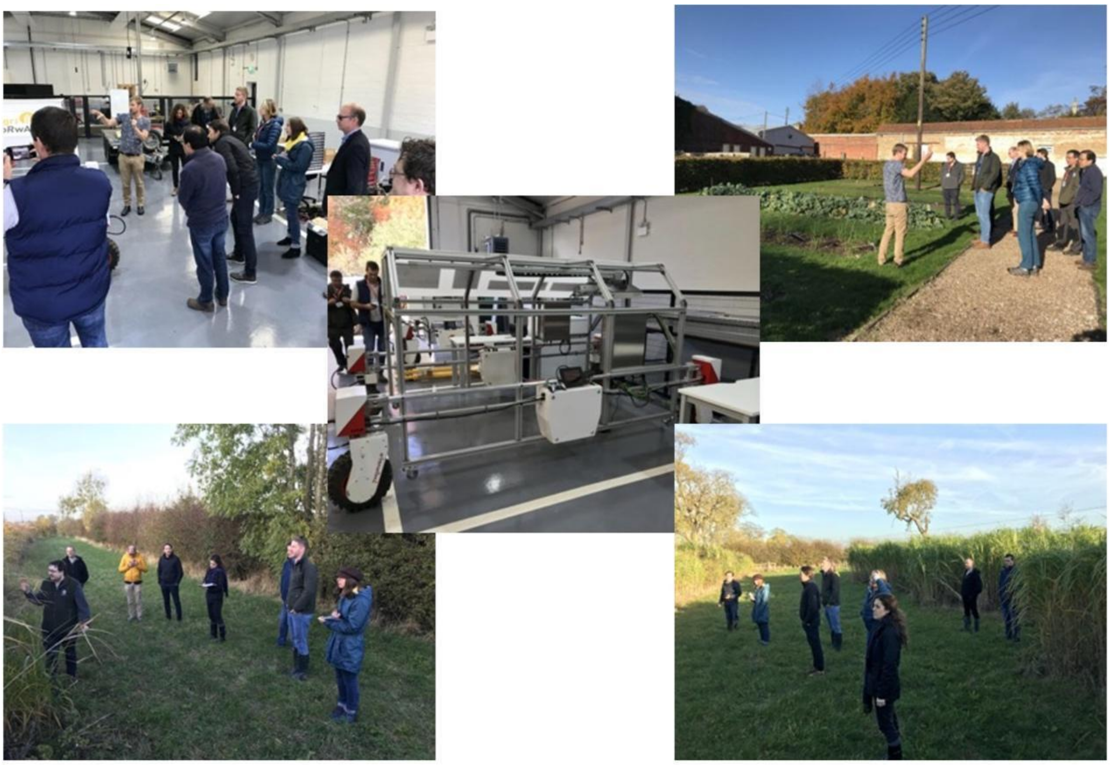
Biomass Feedstock Innovation Programme (Phase 1)

An SBRI Competition: 4887/02/2021

Project OMENZ* final report

- Terravesta Farm Ltd. 07/01/2022



*Optimising Miscanthus Establishment through improved mechanisation and data capture to meet Net Zero targets (TER-303-1-M)

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Preface

The current document corresponds to the final report of the project titled 'Optimising Miscanthus Establishment through improved mechanisation and data capture to meet Net Zero targets' (OMENZ), under Phase 1 of the Biomass Feedstocks Innovation Programme funded by BEIS.

This final report has been compiled according to the report specifications. The first section provides an assessment of the proposed innovation, section two describes the project plan for Phase 2, and the commercialisation plan is outlined in section three. Further information and data of the assessment and work undertaken during Phase 1 are included in the Appendices.

1. Assessment of the proposed innovation

1.1 Technical Description of Innovation

1.1.1 Crop Biology

Unlike most arable crops, Miscanthus is a relatively new crop that has only been planted at scale in the last ~20 years. The fact that it is not a UK native species is also part of the cause of the knowledge gap. Whilst improvements have been made in the last 10 years in terms of planting and agronomy, as well as breeding for new hybrids, further research is needed to better understand Miscanthus physiology with the ultimate goal of exploiting unique characteristics. Therefore, during Phase 1 we worked to identify critical knowledge gaps and potential indications for a quick win through the preliminary study of Miscanthus crop biology.

The aim of the assessment of crop biology was identifying potential treatments that could enhance the germination of Miscanthus rhizomes, disrupting dormancy and allowing faster germination and subsequent establishment to be trialled in Phase 2.

1.1.1.1 Rhizome improvements

From the investigations carried out in Phase 1, a number of treatments showed promising results on rhizome germination. There is a cautionary note to be made as this experiment was conducted very late and since this was a pilot study, technical replicates were not possible due to the resource constraint.

a) Temperature treatment (consisting of warming up the rhizomes before planting): This work has shown that by warming the rhizome at 25 °C for 2 hours, the germination rate increased by about 35% when compared with control (Appendix 1 D3.4C). A second test was carried out in late summer to test a range of temperature treatments (25/30/35 °C). The results showed that the highest germination rate was achieved at 25 °C and 35 °C for 2 hours. Interestingly, the 30 °C treatment failed to improve germination. The 25 °C temperature treatment has repeatedly shown to be effective in improving germination, proving the concept of our approach through plant biology to be valid.

b) Hormone treatment: Studies conducted during Phase 1 (Appendix 1 D3.4B) revealed that the application of Plant Growth Regulators (PGR), IAA and I3B, at 1/5000 concentration in a starch-based paste coating to the rhizome just before planting, has various effects on germination. We first applied each PGR separately which did not show any improvement in germination. However, when the 2 PGRs were combined, the germination rate improved by >10 % when compared to untreated rhizomes. The experiment was repeated with the concentration of the IAA and I3B mix treatment increased to 1/2000. A further increase in dormancy break was observed with this increased concentration of PGRs.

In conclusion: Together, these results have laid the foundation for further innovation in Phase 2 where pre-treatment of the rhizomes with higher temperature and PGR application will be applied at a larger scale to investigate the most feasible approach. This treatment shall be discussed in Section 2 of this report.

1.1.1.2 Seed improvements

a) Seed assessment: During Phase 1, consideration was made based on not-currently-exploited known plant physiology. The current approach of seed assessment for harvest was revisited to develop a different seed assessment process with the objective of reducing the skill level required (current minimum qualification is PhD research student), as well as improving the quality of the selected seeds (increasing subsequent vigour). The current new seed production site allows for better commercial direction and operational freedom during the seed collection process. A proposal has been made based on the plant biology of seed propagation which will be tested in Phase 2 (see Section 2.2.1c of this report).

b) The Requirement Matrix: In addition, a Requirement Matrix covering seed planting was defined taking into account our current practices. The Requirement Matrix identified the data that was required ahead of planting to determine the suitability of the land, as well as any necessary amendments. Land characteristics are further divided into two categories: those that can be amended (e.g. nutrient, pH) and those that cannot be amended (e.g. climate condition). A literature review identified available standards for planting which are currently available (upon request as it is Terravesta’s internal document). Although some information is still lacking, it will become available after testing on a selection of commercial cultivars during Phase 2.

1.1.2 Planting Material Production

Planting material production will be supported by crop biology thus having some crossover.

Analysing the chain of production of Miscanthus rhizomes during Phase 1 revealed issues in the quality of rhizomes received from the suppliers, which currently lack a standardised form of quality control. Ensuring rhizome quality is critical to guarantee good germination and establishment. Hence, research is needed to define and implement a straightforward method to conduct quality assessment (QA) during the production chain of Miscanthus rhizomes.

Assessing potential implementation of automated processes in Phase 1 exposed the following:

- Mechanisation is already used through the rhizome lifting process, hence there is no change needed in this step.

- Separating of the whole rhizome ball into individual rhizome pieces in the nursery is currently a manual process, making rhizome uniformity difficult for later automation. In addition, current dependence on labour has recently become even more critical with the existing labour shortages in the agricultural sector, increasing the importance of finding alternatives in automation.

1.1.3 Planting Process

During Phase 1, the planting process was reviewed to look for improvement in automation/mechanisation, identifying a number of strategies to be incorporated into the process.

1.1.3.1 During the land preparation phase:

- The Requirement Matrix (Appendix 1 D1.2): It will be important to match different land types, climatic conditions, soil nutrient availability and soil type with currently available cultivars. The Requirement Matrix parameters were defined based on current operation requirements and from that, considerations were made to highlight areas that need additional information for better decision making. This will be investigated in Phase 2. We are expecting our improvements will be informed by our Crop Biology investigations.
- Min-till option: The recent Terravesta Miscanthus carbon assessment report (https://www.terravesta.com/Miscanthus-carbon/) revealed that land preparation could contribute to reducing the carbon footprint of the overall process. Min-till options are generally separated into "no-till" or "strip-till". We know from experience that with no-till, rhizome establishment would be very difficult, while strip-till is the most common practice currently for min-till cultivation and could be a suitable method for Miscanthus planting. Hence, we have identified suitable machinery and processes to cater for both light and heavy land cultivation (see Appendix 1, D5.2) and opted to trial strip-till land preparation in Phase 2.

1.1.3.2 Automated planting:

- For seed based Miscanthus hybrids, automated planters are currently available on the market, therefore key optimisation should focus on seed vigour and production.
- For plug establishment, automated planting should be trialled during Phase 2 to demonstrate the plausibility of deployment, which would tackle the agricultural labour shortage in the UK. Under the current commercial model, plug planting is normally sub-contracted meaning it is up to the sub-contractor to invest in automated planters. However, the demonstration during Phase 2 would give confidence to the sub-contractor of the benefits of investing in such machines.
- In contrast, rhizome planting machinery requires much more innovation. Under the current business model, Terravesta supplies the planter to the grower. The planter requires four people at the back operating the planting function plus one tractor driver. It is a slow process requiring a lot of personnel time. With the looming UK

labour shortage due to current circumstances, automation would be important to implement. Phase 1 has identified mechanisation concepts that can be tested in Phase 2. However, during the assessment, the importance of rhizome quality at the production stage has been identified as an urgent area of revision. The importance of having an appropriate QA system in place has been realised. This is a major step forward in terms of identifying the most urgent need for innovation.

1.1.4 Effective Monitoring

Monitoring the establishment process aims to underpin the assessment of the success of the process and reduce potential inefficiencies.

A suitable Artificial Intelligence (AI) recognition software has been identified during Phase 1, which is capable of distinguishing Miscanthus plants from weeds (Appendix 1 D4.1 and D4.3). This is a major step forwards in establishment monitoring and validation as currently monitoring is conducted by eye during field surveys.

In addition, a rhizome planting counter has been designed during Phase 1 to monitor planting that could potentially eliminate the cause of establishment failure. The rhizome planting counter has an integrated GPS to record planting position, which can help with identifying emergent crops by integrated analysis with the AI also developed in Phase 1. The rhizome planting counter is currently being finalised and fitted onto the planter ready to be deployed in this year's planting.

1.2 Contribution to Increasing Sustainable Biomass Supply

Terravesta already operates a successful biomass supply chain consisting of 5000 ha of Miscanthus plantations owned by over 200 contracted growers.

Terravesta's current growers are made up of those growing old crops and those growing new crops, with Terravesta during its inception taking on lots of existing growers, many of whom had planted Miscanthus under the previous Energy Crops Scheme (https://www.gov.uk/guidance/industrial-energy-and-non-food-crops-business-opportunities-for-farmers). Their grower network includes some Miscanthus crops over 20 years old, through to more recent plantings.

The quality of Miscanthus planting has improved over the years as the industry learned better agronomic practices. Terravesta has witnessed how many of these older plantations produce a significantly lower yield than numbers published (DEFRA, 2021).

Terravesta began to establish new crops in 2017 (Figure 1), increasing their existing biomass supply with a select number of growers to develop the skills and technology needed to effectively establish new Miscanthus plantations and learn from the mistakes of previous practices.

Figure 1. -Redacted-

In 2017, Terravesta launched their own Miscanthus Variety, Terravesta Athena™ (https://www.terravesta.com/news/new-Miscanthus-variety-cereals/), and began to establish new crops for its customers. Over the last five years, they have learnt a lot, and the planting success rate has increased year on year leading to higher yields.

However, Terravesta's current planting rate has only been in the hundreds of hectares a year. To reach the thousands of hectares per year of planting which the CCC land use change report (2020) suggests is needed to reach Net Zero, more innovative approaches to establishment and monitoring are required. To increase planting rates, Terravesta needs improvements in germplasm preparation and handling, new techniques for soil cultivation, and better crop monitoring through more scalable technologies. The work done in the OMENZ project has provided the foundation for these improvements and will allow Terravesta to plant thousands of hectares a year more efficiently. Terravesta is also bringing other Miscanthus varieties to the market, and the studies to be conducted as part of the OMENZ project will help best match those crops to climate, soil type, and end-use to provide a cost-effective and stable biomass supply.

Terravesta’s current planting regime sees the rhizome quantity per ha vary, based on the land type and other factors, like geographic location, to establish 12,000 plants per ha. This planting density can range from 15,000 per ha to 17,000 per ha to ensure the planting target is reached. Terravesta still believes that there are many more efficiencies that could be improved in the planting regime through better rhizome and land preparation, all of which are to be examined in Phase 2. If they can improve on the emergence rate to reduce initial planting density while still achieving the target of 12,000 plants per ha, this would allow the planting of more hectares from their existing nursery stock.

Terravesta ensures that every crop they plant has an end-use to ensure the profitability of the growers. To do this, they have a long term contract with two straw burning power stations operated by BwSC, one located in North Lincolnshire (Brigg power station, 40MWe) and one in South Norfolk (Snetterton power station 44.2MWe). The current contract of 5,000 ha represents approximately 10% of their biomass requirement, with their primary source of biomass being agricultural residues, e.g. straw from crops, such as wheat and barley. With the recent rises in cost in obtaining straw, due to several years of poor harvests and competition from other markets like animal bedding, BwSC has expressed their interest in increasing their intake of Miscanthus, whose cost is less volatile than straw. Without a stable biomass supply, the cost of biomass could rise even further, with increases in costs of other farming inputs like fuel and fertiliser likely to drive up the cost of 'waste products' from traditional crops. With its low input requirements, Miscanthus should provide a more stable economic option as a feedstock supply.

Key to Terravesta's successful supply chain is its network of growers. Without growers planting and harvesting Miscanthus, it would be impossible to provide a stable biomass supply. Terravesta dedicates much of its resources to recruiting more growers to increase the amount of biomass within its supply chain. Terravesta regularly hosts Farm Walks with some of the growers, allowing farmers to visit and speak to a Miscanthus grower directly to learn the benefit of the crop from another grower. These Farm Walks allow for frank discussions over the economics of the crop, granting farmers the opportunity to learn first-hand that Miscanthus biomass production represents a good choice for their farm.

To manage the supply chain and monitor the crop performance across the UK, Terravesta has invested heavily into software development, initially utilising off-the-shelf CRM software with a custom layer to manage grower and collection data. However, as the company has grown, and with increasing utilisation of advanced technologies like drone monitoring and plans to utilise more modern analysis approaches like machine learning, they have been developing their own bespoke biomass supply chain software. They officially launched Harvest Hub to their grower network in 2021, a unique software that increases the amount of data collected from growers in a user-friendly way to help them better understand the performance of existing and new crops. Much of the work in the OMENZ project will be integrated into Terravesta's Harvest Hub, providing improvement across the whole supply chain. The platform also provides growers with more access to their data, with each new update adding additional features to help growers understand their impact on the biomass supply chain.

To conduct harvests and deliveries, Terravesta operates a network of approved contractors and hauliers, as well as maintaining a list of approved harvesting and baling contractors (who attend Terravesta's contractor forums to ensure that the best practises are applied on the farm). This process has led to an increase in bale weights, leading to reduced deliveries from each farm, thereby increasing the growers' profits and lowering the greenhouse gas emissions involved in the delivery process. Terravesta operates a haulier network which ensures a smooth and continuous flow of biomass from farm to end-user. All of these have been serving as increasingly incentivising elements for the growers to take up Miscanthus, growing the feedstock volume and the subsequent interest in the bioeconomy. These includes Agri-Fibreboard and Arcitekbio as example of industries constantly looking for biomass feedstock.

