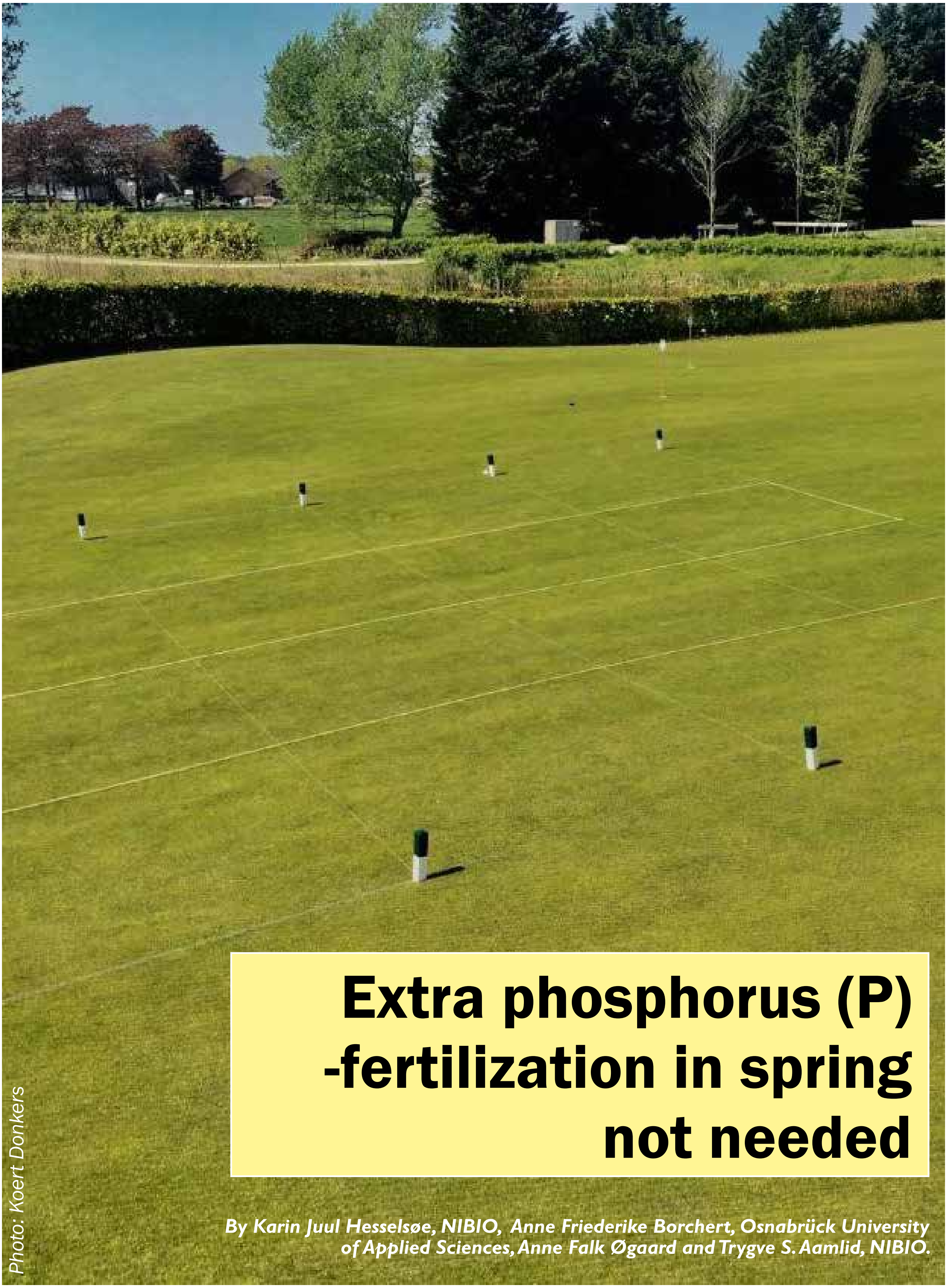
Photo: Koert Donkers

Extra phosphorus (P) -fertilization in spring not needed

By Karin Juul Hesselsøe, NIBIO, Anne Friederike Borchert, Osnabrück University of Applied Sciences, Anne Falk Øgaard and Trygve S. Aamlid, NIBIO.

