EFFECTS OF SLOW-RELEASE FERTILIZERS OF ZINC AND IRON ON GROWTH PERFORMANCE IN THE PISCIPONIC SYSTEM OF LEMON FIN BARB HYBRIDS *Brassica rapa* L. var. *Chinensis*

By

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The challenge of finding an optimal supplementation in a pisciponic system is due to its nutrient input and nutrient uptake as the main element in the system. A good amount of fish without enough nutrients leads to low production of crop plants in a pisciponic system. Other than that, it has been reported that the pisciponic system that relies exclusively on fish waste to provide nutrients for plants have low levels of micronutrients (Ru et al., 2017). Granular fertilization is an interesting strategy for nutrition with micronutrients in the pisciponic system. Among the micronutrients, Zinc (Zn) and Iron (Fe) are the most frequent in the system. A pisciponic system is an integrated farming concept that combines fish and hydroponic plant production in a recirculating water system. However, finding an optimal supplementation in the pisciponic system is challenging due to its nutrient input and nutrient uptake as the main element in the system. Therefore, having a good amount of fish with insufficient nutrients would lead to low production of crop plants in the pisciponic system. Ru et al. (2017) reported that the pisciponic system relies exclusively on fish waste to provide nutrients for plants that contain a low level of micronutrients. Granular fertilization is, hence, suggested as an interesting strategy for nutrition with micronutrients in the pisciponic system, which consist of Zinc (Zn) and Iron (Fe) since these elements are frequently lacking in the system. The present study aims to investigate the effects of supplementation in the pisciponic system on growth performance through granular form application for the plants in the pisciponic system.

The study was conducted at the Aquaculture Experimental Station in Puchong, Selangor. The experiment was set up in a greenhouse covered with plastic liner at the bottom. The coated fertilizers were immersed into the beakers containing 500 ml of distilled water. The immersion times were analyzed for each 3, 6 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, and 72 hours. Insoluble solids and water were then filtered using a filter paper and dried in the oven, followed by the drying process to obtain a constant weight before being put in the desiccators. During the release test, the distilled water was taken at every 48-hour interval and the concentration nutrients were determined from the atomic absorption spectrometer. A second experiment was conducted to evaluate the effect of selected micronutrients in the pisciponic system. The coated zinc and iron were placed in each pot with different treatment levels. Seedlings of pak choi were transferred into the pisciponic system 14 days after sowing and harvesting were conducted after 30 days.

The weights of release fertilizers, specifically Zn and Fe were significantly decreasing over time. At the lowest concentration, the weights of coated zinc and iron were decreasing as time increased. According to Borges et al. (2012), the amount of fertilizers supplied would affect the amount of SPAD values and the chlorophyll. By referring to the curve results, the Zn fertilizer started to drastically decrease its weight at hour 24, whereby the weight decreased approximately to 0.002 for every subsequent hour. Meanwhile, Fe fertilizer decreased drastically at hour 66, where the weight dropped from 0.10467 to 0.039. However, the final weights for both fertilizers at hour 72 were about the same. The highest chlorophyll contents for pak choi were recorded in the first treatment, which is 5 weeks in the pisciponic system. The first treatment of zinc and iron showed the highest chlorophyll contents. According to Babaeian et al. (2012), chlorophyll formation and photosynthesis need iron for the enzyme system and respiration of plants. In conclusion, this work has demonstrated the potential of this new slow-release zinc and iron fertilizer of palm stearin.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN PELEPASAN PERLAHAN ZINK DAN BESI PADA PRESTASI PERTUMBUHAN SISTEM PSICIPONIK MENGGUNAKAN LEMON FIN BARB HYBRID PADA *Brassica rapa* L. var. *Chinensis*

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Dunia menghadapi sejumlah masalah serius di mana peningkatan populasi, perubahan iklim, kemerosotan tanah dan keselamatan makanan adalah antara yang paling penting. Pisciponik adalah sistem peredaran semula yang terdiri daripada unsur hidroponik dan akuakultur. Walau bagaimanapun, terdapat ketidak seimbangan antara bekalan nutrien oleh keperluan ikan dari tanaman. Besi dan zink adalah mikronutrien yang paling penting untuk pertumbuhan ikan dan pertumbuhan tanaman dalam sistem pisciponik. Oleh itu, zat besi penting untuk tanaman fisiologi untuk fotosintesis dan zink penting untuk peraturan pertumbuhan dan peraturan batang. Walau bagaimanapun, dilaporkan bahawa sistem pisciponik yang bergantung sepenuhnya pada sisa ikan untuk menyediakan nutrien untuk tanaman mempunyai tahap mikronutrien yang rendah dan juga laporan mengenai pengurusan dan suplemen besi dan zink dalam sistem pisciponic kekurangan. Pembebasan lambat pembajaan adalah strategi menarik untuk pemakanan dengan mikronutrien dalam sistem picsiponik; di antara mikronutrien, Zink (Zn) dan Besi (Fe) adalah mikronutrien yang paling kerap diperlukan untuk memastikan prestasi tanaman yang optimum. Menemukan suplemen yang optimum dalam sistem pisciponik sangat mencabarkerana input nutrien dan pengambilan nutrien sebagai elemen utama dalam sistem pisciponik. Kajian ini bertujuan untuk mengkaji kesan pelepasan perlahan zink dan zat besi terhadap prestasi pertumbuhan sistem pisciponik menggunakan ikan Lemon fin hybrid pada *Brassica chinensis* var. *chinensis*. Kajian dilakukan di Stesen Eksperimen Akuakultur di Puchong, Selangor. Eksperimen ini dibuat di rumah hijau. Baja yang dilapisi direndam ke dalam bikar yang berisi 500 ml air suling. Masa rendaman dianalisis untuk setiap 3, 6 12, 18, 24, 30, 36, 42, 48, 54, 60, 66 dan 72 jam untuk kadar pembubaran. Kemudian, pepejal dan air yang tidak larut disaring menggunakan kertas turas dan

