The effect of the *Agroblen* fertilizer on Norway spruce seedling growth

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Photos and illustrations: The author, if not stated otherwise.

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Errata list

The following tables have been changed to the text marked in red.

Table 4. *Average seedling height at planting time (May 15) and seedling height and length of leading shoot after one, two and three growing seasons (Oct 15, Oct 15 and Oct 17). Different letters show significant differences at the 0.05 level.*

Formula ID	Longevity	Rate	Height, cm				Length of leading shoot, cm		
			May 15	Oct 15	Oct 16	Oct 17	Oct 15	Oct 16	Oct 17
Control			30[a]	35[a]	43[a]	64[a]	5[a]	9[a]	21[a]
1	5-6M	20	33[a]	42[b]	60[b]	83[b]	10[b]	19[bc]	20[a]
1	5-6M	30	33[a]	42[b]	59[b]	81[b]	9[b]	18[bc]	23[a]
1	8-9M	20	32[a]	41[b]	56[b]	77[b]	9[b]	17[bc]	20[a]
1	8-9M	30	32[a]	42[b]	61[b]	88[b]	10[b]	21[c]	26[a]
2	5-6M	20	32[a]	42[b]	58[b]	81[b]	11[b]	18[bc]	23[a]
2	5-6M	30	32[a]	41[b]	55[b]	79[b]	10[b]	15[ab]	24[a]

Table 5. *Average root collar diameter at planting time (May 15) and after one, two and three growing seasons (Oct 15, Oct 15 and Oct 17). Different letters show significant differences at the 0.05 level.*

Formula ID	Longevity	Rate	Root collar diameter, mm			
			May 15	Oct 15	Oct 16	Oct 17
Control			4.4[a]	4.9[a]	7.9[a]	11.6[a]
1	5-6M	20	4.6[a]	6.6[b]	10.8[b]	15.7[b]
1	5-6M	30	4.5[a]	6.6[b]	10.7[b]	15.2[b]
1	8-9M	20	4.6[a]	6.4[b]	10.4[b]	14.4[b]
1	8-9M	30	4.4[a]	6.6[b]	11.4[b]	16.6[b]
2	5-6M	20	4.6[a]	6.5[b]	10.5[b]	15.3[b]
2	5-6M	30	4.5[a]	6.6 [b]	10.4[b]	15.0[b]

Table 6*. Seedling height, root collar diameter and browsing damage, divided on each of the three sites included in the trial; Borsaskögle (1), Ösjöbol (2) and Kosta (3). Seedling height and root collar diameter were measured in October 2017 and the browsing damage was assessed in October 2016 (percentage of seedlings having any kind of browsing damage, most of them classified as slightly damaged).*

Formula ID	Long-evity	Rate	Height 2017, cm			Diameter 2017, mm			Browsing damage 2016, %		
			Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Control			56	69	66	10,0	12,7	12,0	0	0	10
1	5-6M	20	76	83	90	13,7	17,1	16,2	0	0	18
1	5-6M	30	77	89	77	13,9	17,9	14,0	2	0	22
1	8-9M	20	70	82	80	13,0	16,2	14,2	2	0	20
1	8-9M	30	81	922	90	15,2	18,1	16,3	0	0	23
2	5-6M	20	75	79	91	14,5	15,8	15,7	0	3	28
2	5-6M	30	79	80	78	15,2	16,0	13,8	3	0	16

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Summary

The Agroblen fertilizer contains encapsulated NPK and provides the seedling with the nutrients it needs during the first year of establishment. In this trial we tested two different formulas of long lasting release, two different doses and two different proportions of nitrogen, phosphorous and potassium; 9-20-8 and 15-9-11 as oxides (9-8.7-6.6 and 15-3.9-9.1 in elements). The longevity of the formulations tested were 5-6M and 8-9M (claimed at 21 °C), which under south Swedish climate conditions would last for 8 months (5-6M) and 12 months (8-9M), respectively. The fertilized seedlings were compared to unfertilized control seedlings, as being the standard practice in Swedish forestry. Containerized seedlings of Norway spruce (*Picea abies* [L.] Karst.) were planted on fresh clear-cuttings at three different sites in south Sweden in May 2015. Assessments were conducted during three years, the last one in October 2017. The seedlings were treated with an insecticide against damage by pine weevil and with a repellent against browsing from roe deer and elk.