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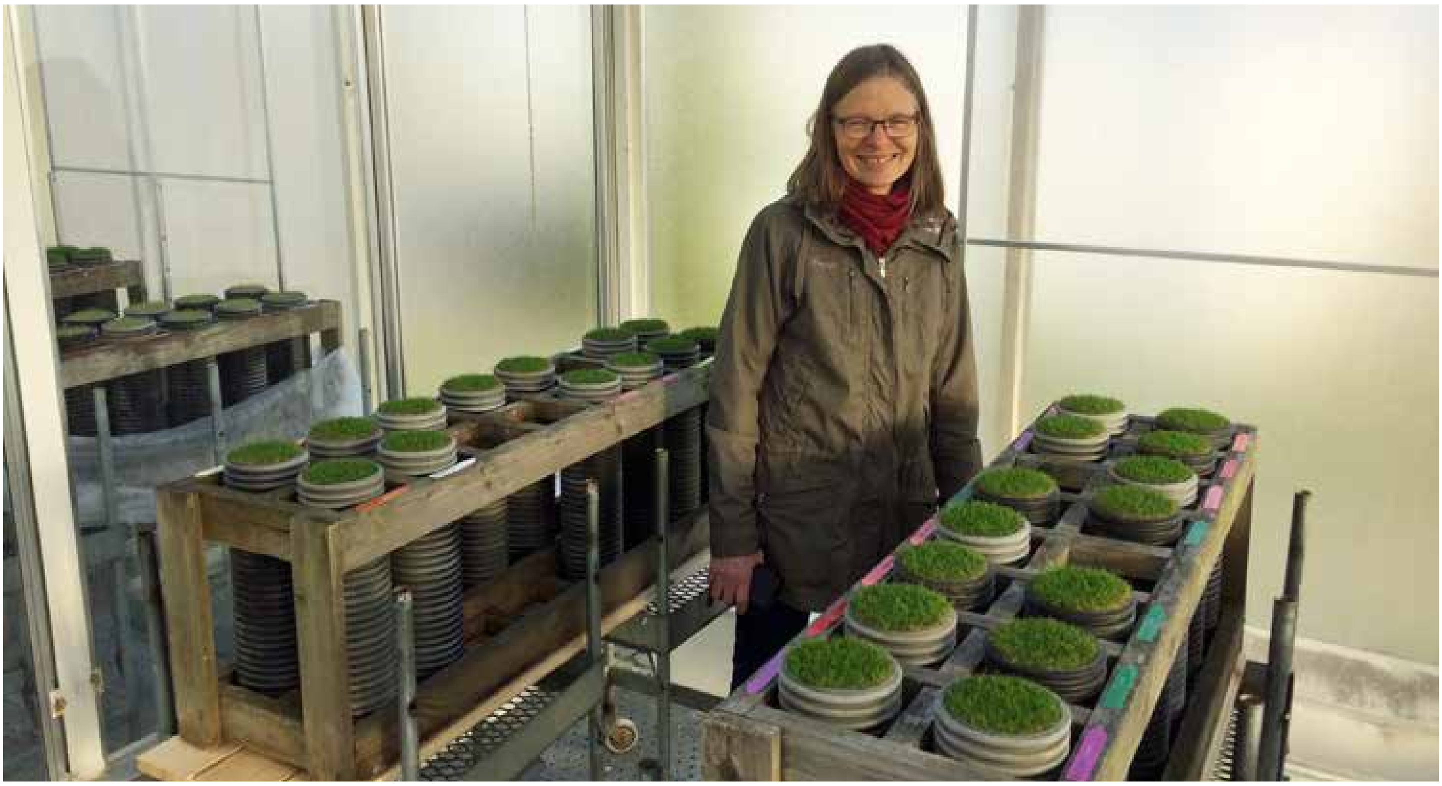

Photo 1: *Anne Falk Øgaard in the pot trial investigating P requirements for creeping bentgrass establishment at different soil temperatures. Photo: Trygve S. Aamlid.*

During the past 5-10 years, many industriess have shown rising awareness in about environmental issues such a climate change, land deterioration, unsustainable use of fertilizers and pesticides and loss of biodiversity. As with agriculture and other industries it is important that the turfgrass sector show environmental stewardship, thus contributing to a more sustainable future. Sustainabale use of phosphous (P) is particularly important since it is the primary plant nutrient of which the world's reserves are most limited and also a nutrient that can cause deterioration of many freshwater systems.

In the STERF project 'SUSPHOS: Sustainable use of phosphorus on Nordic golf courses', we have studied P requirements both for turfgrass grow-in and on established greens. As compared with earlier recommendations, the overall conclustion is that P rates can be reduced signficantly without negative implications for turfgrass quality.

The objective of this article is to summarize results form a greenhouse study in which we investigated turfgrass P nutrition during establishment at low soil tempertures in spring. Preliminary results from field trials on golf course putting greens in different parts of the world are also presented. Readers looking for a more complete discussion of SUSPHOS merthodology and results are referred to Øgaard & Aamlid (2020) and Hesselsøe et al. (submitted).

