Crude Protein, Crude Fiber, Tannin, and Oxalate Concentrations of 33 *Astragalus* Species

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Abstract

Plant introduction collections grown at the Western Regional Plant Introduction Station for preliminary evaluation and seed increase were evaluated for crude protein, crude fiber, tannin, oxalates, and readily detectable alkaloids. Sixty-eight *Astragalus* accessions representing 33 species and 1 unidentified accession had a range of 8.2 to 24.2% crude protein, 11.3 to 28.6% crude fiber, 4.2 to 10.0 mg/g tannin, and 0.15 to 1.10% oxalates. Species with more than 18% crude protein and less than 28% crude fiber (i.e., comparable to good quality alfalfa (*Medicago sativa*) hay) and acceptable levels of tannin and oxalate were *A. canadensis*, P.I. 19978 and *A. siliquosus*, P.I. 330696. None of the accessions tested gave a positive Dragendorff reagent color test for alkaloids. Some of the species reported are known to be selenium accumulators and/or contain toxic nitro-compounds that may be damaging to grazing animals. *A. siliquosus* is a species that contains nitro-compounds and will accumulate selenium.

The genus *Astragalus* is widely distributed throughout the temperate regions of the world, but is particularly abundant in the temperate regions of North America, Europe, and Asia. The most common use of *Astragalus* is forage for livestock and wildlife, but Uphof (1968) listed 32 species known to have been used by man for food, medicine, cosmetics, substitutes for tea or coffee, or sources of vegetable gums.

The USDA Plant Introduction System has introduced 99 species and many unidentified accessions of *Astragalus* in recent years. Some species have been shown to be selenium accumulators (Davis 1972). Only a few have had sufficient alkaloids to respond positively to a Dragendorff reagent color test as modified by Burns (1964) and reported by Davis (1973). Two introduced species, *A. cicer* and *A. falcatus* (cicer and sicklepod milkvetch), are being used in range revegetation and reclamation (Barneby 1964). Others are being evaluated for their forage potential.

Chamberlain and Matthews (1969) reported that the genus *Astragalus* has the most extensive speciation of any genus in Leguminosae, with 370 recognized species in Turkey. Komarov (1965) described 575 species of the known 849 species found in the USSR. Some of the species are known to exist in both countries. North American speciation has been cataloged by Barneby (1964), who recognized about 500 species and developed descriptions and distribution maps for 368 of these.

Seventeen of the 33 *Astragalus* species reported here were shown to accumulate selenium (Davis 1972); these species are so-designated in Table 1. Investigations by Williams and Barneby (1977), Williams and James (1975), and Williams et al. (1976) have shown that nitro-compound toxicity is common in the *Astragalus* genus. They showed that five of the species presented here have proven toxic to animals. *A. canadensis* L. and *A. falcatus* Lam.

appear to be among the more hazardous. Others with nitro-compounds were *A. galegiformis* L., *A. kotschyanus* Boiss., and *A. siliquosus* Boiss. Unpublished data from M.C. Williams show that *A. filicaulis*, *A. glycyphylus*, *A. hamosus*, *A. odoratus*, *A. podocarpus*, *A. refractus*, and *A. trimestris* also contain nitro-compounds in toxic quantities (personal communication).

Materials and Methods

The *Astragalus* species were grown at Central Ferry, Washington, and were of diverse geographical origins. The annual species were sampled and analyzed the season of establishment and the perennials were sampled and analyzed the following year. The soil was "Chard" coarse-loamy, mixed, mesic calcic haploxerolls, which developed on bars along the Snake River. This soil has generally good internal and external drainage. Water was applied throughout the growing season to maintain vigorous growth. Accessions were seeded in rows 1.5 m wide and 6 m long and after establishment were sidedressed with 67-87-0-11 kg/ha (N-P-K-S). Nitrogen was added to assist in the breakdown of the barley straw from the previous crop year. Forage samples were taken from all plants to the row. Plots were cultivated and hand hoed for weed control.