All treatments resulted in significant higher growth. Both height and root collar diameter were significantly larger for fertilized seedlings compared to untreated seedlings during the three years. The leading shoots were significantly longer on fertilized seedlings during the first two years, the third year no differences were found compared to the control. There were no significant differences between any of the fertilizing treatments during the period the trial was monitored, concerning height and root collar diameter growth.

Mortality was low in the experiment regardless of treatment. In average less than 5 % of the seedlings died. The main cause for mortality was damage by pine weevil, damage caused by animals pulling up the seedlings or damage classified as unknown.

After two years the root collar diameter for the fertilized seedlings had reached in average more than 10 mm, while for untreated seedlings it took another year to reach the same size. A large root collar diameter is very important for the seedling's ability to withstand damage by pine weevils and is one of the most interesting findings in this experiment.

Keywords: Agroblen, fertilizer, Norway spruce, planting, seedlings

Sammanfattning

Gödselmedlet Agroblen innehåller inkapslad NPK och ger plantan de näringsämnen den behöver under första etableringsåret. I detta försök testades två formuleringar med olika långtidsverkan, två olika doser och två olika proportioner av kväve, fosfor och kalium (9-20-8 och 15 -9-11). Tidsperioden för långtidsverkan hos de testade formuleringarna var 5-6M respektive 8-9M (beräknade vid 21 °C). Verkningstiderna för dessa bör för klimatförhållandena i södra Sverige ligga på 8 (5-6M) respektive 12 månader (8-9M). De gödslade plantorna jämfördes med ogödslade kontrollplantor, vilket är det som normalt används i svenskt skogsbruk. Täckrotsplantor av gran (*Picea abies* [L.] Karst.) plantades på färskt hygge på tre olika platser i södra Sverige i maj 2015. Plantmätningar genomfördes under tre år, den sista i oktober 2017. Plantorna behandlades med en insekticid mot skador av snytbagge och med ett viltskyddsmedel för att förhindra bete av älg och rådjur.

Alla behandlingar med gödsling resulterade i signifikant högre höjd och större rothalsdiameter jämfört med ogödslade plantor, under de tre åren. Toppskotten var signifikant längre för gödslade plantor under de första två åren, men det tredje året fanns inga skillnader jämfört med kontrollen. Inga signifikanta skillnader kunde påvisas mellan de olika behandlingarna med gödsling, doser och långtidsverkan, under de tre år som försöket mättes.

Dödligheten var låg i experimentet oavsett behandling. I genomsnitt dog mindre än 5 % av plantorna. Den främsta orsaken till avgångar var skador av snytbagge, skador orsakade av djur som drog upp plantorna eller skador som klassificerades som okända.

Efter två år var rothalsdiametern för de gödslade plantorna i genomsnitt mer än 10 mm. För obehandlade plantor tog det ytterligare ett år för att nå samma storlek. Rothalsdiameterns storlek är av stor betydelse för plantans förmåga att klara skador av snytbagge och är ett av de mest intressanta resultaten av detta försök.

Nyckelord: Agroblen, gran, gödsling, plantering, plantor

Introduction

Fertilization of forest plants occurs in a number of countries, in the EU mainly to spruce in the UK and Ireland (Miller 1998) and to eucalyptus in Spain and Portugal (Pereira et al. 1989). In Sweden fertilizing of young seedlings in the forest is rare and the Asa Research Station at the Swedish University of Agricultural Sciences was given an assignment by the company ICL Specialty Fertilizers (Geldermalsen, The Netherlands) to conduct an experiment in order to test different doses of the fertilizer Agroblen, applied to Norway spruce (*Picea abies* [L.] Karst.) seedlings planted on forest land in southern Sweden.

Agroblen contains encapsulated NPK and provides the seedling with the nutrients it needs during the first year of establishment. After Agroblen is applied to the soil, moisture penetrates the capsule, dissolves the nutrients and triggers their gradual release. Different doses as well as different long-lasting effect of the fertilizer could be chosen. The release time is based on a 21 °C soil temperature, which means that the release period is considerably longer under Swedish soil temperature conditions. Since the release is controlled by soil moisture and temperature, no release occurs during the winter, when the plant is not active.

