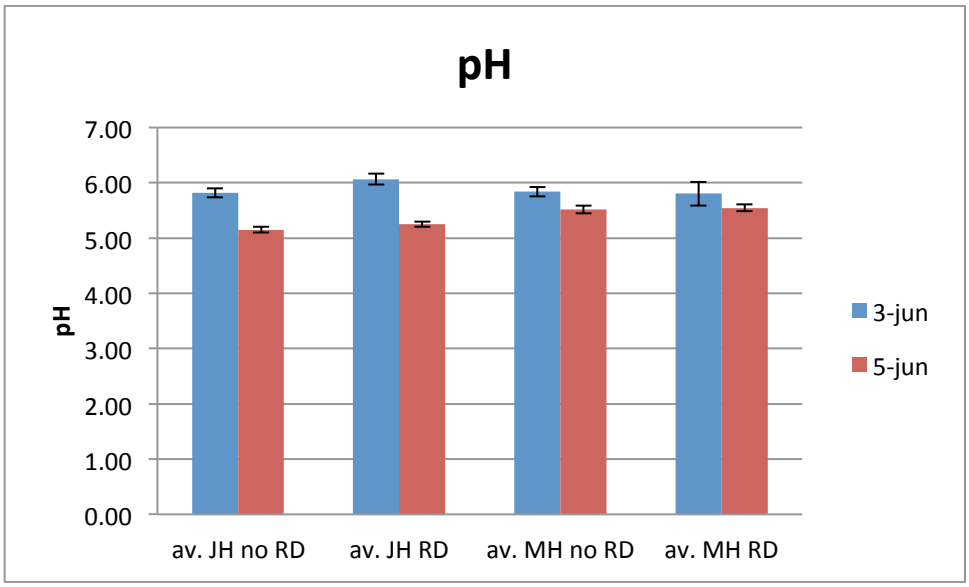

Figure 1: soil pH as measured after 48h incubation for samples with (RD) and without (no RD) rock dust, for both fields (MH & JH).

Redox and rH_2

The redox potential dropped on average by about 400 to 450 mV, mostly ending up with negative or very low redox values (Figure 2). Initial redox values for field MH were consistently higher than those of field JH for both treatments, but the change in redox after incubation was seemingly higher in JH samples than in MH samples, though this was not statistically significant.

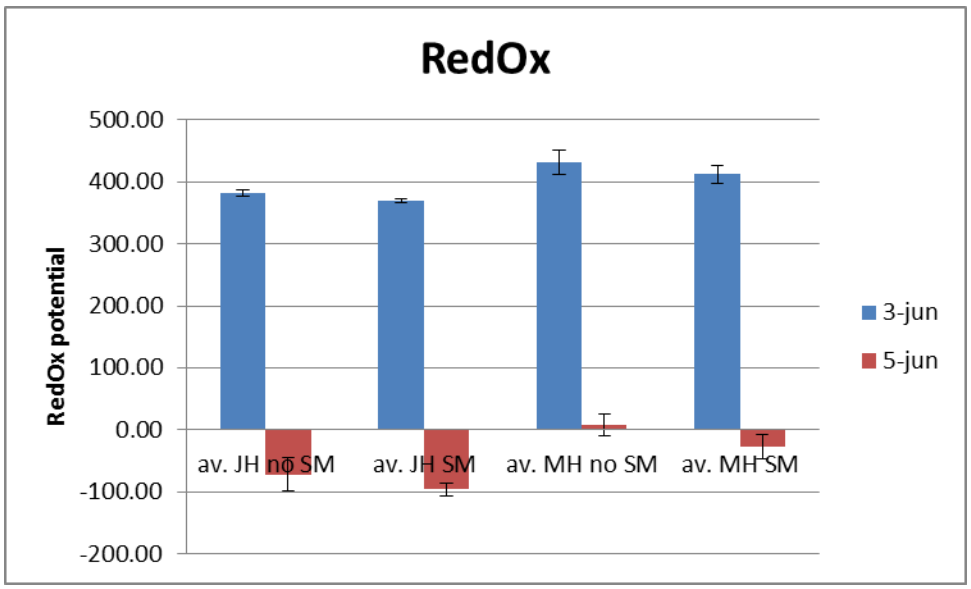

Figure 2: Redox values (mV) for samples with (RD) and without (no RD) rock dust at both farms (MH & JH), before and after 48h incubation.

However, when corrected for pH by computing the oxidizing potential (a measure for O_2 levels) (Figure 3), differences between samples of JH and those of MH were more evident and statistically significant for samples of the rock dust-treated strips ($P<0.05$) but not for the samples of strips untreated with rock dust. Differences in O_2 consumption between samples with rock dust and those without rock dust were insignificant.

