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Irrigated Pastures in Arizona

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A pasture is a parcel of land sown to low growing plants suitable for grazing by animals (Fig. 1). The plants could be grasses and/or legumes. Pastures may be intended for only a single cropping season or, more typically, are more permanent in nature and based on perennial plant species although annual plant species may be over-seeded into a permanent pasture. The animals that graze pastures may include cattle, horses, sheep, and goats. Irrigated pastures are used as a convenient way to feed livestock without the labor, expense, and equipment required to harvest forage particularly for small farms. Most pastures in Arizona are not productive without irrigation and tend to be intentionally seeded with particular plant species, which will be the focus of this publication.

Before establishing a pasture, the goals and feasibility of the project should be seriously considered. For example, is the goal of the pasture to provide all or just some of the feed requirement for livestock, a holding area, an exercise lot, or a safe place during breeding and while giving birth. All these goals can be achievable, but it is difficult for pastures to provide all the feed requirement of livestock due to the seasonal nature of pasture plant growth. For the number of animals a pasture can support (carrying capacity) see the "Carrying Capacity" section in this publication.

The feasibility of establishing and maintaining a pasture depends on the site characteristics, available equipment and resources, and the ability to commit the time required. Successful pastures are planted on deep well-drained soil with adequate water-holding capacity. The area is usually fenced and divided into smaller sections for the purposes of moving animals, or at the very least, an area needs to be provided for the animals when the soil is too wet to tolerate animal traffic. The most important resource is the availability of irrigation water of sufficient quality for growing plants, and a method for applying the water through surface or sprinkler irrigation. Necessary equipment includes a tractor capable of pulling tillage equipment, a fertilizer spreader or a way to inject the fertilizer into irrigation water, a mower to knock down weeds and non-palatable forage, a harrow to distribute manure, a sprayer for weeds, and possibly a swather and baler to make hay in cases where the animals are not able to graze all the available forage. Well-managed pastures are preferably inspected daily and at a minimum, a few days a week. The number of animals and their specific feed requirements must be determined. For an excellent discussion of pasture resources, goals, and planning see Williams and Baker (2010).

Figure 1. Horses grazing bermudagrass pasture in Tucson, AZ. (Photo by Michael Ottman)

Pasture Establishment

Soils

The typical soil contains the following components by volume: minerals (45%), water (25%), air (25%), and organic components (5%). The organic components include humus, roots, and organisms. Humus is a partially decomposed plant and animal matter. The organic component of soils is primarily in the surface soil to a depth of approximately 6 inches. The subsoil is beneath the surface soil, has lower organic matter content than the surface soil, and the thickness of this layer may vary tremendously. Beneath the subsoil is the weathered bedrock. Various soil characteristics pertinent to pastures are discussed below.

Soil Texture – is defined as the relative composition of soil particle sizes classified as sand (large), silt (medium), and clay (small). Coarse-textured soils have a higher percentage of large particles (sand) than fine-textured soils which have less sand and more fine particles (silt and clay). There are 12 major soil texture classes with varying percentages of sand, silt, and clay and are as follows listed from most to least amount of sand: sand, loamy sand, sandy loam, sandy clay loam, loam, clay loam, silt loam, clay, silt, silty clay loam, and silty clay. A loam contains mostly sand and silt with a smaller percentage of clay.

Water-holding Capacity – Irrigated pastures require a deep soil with adequate water holding capacity. A deep soil is one that has at least 3 feet of soil below which is weathered bedrock that cannot sustain plant growth. Soils with adequate water holding capacity are those that can provide plants with enough water to prevent water stress before the next irrigation which is generally 10 to 14 days with flood irrigation and about half that time with sprinkler irrigation.

Infiltration Rate – Irrigated pastures require a well-drained soil. A well-drained soil is one that allows water to infiltrate in at least 24 hours after an irrigation or rain event. Infiltration rate is affected by soil texture. Coarse-textured soils have a faster infiltration rate than fine-textured soils assuming the texture is uniform and there are no obstructive layers in the soil. Abrupt changes in soil texture in the soil profile will slow water infiltration. Soil texture changes with depth are common with soils in Arizona which are alluvial in nature, meaning the soil was deposited by water from numerous flooding events. Obstructive layers in the soil can also be found, and most commonly these layers are caliche ("petrocalcic horizon"), a cement-like mixture of calcium carbonate (lime) and clay.

pH, Sodium, and Salt – Soil pH is a measure of the acidity of the soil. Soils may be classified as acidic (pH<7) or alkaline (pH>7). Most Arizona soils are alkaline and do not require pH adjustment but there are exceptions. Soils with pH>8 (calcareous soils) may have reduced availability of phosphorus and micronutrients (chlorine, iron, zinc, manganese, boron, copper, molybdenum, and nickel), but acidifying these soils is usually not cost effective especially for pastures. However, soils with a pH above 8.5 (sodic soils) definitely need amending because a preponderance of sodium compared to other salts causes the soil to disperse and seal leading to poor water infiltration (Walworth, 2012). Many Arizona soils are salty (saline) but contain a balance of salts other than sodium such as calcium, magnesium, and potassium that prevents the soil from dispersing as in sodic soils. Nevertheless, saline soils inhibit plant growth and are amended by leaching of the salts with irrigation water.

Nutrient Content – Most Arizona soils contain enough nutrients for plant growth except for nitrogen (commonly deficient), phosphorus (sometimes deficient), and potassium (rarely deficient). Fertilizers can be applied as dry granules or as liquid solutions in the irrigation water. When applying fertilizer in the irrigation water, be aware that the distribution uniformity of the fertilizer will only be as good as that of the irrigation water. Also, nitrogen in particular is subject to leaching below the root zone which is more likely on coarse-textured compared to fine-textured soils. Because nitrogen is subject to leaching it is called a "mobile" nutrient whereas phosphorus and potassium are not subject to leaching and are called "immobile" nutrients. The organic matter in the soil (and manure) are good sources of plant nutrients but especially of phosphorus. The ability of the soil to provide the nutrients necessary for plant growth can be determined with a soil analysis (Walworth, 2011) by a soil testing lab (Schalau, 2020).

Land Preparation

After the previous crop is removed and crop residue incorporated into the soil, land leveling is usually the first step in the seedbed preparation for irrigated pasture to be flood irrigated. However, land leveling may not be required if sprinkler irrigation is to be used. After land leveling, the soil should be tilled with a disk, harrow, or other implements. The goal is to prepare a firm seedbed that can be depressed by your foot by no more than ½ inch and is not overworked to a powder.

When earthen dykes (sometimes called borders or border ridges) are used along the edges of areas to be flood irrigated, they should be constructed so that so that the entire border ridge can be seeded. Border ridges should be large enough to withstand livestock walking over them. On sandy soils, earthen dykes may need to be rerun periodically.

Plant Species

Pasture plant species for Arizona are described in Table 1 and Appendix I.

Climate and Elevation – The best-adapted pasture plant species for a particular location is influenced by climate, which is determined in Arizona by elevation, primarily. In this publication, elevation is used as an indicator of plant species adaptation.

Plant Species Classification – Pasture plant species can be classified as either grasses or legumes, annual or perennial, and cool season or warm season. Grasses are resistant to trampling by animals, suppress weeds, and are generally more productive whereas legumes are lower in fiber, higher in protein, and do not need the addition of nitrogen fertilizer. Pastures are often based on some sort of perennial species for longevity, but annual pastures can be very productive although they do require reseeding each year. Cool-season species are often recommended for higher elevations over warm-season species.

Pasture Mixes – Pasture mixes, when used, should be kept simple, usually consisting of one grass and one legume. The exception is mixtures of similar species such as found in winter grass pasture mixes. A mixture of tall fescue and alfalfa is an example of a common and viable pasture mix. Complex mixtures of grasses and legumes, consisting of 4 or more dissimilar species are not recommended since they are more difficult to manage because species may not mature at similar times. The type of grazing schedule used determines the plant species and should influence your species choice. For example, frequent grazing favors grasses over legumes. Nevertheless, the addition of a legume to a grass will help maintain the animals' nutritional needs through the summer period when nutritional quality of grasses is low. Dairy cattle have high nutritional requirements to support lactation and are most productive when a fairly high percentage of the pasture mixture consists of legumes. However, they will still likely require a supplemental concentrate feed (grain mix, etc.) to meet all of their nutritional requirements. Beef cattle, sheep, and goats have much lower energy requirements and generally do well even when most plants in the mixture are grasses. A pasture that is mostly alfalfa may be too rich for sheep and some horses (those with metabolic syndrome, for example). Horses can do well with an all-legume pasture if they are heavily worked, growing, or lactating, however a grass-legume mix may be more appropriate for overweight or lightly used recreational horses.

Planting

Planting Date – The optimum planting date depends on the elevation and whether planting a warm or cool-season species. For cool-season species, the optimum planting date is August (>4000 ft), September (2000-4000 ft), and October (<2000 ft). For warm-season species, the optimum planting date is April (<2000 ft), May (2000-4000 ft), and June (>4000 ft).

Seeding – Best results are usually obtained when seeds are planted in pre-irrigated soil with borders in place. The rate of seeding varies with the method of seeding, and more seeds are required with broadcast methods than when a drill or cultipacker type seeder is used. One should use the correct amount of seed sown at the appropriate depth (Table 1). The goal is to plant seeds about four times as deep as their greatest length. After planting use light irrigations to keep the surface soil moist to increase germination rates and seedling emergence. As seedling plants become established, the irrigation interval may be lengthened.

