CHAPTER

17

Forbs and Browse Species

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Focus on biodiversity, ecosystem function, and low-input approaches to pasture production has stimulated renewed interest in forbs, herbs, and nontraditional forage plants. Smith and Collins (2003) present a general and practical overview of forbs in agroecosystems. In our context, forbs are herbaceous dicotyledonous plants that are neither grass nor legume and are purported to have beneficial influences on overall pasture productivity and soil quality. This is based on lore that many forbs have (1) high mineral concentrations, (2) potentially beneficial health effects on livestock, (3) the ability to create favorable rhizosphere conditions because of interactions of root architecture with the soil profile, and (4) root exudates that interact with microbial populations to influence soil mineral dynamics (Foster, 1988).

Forbs and browse (the leaf and young stem portion of woody plants and shrubs that can be consumed by livestock) typically help extend the temporal and spatial limits of forage availability, often as unmanaged parts of the plant community of a particular landscape. Whereas contributions to enhanced soil quality and livestock health remain to be explained, forbs and browse improve the seasonal distribution and availability of herbage by contributing to increased diversity of plant functional groups. Apparently, forbs and browse species acquire and use nutrients at different times and from different resource sites relative to co-occurring grasses and legumes in complex pasture communities.

Leaves and young shoots of trees and shrubs provide an estimated 75% of livestock feed in the tropics but are overlooked or ignored, for the most part, as a feed resource in temperate zones (Dupraz, 1999). Production patterns, unlike those of companion grasses, often are not synchronized with weather patterns, especially conditions associated with soil water availability. The asynchrony of production and soil water might be a product of the deep rooting characteristics of many forb and browse species.

Forbs

Many forbs are compatible with traditional range and pasture species and, depending on growth habit and composition, could influence livestock selectivity and grazing behavior. Forbs provide high-quality herbage at times when forage is inadequate in perennial grass-based pasture systems.

Brassicas

Improved cultivars and establishment methods and a recognized need to extend the grazing season have led to renewed interest in brassicas. The Brassicaceae (Cruciferae) family includes a number of species used as livestock feed since ancient times. *Brassica*, *Raphanus*, and *Sinapis* are the most widely used of the 51 genera (Tsunoda et al., 1980). The term *brassica* will be used to refer to species of this family with examples that include turnip, kale, rape, cabbage, and swede. These species are also known as crucifers.

Most forage brassicas are fast-growing, cold-tolerant, succulent (low dry matter, or DM, content), cool-season annuals. Brassicas have high nutrient concentration and can retain these nutrients when stockpiled in the fall, which makes them useful in livestock production systems. Low fiber content coupled with high energy density produce rumen responses similar to those of concentrate feeds. The fleshy roots of some species can be grazed.

Uses

Brassicas are planted in spring and grazed in summer or planted in midseason and stockpiled for fall–winter use. Alternatively, planting late after a short-season crop extends the grazing season into December or January, even in the northern United States and Maritime Provinces of Canada. Late-season growth provides livestock producers with a high-quality forage resource for livestock finishing or ewe breeding.

The highly competitive brassica canopy can help control weeds and improve the seedbed for subsequent perennial forage establishment in pasture renovation programs. Brassicas can also serve as a break crop for thin stands of alfalfa and other hay crops. Brassicas were interseeded successfully into sweet corn without affecting corn yield (Guldan et al., 1998). Sugarbeet nematode-resistant cultivars of fodder radish are used in rotation to control sugarbeet nematodes (*Hederodera schactii* Schmidt) in lieu of or as a supplement to nematicides (Gardner and Caswell-Chen, 1993).

Genetics and Species

Turnip

Turnip is a cool-season biennial that produces useable roots and foliage. Up to 60% of total DM can be partitioned to roots. Fleshy-root DM is maximized by low seeding rates, earlier seeding date, stockpiling, and delayed grazing. Cultivars vary in the amount of DM that is allocated to roots (Kalmbacher et al., 1982; Rao and Horn, 1986; Jung and Shaffer, 1993). Root shape varies from globe-shaped to cylindrical, and cultivars differ in the proportion of fleshy root that develops above ground. Multi-crowned cultivars (e.g., 'Appin') with improved regrowth potential are available.

Rape

Rape produces a more fibrous and deeper root system than turnip, but has no fleshy root. The leafy canopy varies from an erect, tall type (e.g., 'Emerald') to dwarf (e.g., 'Dwarf Essex'). Rape tolerates repeated grazing (Kalmbacher et al., 1982). Most rape cultivars reach peak production in about 120 d (Jung et al., 1986).

Swede or Rutabaga

Swede is a foliage–root crop that is similar to turnip in response and management, but requires more time to reach peak production. Swede produces larger fleshy roots and short stems at low plant density. At high plant density, stems can reach 75 cm in height. Swede does not regrow after harvest.

Kale

Forage kale includes marrow-stem and thousand-headed types. The former is taller and produces more stem, while the latter produces short, leafier stems. Kale is the most cold tolerant of the brassicas and is the best suited among the brassicas for winter use.

Thousand-headed kale (e.g., 'Premier') has excellent regrowth potential if not grazed or cut to less than 8 cm (Prestbye and Welty, 1993), but marrow-stem kale (e.g., 'Gruner Ring') failed to regrow when cut to 10 cm (Kalmbacher et al., 1982). Kale planted in spring has greater yield potential than rape and turnip. In Canada, northern Europe, and the northern United States, kale requires the entire growing season to reach maximum DM production (Fulkerson and Tossell, 1972; Kunelius et al., 1987).

Fodder Radish

Fodder radish, an annual with maturity time varying from 60 d to 80 d, produces leafy topgrowth and fleshy roots, similar to the turnip. Fodder radish and other brassicas are used as trap crops for control of the sugar beet nematode. Most brassica cultivars are susceptible hosts and need to be plowed down prior to nematode reproduction. Recently developed radish cultivars that are resistant to sugar beet nematode effectively induce nematodes to hatch, but not reproduce. These resistant cultivars can be used in lieu of nematicides and can be grazed in the fall after soil temperatures reach 12°C, without affecting nematode control (Yun et al., 1999; Gray and Koch, 2002). Resistant radish cultivars (e.g., 'Adagio', 'Colonel', 'Arena', and 'Rimbo') should be used in place of susceptible radish cultivars and *Brassica* spp. on nematode-infested soils in rotations with sugar beet.

