EVALUATION OF KOCHIA AS A HIGH YIELDING FORAGE CROP FOR SALINE SOILS

by

D. Green[1], J. Knipfel[2], J. Kernan[3] and E. Coxworth[3]

[1] Agriculture Canada Research Station, Swift Current, Saskatchewan S9H 3X2
[2] Agriculture Canada Prairie Regional Headquarters, Regina, Saskatchewan S4P 4E6
[3] Saskatchewan Research Council, Saskatoon, Saskatchewan S7N 2X8

ABSTRACT

Forage dry matter yields of up to 11670 kg/ha, at a soil conductivity of 12 ms/cm, were measured in three years of trials at several saline sites in Saskatchewan. Feed values were comparable to common hays, based on in vitro analyses and a digestibility and intake trial done with sheep. Salt accumulation in kochia forage was higher than other forages but was calculated to be not significant in saline soil reclamation. Potassium was the major cation accumulated by kochia forage even though the saline soils were high in soluble sodium and magnesium cations. A Texas accession gave a much higher forage yield in a greenhouse trial than a Saskatchewan selection, and did not set seed in greenhouse and field trials. Further work needed to turn this wild plant into a crop is discussed.

INTRODUCTION

Kochia (*Kochia scoparia* (L.) Schrad.) is a wild annual plant widely adapted to many geographical areas of Canada and the United States. It was introduced to the United States as an ornamental (called variously summer cypress and burning bush) in the early 1900s and has since become naturalized over a wide area of North America from Texas to Saskatchewan (Durham and Durham, 1979). Kochia has the C_4 photosynthesis pathway (Welkie and Caldwell, 1970) which tends to give plants a competitive advantage under hot, dry, sunny conditions (Björkman and Berry, 1973). It requires less moisture to produce an equivalent amount of dry matter than many common forage crops such as alfalfa and the perennial grasses (Baker, 1974; Foster et al., 1980; Nussbaum et al., 1985).

While kochia can be a weed if it grows in the wrong place at the wrong time, it is also a highly palatable and productive forage species. Several cattle diet studies have reported high use and preference for kochia (Beck, 1975, Vavra et al., 1977). Its protein content and digestibility can be as high as alfalfa (Bell et al., 1952; Sherrod, 1971; Sherrod, 1973). Sherrod (1971) reported that under dryland conditions in the Texas Panhandle, kochia had a dry matter yield of 11,327 kg/ha from a single cutting in mid-July. Studies in New Mexico found that irrigated and fertilized kochia, cut four times during the growing season, had a total dry matter yield of up to 26,000 kg/ha (Fuehring, 1984). In Saskatchewan, in the 1950s, Bell and co-workers (1952), at the University of Saskatchewan, measured yields of planted kochia under various row spacings, and assessed kochia accessions from several locations in North America. A Utah accession, at a row spacing of 15 cm (6"), gave the highest yield (dryland) of 11210 kg/ha (5 tons/acre).

Because of its high yield, and efficient use of water, kochia has been evaluated as an industrial crop for the production of chemicals, fuel additives, and animal feed by products (Sosulski et al. 1984). Studies in Colorado (Linden et al. 1982) showed that kochia had total dry matter yields of 11,500 kg/ha, which was twice the yield of forage sorghum or sorghum-sudan grass. Yields of fermentable carbohydrate (to produce fuel additives) were high, indicating considerable potential for further development of the crop for this purpose.

Kochia is a halophyte. A recent survey of disturbed saline soil sites in western Canada revealed that kochia was one of the most common wild plants present (Braidek et al., 1984). Goodin (1979) proposed that halophytes, with their high yield and high salt content, could be used to harvest soil salts and hence aid in the reclamation of such soils for eventual production of less salt tolerant crops. O'Leary (1984) has discussed the potential usefulness of native and introduced halophytes as forage and seed crops.

The objectives of this study were four. The first was to measure the yield of kochia forage on saline soils compared to crops of known saline tolerance such as barley. The second objective was to measure the forage quality of kochia grown on saline soil, by a digestibility and intake trial with sheep. The third objective was to measure the yield and salt content of kochia grown on saline soil, and compare this with the salt content of the soil, so as to assess if kochia production and harvest could significantly reduce the salt content of the soil. The fourth objective was to use a greenhouse trial to compare kochia accessions from Texas, Colorado and Saskatchewan for yield and plant composition and in vitro digestibility. This would be the first step in selecting kochia lines most suitable for forage production on saline and non-saline soils in western Canada.

MATERIALS AND METHODS

Yield of kochia compared to other crops when grown on saline soil.

Five crops were compared at a saline seep area near the airport at Swift Current in 1982.

The trial was conducted to determine the yield of milkweed (*Asclepias speciosa*, showy milkweed), kochia (*Kochia scoparia*), fodder beets (var. Monorosa), Jerusalem artichoke (var. Columbia) and barley (var. Bonanza) at three seeding rates. The plots, 12.2 m (40 ft.) by 11.9 m (39 ft.) were arranged in a latin square having five replicates, with each plot subdivided into three sections. A 0.61 m (two foot) space separated each plot. Crops were planted with 30 cm (one foot) row spacing.

After harvest, all samples were dried at 40°C in a forced air oven for dry matter yield and chemical analyses. Proximate analyses were conducted by AOAC methods, and rumen fluid digestibility by the method of Troelsen and Hanel (1969).

Digestibility and intake trial with sheep

Kochia used for this trial was planted in October 1983 from locally harvested seed, in a saline area near Swift Current (site 3 of table 5). Sufficient kochia was swathed on August 3, 1984 and August 29, 1984 at the full bloom and early mature seed stages of maturity respectively, to permit a digestibility trial to be run. These cuts were allowed to dry in the swath and were baled in the daytime under a hot sun. This resulted in considerable leaf loss.

