Variability for Morphological and Forage Quality Traits in Sericea Lespedeza [*Lespedeza cuneata* (Dumont de Courset) G. Don] Cultivars

by

Gaganjot Sidhu

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Approved by

Jorge A. Mosjidis, Chair, Professor of Agronomy and Soils
David B. Weaver, Professor of Agronomy and Soils
Donald M. Ball, Extension Specialist & Professor of Agronomy and Soils

Abstract

Sericea lespedeza is a summer perennial forage legume adapted to the environmental conditions of the southeastern USA. Seasonal variations in temperature and genotype play an important role in early growth in this plant but their effect on late growth and regrowth needed to be ascertained. Morphological differences within the canopy have been observed among genotypes developed due to breeding efforts, but they have not been documented experimentally. A growth chamber study that included two experiments was undertaken to determine the effect of temperature and genotype influencing growth and regrowth in five cultivars of sericea lespedeza. Additionally, field experiments were conducted in 2008 and 2009 using five cultivars of sericea lespedeza namely Arlington, Okinawa, Serala, AU Lotan, and AU Grazer released in 1939, 1944, 1962, 1980, and 1997, respectively, to compare characteristics of plant parts such as leaves and stems in the canopy.

The growth chamber study revealed that temperature had a significant ($P < 0.01$) effect- either linear or quadratic on all the traits measured for growth, regrowth as well as on the strata of the plant canopy. Cultivar-temperature interaction was significant for leaf dry weight, stem dry weight, total dry weight for first cut, height and stem thickness for second cut in the first experiment as well as for number of branches and leaf dry weight for upper portion in the second experiment. Results of the field study indicate that portion effects were significant ($P < 0.001$) in both years. Cultivar-portion interaction was significant mostly for the first year (2008) for stem dry weight, number of branches, branch stem weight and branch leaf weight for cut 1 and for

stem dry weight, leaf dry weight, number of branches and total dry weight for cut 2. Shear force was the only trait for which interaction was significant in second year (2009).

AU Grazer was the best or among the best cultivars for plant characteristics important from a production point of view. It ranked last (most pliable) or among the last cultivars in terms of characteristics that reduce pliability such as stem thickness and shear force. Okinawa was judged as the poor performer as it had more stem thickness and required more shear force, though it had a good proportion of leaves as compared to stems.

Forage quality analysis conducted on the plants harvested from field in 2009 showed that there was little variation for all the traits measured such as Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), Tannin and nitrogen content across cultivars in leaves and stems of both plant portions. NDF, ADF, tannin and nitrogen values for upper and lower portion leaves were almost similar in both the cuts. ADL content for leaves was similar in both portions during growth while upper portion showed less ADL values during regrowth. NDF, ADF and ADL content was lower while tannin and nitrogen content was higher for the upper portion stems in both the cuts. New cultivars had lower NDF and ADF values than old cultivars while they had higher ADL values for upper portion stems and leaves during growth and regrowth. Tannin content was also higher in new cultivars. Nitrogen (protein) content was higher in old cultivars.

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I. Literature Review

Species origin, spread and description

Sericea lespedeza (Chinese lespedeza) is a summer perennial legume belonging to Fabaceae family, that originated in Eastern Asia (Pieters, 1939) especially Sino-Indian region of Asia (Mosjidis, 1997). It was introduced into the US towards the end of 19th century. During the period of 1930 to 1940 it was widely seeded for soil conservation in the southeastern US (Pieters et al., 1950) leading to its naturalization to this region (Mosjidis, 1997).

This forage legume has deep roots which can extend up to 120 cm or more in the soil (Guernsey, 1970), and an erect stem with leaves all along the striated stem (Mcgraw and Hoveland, 1995; Mosjidis, 1997). The leaves are alternate, trifoliate with long and narrow leaflets having truncate tips (Mcgraw and Hoveland, 1995). Both cleistogamous as well as chasmogamous flowers, and seeds can be found on this plant where the former are always self fertilized and the latter are cross-pollinated by bees (Cope, 1966b; Donnelly, 1979). Seeds are small and ovoid in shape (Mosjidis, 1997) and the two seed types can be distinguished on the basis of pod shape. Chasmogamous seed production ranged from 10 to 38% of the total seed produced (Cope, 1966b). Chasmogamous seeds are 20% heavier than the cleistogamous seeds (Cope, 1966a).

A significant amount of heterosis exists in sericea lespedeza as is evident from increased herbage and seed yield of hybrids (Donnelly, 1955). The means of segregating populations exceeded the mid parent value for growth traits such as plant height, forage yield, and seed yield.

These traits also showed a sufficiently high heritability ranging from 45.4% to 70.5% (Cope and Moll, 1969). In another study aimed at inheritance of certain morphological and chemical characters and their correlation in sericea lespedeza, heritability estimates for yield, stem number, stem size, and stem pliability were 64%, 60%, 59%, and 76% respectively. A positive correlation (0.62) of yield with number of stems was found. Stem number increased with small stem size (Cope, 1962).

Growth and development

Sericea lespedeza exhibits slow germination and poor seedling establishment attributed to the presence of a germination inhibitor in its seed coat (Logan et al., 1969). Optimum temperatures are central to germination in sericea which are between 20˚C and 30˚C, higher temperature giving more uniform germination (Qiu et al., 1995). Similarly, emergence was reduced by 20% with each reduction of 3˚C in day/night temperature. Hence, early planting in the spring would not be recommended in Alabama (Mosjidis, 1990). However, seedling emergence can be improved by using heavier seeds (Qiu and Mosjidis, 1993). Given the optimum temperature and soil moisture, seedlings emerge 7 to 8 days after sowing.

Towards the end of the season, crown buds are formed at the soil line. Being a warm season perennial legume, it becomes dormant during autumn and new stems arise the following spring from the crown buds. After an active growing season in summer, the shoot growth starts declining in August and food reserves are stored in the taproot for winter (Mosjidis, 1997). Once established, it can persist for years with appropriate management (Ball and Mosjidis, 1995).

Temperature and day length effects on sericea growth

Interaction between the genotype and the environment in which a plant grows determines the plant growth, development as well as the quality. Plant environment is constituted by biotic and abiotic factors. Temperature effects, water deficit, shade and photoperiod are just a few of the factors influencing plant morphology and physiology (Buxton and Casler, 1993). Seasonal variations in temperature and day length as well as genotype have prominent effects on early growth of sericea lespedeza. Temperature produced a linear effect on the emergence of sericea genotypes (Kalburtji et al., 2007; Mosjidis, 1990). Temperature and daylength gave a linear effect on seedling plant characteristics such as height, stem dry weight, and leaf dry weight. Daylength also had a quadratic effect on the seedling height of genotypes. Development of the most vigorous seedlings occurred at 26/22˚C or 30/26˚C and 13 or 15 hour daylength (Mosjidis, 1990). Additionally, during early growth of sericea genotypes temperature had quadratic effects on height and leaf dry weight and exponential effect on the number of branches (Kalburtji et al., 2007).

At reproductive phase, daylength of 13-hour produced the most flowering, gave rise to chasmogamous flowers in all strains and the best seed production. Photoperiods of 14 hours or longer produced neither chasmogamous nor cleistogamous flowers (Bates, 1955).

Breeding history

The introduced sericea possessed thick and coarse stems with high tannin content resulting in low palatability and digestibility. Cattle prefer plants with fine, pliable stems and low tannin content (Donnelly, 1954). Likewise, in a digestion trial with rabbits, significant daily body weight gain was observed in rabbits that consumed the fine stemmed sericea compared to those that consumed coarse stemmed suggesting a relationship of stem type to nutritive quality. Chemical analysis revealed that nutritive characteristics of the two types differ: fine stemmed contained more total digestible nutrients providing more energy than the coarse ones. Fine stemmed sericea was superior than coarse stemmed in terms of digestibility of crude fiber, nitrogen free extract, total carbohydrates and total digestible nutrients by rabbits (Donnelly and Hawkins, 1959). Although the structural constituents of cell were statistically similar in sericea and alfalfa, sericea had more concentration of secondary compounds. Nevertheless, the heifers gave similar daily weight gains suggesting adaptation of rumen organisms to chemical compounds in the forage (Burns et al., 1972). Conversely, tester average daily gain and gain per acre were higher in beef steers grazed on alfalfa than on steers grazed on sericea lespedeza, but AU Lotan sericea was better than Serala sericea (Schmidt et al., 1987). Hence, breeding of sericea was directed toward crop improvement through enhanced morphological characters affecting intake and chemical components related to intake as well as nutritive value.

In recent years, its image has been changed due to breeding programs which facilitated development of sericea cultivars/genotypes with high forage quality and pliable stems. Serala was the first variety developed with fine, pliable stems, more stems per plant and more suited for animal consumption (Donnelly, 1965). Another important landmark in sericea breeding was development of AU Lotan which was similar to Serala in stem type and height but low in tannin content. Additionally, it showed good resistance to foliar disease caused by Rhizoctonia spp. and to three root knot nematodes (Donnelly, 1981; Donnelly and Anthony, 1980). Another cultivar, AU Donnelly released in 1987, averaged 6% higher digestible dry matter and 10% higher crude protein than AU Lotan in conjunction with early spring growth (Mosjidis and Donnelly, 1989). The latest cultivar released was AU Grazer, which is the first grazing tolerant sericea lespedeza

(Mosjidis, 2001). These genotypes vary in terms of yield, resistance to pathogens, tannin content and grazing tolerance. Additional morphological differences have been observed among these genotypes but not experimentally documented.

Forage quality

Chemical composition and most importantly animal performance in terms of daily gain, reproduction, milk or fiber production determines forage quality (Ball et al., 2002). Beside 90% water, forage constituents are mainly of two types: a) cell contents such as protein, sugar and starch b) structural components of cell wall such as cellulose, hemicelluloses and lignin. The cost and time involved in using animals to evaluate forage quality limits their use (Buxton and Mertens, 1995). Hence, forage quality is estimated by chemical methods and microbial or enzymatic methods (Sollenberger and Cherney, 1995). Generally, chemical methods such as Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) measure all cell wall contents and lignin content respectively whereas the protein and energy content is measured in terms of Crude Protein (CP) and In Vitro Dry Matter digestibility (IVDMD) (Ball et al., 2002; Sollenberger and Cherney, 1995). There are several factors affecting forage quality such as plant species, plant part, environment, stage of maturity, fertilization and diurnal fluctuations (Ball et al., 2002).

Various other compounds are also present in forages such as tannins, nitrates, alkaloids, cyanoglycosides, estrogens and mycotoxins, which are referred to as anti-quality factors (Ball et al., 2001). Out of these compounds, tannins are of foremost importance in sericea lespedeza especially condensed tannins since it was thought that high tannin content is less desirable for forage use because of its association with low palatability (Mcgraw and Hoveland, 1995; Wilkins et al., 1953). Tannins are plant phenolic polymers which are commonly divided into two types:

condensed tannins and hydrolysable tannins (Taiz and Zeiger, 2006). Condensed tannins are plant compounds that bind to proteins and other macromolecules; the number of possible bonding sites on both the protein and the CT molecules will determine the extent of their capacity to bind one another. Their effects vary depending on the source of tannin, molecular weight, degree of polymerization, and the type of protein (Mcallister et al., 2005). Sericea lespedeza has both high tannin and low tannin containing cultivars. Low tannin doesn't necessarily means all the plants in that cultivar possess low tannin content, but on an average they possess low tannin content (Mosjidis unpublished data). Similar explanation is viable for high tannin cultivars. Condensed tannins in sericea lespedeza are found to be localized in paraveinal mesophyll cells of leaves and perivascular and vascular parenchyma cells of stems. Amount of polyphenols in leaves of low phenolic (LP) content sericea lespedeza genotype declined with leaf maturity whereas the condensed tannins were highest in half mature leaf as compared to one fourth and full size leaf. In contrast, the polyphenol content and condensed tannins were the same at all stages of leaf development in high phenolic (HP) content genotype. Similarly, fewer polyphenols were found in the stem pith cells in LP genotypes than HP genotypes at half mature and fully mature stage of development. The presence of polyphenols and largely condensed tannins in the vacuoles of paraveinal mesophyll cells revealed their role in photosynthate transport or represent a stored form of excess photosynthates (Mosjidis et al., 1990).

Extensive research has been conducted to study variation in forage quality factors in low tannin and high tannin sericea genotypes. In different years, locations and harvests, low tannin sericea consistently gave 25% higher in vitro dry matter digestibility (IVDMD) than high tannin sericea (Cope and Burns, 1971). Similar result for digestible dry matter (DDM) of low and high tannin sericea plants was obtained using *in vivo* nylon bag technique. A small increase of tannin content in low tannin sericea as compared to greater increase in high tannin sericea was also recorded between two successive cuttings. However, the data also suggested a tannin threshold (near the upper limit of low tannin group) in relation to DDM (Donnelly and Anthony, 1970). Even though the crude protein percentage was the same for both high and low tannin forages, less crude protein in feces was found for steers consuming low tannin sericea, indicating higher digestibility (Donnelly et al., 1971). Differences among low tannin lines and cuttings were found for digestible dry matter, crude protein, and tannin content. However, their interaction was significant for crude protein only. Lines with similar tannin content gave varied amount of IVDDM suggesting another factor/factors affecting IVDDM (Donnelly and Anthony, 1983). Seasonal factors such as temperature and rainfall as well as plant maturity affect the tannin content in sericea plants. It was found that tannin content increased with increase in temperature and decrease in rainfall. The oldest plant tissue had higher tannin content than the youngest tissue. Moreover, successive cuts on the same plant material had higher tannin content. No relationship was found between tannin content and height of the plants (Donnelly, 1959).

