Fire Effects on Rangeland
FACTSHEET

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Fire Effects on Grasses and Forbs

This factsheet will focus on how fire affects grasses and forbs. Fire is a dynamic process that affects grass and forbs in a variety of different ways. When determining the effects of fire on individual species and ecosystems, it is important to understand the condition of the plant community and individual species existing before a fire occurs. That is, the impact of fire on an individual plant species or communities may increase if the community has been subjected to other disturbances such as drought, disease, insect infestations, overgrazing, or a combination of these factors.

The response of individual grasses and forbs to fire varies significantly between, and within, species and is dependant on the parameter being measured. Moreover, this response is influenced by a variety of fire parameters including intensity, severity (e.g.,, amount of organic matter consumed), residence time, soil heating, season of burn, and time since last fire, all of which can vary significantly among fires and within a fire. These variations can and will cause differences in the response of individual species and the community as a whole. In addition, numerous physical and climatic factors (e.g.,, fuel condition, weather, slope, and aspect) as well as biological factors (plant morphology and physiology) will influence post-fire effects on plant communities. This includes direct effects such as the ability of individual species to resist the heat of a fire (depending on age and seasonality) and the mechanisms by which they recover after fire.

Finally, in addition to fire parameters and individual species response, numerous external factors such as post-fire weather, post-fire animal use, and plant competition can also determine how the grassland and individual species will respond to fire. Common effects include grass and forb mortality, increased flowering and seed production, increased and decreased productivity (please see **Factsheet 5**), increased forage quality (please see **Factsheet 5**), reduced/increased vigour and abundance of dominant species as well as numerous communal effects, including increased forb layer diversity and cover, when compared to long-term unburned communities.

INDIVIDUAL PLANT TISSUE

Numerous studies have attempted to define the temperature required to kill vascular plant tissue. A temperature of 60°C has been considered as a reasonable approximation of a lethal temperature required to kill shoot tissues of land plants, while others reported temperatures as low as 45°C resulted in tissue death. Other, more recent publications, described 50 to 55 °C as being the temperature that typically results in tissue death. In general, the likelihood of plant tissue being killed is dependant on the amount of heat it receives, which is described as being the combination of the temperature reached and the duration of exposure.

Overall, it appears that individual plant mortality can occur at high temperatures after a short period as well as low temperatures over longer periods with individual plant sensitivity varying depending on season. For example, growing points are often considered more sensitive to heat when they are actively growing and their moisture content is high.

FIRE EFFECTS ON INDIVIDUAL GRASSES

Seasonality generally has the greatest influence in determining the effect of fire, with fires occurring during a metabolically active period tending to be the most damaging. If a plant is actively metabolizing (e.g.,, growing) consumption of the entire aboveground portion of the plant, will stress the plant or even cause plant mortality. However, grasses are more likely to die if growing points, including meristems and buds, are subjected to lethal temperatures or increased residence time. Whether or not lethal temperatures occur is dependant on growth form, fuel loading, adjacent plant species as well as foliar and fuel moisture levels.

The importance of growing point location in determining fire impacts on grass tillers is primarily related to the susceptibility of growing points to fire as well as the cycling of plant energy reserves. The location of these growing points is critical since aboveground herbaceous material rarely survives fire. Exactly where these growing points are, and when they are elevated, is species specific and dependant on plant maturity and plant-growth characteristics. For example, even though species may occur within the same community, some may be actively growing with their growing points elevated above the soil surface, whereas others may have these points buried in the soil, thus increasing their tolerance of fire. In general, if stem elongation has occurred (actively growing annuals and perennials) the greater the chance these growing points will be exposed to lethal temperatures, and thus be damaged or killed. The individual is also vulnerable since most of its carbohydrate reserves have already been used to produce foliage or seeds. This compromises it's ability to sprout from dormant buds.

If the growing points are at or below the soil surface, an individual grass tiller generally has a greater chance of tolerating a fire. This tolerance is attributed to the fact that the upper 2.5 cm of soil typically only experiences a very brief increase in temperature. Rhizomatous grasses often fall into this category since their meristems and buds are typically located under litter, duff, or within the soil profile. Exactly how these grasses are impacted however, is dependant upon the location of their growing points. For example, the growing points of many rhizomatous grasses, such as Kentucky bluegrass and western wheatgrass are located beneath the soil surface, thus allowing them to sometimes escape lethal temperatures. Rhizomatous grasses located in forested stands however, are generally more likely to have their growing points located in the litter or duff layers or in association with dead woody fuels. This increases their vulnerability to lethal temperatures especially when compared to grassland sites. For example, one of British Columbia's dominate rhizomatous range grasses, pinegrass, is generally only top-killed by fire. It can be killed by severe fires which consume the duff layer. In most cases however, pinegrass is rarely, if ever, eliminated from a site even after severe wildfire. Other grass species, such as stoloniferous grasses, have their meristems and buds located above the soil surface, and thus are typically the most impacted by fire.