The two cuts (hammermilled to pass a 5 cm screen) were each fed to four wether lambs, with initial body weights ranging from 35 to 50 kg, in a randomized block design, at the Swift Current Research Station of Agriculture Canada. Each wether was fed kochia for a 14 day period to assess feed intake, following which a five day total fecal collection was undertaken, with feed intake maintained at the voluntary intake level established in the intake assessment period. Total fecal collections were thoroughly mixed and 10% was taken for analysis. Refused feeds were collected and ground for analysis. Daily samples of feeds were composited and ground.

Feeds, refused feeds and feces were analyzed for dry matter, organic matter and CP by AOAC (1970) methods, cellulose by the Crampton and Maynard (1938) procedure, and ADF and NDF by the procedure of Goering and Van Soest (1970). All analytical data, digestibilities and intake parameters were statistically analyzed by standard procedure for randomized block designs (Steel and Torrie, 1960). All data are reported on a dry matter basis.

Uptake of salts by kochia on saline and non-saline soils.

Three sites, two near Swift Current, and one in Saskatoon, were selected. The site at Saskatoon was in a freshly disturbed area near highway construction and was considered to be non-saline (site 1) (no non-saline site growing pure kochia (wild) could be located in the Swift Current area). One site near Swift Current was in a highly saline area (site 2). The other site near Swift Current was on farm land which appeared to be somewhat saline (site 3). Each site was thickly covered with wild kochia.

Kochia was harvested, on August 22, 1983 in Saskatoon and August 28, 1983 in Swift Current, from one or two square metre plots and the plant height, density and yield determined for each plot. The plants were still green although seed had begun to form two to three weeks earlier. Some of the plants contained mature seed on their lower portions, while others contained green seed. The upper portions of some plants still possessed green leaves. The plant material was dried, chopped through a 1.25 cm screen in a hammer mill and a 1 mm screen in a Wiley mill prior to chemical analyses.

Plant samples were dissolved by wet oxidation using aqua regia and perchloric acid, and were analyzed for Na, K, Mg and Ca by ICP emission spectroscopy by the analytical laboratory of the Saskatchewan Research Council.

One soil sample at depths of 0 - 15 cm, 15 to 30 cm and 30 to 60 cm was taken from the centre of each plot. These were submitted to the Soil Testing Laboratory at the University of Saskatchewan for salinity and a detailed ion analysis. The conductivities were determined by the saturation method.

Calculations for ion content in the soil

The ion contents (μg/mL saturated soln) in the soil were expressed in g/m^2 to a depth of 61 cm. The saturation percentage was expressed as the volume of water in mL used to saturate a 100 g soil sample.

The formulae used to determine the ion content for each 15 cm cross-section were as follows:

$$\text{Ion Concentration} = \frac{\%\ \text{sat'n}}{100} \times \frac{\text{ion conc. } (\mu g/mL)}{10^6} \times 10^3 \text{ in g/kg}$$

$$= \frac{\%\ \text{sat'n} \times \text{ion conc. } (\mu g/mL)}{10^5} \quad \text{in g/kg}$$

$$\text{Wt. of Soil} = \frac{\text{Density} \times 10^6 \times 0.4536 \times 15.24}{0.4047 \times 10^4 \times 15} \text{ in kg/m}^2 \times 15 \text{ cm}$$

$$= \text{Density} \times 113.9 \text{ in kg/m}^2 \times 15 \text{ cm}$$

The calculation for the total ion weight for m^2 by 60 cm deep is as follows:

$$\text{Wt. of ion} = \text{sum of} \int \begin{matrix} 0 - 15 \text{ cm} \\ 15 - 30 \text{ cm} \\ 30 - 60 \text{ cm} \end{matrix} \quad \text{Ion conc.} \times \text{wt of soil in g/m}^2 \times 60 \text{ cm}$$

Statistics

A one-way analysis of variance was conducted on an IBM-PC microcomputer using software provided by R.J. Baker of the Crop Science Department, University of Saskatchewan. Significance of the salinity effect (SSE) was reported as highly significant (**, $p<0.01$) and significant (*, $p<0.05$) as determined by the F test. Least significant differences (LSD) were calculated from the error mean square for three and four plot treatments.

Greenhouse comparison of kochia accessions from Texas, Colorado and Saskatchewan

Kochia seed was obtained from three sources: Texas (Lubbock) (Tx), Colorado (Ft. Collins) (Co), and the local kochia population at the Swift Current Research Station (Sk). The three kochia accessions were compared using a randomized block design with three replicates and three treatments. Each replicate was a box 118 cm x 240 cm x 118 cm deep containing 1 m depth of Swinton silty clay loam over an 18-cm coarse gravel base. Plot size was 80 x 118 cm (3/box). The soil in these boxes had been in place for 3 years and was well packed. This soil has a pH of 6.5, a cation exchange capacity of 23 meg/100 g, a saturation percentage of 50%, an exchangeable sodium percentage of 1.7% and a sodium absorption ratio of 0.23. Eight and six days before seeding the boxes were watered in excess of field capacity following which 9 kg/ha of N, P_2O_5 and K was incorporated into the top 5 cm of soil. Each soil box was divided into 3 plots 80 x 118 cm. A light source of fluorescent and incandescent lamps that supplied 20,900 to 12,650 lux at 30 or 60 cm below lights was used to extend the natural day length to 10 hr from January 25 to April 3, and to 14 hr April 3 to June 20.