Various plant parts of sericea vary from each other in terms of tannin content as well as other quality characteristics. Cope and Burns, 1974 reported that leaves were low in IVDMD and high in tannin as compared to stems when averaged over strains, years, and cuttings while higher values were found for stems for NDF, ADF, Lignin, Lignin/ADF ratio, cellulose and hemicellulose. In contrast to leaves, IVDMD dropped greatly for stems with successive cuts. Stems and leaves of a low tannin strain gave higher IVDMD over all harvests as compared to a fine-stem and a common strain of sericea (Cope and Burns, 1974). The fine stem strain was generally lowest in NDF, ADF and lignin. A negative correlation of fiber content and IVDMD was also reported. However, the researchers indicated that in the case of sericea lespedeza there was a poor correlation between forage quality analysis and animal performance, i.e., animals performed better than predicted by the analysis. Likewise, in a more extensive research effort exploring tannin content within the whole sericea plant, low tannin was found in stems, roots and cotyledons. Intermediate amounts were found in senescent leaves and seeds while higher amounts in younger (top) leaves and flowers (Burns, 1966). Even large strata effects on stem NDF, ADF, protein, cellulose and hemicellulose have been measured. NDF, ADF, cellulose, and hemicellulose concentration was more at the stem base than top whereas protein content reduced from top to bottom of the plant (Mosjidis, 2000). Therefore, forage quality is highest at the top of the stems and decreases in the lower part of the plant.

Small ruminants are increasingly infected with parasitic nematodes and these parasites have acquired resistance to most of the synthetic anthelmintics due to their overuse in the US (Miller and Barras, 1994; Terrill et al., 2001). An effective and viable alternative to the increased anthelmintic resistance is the feeding of condensed tannin-containing forages such as sericea lespedeza hay to the goats infected with nematodes. The effect of feeding sericea lespedeza hay to goats infected with *Haemonchus contortus* was tested in an 8-week feeding trial and it was found that fecal egg count dwindled, suggesting an impact on worm fertility (Shaik et al., 2004). Similarly, when sheep were fed sericea hay, it reduced fecal egg counts and also eliminated established worms of *Haemonchus contortus* and reduced the pasture contamination (Lange et al., 2006). Condensed tannin containing forages resulted in increased milk production in sheep (Barry and Mcnabb, 1999) and dairy cows (Woodward et al., 1999). Tannins in sericea also increase the protein efficiency to animals by escalating the by-pass protein level (Messman et al., 1996).

Economic importance and utilization

As a forage crop, sericea lespedeza possesses numerous desirable qualities that enable it to be used for grazing, hay or conservation purposes. In the USA, it is suited to well drained upland soils especially in the Upper South. Unlike other legumes, it can be grown on a broad range of sites such as highly acidic or infertile. It grows well on eroded land, strip mines and along roadsides. Ideally, it is grown under a pH range of 5.8 – 6.5 (Ball and Mosjidis, 1995) but it can tolerate aluminium toxic conditions in the soil (Campbell et al., 1991) because of its ability to entrap the Al in its inactive form in the roots and reducing Al/P interactions, resulting in normal root and shoot growth (Joost and Hoveland, 1985).

It is relatively more resistant to drought than other forage crops because of its deep taproot system (Ball and Mosjidis, 2007). Significant insect and disease damage has been found to be very rare. Being a legume it fixes its own nitrogen, hence, no nitrogen fertilization is required. As a hay crop, sericea requires short time interval to be baled after mowing because of its tendency to dry rapidly (Ball and Mosjidis, 2007). For conservation purposes, it can shed its lower leaves creating mulch and thereby improving soil structure by increasing soil organic matter. A four year stand of sericea lespedeza grown for hay production and soil conservation or biomass production gave a residue of 3800 kg ha^{-1} and 7600 kg ha^{-1} respectively (Kalburtji and Mosjidis, 1993).

After establishment, sericea incurs very little maintenance costs compared to other forages. In fact, when compared to many other forage crops adapted in Alabama, it was among the most economical in terms of total pasture costs/lb of gain of stocker steers (Ball and Prevatt, 2009). Another important feature of this crop is its potential for biofuel production.

Considerable variation is present for biomass yield. Moreover, it negates the need for storage as it can stay in the field uncut during winters, unlike other herbaceous species (Mosjidis, 1996).

References

Ball, D., and J. Mosjidis. 2007. Sericea Lespedeza: A Pasture, Hay, and Conservation Plant, Alabama Cooperative Extension System., ANR-1318.

Ball, D., and W. Prevatt. 2009. Stocker cattle performance and calculated pasture costs, Alabama Cooperative Extension System, Auburn University, ANR-1348.

Ball, D.M., and J.A. Mosjidis. 1995. An objective look at sericea lespedeza, Proceedings of the 51st southern and pasture forage crop improvement conference, Blacksburg, Virginia.

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 2002. Forage Quality, Southern Forages. pp. 136-145.

Ball, D.M., M. Collins, G.D. Lacefield, N.P. Martin, D.A. Mertens, K.E. Olson, D.H. Putnam, D.J. Undersander, and M.W. Wolf. 2001. Understanding forage quality, American Farm Bureau Federation Publication 1-01, Park Ridge, IL.

Barry, T.N., and W.C. Mcnabb. 1999. The implications of condensed tannins on the nutritive value of temperate forages fed to ruminants. British Journal of Nutrition 81:263-272.

Bates, R.P. 1955. Effects of photoperiods on plant growth, flowering, seed production and tannin content of *Lespedeza cuneata* Don. Agronomy Journal 47:564-567.

Burns, J.C., R.D. Mochrie, and W.A. Cope. 1972. Responses of dairy heifers to crownvetch, sericea lespedeza, and alfalfa forages. Agronomy Journal 64:193-195.

Burns, R.E. 1966. Tannin in sericea lespedeza, Georgia Agricultural Experiment Station Bulletin 164.

Buxton, D.R., and M.D. Casler. 1993. Environmental and genetic effects on cell wall composition and digestibility, in: H. G. Jung, et al. (Eds.), Forage Cell Wall Structure and Digestibility, Madison, Wisconsin. pp. 685-714.

Buxton, D.R., and D.R. Mertens. 1995. Quality-related Characteristics of Forages, in: R. F. Barnes, et al. (Eds.), Forages:The Science of Grassland Agriculture, Iowa State University Press. pp. 83-96.

Campbell, T.A., N.J. Nuernberg, and C.D. Foy. 1991. Differential responses of sericea lespedeza to aluminium stress. Journal of Plant Nutrition 14:1057-1066.

Cope, W.A. 1962. Heritability estimates and correlations of yield and certain morphological and chemical components of forage quality in sericea lespedeza. Crop Science 2:10-12.

Cope, W.A. 1966a. Growth rate and yield in Sericea Lespedeza in relation to seed size and outcrossing. Crop Science 6:566-568.

Cope, W.A. 1966b. Cross Pollination in Sericea Lespedeza. Crop Science 6:469-470.

Cope, W.A., and R.H. Moll. 1969. Inheritence of yield, forage quality and seed characteristics in sericea lespedeza. Crop Science 9:467-470.

Cope, W.A., and J.C. Burns. 1971. Relationship between tannin levels and nutritive value of sericea. Crop Science 11:231-233.

Cope, W.A., and J.C. Burns. 1974. Components of forage quality in sericea lespedeza in relationship to strain, season, and cutting treatments. Agronomy Journal 66:389-394.

Donnelly, E.D. 1954. Some factors that affect palatability in Sericea Lespedeza, *L. cuneata*. Agronomy Journal 46:96-97.

Donnelly, E.D. 1955. The effects of outcrossing on forage and seed yields in sericea lespedeza, *L. cuneata*. Agronomy Journal 47:466-467.

Donnelly, E.D. 1959. The effect of season, plant maturity, and height on the tannin content of sericea lespedeza, *L. cuneata*. Agronomy Journal 51:71-73.

Donnelly, E.D. 1965. Serala Sericea (Reg. No. 4). Crop Science 5:605.

Donnelly, E.D. 1979. Selection for chasmogamy in sericea lespedeza. Crop Science 19:528-531.

Donnelly, E.D. 1981. Registration of AU Lotan Sericea Lespedeza (Reg. No. 11). Crop Science 21:474.

Donnelly, E.D., and G.E. Hawkins. 1959. The effects of stem type on some feeding qualities of sericea lespedeza, *L. cuneata*, as indicated in a digestion trial with rabbits. Agronomy Journal 51:293-294.

Donnelly, E.D., and W.B. Anthony. 1970. Effect of genotype and tannin on dry matter digestibility in sericea lespedeza. Crop Science 10:200-202.

Donnelly, E.D., and W.B. Anthony. 1980. New Auburn Sericea Variety AU Lotan: Low Tannin, Nutritious Forage, Highlights of Agricultural Research. 27., Alabama Agricultural Experiment Station.

Donnelly, E.D., and W.B. Anthony. 1983. Breeding low-tannin sericea. III. Variation in forage quality factors among lines Crop Science 23:982-984.

Donnelly, E.D., W.B. Anthony, and J.W. Langford. 1971. Nutritive relationships in low and high tannin sericea lespedeza under grazing. Agronomy Journal 63:749-751.

Guernsey, W.J. 1970. Sericea lespedeza: its use and management, in: USDA (Ed.), Farmers Bulletin 2245.

Joost, R.E., and C.S. Hoveland. 1985. Mechanism of aluminium tolerance in sericea lespedeza, Proceedings of the XV International Grassland Congress, Kyoto, Japan. pp. 394-396.

Kalburtji, K.L., and J.A. Mosjidis. 1993. Effects of sericea lespedeza residues on cool season grasses. Journal of Range Management 46:315-319.

Kalburtji, K.L., J.A. Mosjidis, and A.P. Mamolos. 2007. Effects of day-night temperature combinations under constant day length on emergence and early growth of sericea lespedeza genotypes. Can. J. Plant Sci. 87.

Lange, K.C., D.D. Olcott, J.E. Miller, J.A. Mosjidis, T.H. Terrill, J.M. Burke, and M.T. Kearney. 2006. Effect of sericea lespedeza (*Lespedeza cuneata*) fed as hay, on natural and experimental *Haemonchus contortus* infections in lambs. Veterinary Parasitology 141:273-278.

Logan, R.H., C.S. Hoveland, and E.D. Donnelly. 1969. A germination inhibitor in the seedcoat of sericea. Agronomy Journal 61:265-266.

Mcallister, T.A., T. Martinez, H.D. Bae, A.D. Muir, L.J. Yanke, and G.A. Jones. 2005. Characterization of condensed tannins purified from legume forages: chromophore production, protein precipitation, and inhibitory effects on cellulose digestion. Journal of Chemical Ecology 31:2049-2068.

Mcgraw, R.L., and C.S. Hoveland. 1995. Lespedezas, in: R. F. Barnes, et al. (Eds.), Forages: An introduction to grassland agriculture, Iowa State University Press, Ames, Iowa. pp. 261-271.

Messman, M.A., W.P. Weiss, and K.A. Albrecht. 1996. In situ disappearance of individual proteins and nitrogen from forage legumes containing varying amounts of tannins. J. Dairy Science 79:1430-1435.

Miller, J.E., and S.R. Barras. 1994. Ivermectin resistant *Haemonchus contortus* in Louisiana lambs. Veterinary Parasitology 55:343-346.

Mosjidis, C.O.H., C.M. Peterson, and J.A. Mosjidis. 1990. Developmental differences in the location of polyphenols and condensed tannins in leaves and stems of sericea lespedeza, Lespedeza cuneata. Annals of Botany 65:355-360.

Mosjidis, J.A. 1990. Daylength and temperature effects on emergence and early growth of sericea lespedeza. Agronomy Journal 82:923-926.

Mosjidis, J.A. 1996. Variability for biomass production and plant composition in sericea lespedeza. Biomass and Bioenergy 11:63-68.

Mosjidis, J.A. 1997. Lespedeza cuneata (Dumont de Courset) G. Don, in: I. F. Hanum and L. J. G. v. d. Maesen (Eds.), Plant Resources of South-East Asia No. 11, Auxiliary plants, Backhuys Publishers, Leiden, The Netherlands. pp. 170-173.

Mosjidis, J.A. 2000. Sericea lespedeza biomass composition for bioenergy in the southeastern USA, 1st World Conference on Biomass for Energy and Industry, Sevilla, Spain. pp. 321-322.

Mosjidis, J.A. 2001. Registration of 'AU Grazer' Sericea Lespedeza. Crop Science 41:262.

Mosjidis, J.A., and E.D. Donnelly. 1989. Registration of 'AU Donnelly' Sericea Lespedeza. Crop Science 29:237-238.

Pieters, A.J. 1939. Lespedeza sericea and other perrenial lespedezas for forage and soil conservation, in: USDA (Ed.), Circ. 534.

Pieters, A.J., P.R. Henson, W.E. Adams, and A.P. Barnett. 1950. Sericea and other perennial lespedezas for forage and soil conservation in: USDA (Ed.), Circ. 863.

Qiu, J., and J.A. Mosjidis. 1993. Relationships among maximum hypocotyl length, seed weight, and emergence in sericea lespedeza. Agronomy Journal 85:995-998.

Qiu, J., J.A. Mosjidis, and J.C. Williams. 1995. Variability for temperature of germination in sericea lespedeza germplasm. Crop Science 35:237-241.

Schmidt, S.P., C.S. Hoveland, E.D. Donnelly, J.A. McGuire, and R.A. Moore. 1987. Beef steer performance on Cimarron alfalfa and Serala and AU Lotan sericea lespedeza pastures, Circular 288, Alabama Agricultural Experiment Station, Auburn University.

Shaik, S.A., T.H. Terrill, J.E. Miller, B. Kouakou, G. Kannan, R.K. Kallu, and J.A. Mosjidis. 2004. Effects of feeding sericea lespedeza hay to goats infected with *Haemonchus contortus*. South African Journal of Animal Science 34 (Supplement 1):248-250.