dikeringkan di dalam ketuhar diikuti dengan pengeringan untuk mendapatkan berat tetap, kemudian dimasukkan ke dalam pengering. Semasa ujian pembebasan, air suling diambil setiap selang 48 jam dan nutrien kepekatan ditentukan dari spektrometer penyerapan atom. Eksperimen kedua dijalankan untuk menilai kesan mikronutrien terpilih dalam sistem pisciponik. Zink dan besi yang dilapisi diletakkan di setiap bikar dengan tahap rawatan yang berbeza. Anak benih pak choi dipindahkan ke sistem pisciponik 14 hari setelah disemai. Penuaian dilakukan selepas 30-35 hari untuk pak choi. Berat baja dibebaskan, di mana berat Zn dan Fe menurun dengan ketara dari masa ke masa. Pada kepekatan terendah, berat zink dan besi yang dilapisi akan menurun seiring bertambahnya waktu. Jumlah baja yang dibekalkan akan mempengaruhi jumlah nilai SPAD dan klorofil. Dengan merujuk kepada hasil, baja Zn mulai menurunkan berat badan secara drastik pada jam 24, di mana berat badannya turun sekitar 0,002 untuk setiap jam berikutnya. Sementara baja Fe menurun secara drastik pada jam 66, di mana berat badan turun dari 0.10467 hingga 0.039. Walau bagaimanapun, berat akhir bagi kedua-dua baja pada jam 72 adalah hampir sama. Untuk kajian kedua, hasil menunjukkan bahawa kombinasi baja dalam satu aplikasi perlakuan, ini menunjukkan peningkatan klorofil, peningkatan diameter daun, berat segar dan kering tanaman dan peningkatan pengambilan nutrien N, P, K, Fe dan Zn. Untuk suplemen zink dan zat besi individu dalam sistem pisciponic, hasilnya menunjukkan bahawa ia kurang efektif dari segi pertumbuhan tanaman dan pengambilan nutrien menunjukkan lebih lambat dibandingkan dengan penggunaan besi kombinasi dan zink dalam satu rawatan. Dengan menggunakan jumlah baja tambahan yang tepat dalam sistem pisciponik, ia dapat meningkatkan kelestarian dan produktiviti sambil mengurangkan pelepasan dan kekuatan persekitaran mempromosikan penggunaan pisciponik di masa depan untuk keselamatan makanan untuk nisbah optimum dalam pengeluaran nutrien dan pengambilan tanaman di setiap sistem. Selain itu, ia juga dapat memberikan dan mencapai hasil tertinggi.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AAS	Atomic Absorption Spectroscopy
BW	Body Weight
DM	Dry Matter
d	Day
DO	Dissolved Oxygen
DOF	Department of Fisheries
FAO	Food Agriculture Organization
FCR	Feed Conversion Ratio
g	Gram
h	Hour
Kcal	Kilocalorie
l	Litre
m	Meter
ml	Millilitre
ppm	Part per million
SAS	Statical Analysis System
SD	Standard Deviation
S.E	Standard Error
SGR	Specific Growth Rate
SRV	Survival Rate
t	Time
WG	Weight Gain

CHAPTER 1

INTRODUCTION

1.1 Background

The aquaculture industry in Malaysia has shown steady growth in production outputs and values in the past few years (Estim, Saufie, & Mustafa, 2018). Aquaculture is a big scope that covers the rearing of aquatic animals or the cultivation of aquatic plants for food (Witus et al., 2016). The combination of aquaculture and hydroponics is known as pisciponic, in which enriched nutrients recirculating from fish tanks is used for plant growth (Goddek et al., 2015a). However, the globe has to be responsible and concerned about how future generations will produce more food sustainably.

In the pisciponic system, nutrients are required for plant growth to support efficient recycling. The system provides essential nutrients to the plants. The pisciponic system is an environment-friendly and sustainable food production. It has been introduced in the country to feed the ever-increasing human population and for food security. It has also received attention due to its potential in sustaining water quality, reducing water consumption, and supplying a marketable vegetable crop. For fish production, the water quality is maintained by biofilter and the plants will consume dissolved fish wastes and products of microbial activity (Maucieri et al., 2018).

The world is facing global population growth that exceeds 7.2 billion and is projected to increase to 9.7 billion by 2050 with over 85 per cent living in urban areas compared to 1990 with only 5 billion people. The world population continues to grow exponentially. As the number of people moving to urban areas increases, malnutrition, urban poverty, and hunger will also rise (United Nations Department of Economic and Social Affairs Population Division, 2017). The diminishing of the land area available for food production and unpredicted climate change poses significant challenges to farming and food production around the globe. Hence, food demand can be increased through a proper management practice (Siwar et al., 2013).

Food security and food production are gaining greater concern both globally and in Malaysia. However, urban agriculture offers a solution to attain greater urban food security. Moreover, it can help relink people with their food systems (Pollard et al., 2017). As the global population increases, the demand for food increases as the fastest growing global population. Likewise, the land for crop production also increases. Thus, the alternatives for urban areas are pisciponic and hydroponic systems as they are soilless systems that produce high crop plants. It is also crucial that more food is produced so that they can balance between increasing human population and food availability (Onada & Ogunola, 2016; Siwar et al., 2013).

Today, the world population utilizes an insufficient amount of micronutrients in vegetables, particularly robust crops such as leafy greens. Micronutrient malnutrition deficiencies are a major public health issue in the growing rural and urban areas. In addition, the vegetarian population also requires the consumption of micronutrients through plant-based food like green leafy vegetables due to limited consumption of animal-based food, which contains good sources of readily available iron, zinc, and preformed vitamin A. This involves more than two billion people globally. Meanwhile, the estimation of micronutrient malnutrition includes iron (Fe) insufficient in over 60% of the seven billion people, over 30% with zinc (Zn) insufficient, 30% with iodine insufficient, and over 15% with selenium (Se) insufficient (Migliozzi et al., 2015). Therefore, research on supplementary zinc and iron in plants is needed as part of the solution to overcome micronutrient deficiency in vegetables.

Fertilizers are chemical substances added to soil to increase crop yields and are crucial for plants to grow healthily. It has also become necessary in agriculture to use various techniques to increase food production and food demand such as increasing the productivity of fertilizers and minimizing costs. Maximized crop yields can be attained by enhancing nutrient efficiency and reducing environmental pollution; innovative research is also needed to develop efficient fertilizers for plants to consume enough nutrients. Efficient production systems are important as the elements of nutrition or fertilization can lead to the physiological process of plants (Ahl & Mahmoud, 2010).