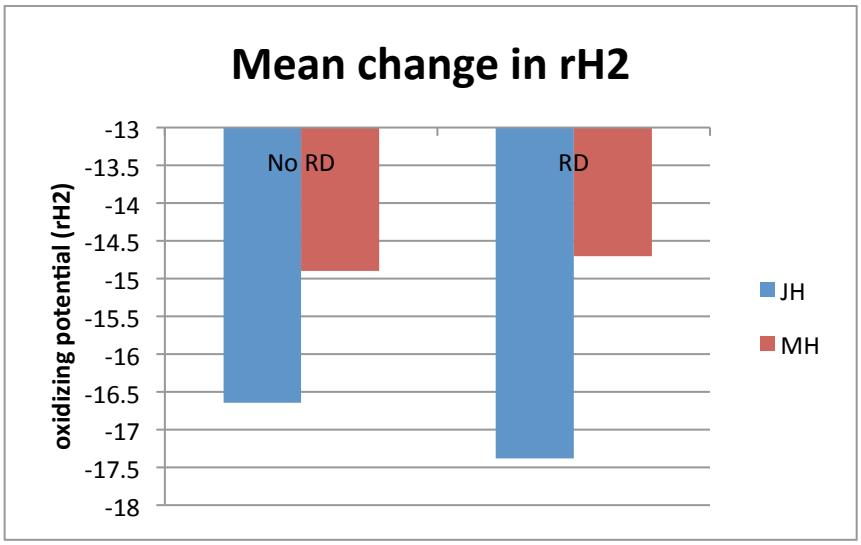

Figure 3: Mean change in oxidizing potential (rH2) , calculated with pH and RedOx for samples with (RD) and without (no RD) rock dust for both farms (MH & JH).

It is important to note in any case that a trend is visible in the measurement data of the redox potential and consequently the calculated oxidation values (particularly on June 5th), suggesting that errors may have been introduced, plausibly due to oxygenation of the samples over time during the measurements (see Discussion-Data and sample errors).

EC

The EC values on the 5th of June were significantly higher than the EC values on the 3rd of June for all samples ($P<0.05$) (Figure 4). Mean change of EC after incubation was significantly higher for MH samples without rock dust ($P<0.05$) but not significantly higher for samples with rock dust, compared to those of field JH. No significant differences were found between samples with rock dust and samples without rock dust within the same field.

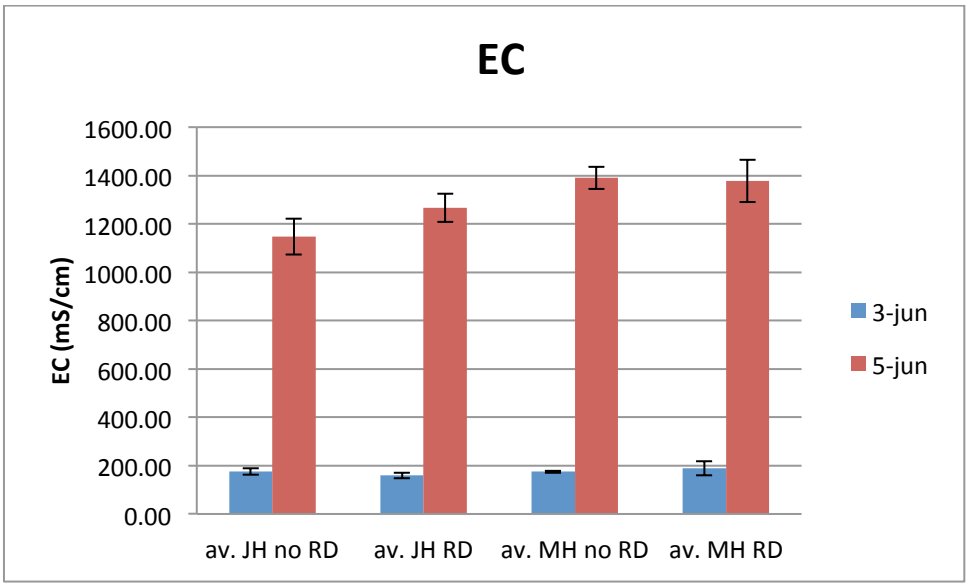

Figure 4: Measured EC for samples with (RD) and without (no RD) rock dust for both farms (MH & JH) before and after 48h incubation.

Mycorrhiza

On field JH, roots from the strips where rock dust was applied showed signs of mycorrhizal colonization (i.e. arbuscules, hyphae) in 34% of the microscopic viewing frames, and 37% for roots from strips without rock dust. On the other hand, mycorrhizal features could be observed in 38% of the microscopic viewing frames of roots from the rock dust treated strips of field MH, but only 21% for roots from strips devoid of rock dust. Pictures of mycorrhizal infections can be found in the appendix under "Mycorrhiza pictures".

