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THE DEVELOPMENT OF NEW SLOW-RELEASE  
BORON FERTILIZERS

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Margaret Abat

*B. Sc. (Hons.) Industrial Chemistry (UPM, Malaysia)*

*M. Agric. Sci. (Uni. Adelaide, Australia)*

A thesis submitted to the University of Adelaide  
in fulfilment of the requirement for the degree of  
Doctor of Philosophy

Soil Science

School of Agriculture, Food and Wine

Waite Research Institute, Waite Campus

University of Adelaide

December 2014



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## Abstract

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Boron (B) deficiency and/or toxicity have caused significant impacts on agricultural crop production worldwide. The most commonly used sources of fertilizer B are water soluble, and are therefore susceptible to leaching in high rainfall environments. This may result in insufficient supply of B for plant growth later in the crop growth cycle (e.g. flowering), when B supply is most needed. Moreover, these highly soluble sources pose an increased risk of B toxicity to seedlings just after planting. One possible way to reduce nutrient losses and avoid seedling toxicity is by using slow-release fertilizer. Slow-release fertilizers provide an effective means to overcome the low use-efficiency and problems associated with highly soluble fertilizers in soils prone to nutrient leaching.

This study has identified boron phosphate ( $\text{BPO}_4$ ) compounds as potential raw materials for incorporation into macronutrient fertilizers to produce compound fertilizers containing slow-release B. The  $\text{BPO}_4$  compounds were found to differ significantly from most commercially available B sources in terms of their physical and chemical characteristics. Boron phosphate compounds synthesized at 500 and 800 °C had low water solubility, with solubility decreasing with decreasing pH, slow kinetics of B release and B concentrations released initially from this B source by water were below the toxicity level for most crops. Products synthesized at these two temperatures were free flowing and were readily incorporated into granular mono-ammonium phosphate (MAP) granules. The solubility of other slow-release B sources, namely ulexite and colemanite, were enhanced when co-granulated with MAP due to the low pH and high P concentrations in this macronutrient fertilizer – they therefore lost their slow release characteristics when co-granulated with MAP. This limitation did not apply to  $\text{BPO}_4$  compounds where low pH and high P concentrations did not affect, or even slowed, B release.

A rapid method to screen fertilizers for possible adverse effects of high B concentrations on germinating seedlings was developed, by assessing canola (*Brassica napus* L.) germination in Petri dishes using image analysis. The MAP fertilizers co-granulated with ulexite, borax and colemanite had an adverse effect on emerging canola seedlings even at a low total B concentration in the product (0.5% B). On the other hand, no toxicity symptoms were observed with the application of MAP co-granulated with  $BPO_4$  even at higher B concentrations in the fertilizer (2.0% B). Concentrations of hot-water soluble B measured around the granule application site were in agreement with the toxicity results, with concentrations in the toxic range close to the granule for the most soluble B sources.

In plant uptake experiments examining the recovery of B by plants from the various slow-release formulations by two crops of canola, the application of co-granulated soluble B sources led to toxicity in the first crop and deficiency in the second crop. The canola shoot dry weight was increased in treatments using co-granulated  $BPO_4$  products compared with the unfertilized control for both crops. This result suggested that a single application of a macronutrient fertilizer containing co-granulated  $BPO_4$  would be an effective slow-release B fertilizer for several cropping cycles.

In summary, co-granulated  $BPO_4$  products have potential as sources of slow-release B for incorporation into macronutrient fertilizers designed for high rainfall environments. This research work could have important implications for future B fertilizer development.

## Declaration

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I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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(Margaret Abat)

Date: 1<sup>st</sup> December 2014



## Acknowledgements

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Wonderful are the ways of God and thanks to Him for what He has done, been doing and going to do.

I am really grateful to all my supervisors: Mike McLaughlin, Fien Degryse and Roslyn Baird. Thank you for your guidance, comments, suggestions and encouragement given to me throughout my study. Thank you for never giving up on me. Your kindness, support and care, forever I will treasure and appreciate. I also would like to thank Sam Stacey, Sola Ajiboye and Rodrigo Coqui da Silva for being part of this journey and I really appreciate that.

Thank you to the University of Adelaide, Australia for awarding the scholarship to pursue my study. I am very grateful to Datu Lai Kui Fong (Director of Agriculture Department, Sarawak, Malaysia), Ms Megir Gumbek [Senior Assistant Director of Agriculture (Research)] for allowing me to take a study leave.

This research project would not have been possible without the technical support of many colleagues at the University of Adelaide and CSIRO (Land and Water). Thank you to Bogumila Tomczak, Colin Rivers, Ashleigh Broadbent, Deepika Setia, Gill Cozen, Cathy Fiebieger, Claire Wright and Caroline Johnson for the technical assistance, understanding and friendship.