The aim of the trial was to enhance growth of height and root collar diameter, during the establishment phase. A vital, well-growing seedling is also able to better withstand different situations of stress that might occur in the field during the first years. The seedling will reach a size where it becomes less vulnerable to damage caused by pine weevil (*Hylobius abietis* L.) and browsing animals faster.

Material and methods

Experimental sites

The experiment was established at three sites in the south-central part of Sweden (within 50 km of the Asa Research Station; 57° 10′N, 14°47 E′) in 2015 (Table 1). The sites were representative of relatively poor forest sites with a potential growth around 5–8 m^3 ha^{-1} $year^{-1}$, with the original stands dominated by Scots pine (*Pinus sylvestris* L.) or Norway spruce.

Harvesting took place during the winter 2014/2015. During felling, harvesting residues were left in piles, which were removed by forwarders during early spring. Site preparation was performed using disc trenching.

The sites were chosen to reflect some variation in vegetation type and fertility, to be able to study if the effect of the fertilizer varied between the three sites.

Table 1. *Name of sites, site index (SI)[a] and vegetation types*

Site	Name	SI	Vegetation type
1	Borsaskögle	T24	*Vaccinium myrtillus*
2	Össjöbol	G26	*Deschampsia flexuosa*
3	Kosta	T24	*Vaccinium myrtillus*

[a] Hägglund and Lundmark, 1977

Weather conditions during the first year

Weather data for the first year of the experiment, 2015, was provided by the weather station at the Asa Research Station (Figure 1, Ottosson Löfvenius 2016).

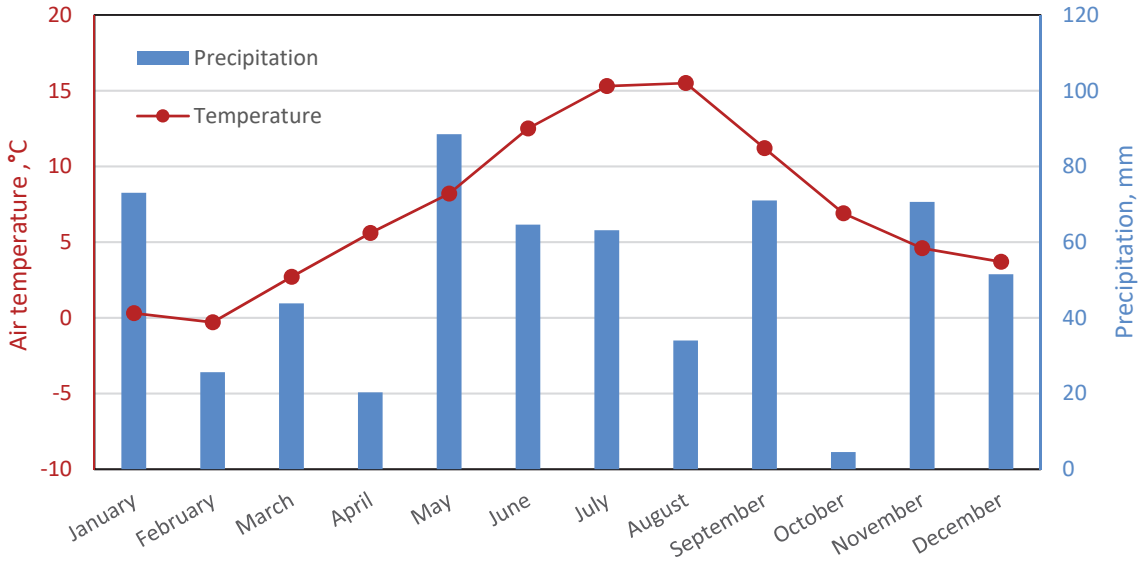

Figure 1. Climograph of weather conditions in Asa during the first year, 2015.

