Effects of Bacteria on the Yield and Quality of Spring Barley

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Abstract – Bacterial formulations have been widely used to improve recycling of nutrients and waste in several sectors including agriculture. This study is conducted to compare the effects of two commercial waste degraders (ACF-32, ACF-SA) on barley productivity in comparison with standard farm practice. This trial was carried out in a randomised design with three replicates. Treatments were control (standard farm practice), ACF-32 treated plants and ACF-SA treated plants. The results showed a significant difference between the treatment with ACF-SA or ACF-32 and standard farm practice where the treatment of barley with ACF-SA performed better than the control and ACF-32. Particularly, protein, nitrogen, phosphorus, potassium and zinc content were higher reflecting an increased yield of 1.94 t/ha for barley treated with ACF-SA than those under standard farm practice.

Keywords – Crop Enhancement, Soil Bacteria, Bio-Fertiliser, Barely and yield.

I. INTRODUCTION

Barley (Hordeum Vulgare L.) is one of the most important food crops produced in the world. It assumes the fourth position in total cereal production in the world after wheat, rice and maize [1]. Despite, the importance of barley and its many useful characteristics, several factors are affecting its production. The most important factors that reduce the yield of barley are poor soil fertility, water logging, drought, frost, soil acidity, diseases and insects, and weed competition [2]. With focus on soil fertility microbes play an important role in promoting plant health and growth as bio-fertilisation [3]. The ability of micro-organisms to promote growth and increase yield has significant economic and environmental benefits including increased income from reduced fertiliser cost [4]. Numbers of different bacteria promote plant growth, including aerobic, facultative anaerobic, chemotropic and photosynthetic species [5-7].

There are several products in the global market under the classification of “waste degrader” in response to global regulatory legislations such as: Urban Waste Water Treatment Directive (1991) [8], Water Framework Directive (2000) [9], Environmental Protection Agency (EPA) and Clean Water Act (1977) [10], Recently, Direct Toxicity Assessment (DTA) and Whole Effluent Toxicity (WET) [11-12] tests have enforced to ensure there are no hazards entering plants. Further, biological waste degraders have been recognized and approved as environmentally safe products. The biological waste degraders include similar species of bacteria as in bio-fertilisers however their use in agriculture has not been studied widely for their effect in crop productivity.

II. MATERIAL AND METHODS

The experiment was designed, performed and evaluated by Crop Intellect Ltd (Lincoln, LN2 2LG, UK) to GEP standards. Two approved biological waste degraders provided by Nutrel Products Ltd (Lincoln, LN1 2LD, UK) namely ACF-SA and ACF-32 were evaluated for application in agriculture using spring barley. ACF-32 is a very stable bacterial cultures designed for use in waste water systems as microbial treatment and contains vegetative bacteria from different species representing aerobic, anaerobic, facultative, chemo-synthetic and photosynthetic species, and it uses biological activity to dissolve solids and it is not hazardous, toxic or harmful to humans, animals or fish and plants. ACF-SA is a natural product, non-pathogenic and with no genetically modified organisms and contains aerobic, facultative anaerobic, chemotropic and photosynthetic species, blended with organic certified humic acid.

The experiment took place in a commercial farm North of Lincoln with each treatment replicated three times. Each plot was 100m2 to ensure that field variation within plots is averaged out and a randomised block design was utilised.

Soil properties, Experimental Field Design

The experiment was performed within a field of 16.35ha at Lodge Farm Ltd. At the start of the experiment, the main characteristics of the soil used for growing barley analysed by third party certified laboratory and are presented in Table 1. The soil was loamy with the following description from the national soil survey “Shallow well drained brashy calcareous fine loamy soils over limestone” and “Free draining permeable soils on 'brashy' or dolomitic limestone substrates with high permeability and moderate storage”.

The field received typical herbicides mixed effectively as a good practice for control of a wide variety of weeds and also to avoid tolerance. Nitrogen and TSP were used as basic fertiliser and for foliar elements received Magnesium, Manganese and a multi-nutrient mix. A growth regulator a-
Table 1. Soil analysis of the experimental field area.

<table>
<thead>
<tr>
<th>Soil test parameter</th>
<th>pH</th>
<th>Copper (EDTA extractable) mg/L</th>
<th>2.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.8</td>
<td>Boron (hot water-soluble) mg/L</td>
<td>1.2</td>
</tr>
<tr>
<td>Sodium ammonium nitrate extractable) mg/L</td>
<td>7.0</td>
<td>Zinc (EDTA extractable) mg/L</td>
<td>2.5</td>
</tr>
<tr>
<td>Calcium (Ammonium nitrate extractable) mg/L</td>
<td>2710</td>
<td>Iron (DPTA extractable) mg/L</td>
<td>21.5</td>
</tr>
<tr>
<td>Organic matter %</td>
<td>3.6</td>
<td>Sulphate (phosphate buffer extractable) mg/L</td>
<td>11.0</td>
</tr>
<tr>
<td>Manganese (DPTA extractable) mg/L</td>
<td>5.3</td>
<td>Essential Cation Exchange capacity, meq/100g</td>
<td>18.3</td>
</tr>
</tbody>
</table>

