Seed Production of Native Grassland Plants

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Key points : Native seeds are used for ecological recreation of grasslands or for forages especially in hot subtropical regions were both exotic tropical and temperate species lack adaptation . Recreation requires multi-species seed mixes using local germplasm introduced as hay , by activating seed banks or as seed . Native based forages are usually delivered as single species delivered as seed using modifications of seed production systems used for exotic seed production . The paper examines factors associated with these two approaches .

Key words : Ecological issues , hay strewing , donor species

Introduction

Seed production of native grassland plants has two broad purposes ; (i) to provide seed to restore or recreate semi-natural grassland areas , often in areas that have had a recent history of being developed for arable cropping or developed and failed to sustain exotic grassland species , or repairing land damaged by civil engineering and evacuation projects (e .g . road construction and utilities access) , or (ii) to provide local germplasm where commercially available cultivars of exotic species fail through poor adaptation . The failure of exotic grassland species are most obvious in warm semi-tropic areas (e .g . Guangxi Province , China) , where occasional winter frosts limit the introduction of tropical species , while high summer temperatures and prolonged post-monsoonal dry periods are too extreme for temperate forage species .

The approaches to seed production for these two broadly different objectives have taken different paths . With recreated grasslands , there is a strong focus on the ecological consequences of species introduction and the use of local ecotype genetics , rather than re-establishing the species with non-local ecotypes or cultivars of the same species . Production of native seeds for recreation and restoration involves the development of seed collection and introduction practices that use local ecotypes . It is by definition multi-species oriented and uses seed mixes that contain many (all) of the species of the historical grassland . Seed industry concepts of seed purity and quality are less important than having a diverse species mix that recreates the original grassland . Traditional seed agronomists are often absent from the ecological teams involved in these projects . In contrast , developing improved grassland with native species is a modification of selection , simple breeding and multiplication approach already used with exotic species with a focus on developing single species seed lots of high purity and germination .

Native plant seed production , especially grasses present problems that plant breeders have reduced in with marketed species ; (i) indeterminate flowering-grasses that have a wide flowering period ; (ii) seed shattering and a rapid loss within one to three days after ripening ; (iii) low seed yield per unit area and (iv) lack of remnant areas for harvesting (Chivers , 2003) . Native grasses are commonly difficult to harvest because of the nature of the seed that include (i) seeds with fluffy appendages (*Bothriochloa* spp) ; (ii) seeds with long , hygrosopoic awns (e .g . *Themeda* spp) and (iii) seeds with adherent lemmas (e .g . *Microlaena* spp) .

Grassland recreation techniques

A number of methods are used to introduce native seeds into grasslands for restoration and recreation :

i . Hay strewing . The collection of seed-rich hay and transfer of hay to species depleted areas is a technology traditionally used in the European Alps to restore swards in pasture and is still implemented in natural grasslands in Scotland (Edwards et al . , 2007) . In contrast to planting and sowing of seed , hay transfer allowed not only quick establishment of target species but also persistence over nine years (Kiehl and Pfadenhauer , 2007 , Kiehl and Wagner , 2006) .

ii . Seed banks . Soil disturbance to release seed banks can be an important contribution to regeneration (Pakeman and Marshall , 1997 ; Murdoch , 2006) . Soil enriched with seed banks have been used as donor seed sources to establish native grasslands on abandoned arable land (Vecrin and Muller 2003) . The donor site was an extensively managed mesophilic meadow and vegetation of the translocated meadow was described 8 to 17 months after soil translocation and compared with vegetation resulting from more classical revegetation by either using natural reseeding or sowing seed mixtures . Results showed that the soil translocation technique permitted the development of many meadow species . However , it is only relevant on small areas .

iii . Exchanges with neighbouring environment through the role of herbivory and transhumance shepherding in aiding seed dispersal was identified as important in maintaining species richness (Poschold et al . , 1998) . Endozoochorous seed dispersal in dung especially by sheep and rabbits (Pakeman et al . , 2002) and cattle (unpublished data of seed survival of 13 cultivated grass and legume species after transit through cattle , Huyghe pers comm .) can have significant effect on the dynamics of species richness .

iv .Sowing seed requires harvested seed e .g . surface sowing of brush harvested seeds (Edwards et al ., 2007) or strip sowing which can provide a lower cost but slower and longer-term alternative to field scale sowing (Jongepierova et al ., 2007) .

