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Maize root growth and P uptake dependency on spatial distribution of sewage sludge, sewage sludge ash, and TSP

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Background

Increased recycling of phosphorus (P) from large waste streams and more targeted P application methods in the field could be potential means to obtain a more sustainable P management.

Localized placement of P under low-P soil conditions is generally considered to induce plant root growth in the P zone and to provide an improved P supply to young plants. However, this general assumption is based on studies where only highly available P sources in the form of nutrient solution or superphosphate were examined. Regarding studies of plant responses to a localized placement of more complex waste-derived P sources, the literature is scarce.

Key questions

We wanted to demonstrate plant responses in terms of root growth and P uptake to a localized near-seed placement of different types of P sources (sewage sludge, sewage sludge ash and triple super phosphate) compared to a homogenous supply of the same P sources. Our main questions were:

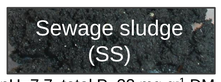
- Does the plant favor root growth around the localized P spot?
- Does the plant take up more P from the P source when the source is localized than when it is homogenously mixed into the soil?
- Is the plant response to placement affected by the type of P source?

Experimental setup

Maize in rhizoboxes

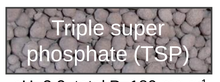
Growth of maize (*Zea Mays* L., cv. Colisee) for 30 days in rhizoboxes, angled at 45° with the transparent side (normally covered) downwards, in greenhouse (day/night=16/8h and 19/15°C).

P sources



pH=7.7, total P=33 mg g^{-1} DM (14% water extractable P)

pH=9.2, total P=104 mg g^{-1} DM (0.7% water extractable P)



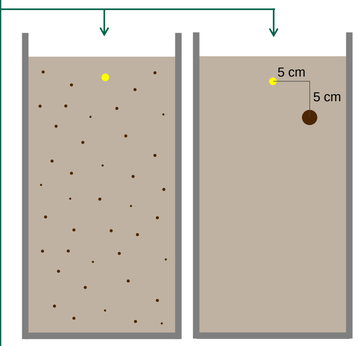
pH=3.2, total P=180 mg g^{-1} DM (63% water extractable P)

The sewage sludge (dewatered) and ash were sampled at the Avedøre wastewater treatment plant in Copenhagen, Denmark, where P removal during wastewater treatment is done by precipitation with ferric chloride.

Soil and ^{33}P labeling

The growth media (2.4 kg pr. rhizobox) was a 1:1 mixture of a sandy loam (16% clay, pH(H_2O)=6.0) and sand. One week prior to sowing, the soil-sand mixture was amended with a nutrient solution (all other nutrients than P) and labelled with ^{33}P.

Application methods

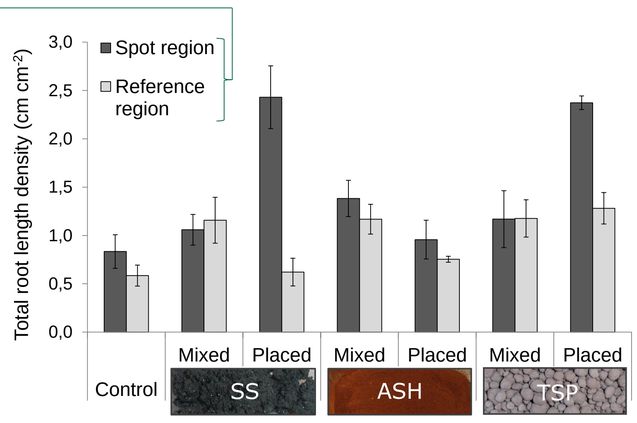


- All P sources were either mixed homogenously into the soil or placed close to the seed
- Applied at equal P levels: 40 mg P kg^{-1} soil
- Also a control receiving no P was included

➡ **In total 7 treatments**

Results

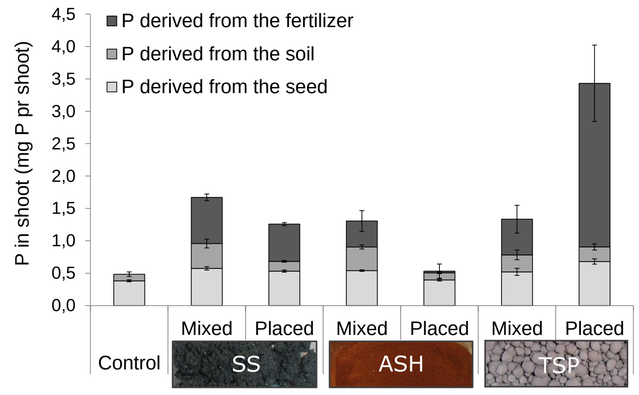
Root growth



Root length densities in the two regions were analyzed with WinRhizo based on the drawings of the visible root system. Error bars represent standard errors (n=4).

