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Cattle Utilization of Forage Kochia (*Kochia prostrata*) and Its Relation to Forage Quality and Plant Morphological Characteristics

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CATTLE UTILIZATION OF FORAGE KOCHIA (*KOCHIA PROSTRATA*) AND ITS RELATION TO FORAGE QUALITY AND MORPHOLOGICAL CHARACTERISTICS

by

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ABSTRACT

Cattle Utilization of Forage Kochia (*Kochia prostrata*) and Its Relation to Forage Quality and Plant Morphological Characteristics

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Several experimental lines of forage kochia [*Kochia prostrata* (L. Shrad.)] have potential to provide taller forage on fall and winter rangelands than the only released variety of forage kochia, Immigrant. This study was conducted to determine differences in cattle utilization among experimental lines of forage kochia and relate them to forage quality and morphological attributes. The utilization of forage kochia was also compared to 'Ladak' alfalfa [*Medicago sativa* (L.)] and two entries of winterfat [*Krashnennikovia* species (Guldenstaedt)]. Cattle utilization was determined by calculating a biomass consumed value and a percent biomass consumed value. Dry weights for each plant were taken after grazing and subtracted from a pre-grazing dry weight (predicted using a quadratic regression equation) that produced the biomass consumed value. The percent consumed value was calculated by dividing biomass consumed by pre-grazing dry weight. Ocularly estimated utilization scores (OU) were also used to measure utilization.

Forage quality traits were analyzed on each entry using near infrared reflectance spectroscopy. Morphologic and phenological characteristics potentially related to utilization were made by physical measurements and visual evaluations. There were significant differences among forage kochia accessions for all traits evaluated. Four entries, including Immigrant and Ladak alfalfa, were significantly higher in percent herbage consumed than the other entries. These same entries were consistently high in OU ratings, forage quality analyses, and most morphological characteristics. Pre-grazing dry weight ($r = -0.96$, $P < 0.0001$), stem length ($r = 0.67$, $P < 0.0001$), and branch density ($r = 0.63$, $P < 0.0001$) were all highly correlated with utilization. Crude protein (partial $R^2 = 0.253$, $P \leq 0.0001$) was the only forage quality trait associated with utilization using a stepwise regression to predict utilization. From this study we conclude that some forage kochia accessions are very palatable. They are comparable to Ladak alfalfa, and utilized more than *Krashnikova spp.*, a desirable forage on western rangelands.

(75 pages)

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Burke Davenport

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INTRODUCTION

Forage kochia (*Kochia prostrata* L. Shrad.), is a valuable forage plant that evolved under heavy grazing in the deserts and semi-deserts of central Eurasia (Harrison et al. 2000). Though forage kochia has been recognized as a valuable plant for livestock grazing (Balyan 1972; Monsen and Turnipseed 1990; ZoBell et al. 2003), only one variety, 'Immigrant,' has been released for planting in the United States. Immigrant's low stature, however, reduces its availability in deep snow. It is also densely branched which may limit its use as habitat for small mammals and upland game birds (personal observation).

In 1999, forage kochia seed was collected from Kazakhstan in order to broaden the germplasm base and obtain ecotypes that had potential to improve fall and winter forage (Waldron et al. 2001b). Some of these accessions were observed to be extensively grazed in Kazakhstan. Other accessions had desirable morphological attributes such as taller, more rigid branches that potentially could remain erect under deep snow accumulations. Some types had more biomass that might lead to increased yield on semiarid sites.

Anecdotal information in the United States has resulted in mixed conclusions about forage kochia's palatability to livestock. There has been little research done to better understand the livestock utilization of Immigrant and experimental accessions of forage kochia. Furthermore, even though Waldron et al. (2001b, 2005) observed that forage kochia was heavily grazed in Kazakhstan and Uzbekistan, Balyan (1972) reported some types of forage kochia in central Asia were unpalatable. In addition, the nutritional aspects of forage kochia are not well understood, particularly as they relate to different morphological characteristics. Though forage kochia is not known to have any significant levels of toxins, we hypothesize that there may be anti-quality factors (Shipley and Yanish 2001) associated with morphologically distinct types of forage kochia. Therefore, we determined that a better understanding of livestock utilization, plant morphology, and forage quality were critical to our forage kochia breeding and research project.

The objectives of this study were: (1) to compare cattle utilization of 19 Kazakhstan forage kochia collections to Immigrant and alfalfa [*Medicago sativa* (L.)] and (2) to determine the relationship between morphological and forage quality attributes of forage kochia and the degree of forage utilization.

We hypothesized that there would be differences in utilization among forage kochia accessions and that Immigrant and entry BC-118 would be among the most preferred forage kochia entries. We predicted that the entries used as standards (Ladak alfalfa, Hatch winterfat and 240-WF winterfat) would be the most utilized entries. We hypothesized that forage quality traits (crude protein, NDF, and IVTD) and morphological characteristics (height, stem length, leaf portion of stem, branch density, leafiness, and phenology) would be correlated with the amount of biomass consumed and the percent biomass consumed.

LITERATURE REVIEW

Forage kochia is an important plant in its native environment in the central Asian region and is becoming increasingly important in the western United States. Its native distributions range from central Europe to the west, Siberia in the north, Afghanistan and Asia Minor in the south, and east to China, Mongolia, and Tibet (Balyan 1972). It is abundant in the countries of Kazakhstan, Uzbekistan, and Kirghistan where it is used extensively for livestock forage (Waldron, personal communication). It is esteemed for its ability to provide relatively large amounts of biomass, protein, carotene, phosphorous, and calcium to grazing animals in harsh, dry ecosystems (Balyan 1972; Davis 1979). Forage kochia ecotypes are found growing naturally on soils ranging from sandy to heavy clay and from elevations of 0 to 2,400 m (Balyan 1972). Individual plants can reach heights of 70 cm and roots can reach depths of 443 cm (Kashkarov and Balyan 1989), with lateral roots stretching 130 to 160 cm (Balyan 1972). It begins flowering in July in its native environment and will continue to flower for 65 to 85 days. Seed ripening begins in late September and is complete by mid-October (Kashkarov and Balyan 1989). Immigrant and other subspecies virescens types, however, do not mature until November and December (personal observation).

There is genetic and phenotypic variation among forage kochia subspecies as well as variation within subspecies (Balyan 1972). Authorities claim that these differences are caused by environmental and ecological variation in its native environment. Diploid, tetraploid, and hexaploid ploidy levels are found in forage kochia (Rubstov et al. 1989), with the principle chromosome number being 9 (Shakhanov and Sagimbaev 1983). Balyan (1972) classifies two different subspecies: *Kochia prostrata* [(L.) Shrad.] subsp. *virescens* [(Frenzl.) Prat.] (green type), and *Kochia prostrata* [(L.) Schrad.] subsp. *grisea* (Prat.) (grey type). Within the subspecies *grisea* are two varieties: var. *canescens* and var. *villosocansa* [also called *villosissima* (Bong. Et Mey. Verz. Gesamm. Pflanz)]. However, some researchers recognize *canescens* and *villosocansa* as two distinct subspecies (Waldron et al. 2005).

American scientists have sought seed from the central Asian countries because of the similarity of the environments and adaptability of these plants to the Intermountain West. The New Crops Research Branch of the Agricultural Research Service received seed for 18 accessions in the mid 1960's (Keller and Bleak 1974). In 1992, the USDA ARS Forage and Range Research Laboratory's Drs. Kay Asay and Doug Johnson brought back 50 collections of forage kochia from Kazakhstan (Asay and Johnson 1992). Additionally Dr. Blair Waldron and Mr. Deane Harrison have collected forage kochia on two different occasions. The first collection trip was in 1999, resulting in the collection of 192 ecotypes that represented three ploidy levels from Kazakhstan (Waldron et al. 2001b). The second collection trip was in October of 2003 from Uzbekistan where they collected six additional ecotypes (Waldron et al. 2005).

Since forage kochia's introduction to the United States in the 1960's, U.S. government research agencies have studied several aspects of the species. Some of these studies include: (1) its adaptability to the Intermountain West (Pendleton et al. 1992; McArthur et al. 1995); (2) ability to establish with minimal seedbed preparation (Young et al. 1981; Stevens and Van Epps 1984; Krylova 1988; Page et al. 1994); (3) salt tolerance (Francois 1976, McFarland et al. 1990, Waldron unpublished data); (4) drought tolerance (Romo and Haferkamp 1988); and (5) competition with alien annuals (Harrison et al. 2000). It has been found to be highly adapted to the Great Basin, making it a candidate for seeding on vast areas of western rangelands (Krylova 1988; Pendleton et al. 1992; Blauer et al. 1993; McArthur et al. 1995). Most rangeland and research-plot plantings of forage kochia are within the boundaries of the Great Basin. However, successful plantings have also been established in the Colorado Plateau, the Wyoming Basin, and the Snake River Plains eco-regions (Harrison et al. 2000).

In 1994, an experiment was conducted to determine the best method of establishing forage kochia. Researchers tested seedbed preparation, seeding methods, and season of planting in an area dominated by cheatgrass in Skull Valley, Utah (Page et al. 1994). Seedbed treatments included: cultivation using a spring tooth harrow, spike toothed harrow, and a control with no seedbed preparation. Seeding rates of 1.12 $kg \cdot ha^{-1}$ (1 $lb \cdot ac^{-1}$) 3.36 $kg \cdot ha^{-1}$ (3 $lb \cdot ac^{-1}$) and 6.73 $kg \cdot ha^{-1}$ (6 $lb \cdot ac^{-1}$) pure live seed were planted in November, December and February to compare seeding rates and month of planting. The seeding methods were a broadcast and drill treatment. The treatment that established with best success was broadcasting in December in cultivated soil using the higher seeding rates. Ten years later the amount of cheatgrass had significantly decreased and forage kochia had persisted in the original research plots (Monaco et al. 2003). Treatments were uniform in cover with little difference between seeding rates.

One problem with planting forage kochia is that the seed does not store well and loses considerable viability after one year (Balyan 1972, Keller and Bleak 1974). Researchers recommended using current year's seed when making fall and winter plantings (Stevens and Van Epps 1984). Forage kochia seed dormancy is influenced by time, moisture, and temperature (Stevens et al. 1985; Romo and Haferkamp 1987). Therefore, fall and winter plantings have shown better results than spring plantings. However, when year-old seed must be used, it is best to plant it in the spring to avoid dormancy issues (Kitchen and Monsen 2001).

One of the greatest benefits of forage kochia is its ability to compete with annual weeds. In 1981, it was planted in an area dominated by the introduced annual weed, halogeton [*Halogeton glomeratus* (Bieb.) C.A. Mey.] (Stevens and McArthur 1989). Throughout the 7-year study, the number of halogeton plants continued to decrease, and forage kochia became the dominant plant in the research plots. Perhaps more importantly, it has been proven to be competitive against cheatgrass (*Bromus tectorum* L.), an introduced annual grass that now dominates millions of acres in the western United States (McArthur et al. 1990). Monsen and Turnipseed (1990) found that kochia could be established in dense stands of cheatgrass. Pendleton et al. (1992) and Harrison et al. (2000) found that in many cases forage kochia suppressed or eliminated cheatgrass within forage kochia plantings.

