The Challenge: High Quality Seed of Native Plants to Ensure Successful Establishment

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ABSTRACT

Native species are planted to re-vegetate former cropland, degraded pastures and rangelands, mined lands, "natural areas", roadside right-of-ways, and other land management areas with plants, usually perennials, to stabilize and provide desirable classes of vegetation. Acceptable stands need to be obtained in a reasonable time. Seed of native plants varies widely in seed quality factors including seed size, purity, dormancy, germination, and vigor. Seed quality tests required for sale of native seeds usually include germination, purity, and hard or dormant seeds. These laboratory tests do not always predict the capability of a seed lot to establish a stand under field conditions and do not give the seed user enough information to determine planting rate. The number of emerged seedlings per gram of seed in species specific stress tests may be a method of quantifying seed quality that is predictive of the seed's capability of producing a stand under field conditions. A standardized establishment test based on a unit of weight could be used to directly calculate planting rates.

INTRODUCTION

There is an increasing demand for seed of native plants, i.e., those plants indigeneous to North America before settlement by Europeans, for use in conservation and re-vegetation of "natural areas", roadside right-of-ways, landscaping, and other land management objectives. For some of the native species, such as the prairie grasses big bluestem (*Andropogon gerardii* Vitman) and switchgrass (*Panicum virgatum* L.), cultivars have been released for certification, methods of reliable seed production developed, and a commercial seed industry exists. For many other species, no cultivars exist, methods of seed production are rudimentary, and seed is often harvested from native stands. Consequently, seed quality, as determined by almost any criteria, varies widely among seed lots of a species. There is often disagreement on the best methods to test seed of specific species for both germination, purity, and dormancy. Since seed of many native plant species is sold on a Pure Live Seed (PLS) basis and since seed for many native species is expensive, differences among laboratories on parameters that measure seed quality, including PLS, can be economically significant to seed producers, seed processors, seed companies, and the end user's of the seed. Stand failures due to poor quality seed can have significant economic and environmental consequences. Landscapes on which establishment failures occur are often subject to high rates of erosion and

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invasion by weedy species. This review will focus on important establishment and seed quality issues confronting native plants.

ESTABLISHMENT

Successful establishment of a full stand of the planted species in a reasonable period of time is the goal of all re-vegetation operations. With cultivated legumes and grasses such as alfalfa (*Medicago sativa* L.) and smooth bromegrass (*Bromus inermis* Leyss.), establishment attempts are rated as failures unless the stands are well established and productive by the end of the growing season the year of establishment. The establishment goals for native species should be the same as for cultivated species. In the USDA-ARS research program with native prairie species at Lincoln, NE, our research goals with grasses such as switchgrass and big bluestem are to obtain full stands the year of establishment, achieve establishment year yields that are 50% of full production, and have stands in full production the year after establishment. We have produced 4.5 to 6.5 Mg ha^{-1} of switchgrass forage the establishment year and 11 to 13.5 Mg ha^{-1} the year after establishment (Vogel et al., 1981, 2002). Switchgrass pastures have been heavily grazed the year after establishment (Anderson et al., 1988). However, the frequency of establishment success is still lower than for many cultivated species.

The principal factors affecting establishment of native species are often weather related environmental conditions, cultural practices including seed bed preparation and planting time and methods, weeds, and seed quality. It is not possible to control the weather, but it is possible to determine the temperatures at which optimal germination is obtained for the species being planted. Temperature gradient table studies with several switchgrass cultivars and seedlots demonstrated that near maximum germination was obtained from 19 to 36°C and optimal germination was between 27 and 30°C (Dierberger, 1991). These results support the Association of Official Seed Analysts (AOSA) germination test warm temperature specifications for switchgrass of 30°C for 8 h but not the 16 h cool temperature specification of 15°C (AOSA, 1988). Weather and climate records can be used to predict periods when soil temperature is optimum or suitable for seed germination and when precipitation is likely to occur. In the Central and Northern Great Plains, optimum planting periods for native warm-season grasses, such as switchgrass, based on soil temperature and precipitation is two weeks before or after the recommended dates for planting maize (*Zea mays* L.) (Hsu and Nelson, 1986; Smart and Moser, 1997; Vassey et al., 1985). Similar temperature profiles are not available for other native species and are needed to determine optimal planting periods.