Plants need macronutrients and micronutrients, which are vital for their growth. Macronutrients are the chemical or substances needed in large amounts than micronutrients such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S). However, micronutrients are chemical elements or any substance required in trace, minuscule amounts for the proper growth and development of living organisms such as boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) (Goddek et al., 2015a). Micronutrients are vital for living organisms and many cases have shown a serious deficiency disease due to inadequate supply of minor plant food elements. However, they can be toxic to the soil or water if the elements are supplied in high quantities (Bakhsh, 2005; Connor, 1941).

Zinc and iron are essential micronutrients in plants. Zinc (Zn) is needed by plants for growth hormone production and internode elongation. Zinc contains both beneficial and toxic effects on plant cells. Zinc also plays a key role in the cell membrane systems. The lack of zinc can reduce growth, tolerance to stress, and chlorophyll (Lohry, 2007; Schulze & Ludewig, 2015). Zinc (Zn), iron (Fe), and manganese (Mn) are the most frequently deficient micronutrients and are recommended to be added as supplements to the system for plant performance. Evidently, the level of nutrients in conventional hydroponics is higher than in the pisciponic system (Nozz et al., 2018). To establish the system and prevent huge costs due to the leaching of nutrients and large volumes of nutrient solutions, this study investigates the effectiveness of using stearin as a coat for zinc chelate and iron chelate in the system. The lack of zinc and iron in plants is one of the major limitations in food production. Even though zinc is broadly used as a fertilizer, the methods are desirable for a specific cropping system to be efficient and economical. The lack of zinc and iron can be complemented through the application of slow-release fertilizers to avoid leaching (Shete et al., 2015). Zinc deficiencies can cause stunting growth, reduced number of tillers, chlorosis, tiny leaves, increased crop maturity duration, and low-quality harvest products. Zinc also plays a part in the basic cellular functions in living organisms to improve the human immune system. Insufficient intake causes hair and memory loss and weakness in body muscles. Several authors have reported that the combination of fish and plants should be consistent with the nutrient uptake by plants (Rakocy et al., 2006).

The challenge of finding an optimal supplementation in the pisciponic system is apparent because there is no specific study about the rate of fertilizers to be applied in the system. According to the United Nations 2020, nutrient runoff from the soil or water has affected the land ecosystem. However, organic farming ways are not the only example of sustainable nutrient management. The leaching of nutrients can also be managed by the right amount of fertilizers and slow-release fertilizers in the pisciponic system to avoid leaching into the environment and water eutrophication. A good amount of fish without sufficient nutrients may lead to low nutrient absorption and the production of crop plants in the pisciponic system. Other than that, it has also been reported that the pisciponic system relies exclusively on fish waste to provide nutrients for plants with low levels of micronutrients (Ru et al., 2017).

However, there is a paucity of information and research on the supplementation of zinc chelate and iron chelate in granular form to be absorbed in water and effectively alleviate nutrient insufficient in crop plants (Roosta & Hamidpour, 2013). Therefore, the objective of this study is to investigate the effects of selected micronutrients mineral composition on crop plants in the pisciponic system in granular form.

Various technologies have been suggested to feature slow coated fertilizers of enhanced efficiency fertilizers (EEFs) throughout the couple decades. In spite of previous efforts, there is no proper method to approach the nutrient release patterns and fertilizer release patterns as well as material performance in this context. Thus, the study was conducted to determine the effect of micronutrient fertilizers in the pisciponic system using coated zinc chelate and iron chelated. According to Delaine (2019), experimental studies on the pisciponic system with insufficient nutrients can promote plant growth. However, not many studies are available on coated fertilizers in the pisciponic system. According to Roosta and Hamidpour (2011), the fish waste to provide nutrients are lacking in the pisciponic system and the composition of fish feed in the feed pellet is enough for the fish and for the fish to grow but not compulsory for plant growth. The requirement for the total iron, potassium, calcium, and zinc needed for plant production is not the same for fish. As a result, the lack of these micronutrients may occur and can be troublesome in the system.

Therefore, it is important to understand the effects of the slow release of zinc and iron supplementations on growth performance in the pisciponic system using lemon fin barb hybrids with *Brassica rapa* var. *chinensis* and *Metha piperita.* This also includes the ways to improve and increase production and decrease costs. Accordingly, the objectives of this study are addressed as follows:

1) To study the slow-release process using stearin as a coat for zinc and iron.
2) To study growth performance in the pisciponic system.

REFERENCES

Abd, I., Eissa, E., Abd, M., & Moneim, E. (2016). Impact of Aquaponic System on Water Quality and Health Status of Nile Tilapia Oreochromis niloticus, (December 2015).

Abdel-Tawwab, M., & Ahmad, M. H. (2009). Live Spirulina (Arthrospira platensis) as a growth and immunity promoter for Nile tilapia, Oreochromis niloticus (L.), challenged with pathogenic Aeromonas hydrophila. *Aquaculture Research*, *40* (9), 1037–1046. https://doi.org/10.1111/j.1365-2109.2009.02195.x

Ahl, H. a H. S., & Mahmoud, A. a. (2010). Effect of zinc and / or iron foliar application on growth and essential oil of sweet basil (Ocimum basilicum L .) under salt stress. *Ozean Journal of Applied Sciences*, *3*(1), 97–111.

Aliyu, S. M. (2017). Dietary carbohydrate Requirement of Lemon Fin Barb Hybrid (Barbonymus gonionotus Bleeker 1849 X Hypsibarbus wetmorei Smith 1931) Fingerlings, (August), 25.

Anizah, M. R., Saad, C. R., Kamarudin, M. S., Rahim, A. A., Keeler, B., Unit, P. C., & Rahman, M. M. (2016). Role of common carp (Cyprinus carpio) in aquaculture production systems. *Frontiers in Life Science*, *37*(4), 399–410. https://doi.org/10.1080/21553769.2015.1045629

Atsdr. (2005). Zinc Zinc. *Public Health Statement Zinc*, (CAS#: 7440-66-6), 1–7.

Azim, M. E., & Little, D. C. (2008). The biofloc technology (BFT) in indoor tanks: Water quality, biofloc composition, and growth and welfare of Nile tilapia (Oreochromis niloticus). *Aquaculture*, *283*(1–4), 29–35. https://doi.org/10.1016/j.aquaculture.2008.06.036

Bakhsh, H. K. (2005). Nutrient Optimization and Computerized Decision Support Program in Recirculting Integrated Aquaculture System. *Universiti Putra Malaysia*.