Ecological considerations

There are numerous ecological considerations on the question of which species , populations and material should be multiplied and sown .

i .The choice of species is critical as shown by Warren (2000) on the impact of white clover through soil fertility and available nitrogen . Introduction of an exotic species may significantly alter soil fertility and ecosystem functioning .

ii .Population size for seed multiplication in order to avoid genetic drift is important . Most species are cross-pollinated and many are polyploid . Hay strewing and vacuum harvesting avoid genetic drift as whole populations are harvested and sown . If a collected sample is multiplied , the initial genetic diversity may be fairly narrow and reduce the adaptability of the population . However , low genetic diversity within a population is less critical than genetic differences between local and non-local ecotypes . Introducing exotic germplasm may endanger the local remnant populations (Gustafson et al ., 2004) , especially when the exotic germplasm is improved varieties . In such cases , exotic germplasm may exhibit improved disease resistance , higher seed production and modified phenology , all three traits inducing a negative selection pressure on the local remnant populations , both through direct competition or through hybridization and gene transfer .

iii .Both local seed mixtures and commercial seed mixtures prevent invasion of local desirable (and undesirable) species (Jongepierova et al ., 2007) . This is relevant with results on sown grasslands where invasibility decreases when the number of species increases (Bezemer and Van der Putten , 2007 ; Fukami et al ., 2005) . Many seeded species can survive and establish in the presence of pre-exisiting vegetation including invasive exotic plants (Guo et al ., 2006) . Complexity of the initial species mixtures will affects the composition of years but competition and facilitation will progressively lead to sward stratification (Guo et al ., 2006) . Both the diversity (number of species) and the identity of the species (Deak et al ., 2004) will play a key role in the changes of the swards and the possibility of future invasion by exotic species .

iv .If exotic species are to be used and introduced , either alone or in mixtures with native species , it creates a situation close to species invasion . It creates conditions which may promote evolutionary diversification and especially establishment of allopatric populations in new environmental conditions , altered ecological opportunities for native species as well as opportunities for hybridisation between previously allopatric taxa , species and populations . Many studies , reviewed by Vellend et al . (2007) showed that introduction of exotic species actually promoted evolutionary diversification via increased genetic differentiation among population of exotic and native species and creation of new hybrid . Thus , the reduction of biodiversity caused by introduction of exotic species may be balanced or outweighed by this diversification .

v .Questions on the importance of seed size are not understood but seedling establishment is a complex process and seed size may affect various traits both in a positive and negative manner .

A conceptual framework of the effects of exotic species introduction on native species and populations and on genetic diversification is shown in Figure 1 .

Seed production

Seed production of native species involves a number of approaches including :

i .Hay strewing , i .e . the use of fresh hay to transfer seed from donor fields . The timing of hay cutting should be appropriate to enable seed of the desired species to be collected (Edwards et al ., 2007) . Time of cutting determines both the number of seeds of the desired species and their viability .

ii .Brush harvesting with modified harvesters (Edwards et al ., 2007) including stripper headers (Anon , 1996) and beater harvesters (Loch and Boyce , 2003) . Repeated collection over the season enables the collection of a wide range of species .

iii .Vacuum (suction) harvesting including hand vacuum harvesting from established communities . Riley et al . (2004) demonstrated the effect of time of harvest in relation to species phenology and presence of mature seed greatly affected the species composition of the collected seed . The most abundant species are also the most abundant in the vacuum collected material but characteristic species may be absent or fail to germinate . It has to be combined with other techniques to target desired species that may be sown with commercial seeds to stabilise the soil with the vacuum harvested seeds only as an inoculum , the rest of the sites being colonized through natural dispersal . Hand vacuum harvesting is slow with low collection rates , e .g . 120 g seed/hr (Riley et al ., 2004) .