Brassica Hybrids

Hybrids of chinese cabbage and turnip (e.g., 'Tyfon'), rape (e.g., 'Perko'), and swede produce high shoot-to-root ratio forage. Hybrid turnip (e.g., 'Pasje') and kale (e.g., 'Maris Kestrel') are also available. Cultivar improvement was shown for beef gain on five hybrid kale cultivars (Garrett et al., 2000). Chromosome number varies with species: *Brassica oleraceae* = 18, *B. napus* = 38, and *B. campestris* var. *rapa* = 20.

Adaptation

Brassicas and related species are adapted to a wide range of climate conditions being grown mostly for summer-fall-winter grazing in cool, temperate climates and for winter-spring grazing in subtropical climates (Kalmbacher et al., 1982). Brassicas often are planted after cereals or other short-season crops in the northern United States, Canada, northern Europe, and New Zealand.

Brassicas require fertile, well-drained soils and thrive over a wide range of soil textures. Soil pH should be 5.5–7.0. In general, salt tolerance is low, although rape has moderate salt tolerance. Turnips will germinate at soil temperatures as low as 4°C. Brassicas grow well during cool weather and have good frost tolerance. The crop will grow with the tops surviving until temperatures reach −6° to −9°C. Roots can withstand temperatures as low as −9 to −12°C (Dunavin, 1987). Kale can survive −24°C.

Nutritive Value

In contrast to perennial forages, brassicas maintain high nutrient value with maturity and stockpiling (Jung et al., 1986; Kunelius and Sanderson, 1990; Wiedenhoeft and Barton, 1994; Koch and Karakaya, 1998). During autumn, in vitro dry matter digestibility (IVDMD) remained relatively unchanged (Jung et al., 1988) or increased (Sheldrick et al., 1981; Kunelius and Sanderson, 1990) as harvest was delayed. The high water content of brassica herbage raises concern for adequacy of DM intake, but its rapid digestion may compensate.

Foliage (leaves and stems) contains 140−250 g crude protein (CP) kg^{-1} DM, and fleshy roots of turnip and swede contain 80–120 g CP kg^{-1} DM. Brassicas are relatively low in fiber, readily digested, and provide high concentrations of energy for ruminant animals. Metabolizable energy ranges from 11 to 14 MJ kg^{-1} DM (Guillard and Allinson, 1988). Nutrient value decreases with warm temperatures. Forage of brassicas planted in spring or early summer is higher in neutral detergent fiber (NDF) and acid detergent fiber (ADF) and lower in CP in July and August than is fall forage of similar age planted in midsummer (Wiedenhoeft and Barton, 1994; Guillard and Allinson, 1988; Rao and Horn, 1986).

Mineral concentrations of brassicas meet recommendations for livestock dietary needs (Jung et al., 1986) although Cu deficiency occurred in cattle and sheep (Barry et al., 1981; Sharman et al., 1981). High foliar-Ca tends to produce a Ca:P relationship that is higher than recommended (Guillard and Allinson, 1989b).

Brassicas contain several secondary metabolites including S-methyl cysteine sulfoxide and glucosinolates, which may interfere with thyroid function or cause anemia (Tookey et al., 1980; Gustine and Jung, 1985; Duncan, 1990), depress DM intake, and/or retard animal growth (Barry et al., 1982; Lambert et al., 1987). The extent to which antiquality components in brassicas affect animal health is undetermined.

Cultural Practices

Brassicas can be drilled or broadcast seeded. A no-till disk drill should be used when planting into stubble or sod. Planting is easier if loose straw is removed from the soil surface. Burning is not recommended because the mulch or plant residue layer helps retain moisture and could influence success of summer plantings. Unless the soil surface can be kept moist for several days, for example, with irrigation, fields should be rolled and compacted after broadcast planting. Turnips and rape have been established by aerial seeding into small grain crops before final irrigation.

The seedbed should be firm and weed free, as recommended for perennial forages. After the seedling stage, brassicas are effective competitors and weeds are generally not troublesome. Compared with a tilled seedbed, seeding directly into residues of a previous crop or an herbicide-suppressed sod conserves soil, water, and energy, saves time, and reduces costs. In addition, residues are a source of high-fiber forage, needed when animals graze the succulent, low-fiber brassicas. Maintaining a sod reduces trampling losses, particularly when grazed during inclement weather (Jung et al., 1984; Koch et al., 1987).

Brassicas can be grown in mixture with other forage species. Mixtures including italian ryegrass and crimson clover had greater digestible organic matter and CP than did turnip or rape alone. Brassicas dominated early, with ryegrass dominating later cuttings (Dunavin, 1987). Brassicas should not be planted in the same field for more than two consecutive years because of pest and disease problems.

Brassica seed are relatively small (200,000–1 million seed kg^{-1}). Recommended seeding rates are 1.7–2.2 kg ha^{-1} for turnips, 4.0–4.5 kg ha^{-1} for rape and kale, and 15 kg ha^{-1} for fodder radish. A dense stand of fodder radish used for biological control of sugarbeet nematode is necessary for fibrous root proliferation and maximum nematode control. Otherwise, radish crop management is similar to that of turnips.

Planting date depends on forage needs, the species planted, and soil temperature. Brassica seed germinate between 10° and 35°C, and turnip germinates better than rape or kale at 5° and 10°C (Wilson et al., 1992). In northern areas, turnips, rape, or thousand-headed (stemless) kale can be planted in the spring after soil temperature reaches 10°C to provide summer pasture (August–September). Swede or kale can be planted in spring, whereas rape, turnips, or a combination can be planted in midsummer providing fall-winter grazing (Jung et al., 1986; Kunelius et al., 1987).

Longer-season brassicas, such as some rapes and kale, produce more forage than turnip and radish over the full season (Jung et al., 1986; Kunelius et al., 1987). Turnip, rape, and radish planted in August in the northern states and in Canada will produce less growth than the same crops planted in July (Kunelius et al., 1987; Koch et al., 2002).

Brassicas respond to fertilizer N inputs (Jung et al., 1984; Guillard and Allinson, 1989a). A minimum of 80 kg ha^{-1} of N is usually needed. More N may be necessary if residual soil N is low, for example if planted after a small grain crop or where straw was incorporated. Excess N accumulates as NO_3^- in herbage. Young plants have a high P requirement (Jung et al., 1984). Soil levels of P and K should be moderate or higher based on soil fertility analysis.

