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Enhancing the conservation of crop wild relatives in Scotland

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ABSTRACT

The impact of climate change upon the agricultural industry is predicted to severely reduce crop yields, leading to a global state of food insecurity. This will be compounded by the necessity to feed almost two billion more people by 2050. Crop wild relatives (CWR), with a wider gene pool than domesticated crops, offer a means of mitigating this situation through the use of novel traits (*e.g.* stress tolerant or disease resistant traits) in crop improvement. The United Kingdom is one of the contracting parties to international policy such as the Strategic Plan for Biodiversity of the Convention on Biological Diversity, which is committed to securing these valuable resources. However, as in the majority of countries around the world, there are as yet no commitments to either *in situ* or *ex situ* conservation of CWR at UK or devolved level. This study (i) has produced an inventory of 120 priority CWR within Scotland, (ii) has identified potential sites suitable for their *in situ* conservation (most notably a site to the west of Glasgow close to the Loch Lomond and Trossachs National Park) and (iii) has prioritised these CWR in terms of the urgency for *ex situ* collection and storage in gene banks. Finally, recommendations have been made as to how active, long-term conservation of these 120 priority CWR in Scotland could be established to secure this resource *in situ* whilst ensuring accessibility of genetically diverse material in UK gene banks for use by plant breeders in crop improvement.

1. Introduction

Global mean surface temperatures are predicted to increase by as much as 2.6–4.8 °C between 2081 and 2100 compared to observed temperatures between 1986 and 2005, according to a climate change projection where greenhouse gas emissions continue to increase over this time period (Collins et al., 2013). Due to this and other impacts of climate change, crop yields are predicted to decrease by up to 2% per decade until 2050 with forecasts becoming more severe during the latter half of the century (Porter et al., 2014). Agricultural crops have limited genetic diversity having been through generations of breeding to obtain high yielding, uniform crop varieties (Tanksley & McCouch, 1997). van de Wouw, Kik, van Hintum, van Treuren, and Visser (2010) attribute this loss of genetic diversity primarily to the shift from the farming of traditional varieties to modern cultivars rather than any significant loss during the twentieth century. This has left crops susceptible to biotic and abiotic stresses associated with climate change. This is an issue compounded by the estimate that the human population is set to reach 9.6 billion people by 2050 according to a medium-variant projection (this estimate ranges from 8.3 billion to 10.9 billion depending on assumed fertility rate) (United Nations, 2013). This presents the significant challenge of providing global food security for an increasing population by improving the resilience of agricultural systems in the face of climate change and additional threats including land use changes, unsustainable agricultural practices and globalisation leading to spread of invasive species (Government Office for Science, 2011).

Crop wild relatives (CWR) are wild plant species that are related to crops and that contain wider pools of genetic diversity that can be, and in many cases are being harnessed for use in crop breeding. The relationship between a crop and its wild relative can be defined using the Gene Pool (GP) Concept (Table 1) (Harlan & de Wet, 1971). Similar classifications are possible based on the taxonomic relationships between CWR and crops and can be useful where experiments into genetic relationships are yet to take place. This classification is called the Taxon Group (TG) Concept (Table 1) (Maxted, Ford-Lloyd, Jury, Kell, & Scholten, 2006). Never having been through the process of domestication, CWR have a much wider gene pool and potentially contain traits that could be bred into existing crop varieties to improve their resilience to a range of stresses (Tanksley & McCouch, 1997). For example, traits from *Hordeum bulbosum* L. (a wild rela-

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Table 1
Gene Pool and Taxon Group concept classifications (Harlan & de Wet, 1971) indicating the degree of relatedness between a CWR and its associated crop and therefore its potential for use as a gene donor for crop improvement.

Gene pool concept (Harlan & de Wet, 1971)		Taxon group concept (Maxted et al., 2006)	
GP1a	Cultivated crop varieties	TG1a	Cultivated crop varieties
GP1b	CWR easily crossable with crops from GP1a	TG1b	CWR of the same species as its related crop
GP2	CWR where breeding genes into a related crop is possible but not always successful	TG2	CWR in the same taxonomic section as its related crop
GP3	CWR where more advanced biotechnologies are required to achieve successful trait transfer to a related crop	TG3	CWR in the same subgenus as its related crop
		TG4	CWR in the same genus as the related crop

tive of barley) have been used as a source of resistance to many diseases including leaf rust, powdery mildew (Zhang, Pickering, & Murray, 2001) and scald (Pickering et al., 2006), all of which result in severe yield losses in susceptible cultivated barley varieties. It has been calculated that the potential value of breeding novel and beneficial traits from CWR into just 29 food crops identified by the Millennium Seed Bank, Royal Botanic Gardens (RGB), Kew could be approximately $120 billion by 2021 (PwC, 2013).

