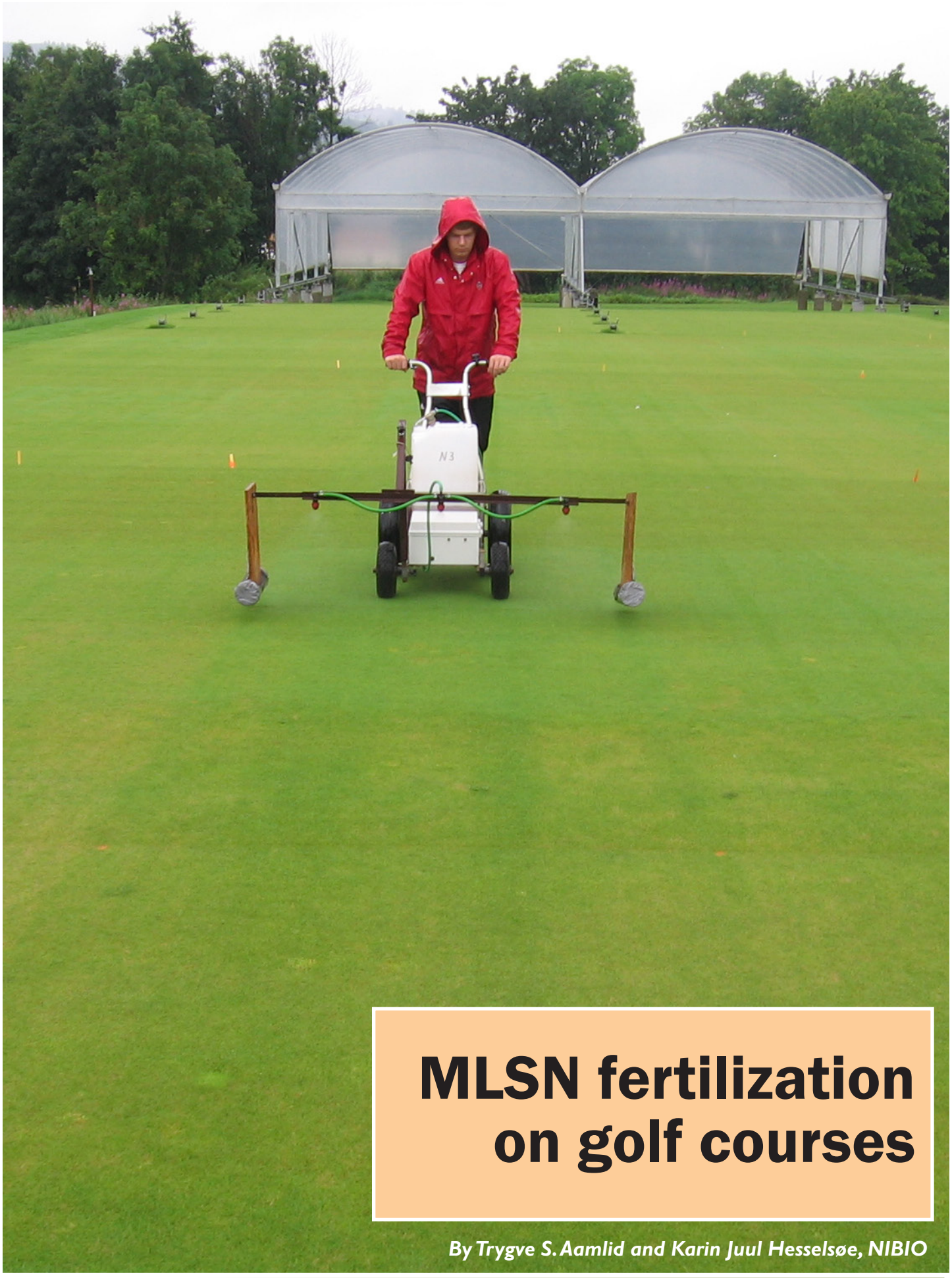

MLSN fertilization on golf courses

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Popular Scientific Articles - STERF, April 2020

Application of liquid fertilizer on experimental green (left) and granular fertilizer on experimental fairway (right) at the NIBIO Turfgrass Research Centre Landvik. Photos: Agnar Kvalbein (left) and Trygve S. Aamlid (right).