Brassicas require ample soil moisture; therefore, late-season irrigation may be necessary, particularly in semi-arid and arid regions. About 30 cm of water over a 75-d period is required when planted as a second crop (Heinemann et al, 1981).

Major Diseases and Pests

Diseases are more severe with spring plantings than with later plantings. Disease incidence was less with frequent harvest or grazing of brassicas (i.e., 60–90 d) than if forage is accumulated for longer periods (Jung et al., 1988). Most disease occurs near physiological maturity. Most cultivars of turnip, rape, swede, and kale have low incidence of leaf spot (*Xanthomonas campestris*, *Alternaria* sp. and *Cercospora* sp.). Incidence of mildew (*Erysiphe cruciferarum*) was high on swede cultivars and on two rape cultivars, but low on turnip, kale, and other rape cultivars (Jung et al., 1986).

Flea beetles (*Phyllotreta cruciferae* Goeze and *P. striolata* Fab.) are the most common insect problem of brassicas. Late-spring plantings are more likely to encounter insect attack than late-summer plantings. Flea beetle attack is less severe when turnip is planted into suppressed sod than when planted into a conventional seedbed (Jung et al., 1983). New Zealand turnip cultivars seem to be more resistant to flea beetle than European cultivars. Swede suffered less injury than turnip.

Aphids (*Hyadaphis pseudobrassicae* Davis) did not injure swede, rape or kale, but damaged some turnip cultivars, mainly between 60 and 90 d after planting (Jung et al., 1986). If needed, insecticides should be approved for use in grazed systems. If brassica use expands, disease and insect problems may develop, increasing the need for resistant cultivars.

Forage Production

Brassica can produce DM yields of 5–9 Mg ha^{-1} or more by 90 d after planting (Jung et al., 1986; Guillard and Allinson, 1988; Koch et al., 2002). In some locations, brassica DM yields can be up to 12 Mg ha^{-1} (Jung et al., 1988). High yields depend on ample moisture and nutrient inputs. After grazing, at least 15–20 cm of rape or turnip stubble should remain to sustain reqrowth.

Turnip and radish produce similar DM yields over 60–90 d; however, fleshy roots of radish, constituting 25%–40% of total radish DM, are not eaten by livestock, whereas turnip roots are (Koch et al., 2002). Multiple cutting increases topgrowth yield at the expense of roots. Rape produces higher topgrowth yields with multiple cuts than with stockpiling. Marrowstem kale, however, yields more when stockpiled than when cut multiple times (Kalmbacher et al., 1982).

Grazing Management

Low DM content restricts use primarily to grazing, but grazing must be managed for optimal livestock performance. Brassicas should not be grazed prior to 60 d after planting. Animals should be allowed to adjust slowly, with the brassica component of the diet increased gradually over 7–10 d. Limiting access with strip grazing or limiting daily duration on pasture will reduce herbage loss caused by trampling and fouling and improve utilization. Roots of turnip and swede are lower in nutritive value, and animals with high nutrient requirements often gain slowly when only roots are consumed.

Animals grazing brassicas should have access to high-fiber forages to increase DM intake, provide normal rumen function, and/or minimize antiquality factors of brassicas (Wikse and Gates, 1987; Guillard and Allinson, 1989b). Lambs should consume about 0.2 kg fiber d^{-1} and cows or steers 1–2 kg fiber d^{-1} from other forages when grazing brassicas. Growing lambs perform better when given access to residues from previous crops or hay supplement (Table 17.1). Lamb gains were generally greater than 0.20 kg d^{-1} with higher-fiber supplements, whereas lambs without high-fiber supplements gained less than 0.15 kg d^{-1}. Supplementing lambs with hay while grazing brassicas improved daily gain in the first 3 wk, but not later, indicating high-fiber forage may be most important during the adjustment stage (Reid et al., 1994).

Animals grazing brassicas had the highest intake of digestible DM and gains when they received 20%–30% of the daily diet in a high-fiber form (Lambert et al., 1987; Pearce et al., 1991). Brassica-based diets supplemented with 25% and 50% hay had lower apparent digestibility, but higher gains in lambs compared with lambs fed only hybrid brassica [*B. rapa* L. × *B. rapa* subsp. *pekinensis* (Lour) Hanelt] (Cassida et al., 1994).

The soil surface tends to be devoid of cover after grazing leafy brassicas. On erodible soils, a stemmy cultivar can be interseeded in a mixture (e.g., rape with turnip), provided the pasture will not be overgrazed. A small grain such as oat or barley can be seeded along with brassicas. Winter wheat, rye, or triticale can be used to extend production for spring grazing.

Livestock Performance

Brassicas are best for livestock with high nutritional requirements. Grazing animal performance on brassicas is highly variable (Faix et al., 1980; Koch et al., 1987; Reid et al., 1994). A summary of New Zealand experiments with brassica crops showed growing lambs gained 0.095–0.147 kg d^{-1} (Nicol and Barry, 1980), less than half that predicted from the nutritive composition (NRC,

Table 17.1. Lamb performance grazing brassica pasture (summary of experiments)

Species	Planting	Grazing dates	Supplement	ADG[1]	Source
Various	Conventional	Various	Unknown	0.10–0.15	Nicol and Barry, 1980
Turnip, rape	No-till; mid-July	23 Oct–14 Dec; 99 DAP[2]	None	0.05–0.09	Faix et al., 1980
Turnip, radish	Conventional; late July	1 Nov–10 Jan; 90 DAP	None	0.11–0.12	Heinemann et al., 1981
Rape, kale, fodder radish	Conventional; late July	Late Sept–mid-Nov; 60 DAP	None	0.11–0.15	Fitzgerald and Black, 1984
Turnip, kale	No-till; late July	Nov–early Dec; 90 DAP	None	0.02–0.05	Reid et al., 1994
Turnip (Tyfon)	No-till; late July	Nov–early Dec; 90 DAP	Switchgrass 15%–20% of DM	0.20–0.24	Reid et al., 1994
(Tyfon)					
Week 1–3	No-till; late July	Nov–early Dec; 90 DAP	No hay	0.36	Reid et al., 1994
Week 1–3			Hay	0.42	
Week 4–7			No hay	0.30	
Week 4–7			Hay	0.24	
Turnip (Tyfon)	No-till late July	Oct–early Dec; 70 DAP	Orchardgrass 11% of DM	0.21–0.25	Koch et al., 1987
Turnip (Tyfon)	No-till early Aug	Nov–mid-Dec; 92 DAP	Flatpea 12% DM	0.20–0.21	Rule et al., 1991
Rape, turnip	Conventional late May	Mid-Jul–late Sept; 58 DAP	Weeds 10–36% DM	0.20–0.23	Thomas et al., 1990
Rape, turnip (Tyfon)	No-till; late Jul–mid-Aug	Mid-Oct–early Jan; 60–90 DAP	Straw/cereal regrowth 20%–32% of DM	0.18	Koch et al., 2002

[1]ADG, average daily live weight gain per head (kg $animal^{-1}$ d^{-1}).
[2]DAP, days after planting.