Bittsánszky, A., Uzinger, N., Gyulai, G., Mathis, A., Junge, R., Villarroel, M., … Kőmíves, T. (2016). Nutrient supply of plants in aquaponic systems. *Ecocycles*, *2*(2), 17–20. https://doi.org/10.19040/ecocycles.v2i2.57

Bley, H., Gianello, C., Santos, L. D. S., & Selau, L. P. R. (2017). Nutrient release, plant nutrition, and potassium leaching from polymer-coated fertilizer. *Revista Brasileira de Ciencia Do Solo*, *41*, 1–11. https://doi.org/10.1590/18069657rbcs20160142

Brassica, C. P., Lewis, J., & Fenwick, G. R. (1988). Glucosinolate Content of Brassica Vegetables -Chinese, 379–386.

Brennan, R. F. (2014). I Short Note I Effectiveness of zinc sulfate and zinc chelate as foliar sprays in alleviating zinc deficiency of wheat grown on, (October). https://doi.org/10.1071/EA9910831

Calone, R., Pennisi, G., Morgenstern, R., Sanyé-mengual, E., Lorleberg, W., Dapprich, P., & Winkler, P. (2019). Science of the Total Environment Improving water management in European cat fi sh recirculating aquaculture systems through cat fi sh-lettuce aquaponics, *687*, 759–767. https://doi.org/10.1016/j.scitotenv.2019.06.167

Chakraborty, S. B., Mazumdar, D., & Banerjee, S. (2010). Determination of ideal stocking density for cage culture of monosex Nile tilapia (Oreochromis niloticus) in India. *Proceedings of the Zoological Society*, *63*(1), 53–59. https://doi.org/10.1007/s12595-010-0007-3

Chenard, C. A., Anderson, M. M., Brooks, L. L., & Zimmerman, M. B. (2019). Measured cup weights of ten raw leafy vegetables are lower than weights previously reported. *Journal of Food Composition and Analysis*, 103279. https://doi.org/10.1016/j.jfca.2019.103279

Chyi, H. H. (2011). Nutrients and Heavy Metals in Vegetables Produced Organically and Conventionally.

Connor, R. T. O. (1941). Spectrochemical Analysis of Trace Elements in Fertilizers Zinc, (8).

Consulting, H. (2013). Aquaponics research project The relevance of aquaponics to the New Zealand aid programme, particularly in the Pacific, (December), 92.

Cretu, A. (2009). No Title.

Delaide, B., Delhaye, G., Dermience, M., Gott, J., & Soyeurt, H. (2017). Plant and fish production performance , nutrient mass balances , energy and water use of the PAFF Box , a small-scale aquaponic system . Aquacultural Engineering Plant and fi sh production performance , nutrient mass balances , energy and water use of the. *Aquacultural Engineering*, *78*(June), 130–139. https://doi.org/10.1016/j.aquaeng.2017.06.002

Dr. G. N. Rameshaiah1, JPallavi2, S. S., & 1Associate. (2015). Nano Fertilizers and Nano Sensors – an Attempt for, *3*(1), 314–320.

Drahansky, M., Paridah, M. ., Moradbak, A., Mohamed, A. ., Owolabi, F. abdulwahab taiwo, Asniza, M., & Abdul Khalid, S. H. . (2016). We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %. *Intech*, *i*(tourism), 13. https://doi.org/http://dx.doi.org/10.5772/57353

Dunwoody, R. K. (2013). Aquaponics and Hydroponics: the Effects of Nutrient Source and Hydroponic Subsystem Design on Sweet Basil Production, 128.

Edaroyati, M. W. P., & Aishah, H. S. (2017). Requirements for inserting intercropping in aquaponics system for sustainability in agricultural production system, *15*(5), 2048–2067.

Endut, A., Jusoh, A., Ali, N., Wan Nik, W. N. S., & Hassan, A. (2009). Effect of flow rate on water quality parameters and plant growth of water spinach (Ipomoea aquatica) in an aquaponic recirculating system. *Desalination and Water Treatment*, *5*(1–3), 19–28. https://doi.org/10.5004/dwt.2009.559

Estim, A., Saufie, S., & Mustafa, S. (2019). Journal of Water Process Engineering Water quality remediation using aquaponics sub-systems as biological and mechanical filters in aquaculture. *Journal of Water Process Engineering*, *30*(January 2018), 100566. https://doi.org/10.1016/j.jwpe.2018.02.001

European Commission. (2013). Regulation (EC) No 2003/2003 of the European Parliament and of the Council of 13 October 2003 relating to fertilisers, (5), 1–156. Retrieved from http://eur-lex.europa.eu/legal-content/En/TXT/PDF/?uri=CELEX:02003R2003-20130607&rid=2

Fernanda Zanoni Cônsolo, F. Z., Melnikov, P., Zanoni, L. Z., Rimoli, J., Silva, A. F., & Nascimento, V. A. do. (2017). Magnesium, Iron, Copper and Zinc in Vegetable Roots from Mato Grosso do Sul, Brazil. *Orbital - The Electronic Journal of Chemistry*, *9*(3). https://doi.org/10.17807/orbital.v9i3.929

Food and Agriculture Organization of the United Nations (FAO). (2014). 6 . Plants in aquaponics. *Aquaponics*, 83–102.

Francisco, A. R. L. (2013). *Hydroponics: A Practical Guide for the Soiless Grower*. *Journal of Chemical Information and Modeling* (Vol. 53). https://doi.org/10.1017/CBO9781107415324.004

Geotechnical Engineering Bureau. (2015). Test Method for the Determination of pH Value of Water or Soil by pH Meter. *Geotechnical Test Method*, (August), 7.