One of the most significant barriers to planting Miscanthus is the distance to an end-user, with haulage having the most significant impact on profitability. That is why Terravesta is working with different industries to offer contracts with new end users in a range of locations across the UK to encourage more planting. (See Industry Letter of support on Appendix 3)

1.3 Wider Environmental Benefits and Trade-offs

Miscanthus has other environmental benefits as shown in scientific studies around the world. Thomas and others (2014), suggested that Miscanthus could lead to a reduction in soil erosion across all the soil types examined when compared to corn-based bioenergy crops, and a reduction in nitrate leaching. Miscanthus can survive on flooded land without any impact upon yield (Kam and others, 2019), therefore Miscanthus could be used on lands prone to have issues with water drainage and still provide a farmer with an income. Miscanthus can also be used as a pasture shelter as demonstrated in New Zealand (Littlejohn and others, 2019).

There are also benefits in phytoremediation of contaminated land (Barbosa and others, 2015; Fagnano and others, 2020) as well as nutrient recycling (Lask and others, 2021; Littlejohn and others, 2019). On top of that, there are limited, but generally agreed, results of Miscanthus having a positive impact on biodiversity on arable land (Lask and others, 2020). These are important aspects to consider for soil management. According to the literature review by McCalmont and others (2017), Miscanthus can sequester between 0.7-2.2 Mg C4-C ha^{-1} y^{-1} of carbon and N_2O emissions can be as low as a fifth of the emissions from annual crops. Miscanthus does not require annual fertilisation nor the use of pesticides, reducing leaching of excess nutrients and contributing to increased soil and environmental health, as well as a more sustainable agriculture. Terravesta carried out a Soil Health Report (Kam 2021) and Biodiversity Report (Squance 2021), which is available upon request.

There is a trade off with Miscanthus that needs to be addressed regarding the use of farmland for biomass production. This is part of the food-fuel debate that has been ongoing over time. This has been investigated and we have found that while Miscanthus would still be required to grow on farmland that otherwise would be growing food, most Miscanthus growing will be done on less productive land, also known as marginal land Agricultural Land Classification (ALC) Grade 4 and 5 that makes it difficult to cultivate food crop. If we are only taking ~10% of the English farmland with least production capability, we are looking at just under 1 million hectares (with total agricultural land being 9 million hectares in England (DEFRA 2020), which would still be a struggle to fill within 30 years.

We also recognise that there will be fear about Miscanthus slowly taking over farmland. Yet, because of the lower value of Miscanthus crop when compared to a food crop, it is not likely that Miscanthus can compete against food crops for top tier land.

The environmental risk identified during Phase 1 was with regards to plastic pollution derived from the plastic mulching used during the initial stage of planting. As concerns were raised, we have found starch based biodegradable film to be a suitable alternative based on assessment done in Phase1.

1.4 Project Delivery

We have a track record of 100% of the deliverables in the project being delivered in Phase 1 (including this report). This is covered in the risk management section of this report.

As demonstrated in Phase 1, we have periodical reports to update and keep track of the project progress. This practice was not required by BEIS but was an internal means to make sure the project findings were periodically assessed and documented. In addition, this allowed us to understand each delay or challenge that may require more time or resources and the assessment to proceed or terminate the task in context. We aim to use the same project management model in Phase 2 to enable the continuation of good practice in project delivery.

2 Phase 2 Project Plan

2.1 Deliverables Timeline and Milestones

Milestone and deliverable summary:

Milestone	Deliverable	**Title**	Due
Milestone 1	D2.11	Film / no film trial	30/06/2022
	WP5	Project management/Quarterly report/review	30/06/2022
Milestone 2	D2.17	Test equipment investigation and assessment	30/09/2022
	D2.18	Target rhizome specification and practical assessment	30/09/2022
	D2.19	Establish target throughput and acceptable equipment cost trade-offs	30/09/2022
	WP5	Project management/Quarterly report/Bi-annual review	30/09/2022
Milestone 3	D1.13	Stratified root and soil sampling programme	30/10/2022
	D2.16	Initial equipment investigation/outlet design	31/12/2022
	D2.21	Conveyor seclection	31/12/2022
	WP5	Project management/Quarterly report/review	21/12/2022
Milestone 4	D2.22	Washdown spray system design/selection and build	30/03/2023
	D4.1	Automatic establishment count - image recognition from existing RGB: (yr1)	31/03/2023
	WP5	Project management/Quarterly report/Bi-annual review	31/03/2023
Milestone 5	D2.1	Investigate rhizome lifting process	31/05/2023
	D2.2	Development and testing of conveyor segment for washdown	30/06/2023
	D2.23	Washdown testing	30/06/2023
	D2.24	Vision/laser scanner analysis initial data collection	30/06/2023
	D2.33	Investigation/assessment of cutting technologies	30/06/2023
	D2.34	Selection/acquisition of cutting system	30/06/2023
	D3.4	Audit supply chain to UK farms	30/06/2023
	WP5	Project management/Quarterly report/review	30/06/2023
Milestone 6	WP5	Project management/Quarterly report/Bi-annual review	30/09/2023

Milestone	Deliverable	**Title**	Due
Milestone 7	D2.2	Define rhizome quality standard and specification	31/12/2023
	D2.25	Iterative approach to vision processing for rhizome identification	31/12/2023
	D2.26	Development of cut-line generation to meet rhizome specification	31/12/2023
	WP5	Project management/Quarterly report/review	31/12/2023
Milestone 8	D2.28	Root hair removal cut-line generation	01/01/2024
	D2.27	Assessment of requirement for root removal	31/01/2024
	D2.4	Batch handling system development - Nursery to farm	30/03/2024
	D3.1	Mesocosm and pot experiment to test the interaction between soil type and flood stress on establishment	31/03/2024
	D4.2	Automatic establishment count – sensor technology: (yr1-2)	31/03/2024
	D4.3	Evaluate establishment count	31/03/2024
	D4.5	Physical plant counter data stream	31/03/2024
	WP5	Project management/Quarterly report/Bi-annual review	31/03/2024
Milestone 9	D3.6	Planting for Demonstrations (Years 2 & 3)	31/05/2024
	D2.3	Testing and iteration	30/06/2024
	D3.5	Promote work at agricultural shows / trade events / conferences	30/06/2024
	WP5	Project management/Quarterly report/review	30/06/2024
Milestone 10	D1.7	An in-depth investigation into the quality of final harvest seeds and their viability	31/08/2024
	D1.6	Seed maturity and development time lapse observation	30/09/2024
	D1.12	Investigating the number of seeds required in a plug, and the subsequent effect of intraspecific competition for resources on seedling establishment and growth	30/09/2024
	D1.14	Quantifying the size of the Miscanthus 'Root Engine'	30/09/2024
	D1.16	limiting factors affecting the Miscanthus 'Root Engine'	30/09/2024
	D2.29	Integration of Washdown and rhizome identification hardware/software	30/09/2024
	D2.31	Integration of cut-line generation	30/09/2024
	D2.32	Assessment of performance w.r.t. rhizome specification	30/09/2024
	D2.35	Development/integration of cutting system with cut-line generation software	30/09/2024
	D2.36	Testing of cutting on pre-washed samples	30/09/2024
	WP5	Project management/Quarterly report/Bi-annual review	30/09/2024
Milestone 11	D4.4	Monitoring feedstock	30/10/2024
	D1.15	Rhizome soluble carbohydrate	30/11/2024
	D2.6	Commercial test on pre-treatment effect on rhizome, based on trial planting in commercial setting	30/11/2024
	D2.7	Investigate current approaches to automate current labour heavy process	30/11/2024
	D1.9	Miscanthus seeds based hybrids rhizome development experiment.	15/12/2024
	D1.11	Investigating the mechanisms of plant growth regulators for seed emergence and vigour	15/12/2024
	D2.1	Seed production revisits	31/12/2024
	WP5	Project management/Quarterly report/review	31/12/2024
Milestone12	D1.1	Addition of commercially available plant growth regulators (PGRs)	31/01/2025
	D1.2	Investigation of rhizome temperature responses	31/01/2025
	D1.3	Investigation of microbial inoculants on rhizome development	31/01/2025
	D1.8	How does the quality of seed used in propagation effect the characteristics of the resulting offspring/plugs production? How does seed quality affect later growth in the field?	31/01/2025
	D1.1	Could lower quality seeds can be improved by additional treatment with plant hormones and/or soil beneficial bacteria/endophytes.	31/01/2025
	D2.8	Investigate costing for semi-automated process	31/01/2025
	D2.14	Preparations conform to the phyto-sanitary requirements	31/01/2025
	D1.5	Investigation of rhizome size and overwintering survival	28/02/2025
	D2.12	Investigate commercial feasibility for discovered pre-treatement for plugs	28/02/2025
	D1.18	Define data matrix	30/03/2025
	D1.19	Investigate establishment: Variety x Soil x Environment	30/03/2025
	D2.13	Implement learning of bespoke commercial process of plug production	30/03/2025
	D1.4	Underlying mechanisms of PGRs on Miscanthus	31/03/2025
	D1.17	Data integration and analysis	31/03/2025

Milestone	Deliverable	Title	Due
Milestone 12	D2.5	Transport and storage quality assessment - transport time length effects on dormancy break	31/03/2025
	D2.9	Implement learning of bespoke commercial process of rhizome production (Depends on D2.8)	31/03/2025
	D2.15	Economic comparison between Seed-based and Rhizome in light of new processes (Depends on D2.8, 2.9, 2.14, 2.13)	31/03/2025
	D2.37	Integration of full system	31/03/2025
	D2.38	Iteration of refinements	31/03/2025
	D2.39	Assessment of performance w.r.t. rhizome specification	31/03/2025
	D2.4	Assessment of performance w.r.t. throughput	31/03/2025
	D2.41	Assessment of performance w.r.t. cost	31/03/2025
	D3.2	Plot trial testing the interaction of rhizome properties with moisture stress	31/03/2025
	D3.3	Field study to understand the role of soil properties on Miscanthus establishment in the field	31/03/2025
	D4.6	AI Data integration with current Terravesta systems	31/03/2025
	D2.3	Define implementation of quality control based on the standard (dependent on 2.1 and 2.2)	31/11/2024
	WP5	Project management/Quarterly report/Bi-annual review	31/11/2024
	WP5 List	**Project, Data and Financial Management**	
	D5.1	Project Management/	Quarterly
	D5.1.1	Data management and implementation with integrated work package learning (Harvest Hub platform)/ and integrate processes to Harvest Hub platform	Quarterly
	D5.1.2	Quarterly Marketing and Engagement Reports	Quarterly
	D5.1.3	Hold 6 monthly reviews of learning	Biannually
	D5.1.4	Continuously update project management plan	Quarterly
	D5.2	Risk Management	Quarterly
	WP5 List	**Project, Data and Financial Management**	
	D5.3	Financial Management	Quarterly
	D5.4	Project Status Meetings/Initial kick-off meeting, weekly technical meetings and MO review meetings	Quarterly
	D5.5	Document Lessons Learnt	Quarterly
	D5.6	Exploitation and Dissemination	Quarterly
	D5.7	Update Records and Systems	Quarterly

For more details and a full written plan, please see Appendix 2.

2.2 Project Management

Terravesta holds a central role in the consortium, working alongside all other members to analyse each stage of the existing Miscanthus supply chain, seeking to meet rising demand. With a proven track record of Miscanthus crop establishment, Terravesta will also benchmark existing machinery and processes, to identify the most significant efficiency gains and cost reductions throughout the supply chain, to achieve the scalability required to deliver Net Zero ambitions. Having been recognised previously by UK investment such as InnovateUK MUST (102527), Terravesta is confident in leading the OMENZ consortium to successfully deliver a realistic improvement in biomass feedstock production innovation during Phase 2.

Other members of the OMENZ consortium include:

Crop Health and Protection Ltd - Subcontractor. Leading WP5
UK Agri-Tech Centre CHAP's project management expertise will be leveraged to

ensure this project's successful completion, using its experience in bringing together scientists/farmers/innovators/businesses to understand industry challenges, drive innovation and trial solutions. CHAP's sector insight will also ensure the project delivers on the scope of the competition in addressing a significant industry opportunity.

Cranfield University – Subcontractor. Leading WP4

Cranfield University (CU) is home to a range of state-of-the-art approaches that integrate remote sensing and ancillary data through model-data fusion. CU is investigating novel methods to monitor and improve the establishment of Miscanthus in the field. Initial trials performed in the phenotyping glasshouse facilities of CHAP and Agri-EPI, located at CU, will inform very high-resolution drone-based field surveys. By automating image processing we can provide accurate information about the Miscanthus canopy to improve establishment and overall crop efficiency.

Energene Seeds Ltd – Subcontractor.

Energene Seeds has a long history of working with Terravesta to produce the new seed-based hybrids of Miscanthus. A biotech company re-established in 2018 by Dr Michal Mos who is a well-established commercial expert in Miscanthus bioenergy development, general physiology, and 'seed/plugs' development. Energene will also investigate the technology needed to establish these new hybrids in the UK.

Liverpool John Moores University - Subcontractor. Leading WP1

Liverpool John Moores University (LJMU), will provide applied scientific innovations. With the novel application of plant hormones, microbial inoculants and environmental stimuli pre-treatments, LJMU will improve breaking of Miscanthus rhizome dormancy, emergence, and resilience, improving Miscanthus establishment, reducing heterogeneity in rhizome development and increasing survival rates. LJMU will also apply techniques to improve Miscanthus seed production, germination and establishment. LJMU will actively work with partners to develop methods for quantifying Miscanthus emergence at field scale. LJMU's contribution will improve Miscanthus crop establishment and economic viability.

Salmac Ltd – Subcontractor.

Salmac, a market leading UK horticultural machinery specialist, has been advising the consortium on the most currently up-to-date market available machinery during Phase1. Salmac will continue the role of machine market consultant in helping to identify existing technology innovations to improve on existing planting methodologies and working with all the consortium members to identify where new equipment could be deployed. Salmac will also assist with the procurement of an automated planter used for seed plug planting to demonstrate its possibilities to the grower and contractor.

Ystumtec Ltd – Subcontractor. Leading WP4
Ystumtec specialises in bespoke electronics and electro-mechanical systems for real-world applications, using cost-effective hardware. Ystumtec has a history of working with Terravesta and other large agricultural organisations developing a diverse range of electronic and robotic systems. Ystumtec is developing add-on technology for Terravesta's existing Miscanthus rhizome planters, to provide accurate mapping of the planting rate. Ystumtec will be investigating automated rhizome preparation processes conforming to quality control standards and downstream automated planting process constraints, expected to include AI image processing and robotic control, with which Ystumtec has significant experience.

University of Lincoln (UoL) - Subcontractor. Leading WP3
Lincoln Institute of Agri-Food Technology (LIAT) of UoL specialise in interdisciplinary research, including the development of robotic and digital solutions to key challenges within agriculture including quality assurance standardisation. UoL has access to facilities and resources to accelerate UK Agri-Tech, including the UK's first Eagle Farm of which Terravesta is a member. Within OMENZ, UoL will support the design of new planting technology and qualifying quality control for planting material. UoL will focus on impacts of soil physical and moisture properties on establishment of both plugs and rhizomes immediately post planting.

2.3 Risks and Risk Management

The project risk register (Appendix 2.1) summarises all risks identified at this early stage, their mitigation strategies and impact/likelihood scores. This will underpin a detailed risk log which will be developed and owned by the Project Manager throughout the project. Any new or increased risks will be highlighted during the project monitoring process.

Risks will be closely monitored and reviewed regularly, throughout the lifecycle of the project.

The main risks and uncertainties are technical. We believe they can be mitigated through the extensive preliminary research already undertaken via the highly technically proficient partnership consisting of organisations and individuals who are experts in their fields.

The commercial and managerial risks are low and very manageable within the partnership. CHAP is highly experienced in the management of Agri-Tech innovation partnership projects across its staff base of academic experts and highly experienced project and technical staff.