The average temperature in May-September varied between 8.2 °C and 15.5 °C, with the highest temperature in July and August. The precipitation was lowest in April, August and October. The vegetation period (threshold temperature +5 °C) started April 7 and ended November 19, lasting 227 days. The temperature was higher than +20 °C for 273 hours and colder than 0 °C for 135 hours during the vegetation period. These figures might not be exactly the same on the actual sites for the experiment, but the information is a guideline to the weather in the area during 2015.

At each site, a LogTag® Trix-8 temperature datalogger (LogTag Recorders Ltd, Auckland, New Zeeland) was placed in the mineral soil in the scarified row between two seedlings, at a level comparable with the planting hole, i.e. at a depth of approximately 10–15 cm. The average soil temperature for the first two years are shown in table 2.

Table 2. *Average soil temperature for the first two years, the results are shown as monthly average for two years*

Month	Temperature
January	0.79
February	1.14
March	2.27
April	5.85
May	10.97
June	13.86
July	15.82
August	15.21
September	12.73
October	7.76
November	5.53
December	3.76
Two year average	**7.97**

Seedling material

The seedlings were provided by the nursery Södra Odlarna, Falkenberg, Sweden and seeds originated from the Bredinge seed orchard. Seedlings were grown for two years in HIKO® containers with a volume of 90 cm^3 and with 40 pots per container. The insecticide used, Merit Forest WG, was applied to the lower part (approx. up to 10 cm above ground) of the seedlings before planting, at the concentration recommended by the manufacturer (14 g of the granulated material per liter of water). The seedlings were again treated with the insecticide Merit Forest in April 2016 and 2017. All seedlings were also treated with the deer-browsing repellent TRICO in October every year.

Experimental design

On each site, three blocks were randomly distributed, in order to reduce any variation regarding topography and soil moisture within each block. Within each block, 20 seedlings from each of 7 treatments (Table 3) were planted in separate scarified rows. Distance between seedlings in a row was approximately 2 m. On each site, 20 seedlings × 7 treatments × 3 blocks were planted = 420 seedlings.

All together 1 260 seedlings were planted in the trial. In addition to planting, the appropriate amount of fertilizer was measured and put into the planting hole before planting the seedling. The planting pipe PottiPottki was used for planting.

Treatments

The Agroblen fertilizer contains encapsulated NPK and provides the seedling with the nutrients it needs during the first year of establishment. In this trial we tested two different formulas of long lasting release (5-6M and 8-9M), two different doses (20 and 30 g) and two different proportions of nitrogen, phosphorous, potassium, magnesium and boron (9-20-8 + 3MgO + 0.1B and 15-9-11 + 3MgO). The formulas are declared in oxides, so the proportions 9-20-8 in elements is; 9 % N, 8.7 % P, 6.6 % K + 1.8 % Mg + 0.1 % B. Additionally, the proportions 15-9-11 are 15 % N, 3.9 % P, 9.1 % K + 1.8 % Mg in elements. Values are expressed in percent of total weight of the product. The longevity of the formulations tested were 5-6M and 8-9M (claimed at 21 °C), which under south Swedish climate conditions would last for 8 months (5-6M) and 12 months (8-9M), respectively.

Assessments

Immediately after planting, an assessment was performed, where the root collar diameter (mm with one decimal) and height (cm) was recorded individually for all seedlings. At the end of the growing season of the three years 2015, 2016 and 2017, an assessment where the root collar diameter, height and length of the leading shoot was measured on each seedling, was performed.

The severity of damage was recorded subjectively using a six-level index: 0 = undamaged, 1 = uncertain or insignificant damage, 2 = slightly damaged, 3 = severe damage, 4 = life-threatening damage, and 5 = dead.

The green color of the seedlings was estimated on a 7-grade index with 1 being the lightest green and 7 being the darkest green color and most vital condition (Bergquist and Örlander 1998).

Table 3. *The different treatments used in the experiment, one untreated control and six treatments with different combinations of fertilizer formula, longevity (based on 21 °C soil temperature) and doses*

Treatment	Formula ID	Formula	Longevitys	Rate, g/tree
1	Control			
2	1	NPK (9-20-8) and MgO+B)	5-6M	20
3	1	NPK (9-20-8) and MgO+B)	5-6M	30
4	1	NPK (9-20-8) and MgO+B)	8-9M	20
5	1	NPK (9-20-8) and MgO+B)	8-9M	30
6	2	NPK (15-9-11 and MgO)	5-6M	20
7	2	NPK (15-9-11 and MgO)	5-6M	30

Statistical analyses

SAS software (SAS Institute, Cary, NC, USA) was used for all data analyses. Mean values were calculated for each block and treatment and used as input data in the analyses. The experiment was treated as a randomized block design with block as random factor, using (PROC MIXED SAS). When significant differences were identified ($p<0.05$), Tukey's test was used to separate effects of individual factors.