When compared to rhizomatous grasses, bunchgrasses are also much more susceptible to fire damage. This increase in susceptibility is often attributed to growing points near the soil surface, accumulation of large amounts of dead plant material (plant residue) within the bunch, stem coarseness, and bunch size. Location of growing points (meristems and dormant buds) is species specific with some species having their growing points above the soil surface or at various depths below the soil surface. For example, bluebunch wheatgrass is somewhat tolerant to fire since its growth points (buds) are protected by soil and/or plant material. In addition, as with other grasses, the location of these growing points may be associated with season. Thus, fire seasonality will play an important role in determining how a fire impacts individual bunchgrasses.

For example, when compared to early season fires, fires which occur following the summer dormancy period in bunchgrass-dominated grasslands subjected to summer drought (e.g.,, BC interior), will typically increase the likelihood of bunchgrass damage or mortality. This effect occurs when bunchgrasses resume growth following summer dormancy. For example, bluebunch wheatgrass often resumes growth slightly before rains moisten the soil of the root zone. Tillers then become visible a few weeks later and often produce two or three fully expanded leaves by winter. These individual tillers then become photosynthetically active during the autumn, winter, and spring and as a result are particularly subject to fire damage during these periods.

Accumulations of plant residue can be damaging, particularly if fire residence time is extended within the centre of the plant after the main fire has passed. This effect, which commonly occurs in large, decadent bunchgrasses, slows the recovery of these communities, especially when compared to rhizomatous and small bunchgrasses that are subjected to a fire of similar severity and intensity. For example, bunchgrasses with densely clustered culms and lots of leaf tissue such as Idaho fescue and needle-and-thread are more intolerant of fire as they tend to burn longer and hotter and thus are slower to recover. Other bunchgrasses however, such as bluebunch wheatgrass, are more tolerant since they often have less dense culms and less leaf tissue. These less-dense bunchgrasses also tend to burn quickly and thus transfer minimal amounts of heat below the soil surface. Stem coarseness also affects the rate at which a bunchgrass clump burns. For example, dense, fine-stemmed bunchgrasses often burn slowly and generate considerable heat that can be transferred to meristems and buds. In comparison, when fire passes through coarse-stemmed bunchgrasses it tends to be quick, and often causes insignificant damage to reproductive organs.

Bunch size may also be a factor. Due to increased fuel loading, fires often burn more slowly through large diameter bunches when compared to small diameter bunches. Overall, damage and mortality will typically increase in larger bunches, and in bunches with fine-leaves, when compared to smaller and coarse-leaved bunches. Since increases in soil temperature are often negligible below 2.5 cm during grassland fires, rooting depth/habit generally does not influence fire effects on individual tillers. Indirect impacts such as pedestalling, resulting from soil erosion however, can significantly impact the roots of these species by increasing the probability of root desiccation and subsequent mortality. Direct impacts on juveniles are usually fatal since there are few plant species capable of tolerating or escaping fire at this stage of their lifecycle. Thus, fire seasonality will play an important role in determining how a fire impacts individual bunchgrasses.

Seed Production. Due to their ability to reproduce vegetatively, the impact of fire on flowering and fruit set in rhizomatous grasses is typically insignificant. Bunchgrasses however, are particularly vulnerable to damage, since they rely solely on seed production to reproduce and maintain healthy, vigorous grass stands. Seed vulnerability, is typically dependant on seed position as well as the amount of moisture they contain. In general, the higher seeds are aboveground the more likely they are to be damaged. Furthermore, if a burn occurs prior to seed shed the impact of the fire on the individual tiller, as well as the seeds, is typically greater than what would have occurred if the seeds had dropped. The increase in vulnerability to the individual tiller is greater due to low levels of carbohydrate reserves whereas seed impact is greater, due to the higher amount of lethal heat experienced aboveground. In general, when compared to sites that were not burned the number of grass flowering stems typically increase following a fire.

