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Wild Service Tree Seed Source Trial

Testing nine seed sources for survival, growth, health and stem quality at three locations in England

Christopher Guest & Jens Peter Skovsgaard

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The wild service tree seed source trial was established under the auspices of *Woodland Heritage*. The experiment was designed, and its establishment was supervised by Christopher Guest of *CJG Silviculture Ltd* and Jens Peter Skovsgaard of the *Swedish University of Agricultural Sciences*. Landowners of Fontmell Hill, Sotterley and Spernal Estates are sincerely acknowledged for their generous support in establishing the trial and for making land available. Thanks are also due to all involved in seed sourcing, plant propagation, soil analysis, site preparation, planting, measuring and other critical tasks during various phases in the establishment of the trial. Maintenance, re-measurements and future analyses will be supervised by Christopher Guest and Jens Peter Skovsgaard.

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Vacare

Setting the scene

Although native to Great Britain, there is very limited experience growing wild service tree (*Sorbus torminalis* (L.) Crantz) for high-quality timber production. Additionally, almost no timber markets exist in Great Britain, nor have any seed source trials or tree breeding ever been carried out. Little is known regarding the location of the best quality trees in Great Britain from which seed can be collected.

In contrast, significant silvicultural knowledge exists particularly in France and the Germanic countries where wild service tree is grown to produce high quality timber, where markets can be very strong, and where seed source trials and tree breeding have been carried out since the late 1970s.

To this end, a seed source trial was established in England in 2019 aiming to test some possible seed sources for tree breeding for the production of high-quality timber in Great Britain.

Objectives

The objectives of the trial are to test different seed sources of wild service tree for survival, growth, health and stem quality in order to provide recommendations for silviculture.

Seed sources

In autumn 2018, fruit were collected from some of the best available wild service trees in woods, forests and seed orchards in England, France, Germany and Italy. A total of 9 seed sources were included in the trial (Figure 1, Table 1, Appendix 1 and 2):

1. England, Ast Wood, 5 km west of Ledbury, Herefordshire, 6 trees
2. England, Stoopers Wood, Warwickshire, ca. 12 trees
3. England, Tortoiseshell Wood, 3.5 km northwest of Castle Bytham, Lincolnshire, 5 trees
4. France, Escatalens, 60 km north of Toulouse ('collection of fine wild service from throughout France', as described by Vilmorin, seed merchant, France)
5. France, Harcourt, 50 km southeast of Rouen, Normandy, seed orchard
6. France, Rahay, 70 km east of Le Mans, Pays de la Loire, seed orchard
7. France, Forests of Lugny, Plottes and Chardonnay, approximately 100 km south of Dijon, Burgundy
8. Germany, Sailershausen, 25 km east of Schweinfurt, Northern Franconia, 25-30 trees (distributed across three parts of the forest covering approximately 100 ha)
9. Italy, Parco Cavaioni, 8 km south of Bologna (seed source no. 157 in the regional register of certified forest seed sources)

All English berries were cleaned and stratified by the professional forest seed merchant Forestart, while all French, German and Italian berries were cleaned by professional seed merchants in each respective country and the seeds sent to Forestart for any further cleaning and stratification required.

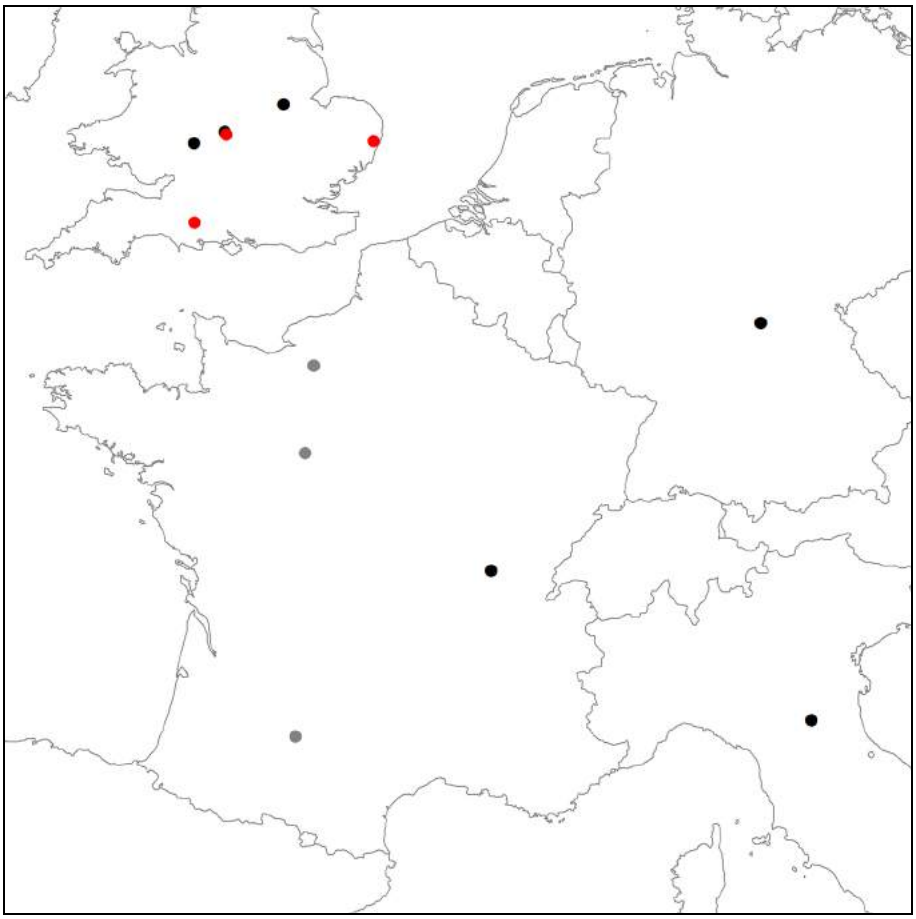


Figure 1
Location of seed sources and trial sites for the experiment. Legend: red = trial sites, black = forest site seed source, grey = seed orchard. Detailed maps can be found in Appendix 1.

Table 1
Seed source locations, collection and treatment information. The naming of seed sources outside of England is by region, nearest town or village. Legend: Name in *italics* indicates forest site(s), name in standard font indicates seed orchard. WGS coordinates indicate exact (*italics*) or approximate location (standard font); detailed maps of each area can be found in Appendix 1.

Seed Source No./Name	WGS84	Date Seed Collected	Received/Inspected by Forestart	Viability on 11 Feb 2019	Sowing Date
1 *Ast Wood*	*52.043180, -2.479185*	Oct-18	8-Nov-18	80 %	End-Mar-19
2 *Stoopers Wood*	*52.268200, -1.822795*	Oct-18	8-Nov-18	70 %	End-Mar-19
3 *Tortoiseshell Wood*	*52.768940, -0.574760*	21-Oct-18	8-Nov-18	80 %	End-Mar-19
4 Escatalens	*43.968020, 1.186480*		24-Jan-19§	40 %	5-Jun-19
5 Harcourt	*49.174440, 0.791125*	Nov-18	24-Jan-19	40 %	5-Jun-19
6 Rahay	*47.940600, 0.816400*		24-Jan-19	60 %	5-Jun-19
7 *Lugny-Plottes-Chard*	46.503180, 4.842420	Nov-18	07-Feb-19	90 %	5-Jun-19
8 *Sailershausen*	50.060000, 10.450585	Oct-18	14-Nov-18	40 %	End-Mar-19
9 *Parco Cavaioni*	44.444630, 11.303430	Nov-18	24-Jan-19	90 %	5-Jun-19

§: dirty seeds

Plant propagation

Forestart propagated seed from all the seed sources using in-house facilities in order to keep seed sources separate, ensure similar treatment throughout the stratification process, maximise germination success and increase the chance of producing strong quality saplings within the growing season of 2019.

900 seeds from each seed source were sown into propagation trays - 20 trays each containing 45 seedlings, making up one table (Figure 2). As the seed from Ast Wood, Stoopers Wood, Tortoiseshell Wood and Sailershausen were received at Forestart facilities in November 2018, the stratification process was completed and sowing of these seed sources could take place at the end of March 2019. Due to the delay in the delivery of the seed from Escatalens, Harcourt, Rahay, Lugny-Plottes-Chardonnay and Parco Cavaioni to Forestart facilities until late January-early February, stratification could only commence in February with seeds only ready for sowing on 5 June 2019.

When assessing growth progress on 16 July 2019, it was evident that those seed sources sown first would produce strong straight 40-60 cm tall saplings ready for planting in November 2019 (Figures 3-4). Major differences in germination success were visible in those seed sources sown later on the 5 June 2019 (Figures 5-6). These French and Italian seed sources except for Lugny-Plottes-Chardonnay (supplied by the ONF) showed signs of low seed viability. This is possibly due to the late arrival of seeds. This may indicate how important careful, quick handling and treatment of the seed is, following collection in the field. Many of the seed sources sown on 5 June 2019 did not grow as straight (sweeping stems) as those sources sown in the first cohort earlier in the season. It is hoped that such stems will straighten over time with the support of short 60 cm Tubex shelter guards.

Figure 2
All 9 wild service seed sources growing at Forestart, 16 July 2019.

Figure 3
High quality wild service saplings. Left: Sailershausen, 16 July 2019. Right: Tortoiseshell Wood, 14 November 2019.

Figure 4
Seed source Ast Wood, England, 16 July 2019 (sown end of March 2019).

Figure 5
Seed source Lugny-Plottes-Chardonnay, France, 16 July 2019 (sown on 5 June 2019).

Figure 6
Seed source Parco Cavaioni, Italy, 16 July 2019 (sown on 5 June 2019). Note: lower germination rate.

Location of trial sites

The seed source trial was established and replicated on three ex-agricultural sites across England (Figures 1, 7, 8 and 9, Table 2). The locations of the sites are as outlined below:

1. Fontmell Hill Estate, Fontmell Magna, Shaftesbury, Dorset. – Woodland name "Nitton West". Located at the end of Parsonage Street to the east. Grid reference (UK): ST869 465.
2. Sotterley Estate, 450 metres east of Shadingfield Hall, Suffolk. – Woodland name "Spatchetts 8 Acres". Grid reference (UK): TM443 842.
3. The Heart of England Forest, Spernal Estate, Warwickshire. – Woodland name "Newnham". Grid reference (UK): SP155 600.

Figure 7
Location of the three trial sites at Fontmell in Dorset, Sotterley in Suffolk and Spernal in Warwickshire.