Results

Height

At the time of planting there were no significant differences in height between treatments. In average the seedlings were 32 cm high (Table 4).

After one growing season the control seedlings, with no applied fertilizer, were significantly smaller than seedlings from all other treatments. After two and three years the control seedlings were still smallest, all other treatments resulted in significantly higher growth, but no difference between the fertilizing treatments were found during the years the experiment was performed.

Length of leading shoot

The first growing season, the control seedlings had significantly shorter leading shoots, in average 5 cm, while seedlings treated with fertilizer had in average 10 cm long shoots (Table 4). After two years the leading shoots of the control seedlings were still shortest but not statistically separated from seedlings treated with the CRF-coated NPK formula 15-9-11+MgO at a release rate 5-6M and dose 30 gram per tree (9 cm and 15 cm, respectively). All other treatments resulted in significantly longer shoots but there were no significant differences found between these treatments.

After the third growing season, the length of the leading shoots were not significantly different for any treatment, including the control (Table 4). In order to avoid the influence of the mean height of seedlings where the leading shoot was damaged, we also made calculations where these were removed. However there were still no significant differences on the length of the leading shoot after three years.

No interactions were found between site and treatments.

Table 4. *Average seedling height at planting time (May 15) and seedling height and length of leading shoot after one, two and three growing seasons (Oct 15, Oct 15 and Oct 17). Different letters show significant differences at the 0.05 level.*

Formula ID	Longevity	Rate	Height, cm				Length of leading shoot, cm		
			May 15	Oct 15	Oct 16	Oct 17	Oct 15	Oct 16	Oct 17
Control			30^{a}	35^{a}	43a	64^{a}	5^{a}	9^{a}	21^{a}
1	5-6M	20	33^{a}	42^{b}	60^{b}	83^{b}	10^{b}	19^{bc}	20^{a}
1	5-6M	30	33^{a}	42^{b}	59^{b}	81^{b}	9^{b}	18^{bc}	23^{a}
1	8-9M	20	32^{a}	41^{b}	56^{b}	77^{b}	9^{b}	17^{bc}	20^{a}
1	8-9M	30	32^{a}	42^{b}	61^{b}	88^{b}	10^{b}	21^{c}	26^{a}
2	5-6M	20	32^{a}	42^{b}	58^{b}	81^{b}	11^{b}	18^{bc}	23^{a}
2	5-6M	30	32^{a}	41^{b}	55^{b}	79^{b}	10^{b}	15^{ab}	24^{a}

Table 5. *Average root collar diameter at planting time (May 15) and after one, two and three growing seasons (Oct 15, Oct 15 and Oct 17). Different letters show significant differences at the 0.05 level.*

Formula ID	Longevity	Rate	Height, cm			
			May 15	Oct 15	Oct 16	Oct 17
Control			4.4[a]	4.9[a]	7.9[a]	11.6[a]
1	5-6M	20	4.6[a]	6.6[b]	10.8[b]	15.7[b]
1	5-6M	30	4.5[a]	6.6[b]	10.7[b]	15.2[b]
1	8-9M	20	4.6[a]	6.4[b]	10.4b	14.4[b]
1	8-9M	30	4.4[a]	6.6[b]	11.4[b]	16.6[b]
2	5-6M	20	4.6[a]	6.5[b]	10.5[b]	15.3[b]
2	5-6M	30	4.5[a]	6.6 [b]	10.4[b]	15.0[b]

Root collar diameter

Root collar diameter was in average the same at the time of planting, 4.5 mm, for seedlings in all treatments (Table 5). After one growing season, the fertilized seedlings had significantly larger root collar diameter, compared to control seedlings. This pattern continued the second and third growing season but no difference could be found between the different fertilized treatments. After two years the root collar diameter for the fertilized seedlings had reached in average more than 10 mm, while for untreated seedlings it took another year to reach the same size.

