Can perennial grain crops combine the soil ecosystem services of grassland with starch production on sandy soils?

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Abstract

Perennial crops, like permanent grassland, provide soil ecosystem services such as carbon storage and water regulation. Novel perennial grain crops, like Kernza (Intermediate wheatgrass; *Thynopyrum intermedium*) combine these services with the production of grain, providing a more sustainable alternative for starch production compared to annual crops such as corn and cereals. A trial was established in 2020–2022 on a sandy soil in The Netherlands. Yields of Kernza were compared to triticale grain and grass-clover. Kernza generally yielded less then triticale grain and grass-clover, and the yields of Kernza decreased over three years. Other studies have shown that Kernza is able to form a deep and extensive root system which is capable of extending the depth of nutrient and water uptake, therefore needing fewer external inputs. However, in the current trial the root zone was only 85 cm deep, and deeper layers consisted of compacted sand that were impenetrable to the roots. We conclude that Kernza did not develop its deep-rooting potential on this shallow sandy soil, which likely resulted in lower-than-expected crop yields from Kernza during our trial.

Keywords: Kernza, perennial, annual fodder crops, grain, ecosystem services

Introduction

In addition to fodder production, grasslands provide valuable soil ecosystem services such as water regulation and carbon storage (Lindborg *et al.*, 2022). Due to disturbance of the soil and the absence of a permanent soil-cover, annual (fodder) crops like maize and other cereals often provide fewer soil ecosystem services (Schils *et al.*, 2022), but have a high production potential that is rich in starch. There has been an advocacy for annual cereal crops to move toward perennial systems in order to combine the production of grain with the benefits of perennial crops, such as grassland (Asbjornsen *et al.*, 2014). Ongoing breeding of Intermediate wheatgrass (*Thynopyrum intermedium*) led to the creation of the perennial grain Kernza. Although grain yields of Kernza are currently lacking behind those of annual grains, the total biomass production is comparable to grassland (Culman *et al.*, 2013; Jungers *et al.*, 2019) and it can be used as fodder. The objective of this trial was to compare Kernza with triticale cereal and grass-clover, for grain and biomass yields, and to study the effect of these crops on soil organic matter (SOM), soil structure and rooting.

Materials and methods

A three-year trial (2020–2022) was setup as a randomised block design with four replicates comparing Kernza, triticale and grass-clover. The trial was performed on a sandy soil in the south of the Netherlands. Kernza and grass-clover were sown in September 2020, triticale was sown yearly in October. Seeding rates were 42, 120 and 34 kg ha^{-1} seeds for Kernza, triticale and grass-clover respectively. Kernza was sown in rows with 30 cm distance. At the start of the trial, all crops received a one-time amount of 30 Mg ha^{-1} of compost that provided 139 kg N ha^{-1}. Each spring, the crops were fertilized with 50 kg N ha^{-1} and other elements from an organic plant feed granulate. Ample K_2O was applied to all plots. In the third year, all plots received an extra 50 kg N ha^{-1} of the organic plant feed granulate. All crops were cut, weighed and analysed to determine dry matter yields. Grass-clover plots were harvested 2–4 times per year, depending on growth. Kernza and triticale were harvested once per year and were threshed to separate grain and straw. Soil organic matter was analysed in soil samples from the 0–10 and 0–30 cm soil layer. The maximum rooting depth was determined from a soil profile pit. At the depths of 0–25 and 25–50 cm, the root intensity was visually scored on a scale of 1–10 and the soil structure was visually assessed and categorized as percentages of crumb, sub-angular, and angular particles. ANOVA statistical analyses were performed using SPSS Statistics.

Results and discussion

Good stands of Kernza and grass-clover were established. However, the yields of all three crop types varied largely over the three-year trial period. Management of the crops was extensive, with small inputs of fertilizer and no irrigation. Therefore, seasonal and weather influences were an important factor, resulting in a large variation in yields. Grain yields of Kernza decreased over the three-year period, with the highest production occurring in the first year (Table 1). It is generally expected that the highest grain yields occur in the first two years (Culman *et al*., 2013) but then decrease. Kernza grain yields were also low compared to triticale, as was expected. In the third year both Kernza and triticale failed to produce any notable amount of grain as both crops suffered losses, likely due to excessive rain and competition from weeds in spring, followed by a drought in summer. The good stand of Kernza in the first and second year had almost disappeared at the end of the third year. The total biomass yield of Kernza was comparable to grass-clover in the second and third year, but lower in the first year, likely because Kernza invests a lot of growth in its rooting system in the first year.

There were no significant differences in the amount of SOM between crops. Although SOM in the 0–10 cm soil layer appeared slightly lower for the triticale crop, as would be expected with the yearly tillage. Due to the slow process of building up or losing SOM, it is likely that the trial would need to be extended over

Table 1. Above- and below-ground parameters of grass-clover, Kernza and triticale.

