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REVIEW

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A review of sod-seeding for pasture improvement in Saskatchewan, Canada

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ABSTRACT

The Canadian province of Saskatchewan is located on the Great Plains of North America and is an important beef (*Bos taurus*) production region. Pasture rejuvenation through sod-seeding has been little adopted by beef producers in the province despite forty years of research. We reviewed the research results to determine the successes and gaps in knowledge to guide current and future research and extension activities and crop insurance programs. Alfalfa (*Medicago sativa L.*) sod-seeding results have been more consistent than other legumes and is currently the standard legume, though both Cicer milkvetch (*Astragalus cicer L.*) and alfalfa established well in sub-humid (wetter) locations. As non-bloat legume species and other such varieties are released by plant breeding programs, more research on alternative legumes, such as sainfoin, (*Onobrychis viciifolia Scop.*), should be conducted. P fertilizer with sod-seeding species improved seedling establishment. Vegetation control of existing pasture species was found to improve sod-seeding success in semi-arid locations, while it was not required in sub-humid locations. The cost of broad-spectrum herbicide to reduce existing pasture species competition has decreased dramatically since much of the research was done. Therefore, the economics of herbicide suppression for successful sod-seeding should be re-examined at current pricing and across a range of soil zones represented in the province. Modern zero-till seed drills can be used for sod-seeding in semi-arid soil zones, while broadcast seeding can be used in subhumid soil zones.

KEYWORDS

Forage; Pasture; Legumes; Competition; Herbicide

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Introduction

Over 5 million acres of seeded pastures (not including native grass rangelands) support the grazing of over 1 million beef cows (*Bos taurus*) in the Canadian province of Saskatchewan. Located at the northern edge of the Great Plains of North America, the agricultural biomes of the province are diverse, with semi-arid grasslands in the south and boreal forests in the central and northern regions [1]. Soil zones are classified on organic matter content and color but also reflect differences in growing season precipitation and evapotranspiration ranging from semi-arid Brown Chernozem soil in the south to sub-humid Black and Grey soils in central Saskatchewan [1]. Pasture grazing of beef cows and calves during late spring, summer, and early fall seasons constitutes a significant portion of the feed base for the beef industry (For the purpose of this review, pasture refers to seeded, introduced forage species and not to native rangeland). Forage production from pasture is grazed from late spring (May/June) until fall freezes up (September/October), depending on the biome within the province [2].

Forage yield of seeded perennial species is usually highest in the first few years after establishment and declines over time [3] due to the loss of productive species to injury from pests or disease, winter kill, or defoliation stress from frequent grazing. The decline in seeded species plant population results in decreased forage production and is followed by an invasion of naturalized or native species [4]. The traditional method to rejuvenate low-productivity pastures has been tillage followed by grain or oilseed crops for two to three years, followed by reseeding and establishment of new perennial pasture species. This practice exposes soil to wind and water erosion, takes several years to complete, and does not fit the increasing specialization of crop farms and beef cattle ranches into separate and mutually exclusive enterprises.

Sod-seeding is a practice whereby the desirable forage species are seeded directly into the existing sod without intensive mechanical tillage to prepare the soil [4]. In some cases, the soil may be partially tilled to prepare a narrow furrow to receive the new seed. Grazing to 80% or more defoliation of the existing pasture, prior to seeding has been utilized to control competition [5]. In other cases, non-selective herbicides may be used to control the existing vegetation prior to seeding. In some cases, the seed is broadcast spread across the existing vegetation without any vegetation control.

There has been research on sod-seeding in Saskatchewan for over four decades, but this information has not resulted in wide adoption of sod-seeding by beef producers. As Waddington points out [6], the research results vary widely from study to study, from very successful sod-seeding results to complete failures. Sufficient research (Table 1) has been conducted to permit a combined analysis of the factors that affect sod-seeding success such as species for seeding, fertilizer, water stress, herbicide, tillage and seeding equipments [6].

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Table 1. Sources of sod-seeding results by location, soil zone, existing vegetation, and sod-seeded species.

