PHALARIS ARUNDINACEA A FURTHER ENERGETIC SPECIES

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Abstract: *Native to the temperate zones of the Northern Hemisphere, RCG is is a perennial grass widely distributed throughout Eurasia where it has different cytotypes. The species is mainly represented by an allotetraploid cytotype (2n=28), named P. arundinacea subsp arundinacea, and by a hexaploid form (2n=42), named subsp oehleri.The genetic data confirm the presence of a distinct population present throughout North America in the early twentieth century, but not present in Europe or Asia, ranging from Alaska, USA to New Brunswick, Canada. The strongest evidence to support the hypothesis that reed canarygrass is native to North America is the presence of herbarium specimens collected in the Northwest United States prior to the movement of agriculture into the region (Merigliano and Lesica 1998). Selection and breeding of reed canary grass cultivars with improved biomass yield potential offers the potential for genetic gains that can be realized across a broad agricultural landscape, due to the broad adaptation of this species and consistent genotypic expression across a wide range of sites. Phalaris arundinacea can be used as raw – material for paper pulp or as biofuel for combustion. Since it tolerates wet, poorly drained soils, it has generally been used for grass waterways. More recently, it has been used as a hay crop under wastewater irrigation systems using treatment effluent. Reed canarygrass is unusual in that it also has excellent drought tolerance and is an outstanding competitor and yielder under high nitrogen (N) conditions. Production of renewable energy from herbaceous crops on agricultural land is of great interest since fossil fuels need to be replaced with sustainable energy sources. Reed canary grass (RCG), Phalaris arundinacea L. is an interesting species for this purpose.*

Key words: *Phalaris arundinacea, genetics features, biofuel.*

1. ORIGIN AND TAXONOMY

Reed canarygrass (*Phalaris arundinacea L.*) is native to Europe and Asia, and has long been considered to be native to North America (Piper 1914). While there have been comparisons evaluating the level of diver- sity in Eurasian and present-day North American populations using genetic markers (Casler et al. 2009; Lavergne and Molofsky 2007), no study has used markers to compare early North American herbarium specimens to Eurasian populations. The strongest evidence to support the hypothesis that reed canary-grass is native to North America is the presence of herbarium specimens collected in the Northwest United States prior to the movement of agriculture into the region (Merigliano and Lesica 1998). Determining whether the species is native to North America+ and howbroad of a distribution it had prior to European settlement is critical to understand the origin of invasiveness of reed canarygrass. Reed canarygrass is one of the worst wetland invaders in North America because of its ability to formmonocultures in disturbed and eutrophic wetlands, although the species is not generally considered invasive in Europe (Lavergne and Molofsky 2004). This has led many researchers to hypothesize that the introduction of nonnativematerial is responsible for the development of invasiveness in North America in some aspect; either that introduced European and Asian populations have outcompeted native North American populations (Lavergne and Molofsky 2004), formerly distinct European popula-tions have hybridized to create progeny with hybrid vigor (Lavergne and Molofsky 2007); or cultivars released by plant breeding programs have outcompet- ed or introgressed with native populations (Dore and McNeill

1980). Several studies have shown the power of combining genetic markers with herbarium specimens and present-day collections of populations to evaluate the population genetics of a species (Wandeler et al. 2007). This method has been used to identify the cryptic invasion of European populations of Phrag- mites australis into North American wetlands (Lelong et al. 2007; Saltonstall 2002). Herbarium specimens have been used to reconstruct the introduction and spread of Bromus tectorum in North America follow ing introduction from Europe (Novak and Mack 2001; Novak and Mack 1993). Similarly, comparisons of populations collected in the native and invasive ranges of a species have been used to determine the origin and dynamics of invasive populations (Gaskin and Schaal 2002; Rosenthal et al. 2008). The lack of confirmed present-day native North American populations and the lack of molecular markers to identify such populations have prevented any comparisons between native Eurasian and native North American populations. However, recent work evaluated the genetic structure of a wide distribution of reed canarygrass populations in Eurasia using genetic markers (Jakubowski et al. 2011a).

