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Fermented and alkaline kelp extracts: a comparison of plant growth responses

Abstract

Global food needs drive the search for sustainable biostimulants to bolster agricultural yields. Fermented Kelp Extract (FKE) presents a viable alternative to lessening the use of synthetic fertilisers, offering potential advantages in crop productivity and soil health enhancement. This study compared the effects of Fermented Kelp Extract (FKE), Alkaline Kelp Extract (AKE), and control on the growth of Triticale seedlings over a 20-day period. The outcomes suggest that FKE performs comparably to AKE in key growth metrics, both outpacing the control group. The notable root growth in FKE-treated seedlings might be linked to elevated auxin levels resulting from fermentation. Additionally, FKE might influence seed coat characteristics, promoting efficient water uptake during germination. Although the benefits of FKE are clear, broader research with diversified samples and varied agricultural settings is paramount.

Keywords: fermented kelp, alkaline kelp, sustainable agriculture

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Abbreviations: KE, kelp extract; FKE, fermented kelp extract; AKE, alkaline kelp extract; NUE, nutrient use efficiency; ANOVA, analysis of variance.

Introduction

Modern agriculture faces a dual challenge: meeting accelerating global food demand while minimising environmental footprint. Over-reliance on synthetic fertilisers has been a staple of conventional agriculture, leading to repercussions like pollution, soil degradation, and declining soil health.[1,2] In this context, sustainable biostimulants such as Fermented Kelp Extract (FKE) become viable alternatives, enhancing crop productivity without the adverse effects of synthetic counterparts.

FKE offers more than just an eco-friendly solution. The fermentation process inherent to FKE breaks down complex compounds, increasing the bioavailability of nutrients.[3] This enhances nutrient use efficiency (NUE), potentially reducing the dependence on synthetic fertilisation inputs.[4] Beyond direct growth stimulation, FKE bolsters plant resilience against abiotic stressors like drought and heat through the action of bioactive compounds, particularly gibberellins and abscisic acid.[5] Additionally, FKE promotes the development of beneficial microbes, highlighting its role in enhancing soil characteristics such as water retention.[6]

Microbiological action of kelp algae

The effectiveness of kelp-based biostimulants is partly due to the interactions between microbial communities and plant roots, which can improve nutrient absorption, stress tolerances, and growth rates. The kelp microbiome is highly diverse, housing numerous bacteria, fungi, and other microorganisms necessary for nutrient cycling and the synthesis of bioactive compounds.[7]

Microbial interactions and plant growth

Microorganisms found on kelp produce a range of beneficial compounds, including hormones, enzymes, and vitamins, which are crucial for plant growth, health, and defence mechanisms.[8] For instance, bacteria like *Pseudoalteromonas spp.* and *Vibrio spp.*, as well as fungi such as *Labyrinthula spp.* and *Halophytophthora spp.*, synthesise plant hormones like indole-3-acetic acid (IAA), cytokinins, and gibberellins.[7,9]

Research on the microbiome of *Macrocystis pyrifera* highlights the role of bacterial communities in carbon cycling and nutrient fluxes within marine ecosystems. These bacteria degrade algae's organic matter, converting it into forms that plants can use.[10] For example, *Psychromonas* and other Gamma proteobacteria found on kelp blades utilise alginate, playing an important role in coastal carbon turnover.[7] Younker et al. identified that kelp's unique bacterial communities can boost its nutrient content. These bacteria undergo various processes, such as nitrogen fixation and producing essential vitamins and amino acids, contributing to kelp's overall nutrient profile.[11]

Fermented Kelp Extract (FKE) production enhances the benefits of kelp as an agricultural biostimulant by transforming complex kelp molecules into simpler, more bioavailable products. FKE improves soil health by enhancing soil structure and nutrient availability while promoting beneficial interactions between plants and microbes.[12]

Role of specific microbial species

Microbial species present on kelp, such as *Pseudoalteromonas spp.* and *Vibrio spp.*, contribute to nutrient cycling and the production of antimicrobial compounds through algae degradation. These compounds can suppress plant pathogens, enhancing plant health and growth.[7] Similarly, fungi like *Halophytophthora spp.* contribute to the nutrient cycling of cellulose, phenols, and sulphated polysaccharides in complex marine vegetation.[9]

Research on *Macrocystis pyrifera* suggests that the microbial communities within its habitat are distinct from those in the surrounding water and particularly suited to their host environment. The bacteria associated with kelp have adapted specialised enzymes for utilising polysaccharides such as alginate, cellulose, and fucoidan, which are plentiful in kelp.[13]

Kelp-associated microorganisms improve plant growth, increase resistance to pests and diseases, and enhance plant-soil microbial interactions. The fermentation process used to produce FKE amplifies these effects by increasing the bioavailability of these beneficial microbial products. These findings may have substantial implications for developing more sustainable and efficient agricultural practices.[12]

Given the promising qualities of FKE, this study aims to examine its effects on specific plant growth parameters, focusing on Triticale seedling development compared to AKE and a control. This analysis aims to enhance the dialogue on sustainable agricultural solutions,

highlighting the potential of FKE and the importance of improving agricultural output.

