PART OF THE DUCHY
FUTURE FARMING PROGRAMME

SeaFEED

On-farm fermentation of sugar kelp seaweed to enhance seed establishment and to reduce powdery mildew progression.

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Executive summary

The fermentation technique was successful. It is recommended that a bokashi inoculum is used with a molasses microbial food source. The container should remain in the dark and extreme temperatures avoided. The ferment is usable after 2 months and used within a time frame of 12 months.

A Tow and Fert machine was used to apply the liquid from the ferment, which ensured that small particles did not block up the nozzle. The seed was treated at the time of drilling which ensured the biology of the inoculum remained viable. The trial involved applying the inoculum on the drilled seed, but ideally the seed would be treated before entering the soil.

On the wheat, the seaweed ferment significantly increased the total length of roots and the longest root at 8 days after sowing. No further effect of grain seaweed treatment was detected on the rate of emergence, soil aggregate stability around the roots (at 8 days after sowing), head count or yield. No crop disease was recorded across the trial.

The vines had a weekly treatment of 1:10 (v:v) seaweed ferment through July and August. There was no phytotoxicity or disease on the vines but just prior to harvest there was a significant drop in the sugar content of 2 of the 3 varieties. The wine varieties were modern fungus resistant (PIWI) varieties selected for the cooler conditions of the UK, Switzerland and France.

The lack of disease on the wheat was highly unusual but may have been principally due to the diversity of the organic cropping system in which the trial was carried out, in addition to the good soil structure. The question remains: would the impact of seaweed extract affect plants grown in a more stressful environment? And would the enhanced seedling root growth provide potential drought resistance in more extreme climatic conditions?

The health and genetic diversity of the vines at the Atlantic vineyard reduced the risk of disease infestation but the seaweed did affect the grape sugar content. High sugar is one of quality attributes for wine-making grapes, and thus the use of seaweed may be disadvantageous. However, further work to assess the quality parameters would be valuable since it is the secondary metabolites which drive flavour in wine and it is this which may be a Unique Selling Point of Atlantic Vineyard wines in the future.

1.0 Introduction

Seaweed extracts are classified as biostimulants because of their ability to enhance nutrition uptake, environmental stress tolerance, and crop yield and or quality without particular emphasis on just the nutrient content of the product (Jardin, 2015).

Seaweed extracts (including *Durvillaea potarorum* and *Acophyhyllum nodosum*) have been shown to increase the nutrient density and flavour of apples (Yang et al, 2023) and yield of tomatoes (Hussain et al, 2021). Further advantages are associated with improved soil health relating to biological activity, water retention, soil aeration, nutrient availability and structure (Khan et al, 2009, Hussain et al, 2021; DuJardin, 2021). The seaweeds can have a bio-stimulation effect on crop plants through the hormones that they contain, which include cytokinins, auxins, abscisic acid, and gibberellins and can increase a plant's resilience to environmental stress (El Boukari et al, 2020).

There is extensive evidence to support the use of Ascophyllum to enhance crop and soil health, but the novel element of this work is to use sugar kelp (virtually all commercially available seaweed extracts are from *Ascophyllum nodosum*), on farm, with bespoke on-farm equipment to de-centralise costs and increase farm sustainability. Virtually no research has been published on the use of sugar kelp, which is a scalable and a sustainable alternative to Ascophyllum, as it can be farmed at sea without input.

On-farm seaweed processing for farms located close to suppliers offers potential benefits in terms of crop (1) seedling vigour (Thorsen et al, 2010); (2) crop quality (Yang et al, 2023; EspinosaAntón, 2025) (3) disease resistance (Catlin, 2020); and (4) soil health (DuJardin,2021). But although *Ascophyllum* extract is commonly used and the benefits are well- known, it is wild harvested and production cannot be scaled sustainably. This project allows for localised management of seaweed which closes nutrient cycles, reduces input costs and improves on-farm economic and environmental sustainability.

The main objective is to use a novel on-farm fermented sugar kelp extract as a foliar feed and seed treatment. Sugar kelp, as opposed to widely-used *Ascophyllum*, can be sustainably cultivated throughout the UK, requiring no input and enhancing marine biodiversity, creating floating reefs. However, the effects of a fermented extract on crops remain poorly understood due to the novelty of sugar kelp as an aquaculture industry. Sugar kelp contains bioactive compounds that influence plant growth and health dynamics differently than the widely used *Ascophyllum*. The local provenance of the seaweed and collaboration with the farm group would offer the opportunity to determine the agronomic merits of home-produced seaweed extract. The novel element of this work is to use sugar

kelp with bespoke on-farm equipment to de-centralise production, reduce costs and increase farm sustainability.