- Root proliferation was clearly increased in the spot region of the placed SS and placed TSP.
- There was no clear difference between the spot region and the reference region in any of the other treatments.
- Root length density of the entire root system (results not shown) was significantly affected by the treatment (p<0.01).

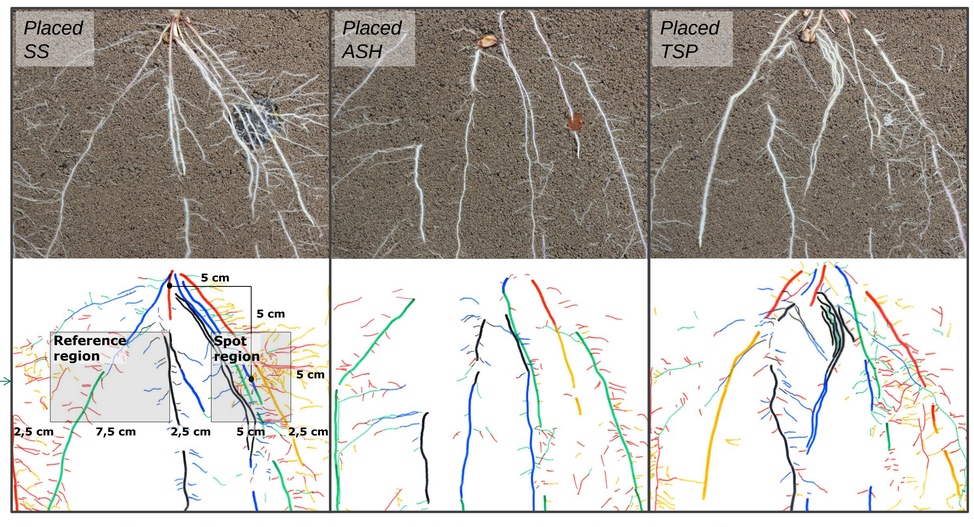
Shoot P uptake



Shoot P uptake at harvest divided on contribution from the different P pools. The fraction of plant P derived from the P source was determined through an indirect labeling of the soil with ^{33}P combined with an additional experiment to determine the contribution of P from the seed. Error bars represent the standard error (n=4) for each fraction.

- Shoot P uptake from TSP was largely increased by the localized placement.
- For the ASH, the localized placement clearly decreased shoot P uptake from the ash.
- For SS, localized placement decreased P uptake from the soil whereas P uptake from the sludge was almost unaffected.
- Overall, total shoot P uptake was significantly affected by the treatment (p<0.005).

Examples of end root photos and drawings



Top: *Part of photos from day 30 (harvest day).* ***Bottom:*** *Part of drawings. Different colors represent root development at different days (black=10, blue=15, green=20, red=25, and orange=30 days after sowing). Thick lines represent axile roots, thin lines represent lateral roots.*

Conclusions

Plant responses (root proliferation and shoot P uptake) to localizing a P source depend on the type of P source:

	Root proliferation responses in the P spot region	Shoot P uptake response to localizing the P source
Sewage sludge	+	0/−
Sewage sludge ashes	0	−
Triple super phosphate	+	+

Discussion points

- Why did the plants exhibit extra root growth around TSP and SS but not around ASH? ➡ Lack of “signal” (available P) from the ash?
- Why did the plants not take up more P from the SS when they did favor root growth in the spot? ➡ P was too little available? Delayed root response?
- Why did the plants take up so much more P when the ASH was mixed into the soil compared to placed? ➡ Dissolution of ash-P when mixed with the acidic soil?

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IRMAR Integrated Resource Management and Recovery