Location	Soil Zone[z]	Existing vegetation	Seeded species[y]	Reference
Regina	Dark Brown	bromegrass	Alfalfa, sainfoin	[4]
Shell Lake	Grey	bromegrass	Birdsfoot trefoil, CMV, meadow brome, PPC, native grasses	[4]
Crane Valley	Brown	grass	Alfalfa	[6]
Indian Head	Black	grass	Alfalfa	[6]
Lanigan	Black	grass	Alfalfa	[6]
Pathlow	Grey	grass	Alfalfa	[6]
Scott	Dark Brown	grass	Alfalfa	[6]
Swift Current	Brown	grass	Alfalfa	[6]
Swift Current	Brown	Crested wheatgrass	Alfalfa	[7]
Swift Current	Brown	Russian wildrye	Alfalfa	[8]
Lanigan	Black	crested wheatgrass	Alfalfa	[9]
Lanigan	Black	bromegrass	Alfalfa, CMV	[10]
Pathlow	Black	grass	Alfalfa & grass	[11]
Kelliher	Grey	bluegrass	Alfalfa & grass	[12]
Neudorf	Black	crested wheatgrass	Alfalfa	[13]
Pathlow	Grey	grass	Alfalfa, CMV	[14]
St Walberg	Grey	bromegrass	Alfalfa, CMV	[15]
Swift Current	Brown	crested wheatgrass	Alfalfa, sweet clover	[15]
Swift Current	Brown	Russian wildrye	Alfalfa, sweet clover	[15]
Swift Current	Brown	crested wheatgrass	Alfalfa	[16]
Hyde	Black	grass	Alfalfa	[17]

z SKSIS Working Group. 2018 [1]
y CMV – Cicer milkvetch, PPC – Purple Prairie Clover

Species for Sod-Seeding

Alfalfa (*Medicago sativa L.*) is a forage legume species widely adapted to soil zones in Saskatchewan. It fixes atmospheric Nitrogen by symbiosis with *Rhizobacterium sp*. contained in root nodules, and this results in a high protein forage with excellent nutritive value for grazing ruminant livestock. Alfalfa has also been shown to associate with root mycorrhizae fungi to provide access to non-soluble soil P [18]. The sustainability of semi-arid prairie grasslands can be improved by the inclusion of alfalfa [18].

Alfalfa is a commonly used forage legume species for rejuvenating pastures due to its seedling vigor, high forage yield potential, biological nitrogen fixation, and forage quality for ruminant grazing [6-9]. When several legume species were compared for sod-seeding in semi-arid southwestern Saskatchewan, alfalfa established most successfully and was most productive [19]. Sweet clover (*Melilotus officinalis L.*) and Cicer milkvetch (CMV) (*Astragalus cicer L.*) have worked well in some sod-seeding experiments in Saskatchewan [4,10], especially in the Black and Grey soil zone locations. Sod-seeded sainfoin (*Onobrychis viciifolia Scop.*) as well as CMV established at Lanigan, Saskatchewan but did not persist as well after 5 years of grazing [10].

Other legume species have been recommended in regions with higher and better rainfall distribution during the growing season. In the wetter regions of North America, legumes such as red clover (*Trifolium pratense L.*), Ladino clover (*Trifolium repens L.*), birds foot trefoil (*Lotus corniculatus L.*), or CMV are desirable for pasture improvement.

Birds foot trefoil and purple prairie clover (PPC) (*Dalea purpurea*) had higher seedling counts than alfalfa or CMV ($P<0.01$, Table 2) when combined across Saskatchewan research studies. Sweet clover and sainfoin seedling counts were not reported for enough studies to permit comparisons that included these species. However, sod-seeded alfalfa produced more ($P=0.04$) forage DM yield than CMV or PPC (Table 2). This appears contradictory in that the species with a smaller number of established seedlings should produce more DM yield than species with a greater number of established plants. However, the greater yield is explained by the relative size of the alfalfa plants compared to the other species. According to Schellenberg and colleagues, alfalfa plants can be affected by competition from adjacent plants [7]. Waddington concluded that 15 to 25 alfalfa plants per meter of seeded row would be sufficient to provide a positive forage yield response [6]. The average number of alfalfa seedlings described in Table 2 is at the low end of this range but still provided a greater yield response than the other forage legume species.