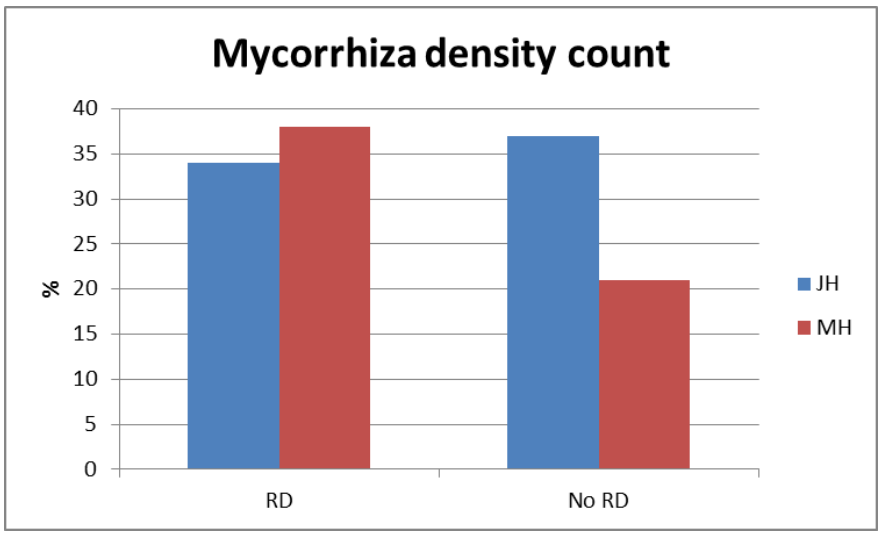

Figure 5: Mycorrhiza density count in percentage of microscopic viewing frames containing mycorrhizal features (arbuscules or hyphae) in fields JH and MH for strips with rock dust application (RD) and without (No RD).

Discussion

Data and sample errors

Results in this study make it difficult to make reliable interpretations and draw conclusions. Generally sample size was too small to yield statistically sound results that would render localised variations of pH, redox and EC - which can be substantial (Husson 2013) - as well as sampling, handling, and measuring errors negligible.

A trendline observed in the data of the redox measurements over time, in particular in the measurements of the 5th of June (Figure 6), show that during the measurements the values of the redox potential increased steadily. The slight increases of these values could have been caused by enlarging time intervals between sample storage and sample analysis during which oxygenation likely occurred, but it is more likely that insufficient waiting time between rinsing of the electrode in water and sample measurement until stabilisation may also have been of influence. For this reason caution must be taken when drawing conclusions based on redox measurements and consequently rH2 calculations regarding the effect of rock dust application as the potentially inaccurate data can lead to incorrect interpretations. This is for instance likely the reason why the initial redox values of MH samples are higher than those of JH samples (Figure 2), despite the fact that the soil at field MH was quite waterlogged, because MH samples were measured after JH samples.

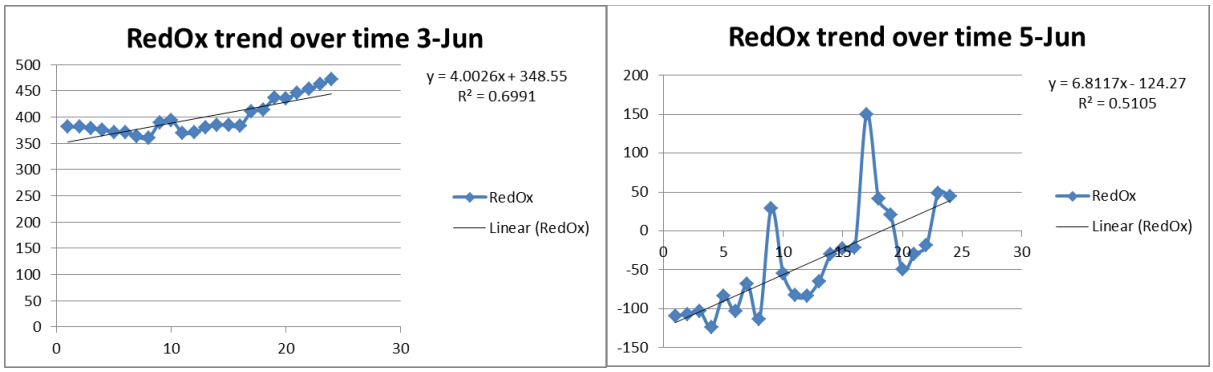

Figure 6: Trend lines visible in the data of the redox measurements over time on 3-June and 5-June

For the experiment two samples were taken per strip, however, no distinction was made between these two samples which could have possibly been switched between measurements of the 3rd and 5th of June. This may have given false values of change in pH, EC and RedOx, though errors were probably limited by averaging these values per strip.
The S6 samples of JH were taken from S4 because the farmer disposed of his excess cow manure on the part of the field including S6 but excluding the rest of the test field. Therefore measurements from S6 would have yielded falsified results due to different fertilization treatments.
The soil samples were transported and stored in manually vacuumed plastic bags. Between receiving the soil samples and measuring the first data, the soil samples were stored in a fridge for 7 days. This could have influenced the data.
The soil samples were incubated in supposedly airtight jars, though unfortunately the jars used for the experiment were not all fully airtight, which could have increased redox and EC values for the second measurement.
One of the samples is not used in the results because of the abnormally high EC values obtained in both measurements, exceeding average of the other samples by about 1000mS/cm.

In this research a two-tailed two sample t-test was used for statistical analysis. However this was likely not the suitable statistical test to use because the data is not normally distributed. A Pearson's chi-squared test or a Mann-Whitney test would have been more suitable and may have yielded more conclusions.

