Forest Research

Summary of FR Seed Origin Trials on Norway spruce (*Picea abies* (L.) Karst.)

Gary Kerr and Toni-Kim Clarke

The Research Agency of the Forestry Commission

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Front cover pictures: Norway spruce planted (and regenerating) in a group system at Clocaenog Forest, northeast Wales, where it is an important species for red squirrel conservation.

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Executive summary

Norway spruce (*Picea abies*) is an important forest tree in Britain but fell out of favour when the more productive Sitka spruce (*Picea sitchensis*) became available. More recently the discovery of the European spruce bark beetle (*Ips typographus*) poses a distinct threat to both species. However, with active control of *Ips*, Norway spruce remains a good alternative to Sitka spruce, particularly on drier sites but not on poor, wet and exposed sites where Sitka is the best choice.

The main aims of this report are to: (i) review past work on this subject; (ii) publish results derived from previously unanalysed data and (iii) review published advice on the seed origin variation of Norway spruce (Lines, 1987; Forest Research, 2021). The main findings of the study are:

1. Current advice on the seed origins of Norway spruce is that 'provenances from eastern Europe (e.g., Romania, southern Poland) are generally preferable' (Forest Research, 2021), based mainly on the earlier work of Lines (1987).

2. There have been four sets of experiments set up to investigate the effects of seed origin on the survival and growth of Norway spruce in Britain. The most comprehensive experiment 'Bin 2' examined 19 seed origins that represented the native range of Norway spruce. Data from this experiment for the 25-year height assessment were re-analysed as part of this study; data from the 50-year height assessment were analysed for the first time.

3. Analysis of the height data showed that: (a) there was no effect of seed origin on height when data were grouped into regions; (b) only one pairwise comparison of the 19 seed origins was significant for the 25-year data; (c) there were no significant effects of latitude, longitude or elevation on height.

4. Following consideration of all the evidence it was decided not to use these new results as a basis for updating guidance on seed origins for Norway spruce. This study has only considered long-term data from one experiment, and this could have missed important information about what happens in the early years after planting in terms of survival, growth, tree health, form and vigour. The original project team led by Roger Lines monitored a large number of seed origins across a range of sites and had different types of data available to them. Hence, it seems risky to change general guidance based on the analysis of data from one experiment some 30 years after the last assessment.

5. The results reported here are from a period before climate change started to affect tree growth in Britain and further work on how climate change will affect the survival and growth of Norway spruce in the UK is required. Another angle that has not been covered by this report but needs to be addressed is to assess UK collected material of Norway spruce.

1.0 Introduction

Norway spruce is a fast-growing, adaptable species that occupies a wide native range in continental Europe. It was widely planted in Britain in the 19th century but in the 20th century the introduction of Sitka spruce became a more popular species choice. More recently the discovery of the European spruce bark beetle (*Ips typographus*) poses a distinct threat to both species in Britain. However, with active control of *Ips*, Norway spruce remains a good alternative to Sitka spruce, particularly on drier sites but not on poor, wet and exposed sites where Sitka is the best choice.

This report focusses on seed origin variation of Norway spruce. The main aim is to review past work on this subject and publish results derived from previously unanalysed data. As with other reports in this series, it was also an aim to consider updating the summary information presented by Lines (1987) and on the Forest Research (FR) species and provenance webpages (Forest Research, 2021), both of which are reproduced below.

Extract from Lines (1987) on Norway spruce

‘Recommendations

1. For commercial forestry, east European origins from Romania, Poland and Czechoslovakia combine fast growth with late flushing times. Some southern Austrian sources also have these characteristics.
2. German origins are rather variable and only the Harz region appears generally suitable.
3. Most French, Alpine and Scandinavian origins are not recommended either because of slow growth, early flushing or both.
4. For Christmas tree production, origins from the Schwabische region of south Germany, Forestry Commission see region (4347), which is mainly of German seed zone 84013, are the first choice.’

