First year report:

Fertilizer strategies for golf turf: Implications for physiological driven fertilization

Principle investigator and contact person:

Karin Blombäck
Swedish University of Agricultural Sciences
Department of Soil Sciences
P.O. Box 7014
SE-750 07 UPPSALA
Sweden

Telephone: +46 (0)18-671000
+46 (0)18-303339
Fax: +46 (0)18-300956
E-mail: karin.blomback@mv.slu.se

Co-applicants: Tom Ericsson, Swedish University of Agricultural Sciences, Sweden
Trygve Aamlid, Bioforsk, Landvik, Norway

This is the first year report of the project "Fertilizer strategies for golf turf: Implications for physiological driven fertilization". The report contains the results from the pot experiment under controlled climatic conditions.

Results from the pot experiment under controlled conditions

Conclusions

- Ranking of growth, and hence nitrogen demand, among the studied species was; (1) annual bluegrass, (0.90) creeping bentgrass ‘Independence’, (0.82) creeping bentgrass ‘Nordlys’, (0.65) colonial bentgrass ‘Barking’, (0.64) velvet bentgrass ‘Legendary’, (0.42) chewings fescue ‘Center’, (0.30) slender creeping red fescue ‘Cezanne’
- Root production in absolute terms was very similar for all species irrespective of nitrogen regime or whether the grass was cut or not
- Root production in relative terms, i.e. the root fraction of total plant mass, was strongly and negatively correlated to nitrogen supply
- A leaf nitrogen concentration on a dry weight basis of approximately 3 percent or higher was required for all studied grasses in order to achieve a fresh green colour of the turf
- The leaf nitrogen concentration at growth maximum was in the order of 5 % for the fescues and 6% for bentgrasses and annual bluegrass
- Leaves became narrower and stiffer in response to N-limitation
- The nitrogen productivity, i.e growth rate per unit nitrogen in the leaves, was positively correlated to the growth capacity of the studied species
- Reduction of the leaf area through cutting had a strong negative impact on N-productivity

Background

Most fertilizing strategies today are based on trial and error because of lack of information concerning the basic physiological relationship between nitrogen status and growth. Neither the maximum growth capacity of the most commonly used turfgrass species is known, nor their ability to tolerate low levels of nitrogen supply, when grown under steady-state nutrient conditions. We also lack information on how the carbon allocation pattern in turfgrasses and the carbohydrate (fructan) stores in the tissues are affected by the rate of nitrogen supply. The objective of the pot experiment was to determine:

- The growth capacity of turfgrass species commonly used on golf greens,
- The linear relationship between plant N-status and growth, i.e. the nitrogen productivity,
- The effects of plant N-status on biomass allocation,

Creeping bentgrass, velvet bentgrass, red fescue, colonial bentgrass and annual bluegrass were chosen. The study was funded by the Scandinavian Turfgrass Research Foundation (STRF) and the departments of Soil Sciences and Urban and Rural Development at SLU.

Material and Methods

The laboratory study was performed as a pot experiment in a growth chamber (photoperiod 18/6 h, PAR 400 µmol m^{-2} s^{-1}, temperature 20/15 °C d/n, RH 70%). Sand was used as growth substrate. Creeping bentgrass (*Agrostis stolonifera*, ‘Nordlys’ and ‘Independence’), velvet bentgrass (*Agrostis canina*, ‘Legendary’), chewings fescue (*Festuca rubra* ssp. commutata ‘Center’), slender creeping red fescue (*Festuca rubra* ssp. trichophylla ‘Cezanne’) and colonial bentgrass (*Agrostis capillaris*, ‘Barking’) were seeded in pots with a surface area of 48 cm^2. After germination a complete (200 mg N $liter^{-1}$) and well-balanced liquid fertilizer (Wallco 51-10-43, Cederroth International AB) was used during a four week period in order to establish the turf.

The seventh species in the study, annual bluegrass (*Poa annua*), was cultivated in the same pot type as the other species, but the plant material was raised from soil cores, 4 cm in diameter, taken from annual bluegrass dominated greens at Ullna GK north of Stockholm. The seeded area of the other species was 3 times bigger than the area of the soil cores. The growth data of annual bluegrass was therefore multiplied by a factor of 3 in order to make comparisons with the other species possible. This deviation from the general experimental layout made the nutrient amounts available for uptake by the annual bluegrass slightly bigger in all nutrient regimes since the substrate volume in relation to plant mass was larger for *Poa* compared to the other species. The soil brought from the golf course also contained fertilizers of unknown quantity.

After the establishment phase, four nitrogen concentrations, 12.5, 25, 50 and 200 mg $liter^{-1}$ were used in the irrigation water in order to create differences in nitrogen availability. The plants were irrigated/fertilized to field capacity three times per week. The turf was either cut at 5-7 mm height twice per week or left uncut during the four week experimental period. The first week of the experimental period was regarded as an acclimation phase and clippings from this period were not included in the data evaluation. Each treatment was replicated six times. In total:

7 species/varieties x 4 N-levels x 2 clipping regimes x 6 replicates per treatment = 336 pots

were included in the study.

Measured variables:

- Plant appearance
- Maximum growth capacity
- Clipping amounts in relation to N-supply
- Carbon allocation between roots and shoots in relation to N-supply
- Relationship between N-status and growth (Nitrogen productivity)

Results and discussion

Plant appearance

A nitrogen concentration of 25 mg $liter^{-1}$ or higher was required for the slow growing fescues in order to achieve a fresh green colour of the leaves. The more fast growing bentgrasses and annual bluegrass required at least 50 mg N $liter^{-1}$ in order to develop an acceptable green colour. Pronounced nitrogen limitation (< 50 mg N $liter^{-1}$) resulted in narrower and stiffer leaves. (Photo1)

Photo 1. Influence of 12.5 mg N liter^{-1} (left) and 200 mg N liter^{-1} (right) on leaf appearance in creeping bentgrass ('Independence'). The photo was taken three days after the previous cut, and illustrates the impact of N availability on leaf growth, leaf colour and leaf morphology.

