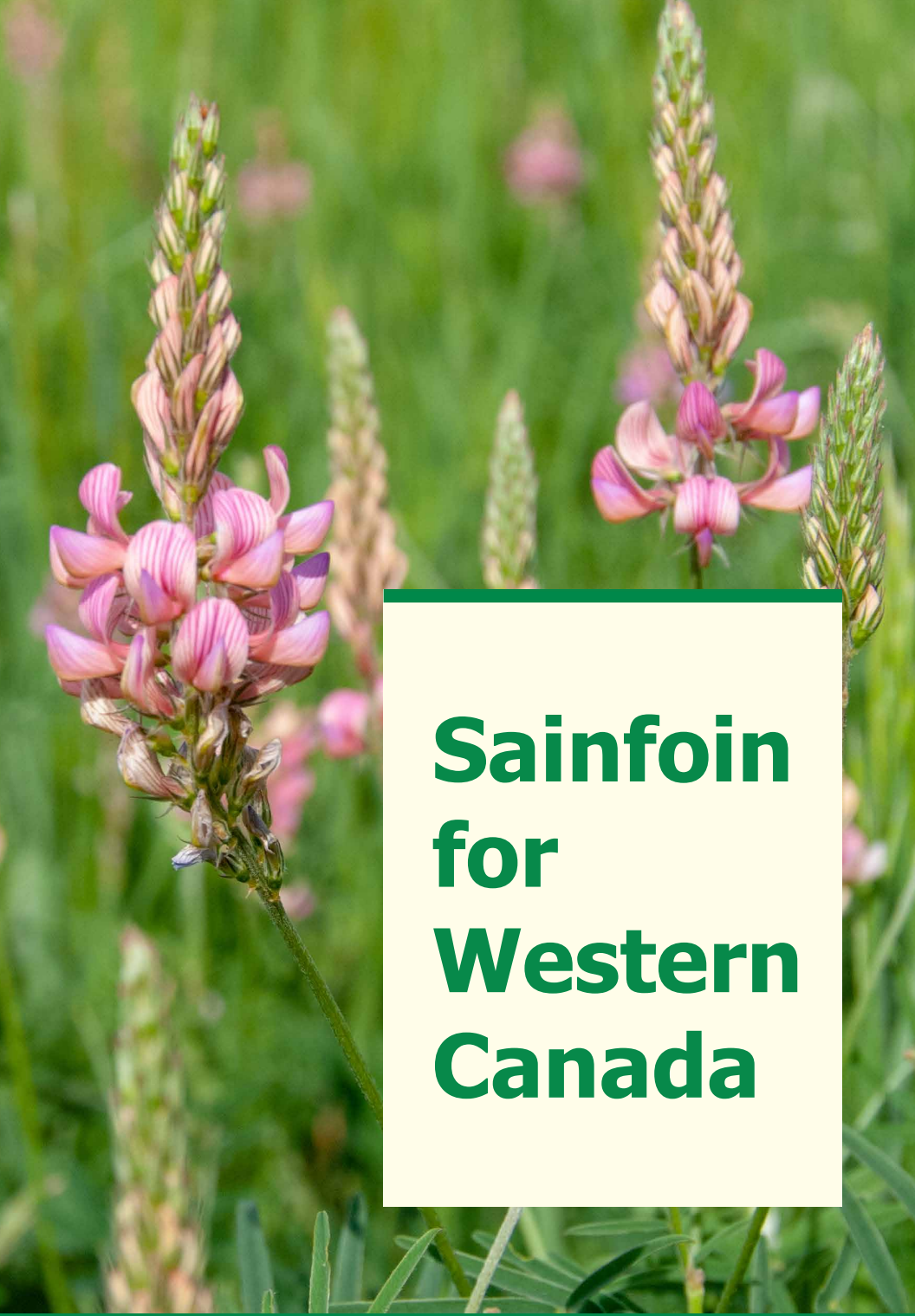

Sainfoin for Western Canada

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Sainfoin for Western Canada

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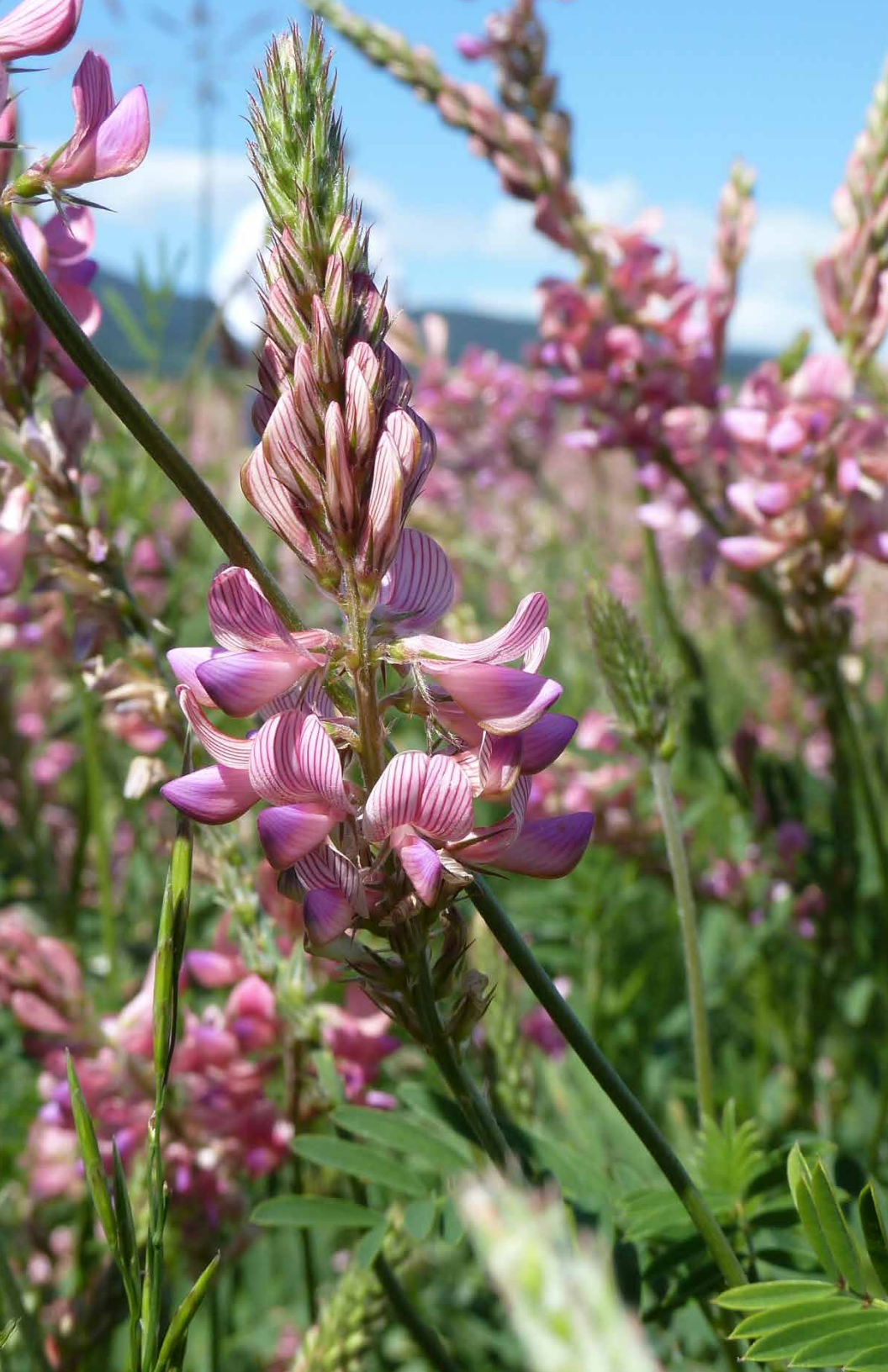