Sollenberger, L.E., and D.J.R. Cherney. 1995. Evaluating Forage Production and Quality, in: R. F. Barnes, et al. (Eds.), Forages: The Science of Grassland Agriculture, Iowa State University Press. pp. 97-110.

Taiz, L., and E. Zeiger. 2006. Secondary metabolites and plant defense, Plant physiology, Sinauer Associates, Inc., Publishers, Sunderland, Massachussets.

Terrill, T.H., R.M. Kaplan, M. Larsen, O.M. Samples, J.E. Miller, and S. Gelaye. 2001. Anthelmintic resistance on goat farms in Georgia. Efficacy of anthelmintics against gastrointestinal nematodes in two selected goat herds. Veterinary Parasitology 97:261-268.

Wilkins, H.L., R.P. Bates, P.R. Henson, I.L. Lindahl, and R.E. Davis. 1953. Tannin and palatability in sericea lespedeza, *L. cuneata*. Agronomy Journal 45:335-336.

Woodward, S.L., M.J. Auldist, P.J. Laboyrie, and E.B.L. Jansen. 1999. Effect of *Lotus corniculatus* and condensed tannins on milk yield and milk composition of dairy cows. Proc. N. Z. Soc. Anim. Prod. 59:152-155.

II. Effect of temperature and genotype on growth of sericea lespedeza cultivars

Abstract

Sericea lespedeza is a summer perennial forage legume adapted to the environmental conditions of the southeast of the USA. Research has determined that seasonal variations in temperature and genotype play an important role on early growth in this plant but their effect on late growth and regrowth as well as on the effect of plant characteristics within the canopy has not been documented. A growth chamber study was undertaken to determine the effect of temperature and genotype influencing growth and regrowth in five cultivars of sericea lespedeza. Two simultaneous experiments were conducted using five cultivars of sericea lespedeza namely Arlington, Okinawa, Serala, AU Lotan, and AU Grazer released in 1939, 1944, 1962, 1980, and 1997, respectively. The plants were grown in environmental chambers under 14 h of daylength at three day-night temperature combinations (32/19°C, 28/15°C, and 24/11°C).

Temperature had a significant ($P < 0.01$) effect-either linear or quadratic on all the traits measured for the growth, regrowth as well as on the strata of the plant. Cultivar-temperature interaction was significant for leaf dry weight, stem dry weight, total dry weight for first cut, height and stem thickness for second cut in first experiment as well as for number of branches and leaf dry weight for upper portion in second experiment. AU Grazer was the best or among the best cultivars for plant characteristics important from production point of view whereas it was the last ranked or among the last ranked cultivars in terms of characteristics affecting

pliability such as stem thickness and shear force. However, it had a higher proportion of stems than the leaves. Okinawa was considered as the poorest performer as it had greater stem thickness and required more shear force, though it had a good proportion of leaves as compared to stems.

Introduction

Sericea lespedeza is a summer perennial forage legume adapted to the environmental conditions of the southeast of the USA. Research has determined that seasonal variations in temperature and genotype play an important role on early growth in this plant. Traits such as germination and emergence can be severely reduced by low temperatures in the spring (Mosjidis, 1990; Qiu et al., 1995).

Seedling plant characteristics such as height, stem dry weight, and leaf dry weight of different genotypes of sericea lespedeza have exhibited mostly a linear relationship with temperature. Seedling vigor was greatest at 26/22˚C or 30/26˚C (Mosjidis, 1990). Additionally, temperature had a quadratic effect on early growth traits such as height and leaf dry weight of 56 sericea lespedeza genotypes studied with an optimum around 23˚C and 21˚C respectively whereas stem dry weight increased linearly with temperature. An exponential effect of temperature on the number of branches was measured by Kalburtji et al. (2007). Variability for early vegetative traits was accounted mostly due to temperature and to a lesser extent due to the genotypes studied (Mosjidis, 1990).

During the last 70 years, breeding programs have developed sericea cultivars/genotypes with higher forage quality and pliable stems. Arlington and Okinawa were the earliest cultivars released in 1939 and 1944 by the Soil Conservation Service (SCS), North Carolina (USDA-ARS; Pieters et al., 1950) and SCS, Georgia (USDA-ARS; C.M. Owsley, personal communication) respectively. Serala, released in 1962, was the first variety with fine, pliable stems and more stems per plant (Donnelly, 1965). In 1980, AU Lotan was released, and was the first variety with reduced tannin content but having 85 % dry matter yield compared to that of Serala (Donnelly, 1981). Subsequently, AU Grazer, released in 1997 (Mosjidis, 2001), was the first grazing tolerant cultivar. These genotypes vary among themselves in terms of yield, resistance to pathogens (Donnelly, 1981), tannin content (Donnelly, 1981) and grazing tolerance (Mosjidis, 2001). Although more morphological differences have been observed among these genotypes, they have not been documented experimentally.

Little is known regarding the effect of temperature or temperature - cultivar interaction on late growth and regrowth as measured by traits such as stem, leaf and total dry weight, stem thickness, number of branches and leaf and stem percentage in sericea lespedeza. The objectives of this study were to determine the effect of temperature and genotype influencing growth and regrowth in five cultivars of sericea lespedeza.

Materials and Methods

Two experiments were conducted in the growth chamber using five cultivars of sericea lespedeza, namely Arlington, Okinawa, Serala, AU Lotan, and AU Grazer released in 1939, 1944, 1962, 1980, and 1997, respectively. The former three were considered as old cultivars while the latter two were considered as new cultivars. The plants were grown in environmental chambers under 14 h of daylength at three day-night temperature combinations (32/19°C, 28/15°C, and 24/11°C). Five replications (pots) of each cultivar were sown in pots, 10 cm diameter by 19.4 cm long (total volume = 3.8 L), filled with Sunshine Mix # 8 (Sun Gro Horticulture Canada Ltd.) for each experiment. After emergence, each pot was thinned to 5 plants. Photosynthetic flux density during daylength was 394 µmol m^{-2} s^{-1} provided by a mixture of fluorescent and incandescent lamps. Water was added only when the soil surface dried.

In the first experiment, the plants were cut twice when they reached a height of approximately 35cm each time. Height, stem thickness, leaf and stem dry weight and number of branches were measured for each plant. Plant height was measured at 5 and 7 weeks after planting and plant growth rate before the first cut was calculated by taking the difference between the height at 5 and 7 weeks and dividing it by the number of days falling in that interval. Similarly, plant height at 6 weeks after the first cut and at the time of second cut were measured and used to calculate plant growth rate after the first cut by dividing the height difference with the number of days falling in that interval. Leaf and stem dry weights were added to get total dry weight. Leaf and stem percentage were calculated by dividing the respective dry weights by total dry weight. Additionally, the numbers of stems regrown were counted after the first cut. Height, stem thickness, number of branches and plant growth rate were averaged per plant per replication (pot). For leaf dry weight and stem dry weight, the values were added within the pot (not averaged per plant).

Data were analyzed by cut as a factorial experiment in a split plot design with temperature as main plots and cultivars as subplots. Data were subjected to analysis of variance using SAS® PROC GLIMMIX. Least square means were used for mean separation at $P \leq 0.05$.

In the second experiment, the plants were cut at approximately 70 cm height and divided in two equal halves, generating upper and lower sections for stems and leaves. Stem thickness, leaf and stem dry weight and number of branches were measured for each portion for each plant. Leaf and stem dry weights of upper portion were added to get total upper dry weight. Similarly, lower total dry weight was calculated. For each portion of the canopy, leaf and stem percentage were calculated by dividing the respective dry weights to total dry weight. For each portion, stem thickness and number of branches were expressed on a plant basis. For leaf dry weight and stem dry weight, the values were expressed on a pot basis for each portion.

Data on the traits measured for upper as well as lower portion were analyzed by portion as a factorial experiment in a split plot design with temperature as main plots and cultivars as subplots. Data were subjected to analysis of variance using SAS® PROC GLIMMIX. Least square means were used for mean separation at $P \leq 0.05$.

In each harvest for both experiments, plants were cut at about 3 cm above the soil line to ensure regrowth, and stem thickness was measured with vernier caliper. Leaves were separated from the stem and freeze dried for 48 hours. A growth of 1.5 cm or more on the stem was considered as a branch. The first run of 32/19°c was used as a template to record the number of days that plants require to attain: a height of 35 cm, regrowth up to the height of 35 cm for the first experiment, and the height of 70 cm for the second experiment. This determined the number of days that the plants were allowed to grow at the other two temperature sets.

Results and Discussion

Experiment 1

Cut 1

Height

The analysis of variance showed that main effects of temperature ($P < 0.0001$) and cultivar ($P < 0.05$) were significant. The temperature-cultivar interaction was not significant; i.e., different cultivars responded similarly to the temperatures. Temperature was found to have mostly a significant ($P < 0.001$) linear effect on height of sericea lespedeza cultivars (Figure 1). As temperature increased plants were taller. Also there was a small quadratic effect. The temperature combination 32/19˚C produced the tallest plants whereas 24/11˚C produced the shortest plants. Plants on an average were 61% more taller at 32/19˚C than plants at 24/11˚C. The average plant height for cultivars across all temperatures ranged from 31.5 cm to 35.8 cm. Okinawa had the shortest plants (31.5 cm) and this cultivar was significantly shorter than AU Grazer (34.6 cm), AU Lotan (35.1 cm) and Arlington (35.8 cm) whereas the latter three cultivars and Serala (34.2 cm) were not significantly different amongst themselves.

Stem thickness

Temperature had a significant ($P < 0.0001$) effect on stem thickness. It was found to have a significant ($P < 0.0001$) quadratic effect. Thickest stems were found at 28/15˚C (Figure 2). Mean stem thickness at 24/11˚C, 28/15˚C and 32/19˚C was 0.59 mm, 0.99 mm and 0.87 mm respectively. Cultivar and temperature-cultivar interaction were not significant.

Number of branches

Temperature had a significant ($P < 0.01$) effect on number of branches. It was found to have a significant ($P < 0.0001$) quadratic effect. The highest number of branches were measured at 28/15˚C (Figure 3). Mean number of branches measured at 24/11˚C, 28/15˚C and 32/19˚C were 0.90, 2.38 and 0.91 respectively. Temperature 28/15˚C was significantly different from 24/11˚C and 32/19˚C whereas the latter two were not significantly different from each other. Cultivar and temperature-cultivar interaction were not significant.

Leaf dry weight

Temperature had a significant ($P < 0.0001$) effect on leaf dry weight. Highest leaf dry weight was found at 32/19˚C. Mean leaf dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.25 g, 0.69 g and 0.80 g. Main effects of cultivar were not significant. Temperature-cultivar interaction was significant ($P < 0.05$). Temperature had a significant ($P < 0.05$) quadratic effect on leaf dry weight of Okinawa, Arlington, Serala and AU Lotan whereas it had a significant ($P < 0.0001$) linear effect on leaf dry weight of AU Grazer (Figure 4). Regression equations with R^2 values are shown in Table 1. Mean leaf dry weight for cultivars at 24/11˚C, 28/15˚C and 32/19˚C ranged from 0.23 to 0.25 g, 0.60 to 0.79 g and 0.68 to 1.00 g, respectively. Cultivars were not significantly different from each other at 24/11˚C. At 28/15˚C, AU Grazer had a leaf dry weight of 0.60 g and this weight was significantly lower than the leaf dry weight of Arlington, the cultivar with the highest value. Remaining cultivars had similar leaf dry weights at $P < 0.05$ at this temperature. However, at 32/19˚C, AU Grazer had the highest leaf dry weight which was significantly higher than the leaf dry weight of AU Lotan, Okinawa and Serala. Remaining cultivars had similar leaf dry weights at $P < 0.05$ at this temperature.

Stem dry weight

Temperature had a significant ($P < 0.0001$) effect on stem dry weight. Highest stem dry weight was found at 32/19˚C. Mean stem dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.14 g, 0.41 g and 0.56 g. Main effects of cultivar were not significant. Temperature-cultivar interaction was significant at $P < 0.07$. Temperature was found to have a significant quadratic effect ($P < 0.05$) on stem dry weight of AU Lotan. Small quadratic effects of temperature were found on stem dry weight of Okinawa and Arlington whereas temperature had a highly significant ($P <$

0.0001) linear effect on stem dry weight of Serala and AU Grazer (Figure 5). Regression equations with R^2 values are shown in Table 2. Mean stem dry weight for cultivars at 24/11˚C, 28/15˚C and 32/19˚C ranged from 0.13 to 0.14 g, 0.35 to 0.47 g and 0.44 to 0.70 g, respectively. Cultivars were not significantly different from each other at 24/11˚C and 28/15˚C. However, at 32/19˚C, AU Grazer had significantly higher stem dry weight than AU Lotan, Okinawa and Serala. Also Arlington had significantly higher stem dry weight than Okinawa. Remaining cultivars had similar stem dry weights at $P < 0.05$ at this temperature.

Total dry weight

Temperature had a significant ($P < 0.0001$) effect on total dry weight. Highest total dry weight was found at 32/19˚C. Mean total dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.38 g, 1.09 g and 1.35 g. Main effects of cultivar were not significant. Temperature-cultivar interaction was also significant ($P < 0.05$). Temperature had a significant ($P < 0.05$) quadratic effect on total dry weight of Okinawa, AU Lotan and Arlington. Small quadratic effects of temperature were found on total dry weight of Serala whereas it was found to have a significant linear effect ($P < 0.0001$) on total dry weight of AU Grazer (Figure 6). Regression equations with R^2 values are shown in Table 3. Mean total dry weight for cultivars at 24/11˚C, 28/15˚C and 32/19˚C ranged from 0.36 to 0.40 g, 0.96 to 1.26 g and 1.13 to 1.70 g, respectively. Cultivars were not significantly different from each other at 24/11˚C. At 28/15˚C, AU Grazer had significantly lower total dry weight than Arlington. Remaining cultivars had similar total dry weights at $P < 0.05$ at this temperature. However, at 32/19˚C, AU Grazer had significantly higher total dry weight than AU Lotan, Okinawa and Serala. Also, Arlington had significantly higher total dry weight than Okinawa. Remaining cultivars had similar total dry weights at $P < 0.05$ at this temperature.

