HOW TOLERANT ARE SWARDS TO DROUGHT?

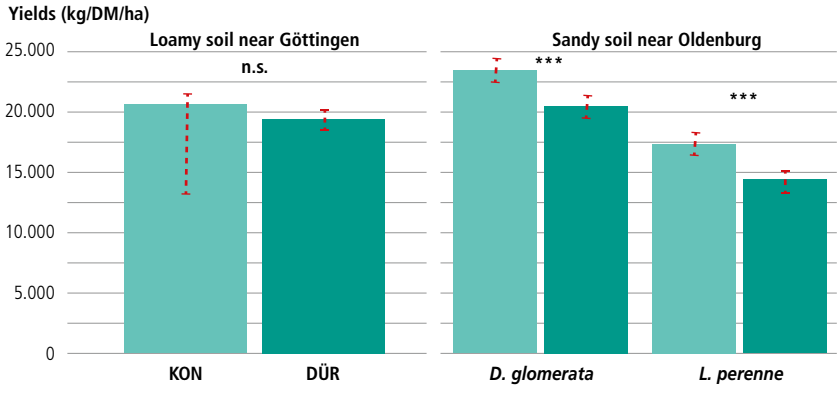
Grass species have diverse characteristics that complement each other in mixes. The University of Göttingen has investigated which grass species are particularly drought-tolerant and how mixes containing herbs and legumes perform.

Spring and summer droughts rapidly cause water scarcity that leads to yield losses – to a greater or lesser extent, depending on the soil type. Forecasts predict that drought and heat waves will occur more frequently and with greater intensity in future. Most recently, the years 2018 and 2019 were characterised by drought, which has increasingly raised the question of what could be adequate adaptation measures. The extent to which yields are affected by extreme events such as drought is referred to as tolerance. The term resilience is also often used to refer to the ability of crops to return to their initial state after a stress event (e.g. drought). In this paper we look at the tolerance of grass swards to drought, basing our statements on our own studies. These studies were conducted either under semi-controlled conditions in mesocosms inside a greenhouse or as field trials in the open. We used different forage crop species and different combinations of forage crop mixes, each answering a different question. Certain parts of these species and mixes were exposed to drought. In the greenhouse, the water supply of the drought-stress variants was cut temporarily and these plants were compared with the control plants which were optimally supplied with water. The drought-stress variants in the open field were covered by a translucent foil roof for a period of about 30 days in spring and summer. The crops that received natural levels of rainfall served as reference or control plants. The field trials were carried out over a period of three years at two locations: a loamy site in Göttingen and a sandy site near Oldenburg. The crop was harvested after the spring and summer drought, with a third cut carried out in autumn.

Which grass species proves to be more drought-tolerant?

Cocksfoot (*Dactylis glomerata* L.) is a species with moderate demands for resources and offers a better drought tolerance than perennial ryegrass (*Lolium perenne* L.). Therefore, cocksfoot and perennial ryegrass

FIGURE 1. DRY MATTER YIELD COMPARED



The effect of drought on cumulative yields over three trial years (kg DM/ha) comparing control plants (KON) with drought-stressed plants (DÜR) on a deep loam site (left) and a sandy site (right). Averaged results across two fertiliser levels. The results at Göttingen site were averaged across both species. *** indicates significant differences between control and drought-stressed plants.

In comparison to perennial ryegrass, Cocksfoot is a species with an increased drought tolerance.