iv .Village based seed production as developed in Thailand is well suited for native species and species not well suited to

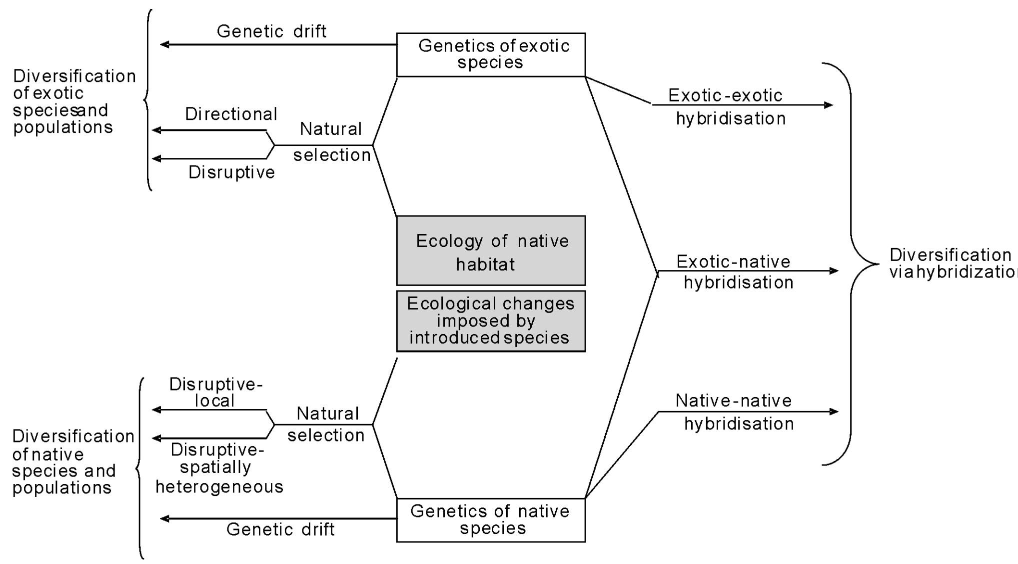

Figure 1 *Conceptual framework of the effects of exotic species introduction on native species and populations and on genetic diversification.*

traditional machine harvesting (Phaikaew and Hare, 1996) or required locally. The village based seed production model used in Thailand (Hare, 2006) is currently producing quantities of 100 to 200 tons of seed of new grass and legume species for use in Thailand and export, Mulato II (*Brachiaria ruziziensis* x *B. brizantha x B. decumbens*), Ubon paspalum (*Paspalum atratum*) and Ubon stylo (*Stylosanthes guianensis* var. *vulgaris* x var. *pauciflora*) using many farmers each growing 10 to 50 kg of seed. Farmers plant individual plants in wide rows, staking them to allow the hand harvesting seed. The harvesting is usually repeated at 2 to 3 day intervals over several weeks, shaking seeds into baskets and hand cleaning to remove very light seed and coarse impurities. After collection seed lots are bulked and machine cleaned to achieve a high purity and germination. The success of this approach is a mix of adequate farmer training, good cash returns compared to traditional crops for village farmers, payment on delivery or collection and the production of high quality seed by machine cleaning bulked seed lots. Village seed production has brought economic benefits to many smallholders through higher returns per hectare and enabled them to grow crops that do not deplete soil fertility. Probably the most important underlying factors contributing to the development of village seed production in Thailand has been the continuity and commitment by the government including continuous research and development for more than 20 years, continuity and experience of key staff. The challenge for future seed supplies in Asia is to gradually transfer the role of marketing from government to the private sector.