Forest Research (FR) species and provenance webpages

‘Provenances from eastern Europe (e.g. Romania, southern Poland) are generally preferable.’

1.1 Objectives of study

Norway spruce is an important forest tree in Britain and as a result there has been a number of studies of the effects of seed origin on growth and flushing date. The most comprehensive experiment is known as 'Bin 2', which is located just west of Huntly in northeast Scotland, which examined 19 seed origins that represented the native range of the species. Results from this experiment and others are summarized by Lines (1987) but the data and analysis from these experiments has been in publications that are not widely available. The objectives of this work are:

1. To review previous work on the seed origins of Norway spruce.

2. To analyse and publish the 25- and 50-year assessment data from the Norway spruce seed origin experiment 'Bin 2'.

3. To consider whether any changes are necessary to Forest Research advice on seed origins of Norway spruce.

2.0 Seed origin variation in Norway spruce

2.1 Experiments

Previous experiments examining seed origins of Norway spruce can be divided into four groups.

2.1.1 Pre-1939 experiments

This group of five sites was planted at Kielder, Newcastleton and Leanachan in the late 1930s. A narrow range of origins were included and at some sites there was no, or limited, replication. A useful review of results is presented by Edwards (1955) who made two main conclusions. The first was that origins from south-east Europe were the most vigorous; seed origins from Finland, Norway and Sweden were the least successful and those from Germany and the Alps were intermediate in vigour and growth. The second conclusion, which really reflects a learning experience with this type of field experiment, was that the differences caused by fire, frost and large differences in age and type of plant made it difficult to draw any firm conclusions.

2.1.2 1964/68 IUFRO experiments

The 1964 experiment was established on Cranborne Chase, near Salisbury in southern England and contained an extensive range of seed origins, an amazing 1100 origins! The experiment was fully randomised single trees, with 25 trees of each origin covering a total of 10 hectares. Two smaller 'sister' experiments were planted in 1968, each containing 200 origins, both were in Scotland at Minard forest (Minard 4) and Drummond Hill (Drummond Hill 25). These smaller experiments had six tree plots arranged in a randomised block design. All three experiments were part of a wider IUFRO project reported by Krutzsch (1974).

Early results from all three experiments are described by Lines (1973a). This publication describes quite a lot of analysis for height, height increment and flushing and reports that significant differences were found between countries, which were used as a method to group the origins in the analysis. However, the results of these analyses are not presented. Instead, an analysis is presented where origins were grouped into 96 regions (using the 'Langlet Regional Grouping') and then groups were ranked at each of the three sites for height increment and flushing score. The results are presented as tables and spatially on a map of Europe. Based on this the author concludes that 'results appear to confirm older experiments showing the superiority of East European provenances and point to some additional areas where vigorous provenances may be found'.

Later results after 11 years growth are described in Lines (1980) but this only covers the two Scottish sites. The method of analysis used the same 96 regions as above and focussed on height and diameter, these are firstly ranked and then expressed as a percentage of a standard mean for both sites. Figures of 'generally above 105%' are shaded on a map of Europe as in the earlier analysis. Based on height and diameter the results show three areas of better growth covering a high proportion of Norway spruce's natural range.

2.1.3 1968/71 Eastern Europe

Five experiments were established in 1968/71 to compare east European seed origins with French, Swiss, Bulgarian and Austrian sources. There has never been a comprehensive analysis of the results from these experiments as they were deemed to be less interesting than Bin 2, as they only had seed origins from a restricted area of the range.

2.1.4 1942 IUFRO experiment

A single experiment was established at Bin forest (Bin 2) in Scotland as part of a wider IUFRO initiative[1]. The experiment included 19 seed origins of Norway spruce, representing a large part of its native range, with five replicated plots of each seed origin. Each plot was 0.048ha and contained 255 plants (13x15).