Growth of shoots and roots

The amount of clippings was strongly and positively correlated to the rate of nitrogen supply (Figure 1). Annual bluegrass and the creeping bentgrasses grow approximately twice as fast as the fescues and about 30 percent faster than velvet- and colonial bentgrass under non-limiting nitrogen conditions (200 mg N liter^{-1}, Table 1).

Root growth, in absolute terms, increased slightly in response to nitrogen supply. However, at non-limiting N-conditions (200 mg N liter^{-1}) root growth was suppressed particularly in the bentgrasses. The data for annual bluegrass deviates strongly from the other species since a well-developed root system was present already at start of the experiment. Thus, a true quantification of the root production during the experimental period was not possible.

Table 1. Ranking* between the grasses regarding growth capacity, and hence nitrogen demand, at non-limiting N-conditions. 'Independence' instead of annual bluegrass has been chosen as reference due to the less strict control in the cultivation of the latter species.

Species/variety	**Ranking**
Poa annua, 'Ullna'	1.12
Agrostis stoloniera, 'Independence'	1
Agrostis stolonifera, 'Nordlys'	0.92
Agrostis capillaris, 'Barking'	0.72
Agrostis canina, 'Legendary'	0.71
Festuca rubra, 'Center'	0.55
Festuca rubra, 'Cezanne'	0.33

**Dry weight of clippings in relation to 'Independence' during the last three weeks of the experiment.*

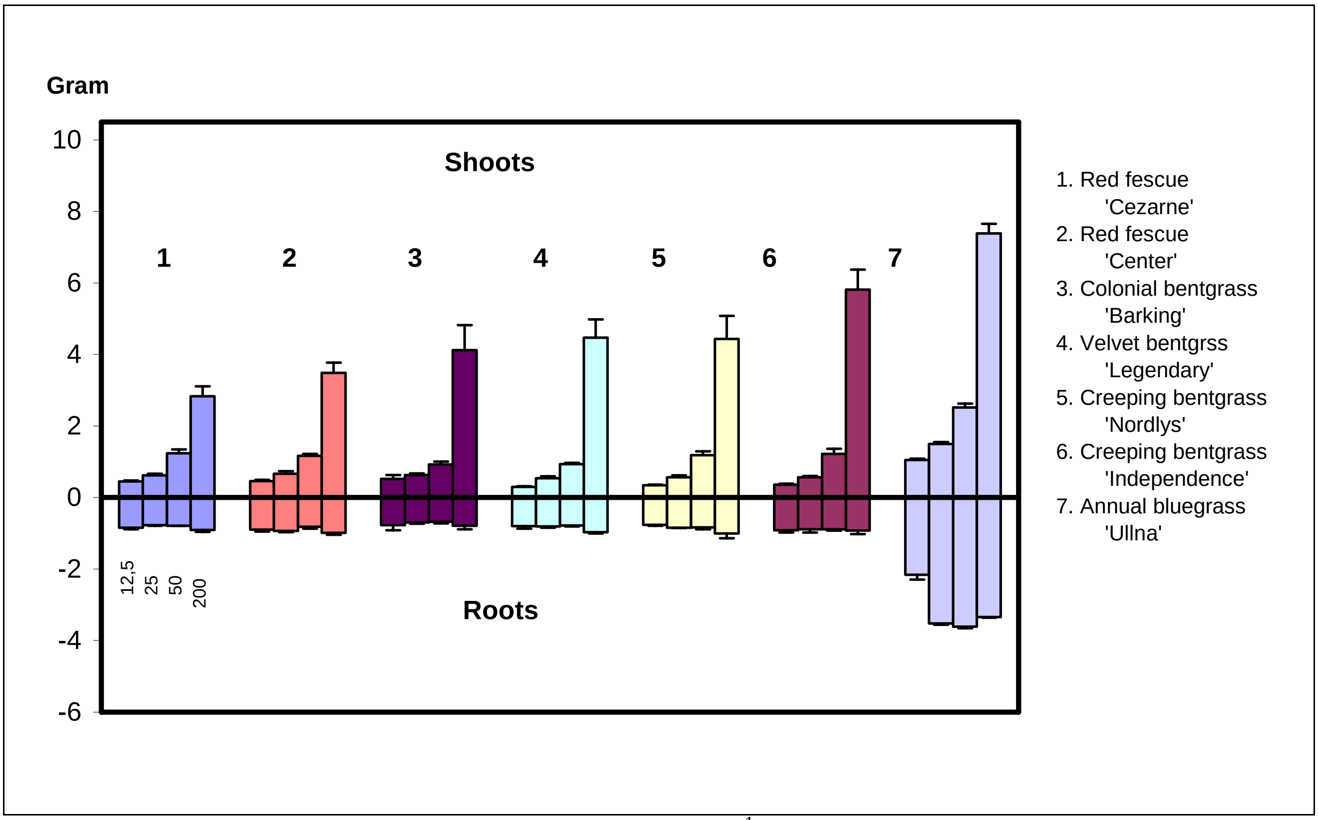


Figure 1. Influence of nitrogen supply, 12.5 – 200 mg N liter^{-1}, on the amount of total grass clippings (dry weight pot^{-1}) removed during three weeks and associated root mass.

On a relative basis root growth was favoured when the supply of N was decreased (Figure 2). The fraction of total plant biomass consisting of roots varied between 40 and 90 % under high (200 mg N liter^{-1}) and low (12.5 mg N liter^{-1}) N-supply, respectively.