The spread of cheatgrass has increased the frequency of wildfires on western rangelands. In many areas, wildfires are a constant concern for government agencies as well as to the public. Because of forage kochia's semi-evergreen nature, research was performed on forage kochia's suitability for use as a greenstrip species to control wildfires (greenstrips are densely planted strips of plant species not likely to burn). Forage kochia has been found to be fire tolerant (McArthur et al. 1990) and has been used successfully in greenstrips to suppress wildfires (Harrison et al. 2002). Forage kochia and crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] were reported to be the most promising species for use in greenstrips on arid lands (Monsen 1994). Forage kochia has many attributes that make it useful in greenstrips including: adaptability, competitiveness with annuals, ease of establishment, low flammability, high palatability, and resilience and regrowth capabilities (Monsen 1994).

Forage kochia has been successfully used to stabilize soil and compete against weeds on severely disturbed areas. It has been used on several roadcuts and road-sides in central Utah (Blauer et al. 1993). It established on all treated sites and had the highest mean cover class of all species being evaluated for road-side plantings. It has also been used successfully on processed oil shale and other types of mine spoils (Ferguson and Frischknecht 1985; McKell 1986).

The focus of many of the early experiments on forage kochia was to evaluate collected accessions for variety release. In 1984, the accession PI314929 was released as the cultivar Immigrant forage kochia by the USDA Forest Service, USDA Soil Conservation Service, Utah Division of Wildlife Resources, and Idaho, Nevada, Oregon, and Utah Agricultural Experiment Stations (Stevens et al. 1985). It was a selection obtained by Wesley Keller and Perry Plummer from the Perkalshy Arboretum in Stravropol, Russia, in 1966. Immigrant is subspecies *virescens* and is a diploid with chromosome number of 2n=18 (Pope and McArthur 1977; Herbel et al. 1981; McArthur et al. 1995). It is characterized by small diameter stems, narrow, green glabrous leaves, and a shorter stature than many other forage kochia accessions. It was released for use as forage and erosion control for rangelands in the Intermountain West. Longevity, forage production, forage quality, palatability, high seed production, salt and drought tolerance, and competitiveness with annuals were characteristics in which Immigrant excelled over other accessions. Immigrant has proven to be a valuable plant material for a variety of applications such as rangeland renovation, forage and habitat for livestock and wildlife, and the addition of biodiversity to rangeland plantings (Harrison et al. 2000).

Because forage kochia has proven to be competitive with annual weeds and adapted to a variety of ecosites, concerns have been raised in its potential to become a weedy species similar to annual kochia [*Kochia scoparia* (L.) Schrad). Therefore, a study was conducted by the USDA Agricultural Research Service in cooperation with the Utah Agricultural Experiment Station to determine the aggressiveness of forage kochia on Intermountain rangelands (Harrison et al. 2000, Waldron et al. 2001a). More than 90 forage kochia sites were visited and examined. Results showed that forage kochia, particularly Immigrant, grew best in disturbed soils at low elevations that were usually occupied by weedy annuals. It did not persist well in more favorable sites dominated by perennials, particularly at higher elevations. It appeared to compete with weedy annuals such as cheatgrass, halogeton, Medusahead [*Taeniatherum caput-medusae* (L.) Nevski], and tumble mustard (*Thelypodiopsis* sp. Rydb.). Forage kochia naturally recruited into disturbed soils or areas dominated by annuals, but did not spread aggressively, especially into perennial vegetation.

In 2004, Schauer et al. studied forage kochia seeds' ability to germinate after ruminal incubation to determine if kochia was likely to spread after being eaten and passed by ruminants. After a 48-and 96-hour incubation, forage kochia had a germination rate of 0% compared to the unincubated control that had a germination rate of 95%. These results suggest that forage kochia is unlikely to be spread into unwanted areas after passing through a ruminant's digestive system.

Forage Kochia as a Forage

The palatability of forage kochia to livestock is not well documented by Russian or U.S. scientists. Some claim it is not palatable to livestock, while others suggest that it is a valuable forage for animal production. While most Russian investigators conclude that it is suitable forage for camels, horses, goats and sheep, some claim that it is not preferred by cattle (Balyan 1972). Scientists in Kazakhstan and Uzbekistan acknowledged differences in palatability between accessions and ecotypes (Waldron et al. 2001b, Waldron et al. 2005). Forage kochia has been an important plant in the Karakul sheep industry, and researchers are working on improving kochia's palatability for sheep in Uzbekistan (Waldron et al. 2005).

The first paper describing nutritional qualities of forage kochia in the United States was written by Davis in 1979. He compared the chemical composition of winterfat [*Krascheninnikovia lanata* (Pursh) A.D.J. Meeuse & Smit], Iranian saltbush (*Atriplex verrucifera* Bieb.) and fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] with 13 accessions of forage kochia. Crude protein content of forage kochia was found to be comparable to the other species in the summer. It declined in crude protein from 14.7% in August to 8.9% in March. Crude fiber levels were much higher in forage kochia in March than in the other shrubs. Secondary compounds, such as tannins and oxalates, were found only at low levels and warranted little concern. Davis also reported that kochia may be a good source of vitamin A for livestock on winter ranges.

Welch and Davis analyzed the *in vitro* digestibility of forage kochia in 1984. The upper stems had higher *in vitro* digestibility (32.2%) than the lower stems (26.3%). Overall, forage kochia digestibility was rather low, ranking 24th out of the 28 species selected for evaluation as potential winter forage species on western rangelands.

The following year Davis and Welch (1985) reported an experiment designed to determine winter preference and nutritive value of forage kochia to mule deer (*Odocoileus hemionus*). Thirteen collections of forage kochia were compared using four captive mule deer (one male and three females) in the preference trial. The kochia samples were presented in buckets to the deer in a cafeteria-style experiment. Immigrant was one of the top 3 accessions in preference.

There is only one study in literature (Nemati 1977) that considered livestock preference for forage kochia. The research was conducted in Iran testing sheep preference for forage kochia compared to *Artemisia herba alba* and *Atriplex canescens*. Forage kochia had higher consumption values than the other species, followed by *Atriplex canescens*.

Shrubs such as forage kochia have been shown to add vital nutrients to animals' diets on winter ranges where grass is dormant (Gade and Provenza 1986). In comparison to winterfat, forage kochia was shown to add more biomass and provide higher levels of additional crude protein to dormant crested wheatgrass pastures than did winterfat (McKell et al. 1989). In 1990, Monsen et al. observed that forage kochia was palatable to cattle during mid-summer and winter and would extend the grazing season. There were differences in preference among cows for kochia, and some differences in palatability among forage kochia plants. Forage kochia was also found to be palatable to cows in south-western Wyoming (Koch, 2002). On an area that receives 15.2 to 25.4 cm of annual precipitation, forage kochia produced 363 $kg \cdot ha^{-1}$ (800 $lbs \cdot ac^{-1}$) of dry matter compared to an adjacent grass pasture that produced only 36 $kg \cdot ha^{-1}$ (80 $lbs \cdot ac^{-1}$). The forage kochia maintained over 7.5% protein throughout the winter months having higher levels than 12 perennial grasses and three legumes.

The relationship between Immigrant forage kochia and a low-quality grass was studied by Stonecipher et al. (2004). Four fistulated steers were given mixtures of forage kochia and tall wheatgrass straw in treatments of 0% to 75% forage kochia diets in 25% increments. They found that as forage kochia increased in the steers' diet, intake and nutrient utilization also increased. In vivo DM digestibility declined as the amount of forage kochia increased, but the in situ rate of DM and NDF digestion increased as the amount of kochia increased.

In order to ascertain the economic benefits of planting forage kochia for livestock production, an experiment was conducted to compare cattle performance on Immigrant forage kochia and grass pastures with that of cattle in feedlot conditions (ZoBell et al. 2003). Cattle in the feedlot were fed *ad libitum* diets of alfalfa hay. These comparisons were made from November through January. Forage kochia, grass, and alfalfa hay's forage quality was also compared. The cattle maintained good condition on the forage kochia and grass pastures and had adequate levels of nutrients. Cattle increased in body condition score and by a rating of 0.5 and 1.2 for cattle on pastures and in the feedlot, respectively. They also gained backfat with increases of 0.11 and 0.33 for pasture and feedlot, respectively. The biggest difference between the two groups of cows were the feed cost savings of $25-$34 / AUM by grazing kochia and grass pastures as opposed to feeding hay in a feedlot.

Although most areas seeded to forage kochia are on public domain, a few ranchers have benefited from planting forage kochia on private land. Robert and Ben Adams of the Salt Wells Cattle Company in Box Elder County, Utah, planted forage kochia as a source of winter forage on land that previously supported primarily cheatgrass, bulbous bluegrass [*Poa bulbosa* (L.)], and halogeton. Since establishing the kochia, they have had marked improvements in cattle performance, including calving percentages and weaning weights (Mr. Robert Adams, personal communication). They have also been able to increase stocking rates allowing doubling of herd size because of the increased forage production on their pastures. They avoid costly hay feeding practices during most winters by allowing the cattle to graze forage kochia from September through March and into April on land that was previously considered to be marginal rangeland.

In another case, Broadbent Land and Resources use some of their kochia pastures for winter grazing by sheep. They also graze stocker cattle in the summer on other kochia pastures. Though forage kochia is not generally recommended for summer use, these cattle have made good gains throughout the season.

Utilization

Three terms often associated with animals like or dislike for forages are preference, palatability, and utilization. Provenza (2003) defines preference as “the choices an animal makes when given alternatives.” He defines palatability as “the interrelationship between a food’s flavor (recognizable features including odor, taste, and texture) and its post-ingestive effects caused by nutrients and toxins (post-ingestive feedback). This is influenced by the plants chemical characteristics, the animals nutritional state, and an animals past experience with the food. Cook and Stoddart (1953) defined utilization as “the amount of total herbage production that has been removed currently.”

There are several methods that have been used to measure preference, palatability and utilization. The method we chose was that of Rumbaugh et al. (1993) where they tested sheep utilization of globemallow (*Sphaeralcea* spp.). They compared 14 accessions of globmallow with ‘Hycrest’ crested wheatgrass [*Agropyron cristatum* (L.) Gaertn. *A.* desertorum (Fisch.) Smith] plants and ‘Spreador 2’ alfalfa. Four pastures were established using transplants with six replications in each pasture. Four plants of globemallow made up each plot. Each plot was surrounded by ‘Hycrest’ crested wheatgrass. One of the four pastures was used to accustom sheep to the experimental design and no measurements were taken on this pasture. All plants were rated for biomass by observers before grazing. After rating, a portion of the plants from each entry was harvested, dried, and weighed. A quadratic regression equation was then developed to estimate plant biomass (predicted pre-grazing dry weight) for each plant. After grazing, all remaining plants were harvested, dried and weighed. By subtracting the harvested weight from the predicted pre-grazing biomass, consumption was determined. They also used Johnston's (1988a, 1988b) method of determining utilization by visual ratings. Each plant was given a rating of livestock use by observers.