Interpretations

The soil structure differed rather significantly between the fields JH and MH. The soil of field JH had an aerated topsoil profile composed of crumbly aggregates with comparatively deep root penetration and oxidised clay layer, whereas the soil of field MH was more compact and badly drained, with a heavy clay layer much closer to the surface and in general a considerably higher clay fraction, as well as lower organic matter content. Some of these differences in soil structure and composition can be caused by and be the cause of differences in soil biota between the two soils (Bronick & Lal, 2005). The higher clay fraction may confer better nutrient retention properties to the soil of MH due to the high sorption capacity of clay minerals caused by the large surface area of particles and high cation exchange capacity (Oh et al., 1999; Sawhiney 1972) . It also probably explains why in soil samples of field MH the changes in pH caused by the acid-producing metabolism of the soil biota measured after incubation were significantly lower than those measured in soil samples of JH, as clay minerals such as montmorillonite and kaolinite contribute greatly to the buffering capacity of soils (Stotzky & Rem, 1966). Moreover, these minerals have been shown to stimulate bacterial respiration for a very broad spectrum of species, primarily due to this buffering capacity, but also by serving as a source of mineral nutrition (Stotzky & Rem, 1966). The role of clay in organic matter retention, provision of surface catalysis and its contribution to protective microhabitat development are also non-negligible factors influencing microbiological activity (Husson, 2013). Furthermore, experiments involving amendments of montmorillonite and kaolinite to soils naturally devoid of these minerals demonstrated that the rate of heterotrophic degradation of glycine and subsequent autotrophic nitrification was enhanced in direct relation to the amounts of montmorillonite incorporated, although such stimulation was not observed as a result of kaolinite addition (Macura & Stotzky, 1980). This effect may partially explain why a significantly greater increase of EC was measured in soils of field MH compared to JH after incubation, and consequently why yield increase was observed at farm MH as a result of rock dust application. Definite interpretations nevertheless remain impossible, as both soils contain the clay minerals supposedly stimulating bacterial activity, albeit in different amounts, and results in this study seemed to show that respiration was greater in JH samples, reflecting higher changes in redox values and consequently degree of oxidation, although the statistical insignificance of these results sustain their inconclusiveness.

When interpreting the degree of mycorrhizal colonization of grass roots in the two fields, the minute sample size and differences in root structure must be taken into account. However the data seem to show that colonization was lowest for samples of MH without rock dust. This may be explained by the influence of soil conditions on the formation and function of mycorrhizal associations. Better soil aeration and higher O_2 levels, up to a certain point, beneficially affect the efficiency of mycorrhizal associations as well as spore germination and hyphal growth (Saif, 1983; Tacon et al, 1983). The performance of mycorrhiza is also dependent upon soil pH; different species respond differently to different conditions of pH, thus the disposition of plant species to benefit optimally from fungal symbioses relies on such conditions (Entry et al., 2002; Green et al, 1976). However it is unlikely that this factor had much impact in the case of this study, as the soils of both fields had a very similar pH. Soil nutrient levels and ratios, in particular soil P, are also an important determinant of the degree of mycorrhizal colonization of root systems (Smith et al., 1997; Peng et al., 1993), reflecting the cost-benefit relationship between the symbiont and the host plant. For instance study showed that a high ammonium: nitrate ratio decreased mycorrhizal formation, although higher levels of P was observed in plants receiving more ammonium (Johnson et al., 1984). No significant differences of nutrient levels measured as EC were found between fields MH and JH or treatments of rock dust application, but analysis of the soil nutrient composition and P concentration may reveal if this might be influential on the status of mycorrhiza and consequently their capacity to liberate minerals from rock dust.

The presence of rock dust may stimulate mycorrhizal association; results seemed to show higher root colonization in strips with rock dust compared to strips without in field MH. Furthermore field studies at Dantumadiel found that mycorrhizal infections visible to the naked eye were approximately three times as numerous on the rock dust strips compared to the untreated strips, but no systematic data was collected to this regard as the studies did not focus on mycorrhiza, hence no general conclusions may be drawn (personal communication with project manager Gino Smeulders).

Moreover, despite being statistically insignificant, results showed a slightly higher change in pH in strips with rock dust compared to strips without rock dust in both fields, and a higher change in RedOx and EC values at field JH. This may reflect greater biological activity resulting from the application of rock dust, but further and more rigorous research is needed to soundly confirm this effect.

Further research

In general studies comparable to this one but with more rigorous and ample sampling and analysis would be useful in order to obtain significant results from which reliable conclusions may be drawn, particularly concerning soil redox conditions. Research focused on differences in mycorrhizal colonization could yield relevant information about disparities between fields that may be determinant for the effectiveness of rock dust in increasing yield, as well as about the effect of rock dust on mycorrhiza. Analysis of the soil nutrient composition, especially P levels, may reveal conditions more favourable to microorganism activity and mycorrhizal associations.
Rock dust is mostly said to have long-term effects, it is therefore advisable to do some research on a longer time scale. Moreover rock dust exists in several different compositions, depending mostly on the nature of the rock used. Research at Dantumadiel deals with basaltic rock dust, however different types of rock dust may have different effects on different fields. It is also possible that the composition of soil communities determines how effective rock dust fertilization is; perhaps the nature of the microbial community for example at field MH is more efficient in liberating basaltic rock minerals. Different rock dusts may then be more or less suitable for different soil communities. Furthermore if deficiencies or adverse properties of a soil are known, the soil quality can improve optimally with the right kind of rock dust. Research would then be necessary to know which kind of rock dust should be applied on which field.