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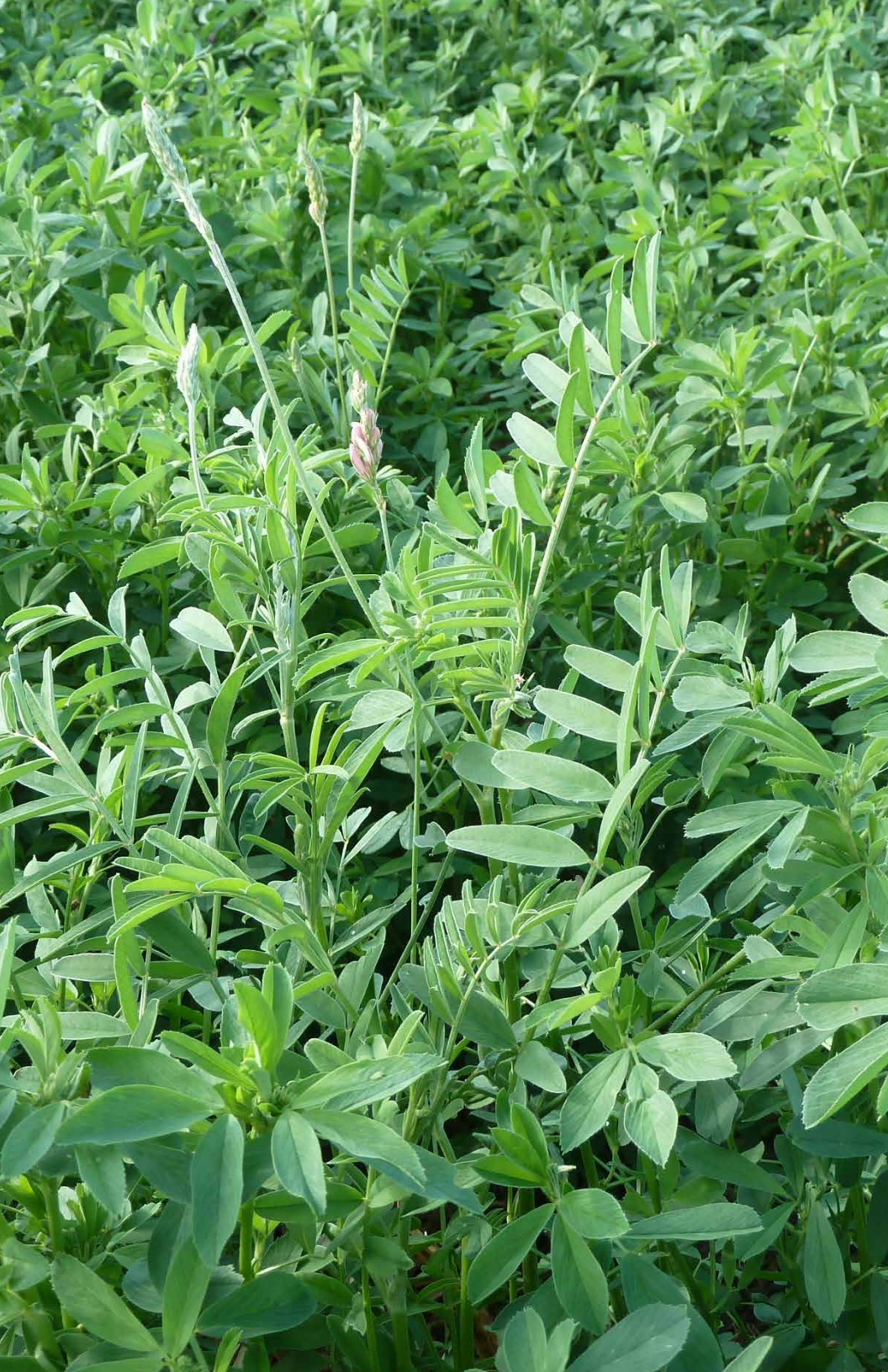

INTRODUCTION

FORAGE LEGUMES AND THE PROBLEM WITH ALFALFA

Forage legumes are widely used in many grassland farming areas around the world because of their nutritional value for livestock and their ability to fix atmospheric nitrogen into the soil. In Western Canada, alfalfa (*Medicago sativa L.*) is the most widely used forage legume and it is grown as a monoculture or in mixtures on approximately 3.7 million hectares (Statistics Canada 2016). Besides its excellent feeding value for ruminants, alfalfa's success is due in part to high yields, wide adaptation and relatively long persistence in fertile, well drained soils. According to Popp et al. (2000), if managed well, beef production can be maximized on a monoculture alfalfa pasture or on a pasture where alfalfa is the dominant species in the forage mixture. However, despite high livestock growth rates, bloat and rapid ruminal protein degradation (resulting in nitrogen loss in urea) (Dahlberg et al. 1988) are major deterrents to grazing alfalfa-based pastures. Furthermore, because of the extensive and rapid protein breakdown, feeding value is often not fully realized (McDonald et al. 1991).

Significant efforts to reduce the bloat potential of alfalfa have had limited success. One solution is to introduce a second forage legume species that either (1) has the same beneficial qualities as alfalfa but without the bloat potential or (2) one that could reduce the bloat potential of alfalfa when the two are grown together. Sainfoin (*Onobrychis viciifolia* Scop.) fits both criteria.