Leaf percentage

The analysis of variance showed that main effects of temperature ($P < 0.0001$) and cultivar ($P < 0.01$) were significant. The temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.01$) quadratic effect on leaf percentage of sericea lespedeza cultivars. Mean leaf percentage found at 24/11˚C, 28/15˚C and 32/19˚C was 64%, 63% and 59% respectively. Temperature 32/19˚C was significantly different from 24/11˚C and 28/15˚C whereas the latter two were not significantly different from each other. Highest leaf percentage was found at 24/11˚C (Figure 7). The average leaf percentage for cultivars across all temperatures ranged from 61% to 64%. Okinawa had the highest leaf percentage (64%) which was significantly higher than Serala (63%), Arlington (62%), AU Grazer (62%) and AU Lotan (61%). Also, Serala had significantly higher leaf percentage than AU Lotan. Remaining cultivars had similar leaf percentage at $P < 0.05$.

Stem percentage

Main effects of temperature ($P < 0.0001$) and cultivar ($P < 0.01$) were significant. The temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.01$) quadratic effect on stem percentage. Mean stem percentage found at 24/11˚C, 28/15˚C and 32/19˚C was 36%, 37% and 41%. Temperature 32/19˚C was significantly different from 24/11˚C and 28/15˚C whereas the latter two were not significantly different from each other. The highest stem percentage was found at 32/19˚C (Figure 8). The average stem percentage for cultivars across all temperatures ranged from 36% to 39%. Okinawa had the smallest stem percentage (36%) and this cultivar was significantly different from AU Lotan (39%), AU Grazer

(38%), Arlington (38%) and Serala (37.5%). Also, Serala had significantly less stem percentage than AU Lotan. Remaining cultivars had similar stem percentage at $P < 0.05$.

Height growth rate

Only main effects of temperature were significant ($P < 0.0001$). Temperature was found to have a significant ($P < 0.001$) quadratic effect on height growth rate. Fastest height growth rate was found at 32/19˚C (Figure 9). Mean height growth rate at 24/11˚C, 28/15˚C and 32/19˚C was 0.38, 0.70 and 0.81 cm/day respectively. Cultivar and temperature-cultivar interaction were not significant.

Cut 2

Height

The analysis of variance showed that temperature had a significant ($P < 0.0001$) effect on height of regrowth in sericea lespedeza cultivars. Temperature 32/19˚C produced the tallest plants whereas 24/11˚C produced the shortest plants. Average height obtained at 24/11˚C, 28/15˚C and 32/19˚C was 14.5 cm, 17.0 cm and 41.3 cm. Main effects of cultivar were not significant. The temperature-cultivar interaction was significant ($P < 0.01$) i.e., different cultivars responded differently to changes in temperature. Temperature was found to have a significant ($P < 0.001$) quadratic effect on the height of all sericea lespedeza cultivars (Figure 10). Regression equations with R^2 values are shown in Table 4. Mean height for cultivars at 24/11˚C, 28/15˚C and 32/19˚C ranged from 11.7 to 17.7 cm, 15.3 to 19.3 cm and 40.4 to 44.5 cm respectively. At 24/11˚C, AU Grazer (11.7 cm), AU Lotan (12.3 cm) and Okinawa (13.1 cm) were significantly shorter than Arlington (17.7 cm) and Serala (17.7 cm) whereas the former three and the latter two cultivars were not significantly different from each other, respectively. At 28/15˚C, AU Grazer (19.3 cm) was significantly taller than Arlington (15.3 cm) whereas all the remaining cultivars were not significantly different from each other. At 32/19˚C, AU Grazer was significantly taller than all the rest of the cultivars ($P < 0.07$).

Stem thickness

Temperature had a significant ($P < 0.0001$) effect on the stem thickness of sericea lespedeza cultivars. Thickest stems were found at 32/19˚C. Average stem thickness measured at 24/11˚C, 28/15˚C and 32/19˚C was 0.29 mm, 0.48 mm and 0.78 mm respectively. The stems on an average were 2.7 times thicker at 32/19˚C as compared to stems at 24/11˚C. Main effects of cultivar were not significant. Temperature-cultivar interaction was significant at $P < 0.07$. Temperature was found to have a significant ($P < 0.0001$) linear effect on stem thickness of Okinawa, AU Lotan and AU Grazer while it had a significant ($P < 0.005$) quadratic effect for Arlington stems. Small quadratic effect of temperature was recorded for Serala stems (Figure 11). Regression equations with R^2 values are shown in Table 5. Mean stem thickness for cultivars at 24/11˚C, 28/15˚C and 32/19˚C ranged from 0.23 to 0.34 mm, 0.45 to 0.50 mm and 0.75 to 0.80 mm respectively. At 24/11˚C, AU Grazer (0.23 mm) and AU Lotan (0.24 mm) were significantly thinner than Arlington (0.34 mm) and Serala (0.34 mm). Okinawa (0.29 mm) was not significantly different from any of the cultivars tested. However, no significant differences were found among cultivars at temperatures 28/15˚C and 32/19˚C.

Number of branches

Temperature had a significant ($P < 0.0001$) effect on number of branches. It was found to have a significant quadratic effect ($P < 0.0001$). The highest number of branches were measured at 32/19˚C (Figure 12). Mean number of branches measured at 24/11˚C, 28/15˚C and 32/19˚C were

0.04, 0.05 and 1.84 respectively. Temperature 32/19˚C was significantly different from 24/11˚C and 28/15˚C whereas the former two were not significantly different from each other. Cultivar and temperature-cultivar interaction were not significant.

Leaf dry weight

Temperature had a significant (*P* < 0.0001) effect on leaf dry weight. It was found to have a significant (*P* < 0.0001) quadratic effect. The highest leaf dry weight was found at 32/19˚C (Figure 13). Mean leaf dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.07 g, 0.19 g and 1.06 g. Cultivar and temperature-cultivar interaction were not significant.

Stem dry weight

Temperature had a significant (*P* < 0.0001) effect on stem dry weight. It was found to have a significant (*P* < 0.0001) quadratic effect. Highest stem dry weight was found at 32/19˚C (Figure 14). Mean stem dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.03 g, 0.09 g and 0.77 g. Temperature 32/19˚C was significantly different from 24/11˚C and 28/15˚C whereas the former two were not significantly different from each other. Cultivar and temperature-cultivar interaction were not significant.

Total dry weight

The analysis of variance showed that temperature had a significant (*P* < 0.0001) effect on total dry weight of sericea lespedeza cultivars. It was found to have a significant (*P* < 0.0001) quadratic effect. Highest total dry weight was found at 32/19˚C (Figure 15). Mean total dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.10 g, 0.28 g and 1.82 g. Cultivar and temperature-cultivar interaction were not significant.

Leaf percentage

Main effects of temperature ($P < 0.0001$) and cultivar ($P < 0.07$) were significant. The temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.0001$) quadratic effect on leaf percentage of sericea lespedeza cultivars. Mean leaf percentage found at 24/11˚C, 28/15˚C and 32/19˚C was 65%, 69% and 58% respectively. Highest leaf percentage was found at 28/15˚C (Figure 16). The average leaf percentage for cultivars across all temperatures ranged from 62% to 65%. AU Lotan (62%) and AU Grazer (63%) had significantly lower leaf percentage than Okinawa (65%). Also, AU Lotan had significantly lower leaf percentage than Arlington (64%). Remaining cultivars had similar leaf percentage at $P < 0.05$.

Stem percentage

Main effects of temperature ($P < 0.0001$) and cultivar ($P < 0.07$) were significant. The temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.0001$) quadratic effect on stem percentage of sericea lespedeza cultivars. Mean leaf percentage found at 24/11˚C, 28/15˚C and 32/19˚C was 35%, 31% and 42% respectively. Highest stem percentage was found at 32/19˚C (Figure 17). The average stem percentage for cultivars across all temperatures ranged from 35% to 38%. AU Lotan (38%) and AU Grazer (37%) had significantly higher stem percentage than Okinawa (35%). Also, AU Lotan had significantly higher stem percentage than Arlington (36%) whereas the remaining cultivars were not significantly different from each other.

Height growth rate

Only main effects of temperature were significant ($P < 0.0001$). Temperature was found to have a significant ($P < 0.001$) linear effect on height growth rate. Fastest height growth rate was found at 32/19˚C (Figure 18). Mean height growth rate at 24/11˚C, 28/15˚C and 32/19˚C was 0.08, 0.17 and 0.31 cm/day respectively. Cultivar and temperature-cultivar interaction were not significant.

Number of stems regrown

Only main effects of temperature were significant ($P < 0.0001$). Temperature was found to have a significant ($P < 0.001$) linear effect on the regrowth of number of stems. Maximum number of stems regrown were found at 32/19˚C (Figure 19). Mean number of stems regrown measured at 24/11˚C, 28/15˚C and 32/19˚C were 6.48, 7.28 and 9.12 cm/day respectively. Cultivar and temperature-cultivar interaction were not significant.

Summary

In summary, for the first growth (cut 1), as temperature increased, height of the cultivars increased linearly whereas stem thickness, number of branches, leaf percentage decreased with a quadratic effect. Stem thickness and number of branches peaked at 28/15˚C. Leaf percentage was highest at 24/11˚C Temperature also produced a quadratic effect on stem percentage and height growth rate peaking at 32/19˚C. Temperature-cultivar interaction was significant for leaf dry weight, stem dry weight and total dry weight. AU Grazer had a different type of response to temperature than the other cultivars. It grew linearly for leaf dry weight, stem dry weight and total dry weight.

Temperature affected regrowth after cutting in a similar manner for stem percentage only. Though the temperature effects were mostly quadratic as that for growth, the trend was opposite.

Height, number of branches, leaf dry weight, stem dry weight, total dry weight peaked at 32/19˚C. Leaf percentage also showed a quadratic response to temperature peaking at 28/15˚C. As temperature increased, the height growth rate increased linearly. Temperature-cultivar interaction was significant for height and stem thickness only. For height, all cultivars showed a quadratic trend whereas for stem thickness a linear trend was observed for all cultivars except for Arlington (linear trend).

Conclusions

Temperature had a significant effect on all the traits studied. The linear response of AU Grazer for leaf dry weight, stem dry weight and total dry weight during growth makes it more suitable for Alabama conditions where 32/19˚C is a common temperature in summers. For regrowth, the production increased for all cultivars for traits such as leaf dry weight, stem dry weight and total dry weight from 24/11˚C to 32/19˚C but with a quadratic response. Quality is expected to decline at 32/19˚C, since leaf percentage decreased at this temperature for growth as well as regrowth.

Experiment 2

Upper Portion

Stem thickness

The analysis of variance showed that main effects of temperature and cultivar were significant ($P < 0.0001$). Temperature-cultivar interaction was not significant; i.e., different cultivars responded similarly at three temperatures. Temperature was found to have a significant ($P < 0.0001$) linear effect on stem thickness of sericea lespedeza cultivars (Figure 20). As temperature increased stems got thicker. Temperature 24/11 ˚C produced the thinnest stems whereas 32/19 ˚C produced the thickest stems. The stems on an average were 92 % more thicker at 32/19 ˚C as compared to stems at 24/11 ˚C. The average stem thickness for cultivars across all temperatures ranged from 0.64 mm to 0.77 mm. AU Lotan (0.64 mm) produced the thinnest stems and this cultivar was significantly different from AU Grazer (0.72 mm), Okinawa (0.72 mm), Serala (0.76 mm) and Arlington (0.77 mm). Remaining cultivars were not significantly different from each other.

Number of branches

Main effects of temperature and cultivar were significant ($P < 0.0001$). The highest number of branches were measured at 32/19˚C. Mean number of branches measured at 24/11˚C, 28/15˚C and 32/19˚C were 0.04, 1.08 and 4.58 respectively. Temperature-cultivar interaction was also significant ($P < 0.01$). Temperature had a significant ($P < 0.01$) quadratic effect on the number of branches of Okinawa and AU Lotan while it had a significant ($P < 0.0001$) linear effect on the number of branches of Serala and Arlington. A small quadratic effect of temperature on the number of stems of AU Grazer was observed (Figure 21). Regression equations with R^2 values are shown in Table 6. Mean number of branches measured for cultivars at 24/11˚C, 28/15˚C and

32/19˚C ranged from 0 to 0.2, 0 to 1.52 and 2.48 to 6.44. No significant differences were observed among cultivars at 24/11 ˚C. At 28/15 ˚C, AU Grazer (1.52) and Arlington (2.08) had significantly more number of branches than Okinawa (0). At 32/19 ˚C, AU Grazer (6.44) and Arlington (5.95) had significantly more branches than AU Lotan (4.32), Serala (3.72) and Okinawa (2.48). Also, AU Lotan had significantly more branches than Okinawa. Remaining cultivars were not significantly different from each other.

