Grower Summary

FV 450

Asparagus: Sustainable soil management for stand longevity and yield optimization

Final Report, April 2018

Project title:	**Asparagus: Sustainable soil management for stand longevity and yield optimization**
Project number:	FV 450
Project leader:	Dr Rob Simmons, Cranfield University
Report:	Final Report, April 2018
Previous report:	Year 1 Annual Report, May 2017
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Location of project:	Gatsford, Ross-on-Wye
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Date project commenced:	01 May 2016
Date project completed (or expected completion date):	30 April 2018

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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

GROWER SUMMARY

Headlines

- Findings indicate a strong trend for Gijnlim roots to expand more into the wheeling than Guelph Millennium. However, no significant differences in the spatial distribution of root mass densities were observed between Gijnlim and Guelph Millennium varieties in a two-year old asparagus stand.
- Although yield data indicates that re-ridging does not reduce yield for either variety, growers are strongly advised to undertake exploratory root profile distribution surveys before undertaking tillage operations. Results suggest that for wheelings on 1.83 m centres, subsoiling operations to 0.3 m depth are safe to undertake where either rye or mustard companion crops are grown. However, in a two-year old asparagus stand there is a risk of damaging 2-5% of the total root mass when sub-soiling in the wheelings at 0.175 cm depth for Guelph Millennium and at 0.3 m depth for Gijnlim.
- Rye or mustard companion crops seem to restrict the development of asparagus storage roots to the ridge zone, with less root growth in the surface (< 0.15 m) of wheelings. The rye/no-Shallow Soil Disturbance (SSD) / non-ridged treatment yielded significantly lower (18.9 – 28.5%) than the mustard/no-SSD/ridged, PAS 100 compost/SSD and straw mulch/SSD, both ridged and non-ridged, bare soil/SSD/non-ridged and bare soil/no-SSD/non-ridged treatments, respectively. The reduction in yield associated with the non-ridged rye no-SSD treatment contrasts strongly with findings of North America asparagus growers and warrants further investigation under FV 450a.

Background

Field work associated with UK asparagus production, i.e. tillage operations, such as ridging and sub-soiling, spray operations, harvesting (foot-trafficked and/or hand harvested using picking rigs) can result in progressive and severe compaction of all inter-bed wheelings.

In addition, research undertaken over the last 20 years has demonstrated that root damage associated with annual re-ridging has a major impact on stand longevity and productivity (Drost & Wilcox-Lee, 2000; Putnam 1972; Reijmerink 1973; Wilcox-Lee & Drost 1991) and increases the susceptibility to crown and root rots caused by *Phytophthora megasperma* (Falloon & Grogan 1991) and *Fusarium oxysporum* f.sp. *asparagi* (Elmer, 2001). Both root damage and crown and root rots significantly contribute to yield decline.

Further, compaction of wheelings leads to a significant reduction in infiltration resulting in an increased risk of surface water ponding and on sloping land, run-off generation and erosion. In turn, surface water ponding and/or erosion compromises field operations by restricting foot and vehicular traffic, and water ponding in furrows increases the risk of crown and root rots leading to yield decline. The long-term field trials established under this project will evaluate a range of best management practices to prevent and/or mitigate compaction, improve soil structural status in asparagus wheelings and facilitate long-term profitability of asparagus production. The experimental trials will compare shallow soil disturbance (SSD) and mulch attenuation options, cover/companion cropping, and non-till options against conventional practice.

Summary

In April 2016 two replicated field experiments were established at Gatsford Farm, Ross-on-Wye within a 4.5 ha asparagus field. Asparagus ‘A’ crowns of both Gijnlim and Guelph Millennium were planted on 20-21st of April 2016 on the flat at an intended depth of 0.14 m at 0.16 m spacing between crowns on 1.83 m wide bed centres.

Experiment 1 (48 experimental plots) is restricted to Gijnlim which represents 70% of UK field grown asparagus. Shallow soil disturbance (SSD) was applied on 20 April 2018 using a winged tine (Niziolomski et al., 2016) at 0.25 - 0.3 m depth with occasional asparagus root damage observed behind the tine. Shallow soil disturbance is included in those treatments to which mulch (PAS 100 compost or straw) will be applied. The principle behind this is that the mulch-SSD treatments are intended to replicate the cover (mulch) and ‘bio-drilling’ (tillage-SSD) associated with the companion crops.