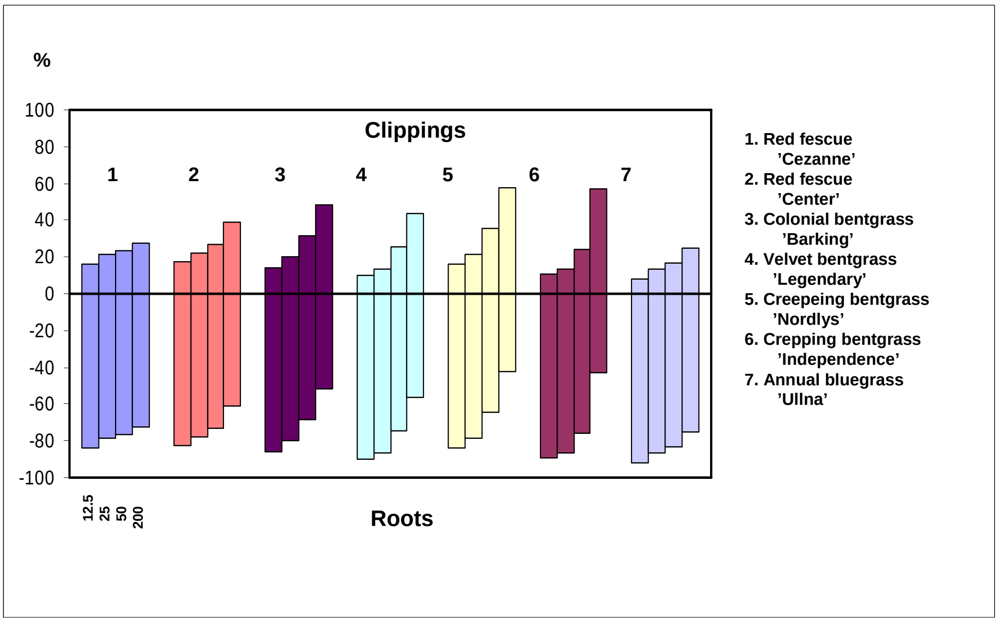


Figure 2. Partitioning of mass between roots and clippings, in percent of total plant mass, in response to nitrogen supply, 12.5 – 200 mg N liter^{-1} in the irrigation water. The turf was cut twice per week at a height of 5 mm.

Cutting the grass twice per week had a strong impact on shoot production. Approximately 10 times more above-ground biomass was produced, independently of N-regime, in the uncut treatment (Figure 3), than when the turf was cut twice per week (Figure 1). Interestingly, the root biomass at the end of the experiment was very similar in all species irrespective of nitrogen regime or whether the turf was cut or not (cf. Figure 1 and 3, photo 2).

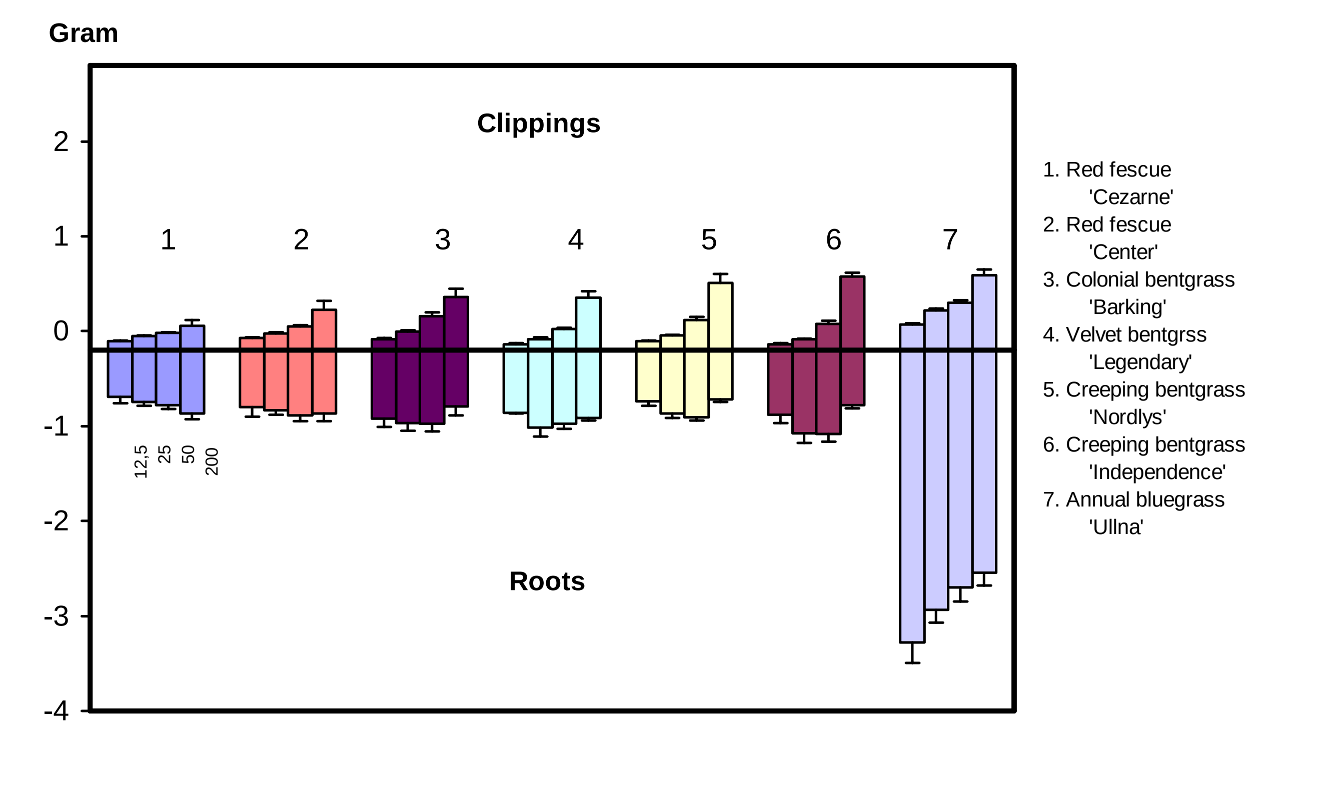


Figure 3. Influence of nitrogen supply, 12.5 – 200 mg N liter^{-1}, on root and shoot growth during four weeks (dry weight pot^{-1}) of turf grasses when uncut.