Some studies have found flowering and seed vigour of grasses in pine forests and high desert regions east of the Cascades to increase following fire, while another study found flowering of both Idaho fescue and bluebunch wheatgrass to significantly increase following fire. Flowering response however, may vary considerably depending on the season in which the fire occurred. In general, increased flowering is typically short-lived, often lasting only two years. Whether or not this response relates to increased seed production or increased survival of germinants however, is still unclear. For example, in the northwest United States seed production in perennial bunchgrasses (needlegrasses, bluebunch wheatgrass, Junegrass) often increase following a fire, whereas other studies determined that increased seed production per inflorescence, partially compensated for decreased inflorescence density among burning treatments. Some studies however, show increases in flowering due to fire as being correlated with increases in viable seed production as well as subsequent increases in seeding establishment. Similarly, other studies found that the number of filled florets (i.e. viable seed) in bluebunch wheatgrass increased on burned plots when compared to control plots. Overall, the effect of fire on seed production appears to be highly variable and dependant on species whereas seedling establishment is generally dependant on source of viable seed, adequate seed coverage, suitable germination temperatures, competition, and the availability of adequate soil moisture to facilitate seeding development. If soil moisture is lacking, a seedlings ability to survive fall and winter droughts will likely be compromised.

FIRE EFFECTS ON INDIVIDUAL FORBS

Seasonality (e.g.,, moisture content), site characteristics (e.g.,, fuel loading), geographic and climatic factors all play an integral role in determining fire intensity and severity and thus when combined with plant morphology all influence the impact of fire on forbs. Whether or not this impact is negative or positive is species dependant, with many species experiencing both positive and negative effects depending on fire severity. Plant morphology, especially growing point location, significantly impacts the effect of fire on forbs. Many forbs are able to avoid fire by either burying their seed or growing points. In fact, forbs with growing points located within the soil profile are generally the most resistant to fire including those with the ability to regenerate from belowground buds, rhizomes or taproots.

Even though it takes a greater amount of heat to ignite a fire in the spring and early summer this is generally when forbs are most vulnerable, as they have often utilized the majority of their energy reserves to facilitate new growth. Thus, if a fire occurs during this time, there may be inadequate energy reserves to promote new growth. If fire occurs during or following dormancy however, forbs are typically more tolerant, due to their ability to spend the majority of the growing season accumulating energy reserves (via photosynthesis), and thus are more likely to sprout during the following spring. Overall, most forbs are vulnerable throughout the growing season and become relatively tolerant during and following dormancy. The ability to sprout from belowground buds, rhizomes or tap roots becomes particularly important if a fire occurs during summer dormancy. This is often the time when fire severity increases and most buds located aboveground or within one centimeter of the soil surface are damaged or consumed. Post-fire sprouting will be discussed further below. Overall, fire typically affects forbs by favouring rhizomatous forbs, including common yarrow and common comandra. For example, numerous rhizomatous species including western yarrow, longleaf phlox, and purple daisy fleabane doubled in production within three to four years following a fire. Some forbs, such as pasture sage, are capable of stump sprouting following fire whereas other forbs, including woody-based forbs, are generally slow to recover. In general, perennial forbs and shrubs that are able to regenerate from underground storage organs typically recover from burning.

Seeding Effects. Fire influences seed production in a variety of ways including, by directly damaging both flowers and fruits as well as increasing post-fire flowering. Increased flowering, which is common in both shrubs and forbs, typically correlates to increased seeding abundance and subsequent increases in viable seed. Numerous species display this characteristic including members of the Grass, Orchid, Iris, and Lily families. Regardless of species specific germination requirements fire typically produces a favourable seedbed that is generally void of competition, typically retains water longer than organic material, and commonly contains more available nutrients. How a species takes advantage of this seedbed is primarily dependant on seed dispersal. Seed dispersal is influenced by numerous variables including seed type, prevailing wind direction and seed availability (amount and distance from source.

Some forbs have adapted special dispersal mechanisms that allow them to regenerate following a disturbance. For example, light seeds (e.g.,, common yarrow, pasture sage) are commonly windblown whereas heavier seeds typically disperse via skidding across the soil (or snow) surface (e.g.,,, kochia, Russian thistle). Some seeds also have parachute-like structures (e.g.,, asters, dandelion) that assist in their dispersal; others have barbs or hooks (e.g.,,, burdock, hounds-tongue) that facilitate animal dispersal or are hard-coated and thus able to be transported through an animal’s digestive tract. The impact of fire on seeding is particularly important for non-sprouting species since they rely on seeding to re-establish on burned areas. Specifically, in order for these species to establish they must re-colonize from off-site (areas not burned) seed sources. These areas can occur either within or immediately adjacent to burned areas.