Seed from each population was planted January 25, 1984 at a rate of 200 seeds per 80 x 118 cm plot. On January 30 the Saskatchewan plots were seeded with a further 200 seeds to compensate for poor stand establishment.

At 'late forage' stage (date varied with population) plant height was measured and the plants were cut at ground level. The Co and Sk were harvested after flowering commenced. Some 23 days later, the Tx plants still showed no signs of flowering. They were arbitrarily harvested at this time. After harvest, the plants were separated into leaf and stem, and dried for 24 hr at 55°C and ground in a laboratory mill to pass a 1 mm screen. Organic matter and ash were determined by standard procedures (AOAC 1970). Contents of acid detergent fibre (ADF) and neutral detergent fibre (NDF) were quantified by the procedures of Goering and Van Soest (1970). Cellulose was determined by the Crampton and Maynard (1938) method, with hemicellulose calculated by difference (ADF-cellulose). Phosphorus (P) was determined by the procedure of Kitson and Mellon (1944). _In vitro_ organic matter digestibilities (IVOMD) were obtained by the procedure of Troelsen (1969). All variables were subjected to analysis of variance and the differences compared using the least significant difference test. The values were also recombined to give whole plant estimates and these were also subjected to analysis.

RESULTS AND DISCUSSION

Yield of kochia compared to other crops when grown on saline soil.

Soil analyses indicated that the airport site at Swift Current was a saline seep with no distinct saline gradient. Salinity varied randomly between replicates and between plots (electrical conductivity from 7.5 - 17.5 mS/cm in the top 0.3 m of soil). Milkweed did not grow successfully (poor germination and poor growth of the few plants that germinated). Jerusalem artichoke showed relatively poor growth. Kochia growth and yield was complicated by volunteer plants originating from seed scattered by wild plants surrounding the site, so actual plant populations were higher than planned. Barley yields were the most consistent.

Seeding rate had a significant effect on kochia yield, with the highest yields obtained at plant row spacings equivalent to 87 plants/m^2, based on planted seed. Plants in the center of a number of plots were somewhat stunted and had pale green leaves, suggestive of overcrowding.

Yields of the four highest yielding crops at the highest yielding stage of maturity and at the highest yielding seeding rate are shown in Table 1.

Figure 1

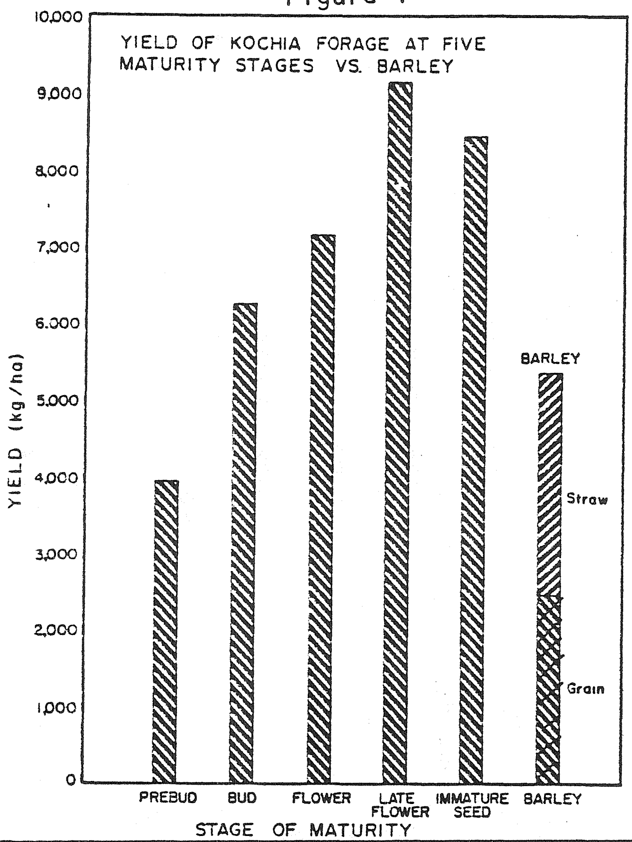

Figure 2

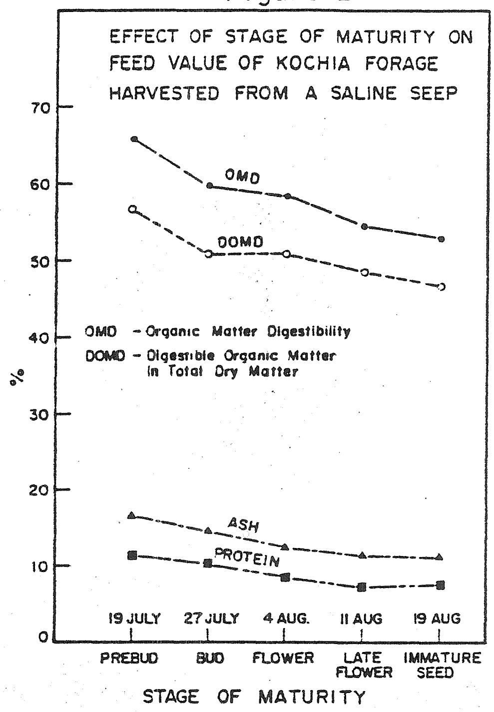

Table 1. Dry matter yields of kochia, barley, fodder beets and Jerusalem artichoke grown on a saline seep near Swift Current in 1982.