Leaf dry weight

Main effects of temperature and cultivar were significant ($P < 0.0001$). The highest leaf dry weight was found at 32/19˚C. Mean leaf dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.27 g, 0.59 g and 1.47 g respectively. Temperature-cultivar interaction was also significant ($P < 0.05$). Temperature had a significant ($P < 0.05$) quadratic effect on leaf dry weight of Okinawa, Serala, AU Lotan and AU Grazer while it had a significant ($P < 0.0001$) linear effect on leaf dry weight of Arlington (Figure 22). Regression equations with R^2 values are shown in Table 7. Mean leaf dry weight found for cultivars at 24/11˚C, 28/15˚C and 32/19˚C ranged from 0.22 to 0.30 g, 0.39 to 0.81 g and 1.15 to 1.74 g. No significant differences were observed among cultivars at 24/11 ˚C. At 28/15 ˚C, Arlington (0.81 g) had significantly more leaf dry weight than AU Grazer (0.57 g), Okinawa (0.52 g) and AU Lotan (0.39 g). Also, Serala (0.65 g) had significantly more leaf dry weight than AU Lotan. At 32/19˚C, Arlington (1.74 g) and Okinawa (1.59 g) had significantly more leaf dry weight than AU Grazer (1.35 g) and AU Lotan (1.15 g). Also, Serala (1.53 g) had significantly more leaf dry weight than AU Lotan. Small but not significant differences were found in remaining contrasts.

Stem dry weight

Temperature had a significant (P < 0.0001) effect on stem dry weight of sericea lespedeza cultivars. It was found to have a significant (P < 0.0001) quadratic effect. Temperature 24/11˚C produced the smallest stem dry weight whereas the temperature 32/19˚C produced the highest stem dry weight (Figure 23). Mean stem dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.10 g, 0.21 g and 0.73 g. Temperature 24/11˚C and 28/15˚C were significantly different from 32/19˚C, however, the former two temperatures were not significantly different from each other. Cultivar and temperature-cultivar interaction were not significant.

Total dry weight

The analysis of variance showed that main effects of temperature and cultivar were significant at P < 0.0001 and P < 0.05 respectively. Temperature-cultivar interaction was not significant; i.e., different cultivars responded similarly at the three temperature regimes. Temperature was found to have a significant (P < 0.0001) quadratic effect on total dry weight. Temperature 24/11˚C produced the smallest total dry weight whereas the temperature 32/19˚C produced the highest total dry weight (Figure 24). The average total dry weight for cultivars across all temperatures ranged from 0.85 g to 1.39 g. AU Lotan had the least total dry weight (0.85 g) and this cultivar was significantly different from Arlington (1.39 g), Serala (1.16 g), Okinawa (1.12 g) and AU Grazer (1.11 g). Arlington had the highest total dry weight and this cultivar was significantly different from AU Grazer, Serala and Okinawa. Small but not significant differences were found in remaining contrasts.

Leaf percentage

Temperature had a significant ($P < 0.0001$) effect on leaf percentage. It was found to have a significant ($P < 0.0001$) quadratic effect. Temperature 28/15˚C produced the highest leaf percentage (Figure 25). Mean leaf percentage found at 24/11˚C, 28/15˚C and 32/19˚C was 73%, 74% and 68% respectively. Temperature 24/11˚C and 28/15˚C were significantly different from 32/19˚C, however they were not significantly different from each other. Cultivar and temperature-cultivar interaction were not significant.

Stem percentage

Temperature had a significant ($P < 0.0001$) effect on stem percentage. It was found to have a significant ($P < 0.0001$) quadratic effect. Temperature 28/15˚C produced the lowest stem percentage (Figure 26). Mean stem percentage found at 24/11˚C, 28/15˚C and 32/19˚C was 27%, 26% and 32% respectively. Temperature 24/11˚C and 28/15˚C were significantly different from 32/19˚C, however they were not significantly different from each other. Cultivar and temperature-cultivar interaction were not significant.

Lower Portion

Stem thickness

The analysis of variance showed that main effects of temperature and cultivar were significant ($P < 0.0001$). Temperature-cultivar interaction was not significant; i.e., different cultivars responded similarly at three temperatures. Temperature was found to have a significant ($P < 0.0001$) quadratic effect on stem thickness. Temperature 24/11 ˚C produced the thinnest stems and this temperature was significantly different from 28/15 ˚C and 32/19 ˚C (Figure 27). However, the latter two temperatures were not significantly different from each other. Mean stem thickness measured at 24/11˚C, 28/15˚C and 32/19˚C was 0.80 mm, 1.14 mm and 1.19 mm. The average stem thickness for cultivars across all temperatures ranged from 0.95 to 1.14 mm. Okinawa had the thickest stems (1.14 mm) and this cultivar was significantly different from AU Grazer (1.06 mm), Arlington (1.05 mm), Serala (1.03 mm) and AU Lotan (0.95 mm). AU Lotan had the thinnest stems and this cultivar was significantly different from AU Grazer, Serala and Arlington. However, the latter three cultivars were not significantly different from each other.

Number of branches

The analysis of variance showed that main effects of temperature and cultivar were significant at $P < 0.0001$ and $P < 0.07$. Temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.0001$) quadratic effect on the number of branches. Temperature 28/15 ˚C produced the highest number of branches whereas 24/11˚C produced the least number of branches (Figure 28). All the temperatures were significantly different from each other. Mean number of branches measured at 24/11˚C, 28/15˚C and 32/19˚C were 2.14, 6.09 and 4.86. The average number of branches for cultivars across all temperatures ranged from 3.54-4.93. Okinawa produced the least number of branches (3.54) and this cultivar was significantly different from AU Lotan (4.93) and AU Grazer (4.81). However, the latter two cultivars and Arlington (4.20) and Serala (4.33) were not significantly different from each other.

Leaf dry weight

Temperature had a significant ($P < 0.0001$) effect on leaf dry weight. It was found to have a significant ($P < 0.0001$) linear trend. As temperature increased, leaf dry weight increased. Temperature 24/11˚C produced the lowest leaf dry weight whereas 32/19˚C produced the highest leaf dry weight (Figure 29). The plants on an average had approximately 4 times more leaf dry weight at 32/19˚C as compared to plants at 24/11˚C. Mean leaf dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.27 g, 0.78 g and 1.32 g respectively. Cultivar and temperature-cultivar interaction were not significant.

Stem dry weight

The analysis of variance showed that main effects of temperature and cultivar were significant at $P < 0.0001$ and $P < 0.06$. Temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.0001$) linear effect on stem dry weight. Temperature 24/11˚C produced the lowest stem dry weight whereas 32/19˚C produced the highest stem dry weight (Figure 30). All the temperatures were significantly different from each other. The plants on an average had approximately 4 times more stem dry weight at 32/19˚C as compared to plants at 24/11˚C. Mean stem dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.31 g, 0.75 g and 1.50 g respectively. The average stem dry weight for cultivars across all temperatures ranged from 0.76 g to 0.94 g. AU Grazer had the lowest stem dry weight (0.76 g). This cultivar and AU Lotan (0.78 g) were significantly different from Arlington (0.93 g) and Okinawa (0.94 g). However, Serala (0.86 g) was not significantly different from any of the cultivars tested.

Total dry weight

Temperature had a significant ($P < 0.0001$) effect on total dry weight. It was found to have a significant ($P < 0.0001$) linear trend. As temperature increased, total dry weight increased. Temperature 24/11˚C produced the lowest total dry weight whereas 32/19˚C produced the highest total dry weight (Figure 31). The plants on an average had approximately 3.75 times more total dry weight at 32/19˚C as compared to plants at 24/11˚C. Mean total dry weight found at 24/11˚C, 28/15˚C and 32/19˚C was 0.59 g, 1.53 g and 2.81 g respectively. Cultivar and temperature-cultivar interaction were not significant.

Leaf percentage

The analysis of variance showed that main effects of temperature and cultivar were significant at $P < 0.01$ and $P < 0.05$ respectively. Temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.0001$) quadratic effect on leaf percentage (Figure 32). Mean leaf percentage found at 24/11˚C, 28/15˚C and 32/19˚C was 46%, 51% and 46% respectively. Temperature 28/15˚ C produced the highest leaf percentage and this temperature was significantly different from 24/11˚ C and 32/19˚ C. However, the latter two temperatures were not significantly different from each other. The average leaf percentage for cultivars across all temperatures ranged from 45% to 50%. Arlington had the lowest leaf percentage (45%) and this cultivar was significantly different from AU Grazer (50%), Okinawa (49%) and AU Lotan (48%). However, the latter three cultivars and Serala (47%) were not significantly different from each other.

Stem percentage

The analysis of variance showed that main effects of temperature and cultivar were significant at $P < 0.01$ and $P < 0.05$ respectively. Temperature-cultivar interaction was not significant. Temperature was found to have a significant ($P < 0.0001$) quadratic effect on stem percentage (Figure 33). Temperature 28/15˚ C produced the lowest stem percentage and this temperature was significantly different from 24/11˚ C and 32/19˚ C. However, the latter two temperatures were not significantly different from each other. The average stem percentage for cultivars across all temperatures ranged from 50% to 55%. Arlington had the highest stem percentage (55%) and this cultivar was significantly different from AU Lotan (52%) and Okinawa (51%) and AU Grazer (50%). However, the latter three cultivars and Serala (53%) were not significantly different from each other.

Summary

In summary, for upper portion, as temperature increased, stem thickness increased. Stem dry weight, total dry weight and stem percentage also increased with temperature, but followed a quadratic trend. Temperature had a quadratic effect on leaf percentage, peaking at 28/15˚C. Temperature-cultivar interaction was significant for number of branches and leaf dry weight.

Temperature affected the lower portion in a similar manner as that of upper portion for leaf percentage and stem percentage, but was different for leaf dry weight, stem dry weight and total dry weight. These traits increased linearly with increase in temperature. Stem thickness and number of branches showed a quadratic trend peaking at 32/19˚C and 28/15˚C respectively.

For upper portion, new cultivars had the lowest stem thickness, leaf dry weight, and total dry weight while higher branch number than old cultivars. For traits such as stem dry weight, leaf percentage and stem percentage, cultivar main effects were non-significant.

For lower portion, new cultivars had the highest number of branches and leaf percentage whereas low to intermediate values for stem thickness. Also, they had low stem dry weight and stem percentage values. For traits such as leaf dry weight and total dry weight, cultivar main effects were non significant.

Conclusion

Temperature had a significant effect on all the traits studied for upper and lower portion. New cultivars had low values for production traits for both portions but they had more pliable stems and more branches than the old cultivars. For lower portion, leaf percentage was more for new cultivars, hence, quality is expected to be higher for them.

References

Donnelly, E.D. 1965. Serala Sericea (Reg. No. 4). Crop Science 5:605.

Donnelly, E.D. 1981. Registration of AU Lotan Sericea Lespedeza (Reg. No. 11). Crop Science 21:474.

Kalburtji, K.L., J.A. Mosjidis, and A.P. Mamolos. 2007. Effects of day-night temperature combinations under constant day length on emergence and early growth of sericea lespedeza genotypes. Can. J. Plant Sci. 87.

Mosjidis, J.A. 1990. Daylength and temperature effects on emergence and early growth of sericea lespedeza. Agronomy Journal 82:923-926.

Mosjidis, J.A. 2001. Registration of 'AU Grazer' Sericea Lespedeza. Crop Science 41:262.

Pieters, A.J., P.R. Henson, W.E. Adams, and A.P. Barnett. 1950. Sericea and other perrenial lespedezas for forage and soil conservation in: USDA (Ed.), Circ. 863.

Qiu, J., J.A. Mosjidis, and J.C. Williams. 1995. Variability for temperature of germination in sericea lespedeza germplasm. Crop Science 35:237-241.

USDA-ARS. National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). Available at: http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1371915 (verified date-June 13, 2010).

USDA-ARS. National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). Available at: http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1088122 (verified date-June 13, 2010)

Table 1: Regression equations representing the cultivar-temperature interaction for Leaf Dry Weight (LDW) for cut 1 in experiment 1

Cultivar	Equation	R^2
AU Grazer	$LDW = -2.01 + 0.094 \times temp$	0.8161
AU Lotan	$LDW = -13.50 + 0.96 \times temp - 0.016 \times temp^2$	0.7980
Serala	$LDW = -7.90 + 0.54 \times temp - 0.008 \times temp^2$	0.8421
Okinawa	$LDW = -11.58 + 0.82 \times temp - 0.014 \times temp^2$	0.8039
Arlington	$LDW = -13.43 + 0.94 \times temp - 0.015 \times temp^2$	0.8301

Table 2: Regression equations representing the cultivar-temperature interaction for Stem Dry Weight (SDW) for cut 1 in experiment 1

Cultivar	Equation	R^2
AU Grazer	$SDW = -1.57 + 0.07 \times temp$	0.8048
AU Lotan	$SDW = -7.76 + 0.54 \times temp - 0.009 \times temp^2$	0.7417
Serala	$SDW = -0.98 + 0.048 \times temp$	0.7837
Okinawa	$SDW = -4.01 + 0.27 \times temp - 0.004 \times temp^2$	0.8193
Arlington	$SDW = -6.23 + 0.42 \times temp - 0.006 \times temp^2$	0.7689

Table 3: Regression equations representing the cultivar-temperature interaction for Total Dry Weight (TDW) for cut 1 in experiment 1

Cultivar	Equation	R^2
AU Grazer	$TDW = -3.58 + 0.16 \times temp$	0.8144
AU Lotan	$TDW = -21.26 + 1.50 \times temp - 0.03 \times temp^2$	0.7823
Serala	$TDW = -11.36 + 0.77 \times temp - 0.01 \times temp^2$	0.8199
Okinawa	$TDW = -15.59 + 1.09 \times temp - 0.02 \times temp^2$	0.8094
Arlington	$TDW = -19.66 + 1.36 \times temp - 0.02 \times temp^2$	0.8071

Table 4: Regression equations representing the cultivar-temperature interaction for Height (Ht) for cut 2 in experiment 1

