

Toxic Effects of Straw

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Abstract

Oregon produces 70% of the world supply of cool season grass seed, including tall fescue (*Lolium arundinaceum*) and perennial ryegrass (*L. perenne*). About 225,000 ha of grass seed are currently in production in Oregon. Traditionally, the seed was harvested in June and July and the straw residue in the fields was burned during July and August. Today, the straw is harvested and used for animal feed, principally in Japan, Korea and Taiwan. In 2006, 33,000 containers of compressed straw were shipped to the Pacific Rim countries from Northwest US ports. The production of cool season grass seed is continuing to increase. Almost all the increase consists of cultivars with high endophyte (*Neotyphodium* spp.) infestation. As a consequence, much more endophyte-infected straw is being produced. Endophytes produce alkaloids that are advantageous to plants but deleterious to livestock when fed straw with too high a concentration of these toxins. In this chapter, the toxic effects of straw feeding and toxin threshold levels will be discussed.

Keywords: endophyte, tall fescue, perennial ryegrass, straw

Oregon produces approximately 70% of the world supply of cool season grass seed. This includes tall fescue and perennial ryegrass. Even though this is a monograph on tall fescue, when straw from the Pacific Northwest is discussed, both tall fescue and perennial ryegrass and their associated alkaloids must be addressed. About 225,000 ha of grass seed are currently in production in Oregon. Traditionally, the seed was harvested in June and July and the straw residues in the fields were burned in July and August of each year.

The commercial grass-seed straw industry is relatively new to the US Pacific Northwest. The straw residue after seed harvest, typically burned in the seed production fields to reduce weed seeds and insect pests, now cannot be burned. In 1991, under pressure from environmental advocates, the Oregon Legislature mandated a field burning phase-down from a maximum 100,000 ha to a cap of 16,000 ha. In reality, grass seed growers have consistently burned less than the maximum allowed by law since the phase-down was implemented. Recent initiatives indicate that field burning will be completely eliminated in Oregon in the future. The state of Washington has already banned all field burning. Idaho courts have instigated a similar ruling.

The Oregon Ag Fiber Association was created as a representative of grass seed straw producers to find commercial uses for the straw residues in response to the increased production of grass straw highly infested with endophyte (Fig. 1) and the cessation of field burning.

Figure 1. Number of tall fescue cultivars grown for seed and their level of endophyte infestation, 1980-2006. (Note the 'high' level increases exponentially. High=61-100%, Medium=31-60%, Low=1-30%, Free=0%). (Young et al., 2007)

The presence of *N. coenophialum* in tall fescue and *N. lolii* in perennial ryegrass presents a dilemma to the seed industry. The endophytes protect the host plant against environmental stresses and some pests but, at the same time, endophyte presence above threshold levels is toxic to herbivores. Therefore, endophytes are advantageous for users of turfgrass seed because they promote low-cost stand maintenance, but are detrimental to users of seed crop residue for animal production.

STRAW MANAGEMENT

Harvest and export of straw residues

A single planting of a grass seed field is harvested once annually for up to 3-5 yr, depending on the cultivar. The harvest season extends from June through early August. High seed yield and harvest efficiency are favored by the cool, dry summer climate in the Pacific Northwest. At harvest, the grass is cut and swathed to dry for one week, being turned once during this time.



Figure 1. Tall fescue straw being gathered into windrows in preparation for baling. (Photo: Steve Van Mouwerik, Anderson Hay and Grain Co.)

When dry, the swath is picked up with a harvester, which threshes the seed and expels the straw back onto the field. The straw is then gathered into larger windrows and baled (Fig. 1), yielding about 1,600 kg/ha. The straw has 5 to 6% protein and can serve as an inexpensive source of fiber in ruminant diets. The bales of straw are collected from the field and stored in barns until compressed and repackaged for export. The bales are compressed to about one-third of their original size (Fig. 2). In general, compressed bales measure about 90 x 90 x 120 cm (3 x 3 x 4 ft) and weigh between 318 and 363 kg (700 to 800 lbs). Compressed bales are placed into shipment containers for export mainly to Japan, Korea and Taiwan.



Figure 2. Loading harvested straw bales onto a trailer truck.
(Photo : Steve Van Mouwerik, Anderson Hay and Grain Co.)

Since 1991, there have been many attempts to find uses for the straw from seed production. The most practical and economically successful use of the straw has been for animal feed. Northwest US ports exported more than 33,000 containers of compressed straw to Asia in 2006. In addition, Northwest cattle producers have used the straw to feed their herds. Consequently, clinical cases due to the endophyte toxins in the straw have been observed and documented in recent years.

STRAW TOXICITY

Fescue foot, ryegrass staggers, and fescue toxicosis

When *Neotyphodium* endophytic fungi are present in large enough concentrations in either tall fescue or ryegrass straws, cattle may suffer from serious, sometimes fatal, diseases. Both of these grass/fungus associations produce various alkaloids that have been identified as causal agents of the diseases.