CHAP's PRINCE2-qualified Project Manager is highly experienced in managing Innovate UK projects. Our projects are managed in full compliance with PRINCE2 requirements around risk.

The activities of this project will not negatively impact the natural environment.

Future risk from COVID-19 has been mitigated as much as possible during project planning. Remote collaboration tools have been successfully tested and work will be undertaken in facilities with established measures in place.

The project is not vulnerable to any inputs being uniquely critical to its successful completion. Any aspect of the work subject to unexpected failure could be quickly replaced by a suitable alternative. Strategies for redundancy and failover systems for resources, expertise, datasets etc have already been given consideration and will be further developed should this project be awarded funding.

Project outputs will achieve full compliance with all regulatory and certification requirements. No ethical issues arise from the project plan. The results generated from this project are fully intended to be used in further research activities.

2.4 Quality Assurance

CHAP's process for the monitoring and assurance of quality within our projects is centred around our monthly technical (catch-up) meetings. These are meetings between representatives from CHAP and the project partners, used to monitor project progress and quality assurance.

By adhering to proven project methodologies we ensure that quality management of the project and our reporting maintains within those tried and tested principles.

2.5 Project Controls and Governance

CHAP's approach to project management is centred around its main focus - to deliver projects on time and budget, to our funders' complete satisfaction.

We utilise best practice project methodology principles throughout, and all our projects have dedicated resources to ensure rigorous planning, structure, monitoring and control. In essence, we provide the integrated vision which leads the nature of the project to a success whilst complying with all specified obligations.

To substantiate this, CHAP have successfully delivered all of our innovative UK or relevant grant funded Agri-Tech projects to date. This success stems from the foundation of our expert Project Management team who bring previous experience and insight gained across a vast number of programmes, portfolios and projects.

2.6 Reporting

CHAP's successful delivery of innovative Agri-Tech projects stems from our experienced and highly capable project management (PM) team. The handling of Phase 1 has shown confidence and flexibility of managing such innovative projects.

Our innovative Agri-Tech projects have been regarded as exemplary by previous Monitoring Officers due to our comprehensive reporting strategy. This can be tailored and aligned to the reporting needs of each project. If we succeed in securing Phase

2, the project team will ensure that all reporting requirements from BEIS are met to the highest standards.

3 Commercialisation Plan

This plan is a living document and will be updated during the project. The aim of the plan is to confirm the business case for the project and describe the partner activities towards exploitation of the results of the project so that 1) changes in the commercial environment can be monitored and accounted for, 2) adequate resources are committed to exploitation, and 3) so that exploitation can be monitored by the stakeholders.

3.1 Partners' Capability to Develop and Exploit the Technology

The overarching project goal is to deliver a practical biomass up-scale strategy to be deployed within an industrial scale Miscanthus planting programme in support of the UK's Net Zero ambitions.

The strategic objectives of the project may be collectively summarised as the successful demonstration of increased efficiencies to be deployed along the length of Terravesta's existing Miscanthus supply chain. To achieve this, the project will draw on various automated technologies, both in development and those currently being utilised within various sectors, to transform both propagation and transplanting techniques within the Miscanthus supply chain.

Terravesta's existing propagation and planting capabilities allow for up to 1000 ha of Miscanthus to be established annually. Much of this capacity currently utilises a semi-automated process, resulting in the need for labour to be deployed along the entire length of the supply chain, making the process both time consuming, overly expensive and at times, high risk, considering the ongoing trend towards permanent labour shortages in both the UK and Europe. Most importantly, the current propagation and planting ceiling at full capacity, falls way below the requirements to scale the industry to meet the UK's Net Zero ambitions.

The innovative aspects of the project have been seen through the analysis of the whole Miscanthus establishment pipeline for both seed and rhizome, to investigate all stages of the supply chain. These include propagation, approaches to field preparation, germplasm production, various mechanisation options, techniques for planting as well as the technology used to monitor early-stage growth, including drone technology and machine learning to quantify overall improvements.

Individual focus will be applied within each of the above-mentioned subject areas, with the overall aim to achieve the most significant gains to both efficiency and cost reduction in each subject area, whether this be a technological improvement, improved process, or a combination of these.

The project will also utilise and further develop a streamlined information management system developed by Terravesta (Harvest Hub), to integrate data collected from all stages of Miscanthus establishment and various growth stages and harvest, to gain insights into long term crop performance.

As lead partner in the consortium, Terravesta currently manages the largest Miscanthus supply chain in Europe, with over 5000 ha of Miscanthus under contract with over 200 growers in the UK. The resultant biomass is procured under contract from the growers, as a sustainable feedstock for use within the UK's network of whole-bale, renewable power stations.

Terravesta's model places it at the centre of the Miscanthus supply chain, with 3 unique areas of IP:

1. Commercial deployment of exclusive Miscanthus varieties.
2. Operational and technological know-how developed along the entire length of the Miscanthus supply chain.
3. The development of bespoke data and process management systems to streamline operational function and inform future research priorities.

3.2 The Market Opportunity

The expected deliverables from the project will all translate to efficiency gains along the length of Terravesta's Miscanthus supply chain. Therefore, allowing for deployment of a cost-effective, scalable operation, to effectively contribute toward Net Zero ambitions. Areas of improvement are expected to be made in propagation, approaches to field preparation, germplasm production, mechanisation options, techniques for planting and the monitoring technologies.

Lastly, it is important to ensure sufficient information is made available from the outset of such deployment. For this reason, data capture and assimilation is included as a key deliverable from the outset, to ensure accurate benchmarking from project commencement and to appreciate the full scale of efficiency gains at project completion.

3.2.1 Commercial Opportunity for Each Deliverable

3.2.1.1 Market niche for each outcome

To sustain and grow this market niche, Terravesta has needed to continually invest in R&D along the Miscanthus supply chain. Project OMENZ Phase 2 will allow Terravesta to retain this market niche in the following ways:

1. Equip the existing Miscanthus supply chain to be fit for the future of the industry, through fully mechanising processes in the absence of readily available labour and enhancing monitoring and recording processes through the use of data and drone technology.

2. Realise much-needed cost efficiencies that can eventually be translated into long term, sustainable price reductions for the Miscanthus grower, thereby making the industry more attractive for new entrants.

3.2.1.2 Predicted value and growth in the selected market niche

To deliver the full extent of the proposed sustainable biomass feedstock, it is estimated that the following mechanised and technical improvements will be required along the length of the supply chain between 2026 and 2045:

- Rhizome nursery refit to new lifting and grading technology: £2.5M.
- Seed-based nursery seeding lines and improvements to basic propagation nursery (15 ha at peak): £1.7M.
- Customised propagation trays (£3.5 per unit): £3.4M.
- Planting technology mechanisation: £30M, up to 60 mechanised planters will need to be built, at approx. market value of £340,000 per unit.

3.2.1.3 Existing or emerging competitive offerings

Terravesta's existing competitive offering is realised through its unique Miscanthus genetic material and exclusive, long-term off-take contracts offered to growers. Miscanthus is still often viewed as being high risk, thereby detracting many potential growers due to the initial establishment cost. Terravesta has recently started promoting a selection of term loans offered through a financial partner, to spread the initial cost of establishment over a number of years.

Future competitive offerings to Miscanthus growers will be seen through a combination of:

- Price reductions resulting from scale-up and further efficiencies along the supply chain.
- Greater guarantees of overall establishment success, leading to increased yields.

3.2.1.4 Means by which IPR will be protected

All consortium members are already familiar with the Intellectual Property Protection laws in the UK.

Any novel IP developed throughout the course of the project shall ultimately remain with the party that created it. Each consortium member will be free to decide how they wish to protect their respective IP.

Terravesta shall reach appropriate licensing agreements with each consortium member, to ensure the respective IP can be successfully deployed along the length of the supply chain.

Within Phase 1, only Ystumtec has produced novel IP. An agreement has already been reached between Ystumtec and Terravesta to deploy the IP.

3.2.2 Expected Commercial Returns and Timescale

Terravesta's current revenue model consists of:

1. Sales of Miscanthus genetic material to both new and existing growers at £1530 per hectare before costs are deducted.

2. Buyback of the resultant baled Miscanthus biomass for onward sale to the end user, in this instance whole bale power plants with onward sale at approx. £90 /t before costs (buyback and haulage).

Terravesta anticipates steady and consistent growth, largely attributed to Miscanthus' attributed benefits to natural capital, but also due to the emergence of new markets.

Terravesta's current overall Miscanthus supply averages at 50,000 t / annum, with annual growth in the region of 500 to 1000 ha per annum. The potential growth ceiling in the current end user demand would easily exceed 500,000 t / annum if the tonnage was readily available. Ultimately, the supply ceiling will determine the size of the UK end-user market.

To take a more conservative approach according to guidelines published by Climate Change Committee (CCC), an independent non-departmental public body formed under the Climate Change Act to advise the UK government, it is assumed that the ultimate achievable supply ceiling for Miscanthus in the UK would be 300,000 ha by 2050. This translates to approximately 4 million t / annum by 2045, assuming an average yield of 14 t ha^{-1}. This is considered realistic and achievable since 7.3 million t of wood pellet is currently imported into the UK annually (Calder 2021).

In summary, Terravesta estimates value, up to delivered feedstock only, to be in the region of £450 million between 2022 and 2050, assuming conservative estimates at current market value and taking account of further efficiency gains.

3.3 Potential Impact

The UK continues to lead globally on Net Zero ambitions through committing resources towards a portfolio of innovative carbon sequestration and reduction measures. Such investment has also driven the emergence of new UK bio-based industries without reliance on fossil fuels. Whilst this presents significant potential to future UK economic growth, the export wins for UK plc are also relevant, through companies like Terravesta, who have the ability to actively export such technologies globally. External impact may start to be realised during the project. The longer term (post project) includes additional capital expenditure to procure propagation infrastructure and the various mechanised components along the Miscanthus supply chain present an opportunity for parties outside the project consortium.

In addition, harvest/post-harvest technologies and mechanisation will need to be scaled within the UK's contracted Miscanthus supply chain. This includes the organisation of specialised haulage contractors to cater for such increased volumes. No figures are currently available for mechanised advances and requirements from the harvest process onwards, as it is envisaged that much of this process post-harvest will likely be developed by the end-user of the biomass.

Impact for environmental benefits has been explained in section 1.3.

From a social standpoint, increasing of Miscanthus plantation will:

First, the removal of intensive agricultural spraying activities due to Miscanthus planting practice will have a big positive influence on the long-term health of communities.

Secondly, provide diversification programmes in decentralised areas of the UK, such as the Scottish Highlands and the Welsh uplands, where Miscanthus is already proving an attractive option for remote farming communities, who consistently struggle to make ends meet due to a host of factors. Terravesta is actively working on an initiative, to couple new Miscanthus growers in these decentralised areas, with industry looking to locate manufacturing capability into regions where feedstock security can be guaranteed. As such remote communities will gain access to additional employment, local upland farmers gaining much needed additional revenue through diversifying into Miscanthus, whilst industry gains long term feedstock security and access to labour.

Thirdly, Terravesta, in collaboration with the Game and Wildlife Conservation Trust (GWCT), is actively promoting Miscanthus as an effective windbreak for livestock and habitat for wildlife in extreme weather conditions. In many cases, access to woodlands for shelter is not possible. Miscanthus is likely to offer a ready solution in such instances.

Fourthly, the project will undoubtedly create a number of novel technological advances through automated planting techniques, as well as the organisation and learning from the resultant data sets. Such IP and data will sit with certain academic partners, who have already expressed interest to launch a series of new academic courses focused on such novel technology and the UK’s future bioeconomy.

From an educational point of view, the academic partners of the consortium have already started including Miscanthus cropping in the programme of selected university courses, as well as actively engaging both undergraduate and postgraduate students to participate in research activities, thus contributing to forge next generations of agronomists and practitioners.

From both a legal and environmental perspective, Miscanthus, when planted at industrial scale will play a critical role within UK natural capital and the subsequent design of the various Environmental Land Management schemes soon to be introduced in the UK. Terravesta is already actively engaged across all spectrums of UK natural capital and places natural capital at the core of its operations, to ensure sustainable outcomes for our rural landscape. It is vital that the rollout of any industrial scale programme is incorporated into the UK’s legal frameworks for sustainable impact, to ensure positive impacts are realised for generations to come.

3.4 Business Plan

In terms of a business plan, the consortium will continue to use Terravesta's existing model post project. In which, contracted growers sit at the core of the business model, within key zones determined by vicinity to the end user. That in turn is based on an outlook for all parties to enter into long term agreements. Such will be the key to attract significant interest from industrial end users and to consider locating key manufacturing facilities within proximity of such guaranteed feedstock sources.

We similarly envisage increased opportunity to attract large scale institutional investment into Miscanthus. Such a scenario is already common within forestry assets. Considering the consistent annual returns from biomass and environmental credit being an attractive proposition, Miscanthus can be a similar asset.

Terravesta will need to make some changes to the way it operates in order to align with the UK government Net Zero Strategy:

1. Operate a fully contracted field operational model, whereby Terravesta appoints a series of contractors, who will own and operate the fully mechanised planters yet to be developed.

2. Deployment of Terravesta's information management system (Harvest Hub) along the length of the supply chain, to coordinate all aspects from propagation through to the end user.

3. Expanding the scope of our customer base in the UK and Europe, to include new offtake agreements into other markets beyond power generation:
   - Immediate other markets, where Miscanthus is already known as a proven feedstock: Power and Heat, construction, fibre-moulded packaging, phytoremediation.
   - Near term (3 to 10 years), validated and nearing commercialisation: Bioplastics, 2G biorefining, biochar.
   - Long term (10 years plus), further validation required: Sustainable Aviation Fuels, (SAF), nanotechnologies, technical bio-based textiles.

4. Secure large scale projects, alongside a continued focus towards individual growers, who will continue to remain integral to Terravesta's longer term ambitions. Such opportunities will likely become evident as Terravesta expands into new markets. Another area where large scale projects may be evident is through both the Landscape Recovery and Nature Recovery schemes being introduced as part of the Environment Land Management Scheme.

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5 Appendix

Appendix 1 - Project deliverables reports

WP1

1.1 Land preparation and planting material preparation process

Soil cultivation is an important part in Miscanthus planting and establishment allowing smooth operation in subsequent planting and soil surface contact that is critical for root and rhizome development. We searched for the best option for minimum tillage after seeking advice with various practitioners, including our own operational manager in Terravesta, CHAP and Salmac. We concluded that strip-till would be the most efficient process for planting Miscanthus as found in many other crops and is well practised.
There are strip-till machines available in the market for the UK and their function and base concept is similar across different makes. The process is designed to minimise soil disturbances, reduce energy consumption and help retain soil integrity. This is a big step towards considering soil health and good land management practice,not to mention the additional benefit of energy saving and reduced carbon emissions.

1.2 Intelligent selection - Identify qualifying standard

Considerations have been made around Miscanthus establishment that looked into:
1. Miscanthus cultivation method.
2. Nutrient requirements to ensure quality establishment.
3. Water requirements for crop establishment.
4. Harvest impact on subsequent yield.

WP2

2.1 Land prep and planting material preparation process

While there are many trays suitable for growing the Miscanthus plant, for automated planting they need to be semi-rigid in form. Depending on the size of the plant and subsequently the soil type there are 3 tray types identified as suitable.

2.2A Seed production and processing - current protocol - Seed Cleaning

Please refer to the protocols collection

2.2B Seed production and processing - current protocol - Seed Production

Please refer to the protocols collection

2.3 Seed production and processing - updated protocol - Seed Production Mechanisation

Please refer to the updated protocols collection

WP3 - 3.1 Data collection on current best practice on establishment

A count has been made to establish the effect of film vs. no film treatment after planting. It has been found that no statistical significant difference on establishment between treatments occurred, while statistically significant differences were observed in both plant height and tiller number. While the treatment of film vs. no film is not showing establishment differences by establishment count, the differences in plant height and tiller have a strong indication of subsequent fitness and survivability of the crop. The proof will have to come next year in re-emergence but so far, indication has favoured film laying after planting to give best crop fitness.