Assumptions and questions to be investigated

STERF's handbook 'Precision fertilization' (Ericsson et al. 2012) recommends frequent applications of plant nutrients in the same proportion that is usually found in plant tissue. For the primary macronutrients, this means appliction of N:P:K in the ratio = 100:12:65. 'Precision fertilization' disregards the need for soil analyses as all nutrients are applied in the same amounts as taken up by the plants. But what happens if the soil contains a nutrient in sufficient amounts to meet plant requirements even without fertilization?

This is a situation that might occur for P, e.g. on old cultivated soils and on sandbased substrates amended wth compost.
Two assumptions about P nutrition commonly heard from greenkeepers are:
a) Turfgrass grow-in, and particularly seedling root development of, is usually limited by P. A fertilizer high in P should theefore be mixed into the soil before seeding.

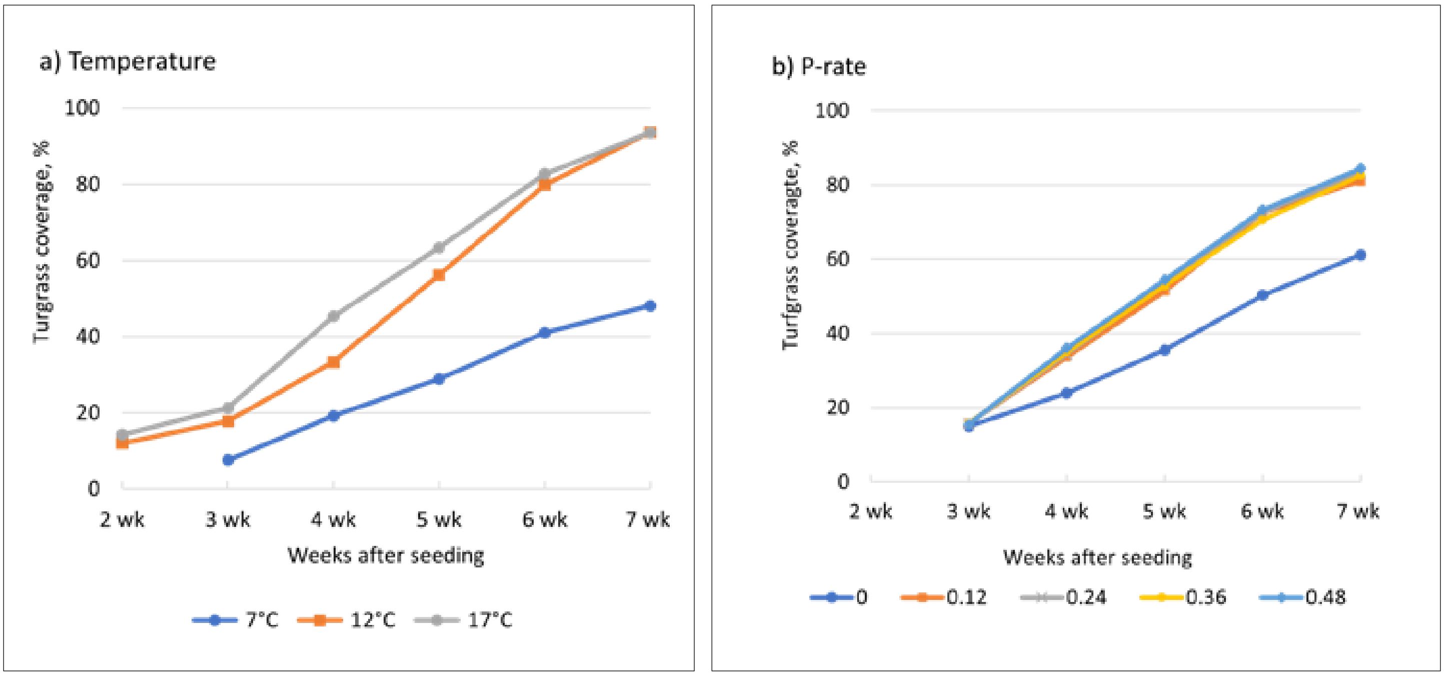

Figure 1: *Left: Main effects of temperature of turfgrass coverage (mean across five P rates). The lowest temperature 7 °C resulted in signifcantly slower establihment than the two higher temperatures which were not signicantly different. The figure to the right shows establishement when P was applied in rates corresponding to 0, 6, 12, 18 och 24% of the N rate (mean across three temperatures). Turfgrass establishement was signifcantly impaired when no P was applied, but there was no difference between P given at rates 6, 12, 18 og 24 % relative to N.*

b) Low soil tempertures increases the need for P. Extra P applications are therefore needed in spring.

These two assumptions are often followed by the question:
c) What is the soil P threshold at which the turf does not respond to additional P in fertilizer ?