The 68 accessions reported in this paper represent 33 species and 1 accession that has not been identified. These represent about one-third of the species held by the Western Regional Plant Introduction Station.

Whole stem samples were taken in duplicate from all above-ground parts of the plants at bloom stage; leaves, stems, petioles, scapes, and flowers were combined to make a composite sample. These samples were dried in a thermal draft oven at 80° C, ground to 20-mesh fineness and stored at 20° C and 35% relative humidity until analyzed. Crude protein was estimated by determining Kjeldahl nitrogen (AOAC 1970) and multiplying by 6.25; crude fiber was determined by the method outlined in AOAC (1970), tannin by the method of Burns (1963), and oxalic acid by the method of Dye (1956). All accessions were checked for alkaloids using the Dragendorff reagent color test as modified by Burns (1964).

Results and Discussion

The crude protein, crude fiber, tannin, and oxalic acid levels in various *Astragalus* species are presented in Table 1.

Crude protein variation was less in this collection than in the collection from USSR reported by Davis (1973). This report includes accessions from Europe and Asia, as well as from North America. The highest crude protein (24.2%) was found in *A. canadensis*, P.I. 232539 from Wyoming, and the lowest (8.2%) in *A. missouriensis*, P.I. 199780 from Canada. The average crude protein found in the annual species was 12.4%; the average for the perennial species was 14.6%. Only *A. canadensis* (2 accessions) and *A. siliquosus* equaled or exceeded the 18% found in good alfalfa hay (Miller 1958).

Crude fiber varied from 32.5% for *A. boeticus*, P.I. 23325, a large robust coarse perennial species, to 11.3% for *A. edulis*, P.I.

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244273, an intermediate-sized annual. Few accessions were as high in crude fiber as good alfalfa hay (28%), as reported by Miller (1958). In fact, only three accessions exceeded 25% crude fiber (Table 1). When samples were collected at full bloom, crude fiber was low, as indicated by these data.

Annual species averaged less crude fiber than perennial species, 16.8% and 18.6%, respectively. This overall crude fiber average was lower than previously reported by Davis (1973) and was due to a different species complex.

Tannin levels were generally low. Only two were higher than 10 mg/g. Donnelly and Anthony (1969) reported that more than 25 mg/g tannin was required in *Lepedeza cuneata* (Dum.) G. Don before animal acceptance was impaired. The average levels found in this collection were 1 mg/g lower than in the previous report (Davis 1973), and no problems with acceptance due to tannin would be expected. The average for the annual species was 5.7 mg/g and for perennials, 6.2 mg/g.

Oxalates were particularly low. All were less than 1% with an average of 0.36 oxalic acid equivalent. Morton et al. (1959) reported that a mature sheep requires 45 g oxalic acid equivalent before toxicity would develop. On this basis, a sheep would have to ingest 12.5 kg of dry matter containing 0.36 oxalate before toxicity would develop. The average oxalate level for annual species was less than that for the perennials, 0.36% and 0.40%, respectively.

None of the accessions in this collection produced a positive Dragendorff color test for alkaloids.

These results and the previous report (Davis 1973) indicate that forage quality in the *Astragalus* genus is highly variable among species and accessions within species. This is well illustrated by the 21 accessions of *A. hamosus* in this report. These varied from 14.2% to 10.7% in protein, from 21.0% to 11.9% in crude fiber, from 7.2 mg/g to 3.5 mg/g in tannin and from 1.10% to 0.15% in oxalates. Plants in this genus, with notable exceptions, are lower in crude protein and crude fiber than good alfalfa hay and none of the accessions analyzed had tannin levels or oxalic acid equivalents high enough to be dangerous or to curtail utilization by livestock.

Ranchers in western states need productive, quality leguminous forages that will grow in areas where alfalfa is not adapted. Some *Astragalus* species now being tested by federal and state agencies may meet this need, although feeding trials should be conducted before any accession is seeded for forage production to avoid introducing undesirable plants into the forage complex.