Seaweed aquaculture is a fast-growing industry but severely hampered by lack of applications. Proving that sugar kelp biostimulant has real crop benefits will significantly boost the viability of this fledgling industry. By providing farmers with both evidence that sugar kelp works and a cheaper way of making it the trial hopes to empower farmers to: invest confidently in seaweed biostimulant, knowing it will be effective; and potentially reduce the costs of purchase and transportation by showing how it can be made on farm. By decentralising the production of the ferment you reduce environmental impact / make it more flexible.

2.0 **Methods** *2.1 Seaweed extract preparation*

The first set of fermented seaweed was created in two IBCs, with 700kg of seaweed added to each IBC in August 2024. A hole was made in the top of the container to aid filling and then sealed (but not anaerobically). The product was deemed ready after 2 months.

The second sets of fermented IBCs were created using commercial bokashi inoculum (Agriton Ltd). Clean IBCs had an estimated 700kg of seaweed added, with a micro-organism activator (molasses) added at a rate of 5l per 10l water. Each tank had either 25l of bokashi premix added, or two 10 litre bottles of bokashi added. These were labelled 'premix' or 'separate'. The IBCs were airtight, with an airlock fitted to allow fermentation gasses to escape and were kept in the dark to avoid light penetration, in a cool barn to ensure a more stable temperature.

The seaweed ferment from the second batch was extracted and sprayed onto wheat at sowing into the coulter lines.

2.2 Phytotoxicity tests

A pot-based trial was used to test the phytotoxicity of a 1:10 (v:v) dilution of the seaweed extract on wheat. There were 5 trays of each of Rosuick and Tregeague field soil. There was one replicate tray containing greater than 20 seeds for each of the following treatments: heated soil (to reduce microbial diversity but not organic matter) and water; IBC seaweed number 1 (no bokashi inoculum); IBC seaweed number 3 (no bokashi inoculum); Bokashi fermented seaweed with inoculum added separately; Bokashi fermented seaweed with inoculum added as a premix; and water control.

A 1:10 dilution of the bokashi fermented seaweed was sprayed with a handheld horticultural sprayer onto domestic vines to observe potential phytotoxicity.

2.3 Trial set up

Spring wheat variety Mulika and pea variety Kameleon were treated with 0.5 litres of concentrate for 100kg seed (70:30 wheat to peas at 100kg/acre) on the 17th April 2025. The field was previously a failed winter rye crop. It was ploughed on the 15th April, and on the 17th April it was harrowed rolled and the seed was drilled using a Horizon drill 4 m width. Four plots of treated wheat and peas (treated) were sown in between four plots of untreated wheat and peas (control). The trial area was harrowed on the 3rd May to manage charlock.

2.2 Plant emergence assessments

Plant counts for wheat and peas were carried out on the 24th April, 2nd May and the 9th May. A round quadrat of diameter 360mm was used to randomly select 6 locations in each plot. It had the one edge aligned with and included a row wheat and the total number of plants was recorded. Emergence was scored if the wheat radicle and the pea first leaf were visible. This assessment was repeated across all 8 plots.

2.3 Root assessments

On the 25 April, 8 days after sowing, 10 randomly selected wheat seedlings were carefully removed from each plot ensuring the roots remained intact. Plants and roots were gently washed to dislodge soil. All root lengths were measured using a ruler, lengths were to an accuracy of 1mm. The curving of roots prohibited a greater level of accuracy. Data was analysed using REML linear model, with treatment as the fixed term and plot plus replicate within plot as the random model.

2.4 Soil aggregate stability

On the 2nd May, 10 replicate sets per plot of soil aggregates were collected from the roots of wheat. Soil aggregates were air dried at room temperature. Four aggregates per sample were submerged in cold tap water for 5 mins though to 2 hours. The stability of the aggregate was assessed based on the slaking test scale of 0 to 4, with 0indicating a stable aggregate and 4 total aggregate disintegration. Data was log transformed and analysed using REML linear mixed model with treatment as the fixed model, and the plot and sub replicate per plot as random models.

2.5 Yield assessment

On the 5th August, each plot was assessed in triplicate for barley head count, and pea pod count per 0.25m^2. Data was analysed using one way ANOVA.

