# Smooth Bromegrass Seed Production:
# A Literature Review

Gary Kruger
Grass Seed Agronomist
Saskatchewan Forage Council



### I. Introduction

Smooth bromegrass, Bromus inermis Leyss, is the most widely grown species of grass in the Dark Brown, Black, and Grey soil climatic zones of Saskatchewan. The first known introduction to Canada was planted in 1898 with seed from northern Germany. Production of smooth bromegrass seed has varied considerably over time. During the 1930's, Western Canadian production averaged nearly 1.1 million kilograms per annum. Average annual production increased dramatically during the 1940's and 1950's to four million kilograms. As the need to revegetate erodible lands decreased, production in the early 1960's dropped to under three million kilograms and declined to under one million kilograms by the arrival of the 1970's. Production jumped again during the late 1980's in response to the needs of the Conservation Reserve Program in the United States. Levels of production in the 1990's have returned to well under 1 million kilograms.

Pedigreed seed production of smooth bromegrass must follow the guidelines for isolation distances and cropping history. Two inspections are required annually for each pedigreed seed lot. The production field must be inspected prior to harvest and the seed must be inspected after harvest. The seed must meet standards for germination, genetic purity, freedom from disease, and absence of the seed of weeds and of other crops. The production of the seed must be pedigreed to be sold as a named variety. The pedigree guarantees to the purchaser the characteristics of the named variety (Bolton, 1985).

There are three classes of pedigreed forage seed production in Canada: Breeder, Foundation, and Certified. Foundation seed is grown from Breeder seed and Certified seed is grown from Foundation seed. Production of a Registered class of a smooth bromegrass variety is permitted when requested by the breeder of the variety to supply adequate quantities of seed for poor seed yielding varieties. In most cases, the Registered class applies to varieties developed outside Canada. The identification tags from the seed bags must be retained for the life of the stand for presentation to the crop inspector.

### II. Types and Varieties

Two "ecotypes" of smooth bromegrass are recognized, a southern and a northern type. The northern bromegrass has finer, less erect stems and narrower, finer, and less glaucous leaves which extend higher up the stem of the grass. The plants of the northern "ecotype" are slightly taller than the southern strains. The seed of northern bromegrass is more rounded and narrower and appears shorter than the seed of the southern ecotype. The southern type, therefore, appears more chaffy than the northern type, although there is no difference in bushel weight or weight per 1000 seeds. The heads of the northern type are more open than the southern type. Although the southern type produces comparable or slightly more forage in drier, warmer areas of the prairies, the northern type will perform better in the northern areas of the province. The southern strain has better resistance to brown spot (Pyrenophora bromi Died.) and leaf blotch (Selenophoma bromigena (Sacc.) Sprague and A.G. Johnson) at Saskatoon. Although the southern type has greater susceptibility to rust (Puccinia bromina Eriksson) in Russia, no evidence of rust disease was observed on either type at Saskatoon. The southern strain flowers two to four days later than the northern strain at Saskatoon. The southern strain is also more susceptible to winter injury because it commenced growth quicker in spring and remained green after the first few light fall frosts (Knowles and White, 1949). Seed yields of the northern type is higher than the seed yields of the southern strain in Western Canada. On the basis of 51 trials, seed yields of the southern type averages only 79% of the seed yield of the northern type (Knowles, 1957). The southern type is generally recommended in the United States as well as in Ontario and Quebec.

The distinction between southern and northern types of smooth bromegrass has become less important with the development of intermediate types in the 1980's. Newer varieties perform equally well when planted in areas within the adaptation of smooth bromegrass. The seed production of intermediate types is much higher than that of the southern type, while the forage production of the intermediate types under more southern latitudes remains comparable or superior to forage production of the southern type.

Pedigreed smooth bromegrass seed was grown on 900 hectares in Saskatchewan in 1994. This area represents 20% of the pedigreed grass seed production in the province. Bravo, Carlton, Grasslands Tiki, Magna, and Signal were the main varieties harvested. At present, five varieties of smooth bromegrass are recommended for forage production in Saskatchewan (Table 1).

Table 1: Smooth bromegrass varieties currently recommended for forage production in Saskatchewan

| Varieties | Type | Registration Year |
|---|---|---|
| Baylor | Southern type | 1969 |
| Carlton | Northern type | 1961 |
| Magna | Southern type | 1968 |
| Rebound | Intermediate type | 1989 |
| Signal | Intermediate type | 1983 |

## III. Field Selection

### A. Adaptation

Smooth bromegrass is recommended for forage production in the Dark Brown, Black, and Grey soil zones in Saskatchewan (Tremblay, 1994), but is better suited for seed production in the Dark Brown and Black soil zones (Knowles et al., 1969). The grass is adapted to most soil textures, but seed production is best suited to sandy loam and loam textured soils (Knowles et al., 1969). The grass is strongly rhizomatous, and thus is prone to becoming sod bound (Bolton, 1985). Special management practices are required to maintain seed yields as the stand ages. It is winter hardy, moderately tolerant of saline soils, and will tolerate spring flooding for 3-4 weeks as a mature plant (Bolton and McKenzie, 1946) and for 5-8 weeks as a seed (McKenzie, 1951). It tolerates drought fairly well, but is better suited to areas with reasonably frequent rainfall.