MLSN fertilization on golf courses

The ' Minimum Level of Sustainable Nutrition ' (MLSN) is becoming a concept for environment-friendly and sustainable fertilization of turfgrass. More than 1000 golf courses i North-America, Asia and Europe have started to use the MLSN standards, and the Golf Environment Organization (GEO) recommends that golf courses to follow MLSN principles. But what does MLSN fertilization really mean, and how is the relationship between the MLSN recommendation and STERF's recommendations for 'Precision fertilization' ?

No difference for nitrogen

For nitrogen (N) there is no difference between MLSN and 'Precision fertilization'. Both recommendations are based on (1) the difference in growth potential among various grass species and (2) the variation in temperature and light during the growing season. For the first of these reasons, annual bluegrass (*Poa annua*) and creeping bentgrass (*Agrostis stolonifera*) typically receive more fertilizer than red fescue (*Festuca rubra*) and velvet bentgrass (*Agrostis canina*), and for the second reason, grass species receive more fertilizer in June when temperature and light are more conducive to to growth than earlier or later in the growing season. 'Precision fertilization' aims at maintaining a constant nitrogen concentration of 3.0-3.5 % in the leaf dry matter throughout the growing season, and the MLSN has no objection to that.

Soil analysis for the other nutrients?

The difference between the two fertilizer norms lies in the view on soil analyzes. In agriculture, soil analyses for pH, phosphorus (P), potassium (K) and magnesium (Mg), and in some cases other nutrients as well, are usually considered an important tool for selecting an appropriate fertilizer type to various crops and on various soils. Therefore, when STERF launched 'Precision fertilization' 10-15 years ago, many greenkeepers questioned the recommendations to apply the same fertilizer type regardless of season or soil type. According to Ericsson et al. (2015), the ratio between the macronutrients N, P, K, Mg, Ca in the ideal fertilizer shall always be 100:14:65:6:7:9, which roughly reflects the ratio between the same elements in plant tissues. The 'ideal fertilizer' according to STERF also contains micronutrients in appropriate concentrations.

At the NIBIO Turfgrass Research Center Landvik, we have for many years been fertilizing according to STERF's 'Precision Fertilization', and our experiences with that have been good. The question is, nonetheless, if this is always the most economical and environmentally friendly fertilizer recommendation ? Some of our USGA-spec. greens have sand amended med 'Green Mix' garden compost in rootzone, and these greens contain far more phosphorus (P) than when using Sphagnum peat as organic amendment. Furthermore, some of our fairways have been established on soils with very high P levels due to earlier vegetable production. Other golf courses may have fairways on clay soils with high potassium (K) reserves. A relevant question is therefore if STERF's 'ideal fertilizer' is optimal even on such areas, or if the P and K inputs ought to be reduced depending on soil analyses ?

SLAN - The old American fertilizer norms for golf courses were developed from agriculture

Many distributors of turfgrass fertilizer offer services by which soil samples are shipped to laboratories in USA or other countries for analyses according to various methods. The protocols for these analyses are not always publically available and unbiased comparisons are therefore difficult.

The traditional American norms are called the 'Sufficiency Level of Available Nutrients (SLAN)' and are based on Mehlich (3) extracts (Carrow et al. 2004a,b). This is a powerful extraction method that usually shows higher levels for P, K and Mg than AL extraction, which is used in Norway and Sweden. For agricultural soils, Mehlich (3) P values can be converted to P-AL by the equation:

- Mehlich (3) (ppm) = 1.47 · P-AL (ppm) + 0.1 (Bechmann et al. 2005)

In Denmark soil P levels are usually presented per 100 g soil after extraction with bicarbonate (so-called 'Olsen-P'). In this case the following relationhip with Mehlich (3) has been calculated for agricultural soils:

- P-Mehlich (ppm) = 43,6 · Olsen-P (mg/100g) - 39.5 (T. Krogstad, Norwegian University of Life Sciences)

Unfortunately, it has not been verified to what extent these equations are applicable also for sand-based greens.

The American SLAN norms were developed from agricultural research. The US golf industry repeatedly asked for research to adapt the standards to sand-based growth media, but such an adaptation would require comprehensive experimentation and that has not been carried out so far. The scientists behind MLSN took a different approach: They developed new norms based on already analyzed soil samples from golf courses in the United States and Asia (Woods et al. 2014, 2016).