Lightweight, chaffy seeds may be mixed with rice hulls, or other inert material and drilled to obtain a more uniform distribution. Some fertilizer spreaders are equipped to plant seeds in this manner. Grain drills are often equipped with agitators specifically designed for fluffy seed.

Inoculation of Legume Seed – Legumes form associations with bacteria in the soil which convert atmospheric nitrogen into a form useable to the plant. The most effective bacterial strains are specific to the plant species. Most agricultural areas with a history of alfalfa production contain *Sinorhizobium meliloti*, a strain specific to alfalfa. This may not be the case for legume species other than alfalfa, and the seed may be pre-inoculated with the appropriate bacterial strain by the seed company or added as fresh bacteria by the farmer at the time of planting. If using pre-inoculated seed, be sure the inoculation date is not expired and the seed has not been exposed to high temperatures during storage. Bacteria that will be used to inoculate seed or self-inoculated seed should be stored at cool temperatures specified on the container and out of direct sunlight. Plant self-inoculated seed within 24 hours after treatment.

Sprigging Bermudagrass – Coastal bermudagrass and other non-seed producing varieties are established by sprigging (planting stems). Sprigging should be done as soon as possible after plant parts have been harvested. Sprigging may be done May through August, but best results are obtained when sprigs are planted in May, after the soil is warm, but before hot weather.

Machine planters may be used to place sprigs in rows 20-40 inches apart, with 12-18 inches between sprigs in the row. Usually, 10-20 bushels of sprigs are used per acre. For best results, sprigs should be placed with about one inch of the tip remaining above the moist soil surface. Sprigs may also be spread over the surface of the soil and disked in. Growth is most rapid when the soil is firmed around the sprigs after the planting operation. Soil should be maintained in a moist condition until plants are well established. Herbicides may be used to control weeds after bermudagrass has become established.

Table 1. Pasture plant species for Arizona and botanical name, adapted elevation, palatability, seeding rate, and seeding depth.

Common name	Botanical name	Adapted elevation	Palatability	Seeding rate* (lb/A)	Seeding depth (in)
Annual Cool-season Grasses					
Annual (Italian) ryegrass	*Lolium multiflorum*	All	Excellent	30	¼-½
Barley	*Hordeum vulgare*	All	Excellent	100	1-1½
Oats	*Avena sativa*	All	Excellent	80	1-1½
Triticale	*×Triticosecale*	All	Excellent	120	1-1½
Wheat	*Triticum aestivum*	All	Excellent	120	1-1½
Annual Warm-season Grasses					
Pearl millet	*Cenchrus americanus*	All	Good	20	½-1
Sorghum**	*Sorghum bicolor*	All	Good	10	1-1½
Sorghum X sudan hybrid**	*Sorghum bicolor x S. bicolor* var. *sudanese*	All	Good	10	1-1½
Sudangrass**	*Sorghum sudanense*	All	Good	20	½-1
Perennial Cool-season Grasses					
Meadow bromegrass	*Bromus biebersteinii*	>3000	Excellent	10	¼-½
Orchardgrass	*Dactylis glomerata*	>3000	Excellent	10	¼-½
Tall fescue	*Lolium arundinaceum*	>2000	Fair	15	¼-½
Tall wheatgrass	*Thinopyrum ponticum*	>2000	Poor	15	¼-½
Perennial Warm-season Grasses					
Bermudagrass	*Cynodon dactylon*	<4000	Good	5	⅛ - ¼
Blue panicgrass	*Panicum antidotale*	<4000	Poor	10	¼-½
Kleingrass***	*Panicum coloratum*	<4000	Good	2-4	⅛ - ¼
Rhodesgrass	*Chloris gayana*	<4000	Good	10	⅛ - ¼
Perennial Cool-season Legumes					
Alfalfa	*Medicago sativa*	All	Excellent	20	¼-½
Birdsfoot trefoil, narrowleaf	*Lotus tenuis*	>2000	Excellent	5	⅛ - ¼
Red clover	*Trifolium pratense*	>2000	Good	10	¼-½
Strawberry clover	*Trifolium fragiferum*	>2000	Good	2-4	⅛ - ¼
White (Ladino) clover	*Trifolium repens* var. *giganteum*	>2000	Excellent	2-4	⅛ - ¼
Annual Cool-season Legumes					
Crimson clover	*Trifolium incarnatum*	All	Excellent	20	¼
Berseem clover	*Trifolium alexandrinum*	All	Excellent	15-20	¼-½
Hairy vetch	*Vicia villosa*	All	Poor	20-25	1
Annual warm-season legumes					
Cowpea	*Vigna unguiculata*	All	Excellent	30	1-2
Lablab	*Lablab purpureus*	All	Excellent	15-20	1
Tepary bean	*Phaseolus acutifolius*	All	Excellent	60	1

* Seeding rate – Double seeding rate if broadcasting seed and half seed rate if species in a mixture.

** Sorghum, sorghum x sudangrass hybrids, and sudangrass should not be fed to horses due to possibility of causing cystitis ataxia syndrome.

*** Kleingrass should not be fed to horses, sheep, or goats due to photosensitization and possible liver damage from saponins in the forage.

Pasture Management

Pastures are maintained longer when they are properly managed. When a seed mixture is used, try to maintain each species in its original proportion. The management program should plan to use pasture forage when it is high in protein, low in fiber, and prolong the life of the stand. In practice, the grower usually utilizes plants somewhat later than their point of maximum nutritive value. This is done to maintain strong plants.

Fertilization

Plants require 17 elements for crop growth. Three of these elements plants receive from air and water (carbon, hydrogen, and oxygen). The remaining 14 elements are minerals that are provided by soil. Mineral nutrients are classified by the relative amount in the plant. Macronutrients are those mineral elements taken up in largest quantities by plants and most commonly deficient in soils for plant growth. Macronutrients include nitrogen, phosphorus, and potassium and will be discussed below. Secondary nutrients (calcium, magnesium, and sulfur) are taken up in a moderate amount and micronutrients (chlorine, iron, zinc, manganese, boron, copper, molybdenum, and nickel) are taken up in a small amount. Secondary and micronutrients are rarely deficient and will not be discussed below.

Pastures often require less fertilization than most crops. The reason is that grazing animals return as much as 85 to 95% of the plant nutrients they consume in the forage back to the pasture in the form of dung and urine (Shewmaker and Boyle, 2010). The problem is that the dung and urine are not evenly distributed and tend to be concentrated near water sources and shade. Dung and urine distribution may be more uniform in rotational vs continuous grazing systems which will be discussed in the grazing section below. Because of the non-uniformity of the nutrient distribution in animal waste, most pastures will require fertilizer application and a soil analysis can help with this decision (Walworth, 2011). Soil testing labs are listed in Schalau (2020).

Nitrogen – Nitrogen is the nutrient element most commonly needed by pasture plants, except for legumes which obtain their nitrogen from the air through a symbiotic relationship with nitrogen-fixing bacteria. Legumes do not benefit from nitrogen fertilizer but grasses in mixtures with legume will benefit. Therefore, nitrogen fertilization of pure stands of legumes is not necessary, but the grass component of seed mixtures of legumes and grasses will respond to nitrogen fertilization.

Nitrogen fertilizer is usually applied after animals are removed from the pasture and incorporated with an irrigation in order to stimulate growth for the next grazing cycle. The fertilizer may be applied as a liquid in the irrigation water or broadcast as granules. When fertilizing with granules, it is important to irrigate as soon as possible after fertilization to prevent fertilizer nitrogen loss from volatilization and foliage burn.

The amount of fertilizer to be applied depends on the anticipated amount of dry matter forage to be removed during a grazing cycle. Generally, about 30 to 50 pounds of nitrogen is required per are per ton of dry matter forage growth (Reed and Forero, 2010) and 1 ton per acre of forage is equivalent to approximately 10 inches of growth (Ball et al., 2016). Small applications of nitrogen (20 to 40 pounds nitrogen per acre) at planting time is usually necessary to establish the plant before any appreciable growth is evident. The largest portion of the total annual nitrogen application should be made when the most vigorous growth occurs, usually during the spring and early summer. For cool season grasses, apply nitrogen again in the early fall to prepare the pasture for growth in the coming cool season.

Vigorous, dark green plants associated with livestock manure or urine spots suggest plants in adjacent areas may be deficient in nitrogen (Fig. 2); however, excessive rates of nitrogen fertilization may result in pasture forage containing toxic amounts of nitrate. Do not use pastures for at least 2-3 weeks after heavy fertilization with nitrogen because of risks associated with nitrate poisoning. See "Nitrate Toxicity" section below for more details about this syndrome.

Phosphorus – Phosphorus is the second most commonly deficient nutrient. On phosphorus deficient soils, the yield of legumes and grasses may be increased by phosphate fertilizer application. The phosphate requirement for several years can be worked into the soil during seedbed preparation. Phosphate may also be applied on an annual basis after stand establishment. For these applications, broadcast the fertilizer on the surface of the soil when this operation will not interfere with the pasture management program. Soil phosphorus tests provide information that is useful in determining optimum levels of phosphate fertilization.

Fertilizer application can influence the makeup of the stand when a mixture of grass and a legume has been planted. Phosphorus favors legume and nitrogen favors grasses. Careful attention to fertilizer application practice helps to keep the desired ratio of legume to grass plants.

Potassium – Generally, potassium applications have failed to increase the yields of field crops in Arizona. Soils in Arizona contain clays with high levels of potassium and the ability to provide this potassium to the plant (Unruh et al., 1993). It is possible, however, that there are specific locations where applications of potassium may increase dry-matter yield and the potassium content of forage, especially on sandy soils.