Conclusion

Although some differences between treatments with and without rock dust in strips of a same field were visible, none proved to be significant. Therefore conclusions presented here are tentative. Differences in measurements of redox values between soil of field MH where yield increased as a result of rock dust application, and soil of field JH where this was not the case, were observable but statistically insignificant in this study. The change in pH measured before and after two day incubation of soil samples was higher in samples of field JH than those of field MH. Increase of the soil EC after incubation was significantly higher in MH samples, suggesting that mineralization by soil biota is greater in the soil of this field, which could explain why rock dust application is more effective. Changes in rH2 suggest the same. An increased mycorrhizal colonization was observed in rock dust-treated strips compared to untreated strips at field MH, which may have been the main driver of yield increase in this field as a result of rock dust application. No significant differences were observed between strips with and without rock dust at field JH.

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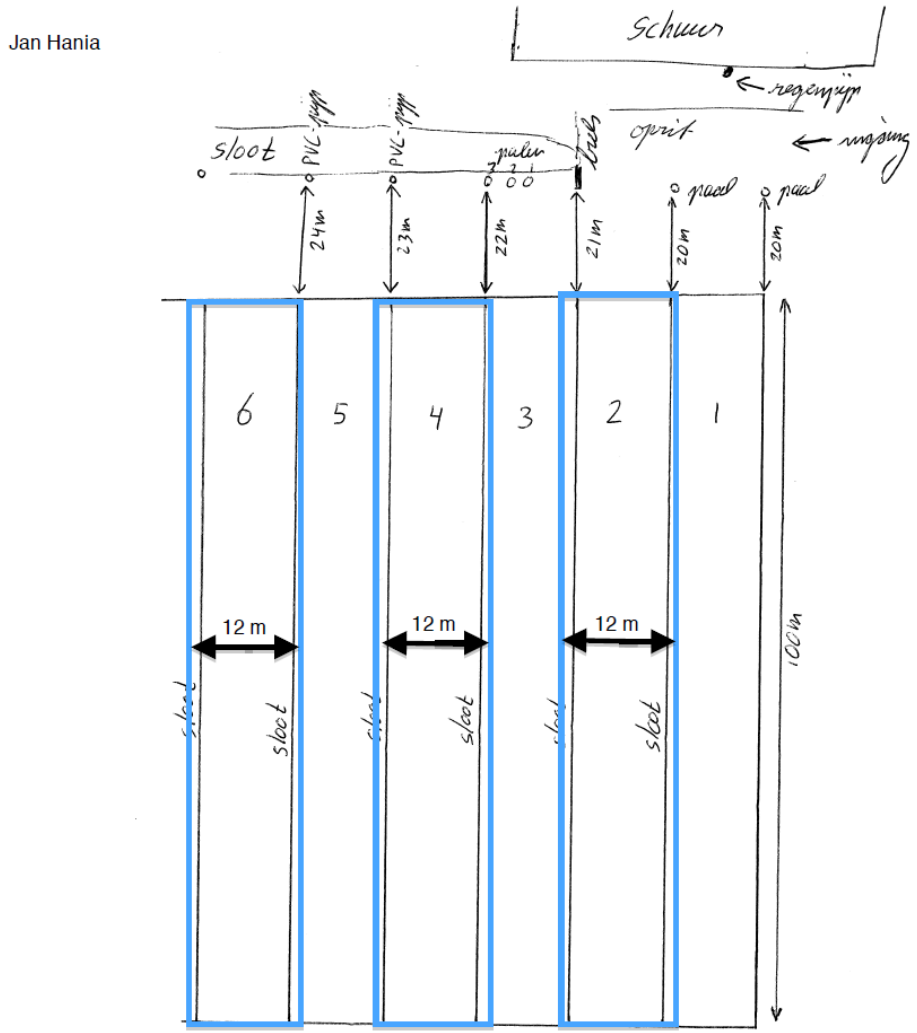
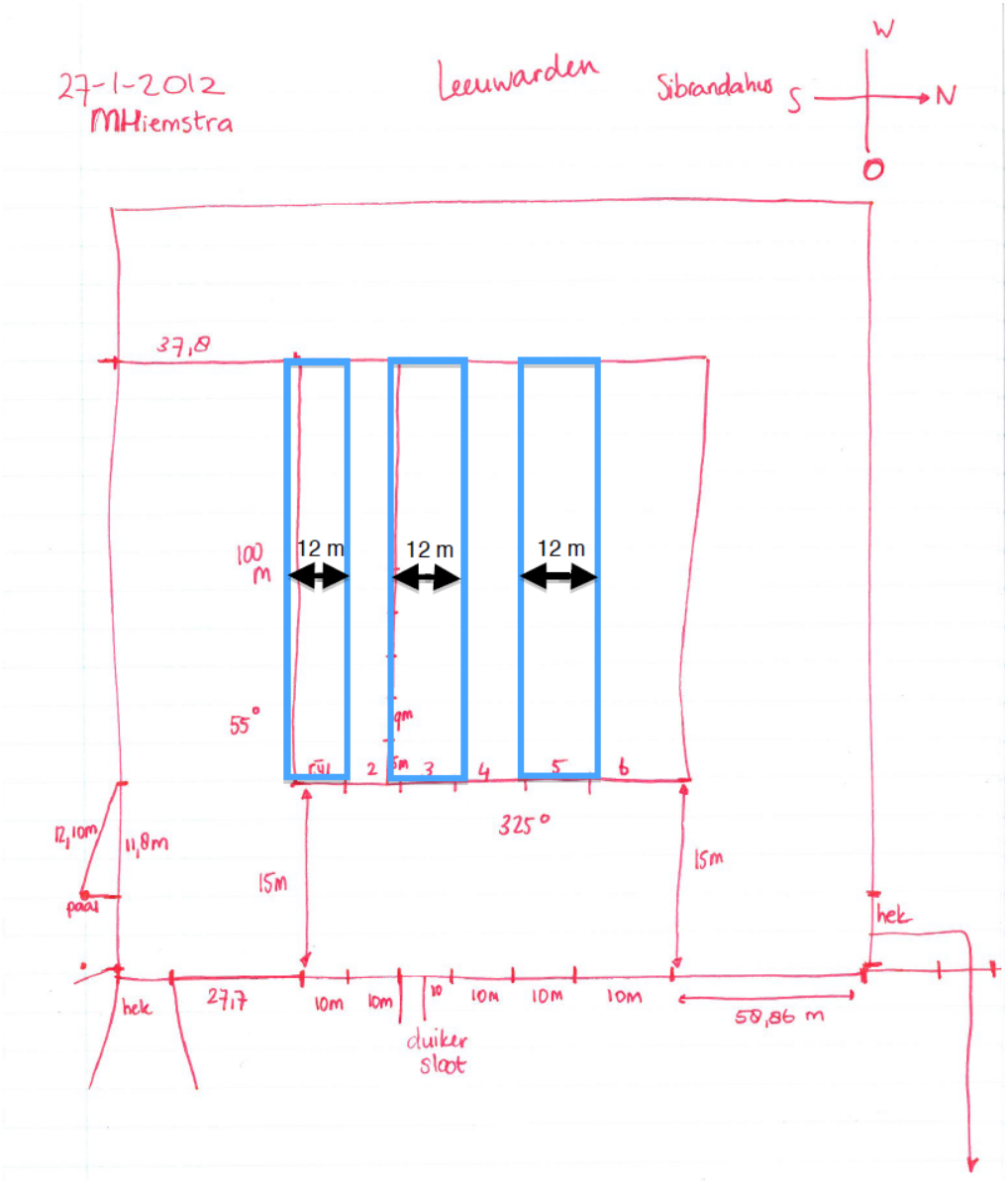
Appendix