3.2A Establish standard practice for subsequent planting and monitoring data collection: Plant counter prototype on planter

A rhizome counter has been designed in the detailed project report. Please refer to the corresponding project report for the design concept and blue print.

3.2B Establish standard practice for subsequent planting and monitoring data collection: Differing planting depth treatment

To study the effect of depth on Miscanthus rhizome planting, we set up a small pot-based trial to see if it impacted the emergence date. Please note that Phase 1 project timing was outside of the typical Miscanthus season. Our experiment showed that the planting depth appears to be linearly correlated to the time to emergence when rhizomes are planted with the shoot directed upwards. As seen by the modelling, the rhizome will grow at a relatively rapid rate of 0.89 cm per day, however, as we saw with the outlier, the direction of travel is not always the most optimal.

We will aim to repeat this experiment in the field in Phase 2 of the project to emulate commercial planting better, as we saw in this experiment how the pot could affect the growth. However, pushing the plant upwards was advantageous in this instance.

3.3A Planting material production and planting - Planting (Rhizome) counter prototype currently under product at the time of first draft submission on track to be ready for Phase 2

3.3B Planting material production and planting - automated planter

After comparison of automated planters available, the Ferrari Futura has been identified as the most appropriate choice. It is a fully automated transplanter that can work with plant material stored in trays of different sizes and material (hard plastic, foam, and disposable). The machine only requires one operator to feed the transplanter robots with trays. Every robot extracts the seedlings using a technology based on cylindrical plungers combined with moving fingers. There is no need to use a specific tray to run a Ferrari Futura, the machine will be adapted to the tray selected by the user, which is one of the features that makes this particular automated transplanter a very suitable machine.

3.4A Conclusion of experiment for preliminary data acquisition and identify further trial for Phase 2: Plug planter comparison

An automated planter has been identified and finance options have been considered for renting. There can be multiple ways to obtain an automated plug planter for trial. However, since there is no funding secured for Phase 2 for Project OMENZ (application result pending), a secure deposit cannot be made at this stage.

3.4B Conclusion of experiment for preliminary data acquisition and identify further trial for Phase 2: Film system / elimination including alternative planting technique

Current plastic usage is concentrated in film covering right after planting with plug plants. Current rhizome methods show no need for plastic coverage. From the result of D3.1 as well as previous experience, it is clear that having film is important for the early establishment and vigour of the seed-based hybrid plants. However, the data is inconclusive based on the fact that one of the benchmarks should be the re-emergence of 2022.

Hence, a two phase approach should be implemented in Phase 2:

1. Confirm the effect of film on re-emergence as well as second year's physiology indicators (i.e. repeat the process of D3.1).

2. If differences were found favourable to film laying, then steps will be taken from eliminating the differences of treatment up to film laying, to implementing learning from increasing vigour from WP1 to be tested and compared with normal film laying.

3.4C Conclusion of investigation for preliminary data acquisition and identify further trial for Phase 2. Glasshouse and hormone / pre-treatment

Initial research has been undertaken to develop pre-treatments for Miscanthus rhizome bud development and enhancing emergence. The preliminary results showed that the tested temperature and selected hormone pretreatment have potential to improve Miscanthus rhizome emergence. These will be taken further in Phase 2.

WP4

4.1 Establish standard practice for subsequent planting and monitoring data collection: Glasshouse experiment setup

Glasshouse setup. This is a checkpoint for progress monitoring.

4.2 Land prep and planting material preparation process identified

There are a few considerations that need to be addressed in the following areas with the improved planting material preparation. These considerations will be entered into the final report with planned experiments:
1. Monitoring technique to determine when seeds are ready to be collected/harvested to maximise seed with high quality.
2. Planting materials may be pre-treated (seed or rhizome) ahead of planting to improve vigour. Especially with seed plugs, a more rugged method or preparation to

allow for a more ready plant for the ground from the currently costly and intensive raising method.

4.3 Intelligent selection - identify hardware and software: Drone technology in monitoring establishment

Identification of commonly available drone and camera attachment has been found to suffice for the bespoke AI technology developed in the time frame of Phase 1. Please see the corresponding project report for further details.

4.4 Conclusion of investigation for preliminary data acquisition and identify further trial for Phase 2: Monitor establishment and subsequent performance

The aim of this work package was to select key indicators and image collection parameters from a review and a glasshouse experiment (imaging in controlled environment), to determine future drone imagery collection parameters. These will be used in the design of field trials for developing an image-based system, alongside crop modelling, to monitor establishment and measure the subsequent yield in Phase 2.

WP5

5.1 Establish standard practice for subsequent planting and monitoring data collection: Pheno robot validation test, Field vs. glasshouse

To consider the deployment of an automated ground monitoring platform, the team needs to familiarise themselves with the target crop being researched. The aim of this deliverable is to assess the requirement for deploying said monitoring technology.

5.2 Land prep and planting material preparation process identified: Mechanisation review

The consideration made here is based on the need for the type of land. Given that in D1.1 the land has been split into light and heavy land, the recommendation was made based on the type of land.

5.3 Seed production and processing - Updated protocol: Mechanisation review

Mechanisation has been deemed unnecessary due to new crossing block showing better work efficiency, where no mechanisation can reduce cost under the current operation (see the corresponding project report). Therefore, effort will be diverted elsewhere to improve seed quality.

5.4A Conclusion of investigation for preliminary data acquisition and identify further trial for Phase 2: Establish reason for failure of establishment with Miscanthus

This particular work package is for establishing possible reasons for establishment failure in hope of identifying points of improvements in the planting process (material prep to planting). A survey was conducted by field inspection of failed rhizome

recovery, drone imagery, soil samples and equipment examination. Soil quality was found to be relatively uniform. Conclusions of investigations into failures are:
1. Establishment failure occurs shortly after planting with no dormant rhizomes found (i.e. lack of moisture caused the rhizome to wilt).
2. Difficulties to find rhizomes in areas with poor establishment further pointed to the suspected operator/machine error (i.e. rhizome not planted).
Further works have been recommended for Phase 2 to investigate cause, detail and to develop counter strategies.

5.4B Conclusion of investigation for preliminary data acquisition and identify further trial for Phase 2: Mechanisation review

Current planting equipment and machines have been inspected and areas of improvement have been identified. It has been divided into rhizome and seed plug planting based on Terravesta's genotypes collection. In each of these categories, different technology readiness as well as challenges have been identified.

Current conclusion suggested that strip-till can be used for both types but will need testing in Phase 2 based on the specific strip-tiller identified.

For seed-based hybrids, it would be necessary to test automated planters and be able to demonstrate to contractors that this is a viable technology. We anticipate that agricultural contractors will be eager to find out the potential of these automated planters in view of the imminent labour shortage crisis in the UK.

As for rhizome planters, while there are improvements that can be implemented, the most important aspect identified is the quality of rhizomes needing better control. The current process depends on the person at the back of the planter to assess and decide the quality of rhizome to be planted. After analysing the production chain, it was concluded that the quality of the rhizomes is not good enough, and the workers are not trained for quality assessment nor do they have time to do so. Therefore, it is important to have quality control at an earlier process.

Appendix 2 - Phase 2 Plan

2.1 Second level planning - Please refer to the following page for second level planning document for Phase 2 operational plan.

SECOND LEVEL PROJECT PLAN

BEIS REFERENCE: **TER-303-1-M**

Optimising Miscanthus Establishment through improved mechanisation and data capture to achieve Net Zero targets (OMENZ)

Date: 11th February 2022

Ref: TER-303-1-M

Vs: 1.11

Responsible Author: James Godber – Project Manager

Circulation: Project Lead

All Project Partners

Monitoring Officer - BEIS

Work Package 1: Improving Miscanthus Emergence, Establishment and Development

Start date: 01/04/2022 Anticipated total man-days: TBC
End date: 31/03/2025

Work Package Leader: Dr Richard Webster (Liverpool John Moores University (LJMU)).
Work Package Collaborators: Dr R. Symonds (LJMU), Dr I. Walkington (LJMU), Dr M.C. Alamar (Cranfield University (CU), Dr R. Simmons (CU)), Dr M. Mos (Energene (EG)), Dr S. Pearson (University of Lincoln (UoL)).
New Post Doc Researcher (research leader) (LJMU).
New Post Doc Researcher (research leader) (CU).

Work Package Objectives:

- Improving planting material vigour
- Improving seed quality and viability
- Improving seedling establishment
- Field based quantification of soil factors affecting Miscanthus root development during establishment and initial crop maturity phases for yield optimization
- Define and fulfil data matrix required for matching right genotype to land and condition

WP1 is a solution orientated series of defined objectives with quantifiable benefits increasing viability, yield and economic security of the biofuels production and utilisation in a national context.

Task 1.
Planting material vigour is a critical agronomic component. Miscanthus is a new emerging crop, and although there has been much work conducted on this species in the past years, we are still in the process of improving and optimising the methods and approaches that can provide improved establishment and biomass yield while increasing the economic viability of the agronomic processes. The components of Task 1 are designed to answer industry identified challenges.

Task 1.1. [D1.1] Investigation of the effect of commercially available plant growth regulators (PGRs) on the emergence and establishment of rhizome from different Terravesta (TV) Miscanthus varieties. This includes novel PGRs treatments and those established for use in the production of other crops, but never trialled with Miscanthus. (Start 01/04/2022 - End 31/01/2025)
Task 1.2. [D1.2] Investigation of the effect of temperature pre-treatment on the emergence and establishment of rhizome from different TV Miscanthus varieties. (Start 01/04/2022 - End 31/01/2025)
Task 1.3. [D1.3] Investigation of the effect of commercially available microbial inoculant pre-treatments on the emergence and establishment of rhizome from different TV Miscanthus varieties. (Start 01/10/2022 – End 31/01/2025)
Task 1.4. [D1.4.] Elucidation of the underlaying mechanisms of externally applied PGRs and temperature pre-treatment on the emergence (bud dormancy break), sprout vigour and rhizome establishment from different TV Miscanthus varieties (Start 01/10/2022 – End 31/03/2025)
Task 1.5. [D1.5] Determine the optimum variety specific rhizome mass required for different key soil types to ensure overwintering success (University of Lincoln). (Start 01/04/2022 – End 28/02/2025)

Tasks 1.1 – 1.4 involve cross institutional collaboration (LJMU, TV, CU), utilising combined facilities (e.g., glasshouses, environmental analytical facilities [*viz*. LC-MS], root imaging systems) to provide solutions for trialling at larger scale (TV).

Task 2.

Seed production improvement will increase the potential for Miscanthus agronomy to be streamlined and economically strengthened for the long-term and facilitate the transition from rhizome propagation to that of a seeded crop. The components of Task 2 will provide evidenced based agronomical solutions for improving seed harvest, germination, and the production of resilient seedlings.

Task 2.1. [D1.6] Investigation to optimise the timing of seed harvesting to capture those seeds that have the optimum maturity and development, and the component of the panicle that contains the mature seed, which will correlate to improve seed germination rate. This includes investigating the growth of seed that is freely separated from the panicle, with those seed that are machine extracted (threshed) from the panicle. (Start 01/09/2022 – End 30/09/2024

Task 2.2. [D1.7] Investigation to identify seed grading criteria and the relationship between seed grades and the germination and establishment success. Some preliminary data will be collected from 2021 harvest but the main experiment will be carried out with seeds harvested in 2022, directed by the results of Task 2.1. (Start 01/08/2022 – End 31/08/2024)

Task 2.3. [D1.8] An investigation to determine the relationship between seed quality and the development and time to harvest of different seed propagated plants. (Start 01/10/2022 – End 31/01/2025)

Task 2.4. [D1.9] Experiments to determine the relationship between variety specific seedling development and soil type and environmental conditions. This experiment will be conduct by UoL with Energene Seeds and two different soil types will be investigated in a pot experiment to quantify seed root development and maturation. (Start 10/01/2022 – End 15/12/2024)

Task 2.5. [D1.10] Investigation of techniques to improve the development of seedlings with the use of PGRs and microbial inoculants, and the implementation of physical manipulation (e.g., leaf and stem agitation). (Start 01/09/2022 End 31/01//2025).

Task 2.6. [D1.11] Investigating the mechanisms of PGRs for seed emergence and vigour (Start 15/12/2022 – End 15/12/2024)

Task 2.7. [1.12]. Investigating the number of seeds required in a plug, and the subsequent effect of intraspecific competition for resources on seedling development, overwintering and establishment of the seedling root mass. This experiment will be run in pots (plugs to pots) as well as plugs to field trial. We will test the seedling development in different conditions. These small trials will compare development in heavy soil and sandy soil conditions. (Start 01/11/2022 – End 30/09/2024).

Tasks 2.1 – 2.7 will input into the reduction of the number of seeds required for planting in plugs, increase the overall success of seed to field economics and viability.

Task 3.

Quantifying field scale soil factors affecting Miscanthus root development during establishment and initial crop maturity phases will identify limiting factors affecting the Miscanthus ‘Root Engine’ and form the basis for pre and post establishment soil management for yield optimization and carbon sequestration. Linkages to Tasks 1 and 2 will ensure that laboratory and pilot scale research outputs are applicable to field scale conditions.

Task 3.1 [D1.13]. Stratified root and soil sampling programme. Data obtained from TV will be used to design a stratified sampling programme that will form the basis of the soil & root coring campaign. (Start 01/04/2022 - End 30/10/2022)

Task 3.2 [D1.14]. Quantifying the size of the Miscanthus ‘Root Engine’. Root coring will be undertaken post-harvest in Jan-Mar 2023 and Jan-Mar 2024. From the root mass data, root mass density (RMD) values for ‘rhizomes’ and ‘feeder roots’ will be quantified and related to yield. (Start 01/11/2023 - End 30/09/2024)

Task 3.3 [D1.15]. Rhizome soluble carbohydrate (COH) content values will be quantified by means of HPLC-ELSD and investigated in the context of the size of the ‘root engine’ as a viable indicator of biomass yield (Start 01/06/2023 - End 30/11/2024)
Task 3.4 [D1.16]. Quantifying soil limiting factors affecting the Miscanthus ‘Root Engine’ will be achieved by determining root limiting physical soil metrics (Penetrative Resistance & bulk density as well as pH, SOM, TOC and texture at each root coring locations undertaken under Task 3.2 (Start 01/10/2023 - End 30/09/2024)
Task 3.5 [D1.17]. Data integration and analysis will focus on the identification of key soil, root and soil management factors affecting the miscanthus ‘Root Engine’ and how this relates to yield. Data generated from Task 3 will feed directly into Task 4. (Start 01/11/2023 - End 31/03/2025)

Task 4.
Developing a data driven genotype selection matrix will reduce the overarching planting risks and increase the potential for improved planting quality, establishment, and overall biomass yield. Task 4 will collect data from other components of the broader research and develop a data matrix. This data will direct decision making to choose the most appropriate Miscanthus genotype, most suitable rhizome/seed plug pre-treatments, and optimum pre-harvest treatments to improve establishment and growth at specific fields and locations (e.g., soil pH, soil type, seasonal environmental variables).