How were the MLSN norms calculated?

The original dataset for development of MLSN consisted of more than 16,000 soil samples submitted to laboratories in Asia and North America. Among these data, a subset of 3683 samples was selected based on the following criteria:

1. All samples should be from greens, fairways and football fields with 'good looking turf', i.e. no problem areas or areas with deficiency symptoms.
2. The pH should be between 5.5 and 8.5, i.e. a relatively wide range around the neutral pH 7.0. This excludes soil at risk for aluminum toxicity (low pH) or sodium toxicity (high pH).
3. The Cation Exchange Capacity (CEC) of the soil should be below 6 cmol(+) / kg soil. CEC is a measure of the soil's sorption capacity for positively charged nutrients,

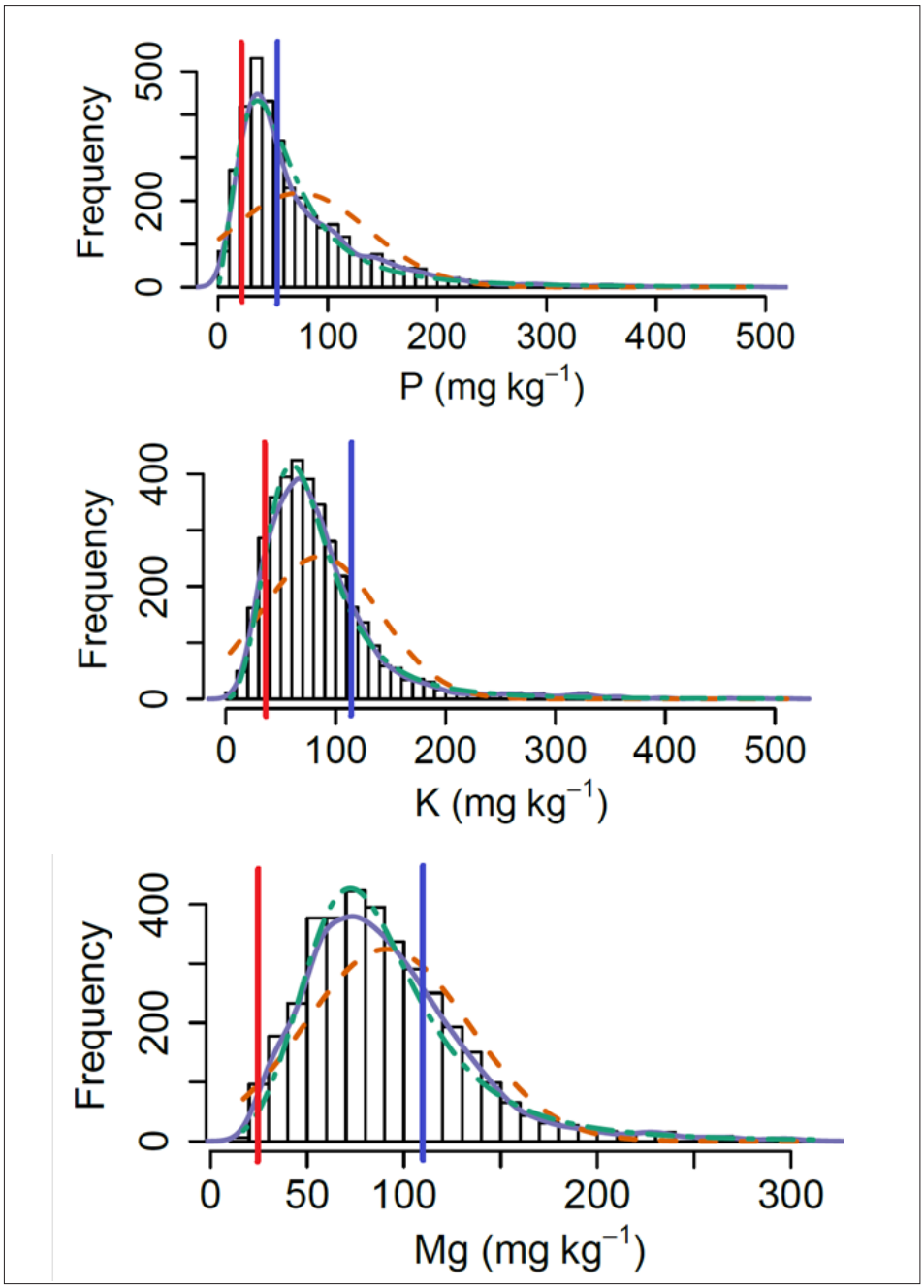

Figure 1. *Distribution of 3683 soil samples from 'good looking turf' according to their content of P, K and Mg. Vertical red and blue lines indicate MLSN and SLAN thresholds, respectively (Woods et al. 2016).*