SAINFOIN

Sainfoin is an introduced perennial forage legume (Figure 1) that has been grown for centuries in parts of Europe and Asia. The name sainfoin is derived from two French words, sain and foin, meaning 'healthy hay'. Most of the cultivated sainfoin cultivars are identified as *O. viciifolia*.

There are two main sainfoin types, 'common' and 'giant'. They are indistinguishable from one another based on plant characteristics (e.g. flower, leaf, root, etc.) (Fortune 1985). Their differences are found mainly in growth behaviour: 'giant' types generally flower at least twice in a growing season while 'common' types flower once and then produce a rosette. Also, most 'common' type cultivars grow slowly during establishment but, when well-managed, they will persist longer than the 'giant' types.

Figure 1. Sainfoin at late flower bud stage

Forage legumes that contain moderate levels of secondary compounds such as condensed tannins and flavonoids offer some advantages to livestock nutrition. They increase nitrogen utilization efficiency within the digestive tract, reduce pasture bloat, provide resilience to resist parasites and reduce methane emissions into the environment from enteric fermentation (McMahon et al. 1999; Theodoridou et al. 2011). Sainfoin, an example of a forage legume with moderate to high condensed tannin content, does not cause pasture bloat (Dahlberg et al. 1988; Berg et al. 2000).

BENEFITS OF GROWING SAINFOIN

Most early introductions to North America originated from Western Europe starting around 1900. Early strains were low yielding and poorly adapted to Canadian growing conditions. Newer introductions from more than a dozen countries have been tested in Canada. They vary widely in seedling vigor, recovery speed, the amount of regrowth after cutting or grazing, leafiness, height, winter hardiness, and forage and seed yield. Recent introductions of improved cultivars originating from Russia, Romania and Turkey have shown greater promise and more farmers in Canada and the USA are now growing sainfoin.

Sainfoin is a relatively high yielding, high quality livestock feed resource with high protein content and palatability. This cool-season legume, alone or in grass mixtures, can be hayed, ensiled or grazed. Other desirable characteristics include early maturity and high productivity with dry matter yields up to 90% of alfalfa (under a one-cut/graze system). In addition, sainfoin has good leaf retention and high frost tolerance. In autumn, sainfoin forms a low rosette that remains green

Figure 2. Sainfoin branched taproot with nodules

under snow cover for most of the winter, making it ideal for late season grazing. It is the main alternative to alfalfa, fulfilling the same roles in forage stands.

SAINFOIN PLANT CHARACTERISTICS

Sainfoin may grow up to 1 meter (3 feet) in height and is usually taller than alfalfa. It has hollow stems and pinnate leaves with 5-14 leaflet pairs and a terminal leaflet. The flowering head is spike-like with attractive rosy-pink flowers. Sainfoin has a deep branched taproot from which fine lateral roots develop, providing sites for nodule development. Orange-white nodules range in size from small 1-millimeter spheroids to large 3 x 6-millimeter wedge-shaped structures (Figure 2).

Single-seeded brown seed pods have a raised network of veins often with short spines along one edge (Figure 3). When mature, the pods shatter from the plant with their seed still enclosed. The smooth, kidney-shaped, tan to dark brown seeds are about 3 millimeters (1/8 inch) long, about 5-6 times larger than an alfalfa seed. During harvest and threshing, they are held within the tough fibrous pods.

Viable sainfoin seed germinates rapidly and produces vigorous seedlings (Fortune 1985; Frame 2005). Sainfoin seeds germinate over a wide range of temperatures from near freezing to moderately high (5-25°C) and seem to be temperature insensitive for total germination (Fortune 1985).

Sainfoin starts growing early in the spring before some of the other perennial forage legumes. Its blooming and ripening period is shorter than alfalfa. Generally, it does not recover or regrow as fast as alfalfa after cutting or grazing – breeding efforts are focused on improving this trait. In the fall, plants develop into a low rosette that may remain green for most of the winter even under the snow cover. The seedlings and mature plants are tolerant of both spring and fall frosts.

Figure 3. Sainfoin seed pods

Early spring growth is fueled by carbohydrates stored in roots from the previous growing season. During the summer, plants need to replenish these reserves while also diverting carbohydrates to feed nitrogen-fixing bacteria and mycorrhiza. Poor nitrogen fixation due to poor nodulation or ineffective rhizobia has been reported in sainfoin.

Some legumes spend a great amount of energy producing flavonoids and tannins to discourage small herbivores (including insects) from eating their leaves. Sainfoin produces condensed tannins in all parts of the plant except the roots. They are produced by tannosomes that sequester large amounts of photosynthate from each cell's chloroplasts. Sainfoin has a lower leaf area index than other legumes such as alfalfa resulting in a smaller surface area to gather light. As a result, sainfoin is often short on energy and is one of the reasons why its regrowth is slower than alfalfa.

Sainfoin suffers more from root and crown rots during the growing season than alfalfa which is likely the reason for reduced sainfoin stand longevity. The worst of these root rots is caused by clover sclerotinia crown and stem rot (*Sclerotinia trifoliorum* Eriks.). Maintaining plant density will depend on allowing sainfoin to mature until seed drop every few years.

BIOMASS YIELD

Sainfoin dry matter biomass yield is quite variable depending on growing conditions, ranging from 7-15 tonnes dry matter/hectare (3.1-6.7 tons dry matter/acre) (Frame 2005; Goplen et al. 1991). Dry matter biomass yield of sainfoin is about 10% lower than alfalfa, likely a result of lower leaf area index, a more erect canopy structure and less efficient nitrogen fixation (Frame 2005). Dry matter biomass yields of 6-13 tonnes dry matter/hectare (2.7-5.8 tons dry matter/acre) have been reported for alfalfa-sainfoin mixed pastures in Western Canada under rain-fed and irrigated conditions (Acharya et al. 2013; Sottie et al. 2017). In Lethbridge, AB, the five-year average dry matter biomass yield for some experimental sainfoin populations was significantly higher than 'AC Blue J', 'AC Grazeland' or 'AC Longview' alfalfa cultivars (Iwaasa et al. 2018).

SAINFOIN ADAPTATION AND GROWING ENVIRONMENT

The hardier sainfoin cultivars can be grown in much the same areas as alfalfa and are well-adapted to Western Canadian growing conditions. In some areas, it experiences winter-kill while alfalfa does not, so sainfoin might be considered slightly less winter hardy than alfalfa.