Crop[1]	Harvest Maturity	Material Harvested	Yield[2] kg/ha	Range (kg/ha)
Kochia	full flower	forage	9120[b]	7400 - 12640
Barley	mature	grain	2500[a]	2250 - 2700
Fodder beets[3]	mature	tubers	4850[ab]	0 - 9120
Jerusalem artichoke	flower	tops and tubers	2680[a]	790 - 4970
Significance of Crop Effect[4]			**	

[1] Crop means with a common letter within colomns are not significantly different at the 5% level according to Duncan's new multiple range test.
[2] Yields at the best seeding rate.
[3] The fodder beets did not germinate on the two plots with highest salinity. The yield mean includes the two plots with zero yield.
[4] Significance was determined by means of a oneway analysis of variance.

Figure 1 illustrates how kochia forage yield varied with stage of maturity. The maturity effect on feed value is shown in Figure 2. Digestibility at different stages of growth was similar to values reported by Finley and Sherrod (1971) for wild stands of kochia grown on non-saline soil in Texas. Crude protein content tended to be lower in our study than in the Texas experiment.

Holm and Henry (1982) reported a yield of 9464 kg/ha for a mixed stand of kochia and tall wheat grass on fertilized (150 kgN/ha) saline soil. A pure stand of tall wheatgrass yielded 7188 kg/ha on the same site with the same rate of fertilizer N.

<u>Digestibility and intake trial with sheep of kochia hay grown on saline soil</u>

The crude protein content (CP) of both cuts, particularly the second, (Table 2) were below those reported by other workers. Bell et al (1952) reported values of up to 21% CP for some Utah and South Dakota accessions of kochia. Sherrod (1971) reported CP contents as high as 25% for early cut forage and about 14% (Sherrod, 1973) for mid-bloom material. Finley and Sherrod (1971) showed the CP content decreasing from 24% at prebloom to 13.5% at full bloom. The low quality of the Swift Current samples was believed due to a combination of cutting both samples at too late a stage of maturity and leaf loss due to bailing under very dry conditions, which is substantiated by the greenhouse study.

The OMD and the energy digestibility decreased significantly between the two cutting dates while the CP digestibility decreased greatly (Table 3). The cellulose digestibility also showed a large decrease while the neutral detergent fibre (NDF) and the acid detergent fibre (ADF) digestibilities decreased as showed in Table 3.

Table 2. Composition of kochia at two stages of maturity.

Date of Harvest Dry Matter	August 3/83	August 29/83
Organic Matter (%)	86.8	90.6
Crude Protein (%)	10.5	6.4
Cellulose (%)	30.7	34.9
NDF (%)	51.0	61.1
ADF (%)	32.2	38.9
Phosphorus (%)	0.21	0.18
Energy (M Kcal/g)	3.97	4.09

Table 3. Nutrient digestibilities in kochia at two stages of maturity.

Nutrient	Digestibility Aug. 3	Digestibility Aug. 29	Sig. of Maturity Effect	Standard Error
Organic Matter (%)	61.7	50.5	*	1.98
Crude Protein (%)	61.1	36.7	* *	3.43
Cellulose (%)	57.8	36.5	* *	0.84
NDF (%)	52.6	42.4	*	2.01
ADF (%)	42.2	37.3	N	1.89
Energy (%)	60.9	49.1	*	2.37

Differences between values are significant at the 5% (*) and the 1% (**) level.

Table 4. Digestible nutrient intakes of kochia at two stages of maturity.

Nutrient	Digestible Intake/kg$^{.75}$ Aug. 3/84	Digestible Intake/kg$^{.75}$ Aug. 29/84	Sig. of Maturity Effect	Standard Error
Organic Matter (g)	31.6	23.2	* *	0.6
Crude Protein (g)	4.22	1.41	* *	neg
Cellulose (g)	10.4	5.7	* *	0.44
NDF (g)	15.0	12.6	* *	0.30
ADF (g)	7.0	7.0	N	neg
Energy (Kcal)	143.8	103.2	* *	1.38

Differences between values within a column are significant at the 5% (*) and 1% (**) levels.

The intakes of digestible OM and CP decreased with advancing maturity (Table 4). The digestible energy intake decreased from 143.8 to 117.2 Kcal/kg$^{.75}$ as the plant material matured from August 3/83 to August 29/83. Energy intake requirements for maintenance range from about 120 to 130 Kcal/kg$^{.75}$. The August third material was adequate in both energy and protein and cows could gain weight on feed of this quality. The August 29th material was marginally adequate for energy, but would require supplemental protein for it to be adequate for a maintenance ration.

Cutting in early August, or earlier, appears necessary in order to obtain high quality hay. Harvesting and baling techniques need to be developed to ensure minimal loss of leaves.

Uptake of salts by kochia on saline and non-saline soils

The conductivities and sodium absorption ratios (SAR) indicate that site 1 is non-saline, site 2 is very highly saline and site 3 is highly saline (Table 5).

Table 5. Soil Salinity

Site	Plots	Conductivity (mS/cm)	pH	SAR
1 Low salinity	3	1.8	7.5	0.8
2 Very high salinity	4	22.3	8.1	12.1
3 High salinity	3	10.7	6.9	4.6
SSE		**	**	**
LSD_3 (p=0.05)		2.5	0.3	2.2
LSD_{3-4} (p=0.05)		2.4	0.27	2.0

The average soil fertility for the four plots at site 2 was 7.1 kg NO_3-N/ha, 79 kg P/ha and 1390 kg K/ha and for the three plots at site 3 was 13 kg NO_3-N/ha, 104 kg P/ha and 2610 kg K/ha (after kochia harvest).

Yields of kochia on the three sites were as shown in Table 6.

Table 6. Plant height, plant density and dry matter yield of kochia.