### B. Freedom from weeds

The field selected for grass seed production must be free of noxious perennial grassy and broadleaf weeds. A clean weed-free field may be left unattended for several weeks with only minimal weed growth without any appearance of quackgrass or Canada thistle. Presence of noxious weed seeds in the sample disqualifies the seed for market as pedigreed seed. Special weed concerns for pedigreed bromegrass seed production include wild oats, quackgrass, and other grasses. Because these seeds cannot be separated from the seed of bromegrass, it is imperative to sow bromegrass for seed production on land which is free of these weeds or to remove these plants from the field by application of appropriate herbicides or roguing. The presence of other weeds are also detrimental to the yield potential of the stand. Heavy weed pressure will weaken and may eliminate the new seedling from the stand (Dodds et. al., 1987).

Prior to seeding the grass, weed control is easily achieved with broad spectrum herbicides and cultivation. Weed control options become severely limited once the bromegrass is sown. The only remaining option for many weeds may be roguing by hand or with a backpack sprayer within the stand which is very time consuming and costly. Achieving this degree of sanitation may require one to two years of planning. Eradication of quack grass is essential prior to seeding any grass. Glyphosate application at 1-2 liter per acre in the fall prior to sowing the grass will control perennial weeds such as quackgrass, Canada thistle, and sow thistle. A fallow or partially fallow field provides opportunity to control several flushes of annual broadleaf and grassy weeds prior to seeding.

**C. Pedigree Requirements**

The selected field must have an adequate cropping interval between the seeded crop and a previous crop of the same kind. Smooth bromegrass planted with Breeder seed for Foundation status must be grown on land which did not grow a non-pedigreed crop of bromegrass or a crop of a different variety of bromegrass for any of the preceding five crop seasons. Smooth bromegrass planted with Breeder seed for Foundation status must be grown on land which did not grow the same variety of bromegrass for the previous three crop years. Smooth bromegrass planted with Breeder or Foundation seed for Registered status must be grown on land which did not grow bromegrass during any of the previous three years. Smooth bromegrass planted with Breeder or Foundation seed for Certified status must be grown on land which did not grow bromegrass for the previous two years. Manure or other contaminating material should not be applied to the field prior to seeding or during the productive life of the stand (Canadian Seed Growers' Association, 1994).

The grower must notify the Canadian Seed Growers' Association in the year of seeding of the pedigree of the seed planted on the production field and the area and previous cropping history of the production field. A field inspection is required each year that a pedigreed seed crop is to be harvested. The inspection should be completed after the crop has headed, but prior to swathing or harvesting. A field sown with Breeder smooth bromegrass seed is eligible for four years of Foundation plus four years of Certified seed production. A field sown with Foundation smooth bromegrass seed is eligible for eight years of Certified seed production (Canadian Seed Growers' Association, 1994).

Smooth bromegrass is cross-pollinated by wind and occasionally by insects. To maintain genetic purity, adequate isolation from other sources of pollen must be observed. For fields larger than 5 acres in size, Foundation, Registered and Certified seed crops must be separated from other bromegrass by at least 300 m, 100 m, and 50 m respectively. Longer isolation distances are required when the field size is less than 5 acres. The requirement for these smaller fields increases to 400 m, 300 m, and 150 m for Foundation, Registered and Certified status, respectively (Canadian Seed Growers' Association, 1994; Knowles and Ghosh, 1968; Knowles, 1983).

**D. Soil fertility**

Soil fertility of the grass seed field should be evaluated. The easiest time to address phosphorus and potassium fertility problems is prior to sowing. Yield responses of brome seed to applications of phosphorus and potassium are seldom economical once the stand is established. Correction of phosphorus and potassium deficiencies prior to seeding will enhance the growth rate of the seedlings and improve the vigour of the young plants. The rate of fertilizer which may be placed safely in the seed row of forage grasses is minimal. Fields which are deficient in phosphorus and potassium should be fertilized at relatively high rates such as 50 kg P205/ha and 50 kg K20/ha prior to sowing the grass. Nitrogen at a rate of 20-40 kg/ha should also be applied to stubble fields prior to sowing if the field will be sown before June 1. This is very important when the field is managed under zero tillage. When sowing the bromegrass on fallow or partial fallow, soil reserves of nitrogen will most likely be adequate to carry the grass for the first seed crop.

Sulphur levels will be adequate if the field has been adequately fertilized with sulphur for optimum canola production within the last two years. Response of smooth bromegrass seed yields to application of micronutrients is uncertain (Stoner and Horton, 1992) . The level of available nutrients, however, is easily checked by submitting a soil sample for analysis.

**E. Moisture requirements**

Seed yields of grasses vary with moisture conditions; therefore, irrigation or relatively dependable rainfall to supply 35-50 cm of moisture are essential for consistent grass seed yields. Without adequate moisture, seed head formation may be inadequate to justify the harvest of the seed crop. Under dryland, harvest of the grass as forage or pasture may be necessary in drier years to obtain revenue from a grass seed field when it has not set seed (Atkins and Smith, 1967). Little research with bromegrass production under irrigation has been conducted.

## IV. Crop establishment

Bromegrass may be sown with any conventional planting equipment if shallow seeding and adequate packing are achieved. Although air seeder cultivators and hoe drills have successfully established bromegrass, disk drills are the most common seeding implement. Some modifications to conventional equipment will simplify the seeding operation and reduce the risk of poor establishment. The addition of depth control bands to disks and agitators in the seed box relieve many of the difficulties associated with seeding bromegrass. Zero tillage implements have also successfully established bromegrass. A good grass seed drill has the following features:

1) a packing wheel ahead of the disk opener to level and firm the soil,
   (for tilled soil)
2) depth control bands on the disk opener to maintain shallow penetration
3) a trailing packer wheel to ensure good seed to soil contact
4) agitation in the seed box to prevent bridging of seed.