In the case of tall fescue, consumption of grass containing ergovaline and related ergot alkaloids, especially in hot weather, can result in fescue toxicosis. If high rates of nitrogen fertilizer have been used, regardless of the season, fat necrosis may develop. The most important disorder resulting from the ingestion of endophyte infested straw is fescue foot, a broad term covering

symptoms of gangrene and necrosis of body extremities. Ergot alkaloids cause constriction of blood vessels, a condition aggravated by cold weather, which is the time when such straw is most often fed. Signs of fescue foot may appear 2-3 wk after ingestion of infested straw or seed screenings, and not all animals are equally susceptible. Persistent cases lead to severe reduction of blood supply to the feet, ears, and tails with resultant dry gangrene and possible loss of those body parts (Aldrich-Markham et al., 2003; Tor-Agbidye et al., 2001).

At least two major outbreaks of fescue foot occurred in Oregon in 2005. In eastern Oregon, a beef cow/calf operation with over 1,800 animals fed tall fescue straw purchased from the Willamette Valley beginning in late November. By 25 December, when temperatures had ranged from -17°C to -1°C, signs of lameness and swollen feet were noted, progressing to dry gangrene of the feet, often with subsequent fracture of the necrotic toes or lower limbs. Three weeks later, the feeding of straw was stopped. By early March, two-thirds of the bulls and almost a third of the cow herd had died or had to be euthanised. All surviving animals in the herd were under stress and in discomfort. Straw samples were subsequently found to contain extremely high concentrations of ergot alkaloids. Prior testing would have identified this feed as very high risk and therefore could have prevented this catastrophe.

The other outbreak, in the lower Willamette Valley, affected 330 cows and 10 Angus bulls which had been fed pelleted tall fescue with seed screenings, starting in mid-December. By February, when there had been periods with temperatures below -7°C, about 10% of the herd suffered severely from fescue toxicosis and many had to be euthanised. Samples of pellets taken in January from the bins used for storing the feed showed that the concentrations of ergovaline and ergotamine were at dangerously elevated levels.

Perennial ryegrass contains a somewhat different profile of alkaloids from tall fescue when infested with its endophyte, *N. lolii*. Infected perennial ryegrass contains lolitrems, peramine and paxilline in addition to ergovaline (Hovermale and Craig, 2001; Rowen, 1993;). The primary disorder associated with *N. lolii* is ryegrass staggers (Fletcher and Harvey, 1981), of which the causal alkaloid is lolitrem B (Blythe et al., 1993; Fisher et al., 2004; Galey et al., 1991; Gallagher et al., 1984; Hunt et al., 1983). Early-stage ryegrass staggers is characterized by a stiff limb gait and disorientation in affected animals. The disorder progresses to ataxia (involuntary body movements), muscle tremors, and reluctance or inability to rise. Excitement worsens these signs. Animals not withdrawn from feed containing high levels of lolitrem B can exhibit a down convulsive state, but seldom die. Withdrawing the animal from such feed usually results in a return to normal status in several days, although in some cases, it may take as long as a few weeks, depending on the severity of the signs.

A practical management procedure to avoid these diseases is to dilute toxic feed with nontoxic feeds to decrease the concentration and thus intake of toxic alkaloids.

There have been several reports of fescue toxicosis in Japan with tall fescue straw exports from Oregon. Some beef cattle receiving straw mixed with various other feeds developed anorexia and lameness and had to be euthanised. The Japanese Ministry of Agriculture (MAFF) reported high ergovaline levels in the straw (Saiga, 1998). Perennial ryegrass is also exported to the Pacific Rim countries; it is used primarily as forage for Japanese Black Cattle because it imparts white

marbling in Kobe Beef. Several instances of perennial ryegrass staggers have been reported as a result of high lolitrem B levels in the perennial ryegrass (Saiga and Maejima, 1998). Such situations, if repeated, could severely diminish the exports of straw from the Pacific Northwest.

Endophyte toxins from tall fescue are also suspected to afflict New World camelids, such as llamas (*Lama glama*), although the number of animals involved is small. Typical signs observed in some animals include poor milk production (Brendemuehl, 2002) and sloughing of distal extremities (Davis, 2002). In addition, ingestion of high-levels of lolitrem B from perennial ryegrass have been associated with tremors in camelids (Smith, 2002).

Threshold studies of alkaloid toxicity

Determination of threshold concentration for toxicity became possible when analytical assays for ergovaline in tall fescue in perennial ryegrass were developed (Craig et al., 1994; Durringer et al., 2005; Rottinghaus et al., 1993; Tor-Agbidye et al., 2001). From those investigations, a threshold for ergovaline in cattle was set at 0.35 to 0.50 $\mu\text{g/g}$ at ambient temperature. The colder the ambient temperature, the lower the threshold ergovaline level. The threshold was set at 0.50 $\mu\text{g/g}$ for low temperatures for sheep, since they appeared to be slightly more tolerant of ergovaline than cattle (Tor-Agbidye et al., 2001).