In its native range, sainfoin is adapted to an ecological niche that includes open grassland and meadows; altitudes lower than 1500 meters (4900 feet) above sea level; north of 40° latitude; well drained and dry sites not subject to flooding that receive 300-500 millimeters (12-20 inches) of annual precipitation; and moderately fertile and weakly saline (<8 decisiemens/meter) calcareous soils with neutral to alkaline pH (≥ 6.06). On the Prairies, it has similar preferences: it is well adapted to calcareous soils and performs best on deep, well-drained soil with good moisture holding capacity in the Brown and Dark Brown soil zones (Frame 2005). Yields, however, tend to be lower in the Black, Light Brown and Grey Luvisol soil zones. Unlike some legumes, it performs well on some coarse gravelly soils. Germinating sainfoin and alfalfa seeds are tolerant of high salinity but, their tolerance decreases during establishment. Moderate levels of salinity reduce sainfoin shoot and root lengths. Sainfoin does not tolerate flooding or sub-irrigation in the root zone.

When seeding sainfoin, avoid obvious signs of salinity at the soil surface such as a white crust, areas where water may regularly saturate the surface or upper soil horizon for a week or less, or drained sloughs or natural ground water recharge/discharge areas where flooding is likely to occur.

Despite the advantages of sainfoin over alfalfa as a non-bloating legume and one that can significantly reduce bloat incidents when consumed in high enough proportion with bloat-causing legumes, sainfoin is not utilized to its full potential in Western Canada due to lower biomass yields, persistence issues in mixed stands, and difficulty in obtaining seeds. While some reports indicate that sainfoin yield can be equal or greater than alfalfa depending on environment, biomass yields have been historically less than alfalfa in Western Canada (Hanna and Smoliak 1968).

SAINFOIN ESTABLISHMENT

SAINFOIN CULTIVARS

Many sainfoin cultivars and strains have been developed in Russia, Romania, Poland, France and other European countries but seeds of these are usually difficult to obtain in North America. Some of them might prove to be useful for hay or pasture in some parts of Canada; however, many have been tested and have not been winter hardy or have produced poor forage yields.

Informally, sainfoin breeders recognized two main types of sainfoin, single cut and double cut, which refers to their ability to regrow. The cultivars 'Eski' and 'Remont', both considered double cut cultivars, were released by the Montana Agricultural Experiment Station in 1964 and 1971, respectively. 'Eski' was selected from Turkish material. 'Remont' has a faster regrowth after cutting or grazing. 'Renumax' (1979) is another double cut cultivar registered in the US. 'Shoshone' (2006) is a synthetic composed of both single and double cut cultivars.

'Melrose' and 'Nova' were released by Agriculture and Agri-Food Canada (AAFC) in 1969 and 1980, respectively. Both are considered single cut cultivars. 'AAC Mountainview', released in 2013 by AAFC, is a multi-cut cultivar for Western Canada conditions. 'AAC Mountainview' was selected for its regrowth potential and persistence in mixture with alfalfa. It is also more winter hardy than some of the American cultivars. 'AAC Glenview' (AAFC) was developed from a high-yielding population with rapid regrowth under grazing conditions – seed to be available after 2018 (Acharya 2017) (Table 1).

INOCULANTS AND FERTILIZER

As a legume, sainfoin can develop a symbiotic relationship with a root-nodule forming bacterium that converts atmospheric nitrogen (N_2) to a plant available form (i.e. NH_3 = ammonia). In return, the bacterium receives sugars and other chemicals required for its growth from the plant through the root connection. The best or most efficient bacterium strain(s) or species is specific to each legume species. In practical terms, this means that sainfoin needs a different inoculant than alfalfa for best performance. Often the optimum bacterial strain can be found within the soil already, particularly if sainfoin has been grown previously on that parcel of land. Trials evaluating the forage yield response to inoculation have been inconsistent. Some trials show either no benefit or nitrogen deficiency with the inoculum suggesting that the bacteria were either ineffective or short lived. Inoculation has

Table 1. List of sainfoin cultivars released in North America*

Cultivar	Release year	Country	Remarks	References
Eski	1964	USA	Dryland pasture	USDA 2015
Melrose	1969	Canada	Dryland hay or pasture and irrigated hay	Cooke et al. 1971
Remont	1971	USA	Multiple-cut hay harvest and pasture	USDA 2015
Renumax	1979	USA	Rapid regrowth	USDA 2015
Nova	1980	Canada	High dry matter yield and winter hardiness	Hanna 1980
Shoshone	2006	USA	High tolerant to northern root-knot nematode	Gray et al. 2006
Delaney	2007	USA	Multi-cut system	USDA 2015
AAC Mountainview	2013	Canada	Rapid regrowth, persistent in alfalfa-sainfoin mixture	Acharya 2015
AAC Glenview	2017	Canada	Rapid regrowth, persistent in alfalfa-sainfoin pasture mixture	Acharya 2018

*From Bhattarai et al. 2016, used with permission

been recommended in the past; however, no inoculants have shown consistent beneficial results. At present, work is progressing to develop inoculant for cold soil conditions of Western Canada. There are no commercial inoculants presently available in Canada.

In nitrogen deficient soils, sainfoin may require a low level of commercial nitrogen fertilizer application to achieve high yields, at least until more effective bacterial strains have been selected and included in commercial inoculants. However, application of small amounts of nitrogen has had varied responses in biomass yields. Alternatively, seeding sainfoin with other legumes may supply the required nitrogen to achieve good growth. Phosphorus may be required over the entire life of the stand. However, a one-time application rarely results in an immediate increase in biomass yield since phosphorous is rapidly tied up in alkaline soils and only released slowly over time. A few naturally

occurring phosphorous-solubilizing soil fungi can improve phosphorous uptake when they form mycorrhiza-root complexes. Micronutrient requirements are complicated under high alkalinity or when high levels of lime are applied to increase soil pH. High soil pH can lead to boron deficiency due to altered nutrient availability and uptake affecting the root and shoot growth.

SEEDING RATES

Sainfoin is available as either 'unmilled seed' which has adhering seed pods or 'milled seed' without pods. The hull contributes about 30% to seed weight and absorbs water faster than milled seed; however, germination rates are similar for milled and unmilled seed. Since the pod is difficult to remove and does not seem to affect germination, it is rarely removed[1] (Figure 3).

Seeding rate recommendations are based on pure live seed and are the minimum necessary to establish a pure stand. This means the actual seeding rate needs to be increased to account for dead seed (about 15% in certified seed lots). As a general rule, regardless of row width, sainfoin within-row seeding rates should be 30-42 live seeds/meter (9-13 seeds/foot). Between-row spacing should not exceed 30 centimeters (12 inches) to maintain adequate sainfoin density in mixed stands.