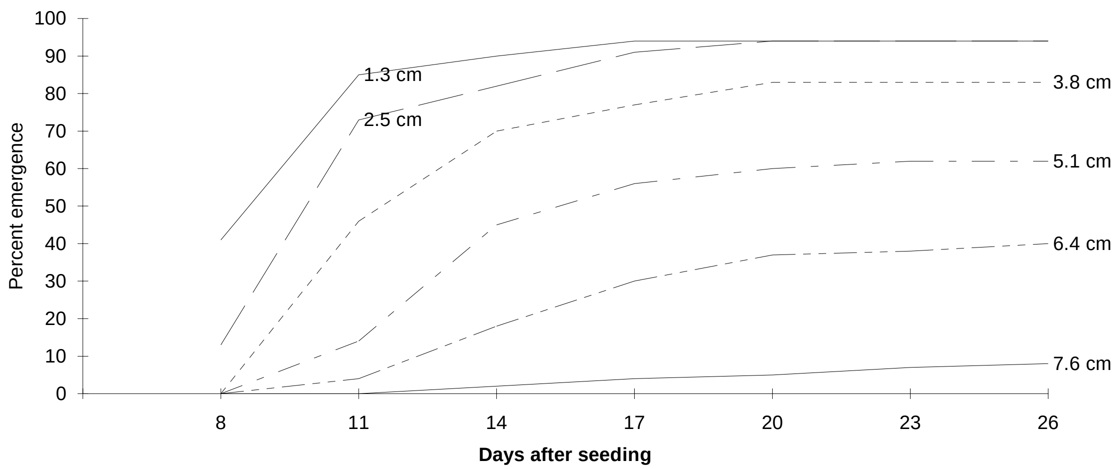
A firm seedbed is essential for shallow even placement of the seed. Packing following the last tillage operation will help to firm the soil. Some grass seed producers roll their fields before seeding to improve control of seeding depth. A rainfall following the final tillage operation will also prepare a firm and moist seedbed for placement of the grass seed.

Bromegrass has a light chaffy seed which will readily bridge in the seed cups. This bridging causes inconsistent plant stands and missing seed rows. Agitators in the seed tank to disturb the grass seed will prevent bridging of the seed. Filling the seedbox only half full and getting extra help to mix the seed in the seedbox while planting will overcome this difficulty if agitators have not been installed in the seedbox. Using seed coated with a polymer film will improve the flow of the seed in the drill and will protect the user from any seed treatments which may be added to control disease organisms. Another helpful approach is to mix an equal volume of low nitrogen fertilizer (12-51-0), cracked wheat, or cereal grain with the seed. Unused seed should be separated from the fertilizer as soon as possible after seeding is completed. Fertilizer will absorb hygroscopic moisture from the air over time and increase the moisture content of the seed. The increase in moisture content of the seed will decrease its viability. Senter et al. (1975) found that the germination of three grass species was reduced if the seed was in contact with a 20-20-0 blended fertilizer for more than nine days under humid conditions. Ahlgren et al. (1950) observed no difference in germination between bromegrass seed alone and bromegrass mixed with 18% super phosphate or fertilizer blends of 5-10-5 and 10-10-10 when the samples were stored in cloth bags at a temperature ranging between 7-13oC over a period of four months. Fertilizers with low water solubility can be safely mixed with bromegrass seed for periods up to 3-4 weeks without injuring the germination of the seed if the mixture is stored under dry conditions.

The quantity of fertilizer which is safely placed in the seedrow with the grass seed is dependent on a number of factors. The texture and organic matter content of the soil are the two most important factors which limit the risk of injury. The moisture content of the soil at seeding time, the proximity of precipitation to the seeding operation, the spacing between rows, and the width of the seedrow itself are the remaining considerations. Soils with a high content of organic matter and clay have a lower risk for fertilizer injury to grass seedlings. A soil with a moisture content near field capacity is less likely to have fertilizer injury. Rainfall immediately after seeding will replenish the moisture content of the soil and remove fertilizer salts from the vicinity of the grass seeds.  As the spacing between the rows widens, the amount of fertilizer next to the seeds will increase if the application rate per unit area remains the same.  A narrow width of the seedrow itself will place more fertilizer in close contact with the seed than a slightly wider seedrow.  The general guideline for forage seeds is for no nitrogen, potassium, or sulphur fertilizers placed in the seedrow.  Application of phosphate fertilizer up to 15 kg P205/ha is generally safe if the preceding principles are kept in mind.

Shallow placement and excellent packing of seed is important to achieve a high percentage of germination and emergence of seedlings.  Control of the seeding depth is critical to successful establishment of the bromegrass stand.  As the seeding depth increases, the time required for the seedling to emerge from the ground increases and the percentage of seedlings that emerge decreases.

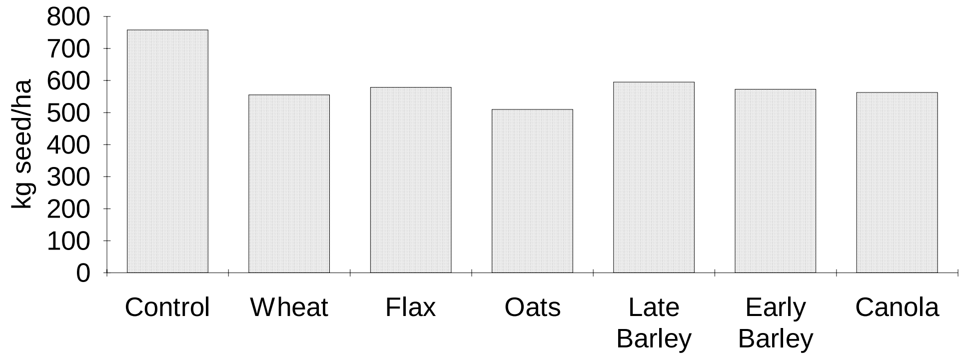
**Figure 1:  Effect of seeding depth on rate of emergence of bromegrass seedlings (McKenzie et al., 1946)**