A single quadrat of 0.25m^2 was hand harvested on the 5th August. The fate of the crop was whole crop, therefore the samples were air dried at room temperature for over two weeks prior to hand threshing, sieving and weighing. Data was analysed using one way ANOVA.

2.6 Disease assessment

Disease assessments were planned upon arrival of the first leaf disease lesions. 10 flag leaves per plot were to be assessed for the area affected by mildew and septoria (the most common diseases in the area). However, leaf senescence took place in the absence of disease development.

2.7 Vine trial establishment

Three vines per variety were sprayed with 1:10 (v:v) seaweed solution on the following dates: 22th July, 27th July, 4th August, 11th August, 18th August, 22nd August, 4th September and the 11th September. Varieties selected for trialling were Cab Cantor, Divico and Johannitor. The adjacent vines to the treated ones acted as controls.

2.8 Vine assessments

Vines had been selected by the grower to be powdery mildew resistant, and no disease lesions formed. Therefore, progress of the trial was assessed using 10 BRIX assessment per treatment per variety using a Milwaukee digital refractometer (milwaukeeinstruments.com). A minimum of one randomly selected grape was used per assessment, and the BRIX assessment was done according to manufacturers instructions. Assessments were carried out between 11 am and 2 pm on the 16th September 2025.

3.0 **Results** *3.1 Phytotoxicity test*

The dilution of the range of seaweed ferments diluted 1:10 (v:v) with water had no phytotoxic effects.

Figure 1 (a) Phytotoxicity tests of fermented seaweed extract diluted 1:10 for (b) Rosuick soil and (c) Tregeague soil. Treatments included heated soil (to reduce microbial diversity but not organic matter) and water; IBC seaweed number 1 (no bokashi inoculum); IBC seaweed number 3 (no bokashi inoculum); Bokashi fermented seaweed with inoculum added separately; Bokashi fermented seaweed with inoculum added as a premix; and water control

3.2 Emergence counts

The seaweed treatment did not significantly affect wheat emergence (P = 0.399). However, there was a consistent but incremental higher count for control plots compared to seaweed treated plots. A greater number of replicate quadrats counts than 5, may potentially identify an effect. The peas were heavily predated and therefore are not included in these analyses.

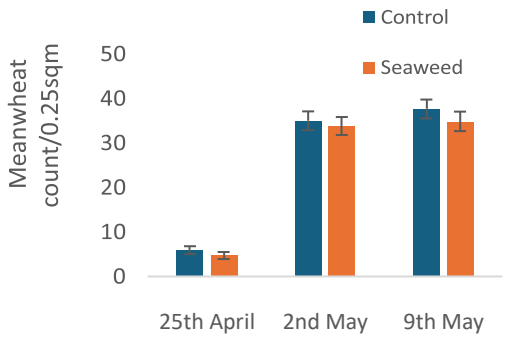

Figure 2: Mean wheat emergence counts for 25th April and the 2nd and 9th May, with 5 quadrat counts per plot for 4 replicate plots per treatment

Figure 3 Trial plot on the 9th May 2025

3.3 Root assessments

The sum of root length was calculated per seedling, and across plots and sub-replicate. There was a significant increase following the seaweed treatment (P=0.031) of an estimated increase of 17.3mm by 8 days after sowing (just over 12% increase).The longest root per seedling was also compared across treatments, and the seaweed had a significant positive effect on increasing the length of the longest wheat root by an estimated 8.5mm by 8 days after sowing.

Figure 4 Images from eight plots of randomly selected seedlings 8 days after sowing, Seedlings on the left are seaweed treated, and are the control treatment on the right.

3.4 Aggregate stability

There was no significant difference in soil aggregate stability between treatments within 1 month of wheat germination.

Table 1 mean scores for aggregate stability, with 0 being the most stable soil aggregate, and 4 indicate total disintegration of the soil clump.

	Mean slaking test score	
Treatment	5 minute submersion	2 hour submersion
Control	0.32	0.89
Seaweed	0.44	1.5

Figure 5 (a) Taking soil aggregate samples from soil adjacent to seedling roots, and one of the trays showing soil aggregate stability after 2 hours of immersion in water.

3.5 Yield assessment

Triplicate counts of wheat head number and pod number were completed for each of the 4 treated and 4 untreated plots. There was no significant difference between treatments.

There was a single harvest quadrat (0.25m^2) per plot (Figure 7). There was no significant difference in wheat or pea yield.

