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EXPLORING THE GENETIC POTENTIAL OF LOCALLY ADAPTED GERMLASM FOR DROUGHT TOLERANCE: A CASE FOR COWPEA (VIGNA UNGUICULATA (L.) Walp) FROM MALAWI

A thesis presented in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Plant Science

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2014
Abstract

The shortage of improved cowpea (Vigna unguiculata (L.) Walp) varieties and increased frequency of droughts in Malawi have created a need to identify drought tolerant genotypes with desirable agronomic and utility characteristics. This research evaluated local germplasm maintained by the Malawi Plant Genetic Resources Centre (MPGRC), as an initial step towards the identification of genotypes with drought tolerance. Eco-geographic characterisation revealed diverse ecologies among the different germplasm collected. These genotypes were subsequently assessed for drought tolerance in a glasshouse study. All genotypes which tolerated low moisture conditions in the glasshouse originated from areas with high rainfall and low temperatures suggesting that extreme environmental conditions and/or human mediated actions interfered with adaptation processes. Furthermore, the eco-geographic characterisation identified germplasm gaps which need to be filled by either collection or repatriation of germplasm from international genebanks. The establishment of on-farm conservation in areas with low rainfall and high temperature such as Chikwawa and Nsanje districts may enhance adaptation of cowpea to drought conditions. Genotypes 479, 601, 645, 2226 and 3254 fully recovered from moisture stress, while 2232 started wilting within one week of drought stress initiation in the first glasshouse experiment. The genotypes which recovered from moisture stress showed low scores for wilting scales, low leaf wilting index (LWI), high relative water content, high scores for stem greenness and high levels for re-growth. In addition, the first glasshouse experiment resulted in the development of a leaf wilting index, which has been identified as an easily used method for scoring wilting, compared to common wilting scales. In a subsequent glasshouse experiment, all the genotypes which fully recovered from moisture stress showed high relative water content during the period of stress, but showed differences in other physiological traits. For example, genotypes 479, 601, 645 and 2226 had reduced stomatal conductance, transpiration rate and net photosynthesis, while 3254 maintained high scores for the three traits from the initial stage of moisture stress. Although 2232 showed a high transpiration rate and stomatal conductance, its net photosynthesis was significantly reduced, compared to all the other genotypes, after the third week of stress. The differences in physiological traits among genotypes indicated that 3254 has drought tolerance; 479, 601, 645 and 2226 avoid drought while 2232 is drought susceptible. The field performance of these six genotypes and two released varieties (Sudan 1 and IT82E16) was assessed in field trials in Malawi at Baka, Bvumbwe, Chitala, Chitedze and Kasinthula. Results from field trials revealed significant
variation for reproductive, yield and seed characteristics. Sudan 1, IT82E16, 409 and 601 matured in less than 65 days after planting; 3254 took 70 days and 645, 2226 and 2232 took more than 85 days. Genotype 3254 consistently gave high yields at sites with low rainfall and high temperatures compared to 2232 which yielded poorly at the same sites. The eight genotypes showed variation in seed size with genotype 2226 producing large seeds (>20g/100 seeds) at all sites. The seed size of 2232 was significantly lower than 2226 at sites with low rainfall and high temperatures. The field performance of these genotypes reflects the physiological responses observed in the glasshouse, confirming the drought response categories of the genotypes. The agreement between glasshouse experiments and the field trial suggests there is intrinsic value in the locally adapted germplasm maintained by the Malawi Plant Genetic Resources Centre. Among the genotypes tested in the field, farmers selected 479 for early maturity; 2226 and 2232 for high leaf biomass; 3254 for high pod load; 2226 and 2232 for large seeds; Sudan 1 for small seeds; and 601, IT82E16 and Sudan 1 for smooth seed texture. Genotype 3254 was ranked poorly at all the sites due to rough seed texture. Genotypes for potential use in improving production of cowpea in drought prone areas were identified. In the absence of released drought tolerant varieties, it is recommended that genotypes with drought avoidance characteristics be promoted in areas with mild droughts, while 3254 with its typical drought tolerance may be suitable for areas with intense droughts. However, the rough seed texture of 3254 may limit its usefulness due to its poor ranking by farmers at all sites. Priorities for future cowpea in Malawi include investigating inheritance of drought tolerance in cowpea.
Acknowledgements

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Above all, I salute the Almighty God for guiding, keeping and protecting me throughout the study period. It was not easy but it was possible with His presence by my side. May the Almighty God continue blessing everyone who took part in the successful completion of this work.
Dedication

I dedicate this work to my wife, son, dad and mum, for being instrumental throughout my academic journey.

I also dedicate this work to the children of Malawi who do not complete their education, often because their parents do not appreciate its value. It is my prayer that such parents begin to realise the importance of education in changing the world. I also dedicate this work to all the people and organisations that selflessly support the education of children in Malawi. May you gain more blessings for this noble cause.

To the parents: “If you think education is expensive, try ignorance” by Derek Bok.

To the goodwill ambassadors: “Education is the most powerful weapon which you can use to change the world” by Nelson Mandela.
Candidate’s declaration

This is to certify that the research carried out for my Doctoral thesis entitled “Exploring the genetic potential of locally adapted germplasm for drought tolerance: A case for cowpea (Vigna unguiculata (L.) Walp) from Malawi” at the Institute of Agriculture and Environment, Massey University, New Zealand is my own work and that the thesis material has not been used in part or whole for any other qualification.

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DATE: 23/10/2014
Supervisor’s declaration

Chief Supervisor’s Name

James Miller

Signature

Signature on behalf

Date

24/10/14
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<td>Abscisic Acid</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>asl</td>
<td>Above Sea Level</td>
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<tr>
<td>ASWAp</td>
<td>Agriculture Sector Wide Approach</td>
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<td>CBD</td>
<td>Convention on Biological Diversity</td>
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<tr>
<td>CIAT</td>
<td>International Centre for Tropical Agriculture</td>
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<td>DAES</td>
<td>Department of Agricultural Extension Services</td>
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<td>DARS</td>
<td>Department of Agricultural Research Services</td>
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<td>DLS</td>
<td>Delayed Leaf Senescence</td>
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<td>E</td>
<td>Net Transpiration</td>
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<td>Extension Planning Area</td>
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<td>General Linear Model</td>
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<td>Gs</td>
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<td>IBPGR</td>
<td>International Board for Plant Genetic Resources</td>
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<td>ICRISAT</td>
<td>International Crops Research Institute for Semi-Arid Tropics</td>
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<td>LWI</td>
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<td>Malawi Growth and Development Strategy II</td>
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<td>MLS</td>
<td>Multilateral System</td>
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