	SLAN	MLSN
P	55	21
K	117	37
Mg	121	47

Table 1. *Old SLAN and new MLSN norms (mg/kg soil) for phosphorus, potassium and magnesium. .*

i.e. how much K^+, Mg^{2+} etc. the soil can hold on to and render available to plants at a later stage. On sand-based greens, CEC is rarely above 6 cmol (+) / kg soil, but it is usually higher on (older) push-up greens and fairways on natural soil. The criterion meant that only the soils, with the greatest risk of nutrient deficiencies, were included when calculating the standards. The rationale was that if the MLSN norms provided adequate fertilization on such soils, they would also be sufficient for nutrient-rich soils with greater buffer capacity.

Figure 1 shows how the 3683 soil samples were distributed in terms of P, K and Mg content. More than 50% of the samples were below SLAN thresholds in which case there, according to the American standard, should be a need for extra fertilizer inputs, despite the fact that the turf was already 'good looking'. This is where the scientists behind MLSN were bold enough to introduce a new and unconventional way of thinking: The defined new thresholds so that the chance for a randomly selected sample to be below the threshold was 10%. In other words, the MLSN norms were not developed from field experiments, but from empirical data of 'good looking turf'. Table 1 shows that the MLSN norms for P, K and Mg are 60-70% lower than the old SLAN norms.

How are MLSN norms used to calculate fertilizer requirements?

When setting a minimum threshold for the content of a particular nutrient in the soil, it is a goal that the content of this nutrient shall never drop below this threshold. The amount of nutrient that must be added in fertilizer during a growing season can then be calculated as:

a) What is taken up by the grass and removed in clippings ?
+ b) Necessary reserve in the soil at the end of the growing season (= MLSN value)
- c) Soil content at the start of the growing season
= Must be applied in fertilizer

For line a) in the equation, MLSN assumes that grass growth is primarily controlled by N and that the amount of all other nutrients removed in the clippings can be calculated as a fixed percentage of the N input. While this is principally in agreement with 'Precision Fertilization', MLSN advocates slightly lower ratios of the other nutrients relative to N, i.e. 12.5% for P (Precision fertilization: 14%), 50% for K (Precision Fertilization: 65%) and 5% for Mg (Precision fertilization: 6%) (Woods et al. 2014).

Lines b) and c) in the equation, i.e. the correction for soil analyses, are what distinguishes MLSN from 'Precision fertilization. Assuming (1) that the soil samples are taken to a depth of 15 cm corresponding to grass root depth, and (2) that the sand-based soil has a density of 1.4 kg / dm^3, the content of a single specific nutrient in grams per m^2 turf surface can be calculated as:

Soil analysis (mg / kg soil) x 210 kg soil / m^2 .
If, for example, the soil analysis shows 50 mg K / kg of soil, then the reserve is:
50 mg / kg soil x 210 kg soil / m^2 = 10500 mg K / m^2 = 10.5 g K / m^2

Conclusion

For American golf courses that have been fertilizing according to SLAN, the new MLSN norms are undoubtedly a huge step towards more economical and environment-friendly fertilization. This difference will be less for Scandinavian courses that have been practicing 'Precision fertilization', but even here, there should be a potential to save both money and the environment by taking into account soil analyses when setting up the fertilizer plans for the season. For Scandinavian golf courses, it still remains an uncertainty that the conversions between Mehlich (3), P-AL and Olsen-P values have not been verified for sand-based growth media. Unless Scandinavian laboratories are able to provide Mehlich (3) analyses, this obstacle clearly needs to be resolved before introducing MLSN for Scandinavian golf courses at large.

In the STERF project SUSPHOS, we compare P-applications according to SLAN, 'Precision fertilization' and MLSN recommendations on sand-based greens in Netherlands, Germany, China, Sweden and Norway. We will return to the results from these experiments in a later article.

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