UNIVERSITI PUTRA MALAYSIA

EFFECTS OF ALUMINIUM TOXICITY ON ROOT MORPHOLOGY AND PHYSIOLOGY OF TWO MAIZE HYBRIDS

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By

TEGUH PRASETYO

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

To my Parents, for the constant prayer, support and the educational opportunities that they gave me, and to my brothers and sister

"[Al-A'râf 7 : 58] The vegetation of a good land comes forth (easily) by the Permission of its Lord; and that which is bad, brings forth nothing but (a little) with difficulty. Thus do We explain variously the Ayât (proofs, evidences, verses, lessons, signs, revelations, etc.) for a people who give thanks".

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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June 2007

Chairman : Associate Professor Zakaria Wahab, PhD

Faculty : Agriculture

Acid soils in Malaysia account for 72% of the country that was classified under Ultisols and Oxisols. Crop production is not favorable in highly weathered Ultisols and Oxisols, due to aluminium (Al) and manganese (Mn) toxicities as well as calcium (Ca) and magnesium (Mg) deficiencies. Acid soils with high Al saturation (> 60%) induce water stress and retards plant growth. Al toxicity and water stress affects every aspect of plant growth, including the anatomy, morphology, physiology and biochemistry. Therefore, a detail understanding of the physiological characteristics of Al stress, will lead to improvement of maize (*Zea mays* L.) with tolerance to Al that can be grown on Ultisols and Oxisols.

Three experiments were conducted to study the effects of aluminium toxicity on root morphology and physiology of two maize hybrids (Putra J-58 and C-7). Experiments were conducted in the laboratory and at Field two, Faculty of Agriculture, Universiti Putra Malaysia. The experiments were conducted to study the effect of Al on seed germination, short-term effect of Al on root structure and effect of high Al

concentrations on maize growth. The experimental designs were randomized complete block design in factorial arrangement, and replicated three times.

Overall results showed that maize seeds were impermeable to Al, even though seeds were soaked in 300 µM Al for 8 h, the seeds when sliced and stained with 0.2% hematoxylin showed that the embryo was not stained. Moreover, seed germination was normal when soaked in Al solution, but after germination, root growth was restricted and root tip became brown, stubby, with lesions on the root surface. The total root length of C-7 was significantly longer than Putra J-58.

Hematoxylin staining showed that tolerance level of Putra J-58 was considered as *intermediate* tolerance to Al, while C-7 was *sensitive* to Al. Al uptake appears to take place within 30 min, and based on the root morphological observations, Al disrupted root cells within 24 h as indicated by lesions in the cortex tissue of the root tip.

High Al concentrations (278 and 556 µM Al) inhibited root growth as well as root branching and induced water stress symptoms. After two days in the Al solution, leaves showed interveinal chlorosis, a symptom of Mg deficiency and supported by result of leaf analysis. This symptom was observed on plant grown in solutions with 278 and 556 µM Al. Ca content in the shoot of maize grown in 0 and 556 µM Al were 8.81 and 4.41 µg/g of DM, respectively. Moreover, Mg content in the shoot of maize grown in 0 and 556 µM Al were 5.51 and 2.33 µg/g of DM, respectively. After six days in the nutrient solution containing 556 µM Al, root and shoot dry matter reduced by 61.1% and 34.8%, respectively, compared to control. In addition, stomatal resistance increased by 84.6% and transpiration rate was reduced 41.8% by 556 µM Al, respectively, compared to control.

Al toxicity induced root lesions, stubby roots and deep-cracking on the epidermal tissue of the roots. However, the degree of root inhibition or root damage and the decreasing plant physiological activities were dependent on the level of Al present. Maize root growth appears to show a linear or almost exponential response to Al toxicity.

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

KESAN KETOKSIKAN ALUMINIUM TERHADAP MORFOLOGI AKAR DAN FISIOLOGI DARIPADA DUA HIBRID JAGUNG

Oleh

TEGUH PRASETYO

Jun 2007

Pengerusi : Profesor Madya Zakaria Wahab, PhD

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Tanah berasid di Malaysia dianggarkan 72% daripada tanah di negara ini dan diklasifikasikan sebagai Ultisol dan Oksisol. Pengeluaran tanaman tidak begitu baik di tanah Ultisol dan Oksisol yang diakibatkan oleh ketoksikan aluminium (Al) dan mangan (Mn) dan juga kekurangan kalsium (Ca) dan magnesium (Mg). Tanah yang berasid dengan ketepuan Al yang tinggi (>60%) menggalakkan ketegasan (kekurangan) air dan merencatkan pertumbuhan tanaman. Ketoksikan Al and kekurangan air memepengaruhi setiap aspek tumbesaran tanaman, termasuk anatomi, morfologi, fisiologi and biokimia. Oleh itu, kefahaman yang mendalam tentang ciri-ciri fisiologi kesan Al akan menghasilkan pembaikan jagung (*Zea mays* L.) supaya toleran terhadap Al dan boleh ditanam di Ultisol dan Oksisol.