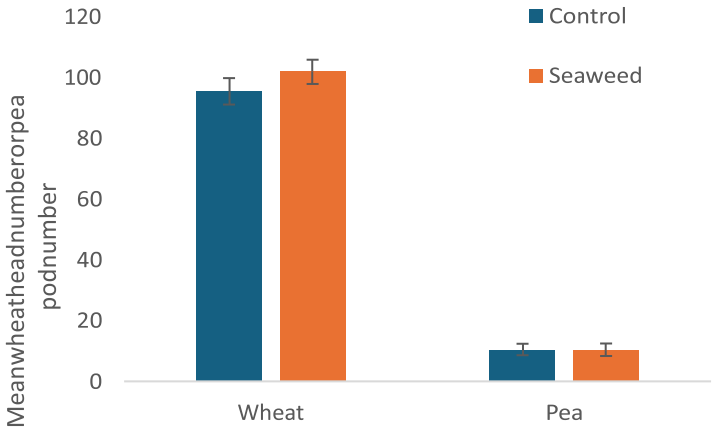

Figure 6 Whole crop barley head and pea pod count per 0.25m^2. Error bars indicate standard error.

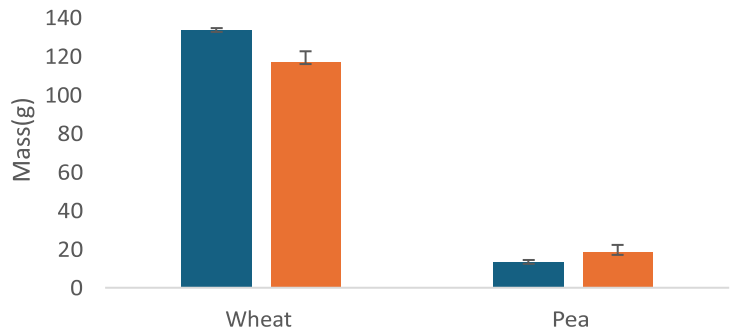

Figure 7 Mass of barley and mass of pea whole crop within 0.25m². Error bars indicate standard error.

3.6 Wheat diseases assessments

There was no wheat disease despite multiple checks through May, June and July.

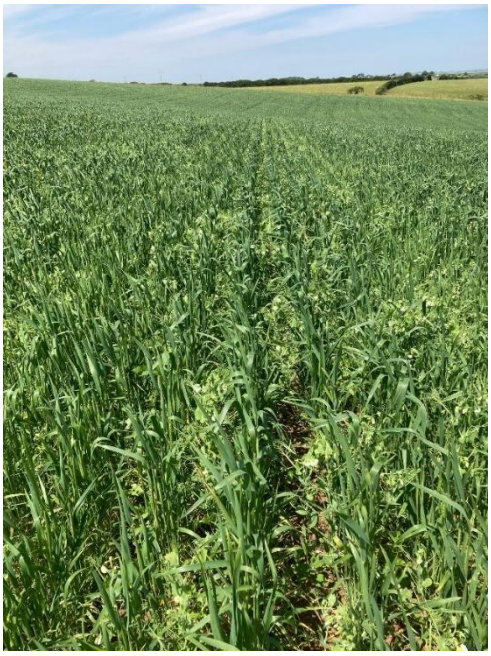

Figure 8 The trial on the 19th June. (a) There remained no disease or pest attack throughout the duration of the trial. Image (b) shows a parasitised aphid.

3.7 Vine assessments

There was a significant reduction in grape BRIX following seaweed treatment for varieties Cab Cantor and Johannitor (P<0.001), with the greatest drop in sugars recorded for variety Johannitor.

Figure 9 Undertaking Brix assessments at the Atlantic Vineyard.

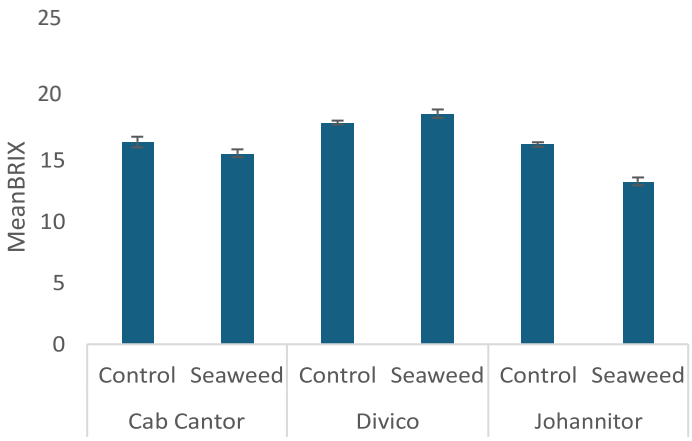

Figure 10 Mean Brix for varieties Cab Cantor, Divico and Johannitor. Results are for 10 assessments per plot. Error bars indicate standard error.