Site	No. of Plots	Height (cm)	Yield (kg/ha)	Harvest
1	3	118	8940	Aug. 22
2	4	157	9230	Aug. 28
3	3	90	8210	Aug. 28
SSE		**	NS	
LSD_3 (p=0.05)		12	1634	
LSD_{3-4} (p=0.05)		11	1529	

The ion content of the top 60 cm of soil (Table 7) after kochia harvest was contrasted with the ion content of kochia forage (Table 8).

Table 7. Soluble ion content of top 60 cm of soil after growth and harvest of kochia hay.

		Ion content (g/m^2 x 60 cm)					
Site	No. of Plots	Ca^{++}	K^{++}	Mg^{++}	Na^+	Cl	$SO_4^=$
1	3	206	35	105	61	83	822
2	4	123	10	1014	1013	380	5801
3	3	172	18	708	420	54	3868
SSE		**	**	**	**	**	**
LSD_3 (p=0.05)		19	3	221	163	59	889
LSD_{3-4} (p=0.05)		18	29	207	153	55	831

SSE = significance of the salinity effect.

Table 8. Ion content of kochia

Site	No. of Plots	Ion content (g/m^2) Ca^{++}	K^+	Mg^{++}	Na^+	Ion content (% of kochia d.m) Ca^{++}	K^+	Mg^{++}	Na^+	Ash (d.m)
1	3	7.8	25.5	5.8	1.5	0.87	2.85	0.65	0.17	9.9
2	4	8.7	23.6	8.5	6.8	0.94	2.56	0.92	0.74	11.8
3	3	4.2	23.9	6.4	1.0	0.51	2.91	0.78	0.12	8.3
SSE		**	NS	NS	**					
LSD_3 (p=0.05)		2.4	10.0	2.7	1.4					
LSD_{3-4} (p=0.05)		2.3	9.3	2.5	1.3					

This study compared three populations of kochia at three different sites. Statistical differences in ion content have been assumed to be due to soil cations and anions and not to climate or other variables. For April 1st to August 31st, growing degrees days at Saskatoon and Swift Current were 1418 and 1408 respectively. Precipitation at Saskatoon was 147% of normal and at Swift Current 107% of normal.

The kochia plants appeared to be regulating plant K^+ concentration to about 2.6 to 2.9% of dry matter. The plants had lower Na^+ cation levels regardless of soil Na^+ concentration (Table 7). Na^+ and Mg^{2+} are the major cations causing salinity problems. Even considering this as a static system, which it is not, less than 1% of these two cations is contained in the plant material compared to that in the same area of soil. The Na^+ content of kochia does increase significantly when the Na^+ content of the soil is high (Table 8), but this increase is very small compared to the amount of Na^+ in the soil. Redmann and Fedec (1986) found higher levels of Na^+ in kochia plants growing on very saline soil, but K^+ was still the major cation on a weight % basis. Ash content was similar to a previous study (Bell et al., 1954) in which kochia had one of the highest values among 37 domestic and wild forages surveyed. The Mg^{2+} content is high compared to common forages and may be a factor in laxative tendencies observed with this species (Bell et al., 1954).

The high percentage of K^+ relative to Na^+, Mg^{2+} and Ca^{2+} is very likely advantageous in terms of forage use for ruminant animals. A survey of forage crops, including kochia, indicated that K^+ levels were 6 to 100 times as high as Na^+ (Bell et al., 1954). Jimenez (1980) indicated that 4-5% potassium ion in rapidly growing forage did not seem to adversely affect cattle performance, but that the ratio of potassium to calcium plus magnesium in the diet should be in the range of 1.1-

2.2:1, i.e., the potassium intake should always be greater than the combined intakes of calcium plus magnesium. Jimenez (1980) recommended that potassium intake should be a minimum of 0.8% of total dry matter intake for dairy cows. In contrast, levels of sodium ion in the diet greater than 2% can have an adverse effect on cellulose digestion (Berger et al., 1979). Intake was more adversely affected by high levels of sodium ion than potassium ion, e.g., Petchey and Mbatya (1977) found that animal intakes of silage: treated straw mixtures containing 4.1% potassium ion were larger than silage: treated straw mixtures containing 1.5% sodium ion. Given adequate available K^+ in the soil, as was the case on saline sites 2 and 3, we conclude that kochia will assimilate more K^+ than Na^+ or Mg^{2+}, and this will lead to better quality hay.

While 'salt mining' does not appear feasible with kochia in accord with the conclusions of O'Leary (1984), the yield potential indicated in this study suggests that kochia forage production on saline soils may still be of interest on the basis of economic return and total water use (Table 9).

Table 9. Yields, economic returns, and water use of various forage crops on saline soils

Crop	Yield Kg/ha (d.m.)	Gross Economic Return[1] $/ha	($/ac)	Water Use Kg water to produce a Kg of forage[2]	Water Use Kg/ha
Kochia	9120	502	(203)	275	2,508,000
Barley (Grain)	2500[3]	343	(139)	518	3,097,600
Wheatgrass	4000	220	(89)	1052	4,208,000
Alfalfa	3000	195	(79)	826	2,478,000

[1] Barley grain prices, Dec. 1983. Kochia and wheat grass hay @ $55/t, alfalfa @ $65/t.
[2] Baker, 1974, Wiese, 1968, Foster et al., 1980.
[3] Total yield (grain + straw) = 5980.

Estimates of yields in Table 9 were based on results from this study (kochia and barley) and data from Holm (1982) for tall wheatgrass and alfalfa.