1985). Reduced voluntary intake of DM because of high water content and plant toxins was implicated (Lambert et al., 1987; Duncan, 1990); however, when brassica and hay were fed in various ratios, DM intake by lambs was not limiting (Cassida et al., 1994).

The change from high-fiber forage to low-fiber brassicas may create abnormal rumen fermentation, affecting performance (Lambert et al., 1987). Sod-seeded brassicas may have some residue from previous crops that is available for grazing (Table 17.1). Animals initially shun brassicas in favor of other forage types; therefore, even small amounts of residue may be adequate to help compensate for low fiber in brassicas. Animals grazing brassicas supplemented with high-fiber dry forage gained better than animals grazing brassicas alone (Lambert et al., 1987).

Intake of DM increased when rape content of a pen-fed diet was supplemented with up to 30% orchardgrass hay. Ideal DM intake of orchardgrass was 18% of the diet. Hay supplement increased average daily gains (ADGs) of lambs during the first 3 wk of brassica grazing, but decreased ADG during weeks 4–7 (Reid et al., 1994). Carcass characteristics were similar for lambs grazing brassica crops or fattened on grass in drylot, but more time was required to reach target weight when grazing brassica (Fitzgerald and Black, 1984; Koch et al., 2002). Lambs grazing radish and turnip with no grain supplement produced carcasses with acceptable yield and quality grade (Yun et al., 1999).

Chicory

Chicory, also known as succory, blueweed, blue sailor, blue bunk, wild bachelor's button, hendibeh, and blue daisy, is a short-lived, perennial herb that is adapted throughout temperate regions. Chicory was mentioned in the writings of Virgil, Horace, and Pliny. The term *chicory* is probably derived from "chicouryeh or chicourey," the name used by Arab physicians. Chicory (referred to as *agon*) was used as a green salad or for medicinal purposes by the ancient Egyptians, by the Greeks (*kichora* or *kichorea*), and by the Romans (*intybus agrestis*).

Chicory originated in the Mediterranean area (Vavilov, 1992), primarily from Abyssinia (northeastern Africa). It is now indigenous to west Asia and southern Europe and became naturalized in North and South America (Simon et al., 1984). Chicory is a member of the Asterales Family; other important species include *Chichorium endiva*, *C. spinosum*, *C. glandulosum* Boiss; *C. bottae* Defl.; and *C. calvum* Schulz-Bip. Early selection and improvement efforts were directed toward producing a table green or salad (witloof) endive.

Documented evidence of chicory growing in North America was made in 1758 by Governor Bowdoin of Massachusetts, but reference to chicory growing in herb gardens of tidewater Virginia was made in the early 1700s. The United States imported large quantities of chicory root for use as a coffee additive (flavor) or substitute, especially in areas with strong French influence. Chicory was in use as a cattle feed in central Europe for the past 300 years (Brenchley, 1920), but its use as a forage crop in North America is relatively new.

Morphology and Physiology

Chicory has a taproot with a large capacity for storage of inulin, a nonstructural carbohydrate polymer of fructose. Leaves arise from a basal rosette on vegetative plants and appear on stems that can be 1–2 m tall at flowering. The rosette type of the perennial plant, while similar in appearance to the wild biennial form, is cultivated as a green vegetable and is the source of the fodder-type chicory that is gaining popularity as a pasture forage resource.

The life cycle can be biennial (weed type) or short-lived perennial, both producing a compressed panicle consisting of 15–25 flowers that are generally self-incompatible and cross-pollinated. The fruit is an achene. The plant has nine chromosome pairs. Leaves are oblong but can vary from oblate to dentate, clasping, and sessile.

Chicory requires a long day (>14 h) for flowering. The pale blue- to purple-colored flowers open in morning and close by noon. Plants are generally vegetative during the first growing season, but flowering can occur in the seeding year if plants experience intervals of drought or cold. An increasing number of flowering stems are expressed in subsequent years (Clapham et al., 2001). Some cultivars require a preceding cold period to flower (Ryder, 1999). Flowers are present from June to September, and maturity varies such that vegetative and reproductive plants occur simultaneously in the population (Clapham et al., 2001).

'Grasslands Puna' chicory, the first commercial cultivar of the perennial forage type, was developed from multiple genotypes selected for dense, leafy, vigorous, and uniform shoot appearance (Rumball, 1986). Chicory persists as a short-lived perennial and is compatible with traditional pasture grass and legume species (Jung et al., 1996; Belesky et al., 1999). Plants persist for 4–6 yr in pastures, with stand loss influenced by sward management and weather. Canopy management is similar to that required for alfalfa. Chicory does not fix nitrogen.

General Adaptation

Chicory grows well in temperate and temperate-maritime climates and grows over a temperature range of 6°–27°C, with preference for cool weather. Basal rosettes begin growth early in spring and, in areas with no prolonged subfreezing temperatures, can remain green and productive throughout the year. Chicory persists under winter conditions in parts of northeastern United States (Skinner and Gustine, 2002) and maritime Canada (Kunelius and MacRae, 1999). Leaf growth and stem development are most active when air temperatures are above 20°C, with pollen germination active at 17°–20°C. Chicory requires deep, moderately to well-drained soil, but it will tolerate wet periods. Chicory grows best at soil pH of 5.5–6.0 and can tolerate drought, salinity, and high nutrient conditions (Alloush et al., 2003; Neel et al., 2002).

Minor pest problems occur with aphids and tomato fruit worms (*Heliothus armigera conferta*) (Hare et al., 1987). Chicory is generally free from foliar and root diseases.