POST-FIRE SPROUTING

In general, the physiological processes controlling post-fire sprouting is similar for all plants including trees, shrubs, forbs, and grasses. The ability of an individual plant to sprout following a fire is dependant on the location of its dormant buds, the subsurface distribution of reproductive structures, and the depths below the surface from which new shoots can develop. These morphological characteristics, combined with fire severity, typically determine the number of growing points (reproductive buds or bud primordia) that are able to survive a fire. That is, the relationship between the depths of reproduction organs, combined with the depth of lethal temperature penetration, will determine a plant’s ability to survive and sprout following a fire. As discussed above, whether or not lethal temperatures occur is dependant on growth form, fuel loading, adjacent vegetation, and fuel and foliar moisture levels. Fuel loading as well as heat from adjacent vegetation (forbs, shrubs, and trees) can dry and preheat grasses to ignition temperature. This can increase grass mortality (particularly bunchgrasses) especially when compared to similar sites, burned under similar conditions, with lighter fuels loads and/or sites with fewer forbs, shrubs, and trees. If however, plants are actively growing, or if a site is relatively moist, foliar and fuel moisture levels may prevent fire from entering a stand of plants. For example, if the center of a bunchgrass is dead and/or dry it has a greater chance of igniting, smouldering, and burning, and thus has a greater chance of killing most or all-growing points whereas, if the bunchgrass is moist, it is unlikely that it will ignite and burn. Other indirect impacts can also influence survival and sprouting following a fire. For example, increased erosion may result in pedestalling around individual plants thus exposing previously protected plant parts to either predation or increasing the possibility of drought stress on these plants, both of which can reduce vigour, limit sprouting, or even cause death.

In general, the response of rhizomatous grasses and forbs (pinegrass, common yarrow, common Comandra) to fire is typically positive. This response is attributed to the protection of growing points and for the most part, the absence of a long-term heat source over large, contiguous areas. Pinegrass for example, often sprouts profusely and establishes from seed following fire and thus generally increases in response to fire, often exceeding preburn levels. How bunchgrasses respond to fire however, is typically more difficult to determine and commonly related to fire residence time within an individual clump. In order to measure this response Conrad and Poulton (1966) developed the following damage classes for bunchgrasses:

1) Unburned, although foliage may be scorched;
2) Plants partially burned, but not within 5 cm of the crown;
3) Plants severely burned, but with some unburned stubble less than 5 cm;
4) Plants extremely burned, all unburned stubble less than 5 cm and mostly confined to an outer ring;
5) Plants completely burned, no unburned material above the root.

This classification system is particularly useful when assessing species with growing points located above the mineral soil surface. In general, species with the least amount of surface litter removed will have the highest post-fire sprouting potential with the amount of sprouting generally decreasing as the amount of basal litter consumption increases. As stated above, complete consumption typically results in plant mortality.

Overall, morphological characteristics can have significant impacts on grassland communities. For example, in bunchgrass-dominated grasslands long-term fire intervals generally increases fuel accumulation which causes an increase in fire severity and subsequent bunchgrass mortality, whereas short-term fire intervals can influence community composition by decreasing seed production and seeding establishment.

Any changes in fire return intervals may impact individual species or communities that are adapted to specific return intervals. In general, species that are typically more tolerant of fire, such as rhizomatous grasses, small bunchgrasses and perennial forbs, as well as species that are able to develop quickly from seed, tend to become important components of the post-fire community. Furthermore, if a community is dominated by less tolerant species, such as large and fine-leaved bunchgrasses, a slow response to fire may subject these communities to deterioration by exotic plant and animal species and re-sprouting shrubs.

The following example describes these effects in southern BC grassland communities: Idaho fescue and needle-and-thread once damaged by fire will often recover relatively slowly, whereas damage to bluebunch wheatgrass, Sandberg bluegrass and prairie junegrass is often relatively slight in comparison thus increasing the probability that these species will experience post-fire stimulation and regeneration.

In addition to these effects, fire can also impact individual grasses and forbs in numerous other ways. For example, fire can indirectly impact plant communities by reducing soil moisture through increased evapotranspiration, runoff, and soil temperatures. This, combined with decreased moisture holding capacity (resulting from combustion of organic matter), can cause burned sites to become more xeric than sites that were not burned. Reduced moisture holding capacity is often associated with decreased litter which can be short-lived, especially in cases where annuals are able to invade burned sites. For example, in northeastern Oregon, when compared to pre-burn levels, burning was found to decrease litter initially, followed by an increase within a few years. This increase was attributed to the additional biomass contributed by annuals. Overall, as is the case with most other fire effects, how a plant responds to fire is dependant upon species, weather, and fuel characteristics as well as timing, intensity, and frequency of burning.

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