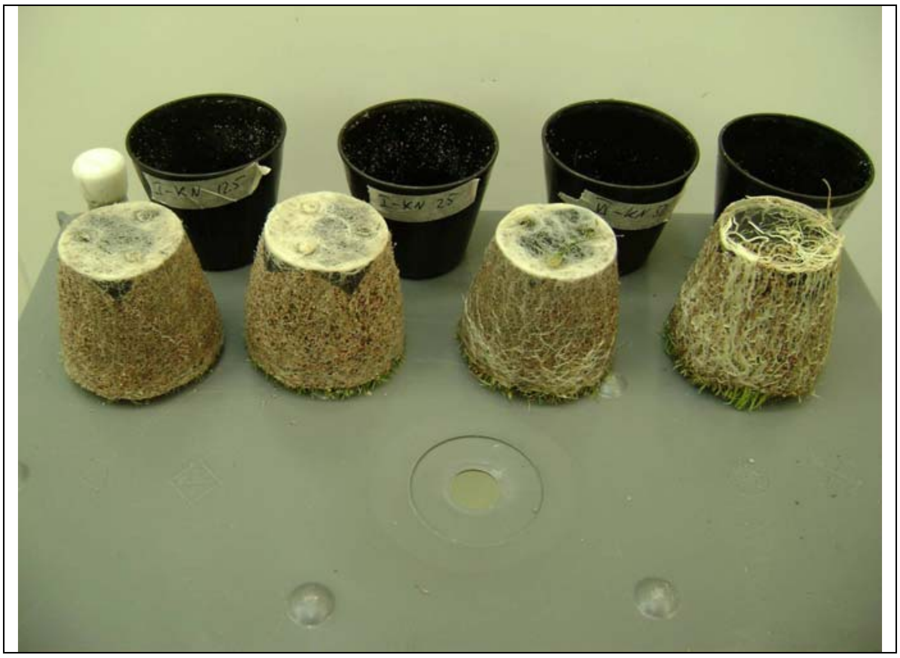


Photo 2. Root development and morphology in creeping bentgrass ('Nordlys') in response to nitrogen availability. From left to right, 12.5, 25, 50 and 200 mg N liter^{-1}

N-status versus growth

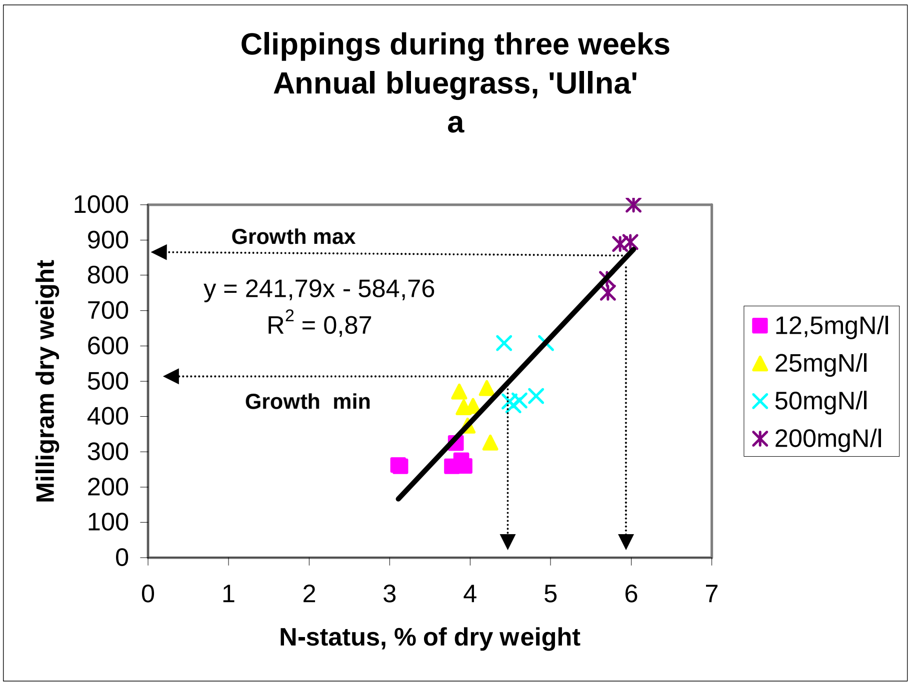
The lowest nitrogen concentration (N_{min}) in the clippings (data from the 25 and 50 mg nitrogen liter^{-1} treatments) associated with a fresh green leaf colour was approximately 3 percent on a dry weight basis for all studied species except annual bluegrass. For this species a tissue nitrogen concentration in the order of 4 % was required for a healthy looking turf (Table 2, Figure 4 a-g).

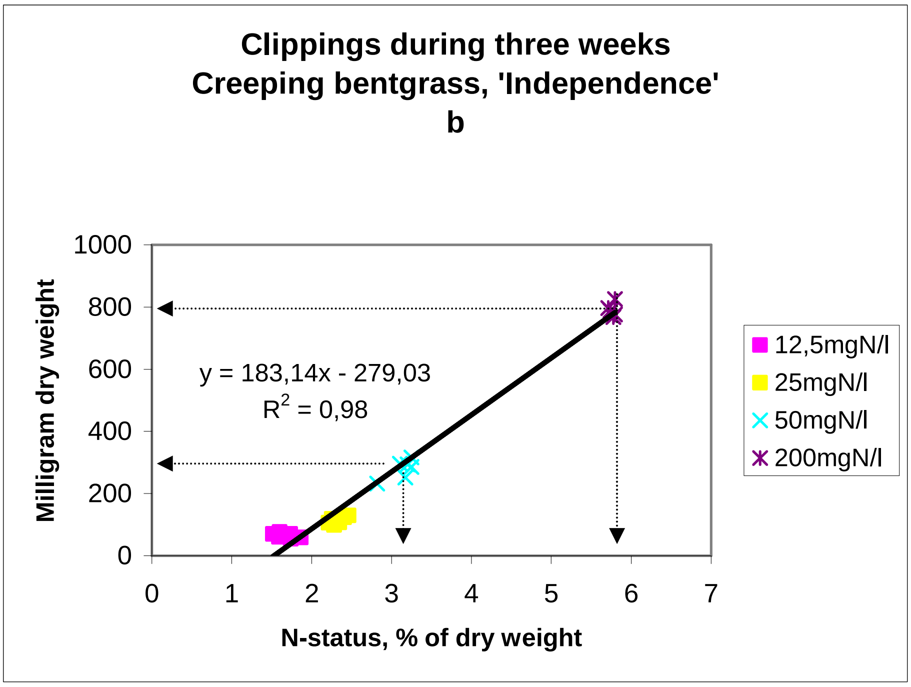
The leaf nitrogen concentration associated with non-limiting nitrogen conditions (N_{max}) ranged from 5 to 6 percent on a dry weight basis and was positively correlated to the growth potential of the species (Table 2, Figure 4 a-g). Velvet bentgrass deviated from this pattern by showing the highest N-concentration despite ranking number 5 with regard to growth. The unexpected high tissue-N content for this species was probably a result of 'luxury' N-uptake.

