Plant biotechnology helps quest for sustainability: With emphasis on climate change and endangered plants

David W.M. Leung, Senior Lecturer, School of Biological Sciences, University of Canterbury, Christchurch, New Zealand

Abstract

Natural resources are not unlimited. Some indigenous plants in different regions have already become extinct. With mounting scientific evidence for climate change, it has been projected that this is an additional threat to this already vulnerable natural resource.

Plant biotechnology which has the potential to help build a sustainable economy based on primary plant production can also be applied to assist indigenous endangered plants. In particular, plant tissue culture technology including micropropagation has much potential in facilitating experimental studies to gain a better understanding of the biology of endangered plants. This will be of benefit to the development of appropriate management strategies to safeguard the sustainability of endangered plants. However, adequate funding must be made available from the public goods domain to achieve this.

Introduction

It is widely accepted that natural resources, for example, clean drinking water, are limited and the current ways of using them are not sustainable (for example, see Conservation International, 2008). In addition, with the mounting scientific evidence for climate change (Intergovernmental Panel on Climate Change, 2007), close scrutiny and debate on the ways of using natural resources including plants in more sustainable manners and with minimal or reduced contribution to climate change have already begun.

Human's dependence on crop plants and forestry trees for economic growth and on medicinal or herbal plants for health is undeniably huge. With the dwindling fossil fuels and the associated economic and environmental impacts of using this non-renewable energy resource and stock for chemicals industry, growing plants could take on a new meaning beyond the traditional purpose of feeding, clothing, housing and sourcing medicine for people. Plants (as a biomass resource) could be an alternative renewable energy source and stock for chemicals industry (Martin, 2006). Moreover, growing plants (as a substantial carbon sink), particularly forestry trees, is now considered as at least one of the measures to mitigate the potential effect of climate change (Woodbury et al., 2007; Dore et al., 2008).

Recent advances in plant biology and the development of tools in biotechnology including plant tissue culture and molecular biology hold much promise for quest of sustainable economic growth. However, the potential of these tools of biotechnology has apparently not been explored to any great extent with the indigenous plants in the natural environments of different regions.
Here, global climate change is seen as a new challenge in addition to others that plants have to cope with. The resilience of native plants grown in the natural environments of different countries to any adverse effects of climate change is largely unknown. This should deserve more close scrutiny as it has been projected that even in the case of minimal climate change as many as 20% species including plants could be endangered and "committed" to a path of extinction by 2050 (Thomas et al., 2004). Therefore, this is selected here to aid a discussion

of the potential of plant biotechnology applied to safeguard the sustainability of the wild populations of indigenous plants.

Limited natural resources include endangered plants

Plants are generally not considered as limited natural resources. However, plants have enemies such as insect pests and plant disease-causing viruses, bacteria and fungi. Some plants as weeds are more aggressive competitors than others. Disastrous abiotic factors such as prolonged drought, flooding, elevating soil salinity and temperature extremes are not only threats to crop plant production but also to indigenous plants in the natural environments including those that are already endangered. Human activities including farming, mining, industrial and urban living have resulted in heavy metal contamination etc. which could further undermine the sustained survival of wild plant populations. Global climate change is the latest challenge that plants in managed and natural environments alike have to cope with.

In modern agriculture and forestry, plant protection is a significant investment.
Agri-chemicals such as pesticides, fungicides and herbicides are important weapons to achieve the level of plant production as we know it (Wilson and Tisdell, 2001). This practice is unsustainable as there are heavy costs to the environment, biodiversity and public health (Wilson and Tisdell, 2001; Huang et al., 2005). Plant biotechnology based on molecular biology-directed gene transfer (genetic engineering) provides some promising alternative solutions to improve defense abilities or abiotic stress tolerance/resilience of crop plants (Gatehouse, 2008). There is still, however, some lingering public concern about the safety and environmental impact of this technology in some countries, for example, in New Zealand.

Many native plants in the natural environments of a country are often left to the forces of nature and increasingly subject to potential infringements from the consequences of human activities. The sustained persistence of native plants in the natural environments has received little benefits from advances in plant biotechnology. Already some indigenous plants have not been found in the wild for years and can be considered to have become extinct. For example, in New Zealand *Lepidium obtusatum* and three other taxa are known to be extinct (de Lange et al., 2004). The number of many others are critically low and can be considered in the category of endangered or threatened plants (de Lange et al., 2004).