Greenhouse comparison of kochia accessions from Texas, Colorado, and Saskatchewan

Tx kochia produced three times as much dry matter/ha as did Co, and four times the Sk yield (Table 10). The Tx plants were taller, were still actively growing and had not flowered 23 to 27 days, respectively, after the Co and Sk had reached the maturity stage of late flower or early seed set and were harvested. The long day length (14 hr photoperiod, 10 hr darkness) did not initiate flowering. The lack of flowering and hence seed production could be advantageous for kochia used in rotations, since it would not reseed itself to become a weed problem in subsequent crops. Since potentially toxic saponins have been reported to accumulate with flowering (Souto and Milano, 1966), the Tx kochia might be expected to contain less saponin than flowering types. This hypothesis is to be investigated in future studies. Population density (plants/m^2) in continuous kochia would also be more predictable if residual seed was not a problem.

Table 10. Yield, population, plant height and percent plant fractions for three kochia accessions grown in the greenhouse

Accession	Whole plant yield (kg/ha)	Number of plants/plot	Height (cm)	% Plant fractions Leaf	Stem
Saskatchewan	5098	56.3	122	53.0	47.0
Colorado	7667	53.6	183	46.7	53.3
Texas	21879	107.3	203	37.0	63.0
Significance of Accession Effect	**		**	*	*
LSD (P=0.05)	6721		30.6	8.6	8.6

Differences between values within a column are significant at the 5% (*) or 1% (**) level.

The feed value of the three accessions, as harvested, is shown in Table 11.

Table 11. Percent crude protein, ash, and organic matter digestibility of greenhouse grown kochia accessions.

Accession	% Crude Protein			% Ash			% OMD[1]		
	Whole Plant	Leaf	Stem	Whole Plant	Leaf	Stem	Whole Plant	Leaf	Stem
Saskatchewan	12.5	17.6	6.0	15.5	19.8	8.4	51.9	70.6	27.6
Colorado	11.3	18.4	5.3	13.8	19.0	7.9	47.4	69.6	29.2
Texas	12.9	17.5	5.3	14.4	22.1	6.2	47.0	70.7	22.1
Significance of Accession Effect	NS	NS	NS	NS	NS	*	NS	NS	**
LSD (P=0.05)	4.4	4.8	2.4	2.3	3.2	1.5	10.1	2.3	3.8

[1] OMD = in vitro organic matter digestibility.

Tx plants were more vigorous in stand establishment, with double the number of Tx plants versus Co and the double seeded Sk kochia. Percent CP and percent IVOMD for whole plants were not significantly different (Table 11), although the stem content of Tx was significantly ($P<0.05$) greater than Co, which was greater than Sk. It should be emphasized that plants were harvested at a later stage of maturity than would be considered desirable to retain good forage quality (Sherrod 1971). Since the leaves contain the bulk of desired nutritional components (Table 11), any treatment such as seeding at optimum plant populations to increase the leaf to stem ratio, or harvesting at an earlier stage of maturity, should improve forage quality.

Tx kochia stems had significantly more acid detergent and neutral detergent fiber consistent with lower digestibility. The inference from these results is that Texas kochia, although phenologically younger than the other two accessions, was showing maturity effects either due to its greater height and yield, or due to greater age based on days from planting.

An observation trial for Texas kochia was established on a saline site (EC=12.2 mS/cm, top 15 cm) by Adrian Johnson, Saskatchewan Agriculture, on the farm of Darald Marin near Radville in 1985. Texas kochia was planted in late May and harvested in early August. In spite of severe drought in southern Saskatchewan, germination and growth were considered acceptable. Based on four random 1 m^2 samples, yield of forage was 3310 kg/ha (air dried basis). Inspection of harvested samples revealed that plants were still in a vegetative stage with no indication of bud or flower formation.

These results indicate that kochia accession from lower latitudes may be day length sensitive and not set seed under Saskatchewan conditions. Further trials are needed to determine if earlier planted Texas kochia would still refuse to flower with a longer growth time.

Summary

These data indicate to us that kochia has considerable potential as a high yielding forage crop for saline soils. However, many things remain to be investigated.

These include:

1. Effective plant establishment on non-saline soils. Kochia has a very small seed size. Surface planting is required for good emergence (Everitt et al., 1983). On several occasions, during the last two drought years, we have observed poor germination and growth of kochia on the drier upslope positions of a saline gradient, but good germination and growth on the lower, wetter, more saline areas. Recent information from Texas confirms that kochia is drought resistant once established but requires moisture for germination and early growth.

2. Response of kochia to fertilizer. Studies elsewhere have indicated that kochia is very responsive to N, P and K fertilizers.

Studies are needed under Saskatchewan conditions, both on saline and non-saline soils.

3. Toxicity problems. On occasion, kochia has caused illness and death to cattle (Dickie and James, 1983, Kiesling et al., 1984). Others have fed kochia extensively without problems (Durham and Durham, 1979). Oxalates, saponins, nitrate, and alkaloids have been suggested as possible toxic constituents. Studies are needed to measure levels of possible toxins and investigate crop breeding, agronomic practice, and other methods to minimize or eliminate possible sources of toxicity. At present, Saskatchewan Agriculture recommends that kochia should not constitute more than 50% of the ration. This approach would also dilute the high salt content of young kochia forage in the ration which can otherwise result in laxative problems.

4. Weed control in planted kochia. Weeds also include volunteer kochia seedlings from wild plants. Kochia forage yields can fall if plant densities are too high (i.e. more than 100 - 200 plants/m^2) (Iverson and Wali, 1981). Texas farmers have used harrowing in the spring to thin plants to the desired density (Durham and Durham, 1979).

5. Studies on kochia in rotation with other crops (e.g. alfalfa, barley). If kochia plant debris is allowed to accumulate, it can inhibit the growth of other following crops including kochia itself (Iverson and Wali, 1981). This phenomenon needs to be investigated in order to develop successful crop rotations involving kochia.