Table 2
Location and site details for the three trial sites. Co-ordinates are approximate and indicate the centre of each trial site.

Site	Replications	Previous Land Use	Lat. (°N)	Long. (°E)	Alt. (m)	Slope	Precip[§] (mm)
Fontmell	4	Arable & pasture	50.948458	-2.1866494	100	North	900
Sotterley	4	Arable & pasture	52.401470	1.5897265	20	South	620
Spernal	4	Arable	52.237656	-1.7742437	70	Flat	610

§: Approximate average annual precipitation

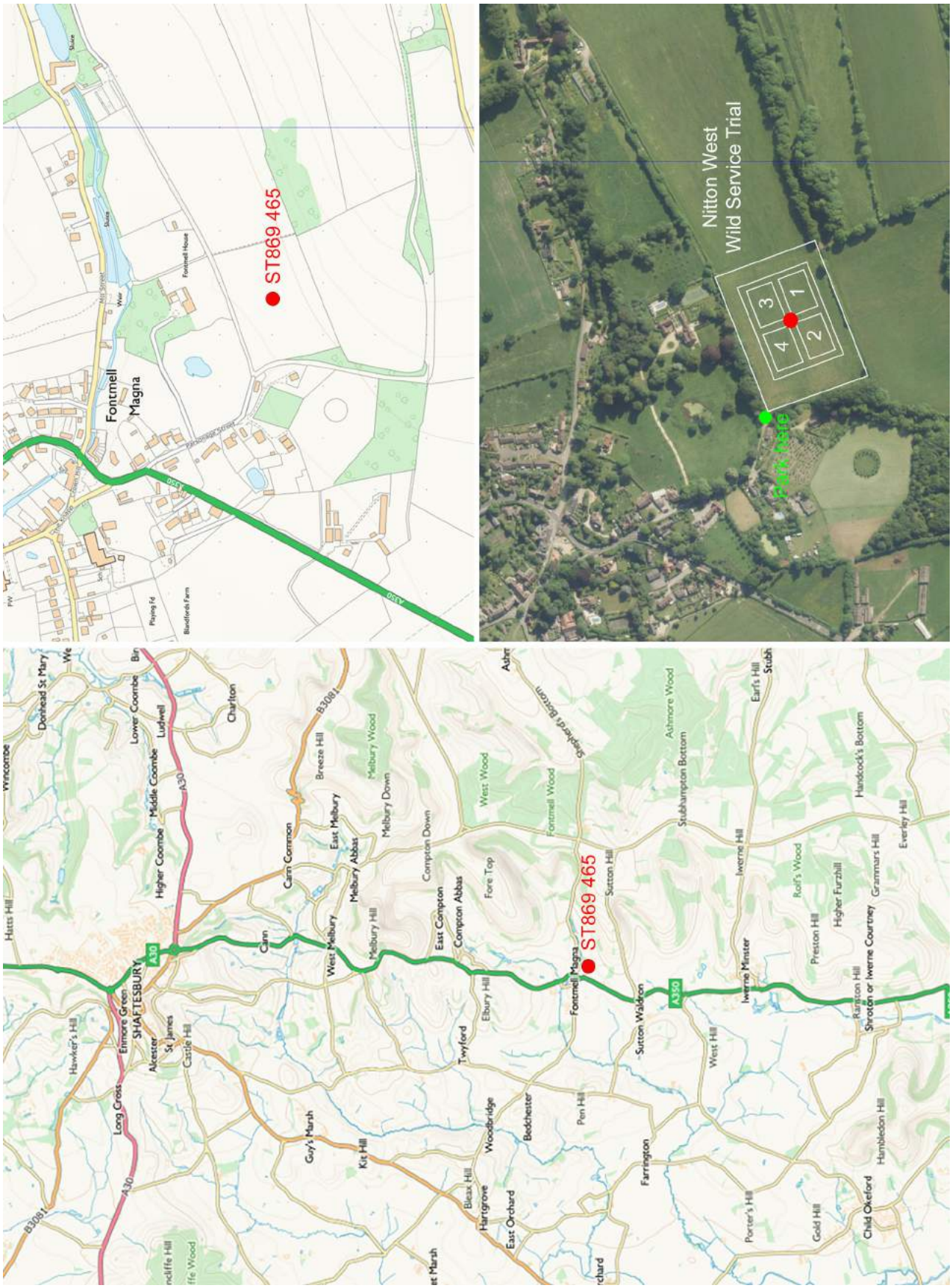


Figure 8a
Local site map for Fontmell / Nitton West, including grid reference and block numbers.

Figure 8b
Local site map for Sotterley / Spatchetts 8 Acres, including grid reference and block numbers.

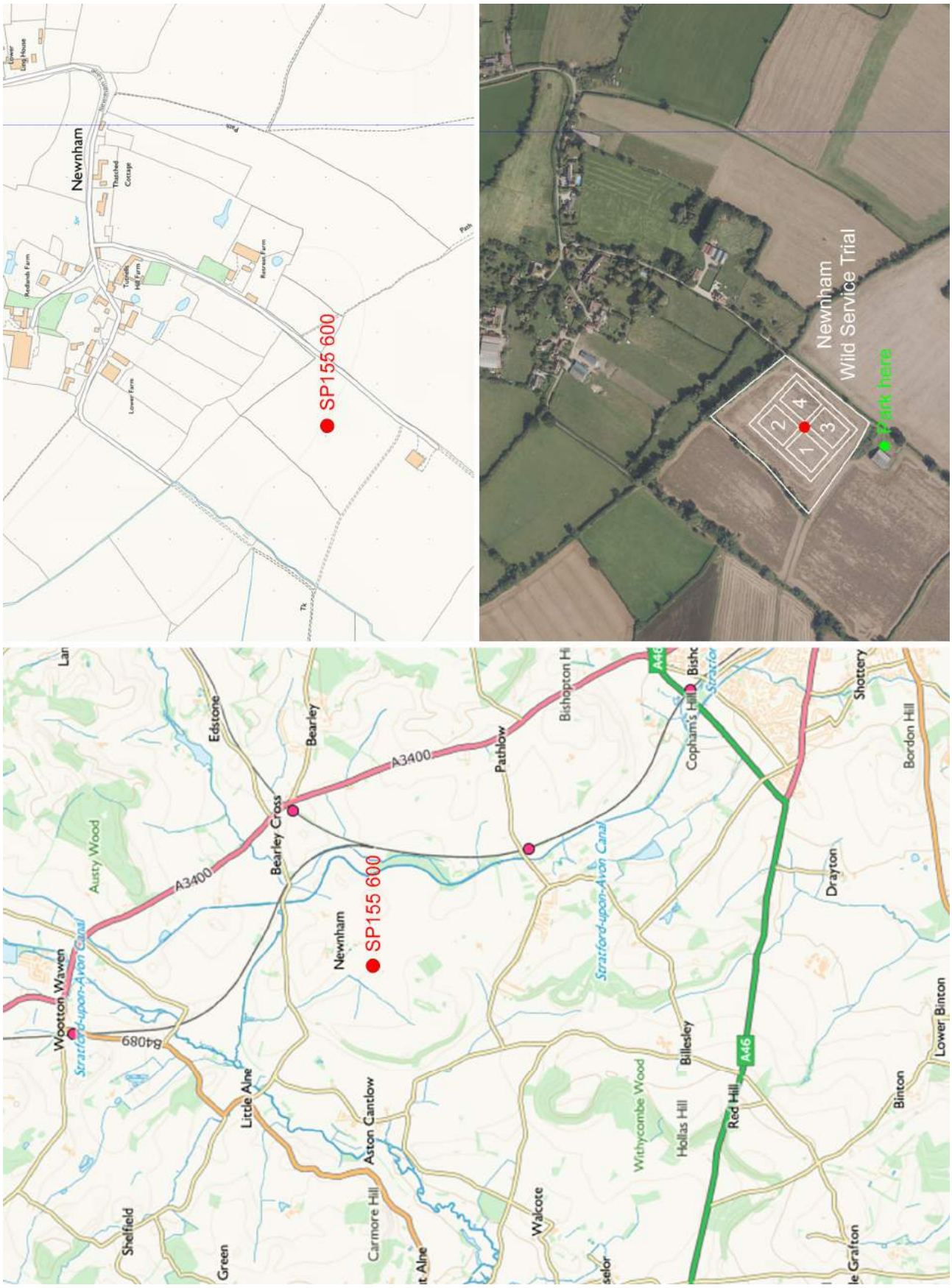


Figure 8c
Local site map for Spernal / Newnham, including grid reference and block numbers.

Site surroundings The surroundings of each trial site at the time of planting are outlined in Table 3.

Table 3
Trial surroundings at the time of planting. Some open areas surrounding the trial were scheduled for planting with other broadleaved tree species. Legend: MBs = mixed broadleaves, POK = pedunculate oak.

Site	Block	North	East	South	West
Fontmell	1	Block 3	Ca. 10 m strip of newly planted MBs. Beyond this open field.	Elder and hawthorn hedge.	Block 2
Fontmell	2	Block 4	Block 1	Elder and hawthorn hedge in places.	Band of newly planted MBs. Beyond this a hedge line of MBs.
Fontmell	3	10-20 m of newly planted MBs. Beyond this a mature hedge line of MBs and standards.	Ca. 10 m strip of newly planted MBs. Beyond this open field.	Block 1	Block 4
Fontmell	4	10-20 m of newly planted MBs. Beyond this a mature hedge line of MBs and standards.	Block 3	Block 2	Band of newly planted MBs. Beyond this a hedge line of MBs.
Sotterley	1	MB hedge with POK standards.	Block 2	Block 3	MB hedge with POK standards.
Sotterley	2	MB hedge with POK standards.	MB hedge with POK standards.	Block 4	Block 1
Sotterley	3	Block 1	Block 4	MB hedge with POK standards.	MB hedge with POK standards.
Sotterley	4	Block 2	MB hedge with POK standards.	MB hedge with POK standards.	Block 3
Spernal	1	MB hedge with ash standards.	Block 2	Block 3	Open field.
Spernal	2	MB hedge with ash standards.	Pollarded willow, ash and hawthorn hedge.	Block 4	Block 1
Spernal	3	Block 1	Block 4	MB hedge with scattered ash and oak standards.	Open field.
Spernal	4	Block 2	Pollarded willow, ash and hawthorn hedge.	MB hedge with scattered ash and oak standards.	Block 3

Soil characteristics Soil pits were dug to a depth of 1 m at the centre of each block at each trial site (Figure 9). The following were recorded at each soil pit: depth of plough layer, horizons present and corresponding depths, presence of free lime within each horizon, presence of reduction/ mottling in B and C horizons and depth at which any groundwater occurs. Soil samples were taken by removing an equal amount of soil through the complete profile irrespective

Figure 9a (site overview)
Trial at Fontmell facing north, 19 November 2019 (tubes on WST & field maple).