The utilization of some species or accessions may be limited by inherent characteristics such as poor seed production, selenium accumulation, inability to withstand repeated defoliation or drought, or the presence of alkaloids or nitro compounds. New research on *Astragalus* is locating accessions, free of such undesirable characteristics, that may become important sources of forage on farms, ranches, and ranges of western America.

Table 1. Protein, crude fiber, tannin, and oxalate content in 33 *Astragalus* species and 1 unidentified accession.

Species acid	Plant inventory number	Origin	Protein (%)	Crude fiber (%)	Tannin ¹ (mg/g)	Oxalic (%)
<i>alpinus</i>	232536	Wyoming	16.6	13.6	5.9	0.91
<i>americanus</i>	236743	Canada	14.6	16.1	5.9	0.89
<i>bisulcatus</i> ²	241039	Utah	15.5	15.5	5.0	0.46
<i>boeticus</i>	233225	Israel	14.5	32.6	5.5	0.19
<i>campylorhynchus</i> ^{2,3}	220280	Afghanistan	8.9	28.6	6.6	0.29
<i>campylorhynchus</i> ^{2,3}	220770	Afghanistan	10.2	25.8	6.9	0.24
<i>campylorhynchus</i> ^{2,3}	227008	Iran	9.9	21.4	5.9	0.22
<i>canadensis</i> ⁴	199778	Canada	18.4	14.8	4.5	0.29
<i>canadensis</i> ⁴	232539	Wyoming	24.2	15.8	5.9	0.29
<i>charborasicus</i>	330693	Iran	13.8	23.3	4.5	0.24
<i>charborasicus</i>	330694	Iran	16.7	24.1	5.9	0.28
<i>cicer</i>	066515	Turkey	14.4	17.8	4.5	0.58
<i>cicer</i>	206404	Sweden	14.9	17.7	5.5	0.51
<i>cicer</i>	206405	Turkey	15.0	18.5	4.5	0.56
<i>coluteocarpus</i>	223245	Afghanistan	11.2	19.8	7.2	0.23
<i>commixtus</i> ^{2,3}	220161	Afghanistan	9.6	23.6	7.1	0.16
<i>corrugatus</i> ^{2,3}	220156	Afghanistan	9.0	24.0	5.9	0.42
<i>cymbacecarpos</i> ^{2,3}	318944	Spain	11.6	12.7	5.0	0.60
<i>cymbacecarpos</i> ^{2,3}	318946	Spain	12.2	12.0	5.5	0.40
<i>edulus</i> ^{2,3}	244273	Spain	13.6	11.3	6.9	0.21
<i>falcatus</i> ^{2,4}	066440	USSR	16.0	14.9	5.0	0.17
<i>filicaulis</i> ^{2,3}	220769	Afghanistan	11.2	21.7	7.2	0.27
<i>filicaulis</i> ^{2,3}	314141	USSR	11.9	17.7	6.9	0.25
<i>galegiformis</i> ^{2,4}	206406	Turkey	15.5	15.1	7.2	0.34
<i>globiceps</i> ²	172376	Turkey	14.4	20.9	8.6	0.21
<i>glycyphylus</i> ^{2,4}	234686	Denmark	14.8	16.5	8.6	0.56
<i>glycyphylus</i> ^{2,4}	235070	Switzerland	14.6	14.0	5.9	0.52
<i>hamosus</i> ^{3,4}	214096	Spain	13.7	13.8	6.9	0.16
<i>hamosus</i> ^{3,4}	214103	Spain	11.2	21.0	5.9	0.17
<i>hamosus</i> ^{3,4}	226627	Iran	11.0	19.6	5.9	0.23
<i>hamosus</i> ^{3,4}	227351	Iran	14.2	14.9	7.2	0.19
<i>hamosus</i> ^{3,4}	227440	Iran	13.7	14.4	5.7	0.28
<i>hamosus</i> ^{3,4}	244274	Spain	12.3	18.0	5.9	0.31
<i>hamosus</i> ^{3,4}	244275	Spain	13.9	17.7	5.9	0.17
<i>hamosus</i> ^{3,4}	244276	Spain	12.7	15.1	5.5	0.19
<i>hamosus</i> ^{3,4}	244308	Spain	13.3	13.3	6.4	0.38
<i>hamosus</i> ^{3,4}	287767	Italy	12.5	16.5	4.5	0.22
<i>hamosus</i> ^{3,4}	287768	Italy	13.5	12.0	5.5	0.84
<i>hamosus</i> ^{3,4}	287769	Italy	13.9	11.9	5.0	1.10
<i>hamosus</i> ^{3,4}	302856	Italy	14.0	12.9	4.5	0.21
<i>hamosus</i> ^{3,4}	302857	Italy	10.7	13.9	6.4	0.19
<i>hamosus</i> ^{3,4}	307949	Algeria	13.5	12.2	6.9	0.18
<i>hamosus</i> ^{3,4}	311360	Spain	13.6	13.4	3.5	0.15