Commonly used abbreviations

RD	Rock dust (dutch: Steenmeel)
JH	Jan Hania (farmer)
MH	M. Hiemstra (farmer)
EC	electrical conductivity
S(1)	Strip (1)
av.	average

Test fields





Timetable

We divided the workload of this study following the schedule elaborated in the timetable below:

Monday 26 May	Meeting with Gino
Tuesday 27 May	Take soil samples in Friesland
Wednesday 28 May	Literature study
Thursday 29 May	**Ascension day**
Friday 30 May	**Free day**
Monday 2 June	Measure initial pH, EC and Redox; Start with the soil life activity test
Tuesday 3 June	Mycorrhiza counting
Wednesday 4 June	Results soil life activity test: Measure end pH, EC and Redox
Thursday 5 June	Extra measurement time, start data analysis
Friday 6 June	Data analysis
Monday 9 June	**Pinksteren**
Tuesday 10 June	Finish data analysis and start writing results

Wednesday 11 June	Write results
Thursday 12 June	Write discussion
Friday 13 June	Write report, turn in results
Monday 16 June	Write scientific report and processing feedback
Tuesday 17 June	Write scientific report
Wednesday 18 June	Write scientific report, turn in discussion
Thursday 19 June	Lecture philosophical aspects of experimental research
Friday 20 June	Improve scientific report after the lecture
Monday 23 June	Make PowerPoint
Tuesday 24 June	Presentation experiment
Wednesday 25 June	Finish the scientific report after presentation and turn in concept
Thursday 26 June	Make the final version of the scientific report with feedback
Friday 27 June	Submit scientific report and make reflection

Mycorrhiza pictures

Pictures are named via: [abbreviation farmer]- [strip numbers]- [picture number].