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Table 2. Legume species effect on sod-seeded legume counts and forage DMY yield and standard errors of the mean after sod-seeding in eight research studies.

Species	Seedling count m^{-1}		DM yield kg ha^{-1}	
	LS mean	SEM	LS mean	SEM
Alfalfa	14.4	3.7	2014	173
Birdsfoot trefoil	104.0	25.0	--	--
Cicer milkvetch	17.4	4.9	1535	520
Purple prairie clover	78.0	22.0	200	76

As alfalfa has been studied in more sod-seeding experiments than any other legume species and has the potential to improve subsequent forage yield more than other legumes, it can be concluded that alfalfa should be considered as the standard legume for sod-seeding in Saskatchewan for pasture rejuvenation. However, plant breeding programs are developing new cultivars of non-bloating legumes such as sainfoin, and this conclusion will need to be re-evaluated with new cultivar releases.

Soil Water

Plant seeds must imbibe sufficient water from the surrounding soil to initiate germination. In Saskatchewan, the probability of precipitation peaks in late June and early July and declines during July and August. The seed dormancy of the species chosen for pasture improvement through sod-seeding must be aligned with seasonal precipitation and temperature patterns needed for germination to permit the greatest probability of successful seedling establishment. The high degree of variability in sod-seeding results in research studies in the past can be partially attributed to the dependence of seedling establishment on timing and amount of precipitation [4].

Soil zones of Saskatchewan are classified based on organic matter content and color but also reflect differences in growing season precipitation and evapotranspiration [1]. The Brown soil zone typically exhibits the lowest precipitation and highest evapotranspiration and thereby, the highest risk of water limitation for seed germination and seedling establishment. The Dark Brown zone soil exhibits higher precipitation and lower evapotranspiration than the Brown soil zone. The Black and Grey soil zones exhibit the lowest evapotranspiration and highest precipitation during the growing season.

Soil water at Swift Current SK, a semi-arid Brown soil zone site, limited alfalfa seedling establishment in sod-seeding research due to the competition from adjacent existing crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) [7,8]. There was less seedling establishment in dry years than in wet years and when a smaller area of adjacent crested wheatgrass was controlled by herbicide.

In the sub-humid Black and Grey soil zones, Waddington and Bowren reported successful seedling establishment at Pathlow SK during summer, if the seeding occurred within two weeks of the herbicide vegetation control [11]. Other reports indicate successful sod-seeding in these soil zones [9,10,12-14,20]. Schellenberg reported that forage yield was less after rejuvenation treatments at St. Walberg, SK [15]. The authors attributed the yield loss to drought conditions in 1995, the year after the rejuvenation treatments were applied. Drought can be a factor in forage rejuvenation success in the Black and Grey soil zones but less frequently than in the semi-arid Brown soil zone.

Several field studies of sod-seeding data on established seedlings had been reported [6-9,12-14,16,20]. When combined across these reports, soil zone was found to have a significant (P=0.01) effect on seedling establishment (Table 3). The Brown soil zone studies resulted in the lowest number of seedlings established, while the Grey soil zone exhibited the highest number. This is consistent with greater soil water limitation in the Brown soil zone compared to Black and Grey soil zones [1]. Sod-seeding programming or insurance programs should account for this soil zone difference in the probability of seedling establishment success. It should also be noted that the largest standard error was observed for the Dark Brown soil zone, but this likely results from the smallest number of research studies (only two) for this region.

Table 3. Least-square mean seedling establishment and standard error of the mean by zone soil from eight research studies.

Soil Zone[1]	Seedlings established (m^{-2})	SEM
Brown	9.5	2.9
Dark Brown	10.0	39.0
Black	20.3	9.2
Grey	58.7	11.8

Fertility

Competition for soil nutrients from existing vegetation may also impact sod-seeded seedling establishment [4]. However, most research studies did not include a fertilizer treatment in conjunction with the sod-seeded species. Studies that included some level of P fertilizer showed a trend (2640 *vs.* 1840 kg ha-1, P=0.06) for improved forage DM yield [11,13,15,17,20,21]. There was no benefit to additional N fertilizer averaged over three published studies [11,13,15].