To many of those from Holy Trinity and St Peter's Cathedral congregations, thank you for the prayers, love and care. Thank you for being part of my family.

To all my friends, thank you very much for your wishes, support and help.

To my parents, siblings and in-laws, thank you for just being there for me.

Last but not least, to my husband, Maclin and my girls, Callysta and Charmaine, my love for you all keep me going. Thank you for loving me and always be there for me.

## Conference Proceedings

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1. Margaret Abat, Michael J McLaughlin, Fien Degryse, Roslyn Baird. (2012)  
A slow-release safe source fertiliser boron to mitigate boron deficiency in high rainfall environments. In Proceedings of the 2012 Postgraduate Symposium at School of Agriculture, Food and Wine, University of Adelaide, 19 – 20 September 2012, p 34.
2. Margaret Abat, Michael J McLaughlin, Fien Degryse, Roslyn Baird. (2012)  
A slow-release safe source of fertiliser boron to mitigate boron deficiency in high rainfall environments. In Proceedings of the 5<sup>th</sup> Joint Australian and New Zealand Soil Science Conference, Hobart, Tasmania, 2 – 7 December 2012, p 533.
3. Margaret Abat, Michael J McLaughlin, Fien Degryse, Roslyn Baird. (2013)  
Boron phosphate (BPO<sub>4</sub>) as safe-seedling and slow-release boron fertilizer. In Proceedings XVII International Plant Nutrition Colloquium (IPNC) and Boron Satellite Meeting 2013, Istanbul, Turkey, 17 – 22 August 2013. p 943

## List of Abbreviations

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Å	Angstrom
Al	Aluminium
ANOVA	Analysis of variance
AR	Analytical reagent
As	Arsenic
B	Boron
B(OH) <sub>3</sub>	Boric acid
B(OH) <sub>4</sub> <sup>-</sup>	Borate ion
BPO <sub>4</sub>	Boron phosphate
°C	Degree Celcius/centigrade
Ca	Calcium
Ca <sub>2</sub> B <sub>6</sub> O <sub>11</sub> .5H <sub>2</sub> O	Calcium borate/colemanite
CaCl <sub>2</sub>	Calcium chloride
CaCO <sub>3</sub>	Calcium carbonate
CaMgB <sub>6</sub> O <sub>11</sub> .6H <sub>2</sub> O	Hydroboracite
CEC	Cation exchange capacity
cm	Centimetre
CSIRO	Commonwealth Scientific and Industrial Research Organization
Cu	Copper
d	Day
DAP	Diammonium phosphate
DCPD	Dicalcium phosphate dihydrate
DI	Deionized water
erfc	Complementary error function
FC	Field capacity
Fe	Iron
g	Gram
h	Hour
H <sup>+</sup>	Hydrogen ion
ha	Hectare
H <sub>3</sub> BO <sub>3</sub>	Boric acid
HCl	Hydrochloric acid
HgCl <sub>2</sub>	Mercuric chloride
HNO <sub>3</sub>	Nitric acid
H <sub>3</sub> PO <sub>4</sub>	Phosphoric acid
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid
ICP-OES	Inductively coupled plasma – optical emission spectroscopy
K	Potassium
K <sub>d</sub>	Soil-solution distribution coefficient
K <sub>sp</sub>	Solubility product constant
kg	Kilogram
L	Litre
LSD	Least significant difference
M	Molar
MAP	Mono-ammonium phosphate
Mg	Magnesium
mg	Milligram

min	Minute
mg/kg	Milligram per kilogram
mg/L	Milligram per litre
mM	Millimolar
mL	Millilitre
Mn	Manganese
Mo	Molybdenum
μL	Microlitre
μM	Micromolar
N	Nitrogen
Na	Sodium
NaCaB <sub>5</sub> O <sub>9</sub> .8H <sub>2</sub> O	Sodium-calcium borate/ulexite
NaOCl	Sodium hypochlorite
NaOH	Sodium hydroxide
Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> .5H <sub>2</sub> O	Sodium tetraborate pentahydrate
Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> .10H <sub>2</sub> O	Sodium tetraborate decahydrate
NH <sub>4</sub> H <sub>2</sub> PO <sub>4</sub>	Mono-ammonium phosphate
NH <sub>3</sub>	Ammonia
OH <sup>-</sup>	Hydroxyl ion
P	Phosphorus
<i>P</i>	Probability
pH	The negative log of hydrogen ion activity, (-log[H <sup>+</sup> ])
pK <sub>a</sub>	The negative log of acid dissociation constant
PV	Pore volume
RCF	Relative centrifugal force
RCBD	Randomized complete block design
s	Second
S	Sulfur
SD	Standard deviation
Si	Silicon
SSP	Single superphosphate
TSP	Triple superphosphate
XRD	X-ray diffraction
Zn	Zinc