Task 4.1. [D1.18] Collaborative assessment of parameters collected by consortium partners to define the data collection strategy, data formats and data QA guarantees from partners. (Start 10/04/2022 - End 30/03/2025)
Task 4.2. [D1.19] Investigation of data provided by partners relating to those TV Miscanthus varieties at multiple and varied field locations (e.g., linking establishment and yield with variable soil pH, type, hydrology, climate) in association with TV and their growers. A key set of establishment and growth parameters will be collected throughout plant development and throughout the season by partners (e.g., pre-treatments, emergence, growth rate, establishment, overwintering success, yield). Soil will also be monitored by partners to determine how Miscanthus influences soil properties over time. These will link with several other WP and tasks, and link growth to carbon capture (TV). (Start 10/04/2022 - End 30/03/2025)

Equipment and Facilities –
[List of Requirements]
Multi-site access to commercial plantings and areas to plant small plots (LJMU).
Access to EG material and facilities in Murcia and El Hierro (LJMU).
Glasshouse and hardstanding access (LJMU).
Plant nursery glasshouse with equipment (EG)
Laboratory scale brusher and thresher for seeds cleaning (EG)
Environmental Analytical Facilities e.g., LC-MS, HPLC-ELSD (CU)
Soil carbon analysis (TV).
Computer(s) (LJMU, CU).
Commercially available plant growth regulators (LJMU, CU).
Commercially available microbial endophytes (LJMU).
Eijkelkamp bi-partite handheld root auger (CU).
Eijkelkamp Soil Column Cylinder Auger and Cobra TT petrol-driven percussion hammer (CU).
Digital Eijkelkamp Penetrologger with a 1.2 cm2 30° internal angle cone (CU).
Field consumables for soil and root sampling (CU).
Field work – staff travel and subsistence, consumables, equipment for in-field data collection (LJMU) (root and soil sampling campaigns (CU)).

Consumables for soluble carbohydrate extraction and quantification: plastic and glassware, standards, solvents, HPLC columns and guard columns (LJMU, CU). Travel and Accommodation (UK, Murcia, El Hierro) (LJMU). Consumables, pots, compost, chemicals, PGR's, inoculants (LJMU).
Summary of Deliverables: Detail the planned external (E) and internal (I) deliverables

Ref	Title	External / Internal	Responsibility	Due Date	Comments / Notes
D1.1	Investigation of effects of PGRs on rhizome	**I/E**	LJMU CU TV	Jan-2025	
D1.2	The effects of temperature priming on rhizome	**I/E**	LJMU CU TV	Jan-2025	
D1.3	Use of microbial inoculants on rhizome establishment	**I/E**	LJMU CU TV	Jan-2025	
D1.4	Determination and quantification of plant growth regulators in Miscanthus rhizomes	**E**	CU	Mar-2025	These deliverables depend on samples provided by T1.1 and T1.2.
D1.5	Rhizome mass requirement for establishment in different soil types	**I/E**	UoL TV LJMU	Feb-2025	Links with WP2
D1.6	Optimising timing of seed harvest in relation to panicle maturity	**I/E**	EG LJMU	Sep-2024	
D1.7	Categorising seed grades with seed vigour and germination success	**E**	EG	Aug-2024	
D1.8	Seed germination development time to harvest	**I/E**	EG TV LJMU	Jan-2025	
D1.9	Variety specific seedling development in varied soil types	**E**	EG UoL	Dec-2024	
D1.10	Improving seedling establishment and development with	**I/E**	EG LJMU CU	Jan-2025	

	PGR's and microbial inoculants.				
D1.11	Determination and quantification of plant growth regulators in Miscanthus seeds	**E**	CU	Dec-2024	This deliverable depends on samples provided by T2.1.
D1.12	Optimising seeds required per plug and effect on establishment and development	**I/E**	EG LJMU	Sep-2024	
D1.13	Stratified root and soil sampling programme	**E**	CU	Oct-2022	
D1.14	Quantifying the size of the Miscanthus ‘Root Engine’	**E**	CU	Sep-2024	
D1.15	Rhizome soluble carbohydrate (COH) content analysis	**E**	CU	Nov-2024	
D1.16	Soil limiting factors affecting the Miscanthus ‘Root Engine’	**E**	CU	Sep-2024	
D1.17	Data integration and analysis	**E**	CU	Mar-2025	
D1.18	Developing data matrix for collating and inputting data from partners	**I/E**	TV LJMU All	Mar-2025	
D1.19	Correlating data from partners to inform on genotype by environment interactions for identifying the better variety for a specific site	**I/E**	TV LJMU All	Mar-2025	

Dependencies –
Field based components of Task 1 are dependant on provision of field space and planting assistance from TV. All Task 1 components are dependant on supply of rhizome and seed from TV and EG.

Design of stratified sampling programme (Task 3.1) is dependent on access to relevant data from Terravesta Miscanthus landbank and growers. Identification of key soil, root and soil management factors affecting the miscanthus 'Root Engine' and how this relates to yield (Task 3.5) is dependent on obtaining annual yield data for each of the miscanthus fields sampled (Task 3.2). Task 4 is wholly reliant on the provision of accurate and correctly organised data from all project partners.	
Items which must be available for this Work Package	**Responsibility**
<u>Task 1.</u> Rhizome and seeds/ seed plugs provided by TV and EG. Consumables for inoculants. Access to TV field locations. Consumables for the extraction and quantification of plant growth regulators: plastic and glassware, labelled (deuterated) and unlabelled standards, solvents, LC-MS columns, and guard columns. Field work – staff travel and subsistence, consumables, equipment for in-field data collection. <u>Task 2.</u> Consumables for seeds sowing experiments run under control environment in glasshouse: trays, compost, small equipment, small microscope for seeds quality control. Access to EG material and facilities in Murcia and El Hierro (LJMU). <u>Task 3.</u> ● Eijkelkamp bi-partite handheld root auger ● Eijkelkamp Soil Column Cylinder Auger and Cobra TT petrol-driven percussion hammer. ● Digital Eijkelkamp Penetrologger with a 1.2 cm2 30° internal angle cone ● Field consumables for soil and root sampling ● Field work – staff travel and subsistence, consumables, equipment for in-field data collection (root and soil sampling campaigns). ● Consumables for soluble carbohydrate extraction and quantification: plastic and glassware, standards, solvents, HPLC columns and guard columns. Multi-site access to commercial plantings and areas to plant small plots (LJMU). Glasshouse and hard-standing access (LJMU). Environmental Analytical Facilities e.g., LC-MS, HPLC-ELSD (CU) Soil carbon analysis (TV). Computer(s) (LJMU, CU, EG). Commercially available plant growth regulators (LJMU, CU, EG). Commercially available microbial endophytes (LJMU, EG). Eijkelkamp bi-partite handheld root auger (CU).	See individual tasks

Eijkelkamp Soil Column Cylinder Auger and Cobra TT petrol-driven percussion hammer (CU). Digital Eijkelkamp Penetrologger with a 1.2 cm2 30° internal angle cone (CU). Field consumables for soil and root sampling (CU). Field work – staff travel and subsistence, consumables, equipment for in-field data collection (LJMU) (root and soil sampling campaigns (CU)). Consumables for soluble carbohydrate extraction and quantification: plastic and glassware, standards, solvents, HPLC columns and guard columns (LJMU, CU). Travel and Accommodation (UK, Murcia, El Hierro) (LJMU). Consumables (LJMU).	
Work Packages dependent on this Work Package	**Responsibility**
Work package 2 and 3 have components dependant on WP1. WP2 feasibility study will be dependent on the finding in WP1 as well as some of the practical trails in WP3 (planting) will depend on the result from WP1. This WP Task 4 is reliant on all other WP's	See individual tasks

Work Package 2: Optimising Production of Planting Material
Start date: 01/04/2022 Anticipated total man-days: TBC End date: 31/03/2025 Work Package Leader: Terravesta Farms Ltd.
Work Package Objectives: ● To optimise the planting material in order to increase establishment successes ● Main focus on quality of material and the implementation of quality assurance/control ● Develop process to maintain such quality

● A. Control quality assurance process - recommendation from UoL for processing then apply recommendation (UoL/TV/YT/LJMU)
- D2.1 Investigate rhizome lifting process (April 2022 – March 2023) Head over to TV rhizome nursery and investigate the process in two seasons.
  - D2.1.1 First year investigation and reporting (April 2022 - May2022)
  - D2.1.2 Second year observation and update reporting (March 2023 – May 2023)
- D2.2 Define rhizome quality standard and specification (April 2022-Dec 2023) based on the investigation made in D2.1
  - D2.2.1 Observation of differences in quality and subsequent development (April 2022 – October 2022)
  - D2.2.2 Observation of plant development with improved quality control (March 2023 – December 2023)
- D2.3 Define implementation of quality control based on the standard and integrate into Terravesta database Harvest Hub (Jan 2024 – Jan 2025)
- Implementation above via cutting and handling (To be handled by WP2 Section C)
- D2.4 Batch handling system development – nursery to farm to trace what was produced, when and shipped to where. How low can that go in that process (April 2022 – March 2024) Iterate over 3 times to build up from previous learnings
  - D2.4.1 First year data collection of rhizome transport nursery to farm (April 2022 – June 2022)
  - D2.4.2 Development of rhizome transport monitoring and implement test of new handling protocol (November 2022 – June 2023)

- D2.4.3 Review handling protocol and implement handling protocol (November 2023 – March 2024)
- D2.5 Transport and storage quality assessment – transport time length effects on dormancy break (April 2022 – March 2025)
  - D2.5.1 First year quality assessment on transport and storage (April 2022 – September 2022)
  - D2.5.2 Implement learning of first year into second year assessment (March 2023 – September 2023)
  - D2.5.3 Final assessment of improved process against dormancy break (April 2024 – September 2024)

● B. Planting material preparation, treatment, and practicality

Rhizome – In-corporate WP1 finding (TV/LJMU/YT):

- D2.6 Pre-treatment effect on rhizome, based on trial planting in commercial setting (April 2022 – May 2023)
  - D2.6.1 Work out implementation of pre-treatment in the field
  - D2.6.2 Plant pre-treated rhizome from previous' learning
  - D2.6.3 Crop review (October 2024 – November 2024)
- D2.7 Investigate current approaches to automate current "labour heavy process" (low cost, high efficiency to reduce labour cost and time) (April 2022 – June 2023)
  - D2.7.1 Study of existing technologies (July 2023 – September 2023)
  - D2.7.2 Comparison with existing technology with new rhizome specifications (August 2024 – November 2024)
- D2.8 Investigate costing for (semi-) automated process (for pre-treatment e.g. "hydro gel" to counter act clean rhizomes with no soil to preserve moisture) (January 2023 – May 2024): Finding out how to implement the system efficiently for operation (e.g. Hormone timed release)
  - D2.8.1 Costing assessment based on D2.7.1 (September 2023 – November 2023)
  - D2.8.2 Costing assessment based on D2.8.2 with consideration of new rhizome specification (November 2024 – January 2025)
- D2.9 Implement learning of bespoke commercial process of rhizome production (TV) (June 2022 – May 2023 – May 2024) Depends on D2.8

Seed-based hybrid – continuation of experimental trial assessment on seedling production and establishment:

- D2.10 Seed production (TV) (Annually Oct-Dec 2022, 2023, 2024) Test during annual maintenance of seed-based crossing block on method developed During WP1
  - D2.10.1 Seed assessment from 2021 harvest (April 2022)
  - D2.10.2 Seed harvest process assessment 2022 (November 2022 – December 2022)
  - D2.10.3 Seed assessment from 2022 harvest (March 2023 – April 2023)
  - D2.10.4 Seed harvest process assessment 2023 (November 2023 – December 2023)
  - D2.10.5 Seed assessment from 2023 harvest (March 2024 – April 2024)
  - D2.10.6 Seed harvest process assessment 2024 (November 2024 – December 2024)
- D2.11 Film/no film trial (TV) (May – June 2022) Assessment to confirm if film showed effect on regrowth (feedback to WP1 for consideration)
- D2.12 Investigate commercial feasibility for discovered pre-treatment for plugs (TV) (April 2022 – May 2024)
  - Assessment after first year establishment count (July 2023 – October 2023)
  - Assessment after first and second year establishment count (July 2024 – October 2024)
- D2.13 Implement learning of bespoke commercial process of plug production (TV) (June 2022 – May 2023 – May 2024) Depends on D2.11, D2.12

D2.14 Preparation conform to the phyto-sanitary requirements as a continual protocol for the business to periodically review any changes to import requirement (Annual review at January 2023, 2024, 2025)

- D2.14.1 Annual revision year 1 (January 2023)
- D2.14.2 Annual revision year 2 (January 2024)
- D2.14.3 Annual revision year 3 (January 2025)

D2.15 Economic comparison between Seed-based and Rhizome in light of new processes (TV) (January 2025 – March 2025) Depends on D2.8, 2.9, 2.14, 2.13

- C. Automated rhizome processing (YT/TV)

  Design
  - D2.16 Initial equipment investigation/outlet design (April – December 2022)
  - D2.17 Test equipment investigation and assessment (April – September 2022)
  - D2.18 Target rhizome specification and practical assessment (July – September 2022)
  - D2.19 Establish target throughput and acceptable equipment cost trade-offs (July – September 2022)

  Washdown prototyping
  - D2.20 Development and testing of conveyor segment for washdown (July 2022 – Jun 2023)
  - D2.21 Conveyor selection (October - December 2022)
  - D2.22 Washdown spray system design/selection and build (Oct 2022 – March 2023)
  - D2.23 Washdown testing (January 2023 – June 2023)

  Imaging prototyping
  - D2.24 Vision/laser scanner analysis initial data collection (April 2023 – June 2023)
  - D2.25 Iterative approach to vision processing for rhizome identification (April 2023 – December 2023)
  - D2.26 Development of cut-line generation to meeting rhizome specification (July 2023 – December 2023)
  - D2.27 Assessment of requirement for root removal (January 2024 – March 2024)
  - D2.28 Root removal cutline generation (January 2024 – March 2024)

  Integration 1
  - D2.29 Integration of Washdown and rhizome identification hardware/software (January 2024 – September 2024)
  - D2.30 Testing and iteration (January 2024 – September 2024)
  - D2.31 Integration of cut-line generation (April 2024 – September 2024)
  - D2.32 Assessment of performance W.R.T. rhizome specification (July 2024 – September 2024)

  Cutting prototyping
  - D2.33 Investigation/assessment of cutting technologies (January 2023 – June 2023)
  - D2.34 Selection/acquisition of cutting system (April 2023 – June 2023)
  - D2.35 Development/integration of cutting system with cut-line generation software (July 2023 – September 2024)
  - D2.36 Testing of cutting on pre-washed samples (January 2024 – September 2024)

  Integration 2
  - D2.37 Integration of full system (January 2024 – March 2025)
  - D2.38 Iteration of refinements (July 2024 – March 2025)
  - D2.39 Assessment of performance W.R.T. rhizome specification (October 2024 – March 2025)
  - D2.40 Assessment of performance W.R.T. throughput (January 2025 – March 2025)
  - D2.41 Assessment of performance W.R.T. cost (January 2025 – March 2025)

Key actions:
UoL to advice on the process
LJMU to look at pretreatment between after rhizome lifting to planting
LJMU to advice on seed production “Quick-Wins”
EG to implement seed production “Quick-Wins”

TV to produce tracking procedure and software
Mike and Jason to investigate current rhizome batches variation on the ground (image based? Borrow Alex's camera)
YT to work on implementation on Rhizome QA

Equipment and Facilities –
Rhizome production facility
Seed crossing block facility
Control environment facility (for rhizome pre-treatment assessment)
Access to water for washing
Washing jets
Conveyer belt
All associated safety equipment
Prototype building workshop
Ability to travel to different facilities including overseas

Summary of Deliverables: Detail the planned external (E) and internal (I) deliverables

Ref	Title	External / Internal	Responsibility	Due Date	Comments / Notes
D2.1	Investigate rhizome lifting process		UoL/TV/YT	Mar 2023	Shall start at March 2022 without BEIS support
D2.2	Define rhizome quality standard and specification		UoL/TV	Dec 2023	
D2.3	Define implementation of quality control based on the standard		UoL/TV/YT	Jan 2025	
D2.4	Batch handling system development –track and trace		TV	Mar 2024	Track and trace nursery to farm
D2.5	Transport and storage quality assessment		UoL/TV	Mar 2025	Transport time length effects on dormancy break
D2.6	Pre-treatment effect on rhizome		TV/LJMU	May 2023	Trial in control environment
D2.7	Investigate current approaches to automation		YT/TV	Jun 2023	To automate currently "Labour heavy" processes