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REFERENCES

AOAC. 1970. Official Methods of Analysis, 11th ed. Washington, D.C.

Baker, L.O. 1974. Growth and water use efficiency of seven annual plant species. Proc. Western Soc. Weed Sci. 27: 73-74.

Beck, R.F. 1975. Steer diets in southeastern Colorado. J. Range Manage. 28: 48-51.

Bell, J.M., Bowman, G.H. and Coupland, R.T. 1952. Chemical composition and digestibility of forage crops grown in central Saskatchewan, with observations on kochia species. Sci. Agric. 32: 463-473.

Bell, J.M., McLaren, P.D. and McKay, G. 1954. Mineral and protein content of forage crops in central Saskatchewan. Can. J. Agric. Sci. 34: 252-260.

Berger, L., Klopfenstein, T., and Britton, R. 1979. Effect of sodium hydroxide on efficiency of rumen digestion. J. Anim. Sci. 49: 1317-1323.

Björkman, O. and Berry, J. 1973. High-efficiency photosynthesis. Scientific American, October, pages 80-93.

Braidek, J.T., Fedec, P. and Jones, D. 1984. Field survey of halophytic plants of disturbed sites on the Canadian prairies. Can. J. Plant Sci. 64: 745-751.

Crampton, E.W., and Maynard, L.A. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15: 383.

Dickie, C.W., and James, L.F. 1983. Kochia scoparia poisoning in cattle. J. Amer. Vet. Med. Assoc. 183: 765-768.

Durham, R.M. and Durham, J.W. 1979. Kochia: its potential for forage production. Proceedings, International Arid Lands Conference on Plant Resources. Texas Tech. Univ., Goodings, J.R. and Northinton, D.K., (editors). Also personal communication between J. Kernan (Sask. Research Council) and R.M. Durham.

Everitt, J.H., Alaniz, M.A. and Lee, J.B. 1983. Seed germination characteristics of Kochia scoparia. J. Range Manage. 36: 662-664.

Finley, L.G. and Sherrod, L.B. 1971. Nutritive value of kochia scoparia II. Intake and digestibility of forage harvested at different maturity stages. J. Dairy Sci. 54(2): 231-234.

Fuehring, H.D. 1984. Cultural practices for kochia forage production. Research Report 538. Agricultural Experimental Station, New Mexico State University , Las Cruces, N.M.

Foster, K.E., Rawles, R.L., Karpiscak, M.M. 1980. Biomass potential in Arizona. Desert Plants 2(3): 197-200.

Goering, H.K., and Van Soest, P.J. 1970. Forage Fibre Analysis. Agric. Handbook #379. Agric. Res. Serv., USDA, Washington, D.C. 20 pp.

Goodin, J.R. 1979. Atriplex as a forage crop for arid lands. Pages 133-148 in G.A. Ritchie, ed., New Agricultural Crops. AAAS Selected Symposium 38. Westview Press, Boulder, Colorado.

Holm, H.M. 1982. Salt tolerance in crops. Soil Salinity. First Annual Western Provincial Conference, Rationalization of Water and Soil Research and Management. Lethbridge, Alta. Published by Alberta Agriculture, Edmonton, Alta.

Holm, H.M. and Henry, J.L. 1982. Understanding salt-affected soils. Saskatchewan Agriculture publication, Plant Industry Branch, Regina, Sask.

Iverson, L.R. and Wali, M.K. 1981. Ecology of Kochia scoparia on surface mined lands. Proc. ND Acad. Sci. 35: 11.

Jimenez, A.A. 1980. Potassium requirements for dairy cattle. Feedstuffs, May 26, page 30.

Kiesling, H.E., Kirksey, R.E., Hallford, D.M., Grigsby, M.E., Thilsted, J.P. 1984. Nutritive value and toxicity problems of kochia for yearling steers. Agric. Exp. Stat. NMSU, Res. Rep. 546.

Kitson, R.E. and Mellon, M.G. 1944. Colorimetric determination of phosphorus as molybdovanadophosphoric acid. Ind. Eng. Chem. 16: 379-383.

Linden, J.C., Murphy, V.G. and Smith, D.H. 1982. Potential of common weeds as feedstocks for fuels and chemicals. Presented at the 184th American Chemical Society National Meeting, Kansas City, Mo. Sept. 12-17.

Nussbaum, E.G., Wiese, A.F., Crutchfield, D.E., Chenault, E.W. and Lavake, D. 1985. The effects of temperature and rainfall on emergence and growth of eight weeds. Weed Science 33: 165-170.

O'Leary, J.W. 1984. The role of halophytes in irrigated agriculture. In Saline Tolerance in Plants: Strategies for Crop Improvement, R.C. Staples (editor). John Wiley and Sons, Inc. New York, N.Y.

Petchey, A.M. and Mbatya, P.B.A. 1977. The intake of steers and heifers fed on mixtures of alkali-treated or untreated straw with grass silage. Anim. Feed Sci. and Technol. 2: 315-326.

Redmann, R.E. and Fedec, P. 1986. Mineral ion composition of halophytes and associated soils in Alberta and Saskatchewan. Unpublished manuscript obtained from the authors (P.F.), POS Pilot Plant Corporation, Saskatoon, Sask.

Sherrod, L.B. 1971. Nutritive value of Kochia scoparia I. Yield and chemical composition at three stages of maturity. Agron. J. 63: 343-344.

Sherrod, L.B. 1973. Nutritive value of Kochia scoparia III. Digestibility of kochia hay compared with alfalfa hay. J. Dairy Sci. 56(7): 923-926.