Parameters	Unit	Grass-clover	Kernza	Triticale	*P* crop	*P* year	*P* C*Y
Above ground							
Mean total biomass yield $year^{-1}$	Mg ha^{-1}	6.3	4.1	4.9	<0.001	0.117	<0.001
2021	Mg ha^{-1}	9.8^{a}	3.4^{b}	3.7^{b}			
2022	Mg ha^{-1}	3.4^{b}	4.5^{b}	7.4^{a}			
2023	Mg ha^{-1}	5.5^{a}	4.5^{ab}	3.6^{b}			
Mean grain yield $year^{-1}$	Mg ha^{-1}	N.A.	0.1	1.5	<0.001	<0.001	<0.001
2021	Mg ha^{-1}	N.A.	0.3^{a}	1.2^{b}			
2022	Mg ha^{-1}	N.A.	0.1^{a}	3.3^{b}			
2023	Mg ha^{-1}	N.A.	0.007	0.001			
Below ground							
SOM 0–10 cm	%	4.1	4.0	3.8	0.510		
SOM 0–30 cm	%	3.6	3.6	3.5	0.765		
Crumbs 0–25 cm	%	55	70	75	0.325		
Sub–angular 0–25 cm	%	34	26	21	0.509		
Angular 0–25 cm	%	11	4	4	0.085		
Crumbs 25–50 cm	%	14	31	21	0.078		
Sub–angular 25–50 cm	%	42	51	44	0.807		
Angular 25–50 cm	%	44	18	35	0.189		
Root score 0–25 cm	1–10 scale	5.9	6.0	5.4	0.583		
Root score 25–50 cm	1–10 scale	4.3	3.9	3.9	0.274		
Max. root dept	cm	82.8	78.3	85.5	0.860		

Crop yields with different superscript are significantly different (P<0.05).

more years for larger amounts of SOM to build-up in the Kernza and grass-clover treatments. Sprunger *et al.* (2018) suggest that it takes more than four years to accumulate a 15% difference in SOM between intermittent wheatgrass and an annual wheat crop.

There were no significant differences in soil structure between the crops. There was a trend (P=0.078) that soil in the Kernza treatment had more crumb structure at 25–50 cm depth.

No differences in root biomass scores or root depth were found between crops. Kernza has been reported to be able to reach rooting depths of up to 3 metres (DeHaan and Ismail, 2017) and a larger root biomass in the topsoil, compared to wheat (Sprunger *et al.*, 2018). However, the fertile soil layer in the current trial reached only 85 cm of depth, with a compacted layer beneath. This prevented all crops from developing a deeper root system. The inability to form deeper roots may also have stunted the growth of the above-ground biomass and affected production, as deep-root development is an important trait of Kernza.

Conclusion

Kernza can establish and produce grain on a sandy soil in The Netherlands. However, in this trial the crop could not reach its full potential, likely due to the relatively shallow sandy soil which did not allow for deep rooting. Both the grain and biomass yields were lower than expected and the crop did not persist into a fourth year. Parameters for SOM, soil structure and rooting were not significantly improved for Kernza, compared to triticale. This is likely due to the relatively short duration of the trial. However, it is possible that Kernza could improve soil quality when grown for a longer period of time. In future experiments Kernza should also be investigated on sandy and clayey soils with deeper soil profiles.

Acknowledgement

This project was part of the Public-Private Partnership KLIMAP.

References

Asbjornsen H., Hernandez-Santana V., Liebman M., Bayala J., Chen J. Helmers M. ... and Schulte L.A. (2014) Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services. *Renewable Agriculture and Food Systems* 29(2), 101–125.

Culman S.W., Snapp S.S., Ollenburger M., Basso B. and DeHaan L.R. (2013) Soil and water quality rapidly responds to the perennial grain Kernza wheatgrass. *Agronomy Journal* 105(3), 735–744.

DeHaan L.R. and Ismail B.P. (2017) Perennial cereals provide ecosystem benefits. *Cereal Foods World* 62(6), 278–281.

Jungers J.M., DeHaan L.R., Mulla D.J., Sheaffer C.C. and Wyse, D.L. (2019) Reduced nitrate leaching in a perennial grain crop compared to maize in the Upper Midwest, USA. *Agriculture, Ecosystems and Environment* 272, 63–73.

Lindborg R., Bernues A., Hartel T., Helm A. and Ripoll-Bosch R. (2022) Ecosystem services provided by semi-natural and improved grasslands – synergies, trade-offs and bundles. *Grassland Science in Europe* 27, 55–66.

Schils R.L.M., Bufe C., Rhymer C.M., Francksen R.M., Klaus V.H., Abdalla M. ... and Price J.P.N. (2022) Permanent grasslands in Europe: Land use change and intensification decrease their multifunctionality. *Agriculture, Ecosystems and Environment* 330, 107891.

Sprunger C.D., Culman S.W., Robertson G.P. and Snapp S.S. (2018) Perennial grain on a Midwest Alfisol shows no sign of early soil carbon gain. *Renewable Agriculture and Food Systems* 33(4), 360–372.

The Netherlands 9-13 June

EGF 2024

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Volume 29
Grassland Science in Europe