Table 2 Mean BRIX values for varieties Cab Cantor, Divico and Johannitor. Different letters indicate values are significantly different at a 5% confidence level with l.s.d = 0.8727.

Variety	Control	Seaweed

Cab Cantor	16.5a	15.59b
Divico	18.09b	18.82b
Johannitor	16.3a	13.29bc

Discussion

The trial has demonstrated the potential value of seaweed biostimulant as a seed dressing to enhance root development. The effect may be a result of the synergistic action or singular effects of minerals, fermentation organisms and plant hormone analogues.

The production of the seaweed biostimulant was crude, with whole plants used rather than pre-chopping or otherwise disintegrating the fronds. Chopping of seaweed increases surface area and helps break down cell walls, which makes the cell contents available in the liquid part of the biostimulant rather than remaining in the solid part, which is discarded. In future trials, a way to homogenize the seaweed before adding it to the water to make the biostimulant will likely benefit the overall dissolved bioactives in the end product, providing more pronounced results.

Time of application is important to determine cost/benefit on physiology in term of protection and yield (Jensen & Jorgenson, 2022). Concentration is important, with root development in a model plant Arabidopsis only enhanced with dilution at or below 0.1% (v/v) of Ulva seaweed extract (Ghaderiardakani et al, 2019).

The impact of plant hormones of secondary metabolites is complex for instance plant hormones abscisic acid, ethylene and auxin increase these flavour compounds, but gibberellic acid has an inverse effect (see Braidot et al, 2008 for a review)

The trial was carried out on organic soils which had good structure and the rotation was diverse. There were significant effects on root development, but it is unknown whether greater effects would be detected in more marginal soils. Furthermore, chopping of seaweed prior to fermentation may influence the potency of the product.

The seaweed ferment reduced the sugar content in the grapes, but the impact of the grape flavour determined by flavonoid and phenolic compounds may also be impacted. The Atlantic Vineyard would value additional trials to determine the impact of seaweed on grape flavour.

Additional root length in the early season may provide benefits to enhanced resilience under drier conditions. The would be merit in repeating the work on drought prone soils to determine if there is a growth benefit, and therefore economic advantage to fermented seaweed application.

Acknowledgements

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References

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Seaweed nutrient analysis carried out by NRM, Coopers Bridge, Braziers Lane, Bracknell, Berkshire, RG42 6NS

SEAWEED BIOSTIMULANT ANALYSIS (Metric Units)

Sample Reference : SEAWEED BIOSTIMULANT

Sample Matrix : SEAWEED BIOSTIMULANT

The sample submitted was of adequate size to complete all analysis requested.

The sample will be kept under refrigeration for at least 3 weeks.

Laboratory References	
Report Number	14941
Sample Number	170690

Date Received	20-AUG-2025
Date Reported	28-AUG-2025

ANALYTICAL RESULTS *on 'as received' basis.*

Determinand on a fresh weight basis	Units	Result	Amount per fresh tonne or m3	Amount applied at an equivalent total Nitrogen application of 250 kg N/ha	Units
pH 1:6 [Fresh]		3.91			
Oven Dry Solids	%	3.87	38.70	19350	kg DM
Total Kjeldahl Nitrogen	% w/w	0.050	0.50	250	kg N
Ammonium Nitrogen	mg/kg	163	0.16	81.50	kg NH4-N
Nitrate Nitrogen	mg/kg	<10	< 0.01		kg NO3-N
Total Phosphorus (P)	mg/kg	63.2	0.14	72.36	kg P2O5
Total Potassium (K)	mg/kg	6133	7.36	3679.80	kg K2O
Total Magnesium (Mg)	mg/kg	481	0.80	399.23	kg MgO
Total Sulphur (S)	mg/kg	607	1.52	758.75	kg SO3
Total Copper (Cu)	mg/kg	0.374	< 0.01		kg Cu
Total Zinc (Zn)	mg/kg	1.26	< 0.01		kg Zn
Total Sodium (Na)	mg/kg	2290	3.09	% 1543.46	kg Na2O
Total Calcium (Ca)	mg/kg	479	0.48	239.50	kg Ca
Equivalent field application rate		—	1.00	500.00	tonnes or m3 / ha