Seeding and Management

Chicory can be sown into a prepared seedbed or sod-seeded with a planter that controls planting depth. Broadcast seedings are a less reliable means of stand establishment. Seed should not be sown deeper than 1 cm (Sanderson and Elwinger, 2000a). Seeding rate should be about 2 kg ha^{-1} when seeded alone or 0.5–1 kg ha^{-1} when sown in mixtures. Soil should be cultipacked after seeding. Spring sowing is common, although chicory tolerates autumn sowing in the southern United States (Pitman and Willis, 1998). Soil temperature at seeding should be at least 10°C.

Medium to high annual inputs of nutrients (75–150 kg N; 25–40 kg P; 20 kg K and 20 kg S ha^{-1}) are required because chicory is very responsive to fertilizer, especially cations and P. Chicory responds to N fertilizer, but can accumulate high concentrations of nitrate (NO_3^-), especially in young, establishing plants in the seeding year.

Chicory is compatible with common forage grasses and legumes. Pure chicory stands are invaded by grasses and weeds in the Appalachian region of the eastern United States. Establishing or attempting to maintain pure stands of chicory is not practical from the standpoint of livestock nutrition. Chicory forage tends to have low amounts of fiber (Turner et al., 1999; Belesky et al., 2000; Holden et al., 2000). Nutritive value depends on management (Table 17.2).

Stems need to be controlled by grazing. Grazing should be started when the average canopy height reaches 15–20 cm. Livestock should be removed at 5-cm residual plant height and the sward rested for 25–30 d before grazing again. Plants in the seeding year may reach 15–20 cm in 80–100 d. If seedlings are grazed earlier, livestock will pull plants from the soil. Plants can winter heave if soil is wet. Close defoliation will accelerate chicory loss from the stand. Long intervals between grazing periods will help the stand persist (Volesky, 1996).

Stems are often avoided by grazing livestock, but in grazing experiments in West Virginia, lambs preferred chicory flowers and consumed herbage with some reluctance. This raised questions about environmental and management influences on types of secondary metabolites in chicory. Chicory contains lactupicrin and lactones, which apparently decrease palatability (Foster et al., 2001). Cultivars differ in concentrations and influence on livestock preference. Livestock and feral deer (*Odocoileus virginianus* Boddaert) avoided 'Forage Feast', which had greater concentrations of polyphenolics than Grasslands Puna or 'Lacerta'.

Cultivars grown in Pennsylvania (calcareous soil) contained less lactupicrin and polyphenolics than did plants

Table 17.2. Dry matter production and some nutritive value characteristics of forage chicory in North America

Management factor	DM (Mg ha^{-1})	IVDMD (g kg^{-1})	CP (g kg^{-1})	Source
Canopy removal				
Light vs. heavy	8.2–11.0	—	—	Jung et al., 1996
	—	—	146–226	Holden et al., 2000
Stocking				
Light vs. heavy	7.9–6.6	709	179–186	Volesky, 1996
Canopy strata	*(g 100 g^{-1})*			
0–10 cm	37	746	162	McCoy et al., 1997
10–20 cm	38	719	248	
> 20 cm	25	741	293	
Nitrogen				
0–200 kg ha^{-1}	1.8–6.7	685–716	132–161	Collins and McCoy, 1997
0–400 kg ha^{-1}	3.5–4.81	—	—	Belesky et al., 1999
		567–507	202–318	Turner et al., 1999
Clipping frequency				
3-cut, Maritime Canada	6.4	—	—	Kunelius and MacRae, 1999
3-cut, Southern US	5.7	—	—	Pitman and Willis, 1998
3-wk or 6-wk	6.5–8.3	631–630	184–166	Belesky et al., 1999

grown in West Virginia (acidic soil matrix). Herbage yield (Table 17.2) ranged from 3.5 to 9.4 Mg ha^{-1} depending on location and management (Jung et al., 1996; Volesky, 1996; Collins and McCoy, 1997; Belesky et al., 1999, 2000). Cultivars available for forage applications include Grasslands Puna (summer active), Forage Feast (resists bolting), 'Good Hunt', Lacerta, 'Oasis', 'Puna II', 'La Niña' (cold tolerant), 'Ceres Grouse', and 'Chico'.

General advantages of forage chicory are high palatability, high production potential, persistence in mixtures, drought resistance, tolerance to acidic and saline soil conditions, rapid recovery from grazing, nonbloating, natural reseeding, good silage potential, and high mineral content. Disadvantages of chicory include the following: needs to stock rotationally, needs N inputs, thrives on better soil (but is productive on soils varying in chemical and physical properties), becomes winter dormant in moderate to severe winters, is susceptible to crown damage, and may taint milk flavor if chicory makes up more than half the diet. There is no evidence of meat "off" flavor.

Plantain

Folklore attributes health-giving and restorative properties to plantain. There is a long record of use in pastures in Europe, with the intent to improve livestock health. Plantain probably originated in the Mediterranean region and is adapted globally in temperate regions and at high elevations of the tropics. The genus name refers to the anthropogenic form of dispersal ("of the foot"). Plantain is mentioned in Roman and Greek herbal pharmacopoeia. Common name synonyms include broad-leaved plantain, ripple grass, waybread, slan-lus, snakeweed, Englishman's foot, white-man's foot, ribwort, and ribgrass.

Major species are *Plantago lanceolata*, *P. major*, and *P. psyllium*. Plantains are members of the Order Plantaginales and the Family Plantaginaceae. They are perennial herbs characterized by a rosette of oblate leaves and a large main root. Plants produce lateral crown buds but not very vigorously. Plantain is a prolific seed producer and does not reproduce vegetatively. Plants are gynodioeceous or androdioeceous (dioeceous plants), self-incompatible, and insect or wind pollinated. *P. lanceolata* has 6 or 12 chromosome pairs (Murin, 1997).

General Adaptation

There is very little information on productivity and response of plantain in North America; most information was developed in New Zealand (Stewart, 1996; Rumball et al., 1997). Plantain tolerates soils with high mineral nutrient content and pH ranging from 4.5 to 8, but not wet or saline soil conditions. *Plantago* species occur in the pioneer stage of site succession and often in pasture areas with a high degree of disturbance (e.g., lanes or trails). The species is generally a poor competitor for light (Kuiper and Bos, 1992).

Seeding and Management

Established plants are productive for 1–3 yr and up to 4 yr if not grazed too closely. The species is responsive to N fertilizer but can be suppressed by competitors when grown in mixed pasture. Plantain generally contributes less than 20% of total DM to the sward, but pure-stand yields of up to 20 Mg ha^{-1} are possible. Plantain is not recommended for use in a pure stand because of weed encroachment. It is best to consider seeding it as part of a mixture with red or white clover, orchardgrass, or tall fescue. Perennial ryegrass is too competitive for plantain.