Fig. 2. Vigorous growth spots in a bermudagrass pasture from urine or manure indicating probable soil nitrogen deficiency. (Photo by Michael Ottman)

Irrigation

Water may be applied by surface methods or by sprinklers. For surface irrigation, make certain the soil has been properly leveled before planting, because high spots receive insufficient water and ponding in low spots scalds plants and encourages weeds.

There are many advantages to planting in pre-irrigated, moist seedbed. Tillage operations during seedbed preparation that follow pre-irrigation help to destroy weeds and allow water to be stored deep in the profile for later use. Many growers prefer to plant in dry soil and irrigate afterwards. After the pasture has been seeded, apply several light irrigations to prevent crusting and to keep the soil surface moist during germination. The frequency of irrigation will be determined by soil type, solar radiation, temperature and other factors, such as humidity and wind velocity. Avoid erosion, which washes seeds out or covers them too deeply, by adjusting rate of water flow into the field or placing concrete blocks or other obstacles to disperse the water as it enters the field.

Growers often prefer using sprinklers because cost of land preparation is greatly reduced; however, the expense of sprinkler irrigation equipment must be considered. Sprinkler irrigation is especially effective during stand establishment since frequent, small irrigations can be applied keeping the surface soil wet and avoiding formation of a crust as often occurs with flood irrigation.

Two or three irrigations are usually needed between grazing cycles during the period of active growth. Less frequent irrigations are required in late fall, winter and early spring when the grasses are dormant. The irrigation interval for sands or sandy loam soils is much shorter than it is for fine-textured soils due to differences in water-holding capacity.

Irrigation should be scheduled so the soil will be firm enough to support livestock without injury to plants when the grazing cycle begins. This helps to avoid soil compaction. Compacted soils take water slowly, are poorly aerated, and produce less forage. There is currently no proven method to correct compacted soils in an existing pasture. A pasture with compacted soil can only be managed to avoid further compaction by making sure the soil is firm before allowing livestock to graze.

Provide readily available water in the soil to the full depth of the root zone to maximize production. Drought causes severe plant stress, depletes food reserves in the root, and reduces forage production. To check soil moisture, observe plants carefully and use a soil probe.

Grazing animals complicate irrigation scheduling. Animals should not be introduced into a pasture if the soil is still too wet and soft from irrigation because soil compaction may result. Once the animals are allowed to graze, they should be removed before the plants are stressed for water and irrigation

is required. In a pasture with paddocks and a rotational grazing system, grazing should be allowed for about 7 days, the animals removed, then the pastured paddock should be fertilized and irrigated. A second irrigation is applied about 10 days later if plant appearance suggests moisture stress and if moisture depletion is verified by examination of the soil with a probe. A third irrigation may be needed during the summer, before the next grazing cycle. All paddocks should be managed the same. Ideally each paddock is grazed 1 week of each of the 5 weeks if the pasture is divided into five parts. Modification of a management plan can be done to fit an individual pasture situation. Temperature, texture of the soil, species of plant, availability of water, month of the year, and other factors will determine the most effective and efficient pasturing and irrigation schedule.

Weed Control

Weeds are rarely a problem in properly managed pastures, but can become an issue if weed sources are not eliminated. Pastures are vulnerable to weed encroachment due to poor irrigation, fertilization, or grazing practices. Weeds are undesirable since because they are often innutritious, unpalatable, spiny, or poisonous.

Strategies to manage weeds include:

1. Eliminate sources of weed seed
   a. A reservoir of seed may have built up in the soil. Before seeding a new pasture, pre-irrigate to germinate any weeds then till the ground to destroy the germinating seedling.
   b. Manure is a source of weed seed. Do not apply manure to pastures that is not composted. Do not allow animals into a pasture that have fed on forage that contain weeds.
   c. Plant certified seed which is virtually free of weed seed.
   d. Never allow weeds in a pasture to produce seed. If necessary, clip pastures after grazing at a blade setting high enough to cut off the developing seed head of the weeds.
   e. Control weeds in adjacent fields and pastures since they can be a source of contamination.
   f. Keep irrigation ditch banks free of weeds to eliminate the chance that seed will fall into the irrigation ditch and be transported via the water into the pasture.
   g. Clean equipment before entering a pasture. Hay harvesting equipment in particular may be contaminated with weed seed.
2. Maintain a vigorous stand
   a. Irrigate to meet the water use demands of the pasture. Under- or over-irrigating can lead to stand loss in dry or wet spots where opportunistic weeds may encroach.
   b. Apply enough fertilizer for optimal growth of the pasture.
   c. Do not overgraze the pasture since doing so will weaken the stand. Continuous grazing, where animals are left on a specific paddock for an extended period of time, can lead to weed problems due to preferential grazing of the forage and not weeds. Rotational grazing is preferred from a weed management perspective.
   d. Do not allow animals to graze a pasture if the soil is still wet from an irrigation or heavy rainfall. This will lead to soil compaction and a weakening of the stand.
3. Mechanical control of weeds
   a. Mowing pastures periodically may be necessary to reduce competition from weeds not grazed by animals and invigorate the pasture by removing old growth near the base of the plant. Mowing is most effective against broadleaf weeds, does not control prostrate weeds, and may be ineffective against perennial weeds with an established root system.
   b. Weeds may be removed with a shovel if sparsely scattered on small acreages.
   c. Certain woody species such as mesquite can become a problem in pastures, and it is important to remove these species early before they become difficult to control.
4. Chemical control of weeds
   a. Chemical control of weeds may be the only option in certain situations. However, herbicide choices for pastures are limited compared to conventional crops. Many herbicides that are effective against weeds commonly found in pastures are not registered for use in pastures.
   b. An appropriate herbicide may not be available 1) for controlling weeds in pasture mixtures of legumes and grasses or 2) for controlling grass weeds in a grass pasture. These problems may be overcome in some cases by applying herbicides in the dormant season of the pasture species if the weeds are actively growing or by applying the herbicide to the weeds only if possible.
   c. Herbicide may be sprayed over the entire field, spot sprayed where infestations are low, or applied with a rope wick to the weeds only. This method is useful if the weeds are taller than the pasture plants and the herbicide applied is non-selective or will damage the pasture.
   d. When using herbicides, always follow the directions on the label, and be aware of the "waiting period" after the chemical is applied before animals are permitted back on the pasture. The waiting period may be different for different animal species, horses vs beef or lactating cattle, for example.

For current recommendations concerning the use of herbicides for the control of weeds, contact your Cooperative Extension County Agent. Several excellent references are available for weeds (DiTomaso, 2007; Whitson, 2012) and poisonous plants (Hall et al., 2020).

Pasture Maintenance

Grazing animals can physically damage pasture plants; therefore, the stand should be well-sodded before they are introduced. Horses in particular can damage pastures rapidly because of their active behavior, larger size, and their ability to graze pasture plants more closely than other classes of livestock. They also tend to spot graze resulting in an uneven pasture growth.

Grazing animals often leave mature, unpalatable clumps of grass. Remove these clumps and uneven growth by clipping or with a flail type chopper so that these areas will not be avoided next grazing cycle. Do this before weed seed has developed and cut high enough to avoid damage to pasture plants. Clippings may be raked and placed along fences or on the tops of border ridges. Livestock may eat these dried plants during the next pasture cycle.

Plants near manure spots may not be eaten by animals. As these plants become mature, they are still avoided. Spread manure with a harrow or other suitable implement once or twice each year after animals are removed from the pasture and before irrigation. After spreading droppings it may be desirable to mow, fertilize and irrigate. This practice helps reduce parasite loads in pastures. Worms are spread through fecal contamination of feedstuffs, but are very susceptible to hot, dry conditions. By spreading manure, parasites are exposed to the sun and manure piles dry out quickly, reducing worm loads on the pasture. Additionally, moving animals before pastures become short and overgrazed can prevent excessive parasite loads. Work with your veterinarian to ensure you have a parasite control program. This may include proper pasture management, multi-species grazing, and use of anthelmintics (drugs used to treat infections of animals with parasitic worms) at strategic times.

Forage production can exceed what is used by livestock. The excess may be mowed and left on the soil without windrowing, or a portion of the forage may be used for hay. Cut when grass seed heads have emerged or when most legume stems have flowers. Do not leave large quantities of dry forage in the field in windrows for livestock. The windrows shade plants beneath them and the animals trample plant crowns growing near the windrows. Remove the forage from the field, fertilize, irrigate, and allow sufficient time for regrowth before pasturing again or making hay.

Plant species composition of the pasture can be affected by grazing frequency. Most legumes do not tolerate frequent grazing. For example, alfalfa needs a rest period of about 1 month between grazing cycles. More frequent grazing in a grass/legume mixture will favor grasses which will become more predominant in the mixture. In addition, bunch grasses are less tolerant of frequent grazing than sod-forming grasses.

Animal Management

Pasturing Systems

There are several options available for managing animals on an irrigated pasture. The traditional and perhaps most common method is continuous grazing. Another method which has grown in favor is rotational grazing where a pasture is divided into several smaller paddocks which are grazed intensively in sequence allowing a rest period for each paddock. Tactical grazing is a combination of continuous and rotational grazing which is a flexible approach that allows the needs of the animals and pastures to be met.

Continuous grazing is the simplest pasturing system and has advantages and disadvantages. Animals are left on a single pasture for an extended period of time, usually as long as the growing season itself. This system has modest fencing costs, low management requirements, and produces acceptable results if the stocking rate is correct. The disadvantages of continuous grazing are that the forage utilization may be uneven, supplemental feed is required if pasture productivity is low, weeds are more likely to become a problem and some forages may not withstand the grazing pressure from this system. Forage plant species not desired by the animals may go to seed and spread in the pasture while desirable species will be overgrazed and reduced in number leading to a lower quality pasture. Additionally, a continuously grazed pasture will not support as many animal units as the same pasture divided and grazed rotationally.