Figure 9b (site overview)
Trial at Sotterley facing north, 19 November 2019 prior to mounting of tubes.

Figure 9c (site overview)
Trial at Spernal facing north, 21 January 2020 prior to mounting of tubes.

Figure 9a (soil profiles)
Soil pits at Fontmell, blocks 1-4 (from left to right).

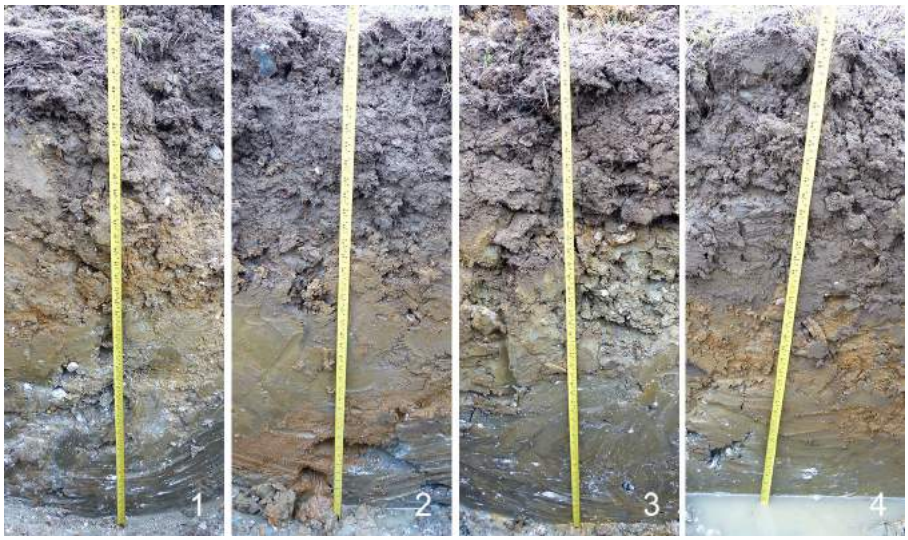


Figure 9b (soil profiles)
Soil pits at Sotterley, blocks 1-4 (from left to right).

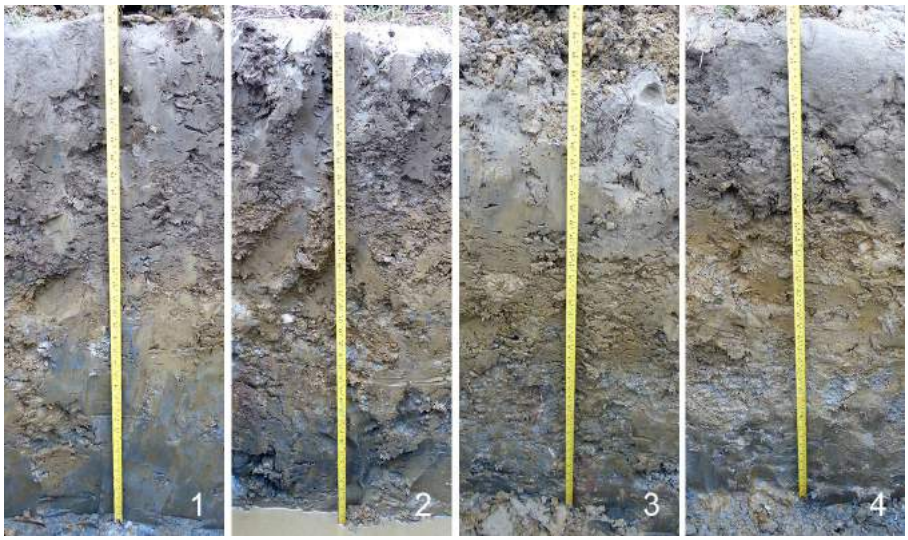


Figure 9c (soil profiles)
Soil pits at Spernal, blocks 1-4 (from left to right).

of the depth of the individual horizons. Each soil sample consisted of approximately 500 grams of soil, which was put in a freezer bag, tied shut and labelled immediately. Each soil sample was subsequently analysed in a laboratory for the following chemical characteristics and elements pH, C, N, P, K, Ca, Mg (and other micro nutrients), organic content and soil texture (Table 4).

All soils at Fontmell, Sotterley and Spernal had distinct 30 cm plough layers. The soils at Fontmell were all well aerated while the soils at Sotterley and Spernal showed mottling and reduction in the B and C horizons which are characteristic of surface water gleys.

Table 4
Summary of soil characteristics for blocks 1-4 (mean values for depth = 0-100 cm) at each site at the time of planting. C/N = carbon/nitrogen ratio, CEC = cation exchange capacity, BS = base saturation (percentage of potential CEC occupied by Ca, Mg, K and Na cations). More detailed soils data can be found in Appendix 3 and separate soil analysis reports from Yara UK Ltd.

Site	Fontmell	Sotterley	Spernal
Soil type	Calcareous brown earth	Surface water gley	Surface water gley
Org. matter (%)	2.5	1.2	2.4
Sand (50 - 2000 µm, %)	50	40	33
Silt (5.69 - 50 µm, %)	28	27	36
Clay (0 - 5.69 µm, %)	22	33	31
pH	8.0	7.9	8.2
C/N	11.0	11.5	12.6
CEC (meq/100g)	14.5	17.0	26.5

Site preparation

Site preparations varied across the trial sites. The agricultural site at Fontmell had been set aside for almost 1 year prior to preparation. In the past the field had been used for pasture and as a wheat field. Prior to cultivation, the site was sprayed with glyphosate to kill the grasses and weeds. Following this the site was shallow ploughed (in very wet conditions) and triticale (variety Fido) was sown in November 2019 by a modern tractor mounted combination drill (combined power harrow and seed drill) at 86.45 kg/ha (Box 1). The triticale germinated well and established uniformly across the site (Figure 10). The site was fenced to keep out deer and rabbits/hares using creosoted 2.4 m tall 3-inch stakes and 1.8 m tall 1 piece high tensile deer netting (Figure 11). Heavy grade rabbit netting was attached with hog rings and dug-in to reduce the risk of entry of any 'vermin'.

The agricultural site at Sotterley was used as a horse paddock until recently and 10 years prior to this it was a very good wheat field. Prior to cultivation the site was sprayed with glyphosate to kill the grasses and weeds present. Subsequently, the site was mole drained and sub-soiled. Mole draining was carried out using a mole plough, which involved a spacer mounted on the back of a tractor being pulled through the subsoil but above the existing clay drainage pipes. This process can improve site drainage. The sub-soiler used had 5 legs set at circa 60 cm apart and circa 30 cm deep and was drawn behind

Figure 10
Triticale at Fontmell providing successful and complete weed control during 2020. Seed source no. 8 in block 4, 15 April 2020.

a tractor. This can break up any iron or ploughing pans and aid drainage. Both of these operations were carried out in dry conditions, which avoided any rutting of the topsoil. Ground that has been sub-soiled may have better moisture retention than ploughed and rotovated soils as the upper soil is less broken down and friable. Following this, ground conditions became very poor due to a very wet October in 2019 and to avoid compaction by levelling and drilling, 100 kg of triticale (variety Fido) was spread by a quad bike mounted slug pelleter in November 2019. Unfortunately, the triticale failed to successfully germinate and establish due to the seed not being drilled, the poor weather and ground conditions, and damage by slugs. By the time the damage had been spotted and slug pellets applied, many of the germinated seeds had been damaged and thus no triticale could be found on this site. The trial site was fenced to keep out muntjac and rabbits/hares using tanalith treated 1.9 m tall stakes and heavy grade rabbit netting attached with hog rings and dug-in. 3 strands of barbed wire were fixed above the rabbit netting to keep the muntjac out.

The agricultural site at Spernal was left fallow for 1 year prior to the establishment of the trial and before this it was a wheat field. All land owned by the Heart of England Forest

Figure 11
Fence erected at Fontmell.

Box 1: Triticale

Wild service can suffer reduced growth in the absence of efficient weed control. To remove or reduce the need for subsequent weed control, the plan was that all the trial sites, which were formerly agricultural land, would be sown with triticale prior to planting. Triticale is an efficient, cheap and environmentally friendly method of weed control.

Timing: The triticale was sown 1-2 weeks prior to planting (laying out the trial and planting the saplings is easier if the triticale is not very tall).

Sowing density: 50-90 kg/ha of triticale seed was sown. 90 kg/ha was recommended if the weather was relatively cold and wet. The relatively low density of sowing results in a crop less dense than a standard rye/wheat crop (which would be 140-200 kg/ha), but sufficient for weed control in afforestation.

A height of up 20 cm can be expected by the following April (the end of its vegetative growth stage). No supplementary weeding should be required in subsequent years, i.e. no trampling or mowing (if the triticale is mown in its reproductive growth phase it will not regrow). In subsequent years, the triticale will regenerate sparsely by self-seeding and will gradually disappear over 2-3 growing seasons.

Monitoring will be carried out where triticale has been established. As the triticale failed to establish at the Sotterley and Spernal sites, alternative weed control regimes will be considered.

is managed organically, therefore the triticale (variety Fido) was sown in October 2019 by direct drilling into the vegetation already present, mainly volunteer wheat and arable weed grasses. Due to extremely wet conditions in October 2019 (the field was under water for a period), the seeds failed to germinate and thus no triticale could be found on the site. The trial site was fenced to keep out all deer species and rabbits/hares using 3-4

inch tanalith treated 2.4 m tall stakes and 1.8 m tall high tensile deer netting. Heavy grade rabbit netting was fixed using hog rings but not dug-in.

Species mixture

Considering the common forest type in which wild service tree is found in continental Europe and given the general and possibly increasing risk associated with the planting of pure stands, wild service tree was planted in mixture with field maple (*Acer campestre)*, hornbeam (*Carpinus betulus)* and pedunculate oak (*Quercus robur)*. This mixture mimics a forest type that prevails in some parts of the natural range of wild service tree.