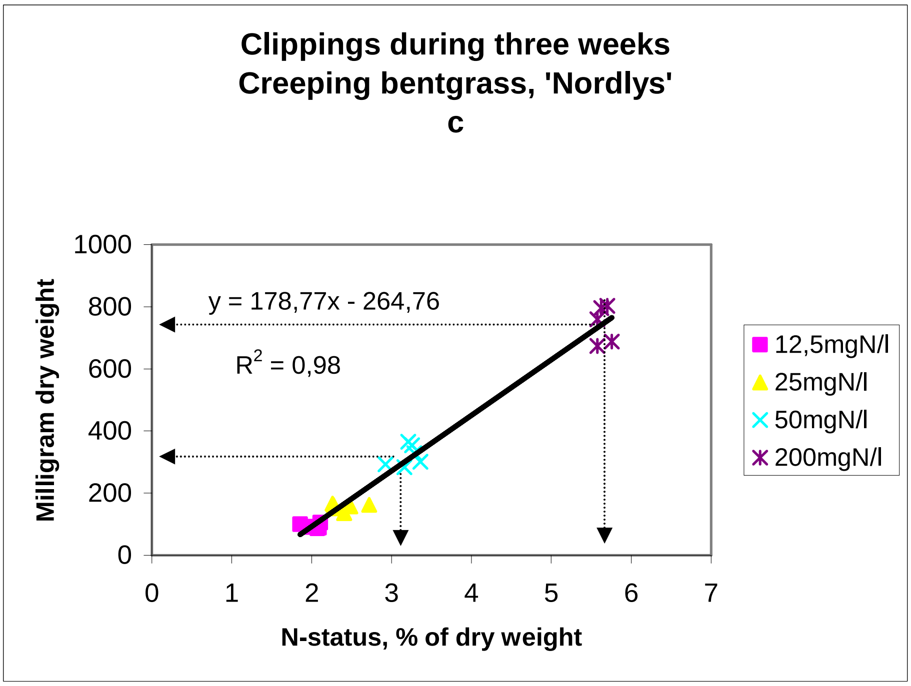
Tabel 2. Nitrogen concentration, % of dry weight, in clippings produced under limiting- (Nmin) and non-limiting nitrogen (N_{max}) conditions.

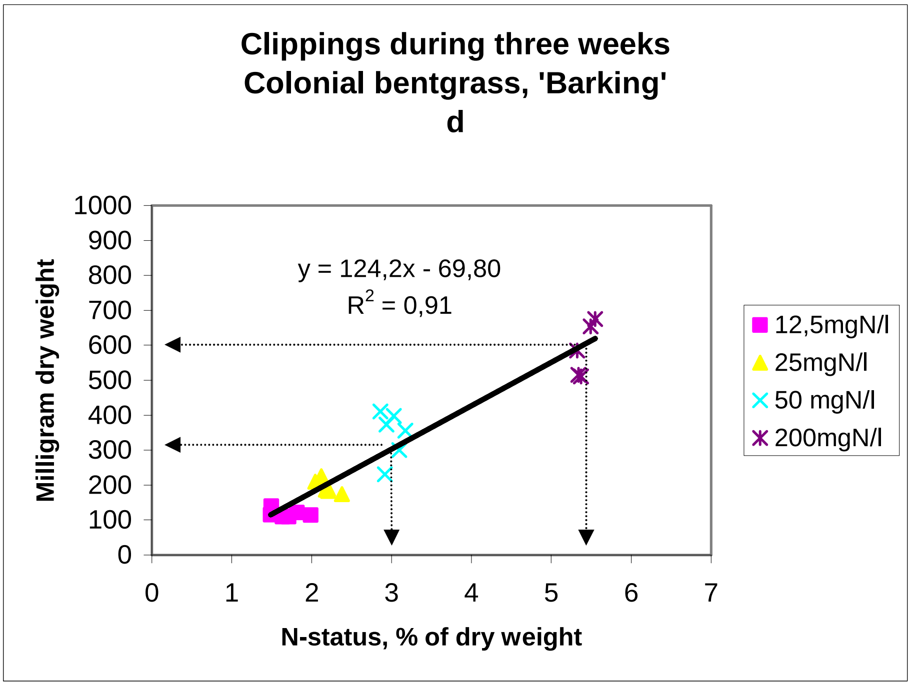
Species/variety	N_{min}	N_{max}
Poa annua 'Ullna'	4,6±0,19	5,9±0,15
Agrostis stolonifera 'Independence'	3,1±0,15	5,8±0,04
Agrostis stolonifera 'Nordlys'	3,2±0,14	5,6±0,08
Agrostis capillaris 'Barking'	3,0±0,11	5,4±0,10
Agrostis canina 'Legendary'	3,2±0,19	6,0±0,16
Festuca rubra 'Center'	3,2±0,12	5,1±0,10
Festuca rubra 'Cezanne'	3,5±0,11	5,0±0,08