Cultivar	Equation	R^2
AU Grazer	$Ht = 335.92 - 26.71 \times temp + 0.55 \times temp^2$	0.9509
AU Lotan	$Ht = 382.52 - 29.65 \times temp + 0.59 \times temp^2$	0.9234
Serala	$Ht = 520.87 - 38.83 \times temp + 0.74 \times temp^2$	0.9661
Okinawa	$Ht = 424.44 - 32.56 \times temp + 0.64 \times temp^2$	0.9632
Arlington	$Ht = 616.83 - 45.85 \times temp + 0.87 \times temp^2$	0.9493

Table 5: Regression equations representing the cultivar-temperature interaction for Stem thickness (St) for cut 2 in experiment 1

Cultivar	Equation	R^2
AU Grazer	$St = -1.45 + 0.07 \times temp$	0.9452
AU Lotan	$St = -1.38 + 0.07 \times temp$	0.8953
Serala	$St = 1.77 - 0.14 \times temp + 0.004 \times temp^2$	0.9393
Okinawa	$St = -1.27 + 0.06 \times temp$	0.9289
Arlington	$St = 3.55 - 0.27 \times temp + 0.01 \times temp^2$	0.9515

Table 6: Regression equations representing the cultivar-temperature interaction for number of branches (Br) for upper portion in experiment 2

Cultivar	Equation	R^2
AU Grazer	$Br = 62.28 - 5.15 \times temp + 0.11 \times temp^2$	0.7894
AU Lotan	$Br = 59.84 - 4.74 \times temp + 0.094 \times temp^2$	0.8399
Serala	$Br = -11.42 + 0.47 \times temp$	0.7256
Okinawa	$Br = 52.08 - 4.03 \times temp + 0.08 \times temp^2$	0.7815
Arlington	$Br = -18.15 + 0.74 \times temp$	0.7629

Table 7: Regression equations representing the cultivar-temperature interaction for Leaf Dry Weight (LDW) for upper portion in experiment 2

Cultivar	Equation	R^2
AU Grazer	$LDW = 9.26 - 0.75 \times temp + 0.02 \times temp^2$	0.8776
AU Lotan	$LDW = 11.58 - 0.92 \times temp + 0.02 \times temp^2$	0.8445
Serala	$LDW = 8.29 - 0.71 \times temp + 0.02 \times temp^2$	0.9167
Okinawa	$LDW = 16.54 - 1.31 \times temp + 0.03 \times temp^2$	0.9508
Arlington	$LDW = -4.11 + 0.18 \times temp$	0.8913

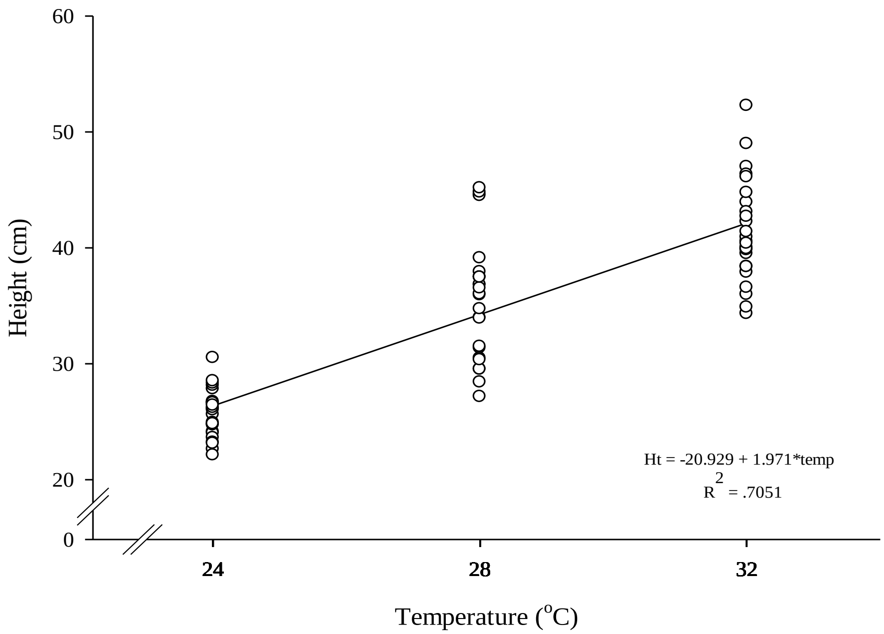

Figure 1: Effect of temperature on the height of cultivars for cut 1 in experiment 1.

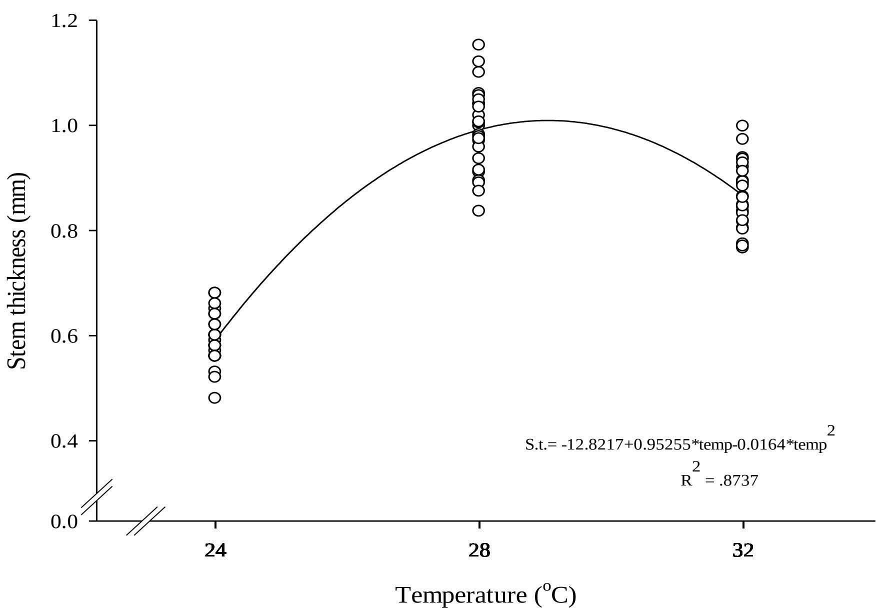

Figure 2: Effect of temperature on the stem thickness of cultivars for cut 1in experiment 1.

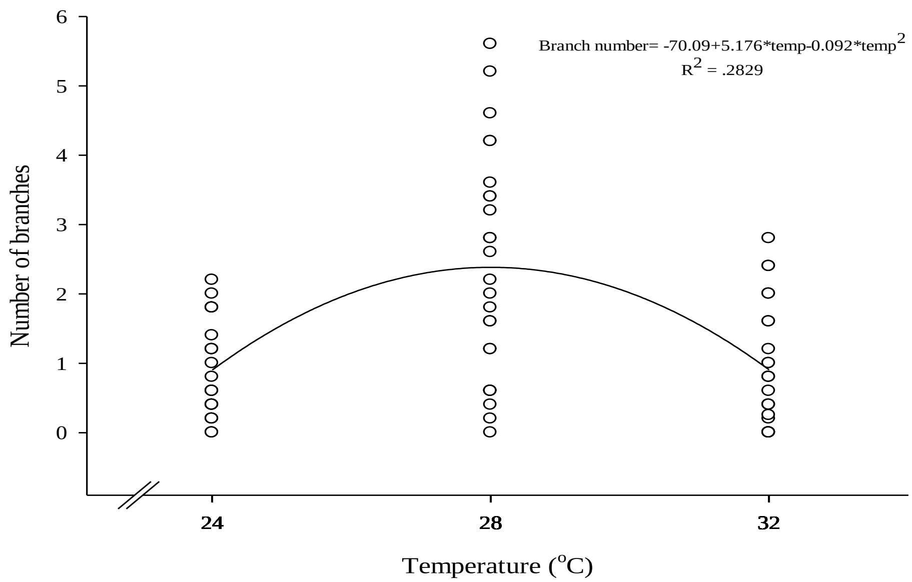

Figure 3: Effect of temperature on the number of branches of cultivars for cut 1 in experiment 1.

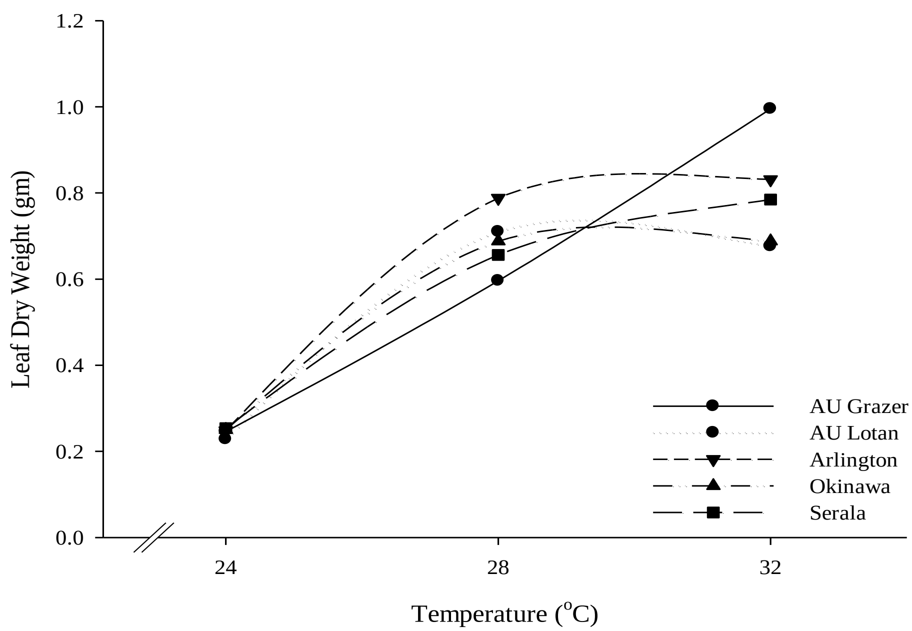

Figure 4: Interaction of cultivars with temperature for the leaf dry weight for cut 1 in experiment 1.

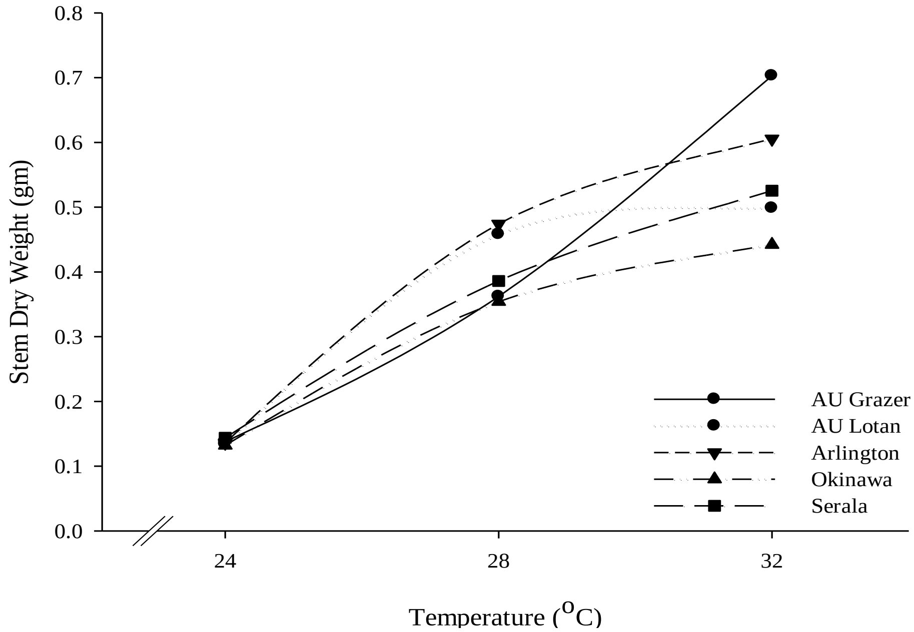

Figure 5: Interaction of cultivars with temperature for the stem dry weight for cut 1 in experiment 1.

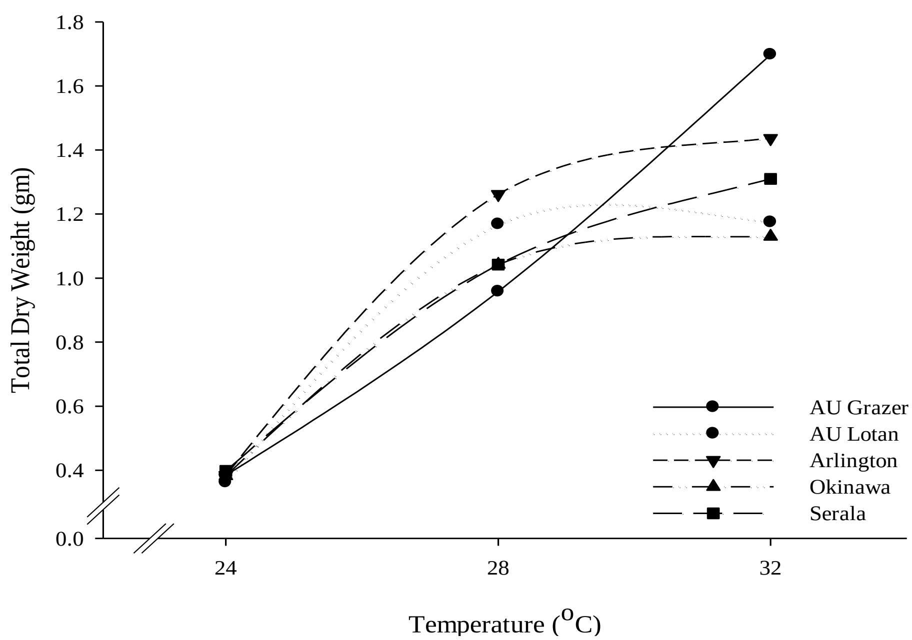

Figure 6: Interaction of cultivars with temperature for the total dry weight for cut 1 in experiment 1.