Note: when not specified in this bulletin, 'seed weight' refers to the unmilled seed weight (i.e. including pod). Sainfoin has relatively large seeds. Seed weight varies with each seed source and cultivar; however, the average seed weight is 52,500 seeds/kilogram (23,800 seeds/pound). For comparison, alfalfa has about ten times more seeds/kilogram or 500,000 seeds/kilogram (227,00 seeds/pound).

In Alberta, recommended seeding rates are based on the mean annual precipitation in a given area (Government of Alberta 2014). Alberta also has recommended seeding rates for pure sainfoin stands (Government of Alberta 2007). In Saskatchewan, there are specific seeding rate recommendations for the Black and Grey Wooded soil zones (Saskatchewan Agriculture 2007) (Table 2).

In general, planting seed of different species can cause uneven distribution of the species throughout the field, especially if the seeds are very different in size or have awns or hairs. It also increases the within-row competition impacting establishment and long-term persistence. When designing a seed mix with sainfoin, other species

1. There has only been one study that showed that removing the pod improved germination and seedling vigor (Noorbankshian et al. 2011)

with similar harvest characteristics and regrowth potential should be chosen. For example, crested wheat grass (*Agropyon cristatum* L.) meadow brome (*Bromus riparius* Rehm.) or hybrid brome (*B. riparius* x *B. inermis*) may be better choices than the aggressively creeping rooted smooth brome (*Bromus inermis* Leyss).

For seeding sainfoin and other forage species in a mixed forage stand with sainfoin, seeding pure sainfoin in alternate rows with other forages can reduce competition and improve sainfoin stand establishment. In this case, seeding rate of sainfoin is reduced by 50% of the monoculture seeding rate. For example, seeding 50% alfalfa and 50% sainfoin using an 18-centimeter (7-inch) row spacing would result in a 36-centimeter (14-inch) sainfoin row spacing and a seeding rate of 19 kilograms/hectare (17 pounds/acre) at 36 sainfoin seeds/meter (11 seeds/foot).

ESTABLISHMENT PRACTICES

Spring seeding is preferred as fall seeding may lead to lower forage yield in the subsequent year. This is an active area of research. Spring seeding also allows for better perennial weed control: apply glyphosate in the fall and again in spring prior to seeding.

For field preparation, the common practice is to completely break the sod and reseed. This may involve using a double disc followed by harrowing. The seed bed should be packed well both before seeding (to produce a firm seed bed) and after (to create good seed-soil contact). Avoid using discs in heavy trash from previous crops because packing will be difficult, the field will dry out quickly and the seed bed depth may increase. Also, the trash may harbour a surprise crop of highly competitive weeds. Avoid using an annual cover crop unless there is a high erosion risk.

Table 2. Recommended sainfoin seeding rates to establish a pure stand†

	Seeding rate: seeds/meter (seeds/ft.)	Seeding rate Kilograms/hectare (pounds/acre) Row spacing			Broadcast seeds/sq. meter (seeds/sq. ft.)
		18-centimeter (7-inch)	25-centimeter (10-inch)	30-centimeter (12-inch)	
Pure monoculture[1]	40-60 (12-18)	53 (47)	38 (34)	32 (29)	175-250 (16-23)
Black and Grey Wooded soil zones[2]			33 (29)*		

†Rates are calculated based on 100% pure live seed and 52,500 seeds/kilogram (23,800 seeds/pound). To calculate actual seeding rate, divide recommended rate by the percent pure living seed declared on the seed analysis report.
*Row spacing not specified

1. Government of Alberta 2007 (www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex81)
2. Saskatchewan Agriculture 2007

POST-SEEDING SAINFOIN MANAGEMENT

WEED CONTROL

Weed competition in the seeding year may affect stand establishment, but sainfoin can eventually outgrow most weeds. Generally, alfalfa and sainfoin were found to be equally tolerant to herbicides in older Canadian trials for grassy and broadleaf weed control. One study showed that sainfoin was six times more tolerant of glyphosate than alfalfa at the seedling stage, and about 20 times more at the mature stage (Peel et al. 2013). This had been also been observed in trials at Saskatchewan (Bill Biligetu, Personal Communication, 2018). Residual herbicide activity should be considered for sainfoin since sainfoin herbicide tolerance has not been tested in trials using current herbicide formulations. When using the mower to control weeds, the best time is when sainfoin is less than 15 centimeters (6 inches) high.

In 2018, there were ten registered herbicides (5 active ingredients) for weed control in sainfoin including

- **Group 1**: Achieve SC (tralkoxydim), Assure II (quizalofop-p-ethyl), Bison (tralkoxydim), Marengo (tralkoxydim), Poast Ultra (sethoxydim), Yuma GL (quizalofop-p-ethyl)
- **Group 3**: Bonanza 480 EC (trifluralin), Rival EC (trifluralin), Treflan EC (trifluralin)
- **Group 6**: Basagran (bentazon)

Always follow manufacturer label instructions when applying herbicides. For up-to-date information on these herbicides, refer to your annual provincial crop protection guide.

SEED PRODUCTION

Sainfoin seed yields are higher under irrigation than under dryland conditions. It is generally seeded in rows to allow cultivation between rows for weed control. Although bumble bees are the natural pollinators for sainfoin, honey bees can be used effectively

Figure 4. A bee on a sainfoin flower

for pollination: set out 5 colonies/hectare (2 colonies/acre) during the peak flowering period (Figure 4). Under optimal conditions, seed yields can range from 500-900 kilograms/hectare (450-800 pounds/acre), sometimes reaching as high as 1100 kilograms/hectare (980 pounds/acre). There can be some seed production in the year of seeding if it is seeded early enough in the spring, but generally seed is harvested in the subsequent years.

Maximum seed yields come from the first growth each year. Pods ripen starting from the base of the flower spike to the top and the basal pods start to shatter before the upper pods are ripe. Therefore, swath the crop when the basal pods have turned brown but not yet shattered. Harvest after a week of drying to allow the top immature pods to dry. Ripened pods thresh easily so a slow cylinder speed with a wide concave clearance should be used. Sainfoin can be separated from most other seeds fairly easily due to their unique size and shape; however, barley or other cereals are the most difficult to remove. The straw/hay can be baled after combining or spread with a chopper.

REJUVENATION STRATEGIES

Since sainfoin is usually shorter-lived than alfalfa, there is significant interest in rejuvenation or reintroduction of sainfoin into existing alfalfa-sainfoin mixed stands. On-going research projects in Western Canada have tested different methods with varying degrees of success. The general principle is to somehow suppress the existing stand and then reseed in order to give the seedlings a chance to establish. Recent research (Alan Iwaasa, Personal Communication, 2018) has not observed any auto-toxicity effect of alfalfa or sainfoin residue (i.e. live or dead plant material) on seeded sainfoin seedlings. Some producers have reported success using a disc drill and seeding directly into a herbicide-treated alfalfa stand without breaking.