The application of fertility to sod-seeding does not appear essential to the success of the endeavor. However, soil-test P concentration is consistently low in long-term pastures, and application of starter P fertility is generally recommended when seeding forage legumes in other scenarios. So, it should be considered as a good management practice for sod-seeding of legume forages in Saskatchewan.

Herbicide

In the semi-arid Brown soil zone of southwestern Saskatchewan, Schellenberg reported more alfalfa seedlings per m row (21.7 *vs.* 3.7), greater DM alfalfa yield (499 *vs.* 39 kg

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ha-1), and a larger contribution to total forage biomass (28.3 *vs.* 3.2 %) for sod-seeding with herbicide control compared to no herbicide control of crested wheatgrass [8]. These authors also reported that more alfalfa seedlings were established, and greater alfalfa forage yield was harvested as the width of the strip of vegetation control adjacent to the sod-seeding row was increased.

Schellenberg also measured etiolated regrowth in the spring after establishment because etiolated regrowth is a measure of over-winter root carbohydrate reserves that can be mobilized for spring growth [7,22]. They reported that the etiolated growth of alfalfa established with vegetation control was 4 to 15-fold greater compared to alfalfa plants seeded with no vegetation control indicating that vegetation control by herbicide increased sod-seeded plant root growth and carbohydrate reserves.

At a Black soil zone site in the Parkland region, Bowes and Zentner reported vegetation control with herbicide prior to seeding improved sod-seeded alfalfa seedling number (10 *vs.* 6) and subsequent DM forage yield (1973 *vs.* 1287 kg ha^{-1}) [12]. DM forage yield was reduced in dry years (1980,1982) compared to wet years (1981,1983), but the proportion of alfalfa in the total forage biomass was similar in either dry or wet years. Malik and Waddington also reported that glyphosate control of existing vegetation improved alfalfa and cicer milkvetch seedling establishment at Pathlow SK [14].

In another Black soil zone trial at Neudorf SK, Peat and Bowes also found that glyphosate treatment of existing crested wheatgrass pasture was necessary for the successful establishment of alfalfa seedlings and alfalfa contribution to increased forage yield [13]. Application of the herbicide in spring (May) to actively growing grass plants, followed by seeding in May or June, resulted in the best establishment of alfalfa seedlings.

At Lanigan SK, Jefferson et al. reported a larger contribution of sod-seeding alfalfa to forage yield when glyphosate herbicide was applied pre-seeding to reduce competition from the existing grass pasture [9]. The seedling establishment was satisfactory without herbicide application (30 seedlings per m row) but the contribution to forage yield was less than 5%. With herbicide application, however, there were more seedlings established (70 per m row), and the contribution to forage yield was nearly 60% of the harvested biomass. Nine-years after sod-seeding, there were still more alfalfa plants in seeded plots compared to the control plots, but no difference in forage yield due to herbicide application was observed.

As Waddington noted, the use of herbicide to control existing vegetation and allow sod-seeded species to establish results in lowered forage DM yield in the season of the herbicide treatment [6]. This means that forage yield is not improved in the year of herbicide application and sod-seeding compared to the check treatment. Some studies reported the botanical composition of the forage crop harvested after sod-seeding, and this information can be used to calculate the yield of the seeded species after sod-seeding [9,11,13,15,16]. When herbicide was used in these research studies, there was increased seedling establishment (P=0.07) and greater DM yield of the seeded species. Where herbicide was not used, there was no correlation (P=0.88) between seedling establishment and forage DM yield of the seeded species.

It is a common practice in wetter regions of North America to heavily graze the existing stands and then direct seed into them either in the late fall after frost or in the early spring. This technique also requires a 25% increase in the legume seeding rate. It is often mentioned in anecdotal reports by producers about sod-seeding, but little research data is available to confirm success rates. It has the advantage of avoiding any herbicide application in organic systems or other situations where herbicide application is undesirable [5].