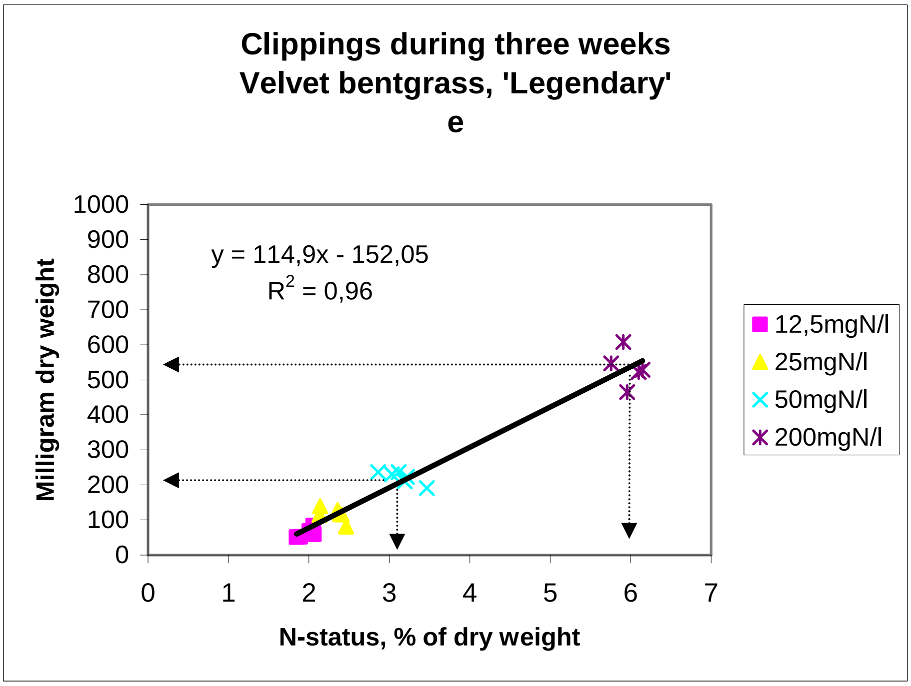
Figure 4a-b. Relationship between nitrogen concentration in clippings and clipping production during three weeks in seven turf grass species. The test plants were exposed to four nitrogen regimes by varying the nitrogen concentration in the irrigation water from 12.5 to 200 mg N liter^{-1}. Arrows indicate the leaf nitrogen concentration and associated growth rate at growth minimum (no pronounced deficiency symptoms) and at growth maximum.