The experiment was located just west of Huntly in the Grampian region of Scotland (NGR NJ494407). This site is at 175 m above sea level with a west to south-west aspect on a slight slope in a gently rolling part of the river Deveron valley. The soil is a flushed gley with a very moist soil moisture regime and a medium soil nutrient regime according to Ecological Site Classification (Pyatt *et al*., 2001).

For each of the seed origins, information was available from the experiment plan on latitude, longitude and altitude (Table 1). The early results up to age 25 have been described by Lines (1973b); data for the assessments after 25 and 50 years were available for this project.

The results presented by Lines (1973b) show each of the 19 seed origins grouped into three geographical areas, Baltic and northern; Hercynian-Carpathian; Alpine and SE Europe (see Figure 9 in Lines (1987)). This publication contains a table showing results for early survival, height at 8 and 10 years, as well as dominant height, dominant diameter and flushing score at 25 years. Fortunately copies of the statistical analysis for height and diameter at 25 years used to produce the table have survived. The analysis of variance compared the 19 seed origins with each other and shows significant differences for dominant height and dominant diameter (both $p<0.01$). The table of results shows values for each seed origin and mean values for each of the three regions. The interpretation of these results lays emphasis on comparison of the groups; for example, in the abstract it states 'height differences were significant, with Rumanian and S. Polish provenances superior to those from Alpine and Scandinavian groups'. However, some poetic licence has been applied here as the analysis showed that differences between the 19 origins were significant but differences between groups were

[1] This established 20 experiments in 11 countries containing 37 seed origins

not tested. The actual differences between the three groups for 25-year height were: Baltic and northern = 6.34m; Hercynian-Carpathian = 7.04m; Alpine and SE Europe = 6.31m. Hence the Hercynian-Carpathian region had 11% greater height than the other two regions, so this interpretation of the results is not without some justification but was not supported by statistical analysis.

2.2 Assessments and analyses

2.2.1 Assessments

Historic data were available from the assessment at year 25 (carried out in July 1967) and year 50 (carried out in January 1992). The 1967 assessment estimated the height of each plot, this was the mean height of 15 trees, each one being the tallest in 4x2 sub-plots in the centre of the plot. The 1992 assessment was compromised by windblow and it was only possible to assess 12 seed origins; height was estimated in similar way as in 1967 but each mean was calculated from 4 trees, each being the tallest in four 4x2 sub-plots in the centre of the plot.

Earlier assessment data have been summarised in Lines (1973b) and shows:

1. Survival at the end of the first year (1942) was 89% with no one plot being below 83%. Following this all plots were beaten-up to full stocking.
2. Initial height growth was slow, and the overall mean height of the tallest trees was 0.83 m after 8 years, 1.21 m after 10 years and 6.56 m after 25 years.
3. In the past when GYC has been assessed generally this was GYC 8, which reflects the poor early height growth.

2.2.2 Effects of seed origin and site

In this study data from the 19 seed origins at the single site were analysed to answer four questions:

1. What are the best regions in which to collect seed of Norway spruce based on the regions described in Figure 9 in FC Bulletin 66 (Lines, 1987)?
2. What are the best regions in which to collect seed of Norway spruce based on the five regions of the native range described in the experiment plan written by Roger Lines?
3. Are there differences between the 19 seed origins when they are directly compared?
4. Do latitude, elevation and longitude of the seed collection sites influence the results?

To examine the first question the 19 seed origins were divided into the three regions (Baltic and northern; Hercynian-Carpathian; Alpine and southeast Europe) shown in Figure 9 of FC Bulletin 66; shown as Region A in Table 1 and method A for the analysis. To examine the second question, the 19 seed origins were divided into five regions as shown as 'Region B' in Table 1 and method B for the analysis.

A separate report is available that describes the analysis of the data (Clarke, 2020) and from this the main results are presented in the next section.

2.3 Results: seed origin and site

2.3.1 Top height at year 25: method A

- The differences in tree height at 25 years according to the method A classification are shown in Figure 1. There was no significant difference in the mean height of the tallest trees after 25 years between seed origins grouped according to method A (p=0.24).