Materials and methods

Triticale (x Triticosecale Wittmack 'Forerunner') seeds from a commercial agricultural supplier underwent stringent screening. A selection process prioritised seeds of the same weight, eliminating potential disparities in nutrient content between treatments and controls.

The FKE was sourced from King Island, Australia, and underwent air-drying and hammer-milling post-harvest before extraction. Confidentiality agreements prevent disclosing further details about the product's name, production techniques, and chemical composition. Conversely, Seasol, a commercially available product, represented AKE. Supplementary data offering an extensive chemical profile of Seasol is available on the manufacturer's website.

The experiment employed a three-factor strip plot design to compare the effects of AKE and FKE against a control group with no treatment, focusing on kelp extracts derived from macroalgae. Triticale seeds, divided into 100 g parcels, underwent all treatment and control protocols. Each batch received 1 ml of the respective treatment and 1 ml of deionised water, mixed for 60 seconds. Seeds were then sorted by weight, and thirty were selected: ten from each treatment group, with an equal split between median weight and the 95th percentile, to evaluate the impact of seed size on germination and initial growth stages. Each seed was assigned a unique identifier and matched with a designated pot for precise observation. The experimental setup involved 85 mm plastic pots in a larger plastic container, initially filled with perlite using a 50 ml laboratory scoop and subsequently topped with oven-dried, sterile, washed sand to a consistent weight of 475 g per pot. The setup was located on a mezzanine, 2.5 meters beneath a skylight in a warehouse. To avoid potential water damage, 75 ml of deionised water was added to the container's base whenever the sand dried out, rather than watering directly. Seeds were sown 35 mm deep. The experiment was subject to termination if germination rates dipped below 50% within the first two weeks.

Seedling heights were documented daily, focusing on key metrics such as germination rates, shoot development, post-experiment dry weights of both shoots and roots and root lengths. Each specimen was placed in an individual marking tray during the examination phase. Seedlings were carefully unpotted and extracted, then oven-dried at 70°C for two hours. Measurements included the dry weight of the shoots, roots, and root lengths.

Analysis of Variance (ANOVA) and Tukey post-hoc tests were conducted to determine any statistically significant differences between the treatment and control groups.

Results

The experiment concluded after 20 days from sowing. Germination rates and shoot height were documented daily (Table 1). Due to the unsatisfactory germination of samples 6-10 from treatments A, B and C, they were excluded from the final analysis. Consequently, only samples 1-5 from treatments A, B, and C were considered (Table 2).

Table 1 Recorded height of sample treatments (A, B, C) taken during the experiment. The first measurement of each sample is the day of germination when witnessed above the soil profile-measurements taken in mm. Missing entries are when no germination was witnessed

	19-Sep	20-Sep	21-Sep	22-Sep	25-Sep	26-Sep	27-Sep	29-Sep	3-Oct	4-Oct
A1	4	30	51	93	100	112	136	151	170	172
A2	24	52	84	107	152	159	160	160	172	175
A3	17	39	71	95	144	162	162	165	165	165
A4	15	42	81	111	181	191	199	202	228	237
A5	1	22	47	69	121	129	136	142	158	160
A6	-	-	-	-	-	-	-	-	-	-
A7	-	-	-	-	-	-	-	-	-	-
A8	-	3	22	55	61	61	72	75	75	75
A9	12	37	55	95	108	113	127	145	145	145
A10	-	-	29	53	78	104	126	145	179	185
B1	5	32	64	88	140	141	141	141	190	192
B2	27	57	85	109	151	151	151	151	205	211
B3	-	12	32	57	105	110	111	111	111	111
B4	1	27	53	77	132	140	141	142	155	156
B5	26	60	82	114	178	180	194	209	229	253
B6	-	23	48	70	115	115	117	145	199	201
B7	-	-	-	-	-	-	-	-	-	-
B8	24	56	85	110	159	163	164	165	185	185
B9	-	2	33	62	92	117	147	163	170	170
B10	-	-	-	-	-	-	-	-	-	-
C1	-	1	23	42	94	94	97	97	127	133
C2	-	14	33	77	85	85	85	90	90	90
C3	22	52	73	93	139	141	142	143	147	147
C4	-	15	37	58	111	118	119	120	145	150
C5	-	-	17	48	76	89	102	109	115	115
C6	-	-	-	-	-	-	-	-	-	-
C7	22	49	76	99	152	152	152	157	211	219
C8	-	-	17	47	114	119	120	125	200	205
C9	-	-	-	-	-	-	-	-	-	-
C10	-	-	-	-	-	-	-	-	-	-