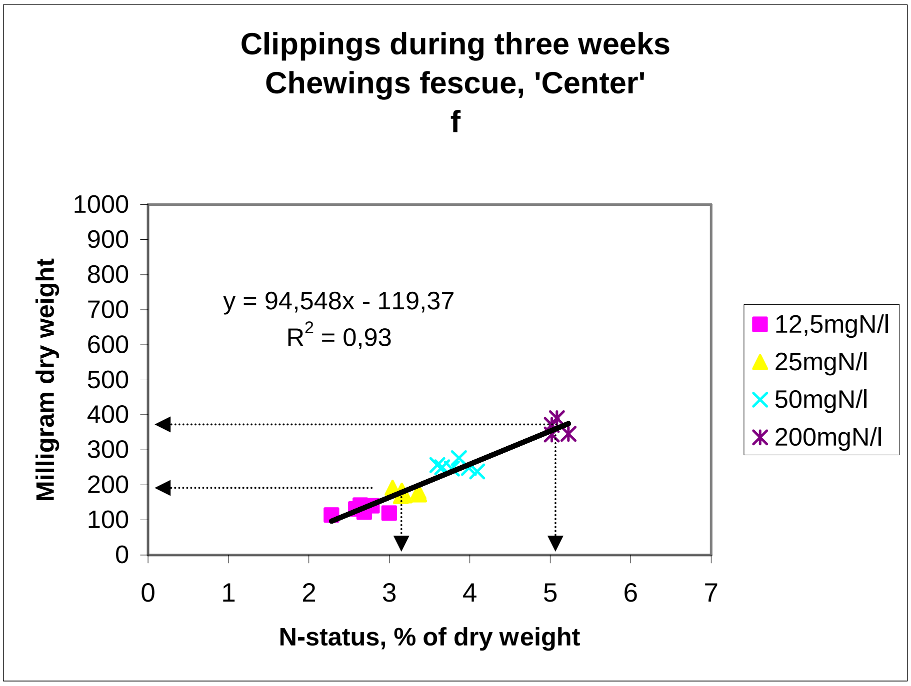


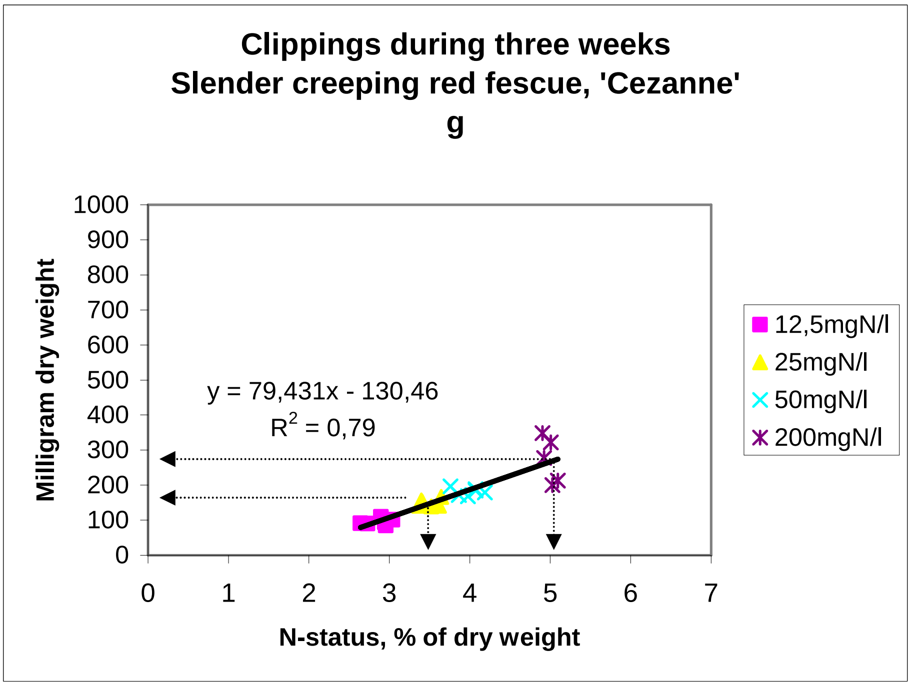

Clippings during three weeks
Creeping bentgrass, 'Independence'
b
Milligram dry weight
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
N-status, % of dry weight
y = 183,14x - 279,03
R2 = 0,98
12,5mgN/l
25mgN/l
50mgN/l
200mgN/l


Clippings during three weeks
Creeping bentgrass, 'Nordlys'
c
Milligram dry weight
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
N-status, % of dry weight
y = 178,77x - 264,76
R2 = 0,98
12,5mgN/l
25mgN/l
50mgN/l
200mgN/l


Clippings during three weeks
Colonial bentgrass, 'Barking'
d
y = 124,2x - 69,80
R2 = 0,91
Milligram dry weight
N-status, % of dry weight
12,5mgN/l
25mgN/l
50 mgN/l
200mgN/l


Clippings during three weeks
Velvet bentgrass, 'Legendary'
e
y = 114,9x - 152,05
R2 = 0,96
Milligram dry weight
N-status, % of dry weight
12,5mgN/l
25mgN/l
50mgN/l
200mgN/l





Nitrogen productivity

The slope of the linear relationship between leaf nitrogen concentration and growth in Figure 4a-b represents the nitrogen productivity of the species under the given growth conditions, i.e. the ability to growth per unit nitrogen in the leaves (cf. Ågren 1985, Ingestad 1988). Fast growing species are generally the most productive ones. This was also the case in this study (Figure 5). For annual bluegrass this relationship was unexpectedly steep with an intersection to the x-axis of 2.5 percent N. This indicates that this species required a higher tissue N-concentration in the leaves, probably N associated with the photosynthetic apparatus, to be able to meet the carbohydrate demand from non-photosynthesising tissues. This was particularly the case at strong nitrogen limitation (treatment 12.5 and 25 mg N liter^{-1}). In comparison to the other studied turf grasses leaves of annual bluegrass had to support a significantly lager root fraction already from the very start of the experiment (cf. Figure 1).

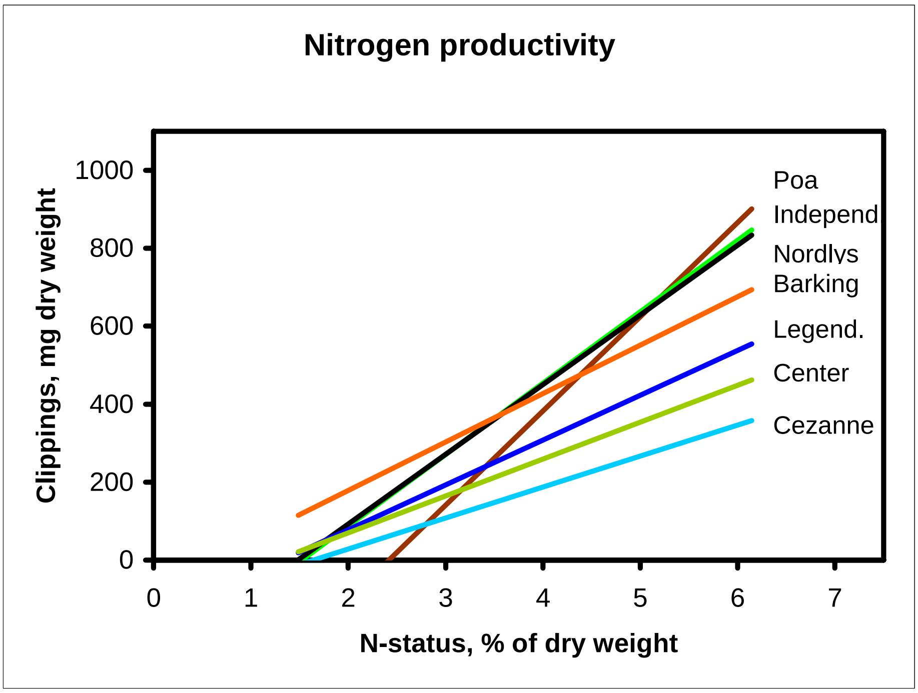


Figure 5. A comparison of the nitrogen growth relationship in seven turf grass species.

Influence of cutting on nitrogen productivity
Reduction of the leaf area through cutting had a strong negative impact on the nitrogen productivity. This phenomenon is exemplified for creeping bentgrass ‘Independence’ in Figure 6. Twice as much leaf mass is being produced per unit of time and nitrogen in the leaves at a leaf nitrogen concentration of 3 percent of dry weight, when the grass is left uncut as compared to plants cut twice per week at a height of 5 mm. This indicates that a golf green becomes more nutrient demanding when the cutting height of the turf is reduced in order to, for example, promote ball roll. The minimum leaf nitrogen concentration required for a fresh green turf is also reduced when the grass is left uncut. In this study, a nitrogen concentration of 2 % was adequate in intact grass plants as compared to 3 % when the turf was cut twice per week (Photo 3).

A leaf nitrogen concentration of approximately 4 % in uncut turf (‘Independence’) indicates that the nitrogen demand at non limiting N-conditions was not met by 200 mg N liter^{-1} in the irrigation water. The relatively small substrate volume in combination with a low water holding capacity of the sand may offer a plausible explanation to the imbalance between N-supply and N-demand in this treatment. No major change in the leaf nitrogen concentration at growth maximum is to be expected regardless type of growth restraint (light, temperature, water, CO_2) according to Ingestad and co-workers (Ingestad & McDonald, 1989, Pettersson et al. 1993).