The main objective for the establishment year is to produce a vigorous stand of healthy seedlings which have profusely tillered.  For sowing on well-prepared fallow or for zero tillage establishment, the best seed yields are often obtained with early spring seedings.  Smooth bromegrass is sensitive, however, to planting in cold soils (McElgunn, 1974).  For a temperature regime which alternates between 2oC and 13oC, the germination rate of bromegrass was only two-thirds as high as for other warmer regimes.  Delaying seeding until the minimum temperature has risen above 4oC may improve the germination of bromegrass.  The bromegrass seed crop may be sown anytime between early May and mid July, however, without much loss in seed yield.  Although the first seed crop may be reduced slightly, subsequent crops often yield more seed which compensates for the smaller initial seed crop.  Research at Beaverlodge indicates that smooth bromegrass should be sown prior to July 25 for a satisfactory seed yield in the next year (Elliott, 1972).

Seed production of grasses is higher when no companion crop is sown with the grass seed.  The seedlings grow more vigorously during the establishment year and are not stunted by the companion crop.  Although the companion crop provides some revenue during the establishment year, the first seed crop of grass is sufficiently reduced to offset the benefit of the companion crop.  Elliott (1973) found that seed yields of smooth bromegrass averaged over six harvest years were a minimum of 160 kg/ha/yr. higher when no companion crop was sown.  Lueck et al.(1949) found that smooth bromegrass plants grown without a companion crop over a wide range of seeding dates had an average of ten times greater seedling weights and 3.7 times more tillers than plants grown with a companion crop.

**Figure 2: Seed yield of Carlton bromegrass seeded with different companion crops (Elliott, 1972)**



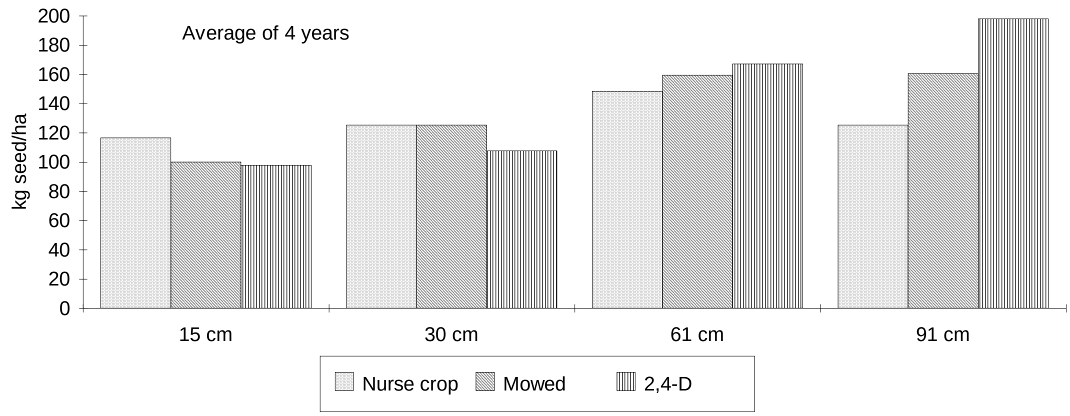

Yields are averages of six seed harvests from three years of seeding

Row planting of grass seed fields provides a number of benefits. Planting in wider-spaced rows reduces the seed requirements which reduces input costs. The stands can be tilled with a row crop cultivator or gang rototiller to control weeds. Seed yields will be higher, especially as the stand ages. Roguing of the field is more thorough and easier (Patterson, 1956). Row production of grass seed under dryland conditions reduces the risk of lower seed yields due to drought (Knowles et al., 1969).

Swaths are often difficult to pick up from between widely spaced seed rows. Cutting the crop at an angle across the seed rows may alleviate this difficulty. If inter-row cultivation is practiced, however, the field becomes too rough to swath the field across the seed rows. One alternative is to straight combine the crop. Another alternative is to sow the crop in groups of three seed rows with a gap between each of these groups of rows. The windrow may be laid on the groups of rows as appropriate. The seed drill may be set up to sow a group of rows where a swath would be laid.

The seed yields of smooth bromegrass sown at four row spacings were determined at Saskatoon for four years. Seed yields were higher with 61 or 91 cm rows than for narrower row spacings (Knowles, 1961). Southern bromegrass responds to wider spacings better than northern bromegrass. Seed yields of southern bromegrass averaged 50 kg/ha higher when grown in rows spaced 91 cm apart as compared to 30 cm. Northern bromegrass seed yields were increased by only 30 kg/ha when grown at the wider row spacing (Knowles et al., 1969). Canode (1968) at Pullman, Washington found no yield response in any given year by increasing row spacings in smooth bromegrass. The accumulative average seed yield over four years, however, was significantly higher for 60 cm rows as compared to 30 or 90 cm row spacings. Fulkerson (1972) threshed a higher seed yield of bromegrass when the grass was sown with a 71 cm row spacing compared to a 36 cm row spacing. Yield levels declined sharply for the 2nd and 3rd seed harvests and the yield advantage for wider row spacing was insignificant at the lower yield levels. Inadequate nitrogen fertility or the moist climate may have contributed to this unexpected observation. In Pennsylvania, Buller et al. (1955) found that bromegrass sown in rows spaced 91 cm apart produced an average of 220 kg/ha more seed than solid stands established by broadcast seeding. The advantage of row cropping was less when nitrogen was applied at 110 kg N/ha as compared to 55 kg N/ha.