Agriculture and Agri-Food Canada scientists in Swift Current, SK are evaluating four alfalfa-sainfoin pasture rejuvenation methods (study results to be available in 2019):

- Break sod and reseed using a double disc (control or standard practice).
- Intense grazing in spring followed by direct seeding into existing stand.
- Spring glyphosate application followed by direct seeding into existing stand.
- Fall glyphosate application followed by direct fall seeding into existing stand.

FORAGE UTILIZATION

Sainfoin can be grown as a monoculture or in mixtures, and either as a pasture or a hay field.

Sainfoin is suited for harvesting as hay as it grows upright and is easily cut. It performs well under irrigation but can be grown under dryland conditions when irrigation is not available (Figure 5).

IRRIGATED HAY PRODUCTION

Of note is that sainfoin tends to hold onto its leaves longer than alfalfa and can be harvested later at a more advanced stage of maturity without appreciable loss of quality.

For optimum tonnage and quality, cut sainfoin for hay between 50-100% bloom. Although sainfoin stems appear coarse, they are actually more digestible than alfalfa stems. Sainfoin and alfalfa qualities are very similar with sainfoin having perhaps slightly lower protein content at the same maturity stages.

Sainfoin persists longer as a pure stand than in mixtures with either grass or alfalfa. For example, with competitive rhizomatous species such as smooth bromegrass, sainfoin may only persist for five years. If it is seeded with a less competitive grass such as Russian wildrye or crested wheatgrass, it may persist longer.

The latest sainfoin cultivar, 'AAC Mountainvew', was specifically selected for increased regrowth and persistence in mixed stands; these remain high priority traits in breeding programs.

DRYLAND HAY PRODUCTION

In Saskatchewan, only one cut is taken on most hay fields. During years with high moisture, producers may take a second cut in the fall. The regrowth potential of alfalfa and sainfoin under dryland production is not a high priority – persistence is. While sainfoin has good drought resistance, alfalfa may still persist longer than sainfoin. However, some of the newer sainfoin cultivars are approaching alfalfa's persistence. Under a one-cut monoculture hay system, the yield and quality of pure stands of sainfoin and alfalfa are comparable.

When grown with other forage species, sainfoin often does not persist as long as a number of other species. Choose a less competitive grass species to improve persistence. Compared to multi-cut irrigated production, sainfoin persists longer when grown in a mixture under a one-cut dryland production system.

Figure 5. Hayed sainfoin

GRAZING MANAGEMENT

Grazing is where sainfoin really shines. Legumes are a high-quality feed and can increase rate of gain when grazed by livestock. Using alfalfa as the only legume brings with it the risk of bloat. The biggest benefit of sainfoin is that it contains condensed tannins making it a non-bloating legume. The condensed tannin content is high enough in sainfoin that growing it together with alfalfa can significantly reduce or eliminate the bloat risk posed by alfalfa (Figure 6).

PASTURE MANAGEMENT TO PREVENT BLOAT CAUSED BY ALFALFA

In pastures with bloat-causing legumes, as plants mature and dry down, the relative amount of soluble leaf proteins decline. Thus, most bloat cases occur when hungry cattle are turned out on to fresh, lush pastures. Start grazing cattle on grass before transitioning onto a pasture with a higher percentage of alfalfa. Do not start grazing cattle on a legume pasture that is wet from dew or rain. Both intake rate and digestion rate are higher in forages with more moisture. There are some bloat preventative products available such as poloxalene (Bloat Guard) or a mixture of pluronic surfactants (Alfasure).

More bloat cause by alfalfa has been observed in some parts of Western Canada than in others. More cases have been reported in the Gray Wooded soil zones compared to the Dark Brown and Brown soil zones (Majak et al. 2003). The incidence of bloat increases in cattle grazing on irrigated alfalfa pastures compared to dry-land pastures. Irrigation may contribute to the lushness of the pasture and to the protein content of alfalfa (Majak et al. 2003). Immediately after a killing frost, the risk of alfalfa-caused bloat is increased due to plant cell walls being ruptured. To mitigate this, allow the forage to stand for at least a week following frost to reduce the risk of bloat.

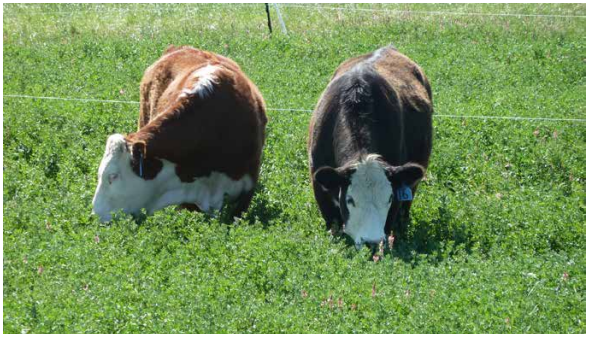

Figure 6. Steers grazing alfalfa-sainfoin mixed pasture

PASTURE BLOAT

Methane and carbon dioxide are normal rumen fermentation products and usually the small gas bubbles coalesce and are belched out. But when a ruminant animal consumes a diet rich in soluble leaf proteins (including high 18-S protein levels) and saponins (e.g. from bloating legumes like alfalfa, white clover, red clover), a stable foam is formed when the gases mix with the protein/saponin-rich rumen fluid. The stable foam blocks gas escape and pressure builds up in the rumen-reticulum. As pressure inside the rumen builds, that pressure is transferred to the diaphragm, limiting the air intake.

Bloat symptoms can occur as quickly as 15 minutes following the grazing of bloat-causing legumes. Often the animal stops eating and waits until the pressure is relieved. In more severe cases, the rumen distends on the left side and the animal urinates and defecates frequently, staggers and bellows. If the pressure is not relieved, the animal can die from asphyxiation or heart failure.

If bloat occurs, affected animals should immediately be taken off the lush pasture and offered dry feed. Walking or trotting a bloated animal sometimes helps as well. A tube can be inserted down the animal's throat to try to release the pressure. An anti-foaming agent such as mineral oil should be administered. In extreme cases, a rumenotomy (a surgical incision into the rumen through the left abdominal wall) is performed with an explosive release of the rumen contents, immediately releasing the pressure.

The risk of bloat from alfalfa is mitigated if harvested as hay and dried before feeding to livestock.

USING SAINFOIN TO PREVENT BLOAT

One of the main benefits of sainfoin over alfalfa is that it is a non-bloating legume. Sainfoin and other non-bloating legumes (e.g. bird's-foot trefoil) contain condensed tannin and thus do not cause bloat. Condensed tannins bind with the soluble proteins at normal ruminal pH thus preventing the protein degradation in the rumen and interfering with stable foam formation.