2. RESEARCHES CONCERNING THE SPECIES GENETICS FEATURES OF *PHALARIS ARUNDINACEA*

Native to the temperate zones of the Northern Hemisphere, RCG iswidely distributed throughout Eurasia (Figure 2b) where it has different cytotypes (Tutin et al., 1964–1993; Carlson et al., 1996). The species ismainly represented by an allotetraploid cytotype (2n=28), named P. arundinacea subsp arundinacea, and by a hexaploid form (2n=42), named subsp oehleri (Bennett and Smith, 1976; Baldini and Jarvis, 1991; Kergu´ elen, 1993). The allotetraploid cytotype normally forms 14 bivalents inmeiosis and can therefore be considered as a diploid for genetic stud ies (Starling, 1961). The diploid cytotype (2n=14) has very seldom been described under the name subsp rotgesii (Baldini and Jarvis, 1991; Kergu´ elen, 1993). Among the three chromosome races, the tetraploid form is the most ubiquitous because of a broad environmental tolerance and iswidely distributed through out temperate zones of Europe and Asia and to a lesser extent in the Northern Mediterranean Region (McWilliam and Neal Smith, 1962; Baldini and Jarvis, 1991). The hexaploid cytotype is adapted to warmer environments and is mostly restricted to the Iberian Peninsula and Northern Africa (Baldini and Jarvis, 1991),while the diploid formis restricted toCorsica (Kergu´ elen, 1993).

3. MANAGEMENT CONSIDERATION. UTILISATION

The potential utility of reed canary grass RCG for bioenergy production has been evaluated in Sweden, several other European countries and the USA (Landström et al., 1996; Finell et al., 2011; Lewandowski et al., 2003). A special technique for harvesting of this grass has also been developed, the delayed harvest system. To date, RCG for commercial production of bioenergy has been most extensively used in Finland (Pahkala, 2007; Pahkala et al., 2008). The commercial RCG production in Sweden is limited to a few areas as the market still is uncertain, and its profitability is low. Thus, in order to increase the use of this and other herbaceous crops for bioenergy production it is important to increase their profitability by decreasing the costs. This can, for instance, be done by reducing the use of mineral fertilizers as sources of plant nutrients, provided this can be done without reducing dry matter (DM) yields (or at least without reducing yields so much that the losses outweigh the cost-benefits of reducing fertilizer applications). A possible way to reduce fertilization costs is to use appropriate waste materials as replacements for mineral fertilizers, for instance RCG ash or sewage sludge. Combustion of RCG leads to the production of relatively large amounts of ash compared to combusting wood fuel ((Burvall, 1997). This has been regarded as a problem, but ash can also be seen as a source of plant nutrients, especially P and, to some extent, K (Dimitriou et al., 2006). Sewage sludge is also rich in P, and could be used as a fertilizer for bioenergy crops, provided it is not contaminated by heavy metals or other undesirable compounds (Eriksson et al., 2008) (Odlare et al., 2011). Upper limits for heavy metal additions with sewage sludge have been issued by the Swedish Environmental Protection Agency (Naturvårdsverket, 1994). A potential way to reduce mineral N requirements for RCG production might be to intercrop RCG with perennial legumes. The legumes fix N2 from the atmosphere by symbiosis with Rhizobium bacteria. Some of the N is transferred to the soil and can be used by the intercropped grass as reviewed by Fustec et al., (2010). Experiments in Lithuania have shown promising results for such mixtures (Kryzeviciene et al., 2008).

4. *PHALARIS ARUNDINACEA* BIOENERGETIC

Reed canary grass (RCG – *Phalaris arundinacea L.*) is a potential bioenergy crop, and it is being increasingly cultivated on boreal organic soils, such as abandoned peat extraction sites. For example, the area under RCG in Finland during 2008 was about 19,000 ha and it is projected to increase to 100,000 ha by 2012. RCG can be used for burning when mixed together with peat and/or wood in thermal power stations (Flyktman and Salo, 2000). However, the atmospheric impact of this cultivation practice is unknown. Organic soils are considered to be risky soil types because of their potential for high emissions of N2O (e.g. Mosier et al., 1996) and they have even been suggested to be banned from biomass production for bioenergy (OECD, 2007). Controlling of greenhouse gas balances of managed organic soils has proven to be difficult. They have been reported to emit large amounts of greenhouse gases into the atmosphere (Kasimir-Klemedtsson et al., 1997, Lohila et al., 2004, Maljanen et al., 2003a, Maljanen et al., 2004 and Mäkiranta et al., 2007).

