AGRONOMISKE EFFEKTER OG UDBYTTE VED TILFØRSEL AF BIOCHAR

Peter Sørensen og Diego Abalos

OVERSIGT

- Næringsstof koncentrationer i biochar (N, P, K)
  - Tilførsel N og P i biochar I relation til Danske gødningsregler
- Andre mekanismer end næringsstoffer der kan påvirke udbyttet
- Negative effekter af biochar på afgrøde udbytte
- Gennemsnitlige effekter på udbytte
- Konklusioner

NÆRINGSSTOF KONCENTRATIONER I BIOCHAR

Type	N kg N/ton	P kg P/ton	K kg K/ton	Ton BC per ha at 30 kg P/ha	Reference
Straw					
Wheat straw LT-CFB 730*	3	4	55	7.5	Li et al. (2017)
Wheat straw LT-CFB 730*	3.7	4.2	57	7.1	Li et al. (2018)
Wheat straw slow pyrolysis 525	15	NA	NA	NA	Bruun et al. (2012)
Wheat straw fast pyrolysis 525	12	NA	NA	NA	Bruun et al. (2012)
Wheat straw, commercial undefined temp (Swedish)	29	9.1	18	3.3	Parvage et al. (2013)
Wheat straw slow pyrolysis 725	5.3	1.2	35	25	Nissen et al. (2021)
Wheat straw flash pyrolysis 750	6.5	3.4	34	8.8	Nissen et al. (2021)
Wheat straw slow pyrolysis 300	24	3.4	27	8.8	Naeem et al. (2017)
Wheat straw slow pyrolysis 400	19	3.8	33	7.9	Naeem et al. (2017)
Wheat straw slow pyrolysis 500	19	4.2	41	7.1	Naeem et al. (2017)
Manures					
Poultry manure LT-CFB 730*	8,3	57	91	0.53	Li et al. (2017)
Solid fraction digested slurry LT_CFB 730*	NA	54	NA	0.56	Kuligowski et al. (2010)
Solid fraction pig slurry 400	NA	40	NA	0.75	Christel et al. (2016)
Solid fraction pig slurry 600	NA	54	NA	0.56	Christel et al. (2016)
Solid fraction pig slurry 550	15	71	NA	0.42	Zhu et al. (2014)
Solid fraction digested slurry 300	19	51	22	0.59	Bruun et al (2017)
Solid fraction digested slurry 450	18	53	24	0.57	Bruun et al (2017)
Solid fraction digested slurry 600	15	60	24	0.50	Bruun et al (2017)
Solid fraction digested slurry 750	9.1	66	27	0.45	Bruun et al (2017)
Solid fraction digested slurry 900	4.5	67	28	0.45	Bruun et al (2017)
Solid fraction digested slurry 1050	3.2	66	34	0.45	Bruun et al (2017)
Sewage sludge					
Straw + sewage sludge LT-CFB 730*	7.8	26	51	1.15	Li et al. (2017)
Straw + sewage sludge LT-CFB 730*	3.1	26	84	1.15	Li et al. (2017)
Sewage sludge 300	61	39	7	0.77	Yuan et al. (2016)
Sewage sludge 400	38	43	9	0.70	Yuan et al. (2016)
Sewage sludge 500	18	45	10	0.67	Yuan et al. (2016)
Sewage sludge 600	15	45	13	0.67	Yuan et al. (2016)
Sewage sludge 700	9	49	17	0.61	Yuan et al. (2016)

Content of N, P and K measured in biochars derived from straw, manures and sewage sludge in selected studies. Numbers indicate the pyrolysis/gasification temperature (°C) of each biochar type. All values are on a dry matter basis.

NÆRINGSSTOF KONCENTRATION OG TILGÆNGELIGHED

Kvælstof (N): Lav tilgængelighed. Indbygget i stabile organiske forbindelser.

N koncentration falder med stigende pyrolyse temperatur.

Tilgængelighed usikker ved temperatur under ca 500^{0}C.

Fosfor (P): P koncentration i biochar varierer meget med input.

P tilgængelighed kan være ganske høj (15-70% i forhold til triplesuperfosfat).

P tilgængelighed falder med stigende pyrolyse temperatur.

Velegnet til at opetholde P status (P-tal) i jord.

Kalium (K): Høj tilgængelighed (50-85%).

K/P ratio meget højere I biochar fra halm end BC fra husdyrgødning.