Rotational grazing allows pastures or portions of pasture time to recuperate after grazing. During the recuperation period, the plants are able to increase their leaf area, and some of the sugars produced by the leaves in photosynthesis are transferred to the lower stem, crowns and roots which may be used for plant growth in the next regrowth cycle. Rotational grazing can be simple or intensive, the difference being the frequency of the movement of animals. Animals are allowed into a paddock when the plants have achieved a certain amount of growth and removed at a certain stubble height specific to each plant species (see Table 2). Animals are not allowed back into a paddock until a certain amount of plant regrowth has occurred. An example rotational grazing system that has worked well in Arizona is to divide a pasture into five paddocks and graze each paddock for a week allowing a recovery period of 4 weeks (Dennis, 1981). The number of animals supported in this system will depend on the size of each of the smaller paddocks. The advantage of this system is the forage is consistently newer, high-

Table 2. The target plant height to begin and end grazing and the usual rest period between grazing cycles for pasture plant species in Arizona. Each inch of plant height is roughly equivalent to 200 lb/acre of forage on a dry matter basis, but the actual amount of forage can be half or twice this number depending on growing conditions. Adapted from Ball et al. (2016).

Common name	Begin grazing plant height (in)	End grazing plant height (in)	Rest between grazing (days)
Annual Cool-season Grasses			
Annual (Italian) ryegrass	6 to 12	3	7 to 15
Barley	8 to 12	4	7 to 15
Oats	8 to 12	4	7 to 15
Triticale	8 to 12	4	7 to 15
Wheat	8 to 12	4	7 to 15
Annual Warm-season Grasses			
Pearl millet	20 to 24	8 to 12	10 to 20
Sorghum	20 to 24	8 to 12	10 to 20
Sorghum X sudan hybrid	20 to 24	8 to 12	10 to 20
Sudangrass	16 to 20	6 to 8	10 to 20
Perennial Cool-season Grasses			
Meadow bromegrass	8 to 12	3 to 4	20 to 30
Orchardgrass	8 to 12	3 to 6	15 to 30
Tall fescue	4 to 8	2 to 3	15 to 30
Tall wheatgrass	8 to 10	3 to 6	20 to 30
Perennial Warm-season Grasses			
Bermudagrass	4 to 8	1 to 2	7 to 15
Blue panicgrass	18 to 24	8 to 10	25 to 35
Kleingrass	12 to 16	4 to 6	20 to 24
Rhodesgrass	16 to 20	6 to 8	25 to 30
Perennial Cool-season Legumes			
Alfalfa	10 to 16	3 to 4	20 to 30
Birdsfoot trefoil, narrowleaf	8 to 10	3 to 5	10 to 20
Red clover	8 to 10	3 to 5	10 to 20
Strawberry clover	8 to 10	3 to 5	10 to 20
White (Ladino) clover	6 to 8	1 to 3	10 to 20
Annual Cool-season Legumes			
Crimson clover	8 to 10	3 to 5	10 to 20
Berseem clover	8 to 10	3 to 5	10 to 20
Hairy vetch	8 to 10	3 to 5	10 to 20
Annual warm-season legumes			
Cowpea	24	6	28 to 56
Lablab	24	6	28 to 56
Tepary bean	24	6	28 to 56

quality growth. If the pasture productivity is higher, the grazing season may be extended, allowing the producer to rely less on stored feed. Rotational systems allow for manure to be distributed more evenly and less forage is wasted. Disadvantages of rotational grazing are more fence needs to be constructed, extra management is required to move the animals, and water and nutrient supplements need to be moved along with the animals or provided in the paddocks where animals are grazing.

Tactical grazing is a flexible system that uses a combination of continuous and rotational grazing. This system allows the producer to meet specific needs of the pasture and animal during the year. Continuous grazing may be best during reproductive times of the animal or for finishing livestock for market, or when there is more than enough forage to meet the needs of the animal. Rotational grazing may be used to increase pasture utilization and growth, control animal intake, or improve the persistence of perennial grasses.

Regardless of the system being used, having a sacrificial "dry lot" area can be of use when environmental conditions (such as drought or extremely wet seasons) interrupt the planned grazing rotation. This area is set aside to house all of the animals when grazing would be detrimental to the longevity of the pasture. Animals are instead provided with supplemental feed (usually hay), allowing the pasture to rest and recover before grazing is reintroduced. This "dry lot" area is likely just large enough to comfortably house the animals and will probably not grow forage, nor should it be expected to. The purpose of this area is to preserve your cultivated pastures when conditions require it, which could occur seasonally or only in extreme circumstances.

Carrying Capacity

Actual carrying capacity during the period of grazing is dependent on many factors. A well-managed pasture will provide sufficient forage for 1 animal unit equivalent (AUE) per acre during its growing season. An AUE is a 1,000 pound animal or an appropriate combination of animals. For example, looking at Table 3 we see that a sheep is 0.2 animal units, so five sheep would be approximately equal to one cow, or one AUE. In a rotational grazing system, the pertinent acreage is the entire pasture, not the individual paddock being grazed at a particular time.

Pasture growth will vary depending on the species and time of year. Cool-season species are most productive in early spring where most of the annual growth may occur, production stops in the summer and growth resumes in the fall. Warm-season species are most productive in the summer but may begin growing in mid-spring or into the fall depending on elevation and temperatures. Little to no growth of any plant species should be expected in the winter. Supplemental feed may be required during the dormant season when a pasture is not actively growing.

The carrying capacity depends on the type of animal, the amount of forage produced by the pasture, and pasture growth utilization. Most animals on pasture consume 2 to 3% of their body weight per day in forage dry matter. This is influenced by the production status of the animal. For example, non-working horses and dry beef cows will consume about 2% of their body weight per day while growing steers and lactating dairy cows may consume closer to 3% of their body weight per day. Each inch of height of a pasture plant is roughly equivalent to 200 lb/acre of forage on a dry matter basis (Ball et al., 2016), but the actual amount of forage can be half or twice this number depending on growing conditions. It is important to remember pasture forage is not 100% dry matter but can vary between 20 and 30% dry matter. Additionally, animals can only utilize 40 to 70% of the pasture growth due to trampling and spoilage from manure and urine. Utilization tends to decrease with lower stocking rates and longer grazing times.

In rotational grazing systems, it is important to know the usual resting period for a pasture species (Table 2) and the optimum grazing period in order to calculate the number of paddocks needed. Lower growing species such as bermudagrass often have a shorter rest period than taller species such as alfalfa. The range in values for the usual rest period is due to seasonal variation in growth. In contrast to the resting period, the grazing period is somewhat fixed. A grazing period of 3 days is considered optimum to prevent grazing of plant regrowth, and a grazing period of 1 day may be even better to optimize forage yield and quality. However, a 7-day rotational period is often used to reduce the amount of labor required to move animals or fences. This period is also convenient for producers with another job and may only have the weekend to manage grazing animals. Calculations for rotational grazing systems can be found in APPENDIX II.

Grazing Interval

The time of first harvest of a newly established stand or the first harvest of the season, should be delayed until most grass seed heads have emerged or until most legume stems have flowered. This permits storage of carbohydrates and nutrients in the roots and stems which the plants will rely on during the dormant season.

After the initial harvest, forage should be grazed at or before seed head emergence in grasses and flowering in legumes. Pasture forage quality decreases as the plants grow and progress through various growth stages. Early growth is the most palatable and nutritious since it is comprised primarily of leaves. As plants continue to grow, the proportion of stem to leaves increases and quality decreases because stems are less digestible than leaves. Once heading or flowering occurs, quality continues to decline to such an extent that the

nutritional content of the forage becomes unacceptable and may be unpalatable to animals.

Grazing should be terminated in the fall soon enough to permit plants to grow to full bloom, just before their period of inactive growth or dormancy. Forage may be removed after the plants have become dormant by pasturing or by cutting for hay.

Salt and Mineral Supplements

Livestock on well fertilized and managed pastures always need salt supplement. Granular salt is preferred but block salt is often used out of convenience. If the pasture is grazed after the growing season is finished, one should use a source of phosphorus with the salt since phosphorus concentration is low in mature plants. This could be 50% salt plus 50% steamed bone meal, or 60% salt and 40% dicalcium phosphate. A loose mineral supplement may also be necessary, depending on the nutritional quality of your pasture and the production status of your animals. It is preferable to provide one supplement that meets all of your production needs rather than multiple products to ensure animals are not over or under-consuming. This is often the more economical approach as well.

Production records can provide data and feedback on animal performance and the success of a grazing and supplement program. Body condition score, BCS, for cattle (Beard, 2021), horses (Iowa State University, 2022), and sheep (Williams and Macdonald, 2018) can give an indication of production status and general animal health, but sub-clinical mineral deficiencies more often show up as reduced reproductive performance (poor semen quality, reduced pregnancy rates, reduced number of live births, reduced birth weights, and unthrifty calves/lambs/kids/foals), as well as reduced immune response to vaccinations and increased susceptibility to disease. Deficiencies can be confirmed through liver biopsies (preferred) or blood serum (only useful for diagnosing severe deficiencies) performed by a veterinarian.

If you provide a loose mineral supplement, be sure it meets the needs of your livestock. Arizona soils are deficient in selenium and copper, therefore a supplement with added selenium is recommended. Many "nationally" marketed supplements do not include added selenium because some parts of the country (particularly the North Central region) contend with selenium toxicity from excessive selenium in the soil. Sheep are susceptible to copper toxicity and should only be supplemented with products specifically labeled for sheep. Mineral supplement consumption can be altered by adding salt to the mixture or adding a palatable feedstuff such as molasses.