2.3.2 Top height at year 25: method B

- Figure 2 shows the means for height with 95% confidence intervals, according to method B; there was no significant main effect of region on tree height (p=0.88).

2.3.3 Top height at year 25: seed origin comparison

- The 19 seed origins were tested for differences in tree height at 25 years (Figure 3). Although there was a significant main effect of seed origin (p=0.008), of the 171 pairwise comparisons only one was significant between an origin in Romania (38-546) and one in Norway (38-552). This is shown in Figure 3 by number-based groupings at the top of the graph; seed origins which share the same number are not significantly different from one another.

2.3.4 Top height at year 50: methods A and B

- The association between region and tree height at 50 years was examined using method A, which was not significant (p=0.06), and method B (4 regions), which was also not significant (p=0.79). The results for method B are shown in Figure 4.

2.3.5 Top height at year 50: seed origins comparison

- The 12 remaining seed origins were tested for differences in tree height at 50 years (Figure 5). There was no significant main effect of seed origin (p=0.79).

2.3.6 Effects of latitude, longitude, and elevation

- The analysis by Clarke (2020) shows that neither latitude, longitude, nor elevation were associated with differences in the mean height of the tallest trees in the 25- or 50-year datasets (p>0.05 in all cases).

2.4 Discussion and conclusions

1. The results of the analysis in this report of the 25- and 50-year data are clear that there are few, if any, significant differences in height between the regions or the individual seed origins of Norway spruce.
2. This is quite a different result to that reported by Lines (1987) and gives general guidance on the preferred seed origins for Norway spruce. There are a number of possible reasons for this:
    a. The methods of statistical analysis and computation are very different now compared to when the 25-year data was last analysed in 1968.
    b. In previous reports the line between reporting differences between seed origins and regions sometimes became blurred, maybe to ensure clear recommendations could be made.
    c. There has always been a lot of variation between seed origins. For example, in the 1968 analysis the top-ranked seed origin (38-534) was from Sweden and the lowest-ranked (38-545) was from Bosnia (Table 1; see column 'Rank in 1968 analysis'). The high levels of variation between seed origins is also clear from some of the spatial presentation of data reported in Lines (1973a; 1980).
    d. The seed origins in the region Hercynian-Carpathian are slightly different between Lines (1973b) and method A used in this report.
3. The analysis presented in this report clearly shows that latitude, longitude and elevation had no effect on the 25- or 50-year tree height data.
4. The expectation when this project started was that the results would confirm the earlier work reported by Lines and present guidance on the FR website that 'provenances from eastern Europe (e.g., Romania, southern Poland) are generally preferable'. The results presented here based on this new analysis show very little variation between seed origins or regions for Norway spruce and therefore the question is whether the guidance should be updated and, if so, to what?
5. The weaker points of the new analysis presented here are that, firstly, only one experiment has been considered, and secondly, only data on the tallest trees after 25 and 50 years has been analysed. Although such long-term data are valuable, they miss what happens in the early years after planting and important factors such as survival, tree health, form and vigour have not been assessed or considered. The project team led by Lines monitored a large number of seed origins on a range of different sites and had different types of data available to them. Hence, it seems risky to change general guidance based on the analysis of data from one experiment some 30 years after the last assessment.