**Product Application**

ACF-32 and ACF-SA were applied by spraying foliarly with high volume of water relative to the standard farm practice in the UK to runoff to reach the soil. The application rate was 3.76 litres per hectare to deliver in 500 litres of de-chlorinated water, using 15 ml of Predator, as recommended by the Nu-trel Group Ltd. Plants were sprayed three times starting from seeding stage to maturity with intervals of around 4-5 weeks using a Berthoud sprayer with yellow Hypro flat fan nozzles x3 at a bar length of 1m applied with a pressure of 2 bar (as recommended). An 18.8ml in 2.5 ml water of product was applied for each 50 m2 plot during ‘light rain’ conditions to ensure the application at suggested application rate exhibited higher average chlorophyll concentrations compared to the control and the other treatments during the first measurement as illustrated in Fig 2(b). Furthermore, there was also a trend that plants treated with ACF-SA had lower average chlorophyll concentrations compared to the control and the ACF-32 treatment at both measurements. The previous results can be explained on the basis that the application treatment of ACF-SA is a treatment of (bio-fertiliser) which led to increasing significantly chlorophyll content in barley leaves and any increase in application rate will not benefit towards rising chlorophyll content. This trend was previously illustrated by Abd El-bake (2008) who found that the application of bio-fertilisers increased the total amount of chlorophyll in crops [13].

Chlorophyll concentration was measured twice at different growth stages, and the results are shown in Fig 2(a). The average chlorophyll concentration was lower during the second measurement. However, there was no significant difference between the different treatments during the first (F (3,196) = 1.95, p = 0.122) and second measurement (F (2,177) = 1.06, p = 0.348). There was only a trend that plants treated with the pure ACF-SA had lower average chlorophyll concentrations compared to the control and the other treatments during the first measurement as illustrated in Fig 2(b).

**Efficacy Measurements**

Measurements were devised to ensure appropriate evaluation between treatments for efficacy and included plant height and flag leaf length, chlorophyll content, standard elements in tissue (leaves only), seed nitrogen content, specific weight, protein and yield. Some treatments were performed by supplying samples to third parties certified laboratories in the UK.

**Statistical Analysis**

The standard analysis of variance was applied to all data Microsoft Excel spread sheet. The results subjected to one-way ANOVA test, Tukey Pairwise Comparisons and Tukey Simultaneous Tests for Differences of Means using.

**III. RESULTS AND DISCUSSION**

**Growth Study**

The field experiments revealed a significant contribution of ACF-32 and ACF-SA to the growth parameters of barley compared with the control. The results are presented in Table 2 and Fig 1 showed variation in measured parameters under different treatments confirming differences. There was a significant effect of applied products on chlorophyll content, plant height, flag leaf length, standard elements in leaves’ tissue, nitrogen content, specific weight and yield.

![Experimental Field Design; Position of the trial site in Nettleham, Randomised plot design for spring barley trials.](image)

![Measured barley growth parameters; Average chlorophyll concentration (a), average plant height (c) and average flag leave length (d).](image)
Barley plant average height shown in Fig 2(c) confirmed that treatments had no significant effect \((p > 0.05)\). Post hoc comparisons using the Turkey HSD test indicated that plants treated with the pure ACF-SA product grew significantly less compared to the ACF-SA (\(p = 0.012\)) and ACF-32 (\(p = 0.005\)) treated plants.

Results of the average flag leaf lengths for the different treatments are shown in Fig 2(d). Overall there was a significant difference between treatments (ANOVA, \(F(2,87) = 4.53, p = 0.013\)). Post-hoc comparisons revealed that plants treated with ACF-SA had significantly longer flag leaves compared to the control (Turkey HSD, \(p = 0.016\)). There was a trend that plants from the ACF-32 treatment had longer leaves compared to the control but not significant (Turkey HSD, \(p = 0.058\)). There was no difference between the two treatments (Turkey HSD, \(p = 0.869\)).

<table>
<thead>
<tr>
<th>Element</th>
<th>Unit</th>
<th>Control</th>
<th>ACF-SA</th>
<th>ACF-32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>% w/w</td>
<td>3.94</td>
<td>4.36</td>
<td>4.28</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>% w/w</td>
<td>0.42</td>
<td>0.44</td>
<td>0.38</td>
</tr>
<tr>
<td>Potassium</td>
<td>% w/w</td>
<td>2.62</td>
<td>3.77</td>
<td>3.22</td>
</tr>
<tr>
<td>Calcium</td>
<td>% w/w</td>
<td>1.35</td>
<td>1.61</td>
<td>1.87</td>
</tr>
<tr>
<td>Magnesium</td>
<td>% w/w</td>
<td>0.23</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>Sulphur</td>
<td>mg/kg</td>
<td>3823</td>
<td>3306</td>
<td>4541</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/kg</td>
<td>133</td>
<td>84</td>
<td>82.5</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg</td>
<td>9.6</td>
<td>12.6</td>
<td>12.8</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>32.7</td>
<td>42.4</td>
<td>41.8</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>113</td>
<td>114</td>
<td>231</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/kg</td>
<td>6.8</td>
<td>6.4</td>
<td>7.4</td>
</tr>
</tbody>
</table>