Several factors are associated with animals utilization for certain feeds including: plant proximate nutritive attributes such as crude protein, crude fiber, and digestibility (Hardison et al. 1954; Heady 1964; Coleman and Barth 1973, and Gesshe and Walton 1981). Other factors relating to the physical properties of a plant like morphological characteristics and the abundance of forage can affect herbivore selection (Rumbaugh 1993; Illius et al. 1999; Provenza 2003). Structural and physical traits such as steminess and canopy structure can affect an herbivores ability to graze as well as their intake rates (Shipley and Yanish 2001). Pubescence or glandular hairs can also affect animal preference (Burns 1978), though there is a question as to whether pubescence is necessarily negatively affected (Lenssen et al. 1989) or how the season of use affects preference for pubescent plants. Rumbaugh et al. (1993) and Illius et al. (1999) found that plant biomass was highly and positively correlated with plant utilization.

MATERIALS AND METHODS

Twenty-four entries of *Kochia prostrata* (L. Shrad.), one entry of *Krashnennikovia lanata* [(Pursh). Meeuse & Smit] (syn = *Ceratoides lanata*), one entry of *K. papposa* (syn = *Ceratoides papposa*) and 1 entry of *Medicago sativa* (L.) were compared for their relative grazing utilization during the autumns of 2002 and 2003. Forage kochia entries included three collections from an evaluation garden near Chelkar, Kazkhstan, in 1992 by Asay and Johnson (1992), one entry originating from a botanical garden in Stravropol, Russia, and maintained by the US Forest Service Shrub Laboratory in Provo, Utah (McArthur et al. 1995), and 18 entries from a 1999 Kazakhstan collection made by Waldron and Harrison of the USDA-Agricultural Research Service, Forage and Range Research Laboratory (Waldron et al. 2001b) (Table 1). Immigrant forage kochia was also included, representing the only released variety in the United States (Stevens et al. 1985). Forage kochia entries were chosen for this study based on collection or research information that suggested they represented a subset of the more promising types for livestock grazing. This information included morphological and physical characteristics such as tall stature, relatively numerous leaves, observed use as a livestock forage, and observed indications of preference by livestock in Kazakhstan.

'Hatch' winterfat, a native U.S. cultivar, and a Kazakhstan winterfat (entry 240-WF, Waldron et al. 2001b), were also included in the trial (Table 1). 'Ladak,' a commonly used dryland alfalfa variety, was included as a highly palatable standard.

Table 1. Collection and forage information for forage kochia, winterfat and alfalfa entries evaluated for cattle utilization differences in 2002 and 2003 in Box Elder County, Utah.

Entries	Species/sub-species	Country/Year of Origin	Collection/Forage Notes
forage kochia	*Kochia prostrata*		
22	*K. prostrata-grisea*	Kazakhstan-1999	salty site, densely tillered, leafy forage
35	*K. prostrata-grisea*	Kazakhstan-1999	salty site, tall, leafy, good hay type
43	*K. prostrata-grisea*	Kazakhstan-1999	salty site, large seeds and stems, few leaves
56	*K. prostrata-grisea*	Kazakhstan-1999	dwarf pasture type
59	*K. prostrata-grisea*	Kazakhstan-1999	tall red stem with leaves up stem
64	*K. prostrata-grisea*	Kazakhstan-1999	tall, leafy, and palatable
107	*K. prostrata-grisea*	Kazakhstan-1999	large, leafy, heavily grazed plants
120	*K. prostrata-virescens*	Kazakhstan-1999	fine stemmed pasture type, northern type
182b	*K. prostrata-grisea*	Kazakhstan-1999	
199	*K. prostrata-grisea*	Kazakhstan-1999	tall red stem, leaves up stem
231	*K. prostrata-grisea*	Kazakhstan-1999	tall leafy large stems
237	*K. prostrata-grisea*	Kazakhstan-1999	tall bushy red stem type, silty south slope
245	*K. prostrata-grisea*	Kazakhstan-1999	tall type in sand dunes
N52	*K. prostrata-grisea*	Kazakhstan-1999	multi-stem, intermediate leafage
N56	*K. prostrata-grisea*	Kazakhstan-1999	tolerant to trample
N59	*K. prostrata-grisea*	Kazakhstan-1999	low, high forage yield
N69	*K. prostrata-grisea*	Kazakhstan-1999	low, thin stem
N70	*K. prostrata-grisea*	Kazakhstan-1999	tall, rough stems, high seed production
N72	*K. prostrata-grisea*	Kazakhstan-1999	tall, high seed production
U20	*K. prostrata-grisea*	Russia	leafy, large plants
BC-102	*K. prostrata-grisea*	Kazakhstan-1992	leafy, large plants
BC-108	*K. prostrata-grisea*	Kazakhstan-1992	leafy, large plants
BC-118	*K. prostrata-virescens*	Uzbekistan-1992	tall yellow stem
Immigrant	*K. prostrata-virescens*	Russia-1966	intermediate ht, red stem
Alfalfa	*Medicago sativa*		
Ladak	*M. sativa*		standard, variety used on rangelands for forage
Winterfat	*Krascheninnikovia spp.*		
240-WF	*K. papposa*	Kazakhstan-1999	forage type of collected winterfat
Hatch	*K. lanata*		standard, variety of a native forage shrub

Plants were started from seeds in a sand and coconut fiber mixture (3:1 ratio) in cones in a greenhouse in December 2000. These seedlings were transplanted to the field on April 4, 2001. The study site was on rangeland owned by the Salt Wells Cattle Company in Box Elder County near Promontory, Utah, with the coordinates of N 41°42.323', W 112°37.700'. The area was fenced from other rangeland pastures. The area was disked and roto-tilled during the summer of 2000 to remove existing perennial grasses. Soils consisted of Stingal loam (coarse-silty Xerollic Camborthids). A few of the transplants died and were replaced in April 2002.

Experimental Design

Though our goal was to determine cattle preference for 24 experimental lines of forage kochia, we found it difficult to compare that many entries in a pasture setting. Therefore we used procedures established by Rumbaugh et al. (1993) to determine utilization as the primary measure.

The experiment consisted of four 0.12-hectare pastures, each with three replications of the 27 entries in a randomized complete block (RCB) design. The design of pastures and plots within pastures consisted of entries transplanted into 4-plant plots, in a 2x2 arrangement on 1-m centers (Fig. 1). Each plot was separated from adjacent plots by plants of 'Vavilov' Siberian Wheatgrass [*Agropyron fragile (Roth)* Candargy]. Vavilov was also seeded in 1.5 m buffer strips between each pasture to minimize weed encroachment. Pasture 1 was used as a conditioning pasture to accustom animals to the experimental environment, the forage entries, and to accustom human observers to

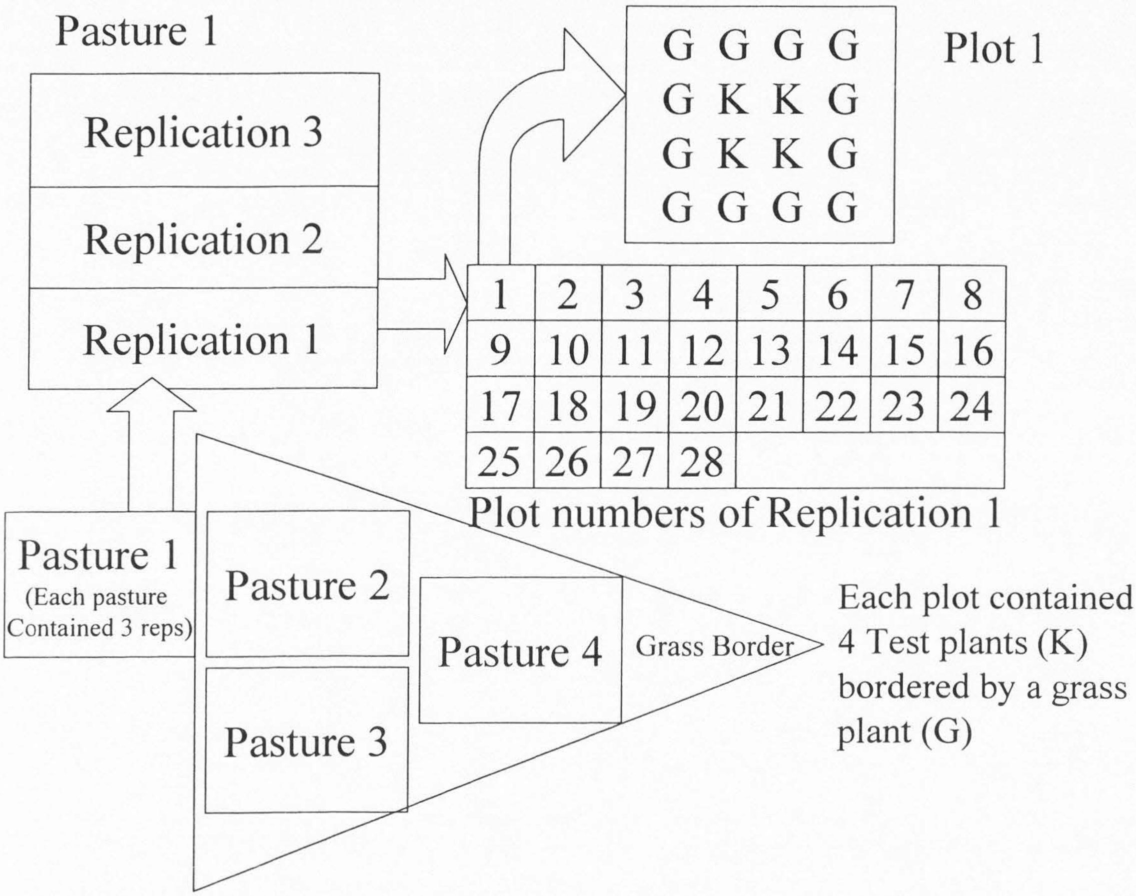

Figure 1. Description of the physical design of pastures, replications, and plots used to determine cattle utilization of forage kochia entries.

animal behavior. Data from this pasture were not used in the statistical analyses. Pastures were enclosed by electric fences with three wires.