Experiment 1: Treatment descriptions

Variety	Treatment description	Re-ridging
Gijnlim	Companion Crop - rye	R
Gijnlim	Companion Crop - rye	Non-R
Gijnlim	Companion Crop – mustard	R
Gijnlim	Companion Crop – mustard	Non-R
Gijnlim	PAS 100_SSD	R
Gijnlim	PAS 100_SSD	Non-R
Gijnlim	Straw Mulch_SSD	R
Gijnlim	Straw Mulch_SSD	Non-R
Gijnlim	Bare soil_SSD	R
Gijnlim	Bare soil_SSD	Non-R
Gijnlim	Bare soil_No-SSD	R
Gijnlim	Bare soil_No-SSD	Non-R

Annual re-ridging (R) or Zero-ridging (Non-R). Treatments highlighted in green will be included in Experiment 2.

The mulch treatments were also applied on 20 April 2018. PAS 100 compost was applied to three wheelings per treatment (central wheeling and guard rows) at a rate of 25 t ha^{-1}. Straw was applied to three wheelings per treatment (central wheeling and guard rows) at 6 t ha^{-1}. Further, SSD was applied using a winged. Companion crops included in this trial were rye (*Cereale secale* L var. Protector) and mustard (*Sinapis alba* L. var. Severka) seeded on 10 August 2017 at rates of 150 kg ha^{-1} and 19 kg ha^{-1}, respectively. Companion crops were applied to the central wheeling only. The efficacy of these rates for run-off and erosion mitigation were confirmed by an MSc project linked to this research (Órpez Milán, 2017). Experiment 2 compares varietal differences in root development/architecture and root profile distribution as affected by subsoiling treatments for two widely grown varieties, Gijnlim and Guelph Millennium.

Experiment 2: Treatment descriptions

Variety	Treatment description	Re-ridging
Gijnlim	Bare soil_SSD	R
Gijnlim	Bare soil_SSD	Non-R
Gijnlim	Bare soil_No-SSD	R
Gijnlim	Bare soil_No-SSD	Non-R
Millennium	Bare soil_SSD	R
Millennium	Bare soil_SSD	Non-R
Millennium	Bare soil_No-SSD	R
Millennium	Bare soil_No-SSD	Non-R

Annual re-ridging (R) or Zero-ridging (Non-R). Treatments highlighted in green are included from Experiment 1.

Re-ridging versus non-ridging (zero) treatments were applied to both Experiment 1 and Experiment 2 in April 2018 and will be evaluated in project FV 450a. Baseline soil sampling undertaken during 17th – 21st October and 1st – 3rd November 2016 indicated that there was no significant difference in the parameters tested (Reference page 7-8) between experimental plots. This is critical as it means that any differences observed can in future, be attributed to the best management practice treatments applied.

Comparison of root architecture for two asparagus varieties

Baseline root coring in Year 1 indicated that root mass densities (RMD) are generally higher for Gijnlim as compared to Guelph Millennium for most soil depths and sample locations. However, no significant differences between varieties were detected in the overall spatial distribution of storage roots. For both varieties, one year after planting, about 65% of the total measured plant root mass is found at the crown zero line (central line of ridge Figure A) near the surface at 0 - 0.15 m depth. Very few roots have explored the soil at 0.3 m, 0.6 m and 0.9 m away from the crown zero line. Further away from the crown zero line, roots tend to be mostly in the 0.15 – 0.30 m and 0.3 - 0.45 m soil layers and avoid the topsoil (0.0 - 0.15 m).

For both varieties, no roots were detected in any of the root cores (0 – 0.45m depth) taken 0.9 m away from the crown zero line. When the dimensions of the re-ridged bed-form are superimposed on the baseline varietal root distribution, the results indicate that for both Guelph Millennium and Gijnlim after 1-year of growth, there is a risk of damaging 7-9% of total root biomass if the rotating tines of the bed-former used were to till soil in the 0.15 - 0.3 m depth zone within 0.3 m of the crown zero line. In addition, for Guelph Millennium there is a risk of damaging 2% of total plant root biomass if the rotating tines of the bed-former till soil in the 0.0 - 0.15 m depth zone within 0.3 m of the crown zero line. The year-one field trial results indicate that due to the absence of storage roots for both Gijnlim and Guelph Millennium, sub-soiling operations (for the control of run-off and erosion) could be undertaken at operating depths of 0.175 – 0.3 m, where crowns are planted on 1.83 m centres.