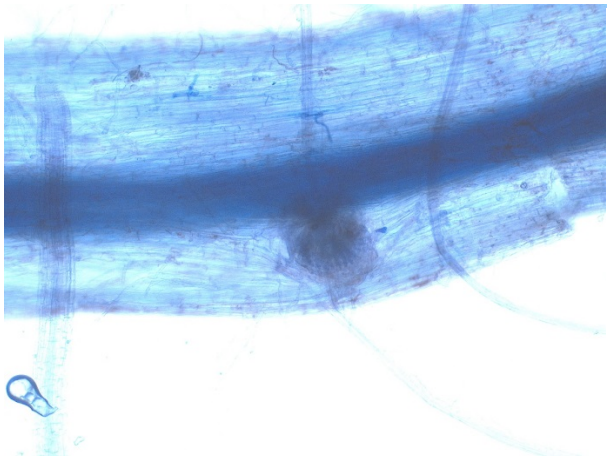


Figure 7: JH-2,4,6-1

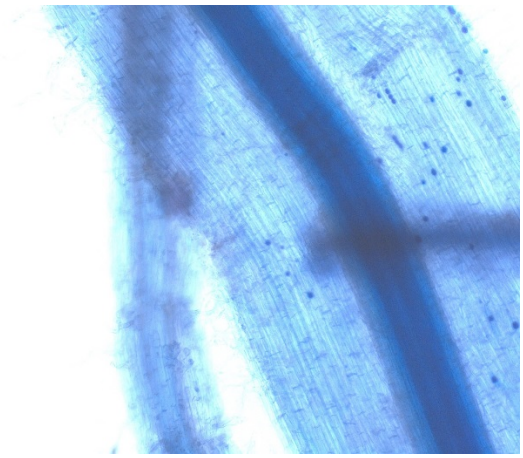


Figure 8: JH-2,4,6-2

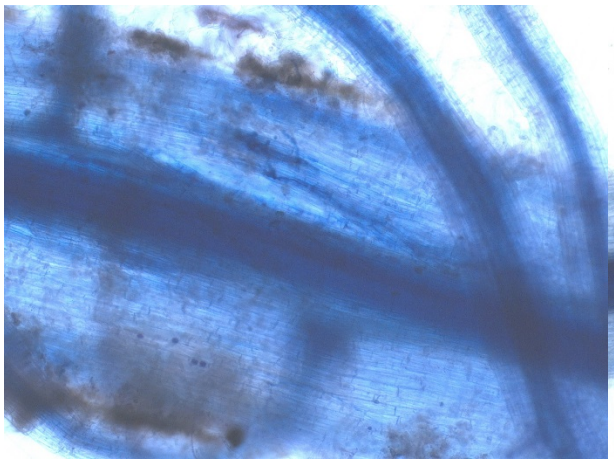


Figure 9: JH-2,4,6-3

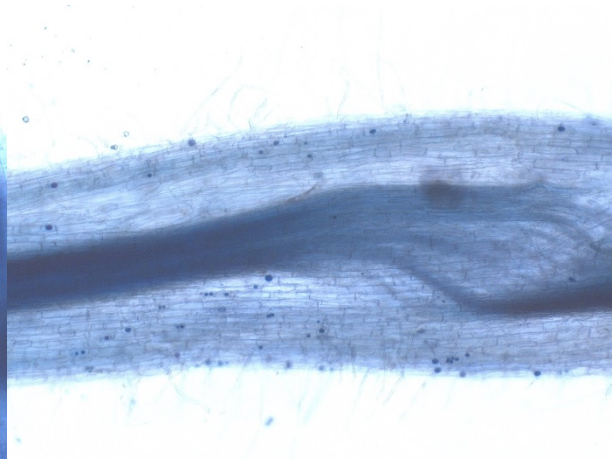


Figure 10: JH-2,4,6-4

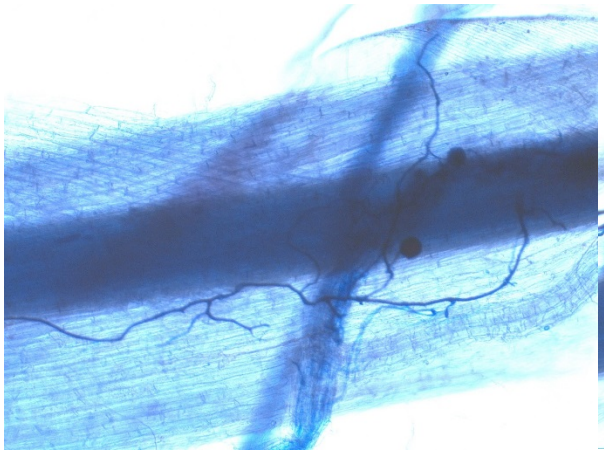


Figure 11: MH-1,3,5-1

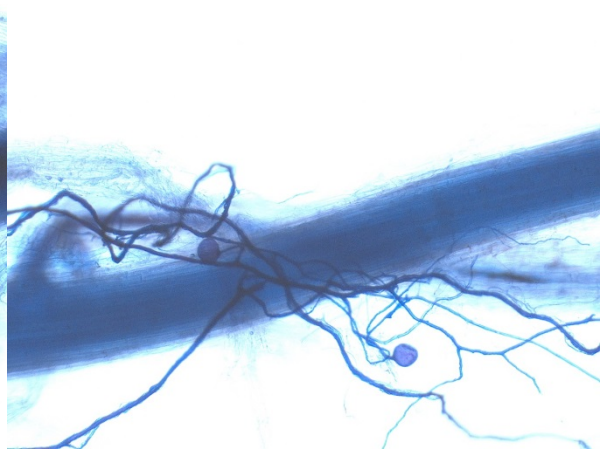


Figure 12: MH-1,3,5-2

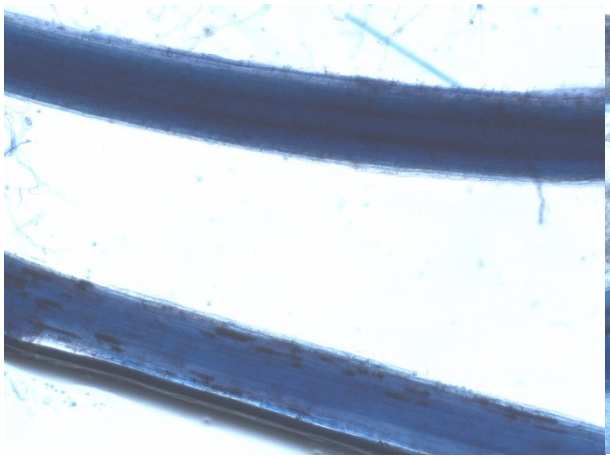


Figure 13: MH-2,4,6-1

Figure 14: MH-2,4,6-2

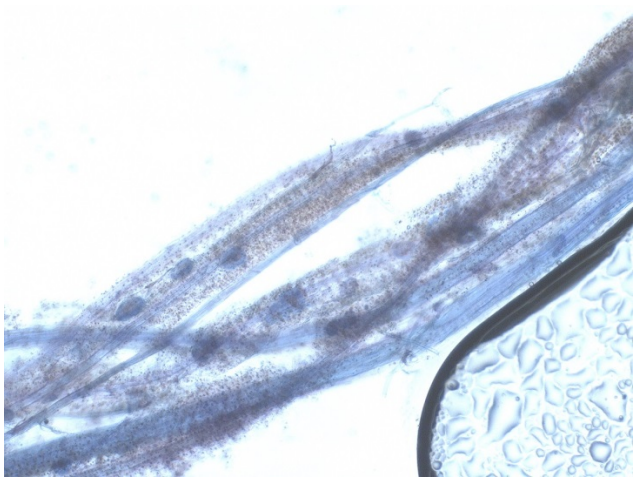


Figure 15: MH-2,4,6-3

Rock dust composition; BasaBox flyer

Basa Box

Boxenstrooisel op basis van basaltmeel

Basa Box is een boxenstrooisel op basis van basaltmeel en is rijk aan sporen-elementen. Voor een droge ligplaats en een goed stalklimaat. Dit ter vervanging van kalk. Het absorbeert vocht, verhoogt pH en is zacht voor de spenen.

Dosering:	ca 250-300 gram per m2

Mineralen	Verbinding	Percentage