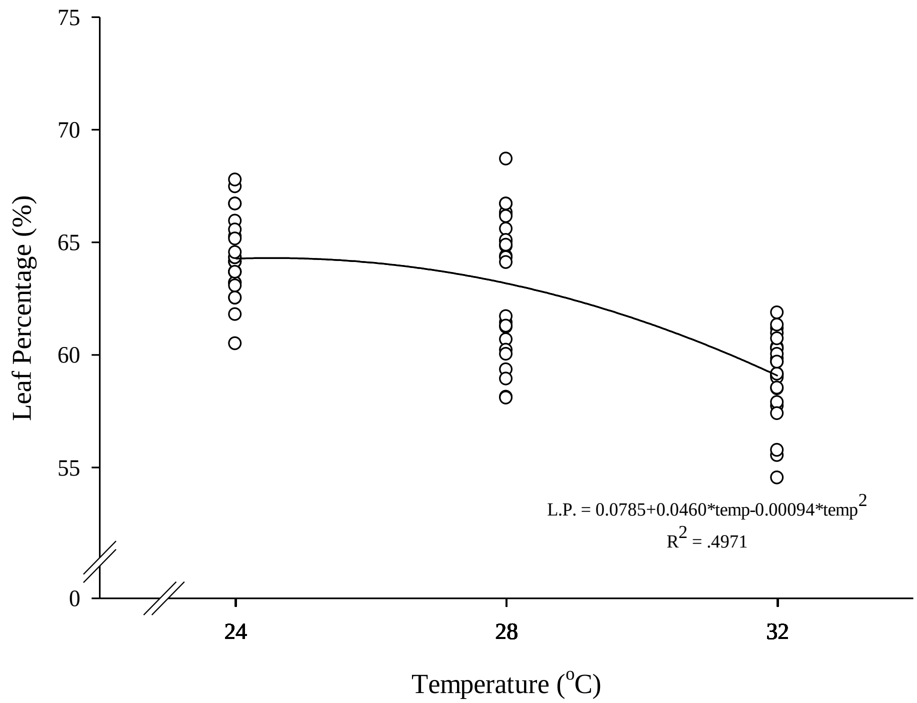

Figure 7: Effect of temperature on the leaf percentage of cultivars for cut 1 in experiment 1.

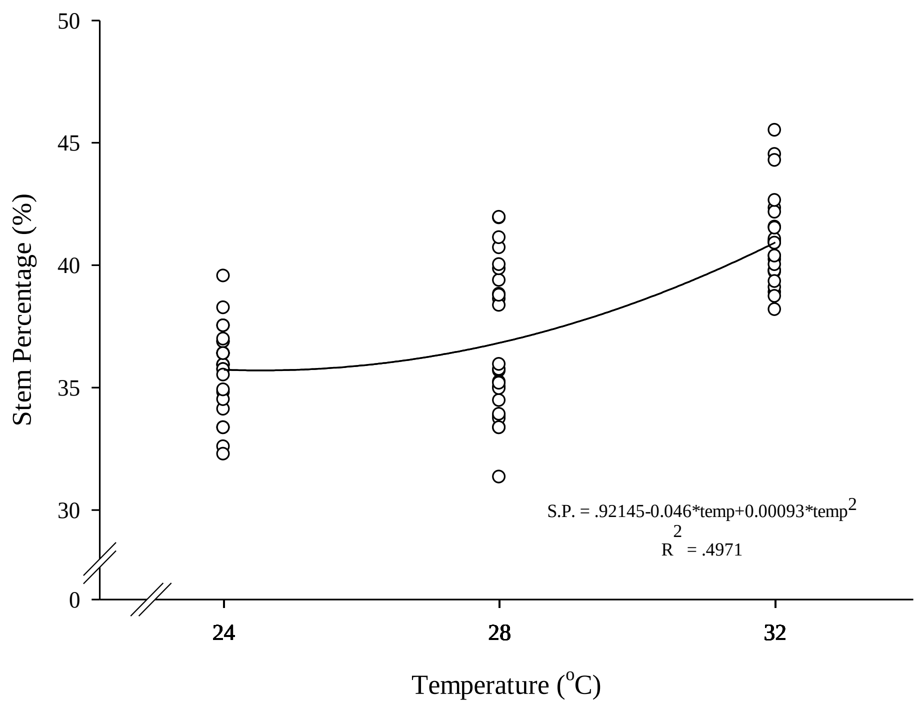

Figure 8: Effect of temperature on the stem percentage of cultivars for cut 1 in experiment 1.

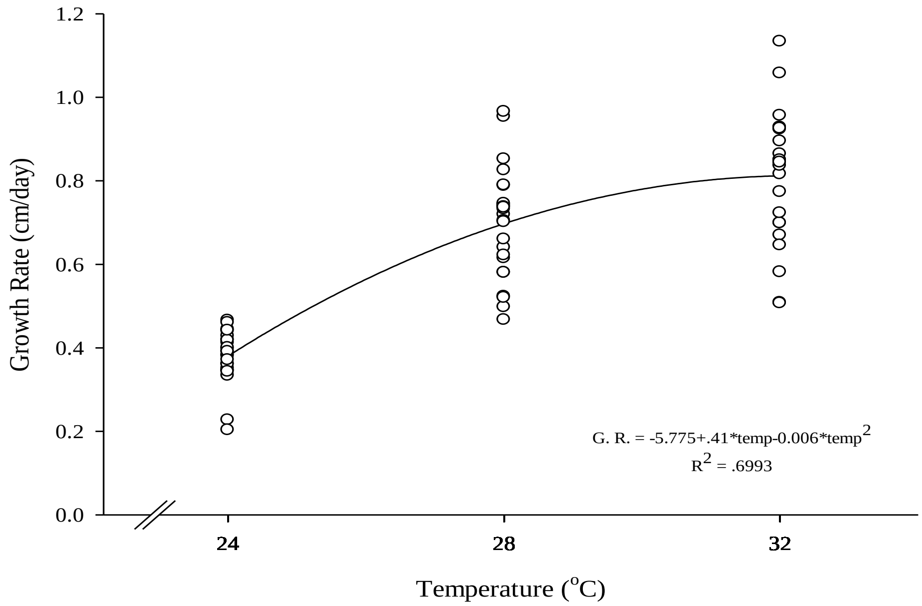

Figure 9: Effect of temperature on the growth rate of cultivars for cut 1 in experiment 1.

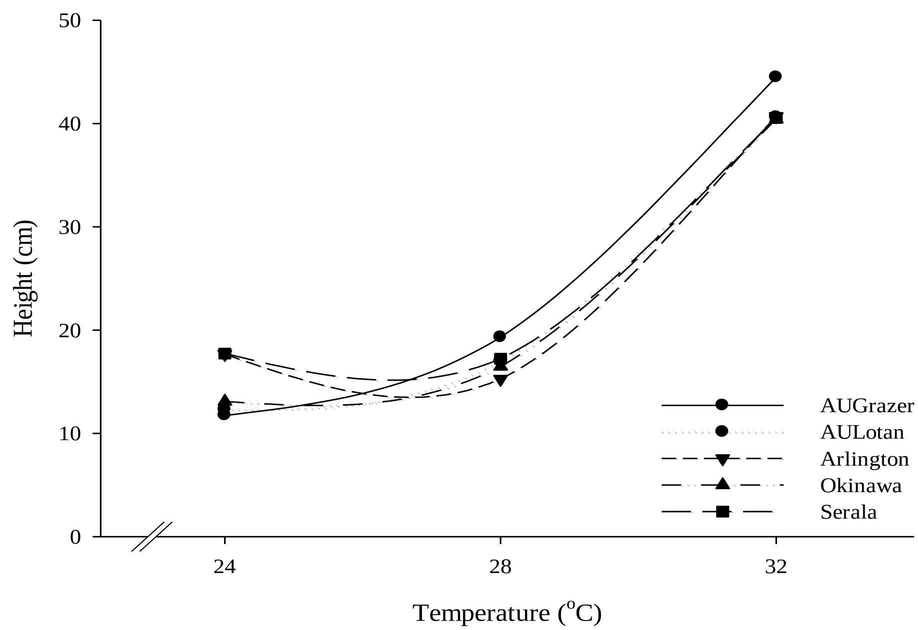

Figure 10: Interaction of cultivars with temperature for the height for cut 2 in experiment 1.

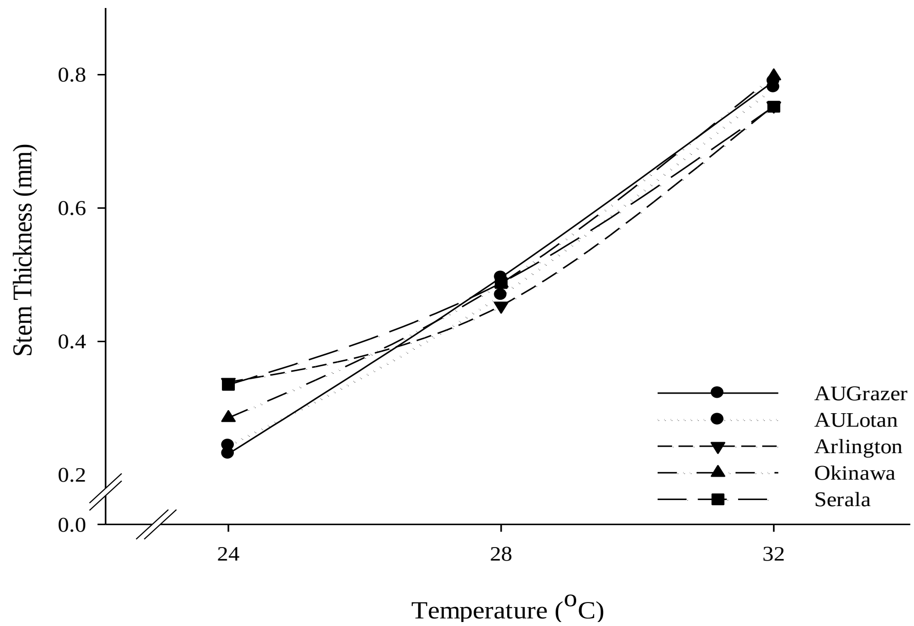

Figure 11: Interaction of cultivars with temperature for the stem thickness for cut 2 in experiment 1.

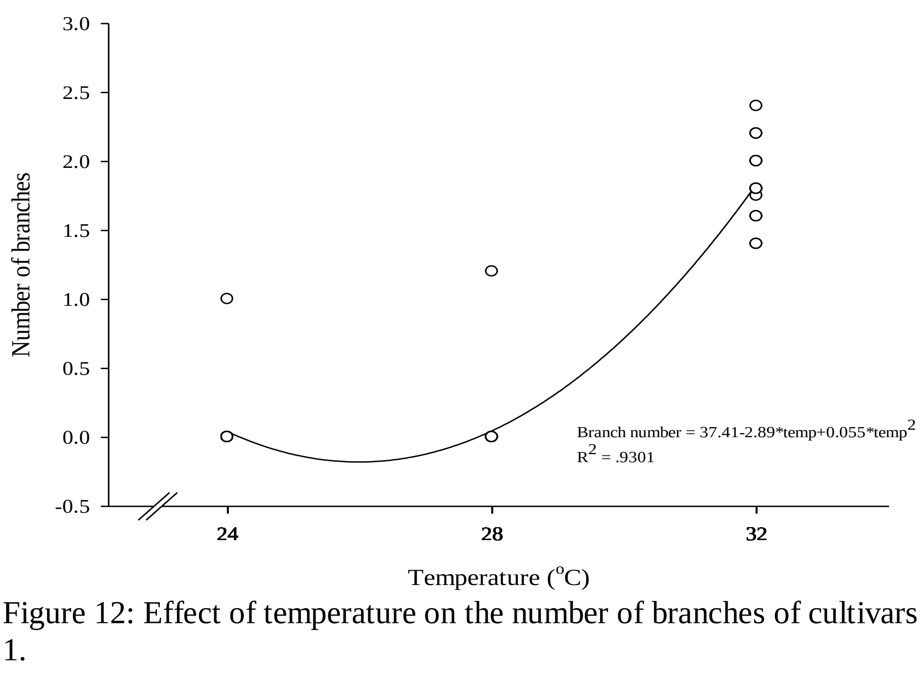

Figure 12: Effect of temperature on the number of branches of cultivars for cut 2 in experiment 1.

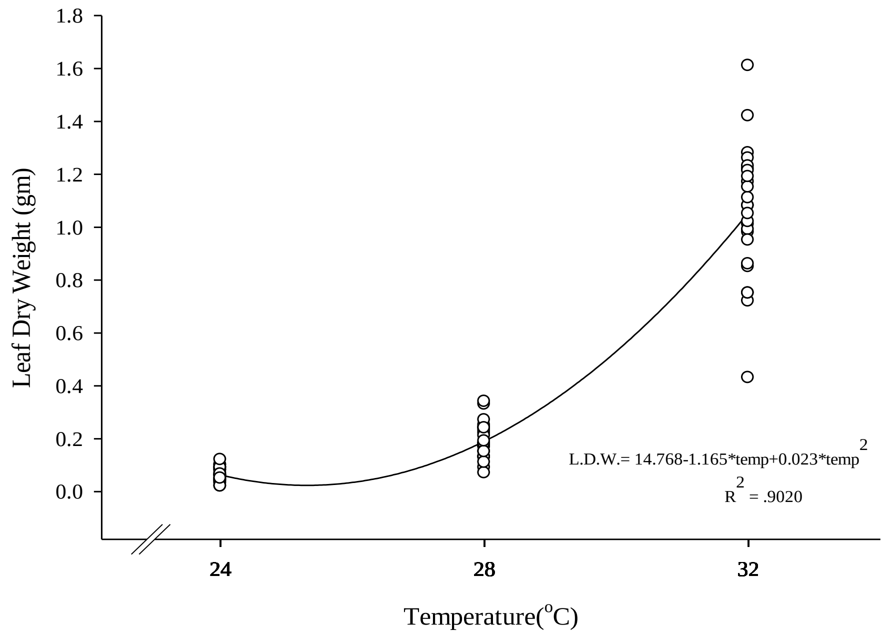

Figure 13: Effect of temperature on the leaf dry weight of cultivars for cut 2 in experiment 1.