Green color

After the first season, the seedlings treated with some kind of fertilizer showed a darker green color, compared to the control seedlings, in average index 4.5 for fertilized seedlings compared to index 3.7 for untreated ones. After two and three growing seasons no difference between any treatment, including control seedlings, could be found. In average the color was estimated to index 4.2 the second year and 4.0 the third.

Mortality

Mortality during the three growing seasons was low, between 2–9 % of the seedlings in the different treatments was affected. The main cause for mortality was damage by pine weevil, damage caused by animals pulling up the seedlings and damage classified as unknown. No effect on mortality by the added fertilizer was found.

Influence of site

The seedlings on all sites responded well to the fertilizing with increased height growth and larger root collar diameter compared to the control seedlings and no interaction between site and treatment were found for these parameters. However, there was a significant difference in the proportion of seedlings damaged by browsing animals, with seedlings on the site Kosta suffering the most (Table 6). No significant difference between control seedlings and fertilized seedlings were found at each site.

Table 6*. Seedling height, root collar diameter and browsing damage, divided on each of the three sites included in the trial; 1. Borsakögle, 2. Ösjöbol and 3. Kosta. Seedling height andd root collar diameter were measured in October 2017 and the browsing damage was assessed in October 2016 (percentage of seedlings having any kind of browsing damage, most of them classified as slightly damaged).*

Formula ID	Long-evity	Rate	Height 2017, cm			Diameter 2017, mm			Browsing damage 2016, %		
			Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Control			56	69	66	10,0	12,7	12,0	0	0	10
1	5-6M	20	76	83	90	13,7	17,1	16,2	0	0	18
1	5-6M	30	77	89	77	13,9	17,9	14,0	2	0	22
1	8-9M	20	70	82	80	13,0	16,2	14,2	2	0	20
1	8-9M	30	81	922	90	15,2	18,1	16,3	0	0	23
2	5-6M	20	75	79	91	14,5	15,8	15,7	0	3	28
2	5-6M	30	79	80	78	15,2	16,0	13,8	3	0	16

Discussion

Seedlings treated with fertilizer were taller and had a larger root collar diameter compared to untreated seedlings during the three years the experiment was measured. No significant differences between fertilizers were found. For the first two years, the leading shoots were significantly longer for the fertilized seedlings, but during the last year the effect of the fertilizer seemed to have ceased.

Diameter growth has shown to be very important for newly planted seedlings because the risk of severe damage to seedlings not only depends on feeding activity, but also on seedling size (Örlander and Nilsson 1999, Thorsén et al. 2001). The vulnerability of seedlings to pine weevil feeding decreases when seedling growth is enhanced. In combination with other silvicultural measures (Petersson and Örlander 2003), fertilizing the seedling with Agroblen might be a valuable tool to reduce the risk of severe pine weevil damage.

The color of the seedling was estimated to indicate the vitality or plant vigor. The first season, fertilized seedlings showed a darker green color, compared to control seedlings. It has been shown that increased plant vitality (as assessed by leader growth and needle color index) lead to more browsing damage, indicating that many herbivores prefer to feed on vigorous plants because they are more nutritious (Bergquist et al. 2003).

In this trial, the seedlings were treated with repellents against browsing to avoid damage but despite this, at one of the sites 10- 28 % of the seedling were registered as damaged by browsing. No significant differences between control seedlings and fertilized seedlings were found at the site. A positive effect of enhanced growth could be that the period of time when the leading shoot is available for herbivores for browsing is shortened.

The treatment with this type of fertilizer showed interesting results and might be a helpful tool in order to increase growth during the establishment phase. In this study no investigations were made on the root growth, to secure that there was a balance between above ground and root biomass. Preliminary results from a pilot trial from 2017 showed that the dry root weight was larger for seedlings fertilized with Agroblen, compared to control seedlings (pers. comm). However that trial was planted on one site only and the results mentioned were received after the first vegetation period so, although it looks promising, we need more data to confirm this result. Also investigating the long term effects of the initial increased growth would be an interesting task for the future.

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