Knowledge of seedling morphology and development is also needed to determine field planting and seed quality testing requirements. For example, warm-season grasses have a panicoid morphology compared to cool-season grasses that have a festucoid morphology (Hoskikawa, 1969). Warm-season grass seedlings typically have a short coleoptile and an elongated subcoleoptile internode or mesocotyl which is the internode between the scutellar and the coleoptilar nodes. The subcoleoptile internode ceases to elongate once the coleoptile reaches the soil surface and receives light. This places the coleoptilar node, which is the source of adventitious roots, near the soil surface, regardless of seed depth (Hyder et al., 1971; Moser, 2000). Planting grass species with panicoid seedling morphology too deep (>1 cm) places significant stress on the seedlings and can result in stand failure regardless of the quality of the seed. Tests using emergence from depth as a stress test for panicoid species will need to use different depths than for cool-season festucoid grasses.

Weed competition is a major factor affecting the establishment of native species. Fortunately, an array of new herbicides are becoming available for renovating and and re-establishing grasslands (Masters and Sheley, 2001). Some of the new herbicides such as Plateau (imazipic) can be used for weed control in establishing both native warm-season grasses and legumes (Beran et al., 2000; Masters et al., 2001). Panicum species, including switchgrass, can be damaged by Plateau. A recently completed study indicates that the herbicide Paramount (quinclorac) appears to be very promising on switchgrass (manuscript in preparation). New management tools to control weeds in new stands of native species including new herbicides will likely be developed. Validating the effectiveness of weed control methods and new herbicides has often been a tedious, labor-intensive process. New techniques such as the frequency grid (Vogel and Masters, 2001) significantly reduce the time and resources required to test and validate new technologies. A land manager can prepare seed beds properly, plant at the optimal time, use the best available weed control technology, and still have stand failures if poor quality seed is used.

SEED QUALITY

The effect that seed quality has on economic production of agricultural crops is well recognized (Finch-Savage, 1995), but little attention has been paid to the effect of seed quality on successful establishment of native grasses and legumes. Seed quality parameters include viability, purity, cleanliness, and vigor. Factors that affect seed quality include growing conditions, field weathering, timing of harvest, harvest procedures and methods, seed drying and handling, cleaning and processing, storage conditions, diseases and insects, and field sanitation (Dornbos, 1995a, b). In contrast to cereal crops, limited management information is available to optimize seed quality of native species in seed production fields. Methods for quantifying seed quality are often limited for native species. Methods for quantifying viability and purity are available, but they are time consuming and tedious for some species, especially purity tests for species with chaffy seed. Germination temperature profiles are also limited for some species, so generic germination and tetrazolium tests are often used to measure viability. In general, accepted tests for vigor and seed cleanliness (absence of non-seed material) are not available or are not used for many native species. This situation exists because of the increasingly large number of native species being used in re-vegetation programs and the limited funds, facilities, and staff available to conduct this research.

Seeds of native species can be produced from cultivated fields or from native or "wild stands" such as native prairies. In native stands, factors that affect seed quality are not controlled. Native stands are often unreliable sources of quality seed because of the negative influence plant competition and adverse climate conditions have on seed production. In addition, management factors that improve both seed yield and seed quality such as fertilization, irrigation, and pest control are not practiced. For prairie species, seed yield from native prairies is highly variable and, in many years, economical yields of seed that will germinate are not obtained (Cornelius, 1950, Masters et al., 1993), especially when rainfall falls below the long-term average. Seed of many species is harvested from native stands when conditions are favorable. It was estimated that about 15% of the 500,000 ha enrolled in the Conservation Reserve Program (CRP program) from 1985 through 1990 was planted with seed from native harvests (Masters et al., 1993). "Wild harvest" seed typically has lower vigor and results in stand failures more often than seed from cultivated fields

Many of the native grasses and other species have chaffy seed. The chaffy seed makes the seed difficult to plant and purity determinations difficult. Mechanical methods for processing seed of chaffy grasses have been developed that can significantly increase seed bulk density and flowability for many species (Brown et al, 1983; Vogel et al., 1998). Methods for debearding or processing chaffy species are not always used because they result in a small loss of seeds or because the "seed lot" contains so much trash that if it was processed, little seed would be left. Drills have been developed that can plant chaffy seed, but even these have limitations. Problems of trashy or unclean seed lots could be resolved by requiring a minimum number of viable seed units per specified unit weight or volume of seed of a species before harvested material could be classified as seed.