Plantain should be seeded at 2–4 kg ha^{-1} in mixture with grasses and legumes, or 2–3 kg ha^{-1} with brassicas. Plantain should not be planted more than 1-cm deep (Sanderson and Elwinger, 2000b). Surface broadcast seeding is successful and can be done anytime, although Sanderson and Elwinger (2000a) found that plantain growth was slow and plants might not establish when seeded in autumn. Seed requires cold stratification (<5°C for 1–3 mo) to germinate and generally does not germinate in the dark. Grazing plants keeps them vegetative and prevents seed stems from forming. Livestock performance is better on mixed swards rather than pure stands of plantain fertilized with N.

Cultivars include 'Lancelot' and 'Tonic'. Lancelot was selected from "broad landraces in New Zealand" for a leafy, uniform and productive plant about 25 to 30 cm tall. Lancelot grows semierect with high summer production and winter dormancy (Rumball et al., 1997). Lancelot can become prostrate with repeated grazing, yet should be stocked rotationally at 20- to 25-d intervals (Stewart, 1996). Tonic, also selected in New Zealand, is more suited to set stocking. It grows actively in winter, due in part to its parental origin (Portugal). In the northeastern United States, Lancelot is more tolerant of winter conditions than is Tonic (Skinner and Gustine, 2002).

Nutritive Value

Plantain provides the fiber needed for livestock grazing swards with leafy brassicas and chicory. However, secondary metabolites that influence rumen microorganisms may impair digestibility. Plantain contains up to 9% of DM of verbascoside, a phenylpropanoid glycoside that has anti-microbial, -fungal, and -helminthic properties (Fajer et al., 1992). Meat flavor is not affected by plantain. Concentrations of Ca, Mg, Na, P, Zn, Cu, and Co can be greater than or equal to those found in most grasses and legumes.

There is some evidence that Lancelot has the medicinal properties suggested in herbal literature. Jarzomski et al. (2000) showed that plant age, leaf age, and nutrient status influenced secondary metabolites in plantain, but herbivory did not. Botanical-medicinal constituents include iridoid glucoside (acubin) and derivatives with concentrations of up to 3% of DM. These are important biologically active compounds that can increase with drought stress. Plantain also contains polysaccharide hydrocolloids, which act as purgatives. Sorbitol is also present and could act as a palatability enhancer.

Other Forbs

Other forbs are used occasionally in seed mixtures for herbal leys and meadows, and these vary depending on location and reseeding objective. Foster (1988) cites "private farmer research" to point out the benefits of including herbs in British pasture seed mixtures. Minimal experimental data for forbs exist for applications in US pastures. Burnet is noted for persistence in New Zealand hill-land pasture but has limited summer production. Burnet does not do well in higher-rainfall, leached soils. It is known to accelerate blood clotting.

Sheep sorrel has wide adaptation and may be an indicator of acidic soil. Sheep sorrel apparently can neutralize soil pH and has biological properties as an antioxidant and diuretic. Yarrow occurs in humid, temperate areas and is a weed in cropland, although considered an acceptable species for grazing lands in New Zealand. It is reported to accelerate blood clotting in sheep. The aforementioned forbs are purported to be rich in minerals, vitamins, and antioxidants. Seeding rates are 1 kg ha^{-1} or less in mixtures.

Browse

Worldwide, browse species occupy many thousands of hectares of extensively managed grassland, rangeland, and grazed forestland, including silvopasture. The areas vary in soil type, topographic features, and environmental characteristics, creating conditions that support a wide array of plant species differing in chemical composition and palatability. Browse is often less desirable as forage for domestic livestock than are co-occurring herbaceous plants; however, they do provide nutrients and cover at certain times of the year.

As many as 500–600 species of browse occur in western rangeland of the United States alone, making generalized statements about management and nutritive value of browse difficult. Of the 155 types of rangeland cover in the contiguous 48 states of the United States, nearly half (43%) are characterized by the dominant shrub species on the site (Shiflet, 1994).

Importance and Use

Some browse species were introduced to improve seasonal distribution of herbage or nutritive value, but generally, browse encroachment reduces animal productivity. Grazing is a practical way to manage browse and influence the floristic composition of grazing lands. Meeting some of the nutrient needs of the grazing animal may be a secondary benefit because the primary benefits often are wildlife habitat and environment stability.

Production and use of browse requires understanding the ecological function in a particular biome. For example, food, water, cover, and space are essential components of wildlife habitat. Browse provides food and cover (Robinette, 1972) and influences water use and nutrient cycling in the landscape. About half of the indigenous mammal and bird species in North America are associated with woody plant cover and have specific habitat requirements (Yeager, 1961). In fact, the common names of many shrub and wildlife species such as rabbitbrush and sage grouse (*Centrocercus urophasianus*) reflect this association.

Browse and herbaceous species compete for water and influence the amount and quality that flows from sites or reaches the groundwater (Thurow and Hester, 1997). This is significant since water quality and conservation are important ecological functions of rangelands. Table 17.3 shows examples of browse species by broad geographic regions of the United States.

During the past 50–100 years, the floristic composition of natural grasslands and savannas in arid and semiarid rangelands shifted to include more browse species because of the presence of domestic livestock (Archer, 1989). In Texas alone, dense, woody plant cover on more than 88% of rangeland (35 million ha) restricts livestock production (Scifres, 1980). Changes in climate, decreased fire frequency, overgrazing, and increased concentrations of atmospheric carbon dioxide (CO_2) are possible causes of increased woody plants in the plant community. Fire favors the occurrence of herbaceous over woody species, whereas grazing favors woody plants by reducing competition and increasing seed dispersal. Increased atmospheric CO_2 may provide a competitive advantage to shrubs because high CO_2 causes grasses to transpire less, thus slowing soil water depletion (Polley et al., 1997).

On some winter range in the western United States, mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) overbrowsed and reduced willows in riparian areas (Kay, 1997) and mountain big sagebrush (Wambolt and Sherwood, 1999) and bitterbrush (Ganskopp et al., 1999) on uplands. These shrubs do not have chemical or mechanical characteristics such as thorns, pubescent leaves, or silica deposits that deter overgrazing. In some parts of the intermountain region of the western United States, big sagebrush decreased when frequency of fire increased because downy cheatgrass invaded and spread among areas covered with species such as big sagebrush (Young and Allen, 1997). Conversely, sagebrush increased in areas where natural fire intervals were disrupted (Bastian et al., 1995).