Table 1. Continued

Species acid	Plant inventory number	Origin	Protein (%)	Crude fiber (%)	Tannin ¹ (mg/g)	Oxalic (%)
<i>hamosus</i> ^{3,4}	311361	Spain	12.8	14.9	3.5	0.20
<i>hamosus</i> ^{3,4}	311362	Spain	13.7	13.5	5.0	0.39
<i>hamosus</i> ^{3,4}	311363	Spain	13.0	16.6	4.2	0.28
<i>hamosus</i> ^{3,4}	318937	Spain	12.6	14.4	5.0	0.28
<i>incanus</i> ³	318948	Spain	14.5	13.5	5.0	0.39
<i>kotschyanus</i> ^{2,4}	330695	Iran	12.5	23.3	4.2	0.26
<i>macrorrhizus</i>	287771	Spain	16.2	16.6	5.0	0.55
<i>macrorrhizus</i>	28772	Spain	15.2	16.0	5.5	0.38
<i>macrorrhizus</i>	318949	Spain	16.7	17.8	5.5	0.36
<i>mexicanus</i>	214097	Spain	16.1	18.8	5.9	0.30
<i>missouriensis</i>	199780	Canada	8.2	13.4	5.9	0.29
<i>odoratus</i> ⁴	223335	Iran	13.5	16.0	6.1	0.23
<i>podocarpus</i> ^{2,4}	214098	Spain	15.0	16.7	6.6	0.22
<i>refractus</i> ⁴	214099	Spain	10.8	19.7	7.7	0.24
<i>scorpiurus</i>	222036	Afghanistan	12.8	21.4	4.9	0.50
<i>siliquosus</i> ^{2,4}	330696	Iran	20.3	23.0	5.9	0.51
sp.	331372	Ethiopia	13.5	23.5	4.5	0.26
<i>striatus</i> ²	232547	Montana	15.7	20.7	6.4	0.28
<i>striatus</i> ²	236749	Canada	13.8	21.8	5.5	0.65
<i>suffalcatus</i>	220572	Afghanistan	15.2	23.1	5.0	0.23
<i>tribuloides</i> ^{2,3}	220085	Afghanistan	10.8	17.7	7.0	0.20
<i>tribuloides</i> ^{2,3}	220155	Afghanistan	9.4	19.8	6.2	0.21
<i>tribuloides</i> ^{2,3}	220157	Afghanistan	10.4	18.1	10.0	0.24
<i>trimestris</i> ⁴	214102	Spain	10.3	17.0	5.0	0.22
Mean			13.7	17.8	5.9	0.36
Standard deviation			2.6	4.1	1.2	0.21
C.V.			19.3	23.2	20.8	58.5

¹Gallotanic acid equivalent²Selenium accumulator³Annual species.⁴Contains toxic nitro compounds

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