Should the wild service tree fail or not develop properly, this mixture will ensure that a reasonable stand of pedunculate oak grows. The field maple and the hornbeam can be considered nurse or serving species and help to create an understorey for pedunculate oak at an early stage. In the event of severe competition from field maple or (more likely) hornbeam, individuals will be selectively removed. The inclusion of both field maple and hornbeam may also be seen as an insurance in relation to damage caused by grey squirrel; if the squirrels should prefer one species over the other, one will still help to ensure the development of an understorey. Moreover, the inclusion of tree species which are preferred by grey squirrels may possibly detract their attention away from wild service tree and pedunculate oak. Finally, by planting the trial as a mixture, the growth depression that sometimes seem to occur in pure stands of *Sorbus* spp*.* may be prevented.

Extraction racks were planted with common hazel (*Corylus avellana*). Early seed setting may give hazel the opportunity to spread across the area as an understorey species.

Statistical design

The trial was laid out as a randomised complete block design. Each wild service tree seed source was planted in a group pattern (4 × 4 saplings per seed source), with one group of each seed source per block (Figure 12). A total of 4 blocks were planted on each of 3 sites. In other words, the experiment was replicated on three sites with four blocks on each site (within-site replications) and 16 trees of each seed source (within-block replications) per block (Figure 13).

Plant spacing

All species were planted at a spacing of 1.5 m × 1.5 m except extraction racks which were planted with common hazel at a spacing of 2.0 m x 2.0 m, i.e. hazel planted 2.0 m from the neighbouring lines of saplings to the left and right and 2.0 m between hazel saplings within this line (Figure 12). The location of each sapling was identified and marked prior to planting so that all species except hazel were planted near to or at exact coordinates.

Buffer zones

The 4 blocks per site were planted with an external buffer zone consisting of 4 rows of pedunculate oak also planted at a spacing of 1.5 m x 1.5 m, except where extraction racks were continued on from the trial with hazel at a spacing of 2.0 m x 2.0 m (Figure 13).

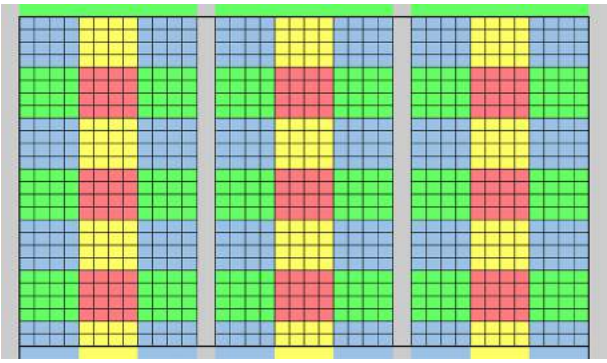


Figure 12
Group pattern layout within a block. Trees for the main stand were planted at 1.5 m x 1.5 m (square spacing, each square indicated by lines), and hazel in the 4.0 m wide extraction racks were planted at 2.0 m in the centre of each rack (no lines). Legend: red = wild service tree, green = oak, blue = hornbeam, yellow = field maple, grey = hazel.

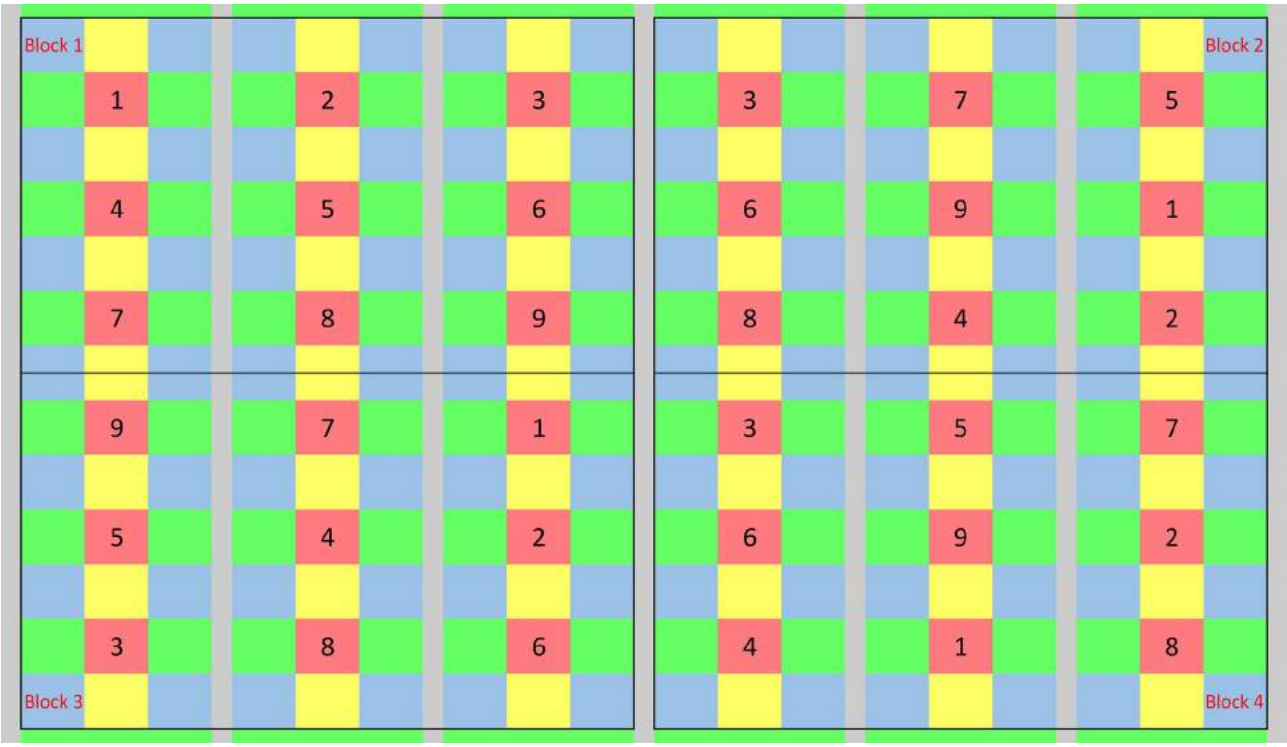


Figure 13
Block layout at site level (blocks 1-4), including parts of the buffer zone. Legend: red = wild service tree, green = oak, blue = hornbeam, yellow = field maple, grey = hazel. Seed sources (wild service tree): 1 = Ast Wood (England), 2 = Stoopers Wood (England), 3 = Tortoiseshell Wood (England), 4 = Escatalens (France), 5 = Harcourt (France), 6 = Rahay (France), 7 = Lugny-Plottes-Chardonnay / Burgundy (France), 8 = Sailershausen (Germany), 9 = Parco Cavaioni (Italy). Note the different (randomized) location of seed sources in the blocks. Net block size: 39 m x 58 m (2262 m^2).

Extraction racks

Permanent extraction racks were laid out at establishment in order to provide a 4 m wide rack when the stands are thinned in the future. This will allow good access for harvesting machinery, limit ground compaction and avoid the need to drive any machinery near the groups of wild service tree. The racks were planted with common hazel, which can easily be coppiced prior to any thinning intervention. The distance between rack centres is 20.5 m.

Grading of planting stock

Given the germination success of all of the wild service seed sources, through selection and grading out, a total of 216 saplings (72 saplings per site including 8 spare saplings to replace any damaged saplings or for beating-up the following year) of the best quality, tallest wild service saplings per seed source were used in the trial. A size class of 40-80 cm was achieved for the following seed sources: 1. Ast Wood, 2. Stoopers Wood, 3. Tortoise-shell Wood and 8. Sailershausen. These are the English and German seed sources which were sown by the end of March.

For the second cohort of seed sources (4. Escatalens, 5. Harcourt, 6. Rahay, 7. Lugny-Plottes-Chardonnay and 9. Parco Cavaioni), the best quality tallest saplings per seed source were selected. These seed sources were generally shorter than those in the first cohort as the second cohort was sown on 15 June 2019. The seed source Lugny-Plottes-Chardonnay clearly produced the tallest saplings from these. Generally, a size class of 20-40 cm was achieved for the second cohort of seed sources.

All saplings of wild service tree were selected and graded during the week commencing 11 November 2019 and dispatched and delivered to the 3 participating properties by 15 November 2019.

Delivery

Each seed source per block was assembled into a bundle of 16 saplings and shrink wrapped. Each bundle was clearly marked with a waterproof label to identify the seed source using both the number and name. This was repeated for each replicate/block per trial site. 8 spare saplings per seed source and trial site were bundled, shrink wrapped and labelled as above in case of damage en route and for beating-up the following year.

Other planting stock

The pedunculate oak (Netherlands 01, Renswoude, tested material), hornbeam (UK 404, Lockerly Estate, source identified (this was to be registered as a “selected stand” but the presence of Scots pine prevented this due to categorisation criteria)) and hazel (UK 405, source identified) saplings were supplied by Cheviot Trees as cell grown saplings and were 40-60 cm tall.

The field maple (Sailershausen, Northern Franconia, Germany, collected from impressive straight, large diameter, mature individuals) saplings were supplied by both Forestart and Cheviot Trees as cell grown saplings and were 10-20 cm tall. The field maple saplings were very small as they were only sown in the first week of July as dormancy could not be broken before then. As there were a limited number of field maple saplings from Sailershausen and as they were so small, they were only planted at Fontmell. The field maple saplings were carefully planted out and 60 cm tall Tubex shelterguards were attached, in order to increase survival success and promote height growth.

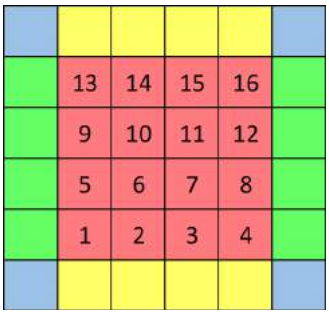


Figure 14
Numbering pattern used for individual trees in each group of wild service seed sources. All groups were numbered according to this pattern, so that each tree is identified uniquely by site, block, seed source and individual number. Note: the location of sapling no. 1 is at the bottom left-hand corner of each seed source group in Figure 13.

The field maple saplings (UK 404, source identified) planted at Sotterley and Spernal were also quite small and 60 cm tall Tubex shelterguards were attached, in order to increase survival success and promote height growth.

Timing of trial planting

The trial sites at Fontmell and Sotterley were planted in mid to end of November 2019. The trial at Spernal was planted at the end of January 2020 due to a delay in receiving an establishment grant contract.

Site layout, planting and numbering of individual trees

Trial layout was carried out using cross-sight ranging poles, measuring wheels, measuring tapes, 2.5 mm bailing twine, forester spray and short bamboo canes.