D2.8	Investigate costing for (semi-) automated processes		TV/YT	May 2024	Implement effective process for operation
D2.9	Implement learning of bespoke commercial process of rhizome production		TV	May 2024	Depends on D2.8
D2.10	Seed production		EG/LJMU	Dec 2024	Annual work between Oct-Dec
D2.11	Film/no film trial		TV	Jun 2022	Confirm value of film and feed back to WP1
D2.12	Investigate commercial feasibility for discovered per-treatment for plugs		LJMU	May 2024	
D2.13	Implement learning of bespoke commercial process of plug production		TV	May 2024	Depends on D2.11, D2.12
D2.14	Preparation conforms to the phyto-sanitary requirements as a continual protocol		TV	Jan 2025	
D2.15	Economic comparison between seed-based and rhizome		TV	Mar 2025	Reassess after new process implemented. Depends on D2.8, 2.9, 2.13, 2.14
D2.16	Initial equipment investigation/outlet design		YT	Dec 2022	
D2.17	Test equipment investigation and assessment		YT	Sep 2022	
D2.18	Target rhizome specification and practical assessment		YT	Sep 2022	
D2.19	Establish target throughput and acceptable equipment cost trade-offs		YT	Sep 2022	
D2.20	Development and testing of conveyor		YT	Jun 2023	

	segment for washdown				
D2.21	Conveyor selection		YT	Dec 2022	
D2.22	Washdown spray system design/ selection and build		YT	Mar 2023	
D2.23	Washdown testing		YT	Jun 2023	
D2.24	Vision/laser scanner analysis initial data collection		YT	Jun 2023	
D2.25	Iterative approach to vision processing for rhizome identification		YT	Dec 2023	
D2.26	Development of cut-line generation to meeting rhizome specification		YT	Dec 2023	
D2.27	Assessment of requirement for root removal		YT	Mar 2024	
D2.28	Root removal cutline generation		YT	Mar 2024	
D2.29	Integration of Washdown and rhizome identification hardware/software		YT	Sep 2024	
D2.30	Testing and iteration		YT	Sep 2024	
D2.31	Integration of cutline generation		YT	Sep 2024	
D2.32	Assessment of performance WRT rhizome specification		YT	Sep 2024	
D2.33	Investigation/ assessment of cutting technologies		YT	Jun 2023	

D2.34	Selection/ acquisition of cutting system		YT	Jun 2023	
D2.35	Development/ integration of cutting system with cutline generation software		YT	Sep 2024	
D2.36	Testing of cutting on pre-washed samples		YT	Sep 2024	
D2.37	Integration of full system		YT	Mar 2025	
D2.38	Iteration of refinements		YT	Mar 2025	
D2.39	Assessment of performance WRT rhizome specification		YT	Mar 2025	
D2.40	Assessment of performance WRT throughput		YT	Mar 2025	
D2.41	Assessment of performance WRT cost		YT	Mar 2025	

Dependencies -	
Items which must be available for this Work Package	**Responsibility**
	See individual tasks
Work Packages dependent on this Work Package	**Responsibility**
•	See individual tasks

Work Package 3: Testing Biological and Environmental Factors that Impact Miscanthus Establishment

Start date: 01/04/2022 Anticipated total man-days: TBC
End date: 31/03/2025

Work Package Leader: University of Lincoln

Work Package Objectives:

- Test the environmental factors controlling Miscanthus establishment at three different scales and levels of experimental control
- Use mesocosm and pot experiment to test the interacting effects of soil type and soil condition on establishment and growth for rhizomes (in mesocosm) seeds (pots) and plugs (pots)
- Use plot trials to test the interacting effects of moisture stress and rhizome quality
- Test the effects of soil and the planting bed in the field using a spatially extensive field study

<u>Tasks 3.1 Soil type mesocosm and pot experiment</u>

To test the interaction between soil type and soil condition for rhizomes we will carry out a mesocosm experiment on two different soil types commonly used for Miscanthus growing in the UK (e.g. clay-silt, clay-limestone) using a trench system. Each mesocosm will allow sufficient space for root development. Within each trench we will install horizontal clear tubes at three different depths (5-10cm, 15-20cm and 25-30cm), which will allow us to non-destructively monitor rhizome and root growth throughout the experiment (McNickle and Cahill 2009 PNAS). The mesocosm experiment will have two treatments (a control and compacted soil), with four replicates per treatment (16 mesocosms overall). We will record establishment, above ground biomass and below ground biomass throughout the experiment. Once established the above and below ground development of the Miscanthus plants in the mesocosm will be recorded across years 1, 2 and 3 of the project to determine if slow growth in one year is leads to slow growth in subsequent years, or if Miscanthus plants can compensate and catch up.

In the second year we will carry out two sets of pot experiments on seeds and plugs. For both seed and plugs we will look at two different soil types, two seed rates and two different soil treatments (e.g. control and compacted), with 10 replicates per treatment. At senescence the plants will be removed from the pot and the rhizome and root structure washed and weighted to estimate biomass.

This set of mesocosm and pot experiments will tell us how managing difficult soils (commonly used to grow Miscanthus), affects the establishment and growth of Miscanthus from the three key planting materials, rhizome, seeds and plugs.

Task 3.2 Moisture stress plot trial

In the second and third years of the project a plot trial will jointly test the effect of moisture stress and rhizome quality on establishment. In the first year we will establish 16 4m x 1.5m Miscanthus plots from rhizomes for four replicates of four treatments; control, rain-sheltered dry, rain-sheltered irrigated, and over irrigated (D3.2.1). There will be 8-10 rhizomes planted in each of the 16 plots. We will use a Latin square design to select rhizomes with combinations of properties (e.g. weight, length, storage method) within each of the 16 trial plots. The best rhizome criteria to test will be identified in WP1 (D1.1-4). We will record the location and set of properties for each rhizome planted, allowing us to test the interaction between these rhizome properties and moisture stress. In each plot we will track the establishment and growth both above ground (with the phenospex system) and below ground (with an in-situ mini rhizotron) (D3.2.2).

To track how establishment and survival change from year 1 to year two we will leave the original 16 trial plots in the ground for the second year and continue to monitor them. To get data from a second year on establishment we will replicate the entire plot trial at a second site (D3.2.3, D3.2.4).

Because we will have treatments at the site/year, plot and rhizome level data will be analysed using hierarchical linear models.

Task 3.3 Soil properties field study

To test the effect of soil conditions in the field on rhizome establishment we will use field data from recently planted Miscanthus fields. We will adapt the Soil Quality of Establishment (SQE) index (Atkinson et al 2007) to field collected data for Miscanthus. This index combines simple to measure soil properties (penetration resistance, volumetric water content, shear strength, bulk density) into a statistical model that predicts establishment. We will measure the establishment of Miscanthus across 10 fields each year. We will carry out this analysis in a grid in each field. At a higher resolution (e.g. 10m grid) we will sample at the surface (5cm depth). At a courser resolution (e.g. 25m grid) we will also do the same SQE analysis at 20-30cm depth. This will allow is to extrapolate the SQE from the surface measurements (which are quick to carry out) to soil properties deeper in the soil profile (which are much more time consuming to obtain).

We will use an RTK-GPS to locate each sample point, which will allow us to link the soil measurements to drone imagery and a count of Miscanthus plants across each field using the Miscanthus counting CNN developed by Canfield university in the phase one OMENZ project. To help ground truth the plant counting CNN we will also carry out plant counts in a 2m by 2m quadrate centred on the soil sample location.

A hierarchical spatial errors model will be used to predict plant counts in newly established Miscanthus fields based on physical soil properties and any field preparation taken before planting, while controlling for spatial autocorrelation between sampling locations (Coutts et al 2021 Ecology). This will tell us what combinations of soil properties leads to higher establishment rates.

Task 3.4 Rhizome supply chain Audit

In the first and second year UoL will audit the supply chain of Miscanthus rhizomes from the propagation fields in Poland, through the transport chain to fields in the UK. This will focus on establishing a quality control standard that includes time out of storage, storage conditions and consistency across the planting material (are all rhizomes treated the same). This will be carried out UoL staff including a plant material supply chain expert.

Task 3.5 Promotion and dissemination of work

UoL will promote the results and key findings of this work to the wider agricultural community through a stand at a major UK agricultural show in the final year of the project.

Task 3.6 2023 and 2024 planting demonstration

TV is responsible for this task which includes two planting demonstration for both rhizome and seed-based hybrid. This task is aimed to demonstrate the combined learning of plant biology, planting material technique improvement as well as mechanised planting methods in to 2 years of planting deliverables in selected commercial fields.

Equipment and Facilities –

Summary of Deliverables: Detail the planned external (E) and internal (I) deliverables

Ref	Title	External / Internal	Responsibility	Due Date	Comments / Notes

D3.1.1	PDRA in post	I	UoL	31/08/2022	
D3.1.2	Data collection complete	I	UoL	30/11/2022	
D3.1.3	Mesocosm analysis report	I	UoL	31/03/2023	
D3.1.4	Pot experiment data gathered	I	UoL	30/11/2023	
D3.1.5	Pot experiment report complete	I	UoL	31/03/2024	
D3.2.1	First plot trial planted	I	UoL	31/05/2023	
D3.2.2	Year 1 trial data gathered	I	UoL	31/10/2023	
D3.2.3	Second plot trial planted	I	UoL	31/05/2024	
D3.2.4	Year 2 trial data gathered	I	UoL	31/10/2024	
D3.2.5	Plot trial analysis report complete	I	UoL	31/03/2025	
D3.3.1	Year 1 soil samples collected	I	UoL	30/06/2022	
D3.3.2	Year 2 soil samples collected	I	UoL	30/06/2023	
D3.3.3	Year 3 soil samples collected	I	UoL	30/06/2024	
D3.3.4	Drone images gathered	E	Terravesta	31/10/2024	
D3.3.5	Report on field study complete	I	UoL	31/03/2025	
D3.4.1	Trip to growing facility (Year 1)	I	UoL	31/05/2022	

D3.4.2	Trip to growing facility (Year 2)	I	UoL	30/04/2023	
D3.4.3	Supply chain report complete	I	UoL	30/06/2023	
D3.6.1	2023 planting complete	I	UoL	31/05/2023	
D3.6.2	2024 planting complete	I	UoL	31/05/2024	

Dependencies -

Items which must be available for this Work Package	**Responsibility**
	See individual tasks

Work Packages dependent on this Work Package	**Responsibility**
•	See individual tasks

Work Package 4: Establishment Monitoring for Upscaling Production

Start date: 01/04/2022 Anticipated total man-days: TBC
End date: 31/03/2025

Work Package Leader: Dr Toby Waine (Cranfield University (CU))

Work Package Objectives:

- Quantify planting success by effective monitoring of establishment for optimised planting strategy, crop management and upscaling of production

(4.1) Automatic establishment count - image recognition from existing RGB: (yr1)
-Continuation of UAV image processing across different land types as well as establishment level.
-Develop/refine the AI model for automatic monitoring of miscanthus establishment using existing deep-neural network for plant identification and drone imaging technology from RGB consumer cameras. This is based on the successful trial of a Mask R-CNN, shown to be suitable for plant detection and separation of miscanthus from weeds on 1.5 cm aerial imagery. It will involve producing additional labelled data for model refinements.
D4.1: Trained AI model for Miscanthus detection from UAV imagery (model code and weights).

(4.2) Automatic establishment count – sensor technology: (yr1-2)
-Assess multi-spectral camera vs. RGB to improve classification accuracy, including field trials for evaluation of new drone and sensor technology. Specifically, new experiments for the collection and analysis of hyperspectral images for identifying a set of spectral filters to develop a low-cost sensor. This can be bench-marked against the AI approach using RGB images and the cost-benefit for operational use. Including a range of different planting ages and varieties.
D4.2: UAV data and field data collections. Analysis and comparison with commercial RGB images (Technical Report).

(4.3) Evaluate Establishment counts: (yr1)
-Evaluate AI model across a wide range of images collected at different growth stages and locations to determine: 1) optimum time for image collection for accurate plant detection; 2) effect of timing on measuring establishment from plant counts/areas; 3) operational parameters for drone flights considering the resolution (linked to flying height), geometric accuracy and crop development/management at timing of aerial survey.
D4.3: Parameters for operational UAV flights (model code and weights and data collection protocol).

(4.4) Monitoring feedstock: (yr1.5-2.5)
-(a) Biomass monitoring and prediction through the further use of drone imagery to make assessment of miscanthus biomass, to supply timely information about feedstock supply. Field assessment of biomass for calibration and validation (CU).
–(b) Growth and biomass monitoring through the use of continuous ground-based ultrasonic and infra-red monitoring with data relay via GSM/IoT. Data to be assessed for use as ground-truth for aerial surveys (MN).
D4.4: UAV and field data collection, model development and analysis (Technical Report).

(4.5) Physical planting counter data-stream - interpretation and alarm from in-field rhizome sensor data-stream: (sub-Lead: Mark Neal (MN)) (yr1-2)

-Consultation with rhizome planter operators and design/build of alarm system for use during planting. Assessment of practicality and use of wireless connection for an in-cab alarm system (MN).
-Feedback to physical planting counter – create planting map from sensor data-stream (MN) to compare with UAV data (MN/CU).
-Develop alarm for driver of threshold missed planting (MN).
-Data analysis from the counter sensor data-stream – identify key performance indicators or inputs for future decisions (MN/CU).
D4.5: Driver Alarm system. Comparison of in-field data-stream with UAV establishment (Technical Report).

(4.6) Data integration (imagery and sensor) to TV current system: (yr 1-3)
-Review TV's existing RGB UAV data collections, image pre-processing chain, storage and for AI automation training and deployment.
-Develop and automate a workflow for processing of raw UAV image frames to plant counts for establishment monitoring to assist replanting, and to optimise crop management decisions.
D4.6: Full workflow, code and working demonstrator, plus documentation.

Equipment and Facilities –

Summary of Deliverables: Detail the planned external (E) and internal (I) deliverables

Ref	Title	External / Internal	Responsibility	Due Date	Comments / Notes
D4.1	Automatic establishment count-image recognition from existing RGB		CU	Mar-2023	Model code and weights
D4.2	Automatic establishment count – sensor technology		CU	Mar-2024	Datasets, technical report
D4.3	Evaluate Establishment counts		CU	Mar-2024	Model code and weights
D4.4	Monitoring feedstock		CU	Dec-2024	Model development and technical report

D4.5	Physical planting counter data-stream		MN	Mar-2024	Alarm system, technical report
D4.6	Data integration (imagery and sensor) to TV current system		CU	Mar-2025	Working demonstrator and documentation

Dependencies -

Items which must be available for this Work Package	**Responsibility**
UAV imagery collections with Multispectral and Hyperspectral sensors – multiple flights 3 fields 6 times per season, plus further 6 fields 2 flights with different sensors, plus 6 flights for ad-hoc investigations. (Total of 36 flights over the project period) Field work – staff travel and subsistence, consumables, equipment for in-field data collection (survey of crop biophysical parameters). Alarm system, and field based sensor: -Parts for sensors and housings, machinery/workshop for manufacture, credit for SIM cards. -Access to planters and operators during planting for assessment of operation environment and practical aspects. Field visits for assessment and testing. -Travel and subsistence.	See individual tasks
Work Packages dependent on this Work Package	**Responsibility**
• WP3 would benefit from the automated plant counts to support their field observations (and visa-versa).	See individual tasks

Work Package 5: Project and Financial Management	
Start date: 01/04/2022 TBC	Anticipated total man-days:

End date: 31/03/2025 Work Package Leader: CHAP
Work Package Objectives: ● Project Management ● Data Management ● Risk Management ● Financial Management ● Project Status Meetings ● Document Lessons Learnt ● Exploitation and Dissemination ● Update Records and Systems
Description of work ● 5.1 Continuously update Project Management Plan ● 5.1.1 Data management and implementation with integrated work package learning (Harvest Hub platform) ● 5.2 Continuously update Risk Register ● 5.3 Continuously update Financial Management Plan ● 5.4 Initial Kick Start Meeting, monthly Technical Meetings and quarterly MO Meetings; ● 5.5 Update records and systems ● 5.6 Exploitation and dissemination of results ● 5.7 Update records, systems and final report.
Equipment and Facilities – ● CHAP
Summary of Deliverables: Detail the planned external (E) and internal (I) deliverables