Animal Disorders Caused by Forages

Bloat – Bloat is a condition in ruminants where excessive amounts of gas accumulate in the rumen due to an interruption of normal gas elimination by belching and can lead to death by asphyxiation. Any plant with highly digestible new growth can cause bloat. However, bloat is most common with immature growth of legumes, like alfalfa, and when animals are first introduced into a new pasture grazing system. The higher the percentage of legume species a pasture contains, the greater the chance of bloat. Maintaining levels of grass other than legume above 50% helps to reduce bloat incidence but does not prevent it.

Bloat can occur in any type of ruminant including cattle, sheep, and goats. The primary sign of bloat is distension on the left, upper flank of the animal. Other symptoms of bloat are bellowing and frequent urination and defecation. There are two types of bloat, frothy bloat and free-gas bloat. The treatment for frothy bloat is anti-foaming agents and the treatment for free-gas bloat is placing a stomach tube into the esophagus.

Horses may develop gas colic when placed onto new, lush pastures. Similar to bloat, excess fermentation gases from digesting lush, growing grasses build up in the intestines of the animal and cause colic symptoms. Colic is a general term for gastrointestinal pain in the horse, caused by several potential factors. Gas colic is generally mild and treatable, with interventions ranging from simply treating the pain and allowing the gas to dissipate naturally, to nasogastric tubing and antispasmodic drugs. Veterinary treatment is advised if you think your horse is colicking.

To reduce the risk of bloat with legumes, provide animals dry forage before turning them into pastures and provide dry roughage for them while they are on pasture. This may be done by mowing strips in the pasture. Dry forage helps to increase the total consumption of dry matter and reduces the incidence of bloat. When heavy rains and wind cause legume plants to fall over, crowns are exposed to sunlight and shoot growth is stimulated. Pasturing this undergrowth has been observed to be especially hazardous from the bloat standpoint.

Nitrate Toxicity – Nitrate toxicity is a condition where nitrates (NO_3) are converted to toxic nitrites (NO_2) in the rumen. These nitrites are absorbed into the bloodstream where they bind hemoglobin (the compound in the blood that binds and carries oxygen), turning it into methemoglobin. As a result, cattle are unable to receive adequate oxygen to their tissues or organs and suffocate. Common signs of nitrate toxicity include blue-tinged membranes, excessive salivation, urination, difficulty breathing, and chocolate colored blood. As poisoning progresses, cattle become

Table 3: Animal unit equivalents (AUE) of common domestic species.

Species	AUE
Cow (1,000 lbs)	1.0
Yearling Cow	0.7
Horse	1.3
Sheep	0.2
Goat	0.2

Table 4. Guidelines for interpretation of nitrate content of forages and water for livestock consumption (Block, 2020).

Form of nitrate measured						Recommendations for use in livestock
Potassium nitrate (KNO_3)		Nitrate Nitrogen (NO_3-N)		Nitrate (NO_3)		
ppm	%	ppm	%	ppm	%	
Forage (DM basis)						
0-7,220	0-0.72	0-1,000	0-0.10	0-4,430	0-0.44	Generally considered to be safe for livestock
7,220-10,830	0.72-1.08	1,000-1,500	0.10-0.15	4,430-6,645	0.44-0.66	Safe for non-pregnant animals; limit to 50% of dry matter for pregnant animals
10,830-14,440	1.08-1.44	1,500-2,000	0.15-0.20	6,645-8,860	0.66-0.88	Limit to 50% of ration dry matter for all animals
14,440-25,270	1.44-2.52	2,000-3,500	0.20-0.35	8,860-15,505	0.88-1.55	Limit to 30 to 35% of ration dry matter; do not feed to pregnant animals
25,270-28,880	2.52-2.88	3,500-4,000	0.35-0.40	15,505-17,720	1.55-1.77	Limit to 25% of ration dry matter; do not feed to pregnant animals
>28,880	>2.88	>4,000	>0.40	>17,720	>1.77	Danger; do not feed
Water (as received basis)						
0-720	0-0.072	0-100	0-0.01	0-443	0-0.04	Generally considered to be safe for livestock
720-2,166	0.072-0.21	100-300	0.01-0.03	443-1,329	0.04-0.13	Caution: possible problems; consider additive effect with nitrate in feed
>2,166	>0.21	>300	>0.03	>1,30	>0.13	Danger: could cause typical signs of nitrate poisoning

weak. Moving cattle around may exacerbate symptoms or cause death because movement of muscle requires oxygen. Pregnant cattle may abort even at low, non-lethal doses of nitrate. Poisoning from nitrate can happen very quickly, often cattle are unexpectedly found dead. Horses, as hind gut fermenters rather than ruminants, are less susceptible than cattle to nitrate toxicity. If cattle are found early, they may be treated with methylene blue. Post-mortem diagnosis can be made through testing the ocular fluid in the eye of a deceased animal.

Any plant can accumulate toxic nitrate levels, although it is most common with annual grasses (warm or cool season). Nitrates can accumulate in certain weeds such as curly dock, johnsongrass, kochia, lambsquarter, nightshade, pigweed, Russian thistle, pale smartweed, and wild sunflower (Block, 2020). Excess nitrates can also be found in hay even if well-cured. Nitrate concentration in plants may increase to toxic levels from high inputs of nitrogen from manure, nitrogen-containing fertilizer or environmental conditions where plant growth is slowed such as cold temperature, cloudy weather, and drought. In the case of drought, the highest level of nitrate may occur 3 to 7 days after the drought condition is alleviated by rainfall or irrigation.

Despite the severity of nitrate toxicity, it is relatively rare for grazing animals whose rate of feed intake is slow. Nevertheless, caution is advisable when animals are grazing on forage that has been subjected to environmental stress. After an environmental stress, it may be warranted to delay grazing by 1 week. In grasses, the lower part of the stem (2-4 inches in cool-season grasses (Gardner and Jackson, 1976) and 6 inches in warm-season grasses (Strickland et al., 2017)) contain the most nitrate, so reducing grazing intensity to not exceed a certain stubble height may be justified in cases where toxic levels of nitrate are suspected.

If you suspect a pasture has excessive nitrogen levels, you can sample your pasture for testing at a lab (Schalau, 2020). Be sure to check how the lab reports the results, they may be reported as Potassium Nitrate (KNO_3), Nitrate Nitrogen (NO_3-N), or Nitrate (NO_3). Use the appropriate table values to determine if your pasture is safe to graze at that time (Table 4). Remember, nitrogen levels may fluctuate based on environmental factors after sampling.

Prussic Acid Poisoning – Prussic acid, also known as cyanide or hydrocyanic acid (HCN), is similar to nitrate poisoning in that it is usually preceded by some sort of plant stressor, such as a frost or drought, and affects the cattle's ability to utilize oxygen. Ruminants are more susceptible to prussic acid poisoning because enzymes in the rumen microbes release prussic acid from plant tissue. Rather than preventing hemoglobin from binding oxygen (as is the case with nitrites), HCN acts to prevent the cattle's tissues from utilizing oxygen. Cattle often have difficulty breathing, foam at the mouth, become progressively weakened, or found dead. Instead of the chocolate-colored blood characteristic of nitrate toxicity, the blood of affected cattle is a bright cherry red color. Treatment is possible with methylene blue or sodium nitrate, however a veterinarian should be consulted to ensure a differential diagnosis from nitrate toxicity.

Sorghum and related species such as sudangrass and sorghum-sudangrass hybrids can cause prussic acid poisoning. The compounds that lead to prussic acid formation are found in the leafy portion of new growth. Prussic acid may accumulate in leaves after frost damage. New growth following any environmental stress such as drought or grazing can be particularly high in prussic acid. Pastures grown with high levels of nitrogen and low levels of phosphorus and potassium are at high risk to develop prussic acid.

The risk of prussic acid poisoning can be reduced by not grazing sorghum and related species until the plants are 18 to 24 inches in height, delaying grazing by at least 7 days after frost damage, feeding ground cereal grains before turning the animals out to pasture, and using heavy stocking rates (4-6 animals per acre).

Grass Tetany – While not a widespread problem in Arizona, there are a few regions around the state that regularly experience bouts of grass tetany in the spring. Grass tetany, also called grass staggers, develops from an imbalance of magnesium and potassium and is most common in ruminants although horses are susceptible as well. Animals grazing cool-season grasses in the spring are subject to grass tetany. Contributing causes to grass tetany are nitrogen and potassium fertilizer use on the pasture, and vigorous pasture growth, high moisture content of the forage, cool and cloudy days associated with wet weather in the spring, low energy and/or roughage intake, stress to the animal from transport or other factors, and low intake of phosphorus or salt.

If the balance of potassium to magnesium becomes too great (high potassium and low magnesium), and animals are unable to mobilize magnesium stores from their skeletal system they may develop grass tetany. In many cases, animals are simply found dead with signs of convulsions. Less severely affected animals may become ill over 2 to 3 days, exhibiting decreased milk, and appearing uncomfortable and nervous. They may stop grazing, stagger, and develop twitches in the face, ears, and flank. Animals may act more flighty than normal and get up and down frequently. If startled or stimulated, they act erratically, and run with an altered (staggered) gait. Eventually, these animals will collapse and suffer convulsions, facial twitching, foreleg paddling, and chewing that increase if the animal is handled. Death from this point usually occurs in a few hours. Older animals, especially those in early lactation, are most susceptible although any animal

can be affected. If caught early, animals can be treated with an injection of calcium and magnesium. There is a risk of causing heart failure if this treatment is administered incorrectly, it is best performed by a veterinarian.