Grazing Procedures

Four mature Angus cows, each weighing 545 to 680 kg and owned by the Salt Wells Cattle Company (Robert and Ben Adams) were used to determine relative grazing utilization of entries. The grazing study was conducted in late September of 2002 and then repeated in September 2003. The cattle had experience grazing Immigrant forage kochia during previous autumns and winters. Different cows were used each year. Cows were introduced to a new pasture on each of four subsequent days, with pasture 1 (day 1) used for conditioning the cows and observers to the experimental conditions. Cows were allowed to graze freely during two feeding bouts beginning at 7:00 am and 4:00 pm on each pasture (day). Feeding bouts lasted 3 to 4 hours. The morning and afternoon feeding bouts simulated normal grazing times for that herd. Between feeding bouts, they were moved to a holding area that contained a sparse stand of crested wheatgrass. There, they were allowed free access to water, but no shade was provided. Within a feeding bout, cows were allowed to graze until they ceased feeding for 15 to 20 minutes or until dark (in the evening bouts). Calves had been weaned from the cows a few days before the trial began in 2002, but in 2003, the cows were still nursing their calves. In the latter case, calves were separated from the cows before each feeding bout. This appeared to only influence grazing behavior in pasture 1 (the conditioning pasture). An observer was positioned on a scaffold platform 2.5 m above the ground and within easy eyesight of all pastures during feeding bouts. Cattle rapidly adapted to the platform and grazing was not noticeably influenced by the observer in pastures 2-4.

Plant Measurements

Morphological and plant stature measurements were taken on the plants in late August and early September each year, prior to the commencement of the grazing trials. Plant height, stem length, and the portion of the stems containing leaves were measured as the average of three stems. Leafiness and branch density were visually rated by an experienced rater on a scale ranging from 1 to 5, with 1 representing the least and 5 representing the highest. All plants were also rated for phenology prior to grazing on a scale of 1 = dormant, 2 = vegetative growth, 3 = flower buds, 4 = flowers open, 5 = seed formed, 6 = plant senesced, seed not shattered, and 7 = seed shattered. Phenology was rated by one experienced rater in 2002 and as the mean of 4 raters in 2003. In 2002, some plants were infested with 2-spotted spider mite (*Tetranychus urticae*) as determined by the Utah State University plant diagnostics laboratory. This caused the plants to senesce earlier than usual. A spider mite rating was therefore used to describe the percentage of spider mite damage ranging from 0 to 100%. These ratings were made by two observers and averaged.

All plants were visually rated for plant size using a 0 to 5 scale in 0.25 increments, 0 equaling no biomass, and 5 representing the most biomass. A subset of plants (1 plant from every plot) was then harvested, dried and weighed. Quadratic regression equations were computed to predict pre-grazing biomass for each entry within each year using the subset weights as the dependant variable and plant size scores as the independent variable. The pre-grazing biomass of the remaining plants (those left for grazing) was then estimated using the appropriate quadratic function for each entry and plant size scores as the independent variable. Following grazing, the residue of all plants were harvested, dried, and weighed. Post-grazing dry weights were subtracted from the estimated pre-grazing biomass to compute grams consumed and percent consumption.

Ocularly estimated utilization scores (OU) were also used to monitor behavioral changes between feeding bouts and overall consumption (Johnston 1988a). OU was visually scored by three observers using a rating of 0 to 5, 0 representing no utilization, and 5 representing 100% use. OU was scored immediately after the first feeding bout and again after the final feeding bout in each pasture.

Scan samples (Altmann 1974) were taken at regular intervals during each feeding bout in order to determine the amount of time spent in each of five behaviors: cows eating individual entries, eating grass borders, standing idle, walking, and lying. This measure was used as a method to estimate preference in comparison to utilization. Scan samples were taken by one observer every 10 minutes in 2002 and every 5 minutes in 2003. Verbal descriptions of the cattle's activities were also recorded with a video recorder during each utilization trial.

Forage Quality

Plants harvested prior to grazing (subset used to formulate regression equations) were also used in forage quality analyses. These plants were dried in forced-air ovens at

60°C and weighed. Samples of these plants were then double ground, first through a Wiley mill and then a Cyclone mill so as to pass through a 1-mm screen. Ground samples were then subjected to analysis in a near infrared reflectance spectroscope (NIRS) Model 6500 instrument (Pacific Scientific Instruments, Silver Spring, MD) for forage quality determination. NIRSystems software was used to create an equation to determine crude protein, neutral detergent fiber (NDF) (Van Soest and Robertson 1980), and i*n vitro* true digestibility (IVTD). Random sub-samples of harvested plants were also analyzed using conventional wet chemistry techniques to form a NIRS validation equation for forage kochia. Validation of the new equation was determined from a different random subset, then used for the NIRS equation and included 76 samples for NDF, 59 for CP, and 53 for IVTD. The R^2 values for validation, computed for both years were 0.94 for CP, 0.83 for NDF, and 0.87 for IVTD. The crude protein values were derived from nitrogen values (nitrogen value x 6.25) obtained from a LECO CHN-2000 Series Elemental Analyzer (LECO Corp., St. Joseph, MI). Rumen inoculum collected from ruminally canulated Holstein steers, was used to incubate forage samples for 48 hours in a batch processor (Ankom Technology Corp., Fairport, NY) to assess *in vitro* digestibility. The ANKOM fiber analyzer procedure (ANKOM Technology 1998) was used to estimate the second stage of IVTD and NDF.

Statistical Analyses

Predicted pre-grazing biomass was calculated using a quadratic regression equation. A scatterplot of pre-grazing dry weight versus ocular plant size suggested that quadratic regression was appropriate. This was verified by plots of residuals and higher R^2 values (for every entry) from quadratic versus linear regression. Individual regression equations were used for each entry. In a few cases, the R^2 from these equations was very low suggesting a poor fit and in these cases we used an overall regression equation, derived from all forage kochia entries to predict pre-grazing dry weight (Table A3).

Data were analyzed across and within years using the MIXED procedure (SAS Institute Inc. 1998). For the across year analysis, the best covariance structure between years was determined and used with the MIXED repeated option (SAS Institute Inc. 1998). Entries, years, and pastures were assumed to be fixed effects and all other variables were random, with replications nested within pastures for all data except scan samples (Table A1). Scan samples were analyzed with the MIXED procedure as described above with the addition of feeding bout as a fixed variable and the addition of cow nested within year as a random, blocking variable. Mean comparisons were made among treatments using Fisher Protected LSD tests at the $P = 0.05$ level of probability.

Correlation among traits was estimated using the CORR procedure (SAS Institute Inc. 1998). Stepwise regression procedures (SAS Institute, Inc. 1998) were performed, using biomass consumed and percent biomass consumed as dependent traits and all other measured traits as independent variables, to identify the best multiple regression model and eliminate traits that failed to maintain significance. The resulting coefficient of determination (R^2) from multiple regression is indicative of the proportion of the variation in cattle utilization (measured as grams and percent of biomass consumed) explained by forage quality and morphological traits.

RESULTS

This study verified that there are phenotypic and livestock preferential differences among forage kochia accessions. The entry effect was significant for all evaluated traits (Table 2). For most traits there were significant Entry × Year interactions. The exceptions were height, stem length, leaf portion of the stem, leafiness, and NDF (Table 2).

Pre-grazing Biomass

A difference in magnitude of biomass production and a few rank changes between 2002 and 2003 were evidenced by a significant Entry × Year interaction ($P < 0.01$). Plants produced 2.57 times more biomass in 2002 than in 2003, with an average of 337 and 131 g, respectively (Table 3). Although some entries changed rank from year to year, in general, those that were high-yielding or low-yielding in 2002 were also high-yielding or low-yielding in 2003.

There was significant variation ($P < 0.01$) in plant biomass among forage kochia entries within each year, ranging from 533 to 120 g in 2002 and from 203 to 52 g in 2003. Immigrant had the highest value for pre-grazing biomass in 2003 and was not significantly different from the top entry in 2002. Closely following Immigrant were experimental lines BC-118, N59, N70, U20, and BC-108 (Table 3). Experimental forage kochia lines 120 and 56 were previously characterized as smaller, fine-stemmed, pasture-types (Table 1) and in this trial they consistently had the lowest yields (Table 3).

Table 2. Statistical significance of factors affecting dietary utilizations for forage kochia (*Kochia prostrata*), winterfat (*Krascheninnikovia spp*), and alfalfa (*Medicago sativa*) evaluated during the fall of 2002 and 2003 in Box Elder County, Utah.

	Entry	Year	Entry × Year
Pre-grazing biomass	**	**	**
Biomass consumed	**	**	**
Percent biomass consumed	**	*	**
Mid-period OU	**	**	**
Final-period OU	**	NS	**
Height	**	**	NS
Stem length	**	**	NS
Leaf part of stem	**	**	NS
Branch density	**	**	**
Leafiness	**	NS	NS
Phenology	**	**	**
Spider mite damage	**	---	---
NDF	**	**	NS
IVTD	**	**	**
Crude protein	**	**	**

*,** Significant at the 0.05 and 0.01 levels, respectively

On average, all forage kochia entries except 120 and 56 produced significantly more biomass than winterfat and alfalfa. Immigrant, the top yielding forage kochia, produced nearly three times more biomass than did winterfat and alfalfa, respectively.

Biomass Consumed

There was extreme variation in size among forage kochia entries. This made it difficult to evaluate utilization strictly by use of the percent biomass consumed trait. One or two bites on a smaller plants resulted in significant percentages of the disappearance of plant biomass. Therefore, biomass consumed and percent biomass consumed were used

Table 3. Predicted pre-grazing biomass in grams for forage kochia, winterfat, and alfalfa entries evaluated for cattle utilization differences in 2002 and 2003 in Box Elder County, Utah. Pre-grazing biomass was estimated as dry wt (g) using the appropriate quadratic function for each entry and plant size visual scores as an independent variable.

	Pre-grazing biomass		
Entry	2002	2003	Mean
	----------------------g·plant^{-1}-------------------------		
Immigrant	504	203	353
BC-118	533	166	349
N59	479	160	319
N70	456	168	312
U20	438	183	310
BC-108	430	174	302
N72	443	155	299
237	394	176	285
BC-102	439	108	273
N69	378	125	251
43	352	144	248
N56	372	121	246
N52	372	120	246
107	336	138	237
35	338	125	231
231	315	148	231
245	325	136	230
59	285	127	206
22	296	114	205
199	286	111	198
182-b	285	109	197
64	258	133	195
56	190	95	142
Hatch	195	77	136
Ladak	153	92	122
120	120	69	95
240-WF	134	52	93
Average	337	131	234
LSD (0.05)	90	40	59

in conjunction to evaluate utilization.

The cows only ate 33% as much biomass per plant in 2003 as they did in 2002, contributing to a significant Entry × Year interaction ($P < 0.01$) (Table 4). This was consistent with overall lower biomass production in 2003 (39% of 2002 production) (Table 3), and resulted in a very high correlation ($r = 0.96$, $P < 0.01$) between pre-grazing biomass and biomass consumed. In general, highly consumed entries in 2002 were readily consumed in 2003; however, notable exceptions were forage kochia entries BC-102 and N56 and Hatch winterfat (Table 4).

Similar to pre-grazing biomass results, significant differences ($P < 0.01$) in biomass consumed were evident within each year of the evaluation. In 2002, 408 $g \cdot plant^{-1}$ were consumed of BC-118 as compared to the low of 49 $g \cdot plant^{-1}$ for entry 240-WF winterfat (Table 4). The range was not as great in 2003, but was still significant with a high of 131 $g \cdot plant^{-1}$ (Immigrant) and a low of 23 $g \cdot plant^{-1}$ (240-WF).