Non-bloating legumes are safe to graze as a monoculture and can also be used in mixtures with alfalfa to prevent alfalfa-caused bloat. Studies in Western Canada have shown that an alfalfa pasture with 20-25% dry matter sainfoin seeded in alternate rows can lower the risk of pasture bloat in cattle (McMahon et al. 1999; Wang et al. 2006; Sottie et al. 2014). Early research on the effectiveness of condensed tannins to bind with alfalfa proteins found that sainfoin condensed tannins bound better than tannins from other plants with the least impact on digestibility. Condensed tannins in sainfoin are highest when the sainfoin is at 50% bloom.

Condensed tannins also have a damaging effect on gastrointestinal parasites and appear to be able to reduce the shedding of *E. coli* O157:H7 (a dangerous pathogenic strain responsible for the Walkerton Tragedy, among other outbreaks). They may also play a role in preventing atypical pneumonia/emphysema infections in pastured cattle.

STAND LONGEVITY

Sainfoin does not tolerate frequent and heavy grazing, especially at the bud and vegetative stages. Allow the stand to mature to the seed shattering stage in year 2 and once every two years thereafter to allow seed shed which can help maintain plant density. In order to maintain the stand, the plants should not be grazed at least 50 days before the first killing frost in the fall. This allows sufficient time for root reserves to replenish.

IRRIGATED PASTURE

Generally, higher value crops are grown under irrigation rather than pasture. However, some producers do irrigate their pastures. These producers are looking for very high production to (1) push the limit on the number of animals per acre that the pasture can support and (2) increase the rate of gain of those animals. This translates to short rotations and intensive grazing of high producing forage.

Grazing irrigated alfalfa, either in a mixture or pure stand, has been tried with varying success. The drawback is that irrigated alfalfa pasture poses the highest risk of bloat and requires intensive attention and management. Including sainfoin would greatly mitigate the bloat risk without impacting feed quality and would reduce the management requirements. However, with multiple passes of grazing combined with the slower sainfoin regrowth potential, it may be difficult to maintain the sainfoin in the mixture over the longer-term.

DRYLAND PASTURE

Dryland pasture is typical in Western Canada. Grass mixtures are very common and often the debate is whether to include alfalfa in the pasture mix. The benefit is that alfalfa improves livestock productivity due to its high feed quality; the downside is higher bloat risk. This is the ideal scenario to include sainfoin in an alfalfa dominated pasture. In a rotational grazing system, seeding one pasture to an alfalfa/sainfoin mixture would allow for significantly increased rate gains with a lower or negligible bloat risk. With only one, possibly two passes over this field, sainfoin can persist for many years. When sainfoin production in the mixture declines, the field could continue to be harvested as hay until the alfalfa yields become unproductive.

Older Western Canadian studies indicated that the standard sainfoin cultivars ('Nova' and 'Melrose') did not persist well in mixtures with alfalfa or exhibited less regrowth than alfalfa after grazing, concluding that alfalfa-sainfoin mixtures were not stable or sustainable in semiarid environments (Jefferson et al. 1994). In a more recent study, several new sainfoin populations were developed at the Lethbridge Research Centre (LRC) using new and old sainfoin germplasm and selecting from mixed alfalfa-sainfoin stands under multiple-cut management (Acharya et al. 2013). These new sainfoin populations had improved persistence in mixtures with alfalfa.

Acharya et al. (2013) conducted research at Lethbridge, AB (Dark Brown soil zone) and Swift Current, SK (Brown soil zone). In Lethbridge, AB, they found that 50:50 mixtures of new sainfoin populations with alfalfa persisted in the stands and reduced bloat incidence in cattle by 90-98%. However, in Swift Current, SK, the older sainfoin cultivar, 'Nova' had similar or higher dry matter biomass yield and stand longevity than some of the new sainfoin populations (Iwaasa et al. 2018). After four to five production years at both locations, there was a sharp reduction in dry matter proportion of sainfoin in the mixture to less than 10% which is below the level required to maintain a bloat-safe alfalfa dominated pasture.

As sainfoin breeding research continues to improve yield and persistence, sainfoin may be considered more and more as a monoculture for pasture situations or a longer term option to include with alfalfa.

GRAZING PREFERENCES

Cattle often show grazing preferences for specific plants. Studies have shown that once the cattle become accustomed to sainfoin, its palatability is similar to alfalfa. For example, a study in Alberta saw steers graze orchard grass (*Dactylis glomerata* L.) first, followed by alfalfa and then sainfoin. But by the third day and third paddock, they ate the sainfoin before the alfalfa. Another study in Alberta showed cattle had a slight preference for alfalfa over sainfoin at the vegetative growth stage of both plants (Sottie et al. 2014). A third study, this one in Saskatchewan, noted that the steers ate sainfoin blossom tops before eating the other components.

NUTRITIVE VALUE OF SAINFOIN AND ANIMAL PERFORMANCE

The nutritive value of sainfoin is comparable to alfalfa with similar crude protein, acid detergent fibre and neutral detergent fibre (Tables 3 and 4). Average daily gains of 0.80 and 0.86 kilograms/day (1.8 and 1.9 pounds/day) have been measured for steers grazing pure sainfoin pastures (Mowrey et al. 1992; Marten et al. 1987). This is comparable to gains in cattle grazing alfalfa pastures. Sottie et al. (2017) reported average daily gains of 0.8-1.2 kilograms/day (1.8-2.6 pounds/day) for steers grazing alfalfa-sainfoin mixed pastures in Alberta and Saskatchewan. Average daily gain and feed consumption were the same for 319-kilogram (703-pound) heifers fed either sainfoin or alfalfa hay for 60 days (Parker and Moss 1981).

Table 3. Sainfoin nutritive value at different growth stages*

Growth stage	Crude protein (grams/kg)	Neutral detergent fibre (grams/kg)	Acid detergent fibre (grams/kg)	References
Vegetative	195-198	378-461	286-334	Bal et al. 2006; Turk et al. 2011
Flowering	116-143	372-457	368-392	Parker and Moss 1981
Flowering	121	478	433	Khalilvandi-Behroozyar et al. 2010
Flowering	114-177	433-476	343-433	Kaplan 2011
Flowering	145	493	372	Bal et al. 2006
Flowering	125-161	-	313-371	McMahon et al. 1999
Seed filling	130	557	402	Bal et al. 2006
Seed filling	171	446	338	Turk et al. 2011
Regrowth (42 days)	148-186	365-454	337-397	Azuhnwi et al. 2012

*Source: Bhattarai et al. 2016, used with permission

Table 4. Mean crude protein, neutral detergent fibre, acid detergent fibre, organic matter and extractable condensed tannin of alfalfa and sainfoin at vegetative growth stage

Species	Crude protein (grams/kg)	Neutral detergent fibre (grams/kg)	Acid detergent fibre (grams/kg)	Organic matter (grams/kg)	Extractable condensed tannins (grams/kg)
Alfalfa	264	326	265	884	0
Sainfoin	220	310	269	909	30

Source: Sottie et al. 2014

SAINFOIN DISEASES AND INSECT PESTS

Sainfoin is relatively free from serious disease and insect problems. It seems resistant to a number of pests that attack other forage species. However, as the area of sainfoin production expands, pests and diseases may become a challenge.