Ved realistisk tilførsel af P med biochar fra fiberfraktioner tilføres lille mængde K.

TILFØRSEL AF N OG P I RELATION TIL DANSKE REGLER

Kvælstof: Biochar betegnes som organisk gødning. Jordbrugere skal indregne en %-del af N fra organisk gødning I gødningsplan.

Ingen undersøgelser har vist N frigivelse af betydning I DK.

Vi vurderer at det ikke er relevant at indregne biochar N I gødningsregnskaber.

N frigivelse på lang sigt er usikker, men vurderes som ubetydelig.

Fosfor: Jordbrugere skal registrere tilførsel af P med gødninger (fosforloft).
De fleste landbrug har et P loft på 30 kg P/ha/år (gns for bedrift).

Relevant at inkludere biochar P I fosforloft. P vil ofte være begrænsende for tilførsel af biochar.
Vanskelligt at kombinere med husdyrgødning (dog måske væskefraktion)

Biochar fra fiberfraktion og slam: max ca 0,5 tons/ha/år.
Biochar fra halm: max ca 7-9 tons/ha/år.

ANDRE MEKANISMER DER KAN PÅVIRKE UDBYTTER I

Plantesygdomme: Low biochar rates can induce systemic resistance to both soil-borne and foliar pathogens (Frenkel et al., 2017). This has been observed in strawberries, peppers and tomatoes, for 15 different pathogens (fungi, oomycetes and nematodes) (Elad et al., 2010; Meller Harel et al., 2012). However, the precise mechanism for this effect remains unclear.

Kalk virkning: Biochar tends to have a neutral to basic pH, and many field experiments show an increase in soil pH after biochar application in acidic soils (Jeffery et al., 2017). Accordingly, biochar can increase yield through a liming effect. This is due to higher soil nutrient availability and plant use (mainly P, but also N, Ca, Mg and Mo), and the reduction of available levels of some elements toxic to plant growth such as Al_3^+ and Mn_2^+.

N tab: From a nutrient perspective, biochar can directly add nutrients present in its biomass, but it can also increase the availability of soil mineral N by reducing N losses. This is because biochar can lower nitrate leaching, N_2O emissions, and ammonia volatilization.

ANDRE MEKANISMER DER KAN PÅVIRKE UDBYTTER II

Biologiske interaktioner: With arbuscular mycorrhizal fungi (AMF) and biological N-fixers. AMF stimulate yields by enhancing N and P plant nutrition (Warnock et al., 2007). Increasing biological N-fixation from the air in legumes can have positive impacts on crop production directly in the legume, and also indirectly in plant mixtures with legumes, due to increased availability of N in the soil (Rondon et al., 2007; Mia et al., 2014).

Vandholdende evne: Biochar can also increase ***soil water retention***, particularly in coarse-textured soils (Razzaghi et al., 2020), which are very common in Denmark. In turn, biochar can increase water availability for crops.

NEGATIVE EFFEKTER PÅ PRODUKTION

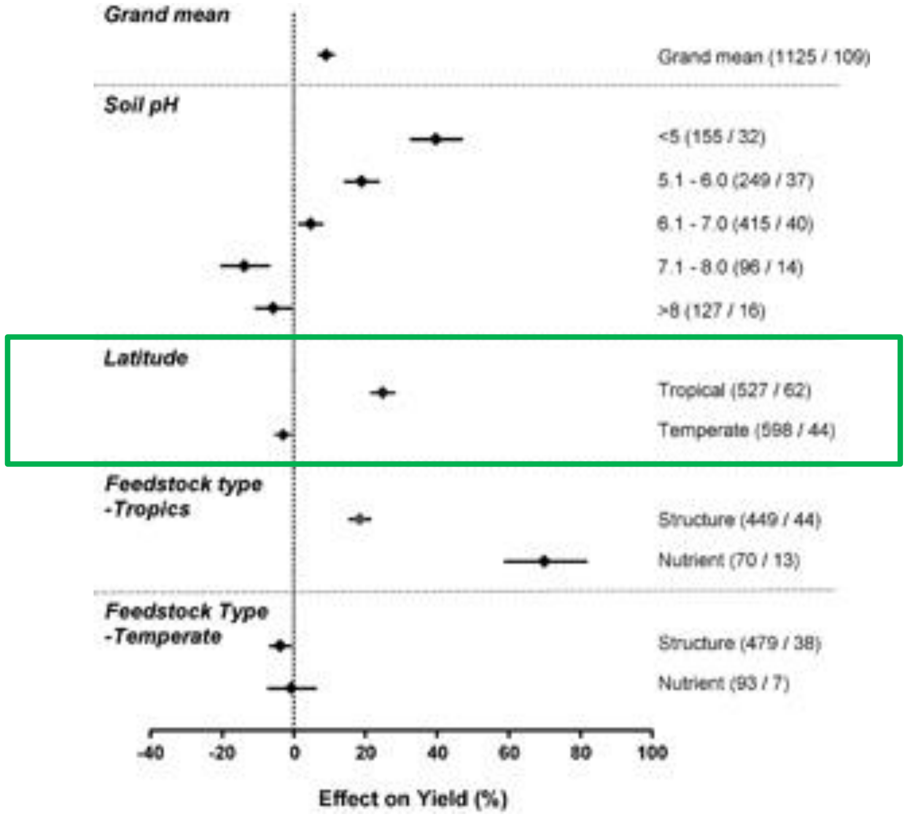
Some studies have reported yield reductions after biochar application. The main processes behind these negative results are not well understood, but several mechanisms have been proposed and tested:

- Nitrogen immobilization is the better-characterized (Bruun et al., 2012), although it is expected to last for only a short period of time during which the labile C fraction of biochar is released to the soil.
- High sulphur content and salinity issues (Elseewi et al., 1978).
- The release of phytotoxic compounds (Jeffery et al., 2015).
- Reduced efficacy of pesticides (Jeffery et al., 2015).

GENNEMSNITLIGE EFFEKTER PÅ UDBYTTE

Mean effects of biochar on crop yield at a global scale: increases of 13% (Jeffery et al., 2017), 10% (Jeffery et al., 2011), 11% (Liu et al., 2013), 15% (Xu et al., 2021), 16% (Dai et al., 2020), and 25% (Bai et al., 2022).

The generally positive effects of biochar on crop yield found in global meta-analyses should not be over-interpreted. Recent research has shown that biochar has, on average, no effect on crop yield in temperate latitudes. Conversely, biochar promotes a 25% increase in yield in the tropics.



This is because arable soils in the tropics often have low soil pH, low fertility, and low fertilizer inputs, whereas arable soils in temperate regions are moderate in pH, higher in fertility, and generally receive higher fertilizer inputs, limiting the potential yield benefits from biochar.

(Jeffery et al. 2017)

GENNEMSNITLIGE EFFEKTER PÅ UDBYTTE

EKSEMPLER FRA NORD-EUROPA

Field experiments conducted in ***Denmark*** support these findings:

- Sun et al. 2014: found that at Risø, oat yields in 2011and barley grain yields in 2012 were not affected by biochar. At Kalundborg, Maize yields in 2011 and 2012 were not affected by biochar (except yield loss at 50 t /ha).
- Hansen et al. 2017: In Zealand, yield of winter wheat and winter oilseed rape was not affected by biochar.

The lack of effect of biochar application on crop yields in Denmark is consistent with other studies from the ***temperate region in the EU on sandy loam soils***.

- O'Toole et al. (2018): 4-year field experiment conducted in Norway, biochar did not alter crop yields of oat and barley during any of the four growing seasons.
- Nelissen et al. (2015): 2-year field trial with maize, located in Belgium, showed no effect on crop yield.
- Tammeorg et al. (2014): 3-year field experiment conducted in Finland, with wheat, turnip rape, and faba bean, the grain yields and N uptake with biochar addition were not significantly different from the control in any year.

KONKLUSIONER

- N indhold afhænger meget af pyrolyse temperatur – falder med stigende temperatur.
- Internationale studier viser både positive og negative effekter på N tilgængelighed. Små effekter I danske forsøg.
- Det vurderes ikke relevant at inddrage N i gødningsregnskaber.

- P tilgængelighed er variabel, men på lang sigt forventes samme P tilgængelighed som for husdyrgødning og handelsgødning.
- P indhold vil ofte være begrænsende for tilførsel af biochar (fosforloft).

- Relativ høj tilgængelighed af K.

- Samlet set forventes ingen signifikante effekter på udbytter i DK . Muligvis positiv effekt på grovsandet jord.

Markforsøg på DTU

AARHUS UNIVERSITY
DEPARTMENT OF AGROECOLOGY

AARHUS
UNIVERSITY