Ladak alfalfa was used as a highly preferred forage control. In 2003, it was readily grazed and only three of the most preferred forage kochia entries had significantly more biomass consumed, however, 12 entries had significantly higher consumption values in 2002 (Table 4). Likewise, Hatch winterfat was readily consumed in 2002, but in 2003 its consumption dropped to 35 $g \cdot plant^{-1}$ and was significantly lower than most forage kochia entries.

Percent Consumed

The percentage of biomass consumed by the cows was not consistent between

Table 4. Biomass consumed in grams for forage kochia, winterfat, and alfalfa entries evaluated for cattle utilization differences in 2002 and 2003 in Box Elder County, Utah. Biomass consumed was calculated taking the difference of the post grazing dry weight from the pre-grazing biomass.

	Biomass consumed		
Entry	2002	2003	Mean
	----------g·plant^{-1}----------		
Immigrant	390	131	260
BC-118	408	103	255
U20	303	127	215
BC-108	293	83	188
N59	304	68	186
N70	274	65	169
N72	253	73	163
237	235	80	158
BC-102	262	39	150
N56	226	39	133
N69	204	57	131
N52	224	35	130
43	187	67	127
245	157	64	111
59	149	71	110
199	155	51	103
22	131	63	97
Ladak	117	75	96
182-b	140	49	95
231	121	67	94
107	139	45	92
35	142	38	90
64	102	76	89
Hatch	137	35	86
56	89	61	75
120	50	34	42
240-WF	49	23	36
Average	194	64	129
LSD (0.05)	79	29	7

years. There were changes in rank, evidenced by a significant Entry × Year ($P < .01$) interaction (Table 2), however, four of the five entries with high percent-consumed values were high over both years.

There was a significant entry effect ($P < 0.01$) in the percentage of forage consumed among forage kochia entries within years. The range of percentages did not differ greatly between years, ranging from 76% to 35% in 2002 and 79% to 25% in 2003 (Table 5). Immigrant, BC-118 and U-20 had the highest percentage of forage consumed among forage kochia entries each year. Entry 56, a plant with a short stature, was also included among the top entries in 2003 because that year it had 66% of its biomass consumed. In 2002, it had only 46% of the biomass consumed. This increase in percent biomass consumed for entry 56 in 2003 is likely due to the effect of a few bites on a small plant. On average, the cows consumed about 50% of each plant (Table 5).

Ladak alfalfa was among the most consumed entries and had the highest value for percent consumed in 2003 (79%) (Table 5). Hatch winterfat was ranked sixth in 2002 (62%), but the cows consumed only 46% of the biomass in 2003. Entry 240-WF had among the lowest percent biomass consumed values of all entries.

Feeding Behavior – Ocular Utilization and Scan Samples

OU scores were not completely consistent with some entries changing in rank over the two years that contributed to a Entry × Year interaction for mid-period OU ($P < 0.01$) and final-period OU ($P < 0.01$) (Table 2). In general, scores became more uniform in 2003 with high ranked entries receiving a lower score, and lower ranked entries

Table 5. Percent biomass consumed for forage kochia, winterfat and alfalfa entries evaluated for cattle utilization differences in 2002 and 2003 in Box Elder County, Utah. Percent biomass consumed was calculated by dividing biomass consumed by pre-grazing biomass.

	Percent biomass consumed		
Entry	2002	2003	Mean
		%	
Ladak	74	79	77
Immigrant	76	65	71
U20	69	70	69
BC-118	76	63	69
BC-108	65	48	57
56	46	66	56
Hatch	62	46	54
237	57	48	52
59	51	53	52
199	54	48	51
N69	54	45	50
64	41	58	49
BC-102	59	38	49
22	41	54	48
N59	60	35	48
245	45	49	47
N72	54	39	47
120	42	51	47
182-b	47	43	45
N56	55	33	44
43	48	39	44
N70	53	33	43
231	38	46	42
N52	58	25	41
107	42	32	37
240-WF	35	38	36
35	41	29	35
Average	53	47	50
LSD (0.05)	11	13	9

receiving a higher score. However, the top ranked entries remained relatively high both years for both traits.

There was a significant entry effect among forage kochia entries for mid-period ($P < 0.01$) and final-period ($P < 0.01$) OU. Ratings for mid-period OU ranged from a score of 3.4 to a score of 0.3 in 2002 and a score of 2.9 to a score of 0.9 in 2003 (Table 6). Final-period OU ranged from a score of 3.9 to a score of 0.8 in 2002 and a score of 3.5 to a score of 1.7 in 2003 (Table 6). Immigrant and BC-118 had among the highest ratings for mid-and final-period OU.

Ladak alfalfa did not differ from Immigrant statistically with high OU ratings for both mid-period and final-period OU. The OU of Hatch was dramatically different between years. In 2002, Hatch had a mid-period OU rating of 2.3, and a mid-period OU rating of 0.0 in 2003 (Table 6). Final-period OU ratings for 2002 and 2003 were 2.7 and 0.7, respectively. Entry 240-WF had consistently low scores for mid-and final-period OU ratings (Table 6).

The rank order of entries was consistent from the mid-period OU to the final-period OU in both years. The data suggest that cattle ate preferred entries consistently from the first feeding bout to the second. I observed that the cows would sample all of the forage kochia entries eating the most preferred parts first (the portion of the branch containing seeds). After the preferred parts were consumed, they would return and eat more of the plants upon subsequent passes resulting in higher final-period OU scores.

The cattle spent significantly more time grazing the grass strips bordering the plots and pastures than they did eating any single entry. They were observed eating grass

Table 6. Ocular Utilization (OU) ratings for forage kochia, winterfat, and alfalfa entries evaluated for cattle utilization differences in 2002 and 2003 in Box Elder County, Utah. OU ratings taken between feeding bouts (mid) and after second feeding bout (final). Ratings were from 0 to 5, with 0 representing no use and 5 representing use of all available forage.

	Mid-period OU			Final-period OU		
Entry	2002	2003	Mean	2002	2003	Mean
Immigrant	3.4	2.9	3.1	3.9	3.5	3.7
Ladak	3.4	2.2	2.8	4.1	3.3	3.7
BC-118	3.0	2.1	2.6	3.9	3.0	3.4
BC-108	2.5	1.6	2.0	3.7	2.5	3.1
BC-102	2.4	1.9	2.1	3.1	3.0	3.1
U20	2.8	1.6	2.2	3.6	2.4	3.0
N69	2.2	1.9	2.0	2.7	2.9	2.8
N59	2.3	1.7	2.0	2.9	2.5	2.7
N70	2.2	1.2	1.7	2.8	2.3	2.6
N52	1.5	1.8	1.6	2.5	2.5	2.5
199	1.8	1.2	1.5	2.6	2.4	2.5
237	1.6	1.6	1.6	2.1	2.7	2.4
N72	2.0	1.2	1.6	2.5	2.2	2.4
N56	1.8	1.3	1.5	2.3	2.4	2.3
59	1.5	1.5	1.5	1.7	2.8	2.2
43	1.5	1.4	1.4	1.8	2.1	2.0
56	1.4	1.2	1.3	1.6	2.3	1.9
22	0.8	1.0	0.9	1.2	2.3	1.7
245	1.5	0.9	1.2	1.8	1.7	1.7
Hatch	2.3	0.0	1.2	2.7	0.7	1.7
35	0.6	1.6	1.1	0.9	2.5	1.7
120	0.8	0.9	0.9	1.1	2.2	1.7
107	0.9	1.4	1.1	1.1	2.2	1.6
182-b	1.0	1.2	1.1	1.2	2.0	1.6
64	0.7	0.9	0.8	1.0	1.9	1.4
231	0.3	1.0	0.6	0.8	1.9	1.4
240-WF	0.1	0.2	0.2	0.2	0.5	0.4
Average	1.7	1.4	1.5	2.2	2.3	2.3
LSD (0.05)	0.6	0.6	0.4	0.6	0.6	0.5

31.6% of the time in 2002 and 56.2% in 2003 (Table 7). This compares to eating experimental entries 40% of the time in 2002 and 17 % in 2003. They spent 22.5% and 23.6% of the time standing in 2002 and 2003, respectively; presumably time spent ruminating. In 2002, BC-118 was observed being grazed more than any other forage kochia entry (3.5%) (Table 7), but was not significantly different than 5 other entries. In 2003, there were no significant differences between entries. Entry 240-WF was not observed being grazed in either year.

Forage Quality

Crude protein levels varied significantly both by entry ($P < 0.01$) and by year ($P < 0.01$). Crude protein values ranged from 115 $g \cdot kg^{-1}$ (Immigrant) to 56 $g \cdot kg^{-1}$ (entry 231) in 2002 (Table 8). In 2003 they ranged from 135 $g \cdot kg^{-1}$ (entry 59) to 68 $g \cdot kg^{-1}$ (Ladak). In 2003, every entry increased in crude protein except Immigrant and Ladak. Immigrant's protein levels remained fairly constant between the two years, but Ladak's crude protein levels dropped from 82 $g \cdot kg^{-1}$ to 68 $g \cdot kg^{-1}$ (Table 8). Surprisingly, Ladak alfalfa had the lowest crude protein value in 2003, though alfalfa is generally considered to be high in protein.

Average NDF values computed for each entry over the two years ranged from 497 $g \cdot kg^{-1}$ for entry Immigrant to 586 $g \cdot kg^{-1}$ for entry 35 (Table 8). Ladak alfalfa, the two winterfat species, BC-118 and U-20 were entries that did not differ from Immigrant in significance. NDF values were similar between 2002 and 2003, resulting in no Entry × Year interaction.

Table 7. Percentage of time spent in a foraging behavior or eating forage kochia, winterfat, and alfalfa entries in 2002 and 2003 in Box Elder County, Utah.

Entry	2002	2003	Mean
	------------------	%	------------------
Grass	31.6	56.2	43.9
Standing	22.5	23.6	23.1
Lying	4.8	0.0	2.4
Walking	0.0	1.4	0.7
Forage Kochia	40.0	17.5	28.8
BC-118	3.5	1.2	2.3
BC-108	3.3	0.7	2.0
BC-102	2.6	0.7	1.7
N59	1.9	1.3	1.6
Immigrant	1.8	1.4	1.6
107	2.3	0.8	1.6
N52	2.3	0.7	1.5
N69	2.2	0.8	1.7
N72	2.5	0.4	1.4
U20	2.2	0.6	1.4
N70	1.4	1.1	1.3
N56	1.4	1.1	1.2
237	1.0	1.2	1.1
U11	1.6	0.6	1.1
199	1.9	0.3	1.1
182-b	0.6	1.0	0.8
56	1.4	0.2	0.8
43	1.3	0.1	0.7
59	0.9	0.5	0.7
64	1.0	0.2	0.6
245	0.0	1.0	0.5
22	0.6	0.4	0.5
231	0.7	0.1	0.5
35	0.7	0.2	0.4
120	0.0	0.5	0.2
Ladak alfalfa	0.9	0.2	0.5
Winterfat	0.1	0.2	0.2
Hatch	0.2	0.4	0.3
240-WF	0.0	0.0	0.0
LSD (0.05)	2.6	1.8	1.5

Table 8. Forage quality analysis (crude protein, NDF, and IVTD in g·kg⁻¹) for forage kochia, winterfat, and alfalfa entries evaluated for cattle utilization differences in 2002 and 2003 in Box Elder County, Utah.