**Figure 3: Effect of row spacing and method of establishment on seed yields of smooth bromegrass (Knowles, 1961)**




The sowing rate for grasses is somewhat arbitrary depending on the suitability of the soil for seed germination. Because the weather is an important factor in the success of a seeding, the safe approach is to seed at a higher rate than is suitable for ideal conditions. It is wise to plan for loss of up to 80% of the seedlings. The goal is to sow enough seed to achieve a satisfactory stand without too much inter-plant competition. Seedlings which are vigourously tillering will produce a higher seed yield. Button et al. (1993) recommend a seeding rate of 4.4 kg/ha with a 60 cm row spacing. Knowles et al. (1969) suggest sowing 40-65 seeds per meter of seed row. When another material is mixed with the seed to eliminate bridging of the seed, this method takes much of the guesswork out of determining the drill setting. With a 60 cm row spacing, one hectare (10,000 m2) would contain 16,667 meters of seed row. Since one kilogram of smooth bromegrass contains 300,000 seeds (1 lb = 136,000 seeds), the rate for smooth bromegrass ranges between 2.2 - 3.6 kg/ha (2 - 3.3 lb/ac). Using this approach, it is easy to calibrate the drill by seeding over a sheet of plywood or a pad of concrete and counting the seeds sown over a measured distance.

The injury to germinating seedlings from fertilizer occurs from two sources: the dissolved salts and the ammonium content. Fertilizers which are readily soluble in water are more hazardous than less soluble forms. Nitrogen sources which liberate ammonium are more hazardous than nitrate sources. Ammonium phosphate is relatively safe because the fertilizer is dissolved more slowly when it comes in contact with moisture. The ammonium content of ammonium phosphate is only 10-12% of the weight of the fertilizer.

## V. Crop Management

Herbicide registrations for the control of weeds during the seedling year provide a wide array of options for control of annual grassy and broadleaf weeds. The most difficult weeds to control include quackgrass, downy brome, green foxtail, and Persian darnel. Controlling annual grasses during a seed production year reduces the need for roguing. Refer to Table 2 for currently registered treatments.

Clipping or mowing is another effective strategy for controlling annual weeds. The weeds should be mowed as required to prevent them from setting seed. When the soil is not disturbed, most weed seeds do not germinate. After the grass crop becomes established, few weeds will germinate in the seed production years.

Field roguing is a requirement for production of quality grass seed for the Canadian market. The chaffy grasses such as bromegrass have no tolerance for primary noxious weeds such as quackgrass, Canada thistle, cleavers, and wild mustard. Cleavers are extremely difficult to remove from the finer grasses such as Kentucky bluegrass. Unthreshed wild mustard seeds are often retained in the beak which is impossible to clean out of a chaffy grass sample. Wild oats, Persian darnel, scentless chamomile, shepherd's purse, stickseed, and stinkweed are secondary noxious weeds which are limited to 1 and 2 seeds in 25 g for Canada Registered No. 1 and No. 2 grades

respectively. Any of these weeds which appear in the stand must be eradicated before the field is inspected. Although downy brome is not listed as a noxious weed, some customers will not purchase seed containing this weed. The weedy plants may be uprooted manually by hoe or hand-pulling. Roundup is an effective herbicide for controlling perennial weeds in grass seed stands, but it must be applied by spot treatment directly on the target weeds to prevent injury to the grass seed crop.

## VI. Disease and Insect Problems

Ergot infects cross-pollinated grasses such as bromegrass. The disease is caused by the fungus Claviceps purpurea. The first symptoms of ergot infection are the collection of a sticky honeydew on the surface of infected florets. The deposit contains the spores of the disease. The fungus continues to grow within one or more of the infected florets to form a hard, purplish black ergot body in place of one of the seeds. Often the ergot body or sclerotium is conspicuous because it is black and much larger than the seed it replaces. Ergot-affected heads will produce few seeds. Often infected heads will contain no viable seed. Ergot tends to be spread from infected grasses along field margins. The disease is most prevalent during years when the soil surface is moist during the spring and early summer and when showers prevail during the flowering period of the grass. Moisture stimulates the germination of sclerotia and the release of the infecting spores. Wet cool weather also prolongs pollination which increases the likelihood of infection of florets by spores. Fertilized ovaries are resistant to ergot infection. Seed treatments are ineffective in control of ergot. Sanitation and use of ergot-free seed are the best control measures. Mowing the field edges just prior to heading reduces the risk of ergot infection. If the outside edge of the field is infected, this portion should be harvested and kept separate from the remainder of the seed. Storing the infected seed for three or more years will also reduce the number of viable sclerotia. The Canada Seed Act allows only 1.5% sclerotia in No. 1 seed and 3% in No. 2 seed (Seaman, 1980).

Several leaf spot diseases have reduced seed yields of bromegrass in Saskatchewan. The most common leaf spot disease throughout the province is Selenophoma bromigena. The spores of this disease are transferred on the seed. Pyrenophora bromi is most serious leaf spot disease in the Black and Grey soil zones. Scald, caused by Rhynchosporium secalis, is the third most important bromegrass leaf disease. Other diseases include bacterial leaf spot and black node. Southern strains of bromegrass are more resistant to leaf diseases than northern strains. The variety Magna is more resistant to leaf spot diseases than the earlier northern varieties (Smith and Knowles, 1970).