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Table 2 Post-Experiment Measurements Metrics recorded: Shoot weight (g), root weight (g), and root length (mm) from treatments A, B, and C (samples 1-5)

Sample	Shoot weight (g)	Root weight (g)	Root length (mm)
A1	0.029	0.038	195
A2	0.03	0.042	255
A3	0.026	0.045	180
A4	0.034	0.043	170
A5	0.028	0.033	145
B1	0.024	0.034	140
B2	0.026	0.027	170
B3	0.024	0.045	225
B4	0.025	0.038	160
B5	0.028	0.037	235
C1	0.018	0.03	100
C2	0.014	0.024	160
C3	0.017	0.03	95
C4	0.021	0.028	155
C5	0.015	0.033	105

The study sought to understand the potential benefits of kelp extracts on seedling growth, comparing three treatments: FKE (A), AKE (B), and a control group (C). ANOVA tests indicated differences in some growth parameters among the treatments.

Shoot weights displayed variation, supported by a p-value of less than 0.001. The mean shoot weights for the treatments were 0.0294 g (A), 0.0254 g (B), and 0.0170 g (C) (Figure 1).

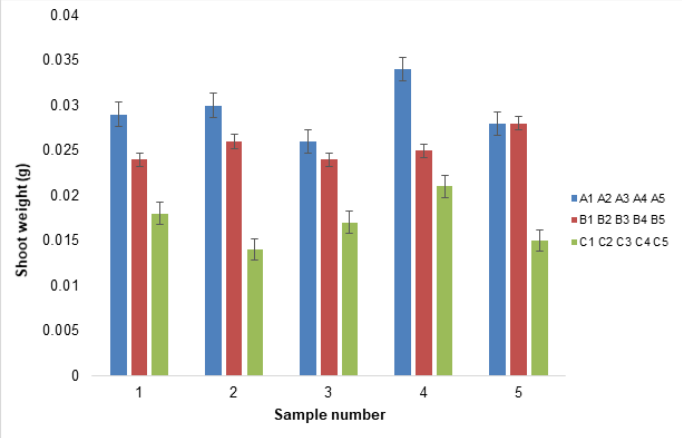

Figure 1 Shoot weights of samples from treatments A, B, and C. Treatments displayed significant variation in shoot weights ($p < 0.001$). Mean weights for each treatment were: A = 0.0294 g, B = 0.0254 g, and C = 0.0170 g.

Root weight differed among the treatments, with a p-value of 0.013. The mean root weights were recorded as 0.0402 g for FKE (A), 0.0362 g for AKE (B), and 0.0290 g for the control (C) (Figure 2).

Differences among the treatments were evident for root length, with a p-value of 0.031. Mean root lengths were 189 mm for FKE (A), 186 mm for AKE (B), and 123 mm for the control (C) (Figure 3).

Visually, seedlings from treatment A appeared to exhibit more pronounced growth, particularly in lateral root expansion. However, the overall root lengths of AKE and FKE were closely aligned.

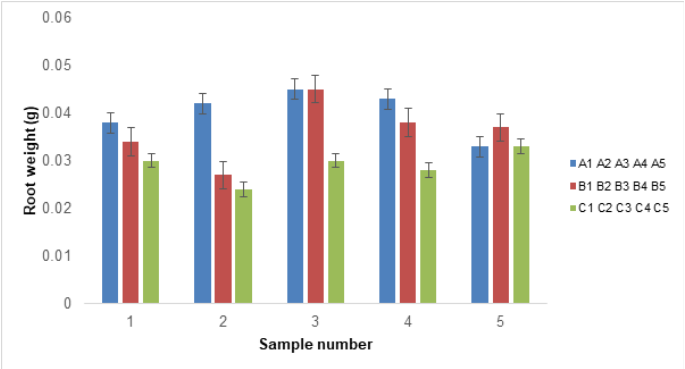

Figure 2 Root weights of samples from treatments FKE (A), AKE (B), and the control (C). There was a significant difference in root weights among the treatments ($p = 0.013$). Mean weights were: FKE (A) = 0.0402 g, AKE (B) = 0.0362 g, and control (C) = 0.02.