Tiga kajian telah dijalankan untuk mengkaji kesan-kesan ketoksikan aluminium terhadap morfologi akar dan fisiologi daripada dua hibrid jagung (Putra J-58 dan C-7). Kajian telah dijalankan di makmal dan di Ladang 2, Fakulti Pertanian, Universiti Putra Malaysia. Kajian telah dijalankan untuk mengkaji kesan Al pada percambahan

biji benih, kesan jangkamasa pendek Al terhadap struktur akar, dan kesan kepekatan Al yang tinggi terhadap pertumbuhan tanaman. Rekabentuk kajian yang digunakan adalah rekabentuk penuh rawak lengkap dalam bentuk faktorial dengan tiga kali replikasi.

Keputusan keseluruhan menunjukkan biji benih jagung tidak telap terhadap Al, walaupun biji benih yang direndam ke dalam 300 µM Al selama 8 jam. Biji benih dipotong dan di letakkan dengan 0.2% hematoksin, tidak menunjukkan kesan pengambilan hematoksin. Tambahan lagi, percambahan biji benih adalah normal di dalam larutan Al tetapi selepas percambahan, pertumbuhan akar dihadkan oleh Al. Hujung akar bertukar menjadi warna coklat, terencat dan melecur di permukaan hujung akar. Jumlah panjang akar C-7 lebih panjang secara signifikan berbanding Putra J-58.

Pelekatan hematoksin menunjukkan tahap toleran Putra J-58 dianggap sebagai pertengahan, sementara C-7 adalah sensitif terhadap Al. Pengambilan Al mengambil masa 30 minit dan berdasarkan kepada pemerhatian morfologi, Al merosakkan sel akar dalam masa 24 jam yang ditunjukkan oleh kesan melecur dalam tisu kortek di hujung akar.

Kepekatan Al yang tinggi (278 dan 556 µM Al) merencat pertumbuhan dan percabangan akar dan menunjukkan simptom ketegasan air. Selepas dua hari dipindahkan kepada larutan nutrien, daun menunjukkan simptom klorosis seperti kekurangan Mg yang disokong oleh keputusan analisis daun. Simptom ini dapat dilihat bagi jagung yang ditanam dengan 278 dan 556 µM Al. Kandungan Ca dalam pucuk pokok jagung apabila ditanam dalam 0 dan 556 µM Al adalah masing-masing 8.81 dan 4.41 µg/g berat kering. Selain itu kandungan Mg dalam pucuk pokok jagung apabila ditanam dalam 0 dan 556 µM Al adalah masing-masing 5.51 dan 2.33 µg/g berat kering. Selepas enam hari dalam larutan nutrien yang mengandungi 556 µM Al, berat kering akar dan pucuk masing-masing berkurang sehingga 61.1% dan 34.8% berbanding dengan kawalan. Selain itu, rintangan stomata meningkat 84.6% dan kadar transpirasi mengurang sebanyak 41.8% berbanding dengan kawalan.

Ketoksikan Al menggalakkan pelecuran akar, akar bantut dan rekahan pada tisu epidermis. Darjah kerosakan akar atau pengurangan aktiviti-aktiviti fisiologi pokok bergantung kepada tahap kepekatan Al. Tumbesaran akar pokok jagung kelihatan menunjukkan sifat linear atau hampir eksponential terhadap kesan ketoksikan Al.

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I certify that an Examination Committee has met on 26 June 2007 to conduct the final examination of Teguh Prasetyo on his Master of Science thesis entitled "Effects of Aluminium Toxicity on Root Morphology and Physiology of Two Maize Hybrids", in accordance with Universiti Pertanian Malaysia (Higher Degree) Act. 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Member of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

TEGUH PRASETYO

Date : 24 July 2007

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LIST OF ABBREVIATIONS

ABA	abscisic acid
ANOVA	analysis of variance
APX	ascorbate peroxidase
CAT	catalase
CEC	cation exchange capacity
cv	coefficient of variation
d	day
DHAR	dehydroascorbate reductase
DM	dry matter
DNMRT	Duncan new multiple range test
FAA	formalin acetic acid alcohol
FAO	food and agriculture organization
FC	field capacity
GPX	glutathione peroxidase
GR	glutathione reductase
h	hour
H_2O_2	hydrogen peroxide
ha	hectare
Hg	hydrargyrum (mercury)
LSD	least significant difference
MPa	mega pascal
MT	microtubule
M.T.	metric ton