Clear instructions were given to ensure that each planter knew how to handle each seed source in order to guarantee that no saplings got mixed up. This was necessary only for wild service saplings. Following the planting of each seed source group, the label supplied with the bundle for that particular group was fixed to sapling no. 1 of that particular group (Figure 14). This allowed for accurate cross checking as the planters worked across the site.

All the wild service saplings were guarded with 0.6 m Tubex shelterguards, as some of the second cohort of wild service saplings were quite small and swept due to the short growing season. Moreover, the shelterguards aid in the location of saplings for any weeding required.

Christopher Guest maintained contact with Miles Barne (Sotterley) and Stephen Coffey (Spernal) throughout the planting of the trial to address any difficulties that arose and ensure consistency across the 3 sites.

Seed source markings

The centre and number of each seed source group was marked at Fontmell to allow for easy future identification and monitoring (Figure 10). At Sotterley and Spernal seed source markers were installed in 2021 near tree no. 1 in each seed source group.

Beating-up

8 extra saplings per seed source and site were bundled separately at the nursery and sent to each site as spares as outlined above. All spare saplings per seed source were planted together at the edge of each trial site but kept clearly separate from the experiment. Each spare sapling's height was measured on the same day as all the other saplings on the same site. Each spare sapling's location was recorded. Beating-up took place in the first week of December 2020 (Appendix 4).

Initial measurements

Following the successful layout and planting of all 3 trial sites, the heights of all wild service saplings were measured to establish a base/reference height for further analyses (Appendix 4). These height measurements were carried out by 31 January 2020. In addition to these, Christopher Guest carried out an assessment of establishment at each site in November 2019 (Fontmell and Sotterley) and January 2020 (Spernal).

The following variables were recorded at each site:

- Identification of each wild service sapling to site, block, seed source (Figure 13), row number and location (Figure 14). Example 1: the sapling located at Fontmell, Block 1, Seed source 1, Row 1 and Tree 1 will have the ID code: *Fontmell:1:1:1:1*. Example 2: Sotterley Estate, Block 3, Seed source 8, Row 3 and Tree 14 will have the ID code: *Sotterley:3:8:3:14*.
- Height: The height of each sapling was measured from ground level to the top of the terminal bud (total tree height). All saplings were measured in centimetres.

Measurement program

There should be an annual re-measurement of growth variables every year for the first three years after planting and subsequently every five years, March 2028, 2033, 2038 and beyond. The first re-measurement and general assessment of the trial was carried out in December 2020 (Appendix 4).

Measurements should preferably be made in spring, for consistency across years of measurement and in order to account for any damage during the dormant season. Where possible, all data collection for each respective site will be carried out by Christopher Guest with the help of a local representative from each respective site. Each wild service tree (ID code) should be measured for the following variables:

- Survival (alive or dead; note that wild service tree often regrows from the base or from below-ground parts following browsing or other damage to the top / above-ground plant parts).
- Total tree height (to be measured from ground level to the top of the terminal bud or, in the event of any damage to the terminal shoot, to the highest living point; measurements to be made in centimetres).
- Diameter at 1.30 m above ground level (diameter at breast height; to be measured on trees taller than 1.30 m; measurements to be made in millimetres).

- Damage (any damage to the tree should be recorded and classified according to type/ origin; for example, browsing, dieback at top due to early, winter or late frost, fungal damage, insect damage, etc.)

Quality attributes should be recorded from years 10-20, i.e. stem form, forking (height to the lowest fork) and height to lowest live branch. Scale for stem form: 2 (stem straight in two perpendicular planes), 1 (straight in one plane), 0 (straight in zero planes (not straight at all)). Intermediate scores (0.5 and 1.5) can be used, resulting in a 5-point scale.

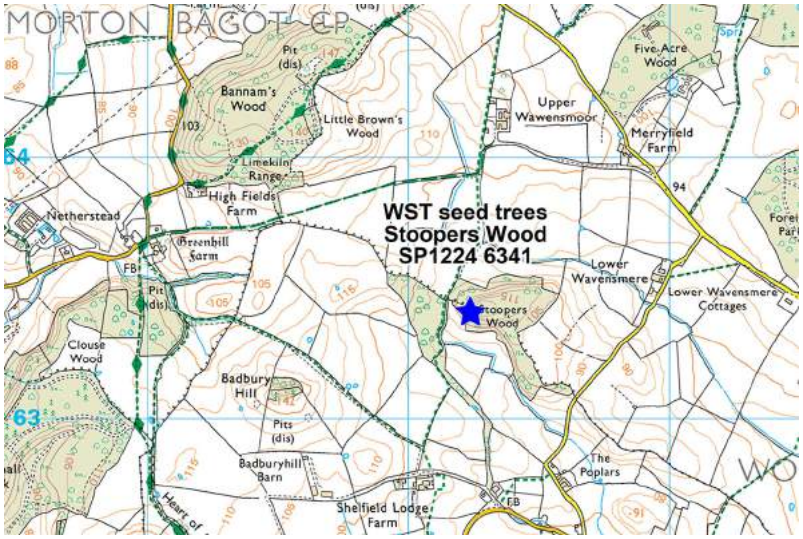
The measurement program and protocol should be re-evaluated every 5-10 years. Tree species other than wild service tree should be measured whenever relevant, for example to account for inter-tree competition, the influence of neighbour trees on the stem quality of wild service tree, or to quantify the total stand environment in terms of tree and stand volume factors.

Duration of trial

The trial is scheduled to run for a full rotation (100-150 years) and the land owners should commit to keep and maintain the experiment for this period of time. Maintenance and measurements will be carried out at regular intervals. It is envisaged that survival and early growth may be analysed after 5 years (phase 1) and again after 15-20 years (at canopy closure; phase 2). The long-term development of the trial could be analysed at 20-30 year intervals (phase 3 and subsequent phases). The long-term potential of the trial and of the blocks at each site will be evaluated at regular intervals (for example, every 10-20 years).