The best preventative measure against grass tetany is to not graze cool-season grasses until at least 4 to 6 inches tall and supplementing animals with extra magnesium during potential danger periods (8-12% Mg at 3-4 oz daily intake is generally recommended). This is most often accomplished through a providing high magnesium lick or switching temporarily to a high magnesium mineral supplement. Magnesium boluses are available, although they are more labor intensive. Magnesium in some forms is somewhat bitter and unpalatable, so make sure that the form you are using is being consumed by the animal.

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APPENDIX I – Plant Species Descriptions

Fig. 3. An alfalfa plant showing shoot regrowth from the crown and a strong taproot. (Photo by Michael Ottman)

Alfalfa

Alfalfa is a cool-season perennial legume that is recommended for all elevations in Arizona (Fig. 3). An important consideration in the selection of an alfalfa variety is its fall dormancy. Nondormant varieties are used at lower elevations and more dormant varieties are used at higher elevations. Alfalfa varieties have been developed that are specifically adapted to grazing which have deeper crowns less subject to damage from trampling by animals. Because of the danger of bloat for ruminants other than sheep, precautions should be taken to avoid bloat such as not grazing immature alfalfa. The risk of bloat is somewhat less when an alfalfa-grass mixture is used rather than alfalfa alone. Alfalfa often crowds outs grasses planted in combination with it due to its quick recovery after grazing. Also, the root system of alfalfa is deeper than most grasses allowing it to survive longer irrigation intervals than most grasses.

Annual (Italian) Ryegrass

Annual ryegrass is a cool-season annual grass that is often used in pasture mixes with winter cereals such as oats and barley or to over-seed warm-season grass sods such as bermudagrass. This grass has low yield potential compared to other cool-season winter annuals, but is used in mixtures because its quick establishment suppresses weeds, produces some forage before other species in the mixture become established, and forms a sod resistant to trampling. It also tolerates wetter soil conditions than other cool-season annuals grasses. Some varieties are not true annuals and may behave as a biennial or short-lived perennial at higher elevations. Annual ryegrass may reseed itself which is an advantage for a perennial pasture but a disadvantage in subsequent crops particularly wheat and barley for grain where it may be difficult to control. Infection by endophyte fungus occurs in perennial ryegrass but not annual ryegrass. The condition known as "annual ryegrass staggers" is not caused by an endophyte fungus but rather by bacteria in galls on the seed head.

Bermudagrass

Bermudagrass is warm-season perennial sod-forming grass. Varieties exist which can survive winters common at higher elevations, but the growing season will be short. 'Arizona Common' and similar varieties are excellent for pasture because of their sod density whereas 'Giant', which does not form as dense a sod as 'Arizona Common' can also be used for pasture but is better suited for hay production. Bermudagrass is very competitive with other plants and should not be used in mixtures. Compared with other perennial grasses, bermudagrass establishes rapidly and has a very long stand life. This grass has excellent tolerance to drought, salt, alkali, and waterlogged soils. Bermudagrass forage quality is highest in the spring and decreases rapidly in the summer. The nutritive value of this grass is highest when grazed at intervals less than 4 weeks and when provided with adequate nitrogen fertilizer. Bermudagrass can be continuously stocked but the stocking rate must be adjusted to the growth rate of the grass.

Berseem (Egyptian) Clover

Berseem clover is a cool-season annual legume. The advantage of this legume compared to alfalfa is that it establishes more quickly, is non-bloating, and is more

tolerant to salt and wet soils. It can be used as alone, in a mixture with winter annual grasses, or overseeded into thinning alfalfa stands. Berseem clover can naturally reseed by removing the animals at the bud stage in the spring, allowing the crop to produce seed, resuming grazing to remove residue and allowing animal hooves to press the seed into the ground, and irrigating in the fall to germinate the seed.

Birdsfoot Trefoil, Narrowleaf

Narrowleaf birdsfoot trefoil is a cool-season perennial legume. It is similar to alfalfa in appearance but has a finer stem and is low-growing. The advantage of birdsfoot trefoil compared to alfalfa is that it is more tolerant of soils that are wet or shallow, does not cause bloat, and is more nutritious and palatable. It also contains condensed tannins (proanthocyanidins) which in low to moderate concentrations (2-4% DM) can improve protein uptake from the forage in ruminants and suppress gastrointestinal parasites in sheep and goats. Narrowleaf birdsfoot trefoil is often used on problem soils that are wet or salty. This crop is difficult to establish, produces little forage the year after planting, the stems are weak and susceptible to lodging, and stand persistence has been a problem in Arizona plantings. Stand persistence can be increased by allowing this crop to reseed itself. It is often planted with a grass to support prostrate birdsfoot trefoil stems and to improve overall yield potential.

Blue Panicgrass

Blue panicgrass is a warm-season perennial grass. It is often planted in 12 to 36 inch rows rather than drilled or broadcast. At low elevations it is very productive during the mid-summer when alfalfa growth slows. It is not adapted to sandy soil but will grow on moderately saline or alkali soils. Blue panicgrass spreads vegetatively by thick, short rhizomes. Stands persist longer and production is higher when plants are not grazed below an 8 to 10 inch stubble height. Blue panicgrass can survive on one irrigation a season when planted on river bottoms or overflow land and where flood waters furnish moisture. While it survives considerable drought, 6 or more acre-feet of water and adequate nitrogen are required each year for maximum production. Blue panicgrass should be grazed intensively since it is vigorous and can reach heights of 6 to 8 ft tall.

Cowpea

Cowpea is a warm-season annual legume that can be planted alone or in mixtures with warm-season annual grasses. Varieties differ in growth habit (bush-like or vine-like) and time of flowering (early and late). This legume is adapted to planting in a mixture with warm-season annual grasses since it is shade tolerant and some varieties have vines that climb up the stalk of plants such as the sorghums. Cowpea does not tolerate salinity or extended flooding but tolerates drought and heat. Compared to lablab, cowpea is less productive in the fall, has better survival and recovery after cutting, and does not tolerate trampling as well. In order to ensure recovery, cowpeas should not be grazed until the flowering stage and animals should be removed once all leaves have been eaten preferably or at a stubble height of 6 inches.

Crimson Clover

Crimson clover is a cool-season annual legume. This legume can be planted alone, in mixtures with cool-season annual grasses or legumes, or overseeded into warm-season perennial grasses once these are dormant. Crimson clover cannot be relied on to reseed itself. Compared to most clovers, it can grow on poorer soil and be productive at lower temperatures. It is usually the first cool-season legume to start growth in the spring. Bloat is less likely with crimson clover than with alfalfa and white clover. The overly mature flower head of crimson clover contains barbed hairs which can be harmful to horses, so graze horses no later than the onset of flowering. In mixtures, graze before grasses shade the crimson clover. This legume can be grazed heavily.

Hairy Vetch

Hairy vetch is a cool-season annual legume with a vine-like growth habit. This legume can be grown alone, in mixtures or overseeded into dormant warm-season perennial grass. Because of its vine-like growth habit, it is often seeded with grasses that can support its growth. Hairy vetch can reseed itself if animals are removed prior to the bud stage and can volunteer and provide winter forage in a bermudagrass pasture during the dormant season of this grass. Establishment is slow and there may not be sufficient forage for grazing until the spring, but once established, this legume withstands trampling. Hairy vetch is adapted to wetter soil and colder temperatures than other cool-season legumes. It can grow on any soil type, and can outperform crimson clover on sandy soils. The quality of this legume is slightly less than alfalfa and clover. Hairy vetch has been associated with a systemic granulomatous disease in cattle, but rarely in horses, where fed in the mature stage or as the major component of the forage.

Kleingrass

Kleingrass is a warm-season perennial bunchgrass related to switchgrass but shorter in stature. It can be grown in mixtures with other grasses and legumes. Compared to bermudagrass, it greens up about 1 month earlier in the spring but growth slows about 1 month earlier in the fall. Kleingrass propagates via seed and rhizomes, and can withstand extended periods of drought. It is drought and salt tolerant but only moderately tolerant of wet soils. Kleingrass provides palatable forage especially in the early stages of growth. After establishment, it can withstand heavy grazing if the stubble height is no less than 8 to 10 inches. This grass is an excellent feed for cattle but saponins in the grass can cause liver damage and photosensitization in horses, sheep, and goats, but cattle are not affected. Fresh growth is more toxic than old or dormant growth.

Lablab

Lablab is a warm-season annual legume that does not cause bloat. Cultivars are available with bush and climbing growth habit and early- and late-flowering characteristics. This legume can be planted alone or in mixtures with other warm-season annual legumes or with warm-season annual grasses. Compared to similar legumes, it is more productive and drought resistant. However, it does not tolerate salinity or wet soils. Overall, lablab is a very palatable plant especially the leaves, but the stems have low palatability. This legume should not be intensively grazed, but can be rotationally grazed 2-3 times per season if the stems are not grazed or stubble height is at least 10 inches.