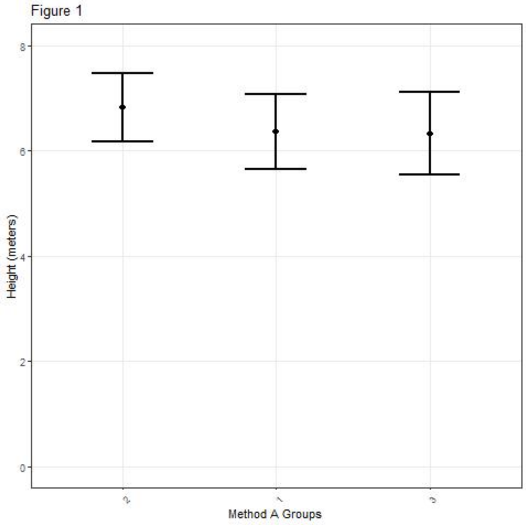
6. In conclusion, on balance there does not seem to be much justification for changing the present guidance that ‘provenances from eastern Europe (e.g., Romania, southern Poland) are generally preferable’. However, these new results suggest that under historic UK climate conditions, differences in tree height between provenances in this species is perhaps less than previous studies suggested.
7. The results reported here were recorded before the present period of rapid environmental warming and some further work on how climate change will affect the survival and growth of Norway spruce in the UK is required. Another angle not been covered by this report but needs to be addressed is to assess UK collected material of Norway spruce.

3.0 Tables and Figures

Table 1: Summary of the Norway spruce seed origin locations

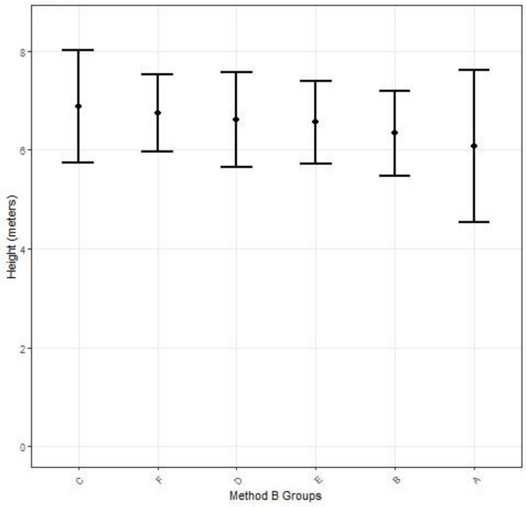
FC Ident No.	Region A	Region B	Country		Elevation (m)	Latitude N	Longitude E	Rank in 1968 analysis
			Scandinavia - high elevation					
38/532	1	1	Norway	Tyldal, Hedmark	550	62.1	10.8	12
			Scandinavia - general					
38/552	1	1	Norway	Follafoss, Trondelag	80	64	11.1	18
38/533	1	1	Norway	Nes, Trondelag	300	63.7	9.5	10
38/531	1	1	Finland	Vilppula, Hame	120	62	24.5	16
38/534	1	1	Sweden	Drangsered, Halland	400	57.1	13	1
			North Europe - lowlands					
38/535	1	2	Latvia	Vecmoka, Tukums	80	57	23.1	6
38/536	2	2	Germany	Pforten, Brandenburg	70	51.8	14.7	8
			Central Europe					
13/539	3	3	Switzerland	Winterthur, Zurich	500	47.5	8.8	13
38/540	3	3	Italy	Val di Fiemme, Trento	1100	46.3	11.3	14
38/549	3	3	Italy	Val di Fiemme, Trento	1100	46.3	11.3	5
			Middle Danube					
37/26	2	4	Austria	Burgenland	350	47.8	16.5	11
38/542	2	4	Austria	Lankowitz, Steiermark	530	47.1	15	7
38/543	2	4	Austria	Obervellach, Karnten	1800	46.9	13.2	9
38/544	2	4	Austria	Obervellach, Karnten	900	46.9	13.2	15
			Eastern Europe					
38/551	2	5	Poland	Stolpce, Minsk	170	53.5	26.7	17
38/550	2	5	Poland	Istebna, Kracow	620	49.6	18.9	2
38/546	2	5	Romania	Crucea, Neamt	720	46.7	26.3	3
38/547	2	5	Romania	Vadul Rau, Severin	917	45.2	22.3	4
38/545	3	5	*Yugoslavia*	Sarajevo	1200	43.8	18.5	19