Native plant seed quality parameters of vital importance to improved establishment are viability and vigor. Seed vigor refers to the ability and strength of a seed to germinate successfully and establish a normal seedling under field conditions. Dormancy breaking procedures and germination tests can be used to measure viable seeds under the ideal conditions of germination cabinets. However, ideal conditions rarely exist in the field, especially in sites where revegetation with native species are often required. As a result, germination test results sometimes are not predictive of emergence under field conditions. Some seed lots of native species can have good germination percentages but lack vigor resulting in stand failures. Stand failures are expensive since the sites have to be re-seeded and production or use of the land is delayed. Stress or vigor tests are needed to identify seed lots with adequate germination but with low vigor. These seed lots are the ones that cause economic problems. Seed lots with low germination should not be used. Even under mild stress conditions, germination test results often are not predictive of emergence (Table 1). TeKrony and Egli (1991) noted that high vigor seed for all crops is needed to ensure adequate stands or plant populations of crop seed across a wide range of field conditions. The same requirements are needed for native plants

TABLE 1. Field seeding rates for two certified switchgrass seed lots with similar germination but differing in seed weight and vigor as measured in a greenhouse pot test.

Seed quality test	Seed lot 2060	Seed lot 2061
Germination %	66	66
Total viable seed % (Germinated and dormant seed %)	94	85
Greenhouse pot test %†	80	38
Seeds g^{-1}	480	680
Desired seeding rate	300 PLS m^{-2}	300 PLS m^{-2}
Greenhouse emerged seedlings g^{-1} seed	384	258
Bulk seeding rate kg ha^{-1}	7.8	11.6

†Greenhouse pot tests consists of four replicates of 100 seeds planted 1 cm deep in soil in greenhouse pot; the number of emerged seedlings are counted.

because the field conditions are often significantly less favorable for seedling establishment and growth than under cultivated conditions. The vigor and stress tests need to be reproducible, correlated with field emergence, objective, simple, rapid, and inexpensive (TeKrony, 1983). Vigor or stress tests that appear to have the most potential with small seeded species and which meet these requirements are emergence from depth (Asay and Johnson, 1980) and accelerated aging (Hall and Weisner, 1990).

Standard germination and purity tests cannot be used directly to calculate planting rates. As an example, field-seeding rates were determined for two certified switchgrass seedlots with the same germination percentages, but with different numbers of seed g^{-1} and different emergence percentages in greenhouse pots. Although the two seed lots had the same germination percentage, emergence percentage differed by over 40% (Table 1.). The number of seeds g^{-1} differed by 200 seeds. Both the number of seeds per gram and the emergence percentage from the mild stress test were used to calculate the kg ha^{-1} of seeds necessary to plant to obtain the desired seeding rate of 300 viable seeds m^2 capable of emergence in soil at field planting depths. Although both seed lots had the same percentage germination, almost 5 kg ha^{-1} more seed of seed lot 2061 should be planted to obtain the desired stand than for seed lot 2060 (Table 1.). In our laboratory, the number of seeds g^{-1} for the cultivar Sunburst has varied from 450 to 850 seeds. Similar variation exists for seed lots of other switchgrass cultivars and seed lots of other native species. Consequently, use of average seed numbers per g of seed to calculate seeding rates has a large margin of error. The number of seeds that can emerge under field conditions is needed to calculate seeding rates.

SUMMARY

New tests need to be developed that can predict establishment capability under field conditions for native species. These tests should be based on a standard unit weight for each species. For example, for switchgrass, 0.25 g could be used as the test unit. The heaviest seed lots of switchgrass have approximately 400 seeds per gram which would result in a minimum of 100 seeds being tested. The number of seedlings that emerge from a standard unit weight of seed of a species under standardized stress conditions "Standarized Establishment Test" (SET) could be easily used to calculate seeding rates. Dormant or hard seed could be ignored because these factors may not be useful in obtaining the rapid re-vegetation needed to stabilize sites. A SET test could reduce seed testing time and costs because it would not be necessary to manually check chaffy seed units for caryopses. A minimum SET score for number of emerged seedlings per unit of seed also could be established below which plant material would not be classified as seed. Inadequately cleaned and processed seed lots would not have the required number of SET seeds per unit weight. Additional research on stress tests and field emergence is needed to obtain practical and reliable seed quality tests for native species.

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