5 Plant Growth Promoting Rhizobacteria Inoculated Peat and Peat-Free Substrates in Potted Herbs

5.1 Introduction

Utilising microorganisms to improve food production by way of yield, improved growth rates and improving overall crop quality has long been accepted as having great potential. The first description of rhizobacteria (Kloepper and Schroth 1978) and the revelation of microbial interactions between plants by Kamienski in 1882, (Berch, Massicotte, and Tackaberry 2005) has brung forth a revolution in the way in which food systems are addressed. Soil health, structure and biodiversity are key drivers in actioning dynamic food production methods; techniques such as the development of no till cultivation's (Elliott and Stott 1997) remain in common use as to preserve and enhance microbial diversity *in situ*. The process of adding bacterial and fungi to enhance crop production has been demonstrated many times over (Walley and Germida 1997; Yang, Kloepper, and Ryu 2009; Bhattacharyya and Jha 2012; Adesemoye, Torbert, and Kloepper 2008).

Bacterial Amendments in this study refers to Plant Growth Promoting Rhizobacteria (PGPR). PGPR are known for their ability to mobilize various nutrient resources, fix atmospheric nitrogen, act as bio-control agents, regulate nutrients and directly infulence plant growth (Ahemad and Kibret 2014; Lugtenberg and Kamilova 2009). Various PGPR have been demonstrated as beneficial amendments in both crop and pot trials, in both axenic and field conditions (Kumar, Prakash, and Johri 2011).

Marketed as a Bio-fertilizer, inoculations such as PGPR are a significant, and potentially influencing element for the future of agrochemical and agricultural practices (Vessey 2003). The continued development of these products will inevitable see wider ranging adoption of bio-fertilizer use (Bhattacharyya and Jha 2012).

However, the intricacies of rhizosphere species interactions are still being researched at great length (Barea 2015), simply due to the complexities of the relationships found therein. The process of this interaction between host plant, indigenous microbial elements and introduced species is not addressed here, merely the effect on crop growth.

The abilities for PGPR to enhance crop production will be assessed in this study, by using leafy herbs as a proxy for treatment efficacy in Peat and Peat-Free substrates in both Basil and Coriander. Following Phytometric assessments, an analysis of Colour values (Red-Blue-Green) was used demonstrate treatment efficacy. Assessment of crop colour via photogrammetric inspection has been demonstrated as effective for crop helth determination (Dwari et al. 2021; Taylor et al. 2021) and disease detection (Nidhis et al. 2019).

This study will utilise four species of PGPR, each selected by the supplier for their demonstrated ability to improve crop quality. These species (referred to as A, B, K, O) were tested individually and in a multi-species mix.

5.2 Methods and Materials

Both commercial grade Peat and Peat-free media were used for the duration of this study. Two species of edible herbs were used, *Ocimum basilicum* and *Coriandum sativum* (Basil and Coriander, respectivley). The same growth conditions (humidity, temperature, light exposure) were used throughout. Different irrigation rates were used dependent on media type.

Design

The trials used in this study were arranged in a randomised block with anonymised labelling for blind assessment. A total of n= 829 pots were used for this study. 3-6 replications were used depending on trial parameters and resource availability. Each replicate comprised of a single pot.

Organisms

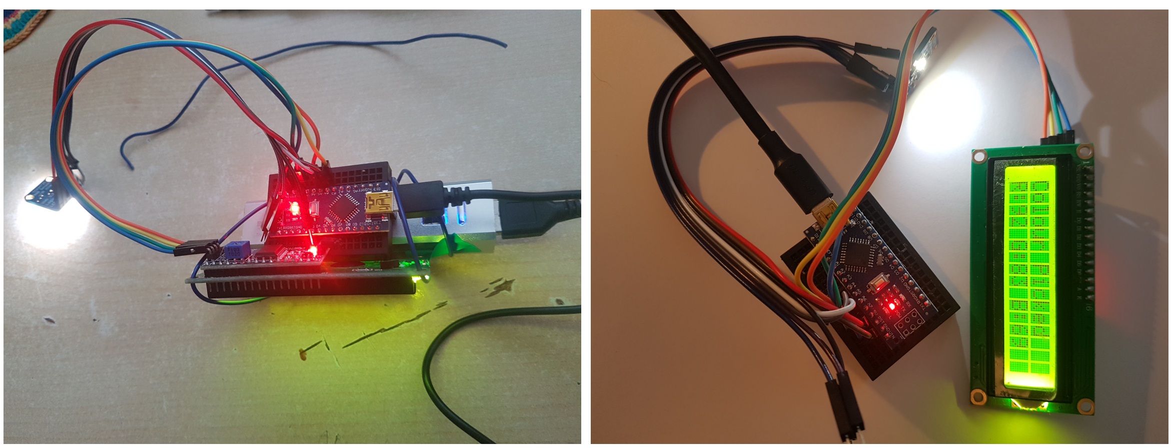
This study was conducted using four bacterial species (PGPR). All species was provided by a commercial sponsor (Plantworks). Species were supplied in concentrate form, which was refrigerated upon reciept and used within 4 days. The species were then diluted with tap water, mixed in a sterile bucket and poured onto pre-saturated pots.