On the question of using herbicides to control existing vegetation, the conclusions of research studies have been mixed due to the loss of forage yield after non-selective herbicide application. If we examine the value of herbicide application where seedling number and DM yield of the seeded species are reported, we must draw the conclusion that the use of herbicide to control existing vegetation in semi-arid biomes is necessary to improve the probability of sod-seeding success. However, in sub-humid locations, herbicide vegetation control was not consistently required for successful sod-seeding.

Tillage

Bowes and Zentner simulated a tillage treatment with several passes of a rotovator prior to seeding alfalfa at a Parkland site near Kelliher, SK [12]. Tillage promoted seedling establishment compared to no treatment (7 *vs.* 6 seedlings per m row) and forage DM yield (1578 *vs.* 1287 kg ha-1). Conversely, Waddington and Bowren reported that rotovating prior to seeding resulted in a light, fluffy seedbed that did not provide for adequate seed: soil contact and resulted in more weeds than seeded forage plants [11].

Schellenberg imposed mechanical root treatment on the existing plants of Russian wildrye (*Psathyrostachys juncea* (Fisch.) Nevski) when alfalfa was sod-seeded between the Russian wildrye rows [8]. This improved alfalfa seedling survival in one year of three years for the trial, and in that year, the precipitation during June (month of seeding) was less than the thirty-year average. Over all three years, there were occasional benefits in soil water content from mechanical severing of existing Russian wildrye grass roots. The value of tillage to reduce competition from the existing vegetation in sod-seeding appears to be minimal.

Seeding Equipment

Pasture conditions vary greatly among soil types, vegetation zones, microtopography, and seeded species. Rocks and uneven surfaces are common in pastures, even where native grassland vegetation has been replaced by seeded grasses. This microscale variation in topography and soil bulk density precludes the use of grain and oilseed drills where the seeding depth is set and controlled for sections or groups of the older generation of seed drill openers [4]. Waddington compared three commercial and two research drills for seeding alfalfa into grass pastures at several locations in Saskatchewan [6]. He reported that the best alfalfa seedling emergence was observed for drills that independent openers had sufficient weight to penetrate litter and hard soil and also had depth control and on-row packing.

Minimal disturbance (narrow) disk or knife openers are recommended for opening the existing sod and placing the seed at the appropriate depth [23]. Packing behind the opener to close the opening and firm the soil for good soil: seed contact is required. Modern grain and oilseed seed drill openers used in zero tillage crop production systems have the desirable soil

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penetration, depth control, and packing characteristics required for sod-seeding of pastures.

Jefferson et al. compared six commercially available seed drill openers for sod-seeding alfalfa in crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) pasture at Lanigan SK [9]. They mounted the openers sequentially on one research seeding implement, so the metering of seeds did not differ between openers. Seed placement and seedling establishment did not differ among the openers, indicating that all the commercially available seed drills equipped with these openers can be successfully used for sod-seeding alfalfa for pasture rejuvenation. They also reported that the double shank opener (seed applied in one shank and fertilizer in the other) had a higher draft requirement than single shank openers.

Schellenberg and Waddington evaluated a technique of "slot-seeding" for establishing alfalfa in crested wheatgrass pastures in Swift Current [16]. Using combinations of disc openers, they removed a ribbon of sod in front of each seed opener, which allowed the seed to be placed in mineral soil with no adjacent competition. Alfalfa seedling establishment was not improved compared to sod seeding after glyphosate application to control the existing vegetation and its competitive effects on the seedlings.

Broadcast seeding is a fast and convenient method to deliver seeds in rough terrain pasture conditions. Alfalfa seedling establishment ($P<0.01$) and alfalfa yield ($P=0.03$) of broadcast seeding were greater than drilled seeding at a Black soil zone site at Lanigan Saskatchewan (Jefferson unpublished data). In semi-arid conditions of the Brown soil zone of Saskatchewan, drilling seed resulted in better seedling establishment [4].