Unfortunately, almost invariably a comprenhensive understanding of the biology of most native plants is lacking. If a native plant does become extinct, we might have lost not merely an insignificant component of the biodiversity on the earth but also an unknown and potentially valuable resource. It might harbour a miracle drug yet to be discovered for humans or a resistance gene to a devastating plant disease, for example. Therefore, initiatives to safeguard biodiversity using the tools of seed banks or botanical gardens/conservation parks should also include seed stores of native plants from different countries and also more biological studies (including those beyond morphological and taxonomic descriptions) on them. Because it is clearly in the interests of public goods that we have a better understanding of the biology of endangered plants, adequate funding from the public goods domain must be made available to support the development and application of appropriate plant biotechnology to help safe keeping and studying this vulnerable natural resource.

Impact of climate change on endangered plants?

There have been many calls for urgent research to assess the potential impacts of climate change on crop plant production systems. There are also calls for investigations into ways to mitigate the possible effects of global climate change including those on crop plant production (Lah, 2004). The plight of iconic animals like the polar bears in light of melting Artic ice might have precipitated public cries to examine urgently the climate change threat faced by threatened animals (Derocher et al., 2004). This also prompted a similar plea for attention in the case of endangered plants (Charles, 2008). Here, it is emphasized that in the interests of public goods we must invest in global change biology of endangered plants so that informed decisions can be made concerning the appropriate management strategies and biotechnology to ensure the sustainability of this natural resource.

Possible roles of plant tissue culture technology

One of the main problems for any credible experimental studies (requiring adequate number of replicate treatments and often destructive sampling) with endangered or threatened plants is that there are so few of them in the natural populations. Plant tissue culture, particularly micropropagation,techniques can be applied to clone a large number of an endangered plant with minimal damage to the natural populations (for example, see Carson and Leung, 1994 and 1997; Faisai et al., 2007; Chaudhuri et al., 2008; Mohammadi-Dehcheshmeh et al., 2008).

Leptinella nana L (Family Asteraceae, Fig. 1), is an endangered plant in New Zealand that has been cloned (Fig. 2) successfully using a micropropagation technique (Carson and Leung, 1994). The clonal micropropagated plants maintained under tissue culture conditions were able to form a large quantity of flowers. These were found to be suitable for subsequent investigations into the requirements for the reproductive success of the plant. Furthermore, the clonal plants have been maintained under tissue culture conditions and micropropagated periodically since 1993 up to the present. Over these 15 years, there does not seem to be any decline in the vigour of the micropropagated plants obtained, both under tissue culture conditions and when they are moved to grow in soil (Leung, unpublished observations). Therefore, it seems possible to operate a long-term germplasm bank of endangered plants under tissue culture conditions. Such live collections of endangered indigenous plants displaying different stages of life cycle without seasonal or climatic limitations could be distributed and used for public appreciation and school children education of these otherwise little known natural resources. This would complement or might even better visits to the herbaria or botanical gardens!

Although the large number of plants regenerated in the tissue culture laboratory can be introduced back to the natural environments, there might be some unforeseen potential risks associated with monoculture practice. Clearly this is not desirable. Therefore, the main utilily of the clonal plants is for experimental studies as there would be little or greatly reduced variability due to plant materials. They can be deployed to gain clearer insights into all aspects of the biology of the endangered plants. These are pre-requisites to development of strategies to manage them in relation to the whole spectrum of potential threats including climate change.

Studies of plants raised from seeds produced by the endangered plants might reveal few natural variations to, for example, a climate change factor like rising carbon dioxide level. The individual variant plant can be micropropagated and the clonal plants can be studied in detail. In this way, it might be possible to recover rapidly new type of native plants that have improved ability and therefore a brighter prospect to cope with climate change.

It is known that plants regenerated from plant cell culture are largely identical to the starting plant material but some might have a few altered or mutant characteristics (Jin et al., 2008). This knowledge may be applied as the basis for experiments to increase variations in the ability of endangered native plants to cope with climate change. For example, plant cell culture can be initiated from a piece of tissue taken from an endangered plant. Before plant regeneration, the cell culture could be selected for more vigorous growth in response to simulated drought condition (for example, using increased concentrations of agar in the culture medium, Gopal et al., 2008). Plants regenerated following this *in vitro* selection scheme might be genetically improved plants with an expanded capacity to cope with or even thrive in drier conditions that are projected to result from climate change. Therefore using this non-controversial, non-genetic engineering approach could be an option to ensure the sustainability of the endangered plant.