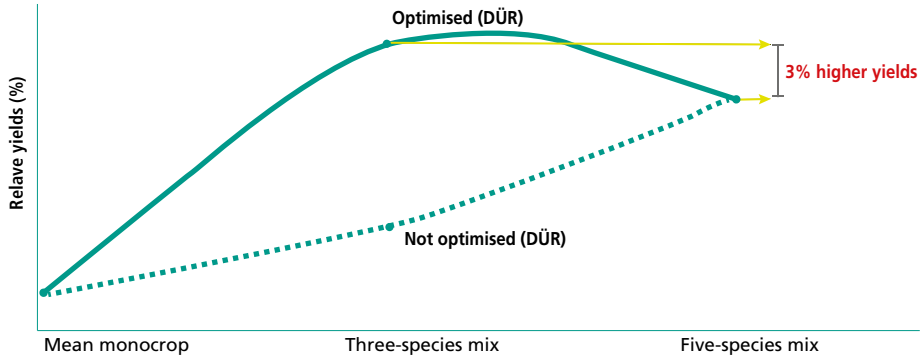
were compared in the field trial. For three years the foil roofs kept out 29% (Oldenburg) and 44% (Göttingen) of the total rainfall during the growing season of the drought-stress variants (April-October). At the deep loam site in Göttingen, the artificially produced drought did not lead to cumulative yield losses over the three-year period (Figure 1); neither were any differences found in terms of yield when comparing the various grass species. By contrast, at the sandy site in Oldenburg cocksfoot was found to fare better than the perennial ryegrass and there was also a significant yield reduction due to drought (Figure 1). With a yield reduction of 13%, the tolerance of cocksfoot to drought was higher than that of perennial ryegrass (17% lower yields). The measure that is often used for the successful adaptation to drought stress is the agronomic Water Use Efficiency (aWUE) parameter which defines the amount of dry biomass produced per unit of available water. By using the rainfall in Oldenburg during the period as the indicator of water availability and by using this parameter to form a simplified aWUE (without unproductive water losses) it was shown that drought improves the aWUE and that the various grass species responded in different ways. Cocksfoot produced 22.3kg and 18.1kg of dry matter per millimetre of rainfall – both in the drought-stress and the control variants. The corresponding values for perennial ryegrass were 15.6kg and 13.4kg DM per mm rainfall. Accordingly, aWUE increased by about 18% (cocksfoot) and 14% (perennial ryegrass) in drought conditions. At this point we cannot yet determine what role is played by different characteristics of the grass species in terms of root depth, endophytes, leaf life, a distinctive wax layer or other factors.

What contribution does plant species diversity make to drought tolerance?

In the context of research on diversity and mixing effects, it is becoming increasingly clear that it is not only species diversity per se that ensures positive yield effects, **but that rather a targeted selection of species with desirable traits is the key to compositing successful mixes** (Mahaut et al. 2019). Here, the diversity of the properties of functional groups such as grasses, herbs and legumes, which all have different "skillsets", is relevant for achieving the intended effect. For example, herbs can be deep-rooted, while grasses tend to be shallow-rooted; this determines where they claim resources and is referred to as 'niche differentiation'. Legumes fix atmospheric nitrogen and thus make nitrogen available to the crops in grassland; an important property, especially in organic farming.

In another study, the following typical representatives of grassland were therefore selected: the above-mentioned grasses perennial ryegrass and cocksfoot, plus ribwort (*Plantago lanceolata* L.), dandelion (*Taraxacum officinale* L.) and white clover (*Trifolium repens* L.). These were grown as monocrops in mesocosms – in every possible combination of three-species mixes and also as a five-species mix containing all species. This produced different levels of plant species diversity and trait expression. The crops were exposed to repeated drought stress events and then harvested. The primary aim was to clarify the relationship between trait diversity and species diversity. Specifically, the question is whether drought tolerance depends on diversity or on the expression and number of traits obtained through the choice of mixing partners in triplicate mixes. The hypothesis was that three-species mixes have an equivalent drought tolerance to the five-species mix when the diversity of functional groups and thus of traits is maximised. Compared to a mean monocrop , the mixes achieved 14%

FIGURE 2. RELATIVE YIELDS IN COMPARISON



Development of relative yields of all three-species mixes (including mixes without white clover) and of the five-species mix compared to the mean monocrop in the drought variant (DÜR) (dashed line) as well as development of the relative yields of optimised three-species mixes (exclusively white clover + herbage + grass) and the five-species mix compared with the mean monocrop (according to Komainda et al. 2020).

/ 29% higher yields under drought / control conditions, with drought tolerance generally improving as plant species diversity increases (1 vs. 3 vs. 5 species) (dashed line, Figure 2). The three-species mixes with optimised trait composition achieved a 3% higher yield than the five-species mix under drought conditions (solid line, Figure 2).

From our study, it appears that a high drought tolerance can potentially be achieved through the combination of legumes (N-fixing), herbage (deep root) and grass (shallow root). The grass species (cocksfoot or perennial ryegrass) is less critical. The yield advantage of 3% for the optimised three-species mix is about the same as the breeding progress of perennial ryegrass (4.2% per decade, Reheul et al. 2017) and illustrates the potential of using diversity in grassland where the focus is on the characteristics of the introduced species.

Herbal leys – seed mixes containing grasses, legumes and herbs – are common in southern Germany and are an option for increasing drought tolerance.

Perennial ryegrass is very productive, but not as drought-tolerant as cocksfoot, for example.

Conclusion

Drought tolerance can be increased by selecting suitable partners for a mix on the basis of their properties and combining them in a targeted manner. Since it is ultimately the traits, their diversity and combination in seed mixes that matter, both breeders and growers must rise to the challenge. The aim is to develop species and varieties and combine them in such a way that the resulting crop has a high drought tolerance. This is achieved by targeting only those species that show desirable traits so as to maximise the overall diversity of traits within the crop.—

The literature can be made available on request.

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