Ladino Clover

Ladino clover is a cool-season perennial legume that is a large type of white clover. White clover can be classified in three different groups based on plant height: small (4-6 inches), intermediate (6-10 inches), or large (10-12 inches). The large type of white clover (Ladino clover) is the highest yielding of the three groups. Ladino clover is adapted to mixtures and can be sown into existing stands of grass. Ladino clover is easy to establish and spreads by creeping stems which root where the nodes contact the soil. Since the stems are prostrate, the growth that is pastured is primarily leaves and flowers and Ladino and other white clovers are the most nutritious legume grown in Arizona. This legume has unusually low fiber content and high protein digestibility. It tolerates close grazing and trampling by livestock. Ladino clover is not tolerant of salt, drought, heat, and sandy soil, is shallow rooted, and requires frequent irrigations. Its stand longevity is similar to alfalfa, but produces less forage. The problem of bloat with Ladino clover is equal to or greater than with alfalfa. To combat bloat, try to maintain an even stand of Ladino clover in a grass mixture so the livestock cannot selectively graze the Ladino clover and keep Ladino clover to less than 40% of the stand in a grass mixture. The proportion of grass to Ladino clover in a mixture can be increased by lengthening the grazing interval allowing the grass to become more dominant. Ladino clover persists well in mixtures with orchardgrass and tall fescue above 3000 ft.

Meadow Bromegrass

Meadow bromegrass is cool-season perennial sod-forming grass. Since the seed is light and chaffy, agitators in the seedbox can help move the seed through the planter. It is often used in pasture mixes and is very productive. Meadow bromegrass develops a large, fibrous root system and can spread vegetatively by vigorous rhizomes which develop near the soil surface. Meadow bromegrass is productive in the early spring through fall and regrows rapidly after cutting. Meadow bromegrass has an especially high leaf-to-stem ratio and is palatable even when mature. Meadow bromegrass is adapted to similar areas as orchardgrass, but it is more tolerant to cold and drought.

Orchardgrass

Orchardgrass is a cool-season perennial bunchgrass recommended at elevations above 3000 ft. This grass tolerates considerable shade, is adaptable to mixtures with legumes, and can be overseeding into thinning stands of legumes. In mixtures with legumes, use later-maturing varieties that will not be at the heading stage or beyond when the legume component is at the ideal stage to be grazed. Orchardgrass should not be planted in mixtures with other grasses due to differences in palatability and maturity. Orchardgrass will only produce a seedhead in the spring, and subsequent growth will be very high quality. During the first growing season, orchardgrass can be damaged by overgrazing and the first grazing should not occur until late summer. Compared to other cool-season perennial grasses recommended in Arizona (meadow bromegrass, tall fescue, and tall wheatgrass), it is not as tolerant to cold, drought (except tall fescue), soil wetness, salt, and alkali but has equal or better palatability and recovery rate after grazing. This grass should be grazed before heading stage since palatability decreases rapidly as the plant matures. The only exception to this

rule is if the stand is thinning and seed production is required to rejuvenate the stand. Orchardgrass is a poor accumulator of magnesium and grass tetany (magnesium deficiency) can be a problem in animals grazing on this grass.

Pearl Millet

Pearl millet is a warm-season annual grass that is suitable for horses since, unlike sorghum, it does not accumulate prussic acid. It does, however, accumulate nitrate similar to most grasses including sorghum. Pearl millet does not yield as well as sorghum. Many species of millet exist such as proso, foxtail, Japanese, and finger millet, but pearl millet is most commonly used for grazing. Pearl millet varieties can be classified according to stature: Dwarf (less than 4 ft), semi-dwarf (4-6 ft), and tall (6-8 ft). Dwarf varieties are the most suitable for grazing since they are leafier due to shorter stems yet the same number of leaves. Brown midrib varieties are also available that are more digestible due to lower lignin content but often are lower yielding. Compared to the sorghums, pearl millet is less tolerant of intense grazing and wet soil but more tolerant of heat, drought, low soil fertility, and iron chlorosis induced by high soil pH. Since pearl millet has more rapid early growth and a shorter growing season than most sorghums, it is often preferred over sorghum for late-planting, double-cropping, or emergencies. Some evidence exists that pearl millet will depress butterfat concentration in lactating dairy animals. Pearl millet is reported not to perform well on soils high in calcium but has done well in trials at Maricopa.

Red Clover

Red clover is a cool-season biennial or short-lived perennial legume. It can be grown in a pure stand, in a mixture, or overseeded into a sod but is best grown in a mixture with a cool-season grass such as orchardgrass or tall fescue to reduce the risk of bloat and stabilize forage production. Red clover can withstand more shading at the seedling stage than most legumes making it a good component of mixtures with grasses. Red clover is high in magnesium and in mixtures can prevent grass tetany from low magnesium content in some grasses. Red clover also contains biochanin A which can help prevent fescue toxicosis. Early-flowering ('medium' type) cultivars may be grazed 2-3 times and are best suited to Arizona whereas late-flowering ('mammoth' type) cultivars may be grazed only a single time per season and are best suited to climates much cooler than anywhere in Arizona. Stand life is shortened by high temperature, drought, or flooding and can be prolonged by allowing the plant to naturally reseed itself. Red clover does not tolerate frequent grazing. Bloat is a problem with red clover when greater than 30% of the pasture mix and it can cause photosensitivity and liver damage. Older cultivars contain estrogenic compounds that can interfere with livestock breeding. Compared to alfalfa, red clover has similar overall forage quality, has lower yield and protein content, but is more digestible and quality does not decline as quickly with maturity. Compared to white clover, red clover is higher yielding and more productive in warmer weather, but has lower quality, grazing tolerance, and longevity.

Rhodesgrass

Rhodesgrass is a warm-season perennial grass. Late-maturing cultivars are best suited to irrigated pastures in Arizona due to their responsiveness to irrigation water and nitrogenous fertilizer. Tetraploid varieties are more palatable than diploids particularly compared when mature. Rhodesgrass is productive, long-lived if provided with adequate fertilizer, and tolerant to salt and drought. Although this grass is not tolerant of shade, it is suited to mixtures with certain legumes such as alfalfa and cowpea and grasses except for bermudagrass. The seed is fluffy and may be difficult to sow. During establishment, Rhodesgrass should be allowed to flower and set seed so that the root system is well-developed before grazing so that plants are not pulled out of the ground by the livestock. Once established, Rhodesgrass should be grazed by flowering since quality diminishes rapidly afterwards. Fresh growth is the most nutritious and Rhodesgrass does tolerate heavy grazing to a certain extent. Rhodesgrass has low levels of oxalate, which can be a problem for horses at high concentrations, in contrast to many other warm-season perennials such as bermudagrass.

Sorghums (forage sorghum, sorghum x sudangrass hybrids, sudangrass)

The sorghums are warm-season annual grasses. Forage sorghum is usually not grazed since the stalks can become thick and unpalatable in contrast to sudangrass and sorghum x sudangrass whose stalks are finer. Sorghums can be extremely productive during the heat of the summer and provide valuable forage during a time of reduced growth of other plant species. Brown midrib (BMR) varieties are available which are more digestible due to lower lignin content. Sorghums can contain toxic levels of nitrate and prussic acid, metabolized from dhurrin under certain conditions. The risk of these problems is greatest in immature forage and can be reduced by delaying grazing

until the plants are 18 to 24 inches in height. Sudangrass contains about half the dhurrin (prussic acid precursor) as sorghums, and 'Piper' sudangrass is a low dhurrin variety. Dhurrin-free sorghum x sudangrass hybrids are being developed. Sorghums have high potassium content and should not be fed to dry cows. Sorghums also accumulate relatively high copper content and sheep should be supplemented with a mineral mix with molybdenum and no copper. Sorghum pasture is not recommended for horses due to cystitis-ataxia syndrome (nerve damage in the urinary tract).

Strawberry Clover

Strawberry clover is a cool-season perennial legume with a prostrate growth habit. This legume spreads readily with stolons into bare areas and tolerates close grazing. Compared to alfalfa, strawberry clover has lower yield potential, palatability, and tolerance to cold and drought but it has higher tolerance of wet soils and is more persistent. It is also the most salt tolerant of all clovers. Strawberry clover can cause bloat and increase the frequency of urinary calculi (kidney stones) in sheep that can be managed by maintaining at least half of the pasture in grass. Compared to Ladino and other white clover, strawberry clover causes less bloat; is more tolerant of salt, alkali, and wet soil; tolerates a wider range of temperature; is more persistent under intense grazing; and is less susceptible to many diseases and insects. Good species to include in a mixture with strawberry clover are tall wheatgrass under saline conditions and tall fescue under non-saline conditions. Strawberry clover should not be grazed initially until strong stolons or runners have developed. Close grazing (stubble height = 2 inches) favors strawberry clover and light grazing (stubble height > 4 inches) favors the grass. Hard seeds can cause strawberry clover to volunteer in subsequent crops.

Tall Fescue

Tall fescue is a long-lived, cool-season perennial bunch grass that eventually forms a sod. It is easy to establish, vigorous, suitable for heavy grazing, and persistent. Tall fescue is a good companion crop in mixtures, and can be overseeded in the dormant season into warm-season grasses. However, care must be taken in choosing companion species in mixtures since tall fescue is allelopathic, that is, the roots exude chemicals that are toxic to some species such as birdsfoot trefoil, red clover, and white clover. Although tall fescue is less palatable than other cool-season grasses and livestock may avoid it when mature, animals will graze it readily and perform well when properly fertilized and grazed frequently. However, the forage quality of tall fescue is too low to be used by dairy animals. At higher elevations, it is most productive during the summer but at lower elevations, most growth occurs in the spring and fall. Tall fescue is subject to an internal fungal infection (endophyte) by the fungus *Neotyphodium coenophialum* that contain a toxic alkaloid (ergovaline) linked to poor animal health and performance (fescue toxicosis). Strategies to deal with endophyte infection include not allowing the grass to develop seed heads which contain a higher concentration of the fungus, diluting the fungus by interseeding the pasture with other plant species or by supplementing the pasture with other feeds, and not grazing tall fescue during the summer when toxicity is greatest. The endophyte infected plants in a stand tend to increase over time since they are more competitive than other tall fescue plants and other plant species in a mixture. The endophyte is transmitted in the seed and low-endophyte (<5%) seed has been produced by treating the seed with heat or chemicals, harvesting the seed from endophyte-free plants, or storing the seed for longer than a year. Endophyte-free varieties were initially developed that improved animal performance but in many cases the stands were not as productive or persistent under non-ideal conditions especially drought in Southern states. It has since been discovered that endophytes in tall fescue produce another alkaloid named loline that provide the plants with pest resistance, drought tolerance, and persistence and is not harmful to the animal unlike the ergovaline alkaloid. Endophyte-friendly tall fescue varieties are now available that have been infected with special strains of endophytes called "novel endophyte" (NE) that produces the non-toxic loline alkaloid that increases plant performance but the alkaloid ergovaline is not present or at levels low enough not to affect animal performance.