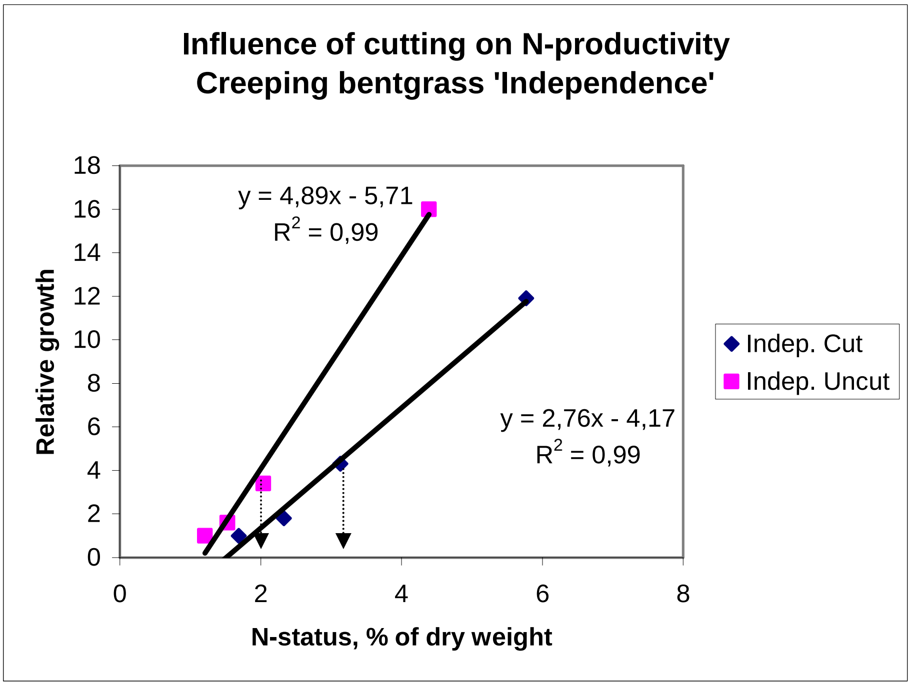


Figure 6. Influence of cutting on nitrogen productivity, i.e. the slope of the linear relationship between leaf nitrogen concentration and growth rate. Growth rate is expressed on a relative basis (growth at 25, 50 and 200 mg N liter^{-1} in relation to growth at 12.5 mg N liter^{-1}) in order to facilitate the comparison between cut and uncut turf. Arrows indicate the lowest tissue-N concentration associated with a fresh green colour of the turf.

Photo 3. Shoot development in creeping bentgrass ('Independence') in response to nitrogen availability. From left to right, 12.5, 25, 50 and 200 mg N liter^{-1}.

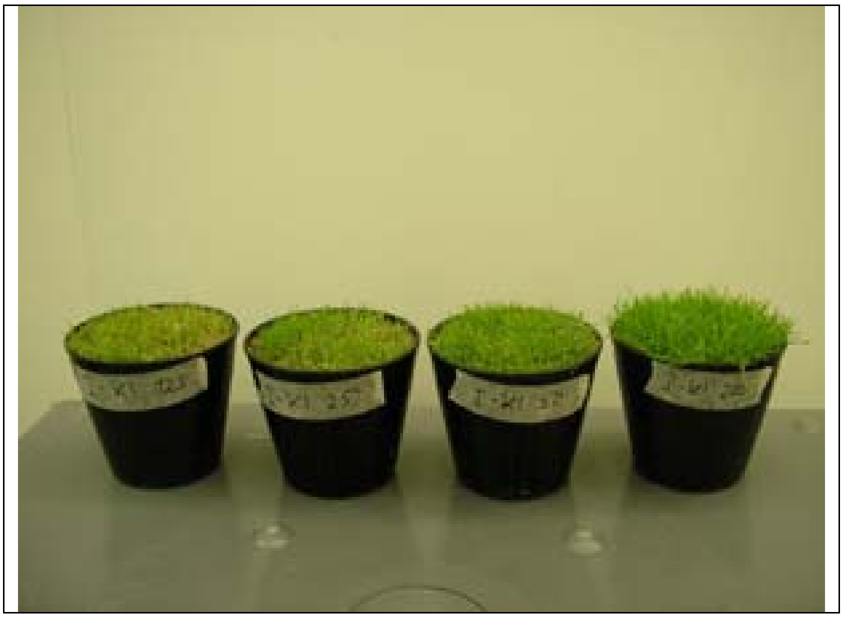


Photo 4. Shoot development in creeping bentgrass (‘Independence’) in response to nitrogen availability and cutting. From left to right, 12.5, 25, 50 and 200 mg N liter^{-1}.

Nitrogen requirement

The nitrogen requirement of the grasses in relative terms followed the ranking in growth since growth and nitrogen uptake are closely linked processes. The absolute N requirement under field conditions, however, depends on several site specific factors (climate, length of growing season, soil conditions, age of the green etc. The ongoing projects in Västerås (‘*Optimal maintenance for hardening and early spring growth of turfgrass for putting greens’*) and Landvik (‘*Fertilizer stategies for golf turf: Implications for physiological driven fertilization’*) make it possible to check whether a leaf-N concentration in the order of 3 % on dry weight basis is required for a well functioning green independent of grass species. The trial in Landvik will also facilitate the transformation of the laboratory data to recommendations in kg of nitrogen per 100 m^2 and year for the most commonly used grass species. Previous experiences with regard to the nitrogen requirement of creeping bentgrass from the project ‘Effects of demand-driven fertilization on growth, appearance and nitrogen use efficiency of turfgrass’ (Ericsson, 2005), is used in conjunction with the ranking data in this study in order to construct the species specific fertilizer programmes tested in Landvik.

References:

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