It is of note that the high Penetrative Resistance measurements (PR value >3 MPa) observed in the upper sub-soil during the baseline sampling could impact asparagus root development. The observed high Bulk Density (BD) measurements (>1.45 g cm^{-3}) in the mid top-soil and more notably in the upper sub-soil are likely to impede root growth (Jones, 1983). Historically, asparagus roots have been observed in soils with PR values of 1.96 MPa and 2.9 MPa (Reijerink, 1973). However, the limiting values of PR and BD for the expansion of the asparagus storage root system and hence ability to store total carbohydrates (COH) is unknown.

Results from Year 2 root sampling showed that for both Gijnlim and Guelph Millennium, the average root mass densities (RMD) at the crown zero line for the 0.15 – 0.3 m depth increased significantly from 8-12 kg m^{-3} in Year 1 up to ca. 20 kg m^{-3} in Year 2.

Year 2 results continue to indicate that Gijnlim roots expand more into the wheeling as compared to Guelph Millennium, although Guelph Millennium roots are found closest to the surface in the inter-row zone. These observed varietal differences are not, however, statistically significant. This trend will be further monitored under FV540a.

Year 2 root maps comparing the spatial distribution of the root mass for Gijnlim crops grown with and without companion crops in the wheelings indicate that the presence of the companion crop seems to restrict the asparagus storage roots to the ridge zone (crown zero line). This is particularly apparent 0.6-0.9 m from the zero crown line at 0.15 – 0.3 m depth. With companion crops growing in the wheeling the wheeling zone shows lower densities of asparagus roots. The results indicate that on average the Gijnlim without companion crops had greater RMD at 0.6 m and 0.9 m from the crown zero line as compared to the companion crop treatments. This trend will continue to be monitored under FV 450a.

Year 2 varietal root distributions indicate that for Gijnlim there is a risk of damaging <2% of total plant root biomass if the rotating tines of the bed-former till soil to 0.15 m depth within 0.3 m and 0.6 m of the crown zero line. For Gijnlim, if ridging tines disturb soil at 0.15 – 0.30 m depth, 0.3 and 0.6 m from the crown zero line there is a risk of damaging *circa* 6% and 2-5% of total plant root biomass respectively (Figure A).

For Guelph Millennium there is also a risk of damaging <2% and 2.2% of total plant root biomass if the rotating tines of the bed-former till soil to <0.15 m depth within 0.3 m and 0.6 m of the crown zero line. If ridging tines disturb soil at 0.15 – 0.30 m depth, 0.3 and 0.6 m from the crown zero line there is a risk of damaging *circa* 5% and 2-5% of total plant root biomass respectively.

The Year 2 results indicate that for Gijnlim, sub-soiling operations to 0.175 m depth with a full range of tine configuration options (Niziolomski et al. 2016) can continue to be undertaken with potential to damage <2.0% of total plant root biomass. In contrast, the root profile distribution of Guelph Millennium suggests that a modified para-plough (Niziolomski et al. 2016) should not be utilised at 0.175 m depth as this has the potential to damage 2-5% of roots at 0-0.15 m depth 0.6 m from the crown zero line.