The bromegrass seed midge, Stenodiplosis bromicola, has caused seed yield losses of up to 50% in smooth bromegrass in some years. Although the midge attacks three species of the genus Bromus in the former Soviet Union, it was only been found on Bromus inermis in Nebraska (Neiman and Manglitz, 1972). Although the level of damage from the midge in Russia was higher with increasing age of the bromegrass stand, no relationship to the age of the stand was noted in Saskatchewan (Curry et al., 1983). Higher midge populations are favoured by high humidity, warm temperatures and wet weather (Soroka, 1991).

Two generations of midge adults emerged per season: the first during early heading of the bromegrass and the second at flowering time about 20-25 days later (Curry et al., 1983). Bromegrass seed yields are reduced by the first generation of adults. Eggs of the midge are deposited within the florets prior to flowering and the freshly hatched larva, subsequently, consume the ovaries. Affected florets do not flower. Yield losses are due to reduced seed setting as well as increased seed shattering (Knowles, 1973). The rachilla joint immediately below an infested floret weakens and the florets adjacent to the infested floret shatter readily. Although damage by the midge is relatively inconspicuous, the severity of damage to the seed crop can be estimated by the abundance of small holes in the bromegrass florets. These holes are caused by a wasp parasite of the midge, Tetrastichus sp. Knowles (1973) observed that the floret fertility of bromegrass and the occurrence of these insect holes were inversely related. The parasite attacks most of the first generation of the larva, but, in later generations, prefers to attack the pupa stage. In Nebraska, the rates of parasitism in June of the midge larva averaged 73% and of the midge pupa averaged 88%. Soroka (1992) found many species of parasitoids on smooth bromegrass in the Peace River area. Application of carbofuran or dimethoate before flowering reduced the population of midges already in the panicles, but did not protect the plants from subsequent midge invasion (Curry et al., 1983).

Silvertop damage to bromegrass may cause substantial yield losses. The condition appears about the time of flowering as silvery-white heads which appear mature, but contain no seed. The flag leaf, sheath, and lower stem remain healthy and show no evidence of any growth problem. The inflorescence of the stem dies from stem injury at one or more points above the terminal node. The damage is thought to be caused by some agent withdrawing sap from the stem. The emerged inflorescence of affected stems is easily pulled from the leaf sheaths with the lower end often shrunken, darkened, necrotic, and infected with a fungal growth. The fungal growth is likely a secondary infection of the plant caused by Fusarium poae. Several plant bugs are suspected agents for the condition (Arnott and Bergis, 1967). Capsus bugs were related to the incidence of silvertop in bluegrass fields in Minnesota (Peterson and Vea, 1971). Capsus simulans punctured the leaf sheath of bluegrass in the greenhouse (Arnott and Bergis, 1967). Holmes et al. (1961) identified thrips as the main source of injury in bromegrass. Mites, Siteroptes graminum, were also found in some of the bromegrass affected with silvertop. The condition has been controlled in bluegrass by burning the grass field after harvest. Grazing the bluegrass field in the fall (Peterson and Vea, 1971) and mechanical removal of the straw (Kamm, 1979) did not control the condition . Application of DDT has been very effective for control of silvertop in bluegrass in Oregon and Minnesota (Hardison, 1959; Peterson and Vea, 1971).

## VII. Harvest

Grasses need about 30 days after flowering for the seeds to develop. Hot, dry weather shortens the ripening period while cool, moist conditions will delay seed maturity (Tober 1988). Grasses grown under irrigation or moister conditions have a higher ash content which increases the likelihood of shattering (Najda et al., 1994). The ripening process begins at the top of the seed head and proceeds down the stem. Seeds at the top of the head may begin to shatter while those at the bottom are only starting to fill seed. Frequent inspection of the seed field is necessary to determine when the maximum yield of seed will be harvested.

The appropriate harvesting approach depends on the seed size, plant height, maturity, shattering traits, seed head abundance, seed fill, and moisture content. Conventional harvest equipment is suitable for most grasses. Bromegrasses are harvested by windrowing and picking the swath up after 5-7 days of drying or by straight combining (Tober, 1988). Smooth bromegrass is ready to swath in most years in late July or early August. Swathing and picking up the windrow is the safest harvesting approach, but in years of lower seed yield, earlier maturity, or reduced foliage, straight combining may be more appropriate. Smooth bromegrass has a moderate shatter risk relative to other grasses and seldom lodges unless very heavy rates of nitrogen have been applied. The crop should be swathed when the moisture content is between 50-55% (Elliott, 1972). This corresponds to the hard dough stage. This stage occurs when firm thumb nail pressure is needed to imprint the seed. The seed heads will be brown with the upper stems starting to turn. If the seed shatters when striking the seed head firmly against the palm of the hand, the crop is ready to swath. Swathing early in the morning or in the evening when the air humidity is higher will reduce shattering losses. If the heads are laid in the center of the swath instead of to the side, some of the shattered seeds will be retained on the top of the swath.

Horning and Canode (1963) found that seed harvested by a windrowing was physiologically mature at 45% moisture content. Maximum seed weight, dry weight per shoot, and vigour score occurred at 45% moisture. Maximum seedling emergence of seed in the greenhouse occurred when seed was harvested at 52% moisture and maximum laboratory germination occurred at 61% moisture. Seed harvested by direct combining was not physiologically mature until it reached 24% moisture. Although maximum seed weight was attained at 34% moisture, other parameters such as maximum laboratory germination, seedling emergence from soil in the greenhouse, dry weight per shoot, and vigour score were not achieved until the seed had dried to 24% moisture. Seed ripening continues in immature grass seed as long as the seed remains attached to the stem until the culm is air dry.