	Crude protein			Neutral detergent fiber			*In vitro* true digestibility		
Entry	2002	2003	Mean	2002	2003	Mean	2002	2003	Mean
	$g \cdot kg^{-1}$								
59	109	135	122	534	489	512	562	635	599
BC-108	108	124	116	521	489	611	594	629	611
Immigrant	115	111	113	499	494	497	627	618	622
BC-118	98	125	112	545	494	520	549	609	579
N59	108	115	111	546	498	522	594	626	610
U20	101	121	111	539	493	516	586	628	607
120	102	120	111	544	516	530	558	607	582
Hatch	105	117	110	512	480	498	666	682	668
N69	98	118	108	547	499	523	549	618	584
56	82	130	106	579	490	534	512	642	577
BC-102	86	122	103	561	488	526	549	636	590
N56	89	117	103	554	494	524	548	641	595
N52	90	113	102	558	506	532	540	620	581
107	83	119	100	562	590	527	532	645	586
237	86	110	98	567	517	542	521	601	561
240-WF	74	122	98	544	482	517	459	667	562
245	86	103	94	570	515	543	519	603	561
22	69	118	93	598	492	546	479	638	556
199	69	105	87	592	521	557	498	609	553
N70	80	91	86	570	526	547	533	589	563
43	70	102	86	608	534	571	473	578	526
N72	73	94	83	593	529	561	516	577	547
64	63	103	83	601	531	567	482	583	534
182-b	68	96	82	611	547	579	460	551	506
231	56	106	81	625	528	576	448	587	518
Ladak	82	68	76	517	528	521	572	558	567
35	58	86	72	620	552	586	457	568	513
Average	85	111	98	564	508	536	533	613	572
LSD (0.05)	49	34	33	63	48	46	23	24	19

Every entry but Immigrant and Ladak increased in IVTD from 2002 to 2003. In 2002 the values ranged from 666 $g \cdot kg^{-1}$ (Hatch) to 448 $g \cdot kg^{-1}$ (entry 231) (Table 8). In 2003, values ranged from 682 $g \cdot kg^{-1}$ (Hatch) to 550 $g \cdot kg^{-1}$ (182 b). Hatch was not significantly different from seven other entries. Hatch did not differ from Immigrant in 2002, but was significantly higher in IVTD than Immigrant in 2003.

Morphological Characteristics

Values for plant height, stem length and leaf portion of the stem were very much inter-related. There were significant differences among entries for average height, stem length and the leaf portion of the stem, and leafiness (P<0.01), but no Entry × Year interactions for these four traits (Table 2). Branch density also varied significantly among entries (P <0.01), but a change in ratings between years contributed to a Entry × Year (P < 0.01) interaction for branch density.

Plant height and stem length

Three entries that had consistently high values for height and stem length were U-20, N72, and N70. U-20 was the tallest entry having a mean score of 54.0 cm but was not significantly different than N72 in height (Table 9). N72 had the longest stems with an average value of 65.9 and was not different than U20, N70, N59, and BC-118 (Table 9). Entries U-20, N72, and N70 were collected originally, and selected for this study, because of their tall stature (Table 1). Entry 120 had the lowest values for height and stem length with values of 22.5 cm and 35.1 cm, respectively (Table 9). Immigrant, consistently high in other traits relating to utilization, had values among the lowest in

Table 9. Plant morphological characteristics (height, stem length, and leaf portion of stem) measured in cm for forage kochia, winterfat, and alfalfa entries evaluated for cattle utilization differences in 2002 and 2003 in Box Elder County, Utah.

	Height			Stem length			Leaf portion of stem		
Entry	2002	2003	Mean	2002	2003	Mean	2002	2003	Mean
	----------	----------	----------	----------	cm	----------	----------	----------	----------
U20	56	52	54	69	58	64	31	29	30
N72	51	53	52	72	59	66	32	30	31
N70	49	50	49	70	57	63	32	29	31
N59	52	47	49	69	53	61	31	27	29
BC-118	52	45	48	69	50	59	30	23	26
BC-108	49	47	48	68	53	61	31	26	28
N56	48	48	48	70	54	62	28	26	27
182-b	50	44	47	69	48	59	26	21	23
BC-102	50	44	47	67	49	58	29	24	27
N69	50	44	47	70	51	60	33	25	29
43	49	44	46	69	52	61	28	23	26
64	46	46	46	73	54	63	30	24	27
35	48	44	46	69	50	60	24	22	23
245	45	46	46	68	52	60	28	23	25
N52	47	43	45	67	49	58	28	23	25
107	47	43	45	68	49	58	25	22	23
237	47	42	45	67	48	57	25	23	24
22	46	43	44	67	49	58	27	23	25
231	44	42	43	66	47	57	26	20	23
Immigrant	41	36	38	55	40	48	25	21	23
59	38	36	37	61	42	52	23	18	21
56	38	36	37	55	42	49	17	17	17
199	40	33	37	62	41	51	27	18	22
120	23	22	23	43	27	35	13	9	11
Mean	46	43	45	66	49	57	27	23	25
LSD (0.05)	6	5	4	5	6	5	4	4	3

height and stem length.

Portion of stem containing leaves and leafiness

Entry N70 had the highest value for the portion of the stem containing leaves with a mean value of 30.9 cm and was not different from U-20, N72, or three other forage kochia entries (Table 9). Entry 120 had the lowest value of 11.1 cm of stem that contained leaves. Leafiness values averaged for each entry over the two years ranged from a score of 3.7 (N70) to a score of 2.6 (120) (Table 9). Entry N70 did not differ from Immigrant or six other entries.

Branch density

The other evaluated morphological characteristic was branch density. Branch density values calculated for each entry ranged from a score of 3.9 (Entry 237) to a score of 2.9 (Entry 120) out of a possible 5 in 2002 (Table 10). In 2003, the values ranged from a score of 4.3 (Immigrant) to a score of 2.3 (entry 56) (Table 10). Immigrant and entry N70 had high values for branch density both years. All entries received a lower branch density rating in 2003, but entries Immigrant, N70, and 120.

Phenology and Spider Mite Damage

Forage kochia plants were infected with the 2-spotted spider mite only in 2002, causing many plants to senesce prematurely. Not all plants were infected uniformly and the effects of the spider mites were more pronounced on some entries than others. The spider mite infection affected plant phenology which contributed to a significant Entry × Year interaction ($P < 0.01$) (Table 2). The forage kochia entry that was most affected by

Table 10. Plant morphological ratings (branch density and leafiness) for forage kochia, winterfat, and alfalfa entries in 2002 and 2003 in Box Elder County, Utah. Ratings were based on a scale of 1 to 5, 1 representing least and 5 representing most.

	Branch density			Leafiness		
Entry	2002	2003	Mean	2002	2003	Mean
	---------------------------scores---------------------------					
Immigrant	3.9	4.3	4.1	3.6	3.7	3.7
237	3.9	3.6	3.8	3.3	3.0	3.2
N70	3.7	3.8	3.8	3.7	3.7	3.7
N59	3.8	3.4	3.6	3.7	3.7	3.7
N72	3.7	3.5	3.6	3.4	3.6	3.5
BC-118	3.6	3.5	3.5	3.1	3.2	3.2
BC-108	3.8	3.3	3.5	3.6	3.3	3.4
35	3.6	3.2	3.4	3.4	3.0	3.2
U20	3.7	3.1	3.4	3.5	3.4	3.4
N56	3.4	3.3	3.4	3.3	3.4	3.4
N52	3.5	3.2	3.4	3.4	3.6	3.5
BC-102	3.7	3.0	3.4	3.4	3.3	3.4
N69	3.5	3.1	3.3	3.4	3.4	3.4
107	3.4	3.1	3.2	3.2	3.4	3.3
231	3.4	3.0	3.2	3.0	2.9	3.0
43	3.5	2.9	3.2	3.2	3.0	3.1
245	3.3	3.1	3.2	3.3	2.9	3.1
22	3.4	2.9	3.1	2.9	3.1	3.0
59	3.4	2.7	3.1	2.7	2.9	2.8
182-b	3.1	2.9	3.0	2.7	2.7	2.7
120	2.9	3.0	2.9	2.7	2.6	2.6
199	3.2	2.5	2.9	3.2	3.0	3.1
56	3.4	2.3	2.8	2.8	2.6	2.7
64	2.9	2.7	2.8	3.0	2.8	2.9
Average	3.4	3.0	3.2	3.1	3.1	3.1
LSD (0.05)	0.3	0.5	0.3	0.4	0.5	0.3

2-spotted spider mites in 2002 was 182-b (63% of the plant) while entry 107 (32 % of the plant) was affected least (Table 11). Ten entries were not significantly different from 107. Ladak and Hatch winterfat were virtually unaffected by the spider mites with scores of 17% and 13%, respectively.

There was a significant entry effect ($P < 0.01$) for phenology in 2002 and 2003. Forage kochia entries differed in their levels of maturation. On a scale of 1 to 7, the entry with the highest (most mature) average phenology rating was 231 (score = 6.7) in 2002 (Table 11). This indicates that plants of entry 231 were senescing and shattering seed. Immigrant was the least mature of the forage kochia entries with a phenology value of 5.0 and it did not differ significantly from BC-118 and U-20. These entries had seed that had formed, but the plants had not senesced. In 2003, all forage kochia plants received lower phenology scores and were considerably more uniform. Entry 182-b was the most advanced entry with a score of 5.4, and Immigrant was the least with a score of 4.9. Immigrant did not differ from 7 other entries in 2003, including BC-118 and U-20. We have observed that Immigrant and BC-118, both taller types of the subspecies *virescens* (Table 1), mature later than the entries that belong to the subspecies, *grisea* or smaller *virescens* types.

Ladak alfalfa was the only entry to get a higher rating in 2003 (5.6) than 2002 (6). Hatch winterfat had scores of 5.0 both years, meaning that the seed had formed, but the plant had not senesced.

Associations among Traits

Overall, correlation coefficients ranged from not significantly different from zero

Table 11. Mean phenological development scores and percent spotted spider mite damage on forage kochia, winterfat, and alfalfa entries evaluated for cattle utilization in 2002 and 2003 in Box Elder County, Utah.