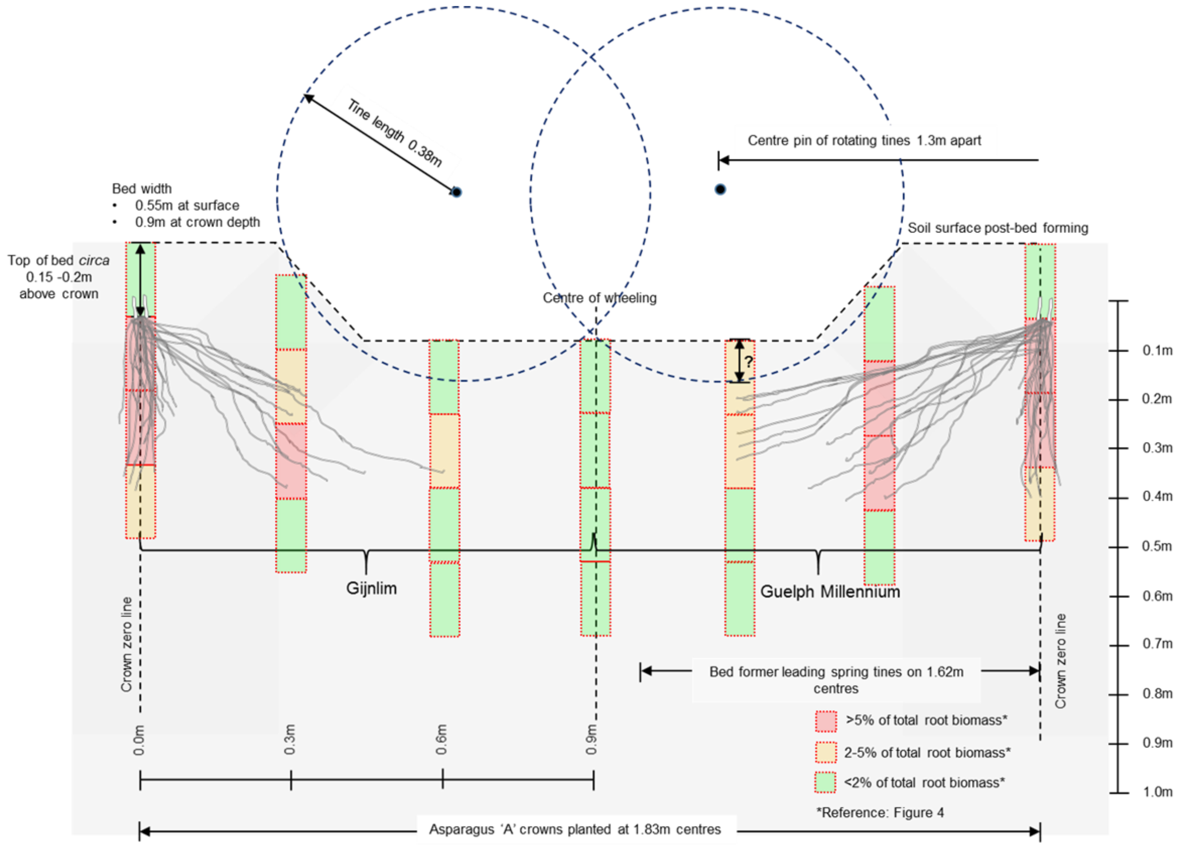

Figure A. Potential root damage associated with annual re-ridging operations, 2 years after planting

At a sub-soiling depth of 0.3 m, neither the modified para-plough or a winged tine of dimensions/configuration investigated by Niziolomski et al. (2016) should be utilised as the below ground disturbance patterns intersect roots within the 0.15-0.30 m depth 0.6 m from the crown zero line suggesting damage to 2-5% of total plant root biomass, both for Gijnlim and for Guelph Millennium.

As stated above, Year 2 root maps comparing the spatial distribution of the root mass for Gijnlim crops grown with and without companion crops in the wheelings show that the presence of the companion crop appears to restrict the asparagus storage roots to the ridge zone (crown zero line- 0.3 m). This is particularly apparent 0.6-0.9 m from the zero crown line at 0.15 – 0.3 m depth. At 0.6 m and 0.9 m away from the crown, the proportions of total root mass stay below 2% for the plots with companion crops, whereas the plots without cover had 2-5% of total root mass present in some of these wheeling positions.

For Gijnlim, this has implications in terms of reducing potential root damage associated with subsoiling (to reduce erosion risk through improved infiltration, surface roughness and surface depression storage) at both 0.175 and 0.3 m depth as root development in the 0-0.15 m and 0.15-0.30 m depth 0.6m from the crown zero line is reduced.

This also implies that when asparagus is undersown with either rye or mustard companion crops sub-soiling operations to 0.3 m depth with a full range of tine configuration options (Niziolomski et al. 2016) can be undertaken with the potential to damage <2.0% of total plant root biomass.

However, it is still strongly recommended that growers undertake exploratory root profile distribution surveys prior to commencing re-ridging and/or sub-soiling operations. Training in root sampling will be provided to growers under FV 450a.

The results of the MSc Thesis (Lee, 2017) indicate that root growth is inhibited under the wheeling due to compaction and probably also due to tillage operations. Correlation analysis showed that there was a significant ($p<0.05$) negative but weak correlation between root mass distribution and soil PR data integrated for the same soil depth intervals and positions; r^2=-0.183. This was a pioneer study, only based on 5 fields. More work is needed to provide a more robust picture of root mass density distribution for different asparagus varieties, stand ages, management practices and soil types. This will be a core objective in FV 450a.

In 2018 a short 4-week (April 24th to May 21st) harvest from 19-cuts was taken from the experimental plots by George Nairn (Cobrey Farms). For Experiment 1 (Gijnlim), Mean (n=19) spear count, Total Harvest (kg per plot^{-1}) and Estimated Yield (kg ha^{-1}) were recorded. For the varietal component of the FV 450 trial (Experiment 2), average spear weight, Total Harvest and Estimated Yield were recorded for both Gijnlim and Guelph Millennium.