Chemical tissue analysis for nitrogen, phosphorous, iron, boron, potassium, calcium, magnesium, sulphur, manganese, copper, zinc is demonstrated in Table 2. In general, tissue analysis showed that nitrogen, phosphorous, potassium and zinc where on their higher level in the plants treated with ACF-SA. However, calcium, sulphur, copper, iron and boron were higher in the plants treated with ACF-32. Only magnesium and manganese were higher in the control plants. ACF-SA and ACF-32 treated plants had slightly higher Nitrogen levels compared to the control content of 3.94% statistically there was no significant difference between the treatments \((p > 0.05)\). Potassium content was on its highest levels in both ACF-SA and ACF-32 treated plants compared to the control plants with significant higher level in ACF-SA treated plants of about 3.77%. The average Calcium content in ACF-32 treated plants had the highest levels compared to the control and ACF-SA. Magnesium contents ranged between 0.13–23 ppm where ACF-SA and ACF-32 treated plants had significantly lower level compared to the control with that of ACF-32 at 0.13 ppm. Interestingly, ACF-32 treated plants had nearly twice the level of Iron compared to the control and ACF-SA.

**Harvest – Ears/Plants/Yield**

Data shown in Fig 3 (a and b) demonstrated that there was a significant difference between the treatments (ANOVA, \(F(2, 24) = 4.74, p = 0.018\)) regarding the average number of ears per plant/ per m². Post-hoc analysis confirmed that ACF-32 treated plants had a significantly higher average number of ears per plant compared to ACF-SA treated plants (Tukey HSD, \(p = 0.019\)) and the control but not significant (Tukey HSD, \(p = 0.083\)). Average number of plants per m² are given in Fig 3 (c) showing there was no significant difference and therefore the comparison between treatments is validated (ANOVA, \(F(2, 24) = 0.11, p = 0.894\)).

The average yield of the treatments is shown in Fig 3 (d and e) for at harvest and dry yield respectively. Overall there was a significant difference between the treatments (ANOVA, \(F(2,6) = 6.15, p = 0.035\)). Post-hoc analysis revealed that plants treated with ACF-SA yielded significantly higher than the control plants (standard farm practice) by 1.94t/ha (Tukey HSD, \(p = 0.030\)), but not significantly higher compared to ACF-32 treated plants (Tukey HSD, \(p = 0.306\)). Fig 3f showed the average dried matter of seeds after adjustment for moisture as it was confirmed that moisture was not different between treatments \((F(2, 6) = 0.28, p = 0.768)\). Furthermore, there was a trend of ACF-32 treated plants yielding higher compared to the control but not significant (Tukey HSD, \(p = 0.096\)).

Further tests for the average grain nitrogen levels in % of dry matter revealed no significant difference between the different treatments and the control (ANOVA, \(F(2, 6) = 0.15, p = 0.866\)) with a great variation between the different plots in the control and the ACF-SA treatment (confidence level of 95%, \(p = 0.01\)) with values of 1.41, 1.43 and 1.39% for the control, plants treated with ACF-SA and plants treated with ACF-32 respectively with standard error up to 5%.
Fig 4. Measured barley yield parameters; Average specific weight of grain (kg/ hl) depending on the different treatments (a), Average percentage of grain passing a 2.25mm standard slotted sieve (b).

Fig 4, shows the average specific weight of the grains (a) and the average percentage of grains that pass a standard slotted sieve. One-way ANOVA test showed no significant difference between the treatments for both of these parameters. However, there is a trend of ACF-32 treated plants to have a lower specific weight compared to the control and ACF-SA. The obtained results agreed with previously published works concerning the effect of bacteria on the yield and other growth parameters [14-15].

Product dosage and timing will vary depending on soil characteristics, crop choice, application equipment and other agronomic factors. The efficacy of the microorganisms will vary depending on environmental condition. In particular, moisture and temperature can affect the survival and colonization of the bacteria which is typical in using bacteria cultures to exert their positive effect.

IV. CONCLUSIONS

In conclusion, there was a significant difference between the treatment with ACF-SA or ACF-32 and standard farm practice (control) where the treatment of barley with ACF-SA performed better than the control and ACF-32. Yield, which is of most importance to farmers, was higher by 1.94 t/ha compared to standard practice. The protein content of standard practice (control) where the treatment of barley with ACF-SA was 1.94 t/ha compared to standard practice. The protein content of ACF-SA treated plants was significantly higher (p<0.05) than that of the control treatment. The results agreed with previous work concerning the effect of bacteria on the yield and other growth parameters [14-15].

REFERENCES


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