Timing of Seeding

Spring seeding is recommended for seeding perennial forages in Saskatchewan in any situation, and similar results have been reported for sod-seeding [4,24]. As spring is often a busy season with other field operations receiving higher priority than seeding forages, late fall seeding dates can provide a satisfactory stand of forage seedlings [24]. The soil temperature must be low enough (<5 °C) to avoid germination until spring. Dormant season seeding in November for Saskatchewan conditions can be done, provided that good seed placement and firm soils are ensured [5].

Saline soils are often wet in early spring. Dormant seeding of forages in fall may be required when saline soils have dried.

Waddington and Bowren found that delay from vegetation control until seeding of the desired forages resulted in higher weed infestation [11]. If glyphosate is used for vegetation control, then the spraying must occur during the active growing season of the existing plants. In most of Saskatchewan, the active growing season is generally spring (May and June). It is recommended that seeding operations should occur within 1 to 2 weeks after herbicide application [4].

Economic

Few research studies have examined the economics of sod seeding for pasture rejuvenation. Bowes and Zentner examined the economics of herbicide application or tillage for vegetation control and concluded that no vegetation control treatment was as profitable as the glyphosate treatment [12]. It should be noted that this research was conducted when glyphosate prices were higher than current prices. Glyphosate herbicide price has dropped since the patent expired in the 1990s, and generic forms of the herbicide have helped to reduce cost of sod-seeding with this product [4].

Kelln et al. examined the live weight gain of beef steers grazing the sod-seeded sainfoin or cicer milkvetch and reported increased beef production compared to the control treatment [10]. They also concluded that net returns were not different because the increase in beef production was not great enough to cover the additional cost of sod-seeding.

The adoption of new technology by beef producers is driven by positive net returns on the investment in the technology. More research on low-cost sod-seeding methods is needed to fill this gap.

Conclusions

The approach taken in this review has limitations that must be kept in mind while discussing our conclusions. For example, the lack of a standard methodology for determining sod-seeded plant density was evident across the multiple studies that we reviewed. A meta-analysis approach would require for the use of standard methodologies so that greater confidence can be attributed to the results. However, we compiled the best available data in the literature to study our hypothesis and draw the conclusions: The use of herbicide to control the existing vegetation completely or in a zone around the seeded species will reduce competition and improve seedling establishment and forage yield of the seeded species. In semi-arid locations, using vegetation control will improve sod-seeding success. In the Black soil zone, successful sod-seeding did not always require vegetation control. Alfalfa is the most widely adapted legume and could be used in all soil zones. Cicer milkvetch could be successfully sod-seeded in the Parkland region (Black and Grey soil zones). More research on new sainfoin cultivars and other bloat-safe legume cultivars is needed to make these technologies become commercially available. Since water is a critical factor for successful germination in sod seeding, agronomic practices that increase germination potential when seeding into existing forage stands must be emphasized. Timing of seeding to coincide with the greatest probability of precipitation, reducing existing species' competition for soil, water, and nutrient resources, and seeding species with vigorous seedling growth should be encouraged. An early spring seeding date is recommended, but in wet and saline soil sites that are inaccessible in spring, dormant seeding in late fall can be successful. P fertilizer can aid in seedling establishment. A zero-till drill with narrow openers can be used for sod seeding to improve the probability of success. In the Black and Grey soil zones, broadcast seeding can be used successfully. Beef cattle producers are interested in pasture improvement techniques like sod-seeding but need more information about the economic risks and benefits. Technology adoption needs clear economic returns on the new investment. The economics of sod-seeding with current seed, herbicide, fertilizer, labor, and tillage costs should be evaluated.

Crop insurance programs could help research and extension efforts to improve the uptake of this technology, but to be successful, they must include changes in soil zone, soil water limits, resource competition, and seedling establishment. Edaphic, especially soil zone, and environmental variability

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were apparent in the sod-seeding research results. Accordingly, each sod-seeding project will require adaptive management to ensure optimal seedling establishment success. This does not preclude the development of crop insurance programs to assist producers in reducing the financial risk of these projects. Technical advice to producers prior to sod-seeding will be the key to reducing the risk of inadequate seedling establishment.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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