	Phenology[1] scores			Spotted spider mite damage[2]
Entry	2002	2003	Mean	2002
				---%----
240-WF	6.7	5.4	6.0	43
35	6.7	5.2	6.0	53
231	6.7	5.2	6.0	52
182-b	6.4	5.4	5.9	63
22	6.6	5.1	5.8	43
107	6.5	5.2	5.8	33
120	6.3	5.3	5.8	35
64	6.5	5.1	5.8	56
Ladak	5.6	6.0	5.8	17
56	6.1	5.1	5.6	50
199	6.1	5.1	5.6	43
N72	6.0	5.2	5.6	46
43	6.0	5.1	5.6	63
245	6.0	5.1	5.6	38
N52	5.9	5.1	5.5	42
N56	5.7	5.1	5.4	50
59	5.7	5.0	5.4	53
BC-102	5.7	5.0	5.4	48
237	5.6	5.1	5.3	50
N59	5.6	5.0	5.3	35
N69	5.5	5.0	5.3	38
N70	5.5	5.0	5.2	36
BC-108	5.4	5.0	5.2	36
BC-118	5.3	5.1	5.2	54
U20	5.1	5.0	5.1	55
Hatch	5.0	5.1	5.0	13
Immigrant	5.0	4.9	5.0	47
Average	5.9	5.2	5.5	44
LSD(0.05)	0.4	0.2	0.2	13

Phenology: 1=dormant, 2=vegetative growth, 3=flower buds, 4=flowers open, 5=seed formed, 6=plant senesced, seed not shattered, 7=seed shattered

[2]% Spider mite damage was determined by estimating the percentage of leaves that were clorotic due to spider mites

to a high of -0.98 between IVTD and NDF (Table 12). Many of these associations were expected, especially those among forage quality traits and among related morphological traits. Stem length and branch density were highly correlated with pre-grazing biomass, and in this study were main contributors to overall forage yield potential. Of most interest were the correlations with and among the utilization indicators (e.g. biomass consumed, percent consumed, and mid and final OU ratings). Pre-grazing biomass had a nearly perfect correlation with biomass consumed ($r = 0.96$, $P < 0.0001$), but a much lower association with percent consumed ($r = 0.52$, $P < 0.0001$). Morphological traits associated with consumption included stem length ($r = 0.67$, $P < 0.0001$) and branch density ($r = 0.63$, $P < 0.0001$), which as indicated above, were correlated to overall biomass production. Phenology, while highly negatively correlated to final OU ($r = -0.69$, $P < 0.0001$), was not associated with the biomass consumed or the percent biomass consumed, suggesting that visual scores of OU were not exact duplicates of measured consumption. Forage quality traits had very little association with consumption or percent consumption and were only moderately correlated with visual estimates of OU (Table 12). Although protein specifically has been associated with utilization in other studies (Heady 1964; Coleman and Barth 1973; Gesshe and Walton 1981), it was not correlated to either biomass or percent consumed.

Mid-OU rating was moderately associated with biomass consumed ($r = 0.68$, $P < 0.0001$) and percent consumed ($r = 0.61$, $P < 0.0001$), indicating that in some cases visual evaluation may be used to determine utilization. Mid-and final OU were highly correlated ($r = 0.90$, $P < 0.0001$) suggesting that utilization did not change between feeding bouts.

Table 12. Correlation coefficients significant at $P \leq 0.05$ for all evaluated traits for forage kochia, winterfat, and alfalfa entries evaluated for cattle preference differences in 2002 and 2003 in Box Elder County, Utah.

	Biomass consumed	Percent biomass consumed	Mid-period utilization	Final period utilization	Height	Stem length	Leaf portion	Branch density	Leafiness	Phenology	NDF	IVTD	Crude protein
Pre-grazing dry matter	0.96	0.52	0.52	---	0.52	0.81	0.66	0.67	0.42	0.39	0.5	-0.48	-0.46
Biomass consumed		0.7	0.68	0.46	0.46	0.67	0.59	0.63	0.41	---	0.3	---	---
Percent consumed			0.61	0.56	---	---	---	---	---	---	---	---	---
Mid period utilization				0.9	---	---	0.38	0.55	0.55	-0.43	-0.3	0.31	0.3
Final period utilization					---	---	---	0.35	0.5	-0.69	-0.55	0.57	0.52
Height						0.76	0.89	0.43	0.54	---	---	---	-0.31
Stem length							0.83	0.48	0.36	0.57	0.68	-0.67	-0.68
Leaf portion of stem								0.53	0.67	---	0..3	---	-0.36
Branch Density									0.67	---	---	---	---
Leafiness										---	---	---	---
Phenology											0.89	-0.89	-0.83
NDF												-0.98	-0.96
IVTD													0.95

Stepwise regression was used to determine if a combination of morphological and forage quality traits could be used to predict palatability. The best multiple regression model for biomass consumed was highly predictive ($R^2 = 0.98$) and consisted of pre-grazing biomass (partial $R^2 = 0.918$, $P \leq 0.0001$), phenology (partial $R^2 = 0.046$, $P \leq 0.0001$), leaf part of the stem (partial $R^2 = 0.012$, $P \leq 0.0001$), and leafiness (partial $R^2 = 0.003$, $P = 0.02$). The large effect of pre-grazing biomass was consistent with the high correlation between biomass consumed and pre-grazing biomass. The regression model for percent biomass consumed was less predictive ($R^2 = 0.64$), but would still be considered substantial. It consisted of pre-grazing biomass (partial $R^2 = 0.272$, $P \leq 0.0001$), protein (partial $R^2 = 0.253$, $P \leq 0.0001$), leafiness (partial $R^2 = 0.093$, $P = 0.002$), and phenology (partial $R^2 = 0.026$, $P = 0.086$). The presence of traits measuring biomass production, leafiness, and phenology in both models suggests that highly productive, leafy, less mature plants of forage kochia are preferred by cattle.

DISCUSSION

All forage kochia accessions had some level of grazing use by the cows in this study. There were, however, differences in utilization among accessions. Several accessions including Immigrant, BC-118, and U-20 had high values for most traits analyzed. Overall, these entries had high values for traits relating to utilization for both years despite different phenological stages and plant size differences between years.

The differences in precipitation between 2002 and 2003 caused differences in measurements among traits. From 1999 to 2003, the Intermountain West was in a severe drought. The Thiokol weather station, 16 km from the cattle utilization pastures, recorded measurements of 288 mm and 182 mm of precipitation in years 2002 and 2003, respectively. This compares to the 30-year normal of 304 mm of annual precipitation. Though forage kochia is very drought tolerant, the sustained drought had a pronounced effect of reducing growth of plants in 2003, exhibited by the Entry × Year interaction for pre-grazing biomass.

The drought also impacted forage quality with much higher values in 2003 than in 2002. One explanation for these differences in forage quality is that the drought arrested growth at a time when crude protein and digestibility were at relatively high levels and fiber was at relatively low levels. The lack of advancing maturity in 2003 essentially caused the forage to cure on the stem. Additionally, the fiber to cell soluble ratio would have been much lower in 2003. The lack of biomass in 2003 would have increased the protein to fiber ratio, as evidenced by increases in crude protein and decreases in NDF values. Livestockmen have observed for many years that though rangelands produce less available biomass, they can wean heavier calves on some dry years than wet years because of the higher quality of forage.

Another difference between years was the damage caused by 2-spotted spider mites in 2002. Two-spotted spider infestations increase on warm dry years like the summer of 2002. They attack the underside of leaves, causing premature senescence. This contributed to the differences in phenology scores from 2002 to 2003. In 2003, spider mite damage was not apparent and phenology scores were uniform and less advanced than in 2002 among forage kochia entries. This infection of spider mites in 2002 may have also affected the percent biomass consumed values. Rumbaugh et al. (1993) found that utilization was closely related to percent dry weight. Some forage kochia plants were phenologically advanced because of spider mite damage and undoubtedly had a higher percent dry weight than those unaffected by spider mites. However, top ranked entries had high values for percent biomass consumed with and without the presence of spider mites. Forage quality attributes may have been affected by the early senescence of many of the forage kochia entries in 2002. The seed and leaves have much higher forage quality values than the stems (Waldron et al. unpublished data). The lack of seed and leaves on the forage kochia on many entries in 2002 would have caused lower crude protein and higher fiber values that year.

The most important attribute in relation to both biomass and percent biomass consumed was pre-grazing biomass. Rumbaugh et al. (1993) found that pre-grazing plant dry weight and percent dry weight had the strongest relationship to sheep utilization for globemallow. Illius et al. (1999) found similar results where forage intake by goats was based on utilization for grass species with the highest biomass density. Ruminants tend to maximize their intake rate by grazing plants that provide the most amounts of forage per bite (Chacon et al. 1978). Theoretically, this could be accomplished by grazing large plants or dense plant stands.

One could argue that the high correlation between pre-grazing biomass and consumption may have been influenced by Immigrant, the only entry the cows had prior experience with, also being the highest producer. Prior experience has been proven to affect animal preferences for certain kinds of plants (Allison 1985; Provenza 2003; Provenza et al. 2003). This might explain their high use of Immigrant, especially early in the grazing part of the study. However, other entries such as BC-118 and U20 also had high values for pre-grazing dry weight and utilization. BC-118 and Immigrant are subspecies *virescens,* characterized by less pubescence. Entry U20 is subspecies *grisea* with moderate to heavy pubescence which did not appear to be a factor in this study. Pubescence can affect animal preference (Burns 1978) though there is some disputation as to the nature and degree of this affect. In some cases the presence of glandular hairs increased the selection of certain plants (Lenssen et al. 1989) and in other cases it has contributed to a negative affect on utilization (Rumbaugh et al. 1993). Furthermore, entry 120 is subspecies *virescens,* like Immigrant, but it had the lowest value for pre-grazing dry weight and the lowest preference values. In addition, though we did not test directly, I observed the cattle to apparently be more selective on the fourth day of grazing than in the first. The cattle consumed all entries to some degree on the first day, with generally uniform use of all entries. By the fourth day, the cows became more selective leaving more material on many entries that were apparently less preferred. Immigrant, BC-118, and U-20 were among these entries that were heavily used the fourth day and also had the most biomass. These results confirm the important association between pre-grazing biomass and cattle utilization.

A factor often associated with utilization, but not evaluated in this study might be the presence of secondary chemical compounds. The only research on potential toxins in forage kochia is that of Davis (1979). He found that both tannins and oxalates were below critical levels for many different accessions of forage kochia. However, I personally observed differences in the taste of different accessions, suggesting there may be some differences in secondary chemical composition. Though not critically high, utilization could have been affected by differing amounts of secondary chemical compounds among plants.

There are opposing views as to the effects of forage quality on the selection of forages. Hardison et al. (1954), Coleman and Barth (1973), and Gesshe and Walton (1981) showed that crude protein content and digestibility were positively associated with forage selection while crude fiber was negatively related. Although not dealing directly with utilization, Van Soest and Robertson (1980) found that digestibility and fiber-content are poor predictors of intake. We found no forage quality attribute to be highly correlated with utilization. Most entries met or exceeded minimum maintenance requirements for crude protein at a time when nutrient requirements are at the lowest for a spring-calving beef cow. This probably explains the low correlation with utilization.