Goddek, S. (2017). *Opportunities and Challenges of Multi-Loop Aquaponic Systems*. https://doi.org/10.18174/412236

Goddek, S., Delaide, B., Mankasingh, U., Ragnarsdottir, K. V., Jijakli, H., & Thorarinsdottir, R. (2015a). Challenges of sustainable and commercial aquaponics. *Sustainability (Switzerland)*, *7*(4), 4199–4224. https://doi.org/10.3390/su7044199

Goddek, S., Delaide, B., Mankasingh, U., Ragnarsdottir, K. V., Jijakli, H., & Thorarinsdottir, R. (2015b). Challenges of sustainable and commercial aquaponics. *Sustainability (Switzerland)*, *7*(4), 4199–4224. https://doi.org/10.3390/su7044199

Grusak, M. A., Abadía, A., & Abadía, J. (2013). Iron deficiency in plants : an insight from proteomic approaches, *4*(July), 1–7. https://doi.org/10.3389/fpls.2013.00254

Hashim, M. M. az, Yusop, M. K., Othman, R., & Wahid, S. (2017). Field evaluation of newly-developed controlled release fertilizer on rice production and nitrogen uptake. *Sains Malaysiana*. https://doi.org/10.17576/jsm-2017-4606-12

Hembrom, R., & Singh, A. K. (2015a). Effect of iron and zinc on growth, flowering and bulb yield in lilium. *International Journal of Agriculture, Environment and Biotechnology*, *8*(1), 61. https://doi.org/10.5958/2230-732x.2015.00007.8

Hembrom, R., & Singh, A. K. (2015b). Effect of iron and zinc on growth , flowering and bulb yield in lilium, *8*(March), 61–64.

Herrera, L. C., Farm, F., & Juventud, L. (2014). The effect of stocking density on growth rate, survival and yieldof gift tilapia (Oreochromis niloticus) In Cuba : case study fish farm la juventud, 1–29.

Hosseini, S. M., Maftoun, M., Karimian, N., Ronaghi, A., & Emam, Y. (2007). Effect of zinc x boron interaction on plant growth and tissue nutrient concentration of corn. *Journal of Plant Nutrition*, *30*(5), 773–781. https://doi.org/10.1080/01904160701289974

Inbrief world fisheries and aquaculture. (2018). Retrieved from http://www.fao.org/3/CA0191EN/CA0191EN.pdf

Ibrahim, K. R. M., Babadi, F. E., & Yunus, R. (2014). Comparative performance of different urea coating materials for slow release. *Particuology*, *17*, 165–172. https://doi.org/10.1016/j.partic.2014.03.009

İncesu, M., Yeşiloğlu, T., Çimen, B., & Yilmaz, B. (2015). Influences of different iron levels on plant growth and photosynthesis of W. Murcott mandarin grafted on two rootstocks under high pH conditions. *Turkish Journal of Agriculture and Forestry*, *39*, 838–844. https://doi.org/10.3906/tar-1501-25

Irfan, M., Bilal, M., Niazi, K., Hussain, A., & Zia, M. H. (2018). Synthesis and characterization of zinc-coated urea fertilizer. *Journal of Plant Nutrition*, *0*(0), 1–11. https://doi.org/10.1080/01904167.2018.1454957

Iuhui, Q. H. U. (2008). Effect of Foliar Application of Zinc , Selenium , and Iron Fertilizers on Nutrients Concentration and Yield of Rice Grain in China, 2079–2084.

Jain, R., Srivastava, S., Solomon, S., Shrivastava, A. K., & Chandra, A. (2010). Impact of excess zinc on growth parameters, cell division, nutrient accumulation, photosynthetic pigments and oxidative stress of sugarcane (saccharum spp.). *Acta Physiologiae Plantarum*, *32*(5), 979–986. https://doi.org/10.1007/s11738-010-0487-9

Kaewchangwat, N., Dueansawang, S., Tumcharern, G., Suttisintong, K., Kaewchangwat, N., Dueansawang, S., & Tumcharern, G. (2017). Synthesis of Copper-Chelates Derived from Amino Acids and Evaluation of Their Efficacy as Copper Source and Growth Stimulator for Lactuca Sativa in Nutrient Solution Culture Synthesis of Copper-Chelates Derived from Amino Acids and Evaluation of Their Eff. https://doi.org/10.1021/acs.jafc.7b03809

Kasozi, N., Tandlich, R., Fick, M., Kaiser, H., & Wilhelmi, B. (2019). Iron supplementation and management in aquaponic systems : A review. *Aquaculture Reports*, *15*(February), 100221. https://doi.org/10.1016/j.aqrep.2019.100221

Khan, M. A., Kim, K. W., Mingzhi, W., Lim, B. K., Lee, W. H., & Lee, J. Y. (2008). Nutrient-impregnated charcoal: An environmentally friendly slow-release fertilizer. *Environmentalist*, *28*(3), 231–235. https://doi.org/10.1007/s10669-007-9133-5

Komives, T., & Junge, R. (2018). Importance of nickel as a micronutrient in aquaponic systems–some theoretical considerations. *Ecocycles*, *4*(2), 7–9. https://doi.org/10.19040/ecocycles.v4i2.99

Kormas, A. K., Aggelaki, A., Kapsis, P., Vlahos, N., & Mente, E. (2018). Aquaponics : a mutually beneficial relationship of fish , plants and bacteria BENEFICIAL RELATIONSHIP Aquaponics :, (December).

Lange, B. M., & Croteau, R. (1999). Genetic engineering of essential oil production in mint. *Current Opinion in Plant Biology*, *2*(2), 139–144. https://doi.org/10.1016/S1369-5266(99)80028-4

Lilly, T. T., Immaculate, J. K., & Jamila, P. (2017). Macro and micronutrients of selected marine fishes in Tuticorin, South East coast of India. *International Food Research Journal*, *24*(1), 191–201.

Liu, H., Gan, W., Rengel, Z., & Zhao, P. (2016). Effects of zinc fertilizer rate and application method on photosynthetic characteristics and grain yield of summer maize. *Journal of Soil Science and Plant Nutrition*, *16*(2), 550–562. https://doi.org/10.4067/S0718-95162016005000045

Liu, Haokun, Li, H., Wei, H., Zhu, X., Han, D., Jin, J., & Yang, Y. (2019). Bio fl oc formation improves water quality and fi sh yield in a freshwater pond aquaculture system. *Aquaculture*, *506*(March), 256–269. https://doi.org/10.1016/j.aquaculture.2019.03.031

Lohry, R. (2007). Micronutrients: functions, sources and application methods. *Indiana CCA Conference Proceedings*, (Cl), 1–15.