Conclusion

Endangered indigenous plants are potentially valuable natural resources that are not well studied beyond morphological-based observations/surveys/descriptions. Like the primary plant production systems they are also to face the challenge of climate change. Plant biotechnology, particularly plant tissue culture technology including micropropagation techniques, which have already been applied to the primary production systems could also be applied to assist advancing our knowledge concerning all aspects of their biology. This is needed for informed management strategies to minimize the projected extinction fate for many of them. Justifiably adequate funding from the public goods domain must be made available to ensure the development and application of the appropriate plant biotechnology needed to better safeguard this public asset.

References

Carson J.A., Leung D.W.M. *In vitro* flowering and propagation of *Leptinella nana* L., an endangered plant. *New Zealand Journal of Botany* (1994), 32: 79-83.

Carson J.A., Leung D.W.M. *In vitro* propagation of *Wahlenbergia stricta* (R.Br.) subsp. Stricta, an adventive plant in New Zealand, can yield plants capable of flowering and setting viable seeds. *New Zealand Natural Sciences* (1997), 23: 87-91.

Charles D. Don't forget our threatened plants. *Science* (2008), 320: 1000.

Chaudhuri R.K., Pal A., Jha T.B. Conservation of *Swertia chirata* through direct shoot multiplication from leaf explants. *Plant Biotechnology Reports* (2008), 2: 213-218.

Conservation International. Fresh water in limited supply. (2008), http://www.conservation.org/FMG/Articles/Pages/freshwater_limited_supply.aspx.

de Lange P.J., Norton D.A., Heenan P.B., Courtney S.P. et. al. Threatened and uncommon plants of New Zealand. (2004), http://hd1.handle.net/10092/415.

Derocher A.E., Lunn N.J., Stirling I. Polar bears in a warming climate. *Integrative and Comparative Biology* (2004), 44: 163-176.

Dore S., Kolb T.E., Montes-Helu M., Sullivan B.W. et. al. Long-term impact of a stand-replacing fire on ecosystem CO_2 exchange of a ponderosa pine forest. *Global Change Biology* (2008), 14: 1801-1820.

Faisai M., Ahmad N., Anis M. An efficient micropropagation system for *Tylophora indica*: an endangered, medicinally important plant. *Plant Biotechnology Reports* (2007), 1: 155-161.

Gatehouse J.A. Biotechnological prospects for engineering insect-resistant plants. *Plant Physiology* (2008), 146: 881-887.

Gospal J., Iwama K., Jitsuyama Y. Effect of water stress mediated through agar on *in vitro* growth of potato. *In Vitro Cellular & Developmental Biology-Plant* (2008), 44: 221-228.

Huang J., Hu R., Rozelle S., Pray C. Insect-resistant GM rice in farmers' fields: assessing productivity and health effects in China. *Science* (2005), 308: 688-690.

Intergovernmental Panel On Climate Change. Climate change 2007: The physical science basis. (2007), http://news.bbc.co.uk/1/shared/bsp/hi/pdfs/02_02_07_climatereport.pdf.

Jin S., Mushke R., Zhu H.G., Tu L.L., Lin Z.X., Zhang Y.X., Zhang X.L. Detection of somaclonal variation of cotton (*Gosypium hirsutum*) using cytogenetics, flow cytometry and molecular markers. *Plant Cell Reports* (2008), 27: 1303-1316.

Lal R. Soil carbon sequestration impacts on global climate change and food security. *Science* (2004), 304: 1623-1627.

Martin J. Price considerations for use of soy feedstocks for the chemicals industry. *Industrial Microbiology* (2006), 2:92-95.

Mohammadi-Dehcheshmeh M., Khalighi A., Nadri R., Sandari M. et.al. Petal: a reliable explant for direct bulblet regeneration of endangered wild populations of *Fritillaria imperialis* L. *Acta Physiologia Plantarum* (2008), 30: 395-399.

Thomas C.D., Cameron A., Green R.E., Bakkenes M., et. al. Extinction risk from climate change. *Nature* (2004), 427: 145-148.

Wilson C., Tisdell C. Why farmers continue to use pesticides despite environmental, health and d sustainability costs. *Ecological Economics* (2001), 39: 449-462.

