Influences of magnetic flux on growth and direction of Chiang Rai Phulae Pineapple roots

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Abstract. Currently, chemicals are widely used in plant cultivation in many countries, allowing plants to have more roots, grow faster, and increase productivity. This research aimed to study application of permanent magnets (Neodymium Magnets (NM)) to accelerate the growth of plant roots instead of using chemicals for cultivation. Pineapples were planted in liquid media under permanent magnetic flux density ($B$) of 1-90 mT intensity. Magnetic flux directions were arranged in two forms, either toward or ejected from the plant roots. The result showed that the number of roots of pineapples planted under the magnetic flux was 2 times greater than the control and the length of roots was also 4.5 times greater in length than those without magnetic flux. The roots exposed toward the magnetic flux had about 2 times greater number and length of roots compared to when the magnetic flux direction was ejected from the plant roots. The direction of the magnetic flux influenced the direction of plant root growth significantly.

1. Introduction

At present, numbers of agricultural methods have been developed that reduce chemical use, but the reduction of agricultural chemicals results in reduced agricultural production. Therefore, it is important to select a suitable technique in order to reduce the use of agricultural chemicals but still promote growing crops. Physics principles are good options used for agriculture [1], becoming the ways that interest farmers. Many techniques based on basic principles of physics can be applied in agriculture to increase productivity [1], one technique is the application of magnets which is an easy to use procedure to reduce the use of chemicals and production costs. The magnetic fields are used to enhance a plant’s growth and productivity due to its effect on water molecules, ability to induce modification on a molecular level, changes in photosynthetic pigments content, weight and water
content in plants and the effect of magnetic fields on plant’s elemental composition [2]. The researchers found that the magnetic field had significant effects on the plant roots, such as Josep Penuelas et al. who researched diamagnetic susceptibility and root growth responses to magnetic fields in *Lens culinaris*, *Glycine soja*, and *Triticum aestivum* [3]. The roots of plants are important for plant growth and help to increase crop yields.

This research focuses on influences of magnetic flux on the growth and direction of pineapple roots. This relationship between biology and physics, via influence of magnetic fields on plant roots, can be applied for growing plants and promoting cultivation of organic and safe food in the future.

2. Theoretical background

The contribution of magnetic flux for a given area is equal to the area times the component of magnetic field perpendicular to the area. No matter how small the volume, the magnetic sources are always dipole sources (like miniature bar magnets), so that there are as many magnetic field lines coming in (to the south pole) as out (from the north pole) as shown in figure 1 (a). Magnetic flux (Phi, \(\Phi\)) with the unit of flux being the Weber, (Wb)) is the product of the average magnetic field times the perpendicular area that it penetrates. The number of lines of force within a given unit area is called the “Flux Density” and since flux (\(\Phi\)) is measured in (Wb) and area (A) is in meters squared, (m\(^2\)), flux density is therefore measured in (Wb/m\(^2\)) and is given the symbol B and flux density in Teslas (\(\theta\)) is an angle between \(B\) and \(A\), when \(B\) is magnetic flux density and the unit of magnetic flux density is the Tesla, and \(A\) is area of the sample in equation (1) and figure 1 (a) and (b) [4].

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\Phi = B \cdot A = BA \cos \theta
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3. Experimental setup and procedures