Calcium	CaO	7,59
Kalium	K2O	0,08
Magnesium	MgO	11,70
Fosfaat	P205	0,12

Sporenelementen		
IJzer	Fe2O3	13,13
Titaan	TiO2	1,58
Mangaan	MnO	0,25
Silicium	SiO2	49,43
Natrium	Na2O	2,79
Aluminiumoxide	Al2O3	13,14

Aantal	**Basa Box per 1000 kg**		**Prijs in Euro**
1	Big Bag	**Basa Box**	235,00
2	Big Bags	**Basa Box**	225,00
3	Big Bags	**Basa Box**	205,00
4	Big Bags	**Basa Box**	195,00

Prijzen franco huis exclusief Europallet en BTW. Statiegeld Europallet is 10 Euro

Molenstraat 10-1, 8391 AJ Noordwolde, Tel. 0031 (0)561 43 31 15

Figure 16: BasaBox flyer, the rock dust used in this experiment

Discussion: Meter solution coloration

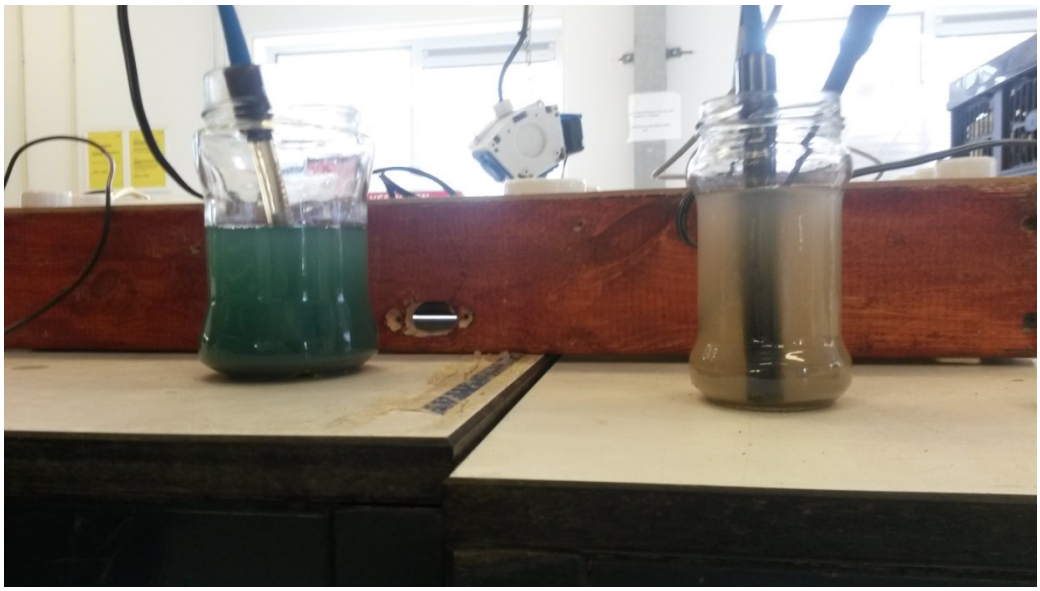


Figure 17: The pH and RedOx meter solution on the left turned blue while the EC meter solution on the right didn't change.

Soil structure pictures

Figure 18: Soil structure of JH

Figure 19: Soil structure profile of JH

Figuur 20: Soil structure profile of MH