Woodbury P.B., Smith J.E., Heath L.S. Carbon sequestration in the US forest sector from 1990 to 2010. *Forest Ecology and Management* (2007), 241: 14-27.

Published by the Forum on Public Policy

Figure 1. *Leptinella nana* L. grown in the glasshouse at the University of Canterbury, Christchurch, New Zealand.

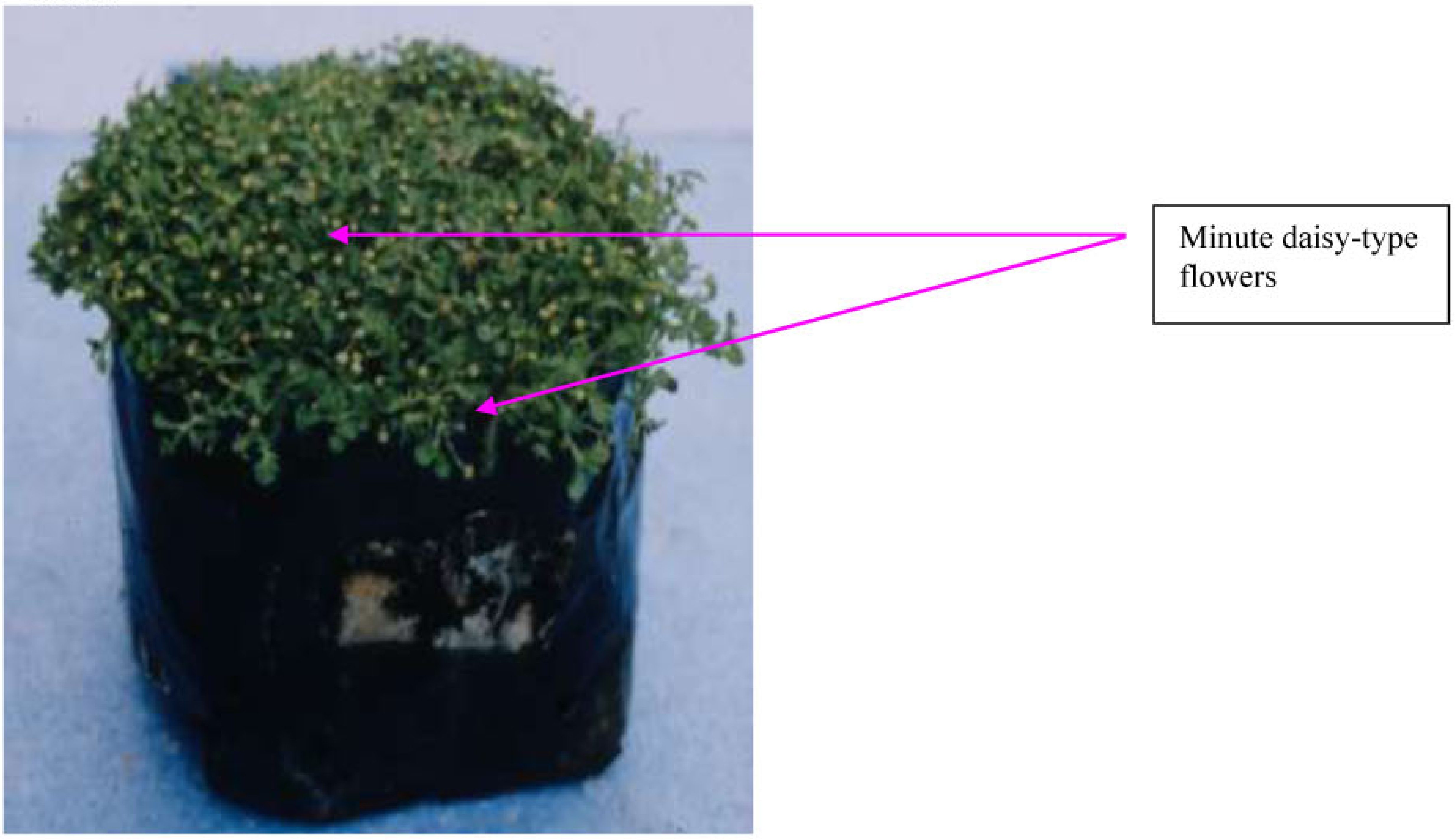

Figure 2. Micropropagated *Leptinella nana* L. plantlets maintained at the University of Canterbury, Christchurch, New Zealand.