Ref	Title	External / Internal	Responsibility	Due Date	Comments / Notes
D5.1	Quarterly Project Reports completed each quarter	I	Terravesta / CHAP	Quarterly	Input from all partners
D5.2	Report on data integrations and continual learning for Harvest	E	Terravesta	31/03/2025	Input from all partners

	Hub platform				
D5.3	Final Project Report completed by March 2025	I	Terravesta / CHAP	31/03/2025	Input from all partners

Dependencies -	
Items which must be available for this Work Package	**Responsibility**
• Project management document; exploitation plan; risk register; financial forecast	See individual tasks
Work Packages dependent on this Work Package	**Responsibility**
• All	See individual tasks

Summary of Milestones

Milestone	Invoice Due Date *mm/yy*	Planned Deliverables
Milestone 1 Quarter 1	Jun-22	D3.4.1 Trip to growing facility (Year 1) D2.4.1 First year data collection of rhizome transport (nursery to farm) D2.11 Film/no film trial D3.3.1 Grid soil samples of at least 10 fields (Year 1) D5.1 Quarterly Project Reports completed each quarter
Milestone 2 Quarter 2	Sep-22	D2.5.1 First year quality assessment on transport and storage D2.17 Test equipment investigation and assessment D2.18 Target rhizome specification and practical assessment D2.19 Establish target throughput and acceptable equipment cost trade-offs D4.5.1 Alarm system specification D5.1 Quarterly Project Reports completed each quarter
Milestone 3 Quarter 3	Dec-22	D1.13 Stratified root and soil sampling programme D2.2.1 Observation of differences in quality and subsequent development D2.16 Initial equipment investigation/outlet design D5.1 Quarterly Project Reports completed each quarter D2.21 Conveyor selection D3.1.2 Data collection complete D4.2.1 Year 1 UAV and field data collections D4.4.4 Ground based deployment D4.5.2 Alarm system interim presentation
Milestone 4 Quarter 4	Mar-23	D2.14.1 Annual revision (Year 1) D2.22 Washdown spray system design/ selection and build D3.1.3 Mesocosm analysis report

		D4.1.1 Continuation of UAV image processing across different land types as well as establishment level D4.1.2 Develop/refine the AI model for automatic monitoring of miscanthus establishment using existing deep-neural network for plant identification and drone imaging technology from RGB consumer cameras. D5.1 Quarterly Project Reports completed each quarter
Milestone 5 Quarter 5	Jun-23	D2.6 Pre-treatment effect on rhizome D2.7 Investigate current approaches to automation D2.1.1 First year investigation and report D2.1.2 Second year observation and updated report D2.4.2 Development of rhizome transport monitoring and implement test of new handling protocol D2.20 Development and testing of conveyor segment for washdown D2.23 Washdown testing D2.24 Vision/laser scanner analysis initial data collection D2.33 Investigation/ assessment of cutting technologies D2.34 Selection/ acquisition of cutting system D3.1.1 Hire PDRA / project set up D3.3.2 Year 2 soil samples collected D3.4.2 Observe miscanthus rhizome production in Poland (Year 2) D3.4.3 Audit supply chain from propagation fields in Poland to growing farms in the UK D4.2.2 Interim presentation D4.4.5 Ground based – interim presentation D4.5.3 Alarm system operational D5.1 Quarterly Project Reports completed each quarter
Milestone 6 Quarter 6	Sep-23	D2.5.2 Implement learning of first year into second year assessment D2.7.1 Study of existing technologies D4.3.1 Interim presentation D4.4.1 Drone – interim presentation D4.5.4 Data stream – interim presentation D5.1 Quarterly Project Reports completed each quarter / Bi-annual review
Milestone 7 Quarter 7	Dec-23	D2.2 Define rhizome quality standard and specification D2.2.2 Observation of plant development with improved quality control

		D2.25 Iterative approach to vision processing for rhizome identification D2.26 Development of cut-line generation to meeting rhizome specification D2.6.1 Assess implementation of pre-treatment in the field D2.8.1 Costing assessment based on D2.7a D3.1.4 Pot experiment data gathered D3.2.2 Data collection for first plot trial (Year 1) D4.2.3 Year 2 UAV and field data collections D5.1 Quarterly Project Reports completed each quarter
Milestone 8 Quarter 8	Mar-24	D2.4.3 Review handling protocol and implement handling protocol D2.27 Assessment of requirement for root removal D2.28 Root removal cutline generation D2.14.2 Annual revision (Year 2) D3.1.5 Pot experiment report complete D4.2.4 Analysis and comparison with commercial RGB images (Technical Report) D4.3.2 Parameters for operational UAV flights D4.4.6 Ground based – technical report D4.5.5 Data stream – comparison with drone – report D4.6.1 Workflow and data definitions and interim presentation D5.1 Quarterly Project Reports completed each quarter
Milestone 9 Quarter 9	Jun-24	D2.6.2 Plant pre-treated rhizome from previous learning D3.2.3 Set up of second plot trial D3.6.1 Planting for Demonstrations (Years 2&3) D2.3 Testing and iteration D3.3.3 Grid soil samples of at least 10 fields (Year 3) D3.5.1 Promote work at agricultural shows / trade events / conferences D5.1 Quarterly Project Reports completed each quarter
Milestone 10 Quarter 10	Sep-24	D1.6 Optimising timing of seed harvest in relation to panicle maturity D1.7 Categorising seed grades with seed vigour and germination success D1.12 Optimising seeds required per plug and effect on establishment and development D1.14 Quantifying the size of the Miscanthus ‘Root Engine’

		D1.16 Soil limiting factors affecting the Miscanthus 'Root Engine'
		D2.29 Integration of Washdown and rhizome identification hardware/software
		D2.31 Integration of cutline generation
		D2.32 Assessment of performance WRT rhizome specification
		D2.35 Development/ integration of cutting system with cutline generation software
		D2.36 Testing of cutting on pre-washed samples
		D5.1 Quarterly Project Reports completed each quarter
Milestone 11 Quarter 11	Dec-24	D1.9 Miscanthus seed based hybrid rhizome development experiment
		D1.11 Investigating the mechanisms of plant growth regulators for seed emergence and vigour
		D1.15 Rhizome soluble carbohydrate (COH) content analysis D2.1 Seed production revisits
		D2.6 Commercial test on pre-treatment effect on rhizome, based on trial planting in commercial setting D2.7 Investigate current approaches to automate current labour heavy process
		D4.4 Monitoring feedstock
		D5.1 Quarterly Project Reports completed each quarter
Milestone 12 Quarter 12	Mar-25	D1.1 Addition of commercially available plant growth regulators (PGRs)
		D1.2 Investigation of rhizome temperature responses
		D1.3 Investigation of microbial inoculants on rhizome development
		D1.4 Underlying mechanisms of PGRs on Miscanthus D1.5 Investigation of rhizome size and overwintering survival
		D1.8 How does the quality of seed used in propagation effect the characteristics of the resulting offspring/plugs production? How does seed quality affect later growth in the field?
		D1.10 Could lower quality seeds can be improved by additional treatment with plant hormones and/or soil beneficial bacteria/endophytes.
		D1.17 Data integration and analysis

		D1.18 Define data matrix
		D1.19 Investigate establishment: Variety x Soil x Environment
		D2.3 Define implementation of quality control based on the standard
		D2.5 Transport and storage quality assessment D2.12 Investigate commercial feasibility for discovered pre-treatment for plugs D2.13 Implement learning of bespoke commercial process of plug production
		D2.14 Preparation conforms to the phyto-sanitary requirements as a continual protocol D2.14.3 Annual revision Year 3
		D2.15 Economic comparison between Seed-based and Rhizome in light of new processes (Depends on D2.8, 2.9, 2.14, 2.13)
		D2.37 Integration of full system
		D2.38 Iteration of refinements
		D2.39 Assessment of performance WRT rhizome specification
		D2.40 Assessment of performance WRT throughput
		D2.41 Assessment of performance WRT cost D2.8.2 Costing assessment based on D2.8B with consideration of new rhizome specification
		D3.2.5 Compile analysis and report writing on plot trials
		D3.3.5 Data analysis to predict establishment from soil analysis
		D4.6.3 Full workflow, code and working demonstrator, plus documentation
		D5.1 Quarterly Project Reports completed each quarter

Gantt Chart

WP	Deliverable	Title	Date		Organisation	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	TASK	**Improving Planting Material Vigour**	**Start**	**End**	**Responsibility**		2022				2023				2024		2025
	1.1	Addition of commercially available plant growth regulators (PGRs)	01/04/2022	31/01/2025	LJMU/CU/TV												
	1.2	Investigation of rhizome temperature responses	01/04/2022	31/01/2025	LJMU/TV												
	1.3	Investigation of microbial inoculants on rhizome development	01/10/2022	31/01/2025	LJMU/CU/TV												
	1.4	Underlying mechanisms of PGRs on Miscanthus	01/10/2022	31/03/2025	CU												
	1.5	Investigation of rhizome size and overwintering survival	01/04/2022	28/02/2025	UoL/TV/LJMU												
	TASK	**Seed Production Improvement**															
	1.6	Seed maturity and development time lapse observation	01/09/2022	30/09/2024	EG												
	1.7	An in-depth investigation into the quality of final harvest seeds and their viability	01/08/2022	31/08/2024	EG												
	1.8	How does the quality of seed used in propagation effect the characteristics of the resulting offspring/plugs production? How does seed quality affect later growth in the field?	01/10/2022	31/01/2025	EG/TV/LJMU												
WP1	1.9	Miscanthus seeds based hybrids rhizome development experiment.	10/01/2023	15/12/2024	EG												
	1.10	Could lower quality seeds can be improved by additional treatment with plant hormones and/or soil beneficial bacteria/endophytes.	01/09/2022	31/01/2025	EG/LJMU/CU												
	1.11	Investigating the mechanisms of plant growth regulators for seed emergence and vigour	15/12/2022	15/12/2024	CU												
	1.12	Investigating the number of seeds required in a plug, and the subsequent effect of intraspecific competition for resources on seedling establishment and growth	01/11/2022	30/09/2024	EG/LJMU												
	TASK	**Quantifying Field Scale Soil Factors Affecting Miscanthus Root Development**															
	1.13	Stratified root and soil sampling programme	01/04/2022	30/10/2022	CU												
	1.14	Quantifying the size of the Miscanthus 'Root Engine'	01/11/2023	30/09/2024	CU												
	1.15	Rhizome soluble carbohydrate	10/06/2023	30/11/2024	CU												
	1.16	limiting factors affecting the Miscanthus 'Root Engine'	01/10/2023	30/09/2024	CU												
	1.17	Data integration and analysis	01/11/2023	31/03/2025	CU												
	1.18	Define data matrix	10/04/2022	30/03/2025	TV/LJMU/ALL												
	1.19	Investigate establishment: Variety x Soil x Environment	10/04/2022	30/03/2025	TV/LJMU/ALL												
	TASK	**Control Quality Assurance Process**															
	2.1	**Investigate rhizome lifting process**															
	2.1.1	First year investigation and report complete	01/04/2022	31/05/2023	TV/YT/UoL												
	2.1.2	Second year observation and updated report complete	01/04/2023	31/05/2023	TV/YT/UoL												
	2.2	**Define rhizome quality standard and specification**															
	2.2.1	Observation of differences in quality and subsequent development	01/04/2022	31/10/2022	TV/UoL												
	2.2.2	Observation of plant development with improved quality control	01/03/2023	31/12/2023	TV/UoL												
	2.3	Define implementation of quality control based on the standard (dependent on 2.1 and 2.2)	01/01/2024	31/11/2024	TV												
	2.4	**Batch handling system development - Nursery to farm**															
	2.4.1	First year data collection of rhizome transport nursery to farm complete	30/04/2022	30/06/2022	TV												
	2.4.2	Development of rhizome transport monitoring and implement test of new handling protocol co	30/04/2023	30/06/2023	TV												
	2.4.3	Review handling protocol and implement handling protocol complete	01/01/2024	30/03/2024	TV												
	2.5	**Transport and storage quality assessment - transport time length effects on dormancy**															
	2.5.1	First year quality assessment on transport and storage	01/04/2022	30/09/2022	TV												
	2.5.2	Implement learning of first year into second year assessment	01/03/2023	30/09/2023	TV												
	2.5.3	Final assessment of improved process against dormancy break	01/04/2024	31/03/2025	TV												
	2.6	**Commercial test on pre-treatment effect on rhizome, based on trial planting in**															
	2.6.1	Assess implementation of pre-treatment in the field	01/03/2023	31/10/2023	TV												
	2.6.2	Plant pre-treated rhizome from previous learning	01/03/2023	31/05/2024	TV												
	2.6.3	Crop review complete	01/10/2024	30/11/2024	TV												
	2.7	**Investigate current approaches to automate current labour heavy process**															
	2.7.1	Study of existing technologies complete	01/07/2023	30/09/2023	TV												
	2.7.2	Comparison with existing technology with new rhizome specifications complete	01/08/2024	30/11/2024	TV												
	2.8	**Investigate costing for semi-automated process**															
	2.8.1	Costing assessment based on D2.7a complete	01/09/2023	30/11/2023	TV												
	2.8.2	Costing assessment based on D2.8b with consideration of new rhizome specification complete	01/11/2024	31/01/2025	TV												
	2.9	Implement learning of bespoke commercial process of rhizome production (Depends on D2.8)	01/01/2025	31/03/2025	TV												
	TASK	**Seed**															
	2.10	Seed production revisits	01/04/2022	31/12/2024	TV												
	2.11	Film / no film trial	01/05/2022	30/06/2022	TV												
	2.12	Investigate commercial feasibility for discovered pre-treatement for plugs	01/07/2022	28/02/2025	TV												
	2.13	Implement learning of bespoke commercial process of plug production	01/01/2025	30/03/2025	TV												
	TASK	**For Both**															
	2.14	**Preparations conform to the phyto-sanitary requirements**															
	2.14.1	Annual revision year 1 complete	01/01/2023	31/01/2023	TV												
WP2	2.14.2	Annual revision year 2 complete	01/01/2024	31/01/2024	TV												