In SUSPHOS, the assumptions a) and b) were tested in repeated pot experiments carried out at 'Centre for plant research in controlled climate' at the Norwegain Univeristy of Life Science, Ås, Norway.

To answeer question c) field trials with increasing rates of P were carried out on established putting greens in Sweden, Germany, The Netherlands, China and Norway.

Turfgrass establishment at low soil temperatures

Creeping bentgrass 'Independence' was seeded on the top of 20 cm high cylinders containing a USGA-profile with a sand that had been amended with Sphagnum peat and had av rather low soil P status (13 mg P / kg dry soil as determined in Mehlich (3) extracts). The cylinders were placed in natural daylight compartments with temperatures maintained at 7, 12 and 17 °C from early April to late May. A liquid fertilizer containing all essential nutrients except P in ratios according to 'Precision fertilization' was appleid weekly at 2.0 g N / m^2 / wk. P was applied at 0, 6, 12, 18 and 24 % of the N rate in the form of 85% monophosphoric acid (H_3PO_4). Turfgrass coverage and dry weight of clippings were recorded weekly during the trial period.

The results showed that temperature was the most decisive factor for turfgrass grow-in (Fig. 1a). Establishement was faster with than without P fertilization , but there was no effect of increasing the P rate beyond 6 % of the N rate (Fig. 1b). The important conclusion was the the current recommendation in 'Precision fertilization', i.e. to apply P at a rate corresponding to 12 % of N, provides a sufficient safety margin, even for turfgrass grow-in at low temperature. This conclusion was also confirmed by the analyses of N and P in clipping dry matter. Samples from grass grown at 7 °C had the highest leaf P concentration, indicating that low tempeture was more limiting to growth than to P uptake. Higher P rates will, in other words, not promote growth, but may rather lead to higher P losses to nearby lakes and rivers in situations with low soil temperatures.

Field trials in five countries

Tradionally, soil samples are taken to obtain information about the soil's reserves for plant nutrients. Most experience for interpretation of soil analyses comes from agriculture where soils are divided into classes to adjust P applications to various crops depending on soil nutrient status. In many countries, the same classes and thresholds thesholds are also used for turf. For example, in Sweden soil P-AL values below 4 mg /100 g soil are often taken as an indication for that extra P application is needed. There is, however, no experimental evidence that this threshold applies to established turf on golf couses.

As part of SUSPHOS, experiments were laid out in 2017 on established greens at the golf courses Falkenberg

Photo 2: *This red fescue / colonial bentgrass green at Princenbosch GC i the Netherlands was divided into 2x2 meter plots that received various rates of P from 2017 to 2020. The N rate in this particular trial was only 5 g N / m². Photo: Koert Donkers.*

in Sweden, Pricenbosch in the Netherlands (Photo 2), Dütedal in Germany, Jingshan lake i China and at NIBIO Landvik Research Center in Norway. The five greens represented a wide range of climatic condtions, cool-season grasses and methods for contruction and maintenace of putting greens. The objective of the experiment was to investigate how increasing rates of P influenced turf quality and the development of soil P values during the four-year proejct period. The greens were split into plots that received P in the form triple superphosphate at monthly intervals (Photo 2). Control plots did not receive P throughout the four year trial period; others received P depending on the soil's P reserves. One treatment was fertilized according to 'Precision fertilization', i.e. with a P-rate equvalent to 12 % of the N rate irrepective of soil analyses (Table 1).

Turfgrass visual quality was assessed monthly from April to October/ November throughout the four year trial period. Other recordings included root length, diseases and Poa annua encroachment. Soil samples from all plots were analyzed by the end of each growing seasons and used to calculate the P-rates used in treatments 2 and 4 in the following year. As the initial soil P content was low in all trials, we experienced significant increases in P values in treatment 4 in all trials.

Overall conclusion: P-rates can be reduced!

Results showed no reduction in turfgrass quality due to reduced P rates in any of the trials. P-deficiency in the form of dark violet color on leaves was never observed, while a significant reduction in in Poa annua encroachement was observed one out of five trials only. All in all, ther seems to be room for significant cuts in P-rates on many golf coursesd without negative implications for turfgrass quality or associated characters.

Table 1: *Experimental treatments in trials in Norway, Sweden, Germany, Netherlands and China, 2017-2020.*

Treatment no	Treatment designation (fertilization concept)	P-input
1	Zero P	No application of P (control)
2	MLSN (Minimum Level of Sustainable Nutrition)	P-application if soil reserves <18 mg P / 100 g soil (Mehlich (3) extract)
3	SPF (Scandinavian Precision Fertilization)	P-rate = 12 % of N-rate irrespective of soil analyses
4	SLAN (Sufficiency Level of Available Nutrients)	P-application if soil reserves <54 mg / 100 g soil (Mehlich (3) extract)

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