Sosulski, K., Coxworth, E. and Kernan, J. 1984. Assessment of the potential of growing unconventional energy crops or multi-use crops on saline or marginal land. Biomass refining to provide fermentable sugars and feed. Fifth Canadian Bioenergy R & D Seminar; Hasnain, S. (editor). Elsevier Applied Science Publishers, New York, N.Y.

Souto, J. and Milano, V.A. 1966. Triterpene saponins in the fruits of Kochia scoparia ("Morenita"). Rev. Invest. Agropec., Series 2, III (24): 367-383. (INTA, Buenos Aires, Argentina).

Steel, R.G.D. and Torrie, J.H. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc. Toronto, Ont.

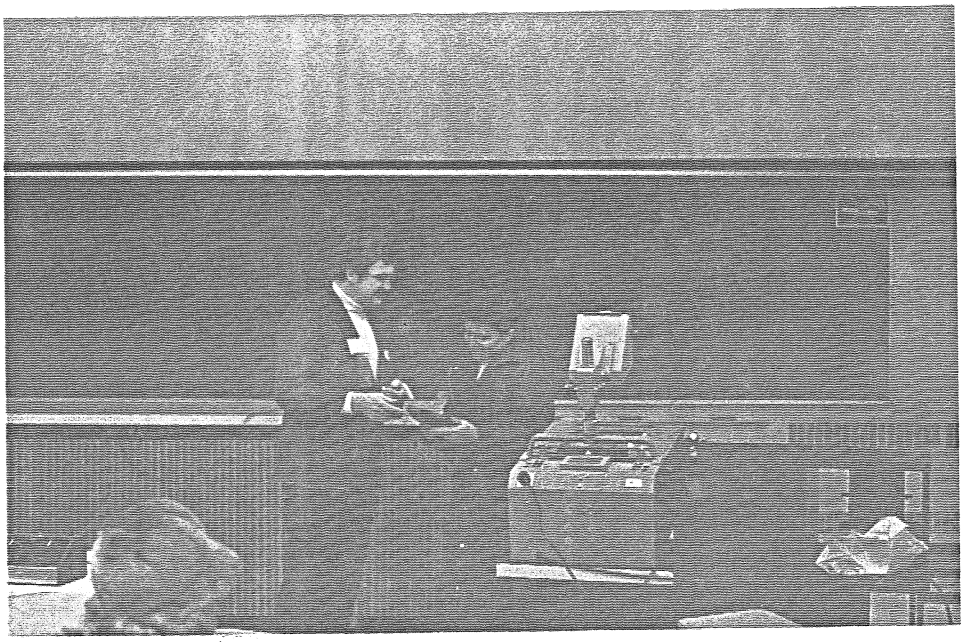
Troelsen, J.E. 1969. Outline of procedure for in vitro digestion of forage samples. Research Station, Research Branch, Agriculture Canada, Swift Current, Sask., S9H 3X2.

Troelsen, J.E. and Hanel, D.J. 1969. Ruminant digestion in vitro as affected by inoculum donor collection day and fermentation time. Can. J. Anim. Sci. 46: 149-156.

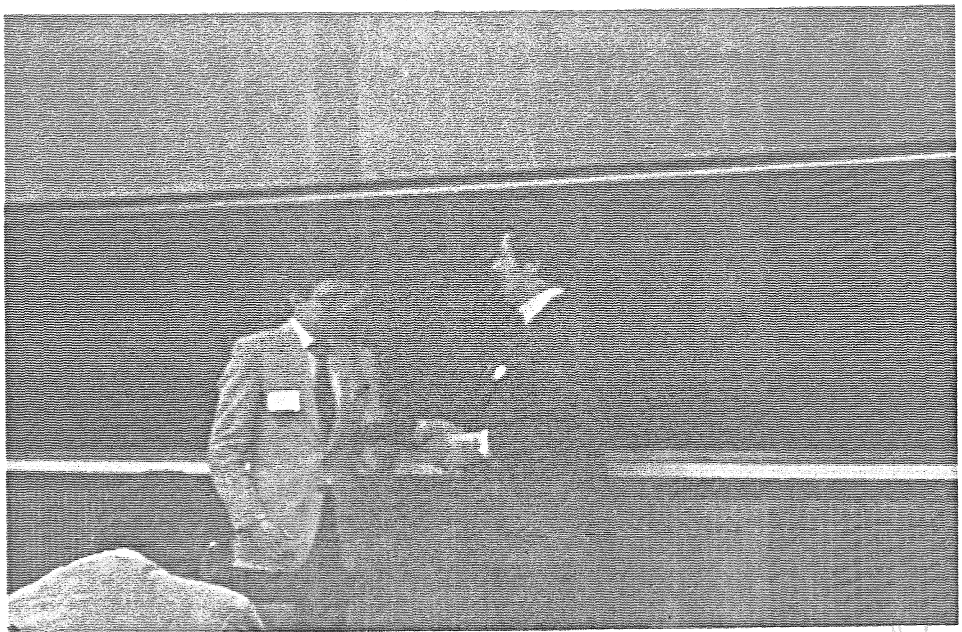
Vavra, M., Rice, R.W., Hansen, R.M. and Sims, D.L. 1977. Food habits of cattle on shortgrass range in northeastern Colorado. J. Range Manage. 30: 261-263.

Welkie, G.W., and Caldwell, M. 1970. Leaf anatomy of species in some dicotyledon families as related to the C_3 and C_4 pathways of carbon fixation. Can. J. Bot. 48: 2135-2146.

Graduate Student Prizes



Chairman Mike Grevers presents a plaque and a cash prize to Sue McColl for the top paper in crops by a graduate student.



The top paper in soils was presented by Lyle Caldwell. He receives a plaque and a cash prize from Mike Grevers.