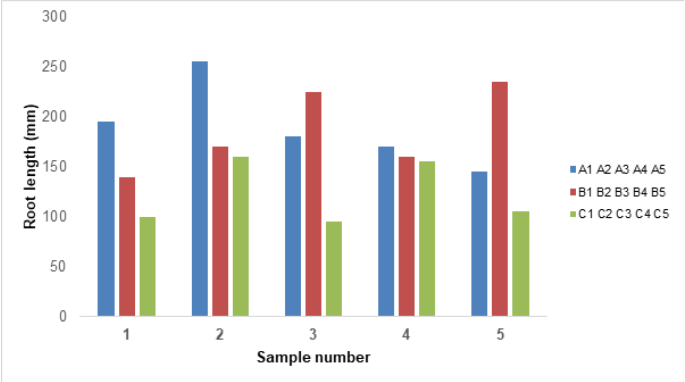

Figure 3 Root lengths of samples from treatments FKE (A), AKE (B), and the control (C). Significant variations in root lengths were observed among the treatments ($p = 0.031$). Mean lengths were: FKE (A) = 189 mm, AKE (B) = 186 mm, and control (C) = 123 mm.

FKE seedlings displayed a mean shoot weight of 0.0294 g and root weight of 0.0402 g, while AKE seedlings displayed a mean shoot weight of 0.0254 g and root weight of 0.0362 g. In contrast, the control group showed a mean shoot weight of 0.0170 g and root weight of 0.0290 g.

Discussion

The study aimed to investigate the influence of kelp extracts, specifically FKE and AKE, on plant growth metrics of root weight, shoot weight, and root length. The results indicated that both FKE and AKE treatments outperformed the control group.

In line with current literature, such as studies by Arioli et al. and Chojnacka et al., both FKE and AKE demonstrated enhanced plant growth during this study.[14,15] Specifically, the fermentation in FKE enhances the bioavailability of organic molecules for plant uptake and amplifies bioactive compounds. This results in the production of beneficial secondary metabolites that foster improved root development.

While FKE and AKE both outperformed the control, with root lengths measuring 189 mm and 186 mm, respectively, FKE seedlings displayed a noticeable difference in lateral root mass. Rayirath et al. suggested that differences in KE composition might arise from the degradation of some bioactive compounds during the alkaline extraction process of KE.[16] Furthermore, the inclusion of secondary metabolites in fermented preparations, especially auxins, has been

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highlighted by Pascual et al. for their role in stimulating root cell division and elongation.[3]

Experimental results affirmed the beneficial nature of both extracts over the control, with FKE marginally outperforming AKE in terms of root weight, shoot weight, and root length. For example, FKE had an average root weight of 0.0402g, slightly higher than AKE at 0.0362g. Although these findings are consistent with prior studies examining fermented kelp extracts, the relatively minor discrepancies observed between FKE and AKE do not conclusively support the hypothesis that FKE's production method is notably superior.

Within broader scientific literature and the study's findings, it is evident that kelp extracts, and in particular FKE, hold significant potential for enhancing plant growth metrics. However, it is essential to approach these findings with caution. Given the limitations in the experiment, such as the sample size and the specific seed weight subset, it is necessary to conduct more comprehensive research spanning a wider seed variety and extended durations to validate and expand upon these initial observations.

Conclusion

This study sought to investigate the influence of production methods- fermented (FKE) versus alkaline (AKE)-on the germination and growth of Triticale seedlings, exploring the potential of these kelp extracts to boost agricultural productivity.

The research underscores kelp extract production methodologies' subtle yet noteworthy impacts on plant growth. Within the framework of Australian agriculture, embracing these extracts could foster more sustainable farming and reduce reliance on synthetic fertilisers. However, when it comes to asserting one extraction technique as superior, the evidence suggests that the advantages of fermentation over alkaline extraction are not as pronounced as expected from the literature.

Both kelp extraction methods present valuable options for sustainable agriculture in the ongoing global challenge of climate change and the urgent need for food security. However, the data stops short of endorsing one method over the other with absolute certainty. As the scientific community continues to seek optimal agricultural solutions, it is critical to remain receptive to emerging research and appreciate the nuanced distinctions that different production methods may offer.

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None.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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