5. WHOLE PLANTS FOR COMBUSTION

Reed canary grass (*Phalaris arundinacea L.*) is a perennial grass that is harvested annually, using conventional forage harvesting machinery. In 2006, 3500 ha were cultivated as field trials, but only a fraction was harvested for biofuel production (Johnsson, 2006). It is a competitor for Salix plantations, since it grows even on poorer soils and tolerates the climate of northern Sweden. However, the annual harvests account for higher cultivation costs combined with a lower biomass yield (Herland, 2005). For economic combustion, it should be pressed into pellets first. Furthermore its biomass has high ash content and a high risk for sintering in the burner. At the moment there is no large-scale utilisation, only co-combustion with peat seems advantages as it binds the sulphur content of the ash. One future option might be the small- or medium-scale cultivation in combination with a production of pellets or briquettes for a local market or as substrate for biogas production (Johnsson, 2006).

6. REED CANARY GRASS AS A BIOENERGY CROP IN NORWAY

About 6 % (16 TWh) of the total energy consumption in Norway is bioenergy, and it originates almost totally from forest resources. So far the agricultural land in Norway is entirely used for production of food and feedstuffs, and there has been limited use of by-product and waste, such as grain straw. Agroenergy crops, annual and perennial, are grown for bio energetic purposes. In Europe the most important crops for bioenergy would be annual oilseed crops and maize, perennial grasses and poplar and willow. Perennial grasses display many beneficial attributes as agroenergy crops, i.e. high yield potentials, high contents of lignin and cellulose, and positive environmental impacts, including reduced soil tillage that lowers soil erosion and increases soil carbon content, preserves biodiversity, and manages cultural landscapes. Previous research and testing of perennial grasses for bioenergy production in the Nordic countries (especially in Sweden and Finland) (e.g. Landström *et al*. 1996; Levandowski *et al*. 2003; Saijonkari-Pahkala 2001) has documented that the perennial rhizomatous grass reed canary grass (*Phalaris arundinacea L.*) is the most productive perennial grass in terms of stable biomass yield at northern latitudes. The delayed harvesting method has been evaluated and accepted in Sweden, Finland, Denmark and many other countries. The harvesting method produces a dry biomass product (10- 15 % of moisture) .This means that drying costs will be reduced or even eliminated in the production chain. In an experiment at Rothamsted, England, the effect of harvest date on the yield and mineral content was examined in 15 genotypes of reed canary grass (Christian *et. al*. 2006). Delayed harvest decreased both yield and moisture content. Reed canary grass is now grown on about 10.000 ha in Finland, on contract with power plants (Pahkala *et al*. 2005). In field trials with reed canary grass and willow harvested in spring, the average DM yields for both crops have been around 6 tons per hectare (Olsson 2007). In Southern Norway Kofoed Nielsen (unpublished data) did harvest reed canary grass in the spring of three years (2004-2006). The DM yield varied between 6.5 and 8 tons per hectare, and per cent water between 8.6 and 25.4 %. The content of ashes was about 2.5 % and the gross calorific value was about 16.5 MJ per kg DM. In a field trial in South Eastern Norway Bakkegard (unpublished data) recorded a DM yield in spring of 5 tons per hectare averaged over two varieties and four years.

7. RESEARCHES CONCERNING THE PRESENT AND FURTHER RESEARCH OF *PHALARIS*

In the recent years several reports have been made on how to increase the utilization of bioenergy potential in Norway. The farmers union (Norges Bondelag) focus on improved use of wastes and less on agroenergy crops. A group of research institutes and organisations have written a report called "From Biomass to Biofuels – A Roadmap for Future Solutions in Norway" BUDELSKY RA AND GALATOWITSCH SM, 2004. Previous research and testing of perennial grasses for bioenergy production in the Nordic countries (especially in Sweden and Finland). MERIGLIANO ME, LESICA P., 1998, KERCHER SM, ZEDLER JB., 2004 has documented that the perennial rhizomatous grass (*Phalaris arundinacea L.*) is the most productive perennial grass in terms of stable biomass yield at northern latitudes.

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