With the exception of the rye No-SSD ridged as compared with the non-ridged treatment, ridging did not result in any significant difference ($p > 0.1$) in yield for the BMPs evaluated in this trial. However, it is of note that rye No-SSD ridged and non-ridged Total Harvest and Estimated Yield values are 43.0 and 33.5 (kg per plot^{-1}) and 2984 and 2327 (kg ha^{-1}), respectively. This equates to a 22% reduction in yield for the non-ridged as compared with ridged rye No-SSD treatments.

Further, and critically, the rye No-SSD non-ridged Estimated Yield (kg ha^{-1}) is significantly, 18.9%, 23.3%, 28.5%, 25.3%, 19.0%, 19.5% and 24.7% lower than the mustard No-SSD ridged, PAS 100 Compost_SSD and Straw Mulch_SSD ridged and non-ridged, Bare soil_SSD non-ridged and Bare soil_No-SSD non-ridged treatments, respectively (Table Y).

This reduction in yield associated with the non-ridged rye No-SSD treatment is contrary to findings of North America asparagus growers (Personal Communication: Prof. Dan Drost) and may in part be due to the continued release of allelopathic exudates from non-ridged rye roots in wheelings not destroyed by the action of re-ridging. This will require further investigation.

PAS 100 compost SSD non-ridged total harvest (kg per plot^{-1}) and estimated yield (kg ha^{-1}) values of 46.9 kg per plot^{-1} and 3255 kg ha^{-1} are significantly ($p < 0.1$) higher compared to the mustard no-SSD non-ridged, rye no-SSD non-ridged, bare soil SSD ridged and bare soil no-SSD ridged treatments respectively.

Varietal yield results for the two year stand indicate that Guelph Millennium yields significantly lower (16 – 31%) than equivalent Gijnlim treatments. The Guelph Millennium, bare soil no-SSD ridged, bare soil no-SSD non-ridged, bare soil-SSD ridged, Bare soil SSD non-ridged treatments are associated with 16%, 31%, 23% and 27.3% lower Total Harvest and Estimated Yield (kg ha^{-1}) as compared with the equivalent Gijnlim treatments. However, growers consulted state that it is normal for Guelph Millennium to be associated with significantly lower yields than Gijnlim in early establishment years and that yields catch up in later years.

It is expected that the continuation of the long-term trials under FV 450a will form an evidence base for a paradigm shift in the way asparagus is cultivated in the UK, particularly the need for, and intensity of, annual re-ridging operations and the efficacy of a suite of BMPs to remediate compaction and their selection to avoid root damage. Minimizing root damage is known to contribute to stand longevity and productivity and decreases the susceptibility to crown and root rot.

Financial Benefits

It is envisaged that this project will provide information on the state of asparagus soils and provide focused, practical and robust guidance on how to identify and alleviate compaction and water-logging in asparagus wheelings, thereby reducing the risk of asparagus decline, increasing asparagus yields and farm profitability, while minimising environmental impact (an important consideration for growers considering GAEC greening rules, the needs of assurance schemes, environmental audits and demonstrating sustainable soil management).

- During 2005 – 2015 the area under asparagus cultivation in the UK increased from 890 – 2235 ha (>250%). In addition, during 2005 – 2015 British asparagus production during the traditional growing season (April-June) increased by >260% (2,050 t to 5,434 t). The ex-farm value of British asparagus in 2005 was circa £5.7 Million and in 2014, £27.6 Million. UK imports during the British season (April to June 2015) of 2,396 t, is valued at £8.4 million. Annual asparagus imports to the UK in 2014 amounted to 14,200 t, valued at £46.8 million. The potential for UK grown asparagus production to expand is significant.
- However, over a 10-year cropping cycle, asparagus decline largely attributed to *Fusarium* and *Phythophtora* can result in up to 60% loss of stand amounting to up to £16M in lost revenue per annum. A 10% reduction in yield losses due to asparagus decline would amount to a saving of >£1.6M to UK asparagus growers per year.
- Improved ability of UK growers to meet customer (supermarket) demand during the British asparagus season.

Action Points

This is only the 2nd year of this long-term replicated field trial now continued under FV 450a. The results support the recommendation that in order to prevent storage root damage through re-ridging operations or SSD, growers should undertake exploratory root profile distribution surveys prior to commencing re-ridging and/or sub-soiling operations.