Crude protein, however, ranked second, next to pre-grazing biomass, in importance for predicting the percentage of forage kochia consumed in a multiple regression equation. Evidence that factors other than forage quality influenced utilization were the observed high values for NDF, IVTD, and crude protein for the winterfat entries, yet they were less preferred than many of the forage kochia entries.

Stem length and branch density were positively associated with utilization. These associations may have been indirect artifacts due to stem length's high correlation with pre-grazing biomass. Branch density's correlation with utilization also contributes to the notion that cattle preferred entries that provided the most biomass per area.

Of all entries measured in this experiment, Immigrant consistently had high values in all traits except plant height, stem length, and length of the leaf portion of the stem. Immigrant was released as a cultivar partly because it was observed to be palatable to livestock and wildlife (Stevens et al. 1985). Although it had the highest value for pre-grazing biomass, it was considerably shorter than many other entries in the experiment. It did, however, have the highest branch density. Other entries that were not significantly different in pre-grazing biomass, and that were similar in utilization, are entries BC-118 and U-20.

Ladak alfalfa was included in the experiment as a standard because of its reputation for high palatability. However, in the environment and season where and when this study was conducted, it was similar in utilization to kochia entries Immigrant, BC-118 and U-20. Moreover, it provided significantly less biomass than these forage kochia entries.

Two winterfat entries were included because of their reputation as a palatable shrubs on arid rangelands. Hatch, representing native winterfat, is highly regarded as a fall and winter forage on western rangelands. Although it was highly ranked in forage quality attributes, it was not shown to be as utilized as Immigrant, BC-118, or U-20. It was not preferred specifically, in 2003. Although Entry 240-WF was selected as a palatable winterfat accession from Kazakhstan, it was ignored by the cattle, and had low values for all traits.

Although biomass consumed and percent consumed were the primary measures used to determine utilization, ocular utilization (OU) scores were also valuable. Rating plants for OU was a relatively quick and easy way to assess preference. Johnston (1988a, 1988b), Buckner and Burrus (1961), and Burns et al. (1988) found that visually evaluating utilization was a suitable way to access preference for forage species. We found that OU ratings were moderately correlated to utilization and accurately identified the most and least preferred entries. The high correlation between mid-period and final-period OU suggests that cattle did not change utilization from one feeding bout to the other.

Scan samples were another valuable measurement. Scan samples are useful for nominal data (mutually exclusive behaviors) or to describe ordinal behavior (behaviors ordered along a uni-dimensional scale) that is easily recognizable (Lehner 1987). We intended to use scan samples to evaluate cattle's preferences for the different experimental lines of forage kochia and to relate it to utilization. However, we did not find statistical differences among entries, but the results from the scan samples showed the differences in time spent in behaviors such as standing, walking, and lying. Scan sampling also substantiated the considerable amount of time the cows spent eating the grass borders as compared to the forage kochia entries. The cows spent more time eating the grass than any single entry of forage kochia. The difference in the amount of time spent eating grass between years (31.6% in 2002 and 56.2% in 2003) can be explained by the mowing of the grass in 2002. This would have provided less biomass available for consumption. Another explanation may be increased crude protein of forage kochia in 2003. The higher forage quality might possibly have provided enough crude protein to supplement the lower quality, dormant grasses.

Scientists have recognized that animals perform better when they can mix their diets. Gade and Provenza (1986) and McKell et al. (1989) found that shrubs increased overall forage quality on grass pastures used for winter grazing. Gade and Provenza (1986) also found that the combination of shrubs and grasses increased forage intake rates, especially after snow accumulations, compared to stands of pure crested wheatgrass. Stonecipher et al. (2004) found that intake rates, digestibility, and nutrient utilization increased as the amount of forage kochia increased in a forage kochia and wheatgrass straw ration as the amount of forage kochia increased. Likewise, livestock producers have suggested that cattle perform better and are less likely to encounter health problems when forage kochia is grown with a mixture of cool season grasses (Bob Adams, personal communication). Cattle in this study were observed spending 44 percent of their time grazing Siberian wheatgrass on the perimeter of the trial plots. Herbivores eat a variety of foods because of a plants flavor, nutrients and toxins

(Provenza 2003). As a ruminant grazes it can reach satiety with a particular flavor, nutrient and/or toxin, especially if it has access to only one kind of forage. As it reaches satiety, intake drops. If multiple kinds of plants are available, an animal can chose another type of plant with different flavor, nutrients and toxins, thus increasing intake. This suggests that it is important to plant complementary, palatable species adapted to the same climatic conditions with forage kochia.

SUMMARY AND CONCLUSIONS

In summary, we found that forage kochia is a palatable shrub for cattle grazing during the fall. All entries received some use by the cows used in the experiment. There were preferential differences among accessions of forage kochia. Entries Immigrant, BC-118 and U-20 were the most utilized forage kochia entries and were comparable in utilization to alfalfa. However, these entries produced significantly more biomass and are more adapted to arid sites than alfalfa. Many entries were more preferred than Hatch winterfat, a cultivar of a conventional forage in the salt desert eco-system used for winter grazing.

The most important trait associated with utilization was pre-grazing biomass. Entries Immigrant, BC-118 and U-20 had the most biomass of all forage kochia entries used in the study. Entries U-20 and BC-118 were very tall in comparison with other entries with coarser stems that may provide more available forage after winter snowfall. Immigrant is also high yielding due to its high branch density, but is among the shorter entries used in the study. Stem length, branch density were other morphological characteristics associated with utilization. Crude protein was the only forage quality attribute associated with preference.

Though forage quality was not strongly associated with utilization, some important discoveries were made about these attributes concerning forage kochia. Forage quality differed between years with higher values in crude protein and digestibility, and lower values in fiber in 2003. The drought caused the plants to be smaller in 2003 that increased crude protein values that year. The 2-spotted spidermites may have also decreased forage quality in 2002 causing premature leaf and seed drop. Winterfat had positive forage quality results in relation to forage kochia, but had much lower utilization scores.

The morphological attributes associated with utilization may have been artifacts in the association with pre-grazing dry weight. However, some taller types were identified as highly utilized. BC-118 and U-20 were among the most utilized and tallest forage kochia entries in the study. These entries may provide more available forage to livestock and wildlife under snow cover.

Cattle spent significantly more time eating the grass borders than any single entry of forage kochia. This suggests the need for cattle to mix their diet with grass species. Forage kochia plants produce more biomass per plant in a mixture with grasses than they do in a mono-culture (personal observation). Forage kochia can provide crude protein to supplement dormant grasses when grass protein levels are low during the late fall and winter. We feel that the mixture of grass and kochia is beneficial for animal performance and the health of the ecosystem as well.

In conclusion, the information gained from this study has helped identify some important traits for evaluating forage kochia accessions with potential of cultivar release. It has also identified some accessions that were most utilized by cattle. This study will aid in the selection of forage kochia plants that may provide more available forage during the winter than the only released cultivar, Immigrant.

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APPENDIX

Table A1. Description of variables used in utilization study

Variable	Degrees of freedom	Random or fixed
Pasture	2	F
Entry	27	F
Pasture x Entry	53	F
Year	1	R
Pastur x Year	2	R
Entry x Year	27	R
Pasture x Entry x Year	53	R

Table A2. Analyses used from MIXED repeated option.

Trait	Repeated measure
Pre-grazing biomass	Split Plot
Biomass consumed	Split Plot
Percent biomass consumed	Compound Symetry
Mid-period OU	Compound Symetry
Final-period OU	Split Plot
Height	Hetero Compound Symetry
Stem length	Split Plot
Leaf part of stem	Compound Symetry
Branch density	Split Plot
Leafiness	Compound Symetry
Phenology	Compound Symetry
NDF	Split Plot
IVTD	Split Plot
Crude Protein	Split Plot

Appendix 3. Perameter estimates and R^2 values for quadratic regression equation[1] used to estimate Predicted pre-grazing biomass.

	Perameter Estimates for 2002				Perameter Estimates for 2003			
Entry	Intercept	Plant biomass	Plant size^2	R^2 2002	Intercept	Plant biomass	Plant size^2	R^2 2003
107	-1.44	1.00	-0.14	0.59	0.05	-0.03	0.02	0.89
120	0.06	0.00	0.03	0.75	0.60	-0.37	0.06	0.45
182-b	0.28	-0.21	0.07	0.58	-0.01	0.01	0.01	0.86
199	0.08	-0.02	0.03	0.91	0.17	-0.13	0.04	0.91
22	0.21	-0.18	0.07	0.81	0.02	-0.01	0.01	0.97
231	0.33	-0.25	0.08	0.90	-0.04	0.05	0.00	0.89
237	-0.58	0.44	-0.04	0.66	0.04	-0.03	0.02	0.92
240-WF	0.37	-0.38	0.13	0.81	0.04	-0.04	0.02	0.77
245	0.15	-0.10	0.06	0.78	0.02	-0.01	0.01	0.84
35	0.75	-0.55	0.13	0.83	0.04	-0.04	0.02	0.89
43	0.56	-0.31	0.07	0.81	0.15	-0.15	0.05	0.92
56	1.57	-1.29	0.30	0.66	0.02	-0.02	0.02	0.95
59	0.43	-0.42	0.13	0.83	0.04	-0.04	0.02	0.96
64	0.66	-0.47	0.12	0.56	-0.02	0.03	0.01	0.85
BC-102	2.11	-1.38	0.26	0.89	-0.15	0.13	-0.02	0.68
BC-108	-0.50	0.35	-0.02	0.70	0.03	-0.03	0.02	0.74
BC-118	0.01	0.00	0.03	0.87	0.01	-0.01	0.01	0.87
Hatch-WF	0.04	0.01	0.03	0.91	-0.12	0.09	0.00	0.77
Immigrant	4.79	-2.61	0.39	0.75	0.04	-0.03	0.02	0.76
Ladak	0.09	-0.04	0.03	0.96	0.27	-0.20	0.04	0.92
N52	0.23	-0.16	0.06	0.91	0.15	-0.13	0.03	0.79
N56	-0.07	0.04	0.03	0.89	0.11	-0.08	0.02	0.77
N59	1.84	-1.05	0.19	0.84	0.47	-0.32	0.06	0.63
N69	-0.19	0.12	0.02	0.89	0.42	-0.26	0.05	0.89
N70	-0.24	0.20	0.00	0.81	0.14	-0.12	0.03	0.78
N72	4.32	-2.46	0.38	0.93	0.25	-0.19	0.04	0.96
U-20	-0.41	0.32	-0.03	0.59	0.07	-0.07	0.03	0.76
One equation	0.14	-0.10	0.05	0.80	0.08	-0.06	0.02	0.68

[1] The equation was as follows: Perameter estimate for Intercept + perameter estimate for plant biomass * plant biomass + perameter estimate for (plant size score)^2 * (plant size score)^2