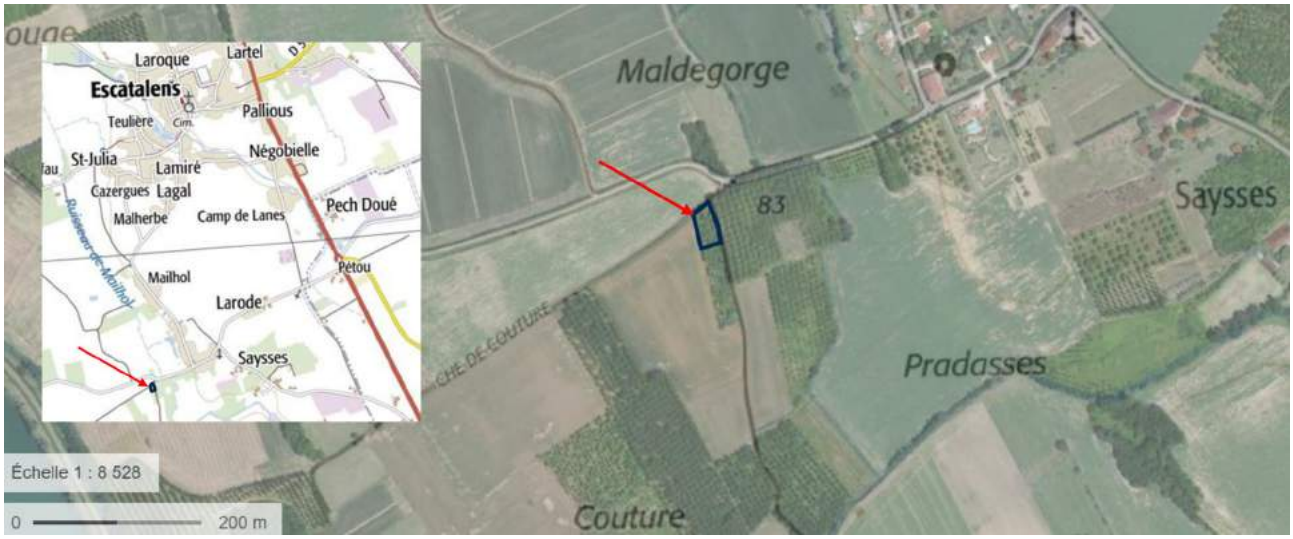
Appendix 1: Seed source maps

Seed source no. 1: Ast Wood

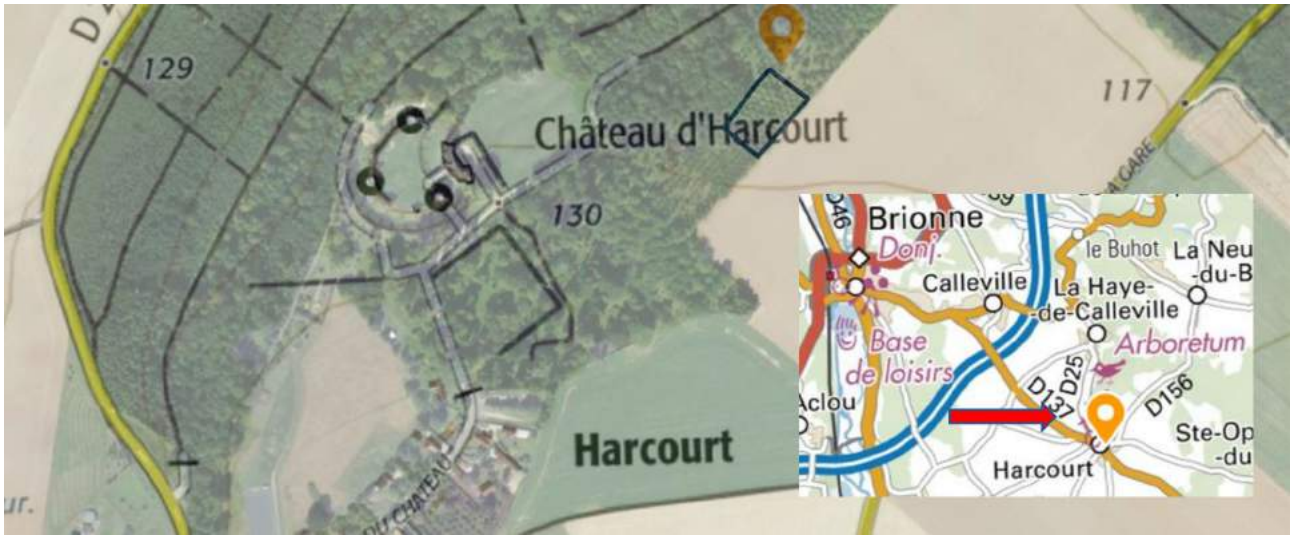


Seed source no. 2: Stoopers Wood

Seed source no. 3: Tortoiseshell Wood

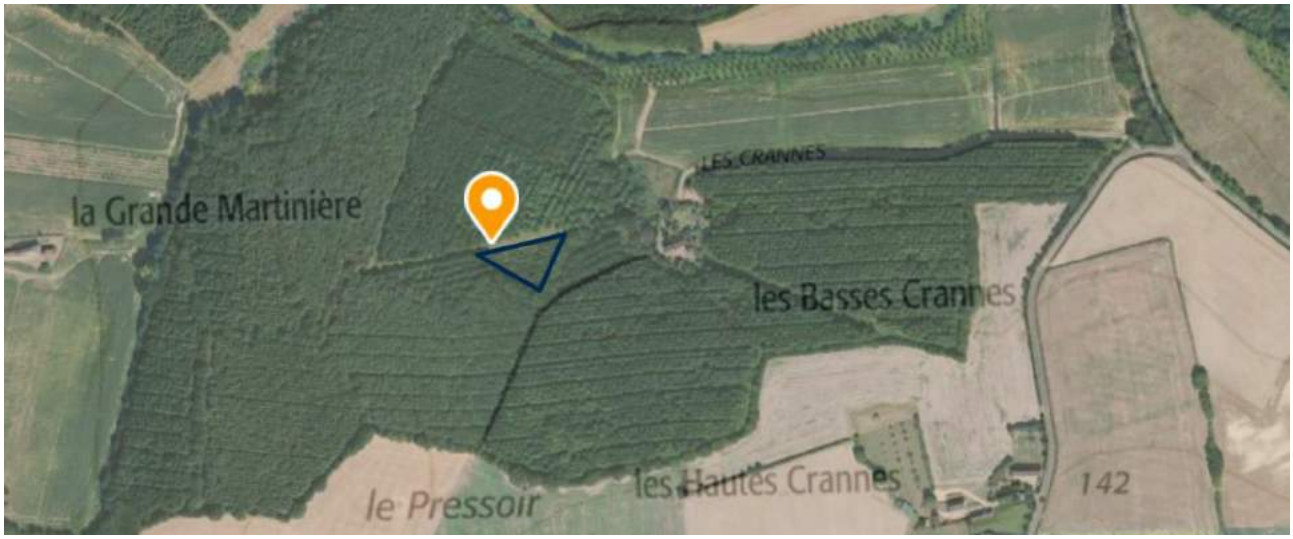


Seed source no. 4: Seed orchard near Escatalens

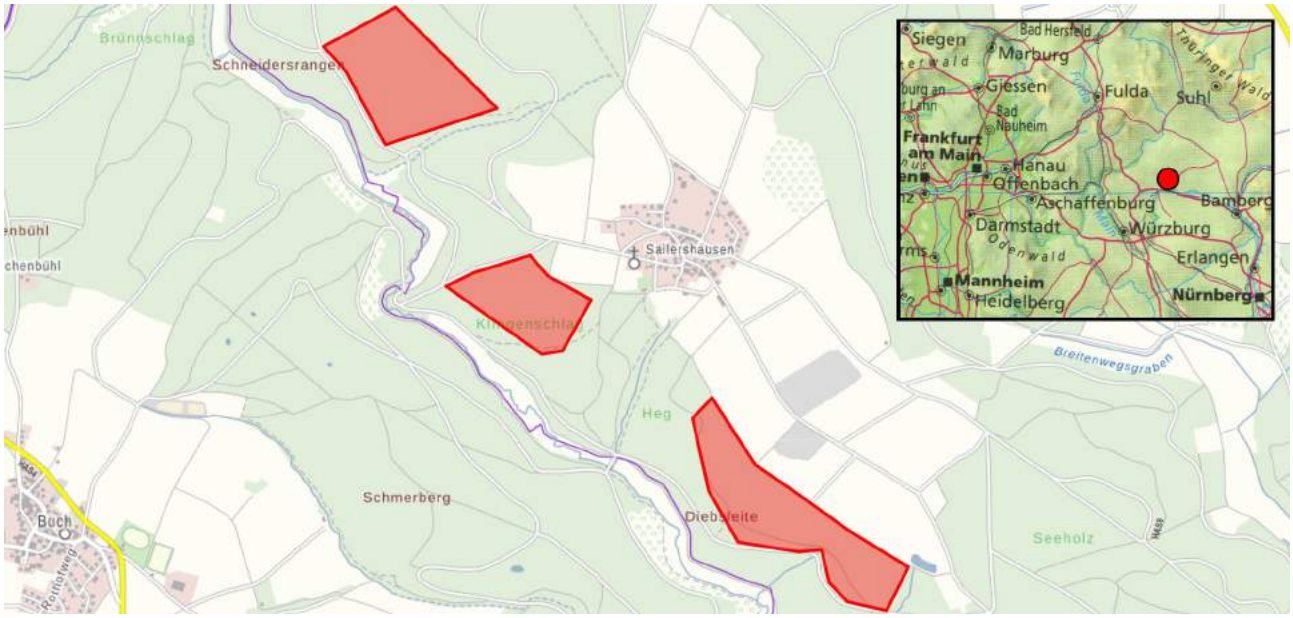


Seed source no. 5: Seed orchard in Harcourt Arboretum (France)

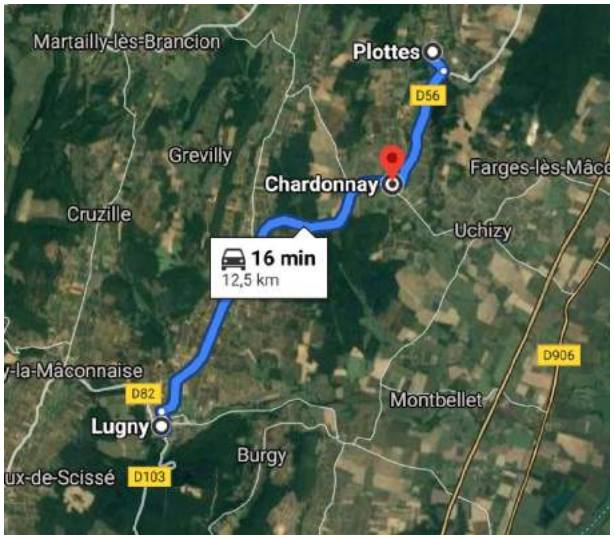
Seed source no. 6 (part 1): Seed orchard near Rahay



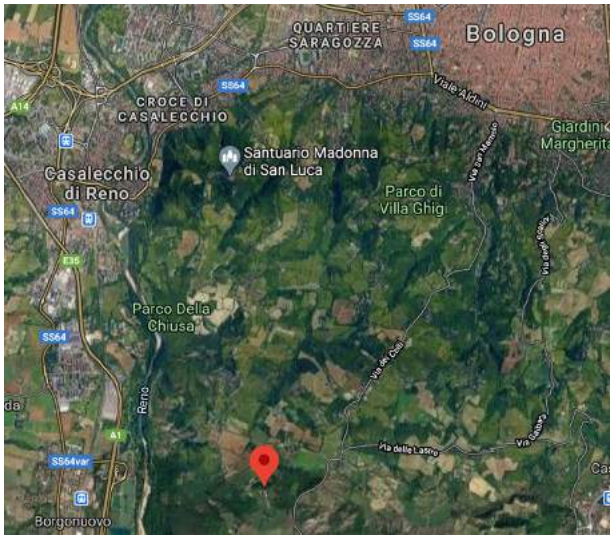
Seed source no. 6 (part 2): Seed orchard near Rahay



Seed source no. 8: Plus-trees within the three parts of the forest marked in red



Seed source no. 7: Forests at Lugny-Plottes-Chardonnay



Seed source no. 9: Parco Cavaioni south of Bologna

Appendix 2: Seed source labels and photographs

Figure 15
Seed source labels with identification numbers.

Figure 16
Seed source no. 1: The population in Ast Wood, England.

Figure 17
Seed source no. 3: The population in Tortoiseshell Wood, England.

Figure 18
Seed source no. 3: Tortoiseshell Wood, England. Three trees harvested for seed (a total of five trees were harvested at this location).

Figure 19
Seed source no. 4: The seed orchard at Escatalens, France.

Figure 20
Seed source no. 5: The seed orchard in the arboretum at Harcourt, France.

Figure 21
Seed source no. 7: Harvesting plus tree no. 1 of ONF's seed source in the forests at Lugny-Plottes-Chardonnay in Burgundy, France.

Figure 22
Seed source no. 8: One of the best plus trees at Sailershausen, Germany. All plus trees were of good or superior stem quality (dbh > 30 cm, clear bole > 5 m).

WST Trial - Soil Analysis

Soil Survey carried out by Christopher Guest

Lab results by Yara UK Ltd.

Date of survey: 19-Nov-19

Last Updated 31-Jan-20

Estate	Block	Depth of Profile (cm)	Groundwater Present	Reduction/ Mottling	Plough Layer Depth (cm)	HCl Reaction (A Horizon)	HCl Reaction (B Horizon)	HCl Reaction (C Horizon)	Horizons Present	Soil Texture Classification	Soil Type
Fontmell Hill Est.	FME-01	100	No	No	32	Yes	Yes	Yes	B (37 cm), C+	Clay Loam	Calcareous Brown Earth
	FME-02	100	No	No	32	Yes	Yes	Yes	B (44 cm), C+	Clay Loam	Calcareous Brown Earth
	FME-03	100	No	No	28	Yes	Yes	Yes	B (30 cm), C+	Sandy Clay Loam	Calcareous Brown Earth
	FME-04	60	No	No	30	Yes	Yes	Yes	B (18 cm), C+	Sandy Clay Loam	Calcareous Brown Earth

	pH	P	K	Mg	Ca	Cu	S	Mn	Na	Zn	B
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
FME-01	8,0	9	101	47	3466	2,3	5	32	16	3,9	1,14
FME-02	7,9	11	90	42	3418	2,4	5	30	17	3,5	1,14
FME-03	8,2	6	82	35	3134	1,5	4	30	16	1,8	0,87
FME-04	7,9	10	120	41	3586	3,1	3	29	18	3,1	1,44
Average	**8,0**	**9,0**	**98,3**	**41,3**	**3401,0**	**2,3**	**4,3**	**30,3**	**16,8**	**3,1**	**1,15**

	Organic Carbon	Total Nitrogen	CEC	Organic Matter	C:N Ratio	Sand	Silt	Clay
	%	%	meq/100 g	DUMUS (%)		%	%	%
FME-01	1,7	0,16	14,8	2,9	10,5	42,87	36,52	20,61
FME-02	1,8	0,15	14,5	3,1	12,0	40,11	38,64	21,25
FME-03	0,9	0,08	13,2	1,6	11,6	53,81	20,32	25,87
FME-04	1,4	0,14	15,3	2,4	10,0	65,63	15,53	18,84
Average	**1,5**	**0,13**	**14,5**	**2,5**	**11,0**	**50,61**	**27,75**	**21,64**

WST Trial - Soil Analysis

Soil Survey carried out by Christopher Guest

Lab results by Yara UK Ltd.