WP	No.	Task	Start	End	Lead
	2.14.3	Annual revision year 3 complete	01/01/2025	31/01/2025	TV
	2.15	Economic comparison between Seed-based and Rhizome in light of new processes (Depends on D2.8, 2.9, 2.14, 2.13)	01/01/2025	31/03/2025	TV
	TASK	**Automated Rhizome Processing - Design**			
	2.16	Initial equipment investigation/outlet design	01/04/2022	31/12/2022	TV/YT
	2.17	Test equipment investigation and assessment	01/04/2022	30/09/2022	TV
	2.18	Target rhizome specification and practical assessment	01/07/2022	30/09/2022	TV
	2.19	Establish target throughput and acceptable equipment cost trade-offs	01/07/2022	30/09/2022	TV
	TASK	**Washdown Prototyping**			
	2.20	Development and testing of conveyor segment for washdown	01/07/2022	30/06/2023	YT
	2.21	Conveyor seclection	01/10/2022	31/12/2022	YT
	2.22	Washdown spray system design/selection and build	01/10/2022	30/03/2023	YT
	2.23	Washdown testing	01/01/2023	30/06/2023	YT
	TASK	**Imaging Prototyping**			
	2.24	Vision/laser scanner analysis initial data collection	01/04/2023	30/06/2023	YT
	2.25	Iterative approach to vision processing for rhizome identification	01/04/2023	31/12/2023	YT
	2.26	Development of cut-line generation to meet rhizome specification	01/07/2023	31/12/2023	YT
	2.27	Assessment of requirement for root removal	01/01/2024	31/01/2024	YT
	2.28	Root hair removal cut-line generation	01/01/2024	01/01/2024	YT
	TASK	**Integration 1**			
	2.29	Integration of Washdown and rhizome identification hardware/software	01/01/2024	30/09/2024	YT
	2.30	Testing and iteration	01/01/2024	30/06/2024	YT
	2.31	Integration of cut-line generation	01/04/2024	30/09/2024	YT
	2.32	Assessment of performance w.r.t. rhizome specification	01/07/2024	30/09/2024	YT
	TASK	**Cutting Prototyping**			
	2.33	Investigation/assessment of cutting technologies	01/01/2023	30/06/2023	YT
	2.34	Selection/acquisition of cutting system	01/04/2023	30/06/2023	YT
	2.35	Development/integration of cutting system with cut-line generation software	01/07/2023	30/09/2024	YT
	2.36	Testing of cutting on pre-washed samples	01/01/2024	30/09/2024	YT
	TASK	**Integration 2**			
	2.37	Integration of full system	01/01/2024	31/03/2025	YT
	2.39	Assessment of performance w.r.t. rhizome specification	01/10/2024	31/03/2025	YT
	2.40	Assessment of performance w.r.t. throughput	01/01/2025	31/03/2025	YT
	2.41	Assessment of performance w.r.t. cost	01/01/2025	31/03/2025	YT
WP3	TASK	**Mesocosm and pot experiment to test the interaction between soil type and flood stress on establishment**			
	3.1.1	Hire PDRA/project set up	01/04/2022	30/06/2023	UoL
	3.1.2	Set up and run mesocosm experiment on soil type and soil condition	01/07/2022	30/11/2022	UoL
	3.1.3	Analysis and report results mesocosm experiment	01/12/2022	31/03/2023	UoL
	3.1.4	Pot experiment on interaction between soil type, condition and seed/plug quality	01/03/2023	30/11/2023	UoL
	3.1.5	Analysis and report on seed/plug	01/10/2023	31/03/2024	UoL
	TASK	**Plot trial testing the interaction of rhizome properties with moisture stress**			
	3.2.1	Set up of first plot trial	01/04/2023	31/05/2023	UoL
	3.2.2	Data collection for first plot trial - Year 1	01/04/2023	31/10/2023	UoL
	3.2.3	Set up of second plot trial	01/04/2024	31/05/2024	UoL
	3.2.4	Data collection for second plot trial - Year 2	01/04/2024	31/10/2024	UoL
	3.2.5	Compile analysis and report writing on plot trials	01/11/2024	31/03/2025	UoL
	TASK	**Field study to understand the role of soil properties on Miscanthus establishment in the**			
	3.3.1	Grid soil samples of at least 10 fields. (Year 1)	01/04/2022	30/06/2022	UoL
	3.3.2	Grid soil samples of at least 10 fields. (Year 2)	01/04/2023	30/06/2023	UoL
	3.3.3	Grid soil samples of at least 10 fields. (Year 3)	01/04/2024	30/06/2024	UoL
	3.3.4	Gather drone images to assess Miscanthus establishment	01/08/2022	31/10/2024	TV
	3.3.5	Data analysis to predict establishment from soil analysis	01/11/2023	31/03/2025	UoL
	TASK	**Audit of rhizome lifting and supply chain to UK farms**			
	3.4.1	Observe Miscanthus rhizome production in Poland (Year 1)	01/04/2022	31/05/2022	UoL
	3.4.2	Observe Miscanthus rhizome production in Poland (Year 2)	01/03/2023	30/04/2023	UoL
	3.4.3	Audit supply chain from propagation fields in Poland to growing farms in the UK	01/06/2022	30/06/2023	UoL
	TASK	**Outreach and Promotion**			
	3.5.1	Promote work at agricultural shows / trade events / conferences	01/04/2022	30/06/2024	UoL/ALL
	TASK	**Planting Demonstration**			

	3.6.1	Planting for Demonstrations (Years 2 & 3)	01/07/2022	31/05/2024	TV/SL
WP4	4.1	**Automatic establishment count - image recognition from existing RGB: (yr1)**			
	4.1.1	Continuation of UAV image processing across different land types as well as	01/04/2022	31/03/2023	CU
	4.1.2	Develop/refine the AI model for automatic monitoring of miscanthus establishment using existing deep-neural network for plant identification and drone imaging technology from RGB consumer cameras.	01/04/2022	31/03/2023	CU
	4.2	**Automatic establishment count – sensor technology: (yr1-2)**			
	4.2.1	Year 1 UAV and field data collections	01/04/2022	31/12/2022	CU
	4.2.2	Interim presentation	01/01/2023	30/06/2023	CU
	4.2.3	Year 2 UAV and field data collections	01/07/2023	31/12/2023	CU
	4.2.4	Analysis and comparison with commercial RGB images (Technical Report)	01/01/2024	31/03/2024	CU
	4.3	**Evaluate establishment count**			
	4.3.1	Interim presentation	01/10/2022	30/09/2023	CU
	4.3.2	Parameters for operational UAV flights	01/10/2023	31/03/2024	CU
	4.4	**Monitoring feedstock**			
	4.4.1	Drone- Interim presentation	01/07/2022	30/09/2023	CU
	4.4.2	Drone- Year 3 UAV and field data collection	01/10/2023	30/10/2024	CU
	4.4.3	Drone- Model development and analysis - Report	01/11/2024	31/12/2024	CU
	4.4.4	ground based - deployment	01/07/2022	31/12/2022	MN
	4.4.5	ground based - interim presentation	01/01/2023	30/06/2023	MN
	4.4.6	ground based - technical report	01/07/2023	31/03/2024	MN/CU
	4.5	**Physical plant counter data stream**			
	4.5.1	Alarm system specification	01/07/2022	30/09/2022	MN
	4.5.2	Alarm sytem interim presentation	01/10/2022	31/12/2022	MN
	4.5.3	Alarm system operational	01/01/2023	30/06/2023	MN
	4.5.4	Data stream - interim presentation	01/07/2023	30/09/2023	CU
	4.5.5	Data stream - comparison with drone - report	01/10/2023	31/03/2024	CU/MN
	4.6	**AI Data integration with current Terravesta systems**			
	4.6.1	Workflow and data definitions and interim presentation	01/10/2023	31/03/2024	CU
	4.6.2	Prototype demonstrator and interim presentation	01/04/2024	30/09/2024	CU
	4.6.3	Full workflow, code and working demonstrator, plus documentation	01/10/2024	31/03/2025	CU
WP5	TASK	Project, Data and Financial Management			
	5.1	Project Management/	01/04/2022	31/03/2025	CHAP / TV
	5.1.1	Data management and implementation with integrated work package learning (Harvest Hub platform)/ and integrate processes to Harvest Hub platform	01/04/2022	31/03/2025	TV
	5.1.2	Quarterly Marketing and Engagement Reports	01/04/2022	31/03/2025	CHAP / TV
	5.1.3	Hold 6 monthly reviews of learning	01/04/2022	31/03/2025	CHAP / TV
	5.1.4	Continuously update project management plan	01/04/2022	31/03/2025	CHAP / TV
	5.2	Risk Management	01/04/2022	31/03/2025	CHAP / TV
	5.3	Financial Management	01/04/2022	31/03/2025	CHAP / TV
	5.4	Project Status Meetings/Initial kick-off meeting, weekly technical meetings and MO review meetings	01/04/2022	31/03/2025	CHAP / TV
	5.5	Document Lessons Learnt	01/04/2022	31/03/2025	CHAP / TV
	5.6	Exploitation and Dissemination	01/04/2022	31/03/2025	CHAP / TV
	5.7	Update Records and Systems	01/04/2022	31/03/2025	CHAP / TV

Risk Register

Risk Name	Risk Owner	WP	Description	Date Raised	Impact	Likelihood	Status	Risk Category	Mitigation Plan
R1	ALL	ALL	Lack of scope definition / or requirements have not been validated, resulting in ambiguity or misinterpretation of project scope resulting in scope creep	10/02/2022	4	3	12	Strategic	Requires detailed decomposition and requirements analysis - Ensure that there is a robust WBS that breaks down deliverables in to work packages, and furthermore, Work Packages must be decomposed to detail full schedule of activities required for each deliverable.
R2	ALL	ALL	Lack of stakeholder involvement, caused by other work priorities or the stakeholder leaving the project, resulting in delays on project schedule / critical path being affected.	10/02/2022	3	3	9	Strategic	Ensure all activities aligned to each deliverable keeps ownership and that each stakeholder commits to the RACI Matrix Standard operating procedures will be recorded for all the key stages in the project. Succession planning is in place for key staff at each organization. All collaborators have standard procedures for providing maternity/paternity cover and resources to employ short-term replacements.
R3	ALL	ALL	The project is delayed.	10/02/2022	5	2	10	Financial	Project management governance tools being used by the team will allow for the early identification of delays. Alternative plans or requests for extensions can be implemented early in the process.
R4	ALL	ALL	Consortium relationship breakdown	10/02/2022	2	2	4	Financial	Regular meetings and a detailed communication plan will be important throughout the project to ensure any potential issues are resolved promptly. A steering board will be established and will aim to resolve any problems that arise internally, and the project manager will agree actions with the project
R5	ALL	ALL	Budget overspend	10/02/2022	2	2	4	Financial	Budget spend will be monitored regularly to maintain stated tolerances as much as possible. Implement budget tracker/report to be distributed fortnightly/ monthly if required. This will be clarified in the Communication Plan
R6	ALL	ALL	Lack of IP protection	10/02/2022	3	3	9	Operational	IP agreements before project commences will clearly state all background IP retained by partners and allocate ahead of time who owns generated IP. Patent applications will be filed were suitable and know-how protected as trade secrets were appropriate.
R7	ALL	ALL	Covid-19 (Restrictions, transmission, travel)	10/02/2022	4	3	12	Managerial	All members will follow Government guideline at this time for Covid safety JMU has prioritised research activities and provided contingencies to allow research to continue as unhindered as possible. As this is a fluid situation regular updates and up-to-date risk assessments are available from: www.ljmu.ac.uk/microsites/moving-forward/information-for-staff/the-workplace/risk-assessment Most meetings will be conducted over video conferencing. Where physical meeting is necessarily, open space, air flow, sanitisation and PPE will be assessed in that order to reduce the chance of transmission. All members will take the lateral flow test as per government guidance. Travel will be kept to a minimum. Where the need arise, infection status of destination, individual immunisation status, mode of transportation, accommodation and PPE will be considered in that order. All members will take the lateral flow test as per government guidance.
R8	TV / YT / UoL	2	Inability to visit rhizome producer in Poland, due to travel restrictions	10/02/2022	2	3	6	Operational	Virtual video call can be arranged if travel is not possible.
R9	TV / YT	2	Rhizome specification not available promptly to feed in to machine design	10/02/2022	3	2	6	Operational	Work on other part first.
R10	YT	2	Difficulties in allocating skilled staffing for mechanical design in early stages	10/02/2022	2	2	4	Managerial	Allocate staff members early
R11	YT	2	Lack of availability of key mechanical components (e.g. conveyors)	10/02/2022	3	3	9	Resource	Procure early, buying second hand, manufacture parts from scratch
R12	YT	2 & 4	Lack of availability of electronic/IT components (e.g. cameras, laser, scanner etc.)	10/02/2022	4	3	12	Resource	Procure early, buying second hand, supply from current YT stock
R13	TV / YT	2	Unable to import rhizome in untreated state for testing rhizome processing system	10/02/2022	2	3	6	Operational	Begin import paperwork early, transport system to Poland for test

R14	YT	2	Unable to separate rhizome effectively for imaging	10/02/2022	3	3	9	Technical	Innovative/flexible approach, consider two separated cutting steps
R15	YT	2	Unable to automatically process laser/camera data for cut location	10/02/2022	4	2	8	Technical	Innovative approach including multiple technologies trial with multiple iterations
R16	YT	2	Unable to reliably cut with water-jet due to displacement	10/02/2022	3	3	9	Technical	Use different cutting approach including different form of cutting with water jet and consideration of laser
R17	YT / TV	2	Damage caused by heating from laser cutting reduces rhizome quality	10/02/2022	3	2	6	Technical	Technical amendment to be trialed to mitgate risk
R18	ALL	ALL	Inability to access land during the project	10/02/2022	5	1	5	Resource	Terravesta has access to a large number of farmers willing to provide land for experimentation to be identified earlier in the project to ensure land availability
R19	ALL	ALL	Planting material (Rhizome and Seed) import disruption due to changing regulations	10/02/2022	5	1	5	Resource	Terravesta operate germplasm import without issue and have annual review on new procedures to ensure smooth delivery of germplasm
R20	ALL	ALL	Disruption of planting material transfer due to COVID 19 causing issue with hauliers	10/02/2022	3	3	9	Operational	Terravesta operates numerous deliveries throughout the planting season to mitigate risk of single delivery failure
R21	ALL	1,2 & 3	Weather induced disruption to planting trials	10/02/2022	2	4	8	Operational	Maintain flexibility to planting schedule and access to land as well as paying close attention to weather closer to the dates
R22	ALL	ALL	Damage to field trial/equipment due to Act of God/Malicious Intents	10/02/2022	2	1	2	Resource	Unlikely to occur, mitigated by running multiple trials in multiple locations
R23	ALL	1	Seed and plant material movement from EU to UK restricted due to the legal implications of "European Union (Withdrawal Agreement) Act 2020".	10/02/2022	5	5	25	Commercial	Ensure constant monitoring of and contact with the plant health authority (DEFRA), for any updates on the implementation of changing legislations. Secure a second location (outside of the UK) for the
R24	TV / EG	1	Poor conditions during seed transport and storage. This includes from the harvest location to the seed processing facility and finishing with long term storage location.	10/02/2022	3	3	9	Commercial	Ensuring the use of responsible and reliable couriers who specialize in plant material transport. Installing both temperature and humidity sensors/loggers to function throughout transport, and during storage.
R25	CU	4	Plant counter fails to collect data	10/02/2022	3	3	9	Technical	Manually sample planting
R26	CU	4	Failure of crop establishment in field trial sites	10/02/2022	2	2	4	Technical	Use existing datasets and existing landbank datasets
R27	ALL	ALL	IT / Connectivity issues preventing users from accessing internal drives, MS Teams and Outlook (MS Office).	10/02/2022	4	2	8	Managerial	Ensure windows updates up to date. Maintain contact with project team via telephone WhatsApp for document transfer. Having an up-to-date copy of important documents on CHAP and TV servers. All sub-contractor and project leads are expected to follow SOP for data back up and redundancy

	Impact/ likelihood
Very Low	1
Low	2
Medium	3
High	4
Very High	5

	Risk Rating
Very Low	7
Medium Risk	12
High Risk	13

Project Start	Total Risk	219
	Red	1
	Amber	15
	Green	11

Risk Summary:

Number of risks added - 27

Number or risks removed – 0

Number of risks mitigated – 0

2.2 Project Team Table

Organisation	Role	Team Member(s)	Role
Terravesta Farms	Project Lead Work Package 2 Lead	R&D manager	Project Lead Work Package 2 Lead
		Director of Business development and production	Business development and production
		Director of Sciences and Technology	Company research direction
		Admin	Admin and accountancy
CHAP	Work Package 5 Lead - Project Management (Sub-contractor)	Innovation Sector Lead	Innovation Support
		Technical Liaison Officer	Scientific Support
		Senior Project Manager	Senior Project Manager
		Assistant Project Manager	Project Manager
		Project Accountant	Project Accountant
Cranfield University	Work Package 4 Lead (Sub-contractor)	Senior Lecturer	Work Package 4 Lead
		Senior Lecturer	Work Package sciences lead
		Scientist	Carbon analyst

		Scientist	Hormonal control scientist
Energene Seeds	Sub-contractor	Seed scientist	Seed and related operation
Liverpool John Moores University	Work Package 1 Lead (Sub-contractor)	Senior Lecturer	Work Package 1 Lead
		Mathematician	Data analysis
		Admin	WP1 admin
Salmac Ltd	Sub-contractor	Mechanical sales	Machine expert
Ystumtec Ltd	Sub-contractor	Director	Electronics expert
University of Lincoln	Work Package 3 Lead (Sub-contractor)	Professor	Work Package 3 Lead
		Scientist	Soil scientist
		Scientist	Data scientist
		Scientist	Physiological scientist

Appendix 3 – Industry support letter (See next page)

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