Nutritive Value

Browse often appears to have high nutritive value based on standard methods of assessment. However, most woody plants have mechanical or chemical means to deter herbivory that compromise the value of standard nutrient

Table 17.3. List of important US browse species by region

Common name	Scientific name
Northeast	
Autumn olive	*Elaeagnus umbellata* Thunb.
Quaking aspen	*Populus tremuloides* Michx.
Black locust	*Robinia pseudoacacia* L.
Multiflora rose	*Rosa multiflora* Thunb.
Southeast	
Yaupon holly	*Ilex vomitoria* Ait.
Blackjack oak	*Quercus marilandica* Muench.
Post oak	*Quercus stellata* Wangenh.
Mexican cliffrose	*Purshia mexicana* (D. Don) S.L. Welsh var. *mexicana*
Black locust	*Robinia pseudoacacia* L.
Multiflora rose	*Rosa multiflora* Thunb.
Northwest	
Silver sagebrush	*Artemisia cana* Pursh
Fringed sagebrush	*Artemisia frigida* Willd.
Cudweed sagewort	*Artemisia ludoviciana* Nutt.
Black sagebrush	*Artemisia nova* A. Nels.
Budsage	*Artemisia spinescens* D.C. Eat.
Big sagebrush	*Artemisia tridentate* Nutt.
Snowberry	*Symphoricarpos albus* (L.) Blake
Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.
Shadscale saltbush	*Atriplex confertifolia* (Torr. & Frem.) S. Wats.
Saltbush	*Atriplex gardneri* Moq. D. Dietr.
Winterfat	*Ceratoides lanata* (Pursh) A. Meeuse & A. Smit
Spiny hopsage	*Grayia spinosa* (Hook.) Moq.
Black greasewood	*Sarcobatus vermiculatus* (Hook.) Torr.
***Northwest** (continued)*	
Leadplant	*Amorpha canescens* Pursh
Serviceberry	*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roem.
True mountain mahogany	*Cercocarpus montanus* Raf.
Shrubby cinquefoil	*Potentilla fruticosa* L.
Antelope bitterbrush	*Purshia tridentata* (Pursh) DC.
Wild rose	*Rosa woodsii* Lindl.
Quaking aspen	*Populus tremuloides* Michx.
Wax currant	*Ribes cereum* Douglas
Southwest	
Skunkbrush sumac	*Rhus trilobata* Nutt. ex Torr. & A. Gray
Sand sagebrush	*Artemisia filifolia* Torr.
White bursage	*Ambrosia dumosa* (A. Gray) W.W. Payne
Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.
Black greasewood	*Sarcobatus vermiculatus* (Hook.) Torr.
Pointleaf manzanita	*Arctostaphylos pungens* Kunth
Guajillo	*Acacia berlandieri* Benth.
Gambel oak	*Quercus gambelii* Nutt.
Fendler ceanothus	*Ceanothus fendleri* A. Gray
Deerbrush	*Ceanothus integerrimus* Hook. & Arn.
True mountain mahogany	*Cercocarpus montanus* Raf.
Blackbrush	*Coleogyne ramosissima* Torr.
Wild rose	*Rosa woodsii* Lindl.

[1]This list is not all inclusive, but represents common browse plants that are considered fair or better forage for livestock.

analysis. Woody plants generally can tolerate removal of only a small amount of the annual browse production and therefore have evolved numerous mechanisms such as spines or secondary metabolic compounds that deter herbivory.

Based on the classification of rangeland forages by Huston and Pinchak (1991), browse species can provide the quality, level, or null component of the total forage resource. The quality component is made up of species that provide only a minor amount of forage, but provide significantly higher amounts of nutrients than the bulk of available forage. For example, mast and current growth of many shrub species are classified as quality components. Representative deciduous shrubs are littleleaf leadtree and mountain mahogany.

Species with fair- to good-quality forage throughout the seasons are the level component of the forage resource. Leaves of evergreen browse species such as fourwing saltbush, ashe juniper, or big sagebrush are examples. The amount of browse as an important component in wildlife diets is shown by low to moderate mortality of pronghorn antelope (*Antilocapra americana*) on areas with abundant sagebrush compared with high mortality in areas with very little sagebrush (Martinka, 1967).

The null component is composed of species such as honeymesquite and tarbush that are not browsed unless the availability of other components is severely restricted. Species importance varies seasonally and with management. For example, at a proper stocking rate, most species listed as level components would probably be null components during the growing season.

Browse plants are a feed source for wild and domestic ruminants on range and certain intensively managed, forage-based livestock production enterprises such as meat-goats (*Capra hircus*) and silvopasture. Each ruminant species has characteristic anatomical features such as the structure of teeth, mouth, and tongue, rumen architecture, or grazing posture that facilitates acquisition and processing of browse plants. Selective grazing among browse species influences competition and persistence among plant species and has substantial effects on plant community structure.

Animal preference seems to depend on the amount of secondary compounds (e.g., tannins) the plants contain. Fourwing saltbush and winterfat contain low amounts of harmful secondary compounds, have few physical barriers (such as spines), and are consumed preferentially by grazers (Holechek et al., 1990). Grazers avoid browse species such as creosotebush, mesquite, and one-seed juniper that have large concentrations of tannins, but there are exceptions. Mountain mahogany, although high in tannin, did not appear to affect forage intake or digestibility by goats when the species composed as much as 60% of the diet (Boutouba et al., 1990).