Date of survey: 21-Nov-19

Last Updated 31-Jan-20

Estate	Block	Depth of Profile (cm)	Groundwater Present	Reduction/ Mottling	Plough Layer Depth (cm)	HCl Reaction (A Horizon)	HCl Reaction (B Horizon)	HCl Reaction (C Horizon)	Horizons Present	Soil Texture Classification	Soil Type
Sotterley Estate	SOE-01	110	No	B & C Horizons	30	No	Yes	Yes	B (35 cm), C+	Clay	Surface water gley
	SOE-02	100	At 97 cm	B & C Horizons	35	No	No	Yes	B (33 cm), C+	Clay	Surface water gley
	SOE-03	100	At 110 cm	B & C Horizons	33	No	Yes	Yes	B (28 cm), C+	Clay Loam	Surface water gley
	SOE-04	100	At 96 cm	B & C Horizons	36	No	No	Yes	B (27 cm), C+	Sandy Clay	Surface water gley

	pH	P	K	Mg	Ca	Cu	S	Mn	Na	Zn	B
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
SOE-01	8,0	4	126	86	4053	3,3	2	29	40	1,7	1,16
SOE-02	7,8	3	104	85	3528	3,2	1	28	39	1,3	1,09
SOE-03	7,9	3	112	86	4179	3,2	3	30	39	1,4	1,16
SOE-04	7,7	3	113	71	3765	3,2	1	44	28	1,4	1,17
Average	**7,9**	**3,3**	**113,8**	**82,0**	**3881,3**	**3,2**	**1,8**	**32,8**	**36,5**	**1,5**	**1,15**

	Organic Carbon	Total Nitrogen	CEC	Organic Matter	C:N Ratio	Sand	Silt	Clay
	%	%	meq/100 g	DUMUS (%)		%	%	%
SOE-01	0,7	0,07	17,8	1,2	10,0	34,74	29,98	35,28
SOE-02	0,5	0,04	15,4	0,8	11,6	40,99	22,76	36,25
SOE-03	0,8	0,06	18,3	1,3	12,6	35,31	36,27	28,42
SOE-04	0,8	0,07	16,3	1,4	11,6	48,09	19,46	32,45
Average	**0,7**	**0,06**	**17,0**	**1,2**	**11,5**	**39,78**	**27,12**	**33,10**

WST Trial - Soil Analysis

Soil Survey carried out by Christopher Guest

Lab results by Yara UK Ltd.

Date of survey: 30-Jan-19

Last Updated 31-Jan-20

Estate	Block	Depth of Profile (cm)	Groundwater Present	Reduction/ Mottling	Plough Layer Depth (cm)	HCl Reaction (A Horizon)	HCl Reaction (B Horizon)	HCl Reaction (C Horizon)	Horizons Present	Soil Texture Classification	Soil Type
Spernal Estate	SPE-01	95	No	B & C Horizons	30	No	No	Yes	B (26 cm), C+	Silty Clay Loam	Surface water gley
	SPE-02	100	At 98 cm	B & C Horizons	26	No	No	Yes	B (37 cm), C+	Clay Loam	Surface water gley
	SPE-03	100	No	B & C Horizons	30	No	No	Yes	B (28 cm), C+	Clay Loam	Surface water gley
	SPE-04	100	No	B & C Horizons	28	No	Yes	Yes	B (28 cm), C+	Clay Loam	Surface water gley

	pH	P	K	Mg	Ca	Cu	S	Mn	Na	Zn	B
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
SPE-01	7,9	7	312	219	6390	11,7	5	52	31	4,8	5,59
SPE-02	8,2	2	208	377	5341	6,0	9	39	44	1,4	3,90
SPE-03	8,3	3	271	436	5309	4,9	18	55	45	1,5	2,74
SPE-04	8,3	2	211	228	5294	3,5	9	47	31	1,1	1,68
Average	**8,2**	**3,5**	**250,5**	**315,0**	**5583,5**	**6,5**	**10,3**	**48,3**	**37,8**	**2,2**	**3,48**

	Organic Carbon	Total Nitrogen	CEC	Organic Matter	C:N Ratio	Sand	Silt	Clay
	%	%	meq/100 g	DUMUS (%)		%	%	%
SPE-01	2,7	0,28	29,5	4,6	9,6	13,87	57,36	28,77
SPE-02	1,0	0,08	25,8	1,7	12,4	37,81	30,95	31,24
SPE-03	1,1	0,08	26,2	1,9	13,8	39,35	31,04	29,61
SPE-04	0,9	0,06	24,4	1,5	14,5	41,98	24,65	33,37
Average	**1,4**	**0,13**	**26,5**	**2,4**	**12,6**	**33,25**	**36,00**	**30,75**

YARA

Analytical Services
Agriculture, Horticulture, Amenity and the Environment

STANDARD ANALYTICAL METHODS (SOIL)

ELEMENT	DIGESTION EXTRACTANT	ANALYTICAL TECHNIQUE
Calcium	1 M Ammonium nitrate	Atomic Absorption or ICP
Magnesium	1 M Ammonium nitrate	Atomic Absorption or ICP
Manganese	1 M Ammonium acetate with 2 g/l quinol	Atomic Absorption or ICP
Boron	Hot water (80°C)	Solution spectrophotometry after complexing with azomethine or ICP
Copper	0.05 M EDTA disodium salt	Atomic Absorption or ICP
Molybdenum	Ammonium acetate (24.9 g/l) + oxalic acid (12.6 g/l)	Atomic Absorption with nitrous oxide or ICP
Iron	0.05 M EDTA disodium salt	Atomic Absorption or ICP
Zinc	0.05 M EDTA disodium salt	Atomic Absorption or ICP
Cobalt	0.05 M EDTA disodium salt	Atomic Absorption or ICP
Iodine	Hot water (80°C)	Ion specific electrode
Phosphorus	OLSEN (sodium hydrogen carbonate)	Solution spectrophotometry after complexing with ammonium molydate
Potassium	1 M Ammonium nitrate	Flame emmission spectrometry or ICP
Sulphur	Calcium tetrahydrogen Diorthophosphate	Solution spectrophotometry of precipitated barium sulphate or ICP
pH	Water	pH electrode/meter
Organic Matter	WALKLEY BLACK (oxidation of organic matter with potassium dichromate + sulphuric acid) OR DUMAS METHOD	Spectrophotometry CNS analyser
Nitrogen	Sulphuric/orthophosphoric acid digestion OR DUMAS METHOD	Kjeldhal distillation CNS analyser
CEC (Cation Exchange	Leached with 1 M ammonium acetate following water rinse	Atomic Absorption or ICP
$CaCO_3$ Total	Conc. Hydrochloric acid	Volume of CO_2 released
$CaCO_3$ Active	Drouineau Galet (ammonium oxalate)	Titration with K permanganate after addition of 5% sulphuric acid
EC Electrical Conductivity	Water or calcium sulphate	Conductivity meter
Nitrate	Water or calcium sulphate	Colourimetric Analyser

ALL METHODS (EXCEPT FOR NITROGEN WHICH IS TOTAL AND MANGANESE WHICH IS EASILY REDUCIBLE) DETERMINE THE LEVELS OF AVAILABLE NUTRIENTS.

ICP Inductively Coupled Plasma Analyser
CNS Carbon/nitrogen/sulphur Dumas combustion analyser

Wellington Road, The Airfield, Pocklington, York YO42 1DN.
Tel: 01759 305116. **Fax:** 01759 306955. **E-mail:** ypl.laboratory@yara.com

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Certificate No: 301/93

Appendix 4: Beating-up, base measurements, mortality and first-year growth

Figure 23
Saplings for beating-up at Fontmell (left) and Sotterley (right).

Saplings for beating-up Spare saplings for beating-up were marked and kept separate by seed source and planted together at the edge of each trial site but kept clearly separate from the experiment (Figure 23).

First-year mortality The greatest wild service mortality was at Spernal with 50 saplings dead followed by 43 dead at Sotterley and 6 dead at Fontmell (Table 5). Significantly lower mortality at Fontmell could be attributed to the use of triticale as a nurse crop in combination with a shorter drought period and some irrigation.

Fontmell Estate Beating-up of wild service was carried out at Fontmell on 2 December 2020. 6 dead wild service saplings were replaced in total. None of the admixed species were replaced in the trial or buffer zone as mortality was < 3%.

Sotterley Estate Beating-up of wild service was carried out at Sotterley on 4 December 2020. 43 dead wild service saplings were replaced in total. There was significant mortality of the admixed species as these were not watered during the summer. Within the trial area a total of 467 hornbeam, 355 oak, 67 maple and 200 hazel were replaced in November 2020. Beating-up of the oak buffer zone was carried out but there are no figures available.

Spernal Estate Beating-up of wild service was carried out at Spernal on 3 December 2020. 49 dead wild service saplings were replaced in total. Despite taking some spare plants from Fontmell to Spernal, there were not quite enough saplings to replace all the failed saplings from the seed sources Lugny-Plottes-Chardonnay, Rahay and Parco Cavaioni. There was significant mortality in the admixed species. Within the trial area a total of 727 hornbeam, 466 oak, 245 maple and 356 hazel were replaced in November 2020. A total of 504 oak were replaced in the buffer zone. The ground was extremely wet when the beating-up was carried out with some mild surface waterlogging. This site can clearly be very wet in winter and very dry in summer. A drainage ditch runs along the north western boundary

Table 5
Summary of first-year measurements (mean values per site and seed source). Legend: H_0 = initial height at planting[§], Mort = first-year mortality (actual sapling number), H_1 = height at the end of first growing season (2020) after planting, I_H = first-year growth.