Tall Wheatgrass

Tal wheatgrass is a cool-season, long-lived perennial bunch grass that has excellent drought and salt tolerance. It is also adapted to wet and alkaline soils. It has poor palatability and its quality declines rapidly after bloom. It can be seeded in pure stands or in mixtures with legumes or grasses. Forage quality is best with new growth in the spring, and quality decreases in the summer even when kept short. Grazing management is a trade-off between forage quality vs productivity and persistence. It must be grazed intensely to avoid seed heads developing and it can be continuously grazed but is best suited to rotational grazing with a rest period of about 4 weeks. If time between

grazing is too long, tall wheatgrass can form clumps that are unpalatable and large enough to make the pasture impassible in a vehicle. It should not be grazed the first year since it is slow to establish. Leave a high stubble after pasturing to avoid stand decline. Tall wheatgrass is used more for dryland than irrigated pastures in Arizona.

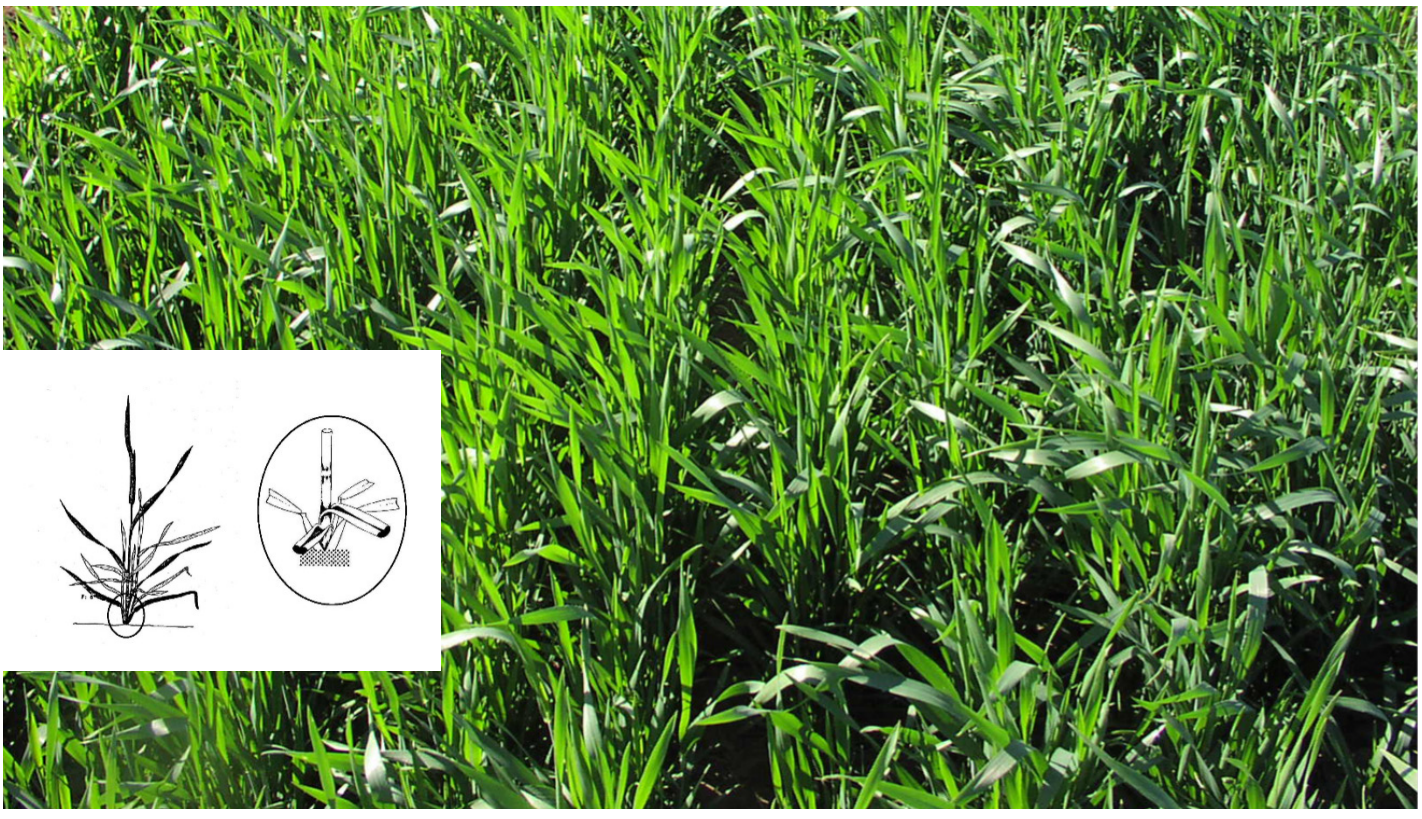
Tepary Bean

Tepary bean is a warm-season annual legume that can be planted alone or in mixtures with warm-season annual grasses. It is a traditional Native American crop and has been grown in arid regions worldwide. Its primary use has been for human consumption of the beans, but it also has value as a cover crop and as forage for livestock. It was grown extensively in the Southwest by Euro-American farmers roughly a hundred years ago as a cover crop and for beans, but it went out of favor. It is native to Arizona, New Mexico, Texas, and Mexico. In the wild, it is adapted to hot, dry environment and it is able to take advantage of episodic rainfall and mature quickly. Wild types of tepary bean are vining and weakly trailing with an indeterminate growth habit whereas domesticated types are more bushy and determinate. Tepary beans are similar to alfalfa in quality and to cowpea in yield. Tepary bean does not have a history as a pasture species, but it has potential due to its yield, quality, and tolerance of heat and drought.

Winter Cereals (barley, oats, triticale, and wheat)

Winter cereals are cool-season annual crops that can be grown for forage or grain. These crops can be planted alone but are often used in mixtures with each other. Winter cereals are highly palatable and nutritious and provide much needed feed during the cooler time of year when forage may be scarce. The plants are typically grazed at or before the beginning of the jointing stage of growth (1-node stage) when the growing point emerges above ground level (Fig. 4). If the plants are allowed to progress past heading, animals may selectively graze one species over another and clumps of ungrazed plants may result. Winter cereals except for oats typically have awns (bristle-like appendages at the tip of the spike) which can be irritating to the grazing animal's mouth and eyes, but awnless varieties intended for forage are available. Bloat, nitrate toxicity, and grass tetany can be a problem with winter cereals.

Fig. 4. The 1-node stage of growth in a wheat plant where the plants may be 8-12 inches tall and jointing begins. The inset drawing (Tottman, 1987) shows the location of the first node above ground encased in the leaf sheaths. Grazing of winter cereals (barley, oats, triticale, and wheat) should begin at or before this stage. (Photo by Michael Ottman)



APPENDIX II - Rotational Stocking Calculations

Adapted from Ball et al., (2016)

- Number of paddocks = (days rested/days grazed) + 1
  (Use to determine ideal number of paddocks based on grazing/resting days)
  - Example:
    - Crop = Alfalfa
    - Days rested = 28
    - Days grazed = 7
  - Number of paddocks =(28/7) + 1 = 5
- Days grazed = days rested/(number of paddocks – 1)
  (Use to determine grazing days based on desired resting days assuming paddocks are predetermined)
  - Example:
    - Crop = Alfalfa
    - Days rested = 28
    - Number of paddocks = 5
  - Days grazed = 28/(5-1) = 7
- Acres per paddock = (animal weight x dry matter consumed as fraction of body weight x number of animals x days on pasture)/(pasture dry matter x fraction dry matter utilized)
  (Use to determine ideal paddock size based on animals and grazing days)
  - Example:
    - animal weight = 1300 lb horse
    - dry matter consumed as a fraction of body weight = 0.02 (2%)
    - number of animals = 5
    - days on pasture = 7
    - pasture dry matter = 9 inches of pasture growth x 200 lb/in/acre = 1800 lb/acre
    - fraction dry matter utilized = 0.50 (50%)
  - Acres per paddock = (1300 x 0.02 x 5 x 7)/(1800 x 0.5) = 1.0
- Total acres required = number of paddocks x acres per paddock
  (Use to determine total acres needed based on paddock numbers and size)
  - Example:
    - number of paddocks = 5
    - acres per paddock = 1.0
  - Total acres required = 5 x 1.0 = 5.0
- Stocking rate (animals per total acres) = number of animals to be grazed/total acres grazed
  (Use to determine how many animals per acre are being grazed on an operation basis)
  - Example:
    - number of animals to be grazed = 5
    - total acres grazed = 5.0
  - Stocking rate = 5/5.0 = 1

- Stocking density (animals per paddock per acre) = number of animals/paddock size in acres
  (Use to determine how many animals per acre are being grazed on a paddock basis)
  - Example:
    - number of animals = 5
    - paddock size in acres = 1.0
  - Stocking density = 5/1.0 = 5

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