Assessment and Analysis

Phytometric measurements were conducted, namely height, emergence count, leaf diameter, fresh/dry weight and rootlength. For each treatment trial, a non-innoculated treatment for each crop and substrate was used as a control.

RGB values

A colour sensor was also used for assessing Red-Green-Blue (RGB) values for Basil leaves at harvest (see Figure 27). This colour sensor was used in tamdem with an Arduino Nano and 16x2 LCD screen for output data. A small, 5.1V battery was used to power the device for extra portability. I^2C was used to form a connection from the Nano to the LCD for data read outs. This device was used as an additional tool in order to improve treatment efficacy assessments. The purpose of this would be to determine if bacterial species effect crop quality by using leaf colour as a proxy for treatment effect. RGB sensors are rapidly being deployed in horticulture and agriculture in order to assess crop quality and promote automation (Zermas et al. 2015; Ruiz-Altisent et al. 2010; Puri, Nayyar, and Raja 2017). Use of RGB values can be used to determine concentration of phytochemical compounds, such as chlorophyll as demonstrated by Özreçberoğlu and Kahramanoğlu (2020) through the use of a smart-phone camera.



(a) (b)

Figure 27: RGB sensor in breadboard prototype (a) and finalised, portable configuration with battery (b). Increased portability allowed for easy use around potted herb trials.

5.3 Results

The results of several trials demonstrated mixed results for the effect of PGPR on container grown herbs in both peat and peat-free medias for each *Ocimum basilicum* and *Coriandum sativum.* At a substrate level, Peat media outperformed peat-free media in all phytometric aspects (crop growth, yield, leaf-diameter). Basil and Coriander performed differently, as was expected.

The only treatment to achieve an increased mean height to that of the control was a combined treatment (A + B + K + O) for both *Ocimum basilicum* and *Coriandum sativum*, only achieved in peat-based substrates.

Increased yield for both fresh and dry weight against the control values was only demonstrated significantly by Basil for both peat and peat-free substrates. Treatment “A” performed the strongest, with an increased fresh yield of 4.29g against the control for peat.

Leaf diameter was less consistent in results for Basil for peat substrate. Peat-Free substrate for Basil demonstrated a negative impact on treatment effects, with consistently lower mean leaf diameters for all treatments compared to the control value.

5.3.1 Crop Height

Overall, total mean over the entire growing period for height was Peat at 8.66 cm (4.75cm SD, n = 1,943) followed by Peat-Free at 6.53 cm (3.67cm SD, n = 2,205), $p < 0.05$. Crop to crop differences demonstrated Basil as having significantly (P <0.001) lower height than Coriander (6.89 cm, 7.87cm respectively). On a treatment level, Peat substrates for both Basil and Coriander performed significantly better than Peat-Free counterparts. 7.4cm (4.25cm SD) mean height for Basil in Peat (n= 1,024) against 6.36 (3.37cm SD) for Basil in Peat-Free substrates (n = 1,019), $p < 0.051$. This trend was also demonstrated in Coriander; 9.74cm (4.88cm SD, n= 919) in Peat against Peat-Free; 6.64cm (3.62cm SD, n= 1,186), $p < 0.05$.

Microbial amendments did not change overall mean height values for the trial period at a significant level above that of the control (7.8cm, 3.95cm SD, n = 2,073), $p < 0.05$, (see Figures 29, Basil and 31, Corriander). On an individual substrate level, the only PGPR treatment in combination with Peat based substrate to achieve a higher mean height was a combination treatment of all species (A + B + K + O); 9.28cm (5.17cm SD, n = 220) against Peat control at 8.87cm (4.4cm SD, n = 809), p <0.05. This result was also replicated on a crop level (Coriander), with total mean height (across both substrate types) for microbial treated croppings achieving a mean height of 10.63cm (3.54cm SD, n = 141) for combinative treatments (A + B + K + O), surpassing the next highest value (Coriander control) at 8.05cm (4.00cm SD, n = 1,068).

Regression analysis on treatment suggested species “K” in Basil (R=0.95) and an all species mix (A + B + K +) in Coriander (R=0.6) had the strongest relationship to growth over time (see Figures 29, Basil and 31, Corriander). These scatter plots also allow for swift observation of the generally increased efficacy of peat substrate in regards to crop height over peat-free substrate.

5.3.1.1 Basil Growth Basil crop height grew slowly compared to Coriander. Basil potted (see Figure 28) in Peat growing media performed significantly better than the Peat-Free alternative. Height at 7 days was not recorded as Basil seedlings were covered in black-out plastic as increased exposure during this initial emergence phase could have resulted in crop damage.

Only slight deviations between biological treatments were apparent in Basil growth, the most succesfull being that of treatments A and K (see Figure 29 and Table 10).

(a) (b)

Figure 28: Basil seedlings at *ca.* 7 days growth. Initial crop emergence period, pots were covered with plastic sheeting to stimulate germination.