Seed quality and yield. Harvesting of donor grassland fields often results in seed of poor quality. In one example the average seed viability of a mix of 47 species collected by vacuum harvesting grassland communities was between 7 and 10%, reflecting high rates of insect and fungal attacks (Stevenson et al., 1995). Seed viability was assessed as seedling emergence in a glasshouse, and does not account for seed dormancy which may also be important in reducing germination and emergence.

Regulation of native seed production

Regulations have been developed in several countries in the world. A similar work has been undertaken in Europe in order to prepare a directive defining the conditions for marketing native grasslands seed mixtures for recreation of species rich meadows. The objective was to define the conditions for marketing seeds from species rich meadows for seeding grasslands in the same region and in similar environmental conditions. It was aimed at targeting environment with a high level of diversity. This work has not been completed yet and it is informative to investigate the pending questions.

i. Species identification and determination of their proportion. As mentioned above the species identity and their respective abundance is critical for the establishment and the long term dynamics of the restored swards. Thus, it would make sense, for the end users to document these items. Even though it is a time-consuming charge, this information should be provided.

ii. Should the species composition be constant? Harvests performed in a same collection sites but in different years will provide a different species composition and different species abundance. Regular vacuum harvests will likely reduce the variation over years but not fully prevent it. The geographic origin of the seed mix then becomes the only constant feature. However, combination of geographic origin and species composition provides key elements to the end-users .

iii .Should there be a standard for germination rate and seed quality ? There is a wide range of seed quality among meadow species and it is not feasible to require a minimum germination rate . However , native species seed with low germination rates and differences among species will not meet the expectations of the users . This may result in fully unpredictable sward compositions . Again , minimum information would be required .

iv .Is there a role for a seed certification process ? Seed certification aims at providing guarantee of seed quality and species (and cultivar) identity . Such a process would be needed due to the high value of the seed in biological , ecological and economic terms . However , it seems very difficult to implement a full certification process , especially a guarantee on the exact source of the material . However , an adapted process with information on the species composition (item i) and actual germination rate (item iii) would be beneficial . Hay for strewing cannot be certified as its seed content cannot be measured and guaranteed . For many years the New Zealand Seed Certification Scheme recognized regional ecotypes of crested dogstail (*Cynosurus cristatus*) and Chewing fescue (*Festuca rubra commutata*) produced within defined geographic boundaries . This approach may be useful in the development of a certification process for native seeds .

Discussion

Can the restoration grassland ecologist learn from the seed production agronomist in the management of donor seed sites ? Seed production technology of exotic species continues to result in improved seed yield and quality with an increasing understanding of seed crop agronomy (e .g . sowing rates and stand density) , nutrient requirements , reduced lodging with plant growth regulators , weed , insect pest and disease control , harvesting approaches and post-harvest crop management . Would native seed crops also benefit from these tools and can these seed production tools be used without compromising the genetic integrity of native seeds ? Chivers (2003) comments that in Australia seed yields per hectare of native grasses are being improved , if slowly , by better agronomic understanding of the requirements of each grass .

References

Anon , 1997 . Ggeneral principles of native grass seed production . In : Native grass seed production manual (including selected forbs) eds . Smith jr . S .R . ; Smith , S . University of Manitobia .

Bezemer , T .M . , Van der Putten , W .H . , 2007 . Ecology-Diversity and stability in plant communities . *Nature* 446 , E6-E7 .

Chivers , I . 2003 . Australian native grasses-why ? how ? Proceedings 5th International Herbage Seed Conference , Gatton , Australia . 69-73 .

Deak , A .M . , Hall , M .H . , Sanderson , M .A . , 2004 . Forage production and forage mixture complexity . Proceedings American Forage Grassland Conference 13 , 220-224 .

Edwards , A .R . , Mortimer , S .R . , Lawson , C .S . , Westbury , D .B . , Harris , S .J . , Woodcock , B .A . , Brown , V .K . , 2007 . Hay strewing , brush harvesting of seed and soil disturbance as tools for the enhancement of botanical diversity in grasslands . *Biological Conservation* 134 , 372-382 .