Figure 1: Top height (m; year 25) of seed origin Regions - method A



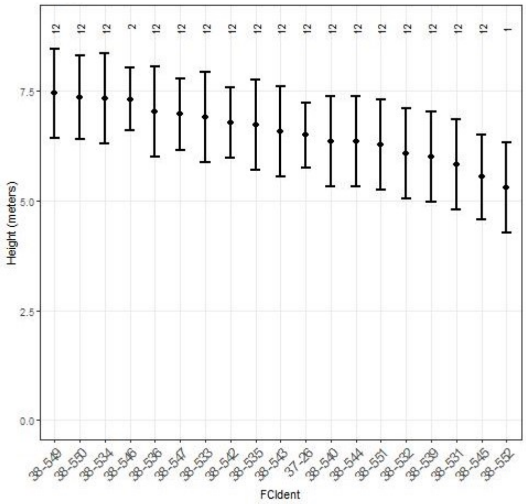
Height was not significantly different between the three groups (p=0.24)

Figure 2: Top height (m year 25) of seed origin Regions - method B



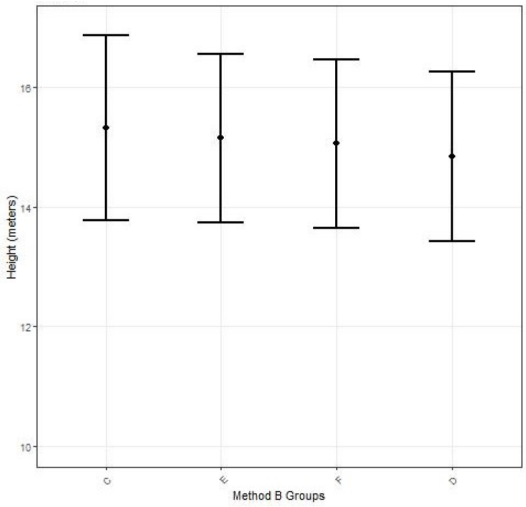
Height was not significantly different between the five groups (p=0.88)

Figure 3: Top height (m; year 25) of the 19 seed origins



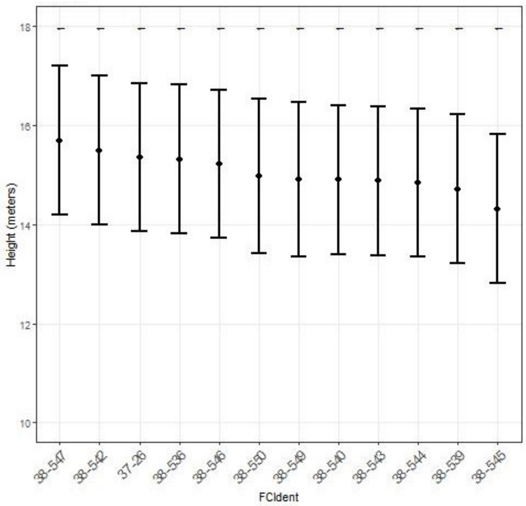
Height was significantly different between the 19 seed origins (p=0.008). Pairwise comparisons are shown by numbers at the top of the Figure, seed origins with the same number are not significantly different. Origin 38-549 were the tallest and the only significant difference (p<0.05) was between 38-534 and 38-552.

Figure 4: Top height (m; year 50) of four seed origin Regions - method B



Height was not significantly different between the four groups (p=0.79)

Figure 5: Top height (m; year 50) of 12 seed origins



Height was not significantly different between the 12 seed origins (p=0.79) and no pairwise comparisons were significant.

4.0 References and acknowledgements

4.1 References

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Forest Research

Alice Holt Lodge
Farnham
Surrey GU10 4LH, UK

Tel: 0300 067 5600

Fax: 01420 23653

Northern Research Station
Roslin
Midlothian EH25 9SY, UK

Tel: 0300 067 5900

Fax: 0 131 445 5124

Forest Research in Wales
Edward Llwyd Building
Penglais Campus
Aberystwyth
Ceredigion
SY23 3DA
Tel: 01970 621559

Email:research.info@forestry.gsi.gov.uk

www.forestry.gov.uk/forestresearch

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