López-rayo, S., Lucena, S., & Lucena, J. J. (2014). Chemical properties and reactivity of manganese chelates and complexes in solution and soils, 189–198. https://doi.org/10.1002/jpln.201300091

Love, D. C., Genello, L., Li, X., Thompson, R. E., & Fry, J. P. (2015). Production and consumption of homegrown produce and fish by noncommercial aquaponics gardeners. *Journal of Agriculture Food Systems and Community Development*, *6*(1), 161–173. https://doi.org/10.5304/jafscd.2015.061.013

Mahfuzah, N., Affendi, N., Mansor, N., & Mathialagan, R. (2019). Development and characterization of allicin using palm stearin as a binder on urea granules. *Journal of Plant Nutrition*, *0*(0), 1–8. https://doi.org/10.1080/01904167.2019.1701021

Mainasara, M. M., Abu Bakar, M. F., Waziri, A. H., & Musa, A. R. (2018). Comparison of Phytochemical, Proximate and Mineral Composition of Fresh and Dried Peppermint (Mentha piperita) Leaves. *Journal of Science and Technology*, *10*(2), 85–91. https://doi.org/10.30880/jst.2018.10.02.014

Mamat, N. Z., Shaari, M. I., & Abdul Wahab, N. A. A. (2016). The Production of Catfish and Vegetables in an Aquaponic System. *Fisheries and Aquaculture Journal*, *07*(04), 5–7. https://doi.org/10.4172/2150-3508.1000181

Marathe, R. A., Murkute, A. A., & Dhinesh Babu, K. (2016). Mineral Nutrient Deficiencies and Nutrient Interactions in Pomegranate. *National Academy Science Letters*, *39*(6), 407–410. https://doi.org/10.1007/s40009-016-0487-4

Maucieri, C., Nicoletto, C., Junge, R., Schmautz, Z., Sambo, P., & Borin, M. (2018). Hydroponic systems and water management in aquaponics: A review. *Italian Journal of Agronomy*, (March). https://doi.org/10.4081/ija.2017.1012

Maucieri, C., Nicoletto, C., Zanin, G., Birolo, M., Trocino, A., Sambo, P., … Xiccato, G. (2019). Effect of stocking density of fish on water quality and growth performance of European Carp and leafy vegetables in a low-tech aquaponic system. *PLoS ONE*, *14*(5), 1–15. https://doi.org/10.1371/journal.pone.0217561

Migliozzi, M., Thavarajah, D., Thavarajah, P., & Smith, P. (2015). Lentil and kale: Complementary nutrient-rich whole food sources to combat micronutrient and calorie malnutrition. *Nutrients*, *7*(11), 9285–9298. https://doi.org/10.3390/nu7115471

Milani, N., McLaughlin, M. J., Stacey, S. P., Kirby, J. K., Hettiarachchi, G. M., Beak, D. G., & Cornelis, G. (2012). Dissolution kinetics of macronutrient fertilizers coated with manufactured zinc oxide nanoparticles. *Journal of Agricultural and Food Chemistry*, *60*(16), 3991–3998. https://doi.org/10.1021/jf205191y

Mousavi, S., Galavi, M., & Rezaei, M. (2012). The interaction of zinc with other elements in plants: a review. *International Journal of Agriculture and Crop Sciences*, *4*(24), 1881–1884. Retrieved from https://www.researchgate.net/profile/Sayed_Roholla_Mousavi/publication/234062115_The_interaction_of_zinc_with_other_elements_in_plants_A_review/links/02bfe50ec02c0a9a14000000/The-interaction-of-zinc-with-other-elements-in-plants-A-review.pdf

Nasiri, Y., Zehtab-Salmasi, S., Nasrullahzadeh, S., Najafi, N., & Ghassemi-Golezani, K. (2010). Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). *Journal of Medicinal Plants Research*, *4*(17), 1733–1737. https://doi.org/10.5897/JMPR10.083

Nemethy, S., Bittsánszky, A., Schmautz, Z., & Junge, R. (2016). Protecting plants from pests and diseases in aquaponic systems Zero Emission Building View project Mass Balance and Nutrient Recycling in Aquaponics View project, (January 2017). Retrieved from https://www.researchgate.net/publication/312553198

Nikiema, J., Cofie, O., Impraim, R., & Adamtey, N. (2013). Processing of Fecal Sludge to Fertilizer Pellets Using a Low-Cost Technology in Ghana. *Environment and Pollution*, *2*(4). https://doi.org/10.5539/ep.v2n4p70

Nozzi, V., Graber, A., Schmautz, Z., Mathis, A., & Junge, R. (2018). Nutrient Management in Aquaponics: Comparison of Three Approaches for Cultivating Lettuce, Mint and Mushroom Herb. *Agronomy*, *8*(3), 27. https://doi.org/10.3390/agronomy8030027

Oké, V., & Goosen, N. J. (2019). The effect of stocking density on profitability of African catfish (Clarias gariepinus)culture in extensive pond systems. *Aquaculture*, *507*(November 2018), 385–392. https://doi.org/10.1016/j.aquaculture.2019.04.043

Oladimeji, A. S., Olufeagba, S. O., Ayuba, V. O., Sololmon, S. G., & Okomoda, V. T. (2018). Effects of different growth media on water quality and plant yield in a catfish-pumpkin aquaponics system. *Journal of King Saud University - Science*, (February). https://doi.org/10.1016/j.jksus.2018.02.001

Oladimeji, A. S., Olufeagba, S. O., Ayuba, V. O., Sololmon, S. G., & Okomoda, V. T. (2020). Effects of different growth media on water quality and plant yield in a catfish-pumpkin aquaponics system. *Journal of King Saud University - Science*, *32*(1), 60–66. https://doi.org/10.1016/j.jksus.2018.02.001

Onada, O. A., & Ogunola, O. S. (2016). Improving Food Security in an Eco-Friendly Manner through Integrated Aquaculture. *OALib*, *03*(03), 1–6. https://doi.org/10.4236/oalib.1102476

Pant, A. P., Radovich, T. J. K., Hue, N. V., Talcott, S. T., & Krenek, K. A. (2009). Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activity in pak choi (Brassica rapa cv. Bonsai, Chinensis group) grown under vermicompost and chemical fertiliser. *Journal of the Science of Food and Agriculture*, *89*(14), 2383–2392. https://doi.org/10.1002/jsfa.3732