Under good drying conditions, the crop will be ready to combine in 5-7 days after swathing. Initial combine settings recommended for bromegrasses are a cylinder speed of 900 rpm and a concave clearance of 3/8". The fan speed is generally set between 400-500 rpm with the sliding covers over the exterior fan housing closed. The combine should be set so that the lemma and palea are retained on the seed. Seeds which retain these seed parts have longer viability if placed in conventional storage or if stored for extended periods (Canode, 1965; 1972). Because of the potential for contamination and the value of grass seed, thoroughly clean the combine before harvesting grass seed. Maintain an even flow of material into the combine. Grass seed crops often require a slower forward speed than conventional crops. Slower combining speeds improve the seed separation from the chaff and straw and greatly reduce losses over the straw walkers and sieves (Najda et al., 1994). Experienced bromegrass seed producers rely more heavily on the seed processing plant to remove chaff and straw than the combine to reduce seed losses out the back of the combine. The seed can be stored safely in open storage up to one year when the moisture content is 10-12%. Mold growth and insect damage may still occur at this moisture content. The safe moisture content for open storage of grasses for longer periods is 8-10% (Harrington, 1960).

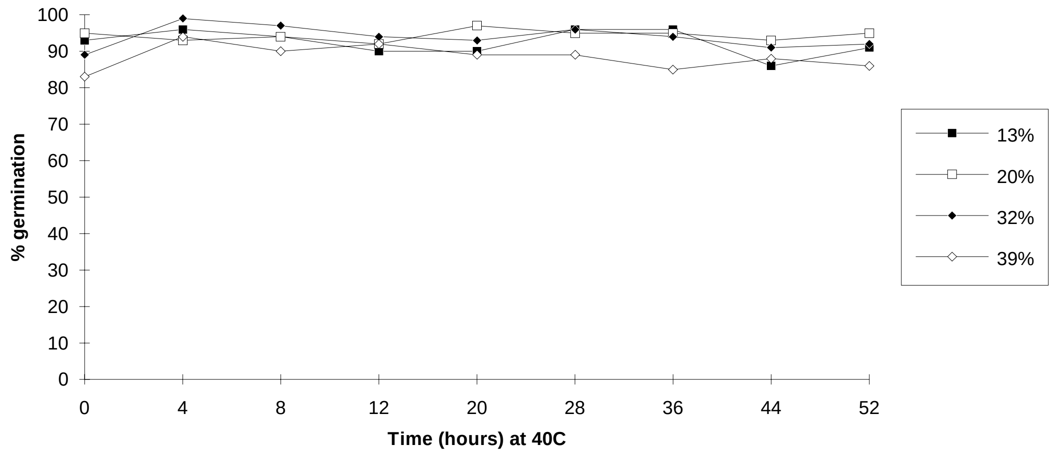
Bromegrass is ready for straight combining at the first hint of seed shatter. When the seed shatters as the seed head is lightly struck against the palm of the had, seed shatter is imminent and the field should be straight combined. This is usually about 10 days after the crop was ready for swathing. The seed will contain about 25% moisture. Because the seed will readily shatter at this moisture content, the risk of losing the crop from a wind storm is high. If the seed yield will be less than 100 kg/ha, straight combining is recommended. Seed that is direct combined will need immediate aeration and drying to maintain the quality of the seed. Many of the short stems that remain in the sample have a high moisture content which promote heating of the seed. Some grass seed growers install an aeration tube directly into their grain truck so that the seed can be easily aerated without dumping into a storage bin. Running the seed over a sieve to remove much of the green leaves, insects, chaff and straw will reduce the risk of heating in the direct combined seed. If the seed is left in a small pile for only a few hours, significant heating may still occur which reduces the viability of the seed. The heating is dependent on the moisture content of the seed, the air temperature, and the position of the seed in the pile. Air temperature is less important as the moisture content of the seed increases, but is significant at lower moisture contents (DeWitt et al., 1962).

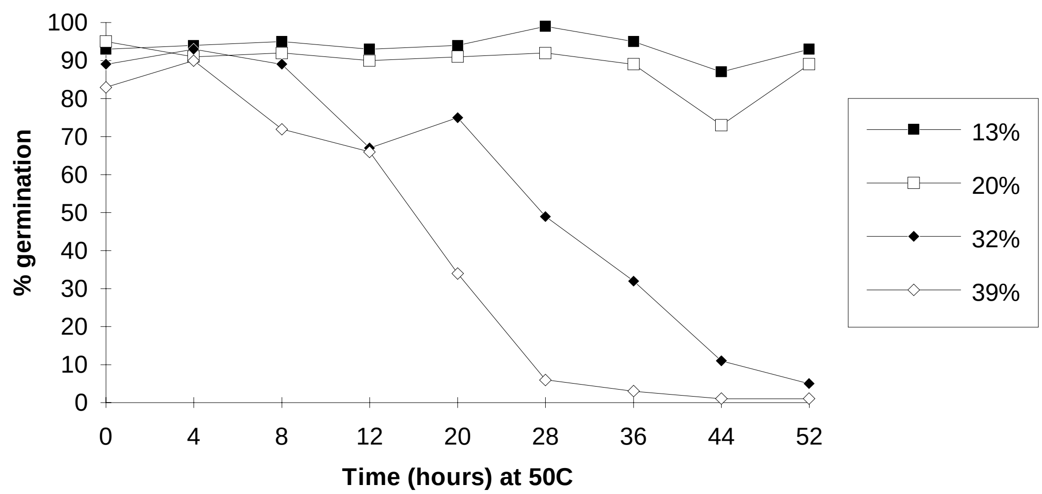
Drying of grass seeds must be conducted with care to maintain the viability of the seed (Figure 4). When the seed has a high moisture content, the temperature of the air flow must be maintained at a lower temperature to prevent injury to the germination of the seed. The resistance of the seed to germination injury from high temperatures increases as the moisture content of the seed decreases. Seed at moisture levels from 15% to 38% maintained germination when stored for 52 hours at 40 C. At 50 C, only the sample with 15% moisture retained germinating power for 52 hours. Samples at 28% and 38% moisture lost germination after 28 and 12 hours respectively (Grabe, 1957).