Generalization about nutritive value of browse is difficult because of variations for the same species among regions and among browse species within regions. Cook (1972) reported that browse species usually contain more P, CP, and carotene, and less digestible energy, than do grasses and forbs (Table 17.4). This changed as the season advanced and plants matured. Huston et al. (1981) re-

Table 17.4. Comparative seasonal nutrient content of forage from grass, forbs, and browse in different regions of the United States

		Spring	Summer	Fall	Winter
Edwards Plateau region of Texas [1]					
			(% of dry weight)		
Crude protein	Grass	8	6	5	5
	Forbs	19	11	14	—
	Browse	16	11	9	—
Digestible organic matter	Grass	44	43	34	31
	Forbs	59	53	53	—
	Browse	70	64	58	—
Phosphorus	Grass	0.13	0.11	0.08	0.06
	Forbs	0.21	0.17	0.20	—
	Browse	0.22	0.10	0.09	—
Intermountain region of the West [2]					
Digestible protein	Grass	10.2	5.5	2.1	0.05
	Forbs	10.2	6.1	4.2	3.6
	Browse	10.4	7.9	5.7	4.8
			(kcal/kg)		
Digestible energy	Grass	680	544	481	413
	Forbs	658	490	481	295
	Browse	653	472	318	249
			(%)		
Phosphorus	Grass	0.25	0.22	0.13	0.06
	Forbs	0.27	0.26	0.23	0.15
	Browse	0.30	0.28	0.24	0.18
Appalachian hill lands [3]					
Crude protein	Browse	22.7	15	20	—
IVDMD	Browse	70.3	61.7	65.5	—

[1] From Huston et al., 1981.
[2] From Cook, 1972.
[3] From Turner and Foster, 2000.

ported similar results, except that browse had greater herbage digestibility compared with forbs and grasses (Table 17.4). The CP and IVDMD of browse in Appalachian hill lands (Table 17.4; Turner and Foster, 2000) were comparable to values reported by Huston et al. (1981). Not all browse plants can supply this level of nutrition. Juniper, which can be an important component of goat diets during winter, has between 6 and 8 g CP kg^{-1} DM for the entire year (Huston et al., 1981). In general, the nutrient content of evergreen shrubs varies less than that of deciduous shrubs among seasons.

Antiquality Factors

Although nutrient composition of browse is an important consideration, of equal or greater importance are the physical antiquality factors and components that reduce the utility and value of browse species. Browse species have greater amounts and variety of plant secondary metabolites than do grasses. In some cases these act as antiquality factors that cause selective browsing by mammals (Bryant et al., 1992). Structural antiquality components such as spines reduce bite mass and slow removal, thus reducing intake. Reduced intake has the greatest consequence in arid environments where primary production is low and where spines are more common (Laca et al., 2001).

Allelochemicals help plants avoid defoliation by reducing palatability (Launchbaugh, 1996). The two most common are tannins (Haslam, 1979) and terpenoids (Mabry and Gill, 1979).

Tannins are soluble polymers able to combine and form precipitates with proteins. Tannin–protein complexes are generally resistant to protease catabolism (Van Soest, 1982). There are two general groups of tannins: condensed and hydrolyzable. By binding with digestive enzymes and dietary proteins, the condensed tannins depress digestion. Tannins also depress intake either by reducing digestibility of the diet components or by the astringency of condensed tannins and short-term post-ingestive malaise (Landau et al., 2000).

Terpenoids consist of a collection of five-carbon units with a branched, isopentanoid skeleton that exhibits remarkable structural and functional diversity (Mabry and Gill, 1979). Although terpenoids in browse species have a variety of functions, the most relevant are toxicity and feeding deterrents. Terpenes and volatile oils in juniper reduce intake (Taylor et al., 1997); those in sagebrush decrease diet digestibility in sheep (Ngugi et al., 1995). High-protein supplements moderate intake suppression.

Cattle, sheep, and goats can consume about 20%, 15%, and 60% browse in their respective diets each year (Van Dyne et al., 1980). Goats consume greater amounts of browse because of several adaptive mechanisms, including secretion of proline-rich saliva that binds tannins (Provenza and Malechek, 1984), rumen microorganisms that degrade tannin-protein complexes (Brooker et al., 1994), and possibly greater activity of a mixed-function oxidase system because of a relatively large liver. In addition, goats have flexible and prehensile lips and a bipedal grazing stance that helps them overcome structural defenses of some browse species. Since goats utilize browse as a nutrient source, they can serve as biological weed control agents where browse species compete with other more desirable plants.

When desirable browse species are present, grazing events should occur during periods when preference for the target browse species is relatively high or when it is in the seedling or fruiting stage (Taylor et al., 1997). Goats can be used to control or slow encroachment by several undesirable shrubs (Table 17.5), leading to increased herbaceous plant production for livestock (Belesky and Wright, 1994) or desirable browse production for wildlife (Hart, 2000). Often, goats control undesirable plants most effectively when combined with other treatments such as fire, mechanical disturbance, or herbicides. Goats are generally more effective at controlling tannin-rich than terpenoid-rich browse species. Using goats as a biological weed control agent offers an environmentally benign method, coupled with production of marketable livestock products (Magee, 1957; Hart, 2001).

Summary

Forbs and browse can improve overall forage DM and seasonal distribution of yield, increase plant diversity, improve system function, provide natural remedies for livestock health, and improve nutritive value in terms of mineral composition. Using forbs and browse in forage systems could increase flexibility and management options allowing grazing lands to be used for pasture, range, hay, silage conservation, co-species grazing, or medicinal and botanical production applications.

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Table 17.5. Browse plants consumed by goats

Common name	Scientific name	Region	Reference
Cedar	*Juniperus ashei* Buchh. *J. pinchotii* (Sudw.) van Melle	Edwards Plateau, Texas	Taylor et al., 1997
Multiflora rose	*Rosa multiflora* Thunb.	Appalachian Region, North Carolina	Luginbuhl et al., 1999
Gambel oak	*Quercus gambelii* Nutt.	Southern Rocky Mountains	Davis et al., 1975
Blackberry	*Rubus* spp. L.	West Virginia hill land	Dabaan et al., 1997
Greenbrier	*Smilax rotundifolia* L.	West Virginia hill land	Dabaan et al., 1997
Live oak	*Q. virginiana* P. Mill.	Central Texas	Magee, 1957
Post oak	*Q. stellata* Wangenh.	Central Texas	Magee, 1957
Spanish oak	*Q. falcata* Michx.	Central Texas	Magee, 1957
Blackjack oak	*Q. marilandica* Muenchh.	Central Texas	Magee, 1957
Chaparral			
Scrub oak	*Q. turbinella* Greene	Arizona	Severson and Debano, 1991
Buckbrush	*Ceanothus greggii* A. Gray		
Wright silktassel	*Garrya wrightii* Torr.		
Spiny redberry	*Rhamnus crocea* Nutt.		
Rough menodora	*Menodora scabra* A. Gray		
Mountain mahagony	*Cercocarpus betuloides* Nutt.		
Lespedeza			
Annual and perennial	*Kummerowia* spp. *Lespedeza cuneata* (Dum. Cours.) G. Don	Kansas, Missouri, Nebraska, Oklahoma	Hart, 2000

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