Pineda, J. (2018). Yield of two cultivars of lettuce (Lactuca sativa L .) in hydroponic and aquaponic systems, (December). https://doi.org/10.17660/ActaHortic.2018.1227.43

Piskin, A. (2017). Effect of Zinc Applied Together with Compound Fertilizer on Yield and Quality of Sugar Beet (Beta vulgaris L .), *4167*(September). https://doi.org/10.1080/01904167.2017.1380815

Pollard, G., Ward, J. D., & Koth, B. (2017). Aquaponics in Urban Agriculture: Social Acceptance and Urban Food Planning. *Horticulturae*, *3*(2), 39. https://doi.org/10.3390/horticulturae3020039

Quagrainie, K. K., Flores, R. M. V., Kim, H. J., & McClain, V. (2018). Economic analysis of aquaponics and hydroponics production in the U.S. Midwest. *Journal of Applied Aquaculture*, *30*(1), 1–14. https://doi.org/10.1080/10454438.2017.1414009

Rakocy, J. E., Bailey, D. S., Shultz, R. C., & Thoman, E. S. (2004). Update on tilapia and vegetable production in the UVI aquaponic system. New dimensions on farmed tilapia. *Proceedings from the 6th International Symposium on Tilapia in Aquaculture*, *000*, 1–15.

Rakshit, R., Patra, A. K., Purakayastha, T. J., Singh, R. D., Pathak, H., & Dhar, S. (2016). Super-Optimal NPK Along with Foliar Iron Application Influences Bioavailability of Iron and Zinc of Wheat. *Proceedings of the National Academy of Sciences India Section B - Biological Sciences*, *86*(1), 159–164. https://doi.org/10.1007/s40011-014-0428-2

Rawashdeh, H., & Sala, F. (2014). Influence of iron foliar fertilization on some growth and physiological parameters of wheat at two growth stages. *Scientific Papers - Series A, Agronomy*, *57*(PG-306-309), 306–309. Retrieved from email: hamz_rawashdeh@yahoo.com NS -

Romano, N., Aliff, A., & Syukri, F. (2018). Improved performance of lemon fin barb hybrid (Hypsibarbus wetmorei Barbodes gonionotus) at elevated salinities. *Journal of Environmental Biology*, *39*(5), 719–724. https://doi.org/10.22438/jeb/39/5(SI)/7

Rono, K., Manyala, J. O., Lusega, D., Sabwa, J. A., Yongo, E., Ngugi, C., … Egna, H. (2018). Growth Performance of Spinach (Spinacia Oleracea) on Diets Supplemented With Iron-Amino Acid Complex in an Aquaponic. *International Journal of Research Science and Management*, *5*(7), 117–127. https://doi.org/10.5281/zenodo.1320099

Rono, Kenneth, Manyala, J. O., Lusega, D., Sabwa, J. A., Yongo, E., Fitzsimmons, K., & Egna, H. (2018). GROWTH PERFORMANCE OF SPINACH (SPINACIA OLERACEA) ON DIETS SUPPLEMENTED WITH IRON-AMINO ACID COMPLEX IN AN AQUAPONIC, *5*(7), 117–127.

Roosta, H. R. (2014). Effects of Foliar Spray of K on Mint, Radish, Parsley and Coriander Plants in Aquaponic System. *Journal of Plant Nutrition*, *37*(14), 2236–2254. https://doi.org/10.1080/01904167.2014.920385

Roosta, H. R., & Hamidpour, M. (2011). Effects of foliar application of some macro- and micro-nutrients on tomato plants in aquaponic and hydroponic systems. *Scientia Horticulturae*, *129*(3), 396–402. https://doi.org/10.1016/j.scienta.2011.04.006

Roosta, H. R., & Hamidpour, M. (2013). Mineral Nutrient Content of Tomato Plants in Aquaponic and Hydroponic Systems: Effect of Foliar Application of Some Macro- and Micro-Nutrients. *Journal of Plant Nutrition*, *36*(13), 2070–2083. https://doi.org/10.1080/01904167.2013.821707

Ru, D., Liu, J., Hu, Z., Zou, Y., Jiang, L., Cheng, X., & Lv, Z. (2017). Improvement of aquaponic performance through micro- and macro-nutrient addition. *Environmental Science and Pollution Research*, *24*(19), 16328–16335. https://doi.org/10.1007/s11356-017-9273-1

Sakarvadia, H. (2019). Effect of zinc and iron application on leaf chlorophyll , carotenoid , grain yield and quality of wheat in calcareous soil of Saurashtra region Effect of zinc and iron application on leaf chlorophyll , carotenoid , grain yield and quality of wheat in calc, (July).

Samreen, T., Humaira, Shah, H. U., Ullah, S., & Javid, M. (2017). Zinc effect on growth rate, chlorophyll, protein and mineral contents of hydroponically grown mungbeans plant (Vigna radiata). *Arabian Journal of Chemistry*, *10*, S1802–S1807. https://doi.org/10.1016/j.arabjc.2013.07.005

Sardare, M. D., Sardare, M. M. D., & Admane, M. S. V. (2016). A REVIEW ON PLANT WITHOUT SOIL - HYDROPONICS A REVIEW ON PLANT WITHOUT SOIL - HYDROPONICS, (March 2013). https://doi.org/10.15623/ijret.2013.0203013

Sawney, P. (2003). [No Title]. *Occupational Medicine*, *53*(4), 246–248.

Schulze, W. X., & Ludewig, U. (2015). Protein Dynamics in Young Maize Root Hairs in Response to Macro- and Micronutrient Deprivation. https://doi.org/10.1021/acs.jproteome.5b00399

Sciences, B., Junejo, N., Hanafi, M. M., & Khanif, Y. M. (2009). Effect of Cu and Palm Stearin Coatings on the Thermal Behavior and Ammonia Volatilization Loss of Urea, *5*(5), 608–612.