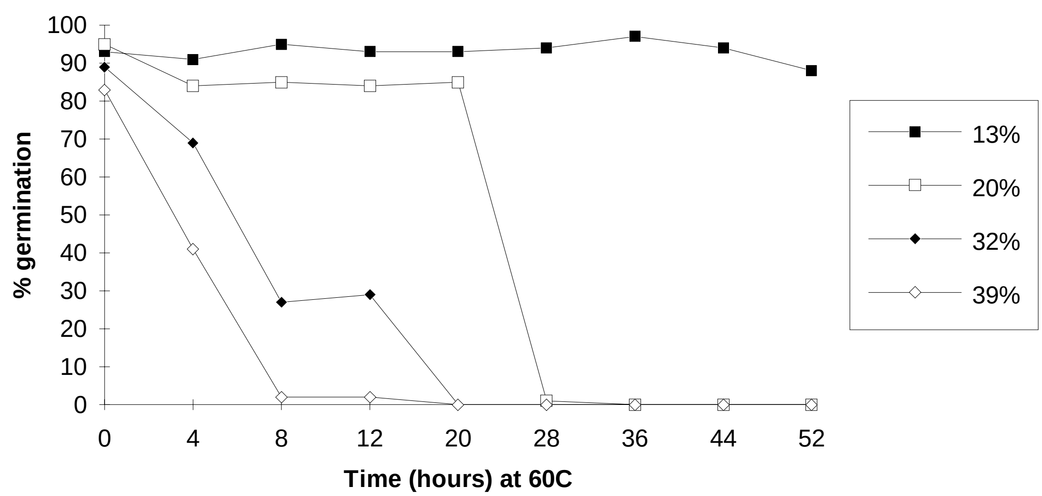
## VIII. Post harvest management

Nitrogen application to bromegrass seed fields is essential for sustained seed yields. Knowles and Cooke (1952) observed a three-fold increase in seed yield by applying 80 lb N as ammonium nitrate (34-0-0) to well-established fields. Application of nitrogen in mid-September increased seed yields more than in early spring. Seed yield responses were greater for ammonium nitrate than ammonium sulphate (21-0-0-24) on a per unit nitrogen basis. Carter (1962) in North Dakota found that seed yields of bromegrass were sustained by a combination of nitrogen fertilization and inter-row cultivation. The inter-row was cultivated in early spring and in August. Higher rates of nitrogen of 150 kg N/ha were required to maintain economical seed yields in the 6th and 7th years of seed production. Anderson et al. (1946) found September applications of nitrogen equal to late March or early April applications in Kansas. Bromegrass on one site which received over 110 kg N/ha was prone to lodging which hindered seed

**Figure 4: Effect of drying temperature and seed moisture content on germination of smooth bromegrass (Grabe, 1957)**



pollination and development. Harrison and Crawford (1941) in Michigan found that seed yields declined as nitrogen application was delayed from mid-April to mid-June. The smooth bromegrass seed yield decreased an average of 33 kg seed/ha for every week that the application of nitrogen was delayed. The extra nitrogen increased the seed weight, especially when the application was too late for maximum seed yield.
Hennig and Elliott (1970) recommend that the best time for nitrogen application to grass seed crops is just prior to floral initiation. Clarke and Elliott (1974) found that fall initiation represented less than 25% of the tillers at Beaverlodge. Some of these tillers suffer cold injury over winter. The majority of the tillers undergo floral initiation during late April and early May. Bromegrass had completed floral initiation by May 8 at Beaverlodge, Alberta (Elliott, 1966). Horton (1991) observed higher seed yields of smooth bromegrass when nitrogen was applied in early spring as compared to after harvest and late fall applications. Klebesadel (1970) found that spring nitrogen applications to bromegrass in Alaska were not effective in stimulating seed production. He speculates that late summer applications in Alaska are more appropriate because suitable conditions for floral initiation do not occur in spring in Alaska.

Knowles (1966) evaluated the practice of removing stubble from bromegrass seed production fields. Many smooth bromegrass fields are straight combined which leaves a stubble of 20 to 50 cm. Mowing the stubble immediately after harvest or in early spring increased seed yields by an average of 170 kg/ha. Burning the stubble in late fall or early spring produced similar yields to mowing the residues. The yield response was partially due to the control of leaf diseases in the bromegrass. Although yields from removal of the stubble in fall by mowing or burning were comparable to yields when these practices were completed in spring, the stubble is useful for catching snow. From the point of view of moisture conservation and protection from winter injury, spring burning is preferable to fall burning. Seed yields based on these practices do not indicate an advantage from the additional moisture trapped by the stubble in the form of snow. Schaber (1992) in Alberta observed a 60% yield increase in smooth bromegrass seed yield by burning the crop residue in April as compared to the seed yield harvested from unburned bromegrass stubble. Canode and Law (1978) found that burning of smooth bromegrass stubble increased seed yields by an average of 275 kg/ha compared to removal of the straw mechanically. Seed yields of smooth bromegrass were intermediate to these two treatments when the stubble and straw was removed as close to the soil surface as possible. A second benefit of stubble burning was the control of downy bromegrass in plots which reached burn temperatures greater than 500 C.

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## **VIII. References:**

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