DISEASES

Some root and crown rotting diseases have caused concern and reduced the life of some stands. Winter crown rot had caused losses in Canada in some years. Sainfoin is not affected by bacterial wilt and has some tolerance to alfalfa stem nematode.

All cultivars tested were found to be infested with and susceptible to Fusarium crown and root rots. This was more pronounced with older stands. Montana and Wyoming research implicated root knot nematode damage related to subsequent root fungal infections. The cultivar 'Shoshone' was selected for higher tolerance to the root rots.

INSECT PESTS

Alfalfa weevil (*Hypera postica* (Gyllenhal)) does not attack sainfoin. Likewise, aphids also do not seem to affect sainfoin. However, the seed head seems to be the target of a number of insect species. A severe insect infestation by the sainfoin-specific bruchid seed beetle (*Bruchidius unicolor* Olivier) was observed at one location in British Columbia where seed had been grown for many years (Bottimer 1968). It has also been recorded in Saskatchewan and Alberta, but serious damage was not reported. The developing beetle larvae feed on the seed inside the pod. That early research suggested that there was only one generation per year and that larvae hibernate overwinter and pupate within the pod, emerging as adults in the spring. Similarly, the sainfoin seed chalcid larvae (*Eurytoma onobrychidis* Nikol'skaya) feed on seed and overwinter in the seed pod. Chemical control (one to two weeks before flowering) is only necessary for infested fields that will be harvested for seed. Infested seed exposed to -40°C for five days or -20°C for fifteen days killed overwintering larvae without affecting seed germination (Richards 1989).

There have been isolated reports of minor damage due to other insects such as *Sitona* sp. weevils and blister beetles. *Sitona* sp. weevils scar the sainfoin root system resulting in fungal infections.

ECONOMICS OF GROWING SAINFOIN

Since sainfoin is relatively easy to harvest, seed prices are not high. On occasion, it can even be cheaper than alfalfa. A call to a local retailer in southwest Saskatchewan in the spring of 2017 reported a seed price of $3.50/pound ($7.72/kilogram) for common 'Eski' seed compared to alfalfa which ranged from $4.99-$5.49/pound ($11.00-$12.10/kilogram).

COST OF PRODUCTION

Production economics will depend on several factors. Establishment costs should be similar to alfalfa. The benefit of mitigating bloat risk should reduce costs associated with grazing management, but because of sainfoin persistence issues, pasture management costs (e.g. rejuvenation) may offset those gains over the long term. As newer sainfoin cultivars with improved yield and persistence are released, mixed alfalfa-sainfoin or pure sainfoin pastures may become very attractive (Tables 5 and 6) (Dyck 2018).

ECONOMICS OF PASTURE UTILIZATION

It is important to compare the economics of growing sainfoin for pasture to current market value pasture rates. If the average cost per animal unit month (AUM) is comparable to other pastures, it makes economic sense to consider utilizing sainfoin. On the other hand, a higher cost per AUM would have to be factored into future cattle selling prices. A recent analysis of dryland (Swift Current, SK) and irrigated (Lethbridge, AB) data shows that under irrigation, growing sainfoin for pasture use in Lethbridge is economical because of higher yields. Under dryland, choosing sainfoin is a somewhat risky investment choice because lower yields increase the cost per AUM. Producers may choose other pastures to minimize cost as an alternative to sainfoin (Table 7) (Dyck 2018).

ECONOMICS OF HAY PRODUCTION

Utilizing sainfoin as a hay crop has economic benefits. Based on $110/tonne ($100/ton) of hay, Table 8 shows the breakeven yields under dryland (Swift Current, SK) and irrigation (Lethbridge, AB). These yields can be compared to other forage yields in the area to determine the economic advantage of sainfoin (Dyck 2018).

Table 5. Sainfoin/Alfalfa total cost of production under dryland conditions (Swift Current, SK)

Treatment	Establishment cost per hectare (per acre)	Annual cost per hectare (per acre)
Break and reseed	$429.22 ($173.70)	$185.38 ($75.02)
Fall spray and seed	$298.95 ($120.98)	$104.72 ($42.38)
Spring spray and seed	$321.29 ($130.02)	$110.97 ($44.91)

Table 6. Sainfoin/Alfalfa total cost of production under irrigation (Lethbridge, AB)

Treatment	Establishment cost per hectare (per acre)	Annual cost per hectare (per acre)
Break and reseed	$545.52 ($220.77)	$235.78 ($95.42)
Fall spray and seed	$313.75 ($126.98)	$119.53 ($48.38)
Spring spray and seed	$399.76 ($161.78)	$161.23 ($65.25)

Table 7. Average cost per animal unit month (AUM) under dryland and irrigation

	Establishment cost per AUM	
Treatment	Dryland (Swift Current, SK)	Irrigation (Lethbridge, AB)
Break and reseed	$57.13	$17.58
Fall spray and seed	$38.10	$13.61
Spring spray and seed	$41.40	$13.16

Table 8. Break even yields with forage valued at $110/tonne ($100/ton) under dryland and irrigation

	Tonnes/hectare (tons/acre)	
Treatment	Dryland (Swift Current, SK)	Irrigation (Lethbridge, AB)
Break and reseed	2.7 (1.2)	3.4 (1.6)
Fall spray and seed	1.6 (0.7)	1.8 (0.8)
Spring spray and seed	1.7 (0.8)	2.4 (1.1)

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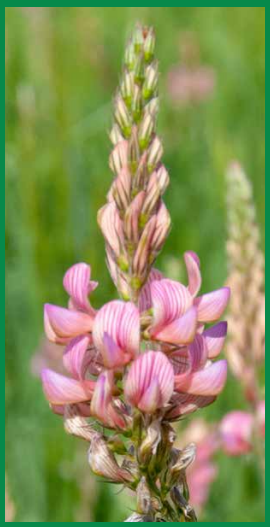

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