Hare , M .D . , 2006 . Applied research leads to successful export seed production of South American forages in Ubon Ratchathani province , Thailand . *International Herbage Seed Group Newsletter* 40 , 6-9 .

Fukami , T . , Bezemer , T .M . , Mortimer , S .R . , Van der Putten , W .H . , 2005 . Species divergence and trait convergence in experimental plant community assembly . **Ecology Letters** 8 , 1283-1290 .

Guo , Q .F . , Shaffer , T . , Buhl , T . , 2006 . Community maturity species saturatation , and the variant diversity-productivity relationship in grasslands . *Ecology Letters* 9 , 1284-1292 .

Gustafson , D .J . , Gibson , D .J . , Nickrent , D .L . , 2004 . Conservation genetics of two co-dominant grass species in an endangered grassland ecosystem , *Journal of Applied Ecology* 41 , 389-397 .

Horne , P .M . , Sturr , W .W . , 1999 . Developing forage technologies with smallholder farmers-how to select the best varieties to offer farmers in Southeast Asia . ACIAR Monograph .

Kiehl , K . , Pfadenhauer , J . , 2007 . Establishment and persistence of target species in newly created calcareous grasslands on former arable fields . *Plant Ecology* 189 , 31-48 .

Kiehl , K . , Wagner , C . , 2006 . Effect of hay transfer on long-term establishment of vegetation and grasshoppers on former arable fields . *Restoration Ecology* 14 , 157-166 .

Jongepierova , I . , Mitchley , J . , Tzanopoulos , J . , 2007 . A field experiment to recreate species rich hay meadows using regional seed mixes . , Biological Conservation 139 , 297-305 .

Loch , D .S . , Boyce , K .G . , 2003 . Overview of the Australian herbage seed industry . Proceedings 5th International Herbage Seed Conference , Gatton , Australia . 10-21 .

Murdoch , A .J . , 2006 . Soil seed banks . In :Handbook of Seed science and Technology . Chapter 18 , 501-520 .

Pakeman , R .J . , Digneffe , G . , Small , J .L . , 2002 . Ecological correlates of endozoochory by herbivores . Functional Eecology 16 , 296-304 .

Pakeman , R .J . , Marshall , AG . , 1997 . The seed banks of the Breckland heaths and heath grasslands , eastern England , and their relationship to the vegetation and the effects of management . Journal of Biogeography 24 , 375-390 .

Phaikaew , C . , Hare , M . , 1996 . Thailands experience with forage seed supply systems . In . Horne , P .M . ; C . Phaikaew and

W.W, Stur (eds.). Forage Seed Supply Systems. Proceedings of International Workshop held in Khon Kaen, Thailand. CIAT Working Document Number 175.

Poschold, P., Kiefer, S., Tranke, U., Fischer, S., Bonn, S., 1998. Plant species richness in calcareous grasslands as affected by dispersability in space and time. *Applied Vegetation Science* 1, 75-90.

Riley, J.D., Craft, I.W., Rimmer, D.L., Smith, R.S., 2004. Restoration of magnesium limestone grassland: optimizing the time for seed collection by vacuum harvesting. *Restoration Ecology* 12, 311-317.

Vellend, M., Harmon, L J., Lockwood, J.L., Mayfield, M.M., Hugues, A.R., Wares, J.P., Sax, D.F., 2007. Effects of exotic species on evolutionary diversification. *Trends in Ecology and Evolution* 22, 481-488.

Stevenson, M.J., Bullock, J.M., Ward, L.K., 1995. Re-creating semi-natural communities: effect of sowing rate on establishment of calcareous grasslands. *Restoration Ecology* 3, 279-289.

Vecrin, M.P., Muller, S. 2003. Top-soil translocation as a technique in the re-creation of species-rich meadows. *Applied Vegetation Science* 6, 271-278.

Warren, J.M., 2000. The role of white clover in the loss of diversity in grassland habitat restoration. *Restoration Ecology* 8, 318-323.