Chiang Rai Phulae pineapples (*Ananas comosus* (L.) Merr, Bromelioidae) from Chiang rai province, Thailand was used for research. A leafy top of pineapple was separated from the pineapple fruit as shown in figure 2 (a) and (b). After that, it was plugged in with a pointed tip to be placed on the edge of the vase, as shown in figure 2 (c). Next, it was placed on the water surface in a transparent vase as shown in figure 2 (d). The vase was filled with liquid media (water), about 78.5 ml with the water level maintained at 5 cm height. Permanent magnet (Neodymium Magnets (NM)), of 4 (length) x 2 (width) x 0.1cm (thickness) in size, was placed in the bottom of the vase where it had a magnetic flux density (B) of 90 mT and 1 mT at the water surface. 3 sets of experiments included one designed to have magnetic flux of permanent magnets placed in the direction toward the roots as in figure 2 (f), one designed to have magnetic flux placed to the direction away from the root in figure 2 (g) and one control vase without permanent magnet in figure 2 (e). In figure 2 (d), each vase was empty in a row with 10 cm spacing. Finally, the number and length measurement of the pineapple roots was observed every 2 days for 16 days.
4. Experimental results
The germination characteristics of pineapple roots in the vase in 3 sets of experiments can be observed from figure 2 (e), (f), and (g). The number of roots of pineapple seedlings were compared between each experiment set in figure 2 (h). The root growth rate, shown in figure 2 (j), was found to be higher under magnetic flux than those with none magnetic flux. The magnetic flux that had the direction away from the root (in the magnetic South Pole) resulted in the highest root growth rate with an average number of roots and maximum root length about 2 times and 4.5 times, respectively, compared to the control as shown in table 1. From equation (1), it could explain the influences of the magnetic flux on growth and direction of pineapple roots. The root was likely to germinate on area A (root origin area) as shown in figure 2 (c). The roots were activated by a magnetic flux either with an angle to the area $\theta = 180^\circ$, $\Phi = -BA$, range $90 > 0 > 270$ (in magnetic North Pole) which was the opposite direction to the root germination direction or $\theta = 0^\circ$, $\Phi = BA$, range $270 > 0 > 90$ (in the magnetic South Pole) which was the same direction with root germination direction of pineapple seedlings in vases in figure 2 (i). As a result, the roots of pineapple grown in the flux magnet received a positive impact, resulting in the highest number of roots and root growth rate of 2.26 cm within 16 day.

Figure 2. Chiang Rai Phulae pineapples (a). A leafy pineapple top (b) was separated and plugged in with pointed tips (c). Each vase was empty in a row (d), nonmagnetic set (e), in magnetic North Pole (f) and in magnetic South Pole (g). Pineapple seedlings (h) and diagrams of growth changes of pineapple seedlings in vases (i). Pineapple root growths form 3 sets were compared in aspects of root growth rate (j).

The permanent magnetic flux enhanced the absorption of water and helped shorten germination period of plants and it stimulated some genes that responded to stress, making the plants developed strong environmental resistance. Faster water absorption also resulted in more height and length of the
roots [5]. Several researches reported the effects of magnetic flux on plant cell growth development, including induction of protein synthesis during development of root cells, extending cellular age and influenced cell organization and cell division. In addition, the magnetic field had an impact on cell reproduction and cellular metabolism, gene expression and DNA/enzyme activity [2]. MF has a very high stimulating effect on cell multiplication, growing and development [6]. MF treatment induces molecular transformation to provide cells with better condition for growth and further development. Several studies reported that MF has affected the molecular level and the nature of MF effect has reached protein synthesis activation, leading to plant growth enhancement such as seeds germination, further development of root system, root length, length of radicle, dry weight of root, and dry weight of radicle [7]. Moreover, the MF effect on water molecules and electrolyte solutions enhances ions and element uptake. MF may act as a plant hormone and proposed to mimic auxin in plant system to increase growth or could activate or accelerate enzymes related to auxin reactions [8].

| Pineapple root growths from 3 sets were compared in aspects of root numbers, root length. |
|-----------------------------------------------|-----------------------|-------------------------------|
| Average number of roots | Maximum root length (cm) |
| In magnetic South Pole | 7 | 2.26 |
| In magnetic North Pole | 4 | 1.51 |
| Non magnetic | 3 | 0.5 |

5. Conclusions
Flux magnets that have direction away from the root (in the magnetic south pole), had a positive effect, resulting in the highest root growth rate. The highest number of roots and root growth rate of 2.26 cm was achieved within about 2 weeks. The average number of roots and maximum root length under a higher magnetic flux was about 2 times and 4.5 times, respectively, than those under none magnetic flux. The results of this research can be applied to grow pineapple in the future.

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References
[1] Jan G, Jozef H and Jerzy L 2013 Soil Sci. Ann. 64 67–80
[2] Faten D 2014 Annu. Res. Rev. Biol. 4 886–96
[3] Josep P, Joan L, Benjamin M and Josep F 2004 Biol. Med. 23 97–112
[4] Serway R A and Jewett J W 2013 Physics for Scientists and Engineers with Modern Physics 9th ed (Boston: Brooks/Cole Cengage Learning) pp 725–31
[5] Sadeghipour O and Aghaei P 2013 J. Bio. Env. Sci. 3 37–43
[6] Yokatani K T, Hashimoto H and Yanagisawa M 2001 Biol. Sci. Space. 15 258–59
[7] Phirke P S, Kudbe A B and Umbarkar S P 1996 Sci. Technol. 24 365–92
[8] Boe A A and Salunkhe D K 1963 Nature 199 91–2