Determination of the threshold level of lolitrem B in ryegrass also became possible when an analytical assay for the molecule and pure standards became available (Gallagher et al., 1985; Hovermale and Craig, 2001; Miles et al., 1992). From studies conducted in pastures where cases of ryegrass staggers had been observed (diMenna et al., 1992; Galey et al., 1991; Tor-Agbidye et al., 2001), the toxic threshold level was set at 2.0 $\mu\text{g/g}$ lolitrem B for cattle and sheep. This threshold level was used to determine which straw would be used for export to Asian countries (USDA Blue Ribbon Committee, 1999-2000).

Subsequent to that action, reports of Japanese Black Cattle being affected by lolitrem B at concentrations lower than this threshold came to the attention of the grass straw industry (Miyazaki et al., 1999, 2001; Saiga, 1998; Saiga and Maejima, 1998). Feeding trials with cattle were conducted with endophyte infected perennial ryegrass straw having known levels of toxin. In the pilot study (Fisher et al., 2004), 72 Angus/Hereford crossbred cows were fed perennial ryegrass straw ad libitum and supplemented with soybean meal during the last trimester of their pregnancy. No signs were observed at 1.4 $\mu\text{g/g}$; but were observed at 1.95 and more $\mu\text{g/g}$). A second study (Blythe et al., 2007) confirmed these values with Angus and Angus crossbred cattle. Japanese Black Cattle did not develop ryegrass staggers at 1.4 $\mu\text{g/g}$ lolitrem B for 28 d, indicating that this breed is not necessarily more susceptible to staggers than other breeds. Based on these results, the current threshold of toxicity of lolitrem B in straw and other feedstuffs is 1.8 to 2 $\mu\text{g/g}$. A later Japanese study has intimated that Japanese Wagyu cattle exhibit ryegrass staggers at 1.2 $\mu\text{g/g}$ lolitrem B (Miyazaki et al., 2004). The authors also were concerned that residues of about 0.2 $\mu\text{g/g}$ lolitrem B found in the fat might raise public health concerns (Miyazaki et al., 2004). Considering these and other studies, a special panel of scientists (USDA Blue Ribbon Committee, 1999-2000) set the toxicity threshold level at 2.0 $\mu\text{g/g}$ lolitrem B for cattle and sheep (determined by Tor-Agbidye et al., 2001). This threshold level was used by USDA to determine which straw would be used for export to the Asian countries.

STRAW ANALYSIS

Straw analyses and diagnostics

As mentioned earlier, the Oregon production and annual export of thousands of containers of grass straw is an important industry. The seed and straw exporters work with the Endophyte Testing Laboratory at Oregon State University to determine levels of lolitrem B and ergovaline in straw to be exported. The laboratory provides to exporters a certificate which lists toxin levels. This is a voluntary testing program. Since not all exporters use it, some shipments of tall fescue and perennial ryegrass straw with above-threshold levels of ergovaline or lolitrem B are delivered to their destinations. Many samples are received from veterinarians, ranchers, and extension agents to ascertain potential toxicity risk in tall fescue and perennial ryegrass feed in North America.

A definitive diagnosis of tall fescue toxicosis or ryegrass staggers depends on quantification of alkaloid levels in the suspected feed. In the ergovaline assay, straw is ground to 0.5 mm, partitioned into chloroform by shaking for 24 h, purified with an SPE column, and quantified with an HPLC fluorescence assay (Rottinghaus et al., 1993; Craig et al., 1994). For the lolitrem B assay, straw is also ground to a 0.5-mm size and partitioned into a chloroform/methanol mixture. After shaking for 18 h, the mixture is evaporated to dryness, reconstituted into a chloroform/acetonitrile mixture, and quantified with an HPLC fluorescence assay (Craig et al., 1994; Hovermale and Craig, 2001).

Sampling of straw bales for toxin analyses

Representative sampling of straw bales must be carried out to accurately quantify the concentration of toxins. To obtain a representative sample from stacks of baled straw, a forage core sampler, available from farm supply sources, must be used. Core samplers are often attached to an electric hand drill for easy penetration. The sample corer should have an external diameter of 1.27 cm (0.5 in) and a core length of at least 30 cm. A bale can be sampled best by centering the core sampler in the end of the bale and drilling horizontally (Fig. 3 and 4). A minimum of 20 cores per stack, and not more than one per bale, should be obtained for each lot.



Figure 3 Hay corer attached to a manual hand drill (Photo: The Samuel Roberts Nobel Foundation)



Figure 4. Core sampling a bale in a straw stack. (Photo: Steve Van Mouwerik, Anderson hay and Grain Co.)

A sampled lot should comprise only one cultivar, harvested from one field. If there are two or more lots in a stack, each lot should be sampled separately. A truckload of straw may be considered a lot if there is no information about its cultivar or field source. Bales within a lot should be sampled at random to guard against bias. Every fourth or fifth bale should be sampled, going around the stack or truck, taking at least five random samples from each of the four sides of the stack. Each sample should be placed in a polyethylene freezer bag and sealed tightly. Each bag should be carefully labeled with the name and telephone number of the sender, the lot identification, and the name of the assay desired. Samples should be sent to the laboratory which can do the analyses reliably. The author is connected with the Endophyte Service Laboratory at Oregon State University, which can do these analyses (1-541-737-2872).

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