Sempeho, S. I., Kim, H. T., Mubofu, E., & Hilonga, A. (2014). Meticulous Overview on the Controlled Release Fertilizers. *Advances in Chemistry*, *2014*, 1–16. https://doi.org/10.1155/2014/363071

Shen, X. L., Zhang, Y. M., Xue, J. Y., Li, M. M., Lin, Y. B., Sun, X. Q., & Hang, Y. Y. (2016). Analysis of genetic diversity of Brassica rapa var. Chinensis using ISSR markers and development of SCAR marker specific for Fragrant Bok Choy, a product of geographic indication. *Genetics and Molecular Research*, *15*(2), 1–11. https://doi.org/10.4238/gmr.15027557

Shiung, S., Ling, N., Jusoh, A., Azmi, M., Lam, S. S., Ma, N. L., … Ambak, M. A. (2015). Biological nutrient removal by recirculating aquaponic system: Optimization of the dimension ratio between the hydroponic & rearing tank components. *International Biodeterioration and Biodegradation*, *102*, 107–115. https://doi.org/10.1016/j.ibiod.2015.03.012

Shoko, A. P., Limbu, S. M., Mrosso, H. D. J., Mkenda, A. F., & Mgaya, Y. D. (2016). Effect of stocking density on growth, production and economic benefits of mixed sex Nile tilapia (Oreochromis niloticus) and African sharptooth catfish (Clarias gariepinus) in polyculture and monoculture. *Aquaculture Research*, *47*(1), 36–50. https://doi.org/10.1111/are.12463

Siwar, C., Ahmed, F., & Begum, R. A. (2013). Climate change, agriculture and food security issues: Malaysian perspective. *Journal of Food Agriculture & Environment*, *11*(2), 1118–1123.

Somerville, C., Cohen, M., Pantanella, E., Stankus, A., & Lovatelli, A. (2014). *Small-scale aquaponic food production. Integrated fish and plant farming*. *FAO Fisheries and Aquaculture*. https://doi.org/10.1002/pssb.201300062

Sultana, S., Naser, H., Quddus, M., Shill, N., & Hossain, M. (2018). Effect of foliar application of iron and zinc on nutrient uptake and grain yield of wheat under different irrigation regimes. *Bangladesh Journal of Agricultural Research*, *43*(3), 395–406. https://doi.org/10.3329/bjar.v43i3.38388

Thapa, A., Rahman, S., & Lee, C. W. (2016). Remediation of nutrients runoff from feedlot by hydroponic treatment. *Agricultural Engineering International: CIGR Journal*, *18*(1), 1–18.

Treadwell, D., Taber, S., Tyson, R., & Simonne, E. (2010). Foliar-Applied Micronutrients in Aquaponics : A Guide to Use and Sourcing 1. *University of Florida*, *HS1163*.

Tsonev, T., & Lidon, F. J. C. (2012). Zinc in plants - An overview. *Emirates Journal of Food and Agriculture*, *24*(4), 322–333.

United Nations Department of Economic and Social Affairs Population Division. (2017). World Population Prospects The 2017 Revision Key Findings and Advance Tables. *World Population Prospects The 2017*, 1–46. https://doi.org/10.1017/CBO9781107415324.004

White, K., O'Niell, B., & Tzankova, Z. (2004). At a Crossroads : Will Aquaculture Fulfill the Promise of the Blue Revolution ? *A SeaWeb Aquaculture Clearinghouse Report*, 17. Retrieved from www.AquacultureClearinghouse.org

Witus, I.W. and Vun, L. W. (2016). Aquaculture in Malaysia: A short review on current policy and legislation. *Transactions on Science and Technology*, *3*(1–2), 150–154.

Wongkiew, S., Popp, B. N., Kim, H. J., & Khanal, S. K. (2017). Fate of nitrogen in floating-raft aquaponic systems using natural abundance nitrogen isotopic compositions. *International Biodeterioration and Biodegradation*, *125*, 24–32. https://doi.org/10.1016/j.ibiod.2017.08.006

Wortman, S. E. (2015). Crop physiological response to nutrient solution electrical conductivity and pH in an ebb-and-flow hydroponic system. *Scientia Horticulturae*, *194*, 34–42. https://doi.org/10.1016/j.scienta.2015.07.045

Wortman, S. E., & Dawson, J. O. (2015). Communications in Soil Science and Plant Analysis Nitrogenase Activity and Nodule Biomass of Cowpea (Vigna unguiculata L . Walp .) Decrease in Cover Crop Mixtures Nitrogenase Activity and Nodule Biomass of Cowpea (Vigna unguiculata L . Walp .) Decrease . *Communications in Soil Science and Plant Analysis*, *46*(11), 1443–1457. https://doi.org/10.1080/00103624.2015.1043457

Wurts, W. A., & Durborow, R. M. (1992). Interactions of pH , Carbon Dioxide , Alkalinity and Hardness in Fish Ponds, *0*(464), 1–4.

Yang, T., & Kim, H. (2019). Scientia Horticulturae Nutrient management regime a ff ects water quality , crop growth , and nitrogen use e ffi ciency of aquaponic systems. *Scientia Horticulturae*, *256*(March), 108619. https://doi.org/10.1016/j.scienta.2019.108619

Yildiz, H. Y., Robaina, L., Pirhonen, J., Mente, E., Domínguez, D., & Parisi, G. (2017). Fish welfare in aquaponic systems: Its relation to water quality with an emphasis on feed and faeces-A review. *Water (Switzerland)*, *9*(1), 1–17. https://doi.org/10.3390/w9010013

Yogev, U., Barnes, A., & Gross, A. (2016). Nutrients and energy balance analysis for a conceptual model of a three loops off grid, aquaponics. *Water (Switzerland)*, *8*(12). https://doi.org/10.3390/w8120589

Zahan, S., Shakil Rana, K. M., Khairul Islam, M., & Islam, T. (2018). Impact of calcium supplement through egg shell on tomato (Solanum lycopersicum) production in aquaponic system Abundance, distribution and standing crop of Green mussel, Oyster and Clam along the coast of Bay of Bengal View project Culture of Spirulina pl, (March). Retrieved from https://www.researchgate.net/publication/323701133

Zambrosi, F. C. B., & Quaggio, J. A. (2017). Micronutrient supply through granular-coated single superphosphate under field conditions. *Journal of Crop Improvement*, *00*(00), 1–12. https://doi.org/10.1080/15427528.2017.1303799

Zhao, A. Q., Bao, Q. L., Tian, X. H., Lu, X. C., & William, J. G. (2011). Combined effect of iron and zinc on micronutrient levels in wheat (Triticum aestivum L.). *Journal of Environmental Biology*, *32*(2), 235–239.