	Fontmell				Sotterley				Spernal			
Seed source	H_0 cm	Mort	H_1 cm	I_H cm/y	H_0 cm	Mort	H_1 cm	I_H cm/y	H_0 cm	Mort	H_1 cm	I_H cm/y
1 Ast Wood	56.6	0	68.4	11.8	54.2	4	76.7	22.5	51.9	4	62.3	10.4
2 Stoopers	60.2	3	70.2	10.1	60.6	7	78.7	18.0	61.7	3	67.8	6.1
3 Tortoise	54.9	2	69.8	15.0	62.1	1	76.5	14.4	54.3	2	65.5	11.2
4 Escatalns	35.1	0	50.5	15.4	29.9	7	55.0	25.1	26.9	9	37.0	10.1
5 Harcourt	27.8	0	44.0	16.2	31.0	7	58.8	27.8	25.9	5	38.5	12.6
6 Rahay	47.5	0	64.3	16.8	43.8	2	80.3	36.5	38.0	10	50.3	12.2
7 Burgundy	45.1	0	60.8	15.6	50.1	5	77.2	27.1	47.3	4	56.9	9.6
8 S-hausen	63.9	1	75.8	11.9	67.2	5	85.1	17.9	64.2	3	72.7	8.5
9 Cavaioni	44.7	0	60.2	15.5	43.1	5	82.3	39.3	39.7	10	48.0	8.3

§: Overall ranking of seed sources according to sapling height at the time of planting: 8 Sailershausen > 2 Stoopers Wood > 3 Tortoiseshell Wood > 1 Ast Wood > 7 Burgundy (Lugny-Plottes-Chardonnay) > 6 Rahay > 9 Parco Cavaioni > 4 Escatalens > 5 Harcourt.

of the field in which the trial is located. Water runs seasonally along this drainage ditch. A drainage ditch also runs along the north eastern field boundary along which water runs throughout the entire year. Old field drains are probably present in the field where the trial is located but cannot be confirmed as the history of the site is unknown. There is probably impeded drainage (due to waterlogging or by the presence of a hardpan) due to years of soil cultivation, which may have damaged the soil structure.

Measurements

The Sailershausen saplings were on average both the tallest at the time of planting and following 1 year's growth across the 3 trial sites (Table 5). The seed sources Escatalens and Harcourt were on average both the shortest saplings at the time of planting and following 1 year's growth across the 3 sites. On average, the saplings across all seed sources were the tallest at Sotterley. On average, the saplings across all seed sources were the shortest at Spernal.

Growth

The average greatest height increment across all seed sources was at Sotterley except for Tortoiseshell Wood, where the height increment was greatest after one year's growth at Fontmell. Based on the data presented in Table 5, a preliminary analysis indicated that first-year height growth decreased with increasing initial height and was largest at Sotterley, smaller at Fontmell and smallest at Spernal (Figure 24). First-year height growth did not depend on seed source origin other than as expressed through initial height.

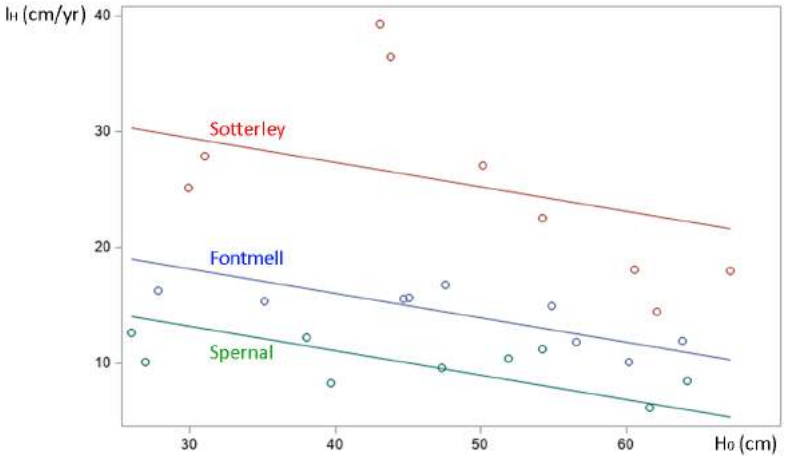

Figure 24
First-year height growth (I_H) vs. initial height (H_0) for all seed sources at Sotterley (red), Fontmell (blue) and Spernal (green). An analysis of variance indicated that first-year height growth decreased with increasing initial height and did not depend on seed source origin other than as expressed through initial height. The lines indicate the level of growth at each site.

Irrigation

Conditions became very dry across England in the late spring and early summer of 2020 when the tree leaves were flushing (Table 6). At Fontmell, rainfall was 63 mm in March, 57 mm in April and 4 mm in May. At Sotterley Estate, rainfall was even more limited, 30 mm in March, 22 mm in April and 3 mm in May. At a NextGen site 2 km north of Spernal Estate, rainfall was 23 mm in March, 28 mm in April and 2 mm in May.

Fontmell Estate

With no rain forecast and dry deeply cracked ground, on 27 May 2020 a tractor drawn 10,000 litre capacity un-pressurised bowser connected to a 12.7 mm garden hose was used to irrigate all wild service and field maple saplings (the field maples were very small and due to the effort put into sourcing this special Sailershausen seed, the decision was taken to irrigate these also). It was estimated that each sapling received between 8-10 litres (Table 7). Watering all of these saplings took a total of 2 days. Due to a combination of the labour costs and forecasted rain in mid June, the wild service saplings were watered only once.

Sotterley Estate

With no rain forecast and deeply cracked ground, on 24 May 2020 a tractor drawn 1,000 litre capacity un-pressurised bowser was brought to site. For practical reasons at the time, each wild service was watered using a 2 gallon (7.57 litre) black bucket and received circa 3.79 litres of water ('half a bucket') (Table 7). A barley straw mulch mat was laid out around each wild service tree following the first watering in order to try to retain moisture within the soil (barley straw mulch was available and did not contain as much nitrogen as hay or digestate).

The wild service saplings were watered a further 4 times ((26 & 29 May, 1 & 5 June) using a tractor drawn 4,000 litre capacity un-pressurised bowser connected to a 75 mm flexi pipe. Each watering of the wild service within the site took about 2 hours. It was estimated that each plant received about circa 6.1 litres of water per watering. The admixed species were not watered.

Table 6
Precipitation (mm per month) during 2020 at Fontmell, Sotterley and Spernal.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fontmell	93	152	63	57	4	82	38	116	55	171	79	146
Sotterley	40	89	30	22	3	60	42	37	118	89	30	111
Spernal	46	120	23	28	2	85	63	115	35	130	48	111

Table 7
Estimated volume of irrigation water (litres per wild service sapling ≈ mm per square metre) during 24 May - 25 June 2020.

Date	Fontmell	Sotterley	Spernal
24 May		3.8	
26 May		6.1	40
27-28 May	9		
29 May		6.1	30
1 June		6.1	
2 June			30
5 June		6.1	
11 June			30
25 June			30
Total	9	28.2	160

The ground in between the planting lines was rotovated after the first watering. This was carried out to improve the water absorption capability of the soil due to the significant large cracks present during the drought. The saplings did not have much protection from drying conditions as the triticale had failed following sowing and the very limited weed growth in the early part of the season due to the drought.

Spernal Estate

Following a very wet winter with saturated soils, the soil started drying out from February with cracks appearing within 3 weeks. By late spring, cracks were the width of a fist and over 60 cm deep. With no rain forecast, deeply cracked ground and the wild service appearing to struggle (wild service looked ok and to be coping better than the admixed species 2 weeks previous), on 26 May 2020 a 22 mm pipe was connected to the mains water supply and stepping down to a 12 mm flexi pipe for actual watering. Each wild service received ca. 40 litres (one minute of watering) at first watering whilst the subsequent 4 waterings (29 May, 2, 11 and 25 June) each provided every sapling with ca. 30 litres (Table 7). Once set up, watering all wild service took one day. The saplings did not have much protection from drying conditions as the triticale had failed following sowing and the very limited weed growth in the early part of the season due to the drought.

Water and growth

According to unpublished local records (Table 6), Fontmell received ca. 295 mm natural rainfall during the five months of April-August 2020, 116 mm (39 %) of which fell during August. Sotterley received ca. 165 mm during that same period, with only 37 mm (23 %) in August. Spernal (measured at the NextGen site 2 km further north) received ca. 295 mm, with 115 mm (30 %) in August. In summary, Fontmell and Spernal had quite similar water

supply from natural rainfall during the growing season, while Sotterley received approximately half as much water. Adding the estimated volumes of irrigation water to the natural precipitation in May and June, the wild service saplings planted at Fontmell received ca. 95 mm in these two months, Sotterley 91 mm and Spernal 247 mm.

The slightly higher growth rates (Figure 24) and lower mortality rates (Table 5) at Fontmell as compared to Spernal are consistent with the less compact and naturally better drained soil at Fontmell (50 vs. 33 percent sand, Table 4) as these soil characteristics may be beneficial during summer drought. Clearly, the larger volume of irrigation water at Spernal did not result in larger growth rates.

The substantially higher growth rates at Sotterley as compared to Fontmell, the two sites having almost identical sums of rainfall + irrigation in the critical months of May and June, are consistent with the somewhat more fertile and ameliorated soil at Sotterley. Moreover, the use of straw mulch at Sotterley may have improved soil water retention.

The much lower growth rates at Spernal as compared to Sotterley, even though substantially more irrigation water was supplied at Spernal, may be attributed to the relatively high content of silt in the soil at Spernal, resulting in a very compact soil, and the soil amelioration at Sotterley, resulting in a well-aerated soil, improved drainage and overall better conditions for root growth. Again, the use of straw mulch at Sotterley may have improved soil water retention, thus contributing to better growth.

Maintenance

Fontmell Estate

The triticale established very well. It may be that general mortality across this site was relatively low compared to the other sites due to the shelter provided by the triticale against the sun in the drought.

The only weeding carried out was the removal of occasional weeds growing in the tubes containing the wild service and the field maple. Bindweed became visible by 11 0ctober 2020 when the triticale was starting to cast seed and collapse. Bind weed could become a problem in summer 2021 and mowing in between the lines may become necessary to prevent it ‘strangling’ the saplings. There was also evidence of significant localized rat activity in October 2020 and probably due to the triticale seed present. Due to this, regeneration of triticale in subsequent years may be compromised.

Sotterley Estate

By August, there were a number of broadleaved weeds including thistles across the site therefore, a rear mounted flail on a compact tractor was used to cut the weeds between the planting lines.

Spernal Estate

Weeding around the wild service saplings occurred while the trees were being watered in late May. This involved pulling weeds out of tubes and some trampling. Tall ragwort had established by late summer. A rough-cut mower was used to clear weeds between the

planting lines in October 2020 in order to make the saplings more visible for a beating-up assessment.