Despite their clear economic value, CWR themselves, as with all wild plant species, are exposed to a range of factors that may threaten their survival, including habitat destruction and climate change (Kell, Maxted, & Bilz, 2012). In recognition of their potential value and the threats to which they are exposed, the conservation of CWR and of the range of genetic diversity within them is increasingly becoming a priority in global and regional conservation policy (Convention on Biological Diversity (CBD, 1992)), Global Strategy for Plant Conservation (CBD, 2010a), Strategic Plan for Biodiversity (CBD, 2010b), International Seed Treaty (FAO, 2001), European Strategy for Plant Conservation (Planta Europa, 2008) and European Biodiversity 2020 Strategy (European Union, 2011). Priority CWR and recommended conservation actions for CWR are now starting to be identified in a range of countries in response to policy documents (*e.g.* Benin (Idohou et al., 2012); USA (Khoury et al., 2013); Finland (Fitzgerald, 2013); Spain (Rubio Teso, Iriondo, Parra, & Torres, 2013); Italy (Panella et al., 2014)). Within the UK however, active conservation of CWR has not yet been established. To address this, recent research effort has focussed on identifying priority CWR and finding effective means of establishing active conservation, both *in situ* and *ex situ*, for these plants in England and Wales (Fielder, B. Brotherton, et al., 2015; Fielder, Burrows, Woodman, Ford-Lloyd, & Maxted, 2015, respectively). The current study addresses these same issues within the context of Scotland. These three studies are each part of one wider study that aims to encourage the implementation of active CWR conservation across the UK. Each of these three administrations has been studied separately due to the devolution of many aspects of conservation planning across the UK, making this the most likely approach to result in a positive change in CWR conservation provision.

According to Scotland's State of the Environment Report (Critchlow-Watton et al., 2014), agriculture is the main land use in Scotland, covering close to 80% of the total land area. Nine percent of Scotland's agricultural land area is specifically used for crop production and is located primarily in the east of the country. Though this may seem a small percentage, the contribution of this land area to the economic output of agriculture in Scotland far exceeds this value, contributing 34%. The most commonly grown crops in Scotland are barley, wheat, oilseed rape, oats, potatoes and strawberries of which CWR of barley, oilseed rape, oats and strawberries are present within Scotland. No CWR of wheat or potatoes are present within Scotland as these crops originate from the Middle East and South America respectively (Vavilov, 1926). A total of 12% of UK cereal production originates from Scotland (CCRA, 2012). A further 21% of agricultural land area is used as managed grassland supporting livestock through grazing (with the remaining agricultural land used for rough grazing) (Critchlow-Watton et al., 2014). This highlights the value not only of crops grown as a human food source but also of forage and fodder crops for livestock farming.

The UK Climate Change Impact Programme (UKCP09, 2009) has outlined the expected long-term effects of climate change across the UK. It is predicted that Scotland will experience increasingly hotter, drier summers and milder, wetter winters (UKCP09, 2009). Though there is a high degree of uncertainty in future climate prediction models and the magnitude of change will depend heavily on emissions, the general trends described for temperature and precipitation are apparent in low, medium and high emissions scenarios. This in turn is predicted to have some beneficial effects on agriculture, such as a longer growing season and the ability to grow a wider range of crops. However, a range of deleterious effects are also likely, including but not limited to decreased yields due to drought in summer, the increased incidence of pests and diseases that are able to survive through milder winters and the spread of invasive species (Critchlow-Watton et al., 2014). Crops in Scotland could be further threatened due to their being cultivated in coastal locations, leaving them susceptible to rising sea levels (CCRA, 2012). In order to maintain or ideally increase crop yields over time it will be necessary for them to become more resilient and stress tolerant in response to the predicted changes in climate. This presents a strong case for the conservation of CWR in Scotland and the subsequent utilisation of their genetic diversity to breed new crop varieties able to withstand these changes.

The UK is a contracting party to the Aichi targets under the CBD Strategic Plan (CBD, 2010b), which explicitly state the need for the conservation of crops' genetic diversity and of their wild relatives. The Scottish Biodiversity Strategy (Scottish Executive, 2004) and the recently published 2013 update, 'The 2020 challenge for Scotland's biodiversity' (Scottish Government, 2013) set out Scotland's strategy for protecting biodiversity and harnessing nature to improve Scotland's prosperity and welfare. It acknowledges genetic diversity as an important element of Scotland's natural capital and recognises the contribution it can make towards maintaining the robustness of food production. While conservation of landraces (traditional crop varieties) is being undertaken through the Scottish Landrace Protection Scheme (Green, Campbell, Tulloch, & Scholten, 2009), at present no conservation actions are being undertaken for conserving CWR in Scotland despite the range of threats likely to have a detrimental impact on wild plant populations, such as land use change, invasive species and some agricultural practices.

The objective of the current study was to identify ways to enhance CWR conservation within Scotland. It first aimed to inventory Scotland's CWR, identifying those present in the country and those of particular conservation priority, and then to perform a gap analysis investigating the extent of their current protection both *in situ* and *ex situ*. This process was carried out with advice from Scottish Natural Heritage (SNH). Based on the results of the study it was possible to make recommendations for providing active management of CWR in Scotland, which ultimately would ensure the persistence of CWR populations, making them available as a resource for use in crop improvement.