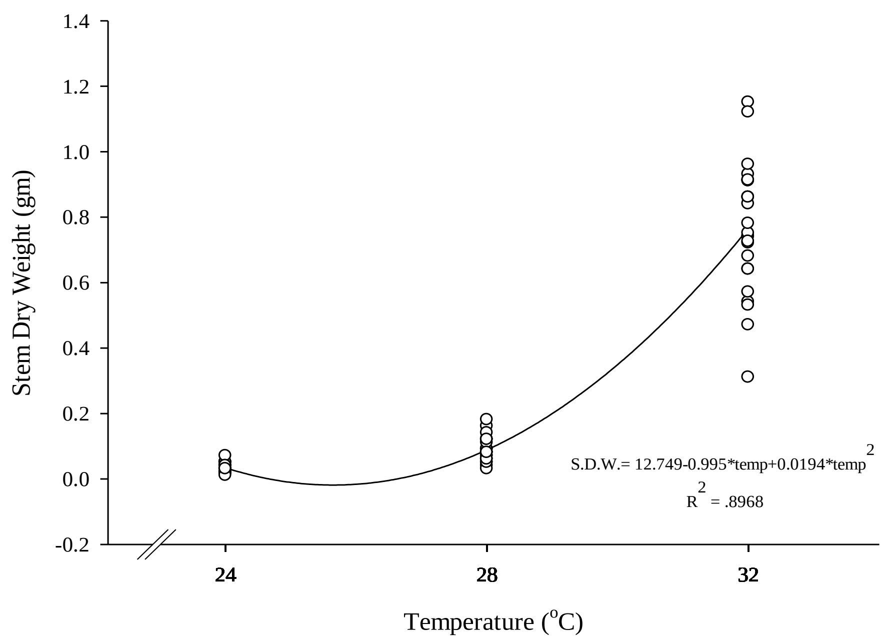

Figure 14: Effect of temperature on the stem dry weight of cultivars for cut 2 in experiment 1.

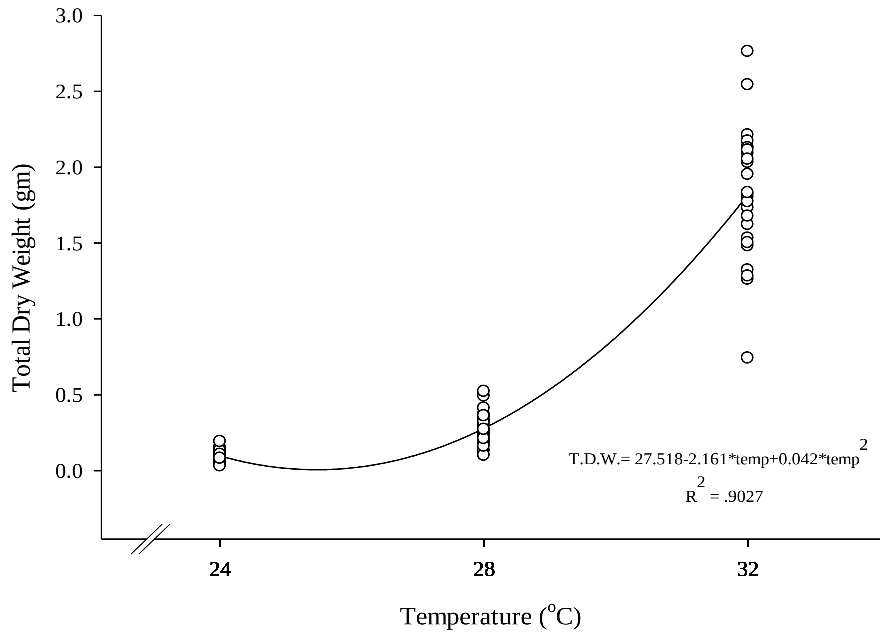

Figure 15: Effect of temperature on the total dry weight of cultivars for cut 2 in experiment 1.

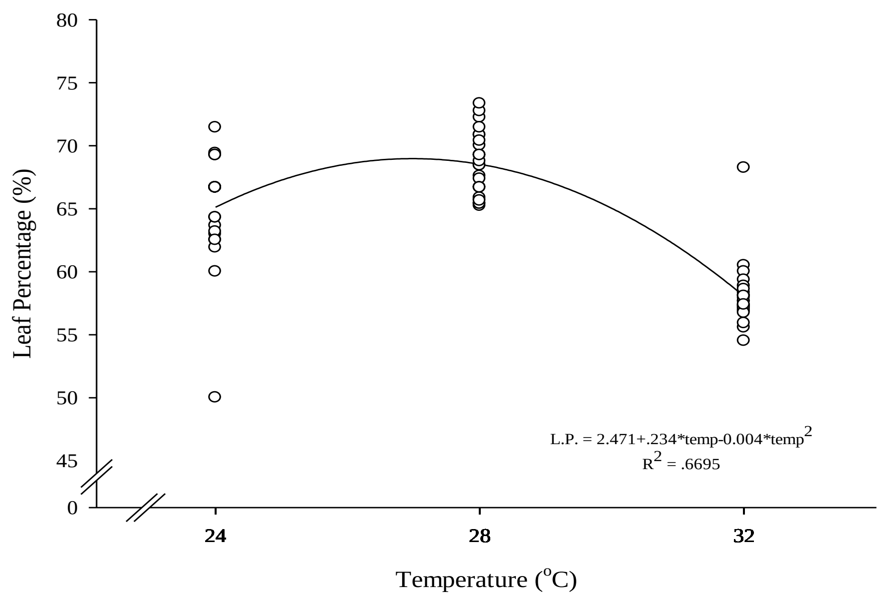

Figure 16: Effect of temperature on the leaf percentage of cultivars for cut 2 in experiment 1.

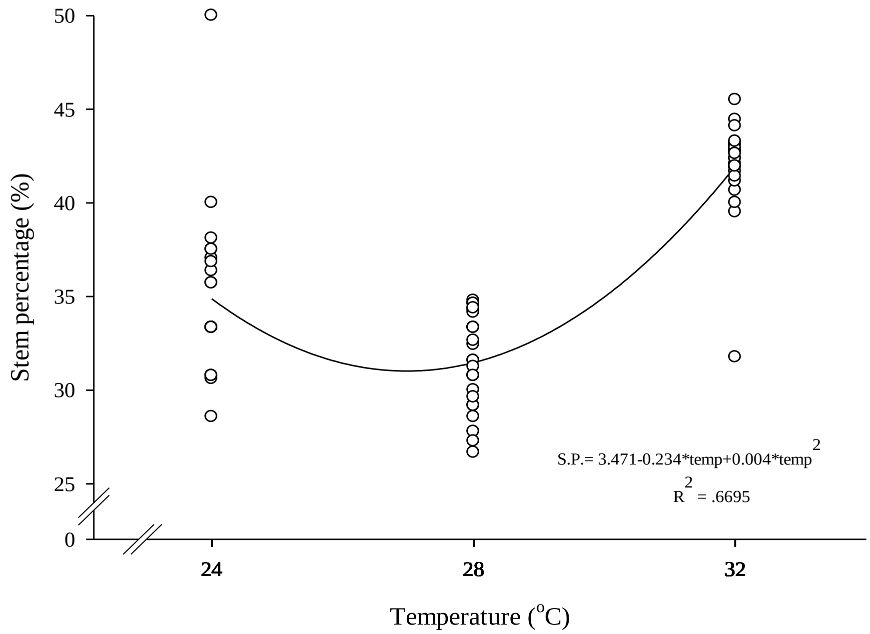

Figure 17: Effect of temperature on the stem percentage of cultivars for cut 2 in experiment 1.

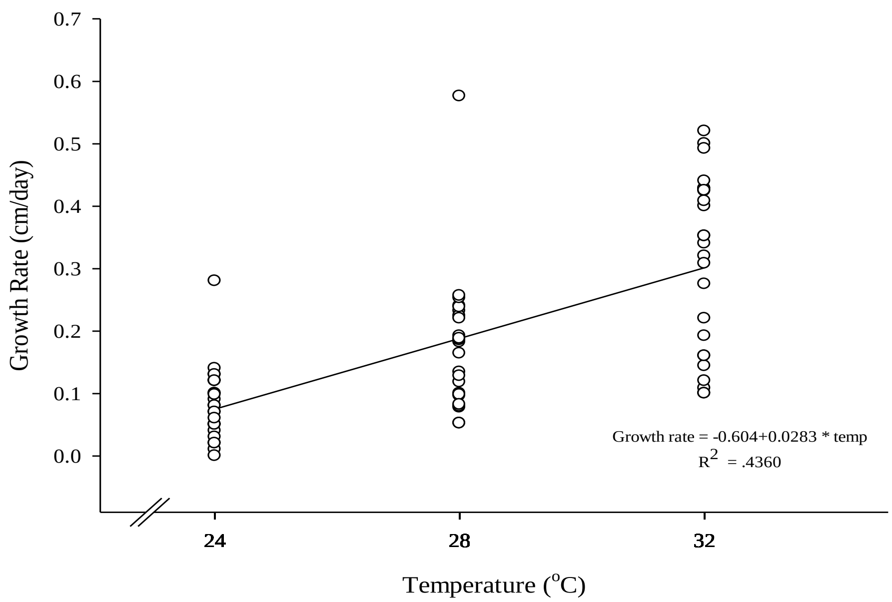

Figure 18: Effect of temperature on the growth rate of cultivars for cut 2 in experiment 1.

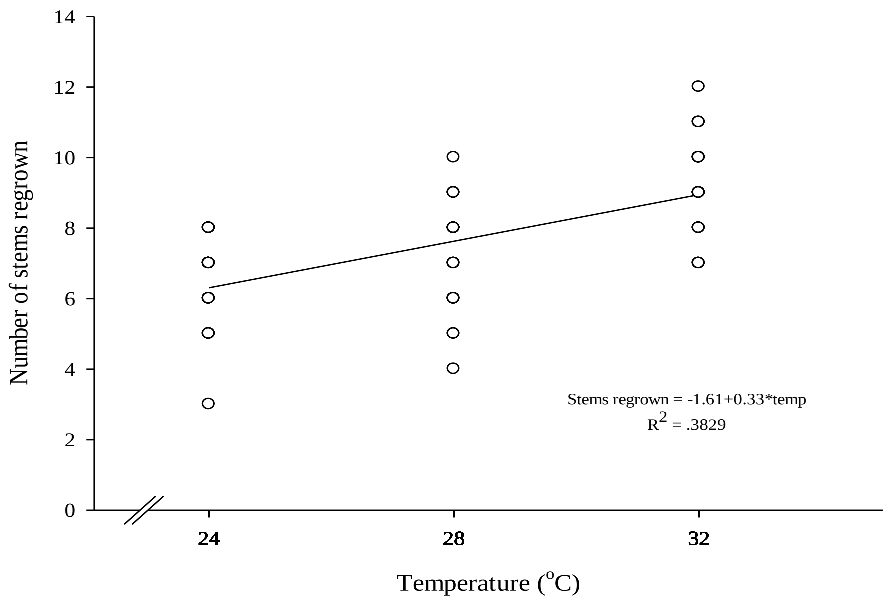

Figure 19: Effect of temperature on the number of regrown stems of cultivars for cut 2 in experiment 1.

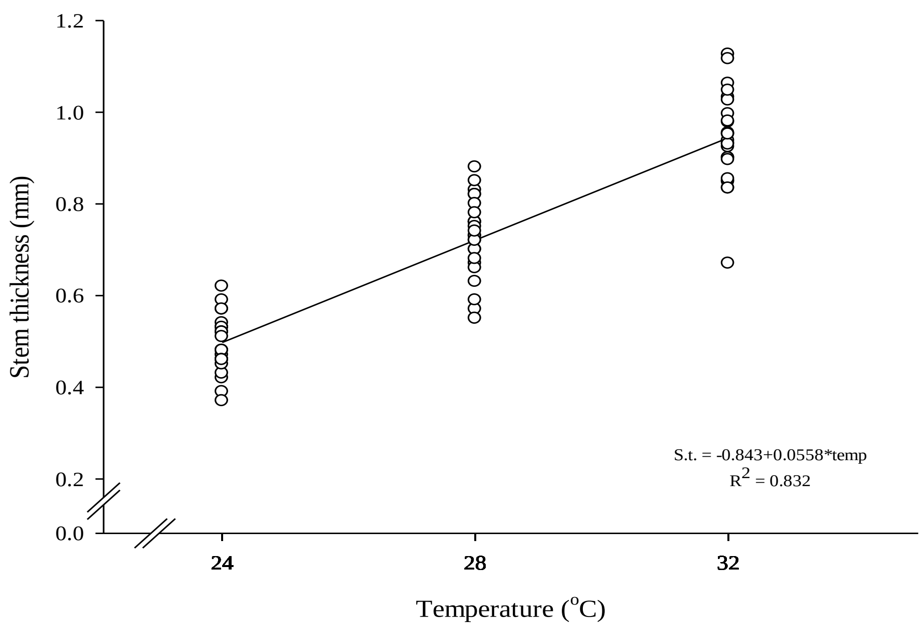

Figure 20: Effect of temperature on the stem thickness of cultivars for upper portion in experiment 2.

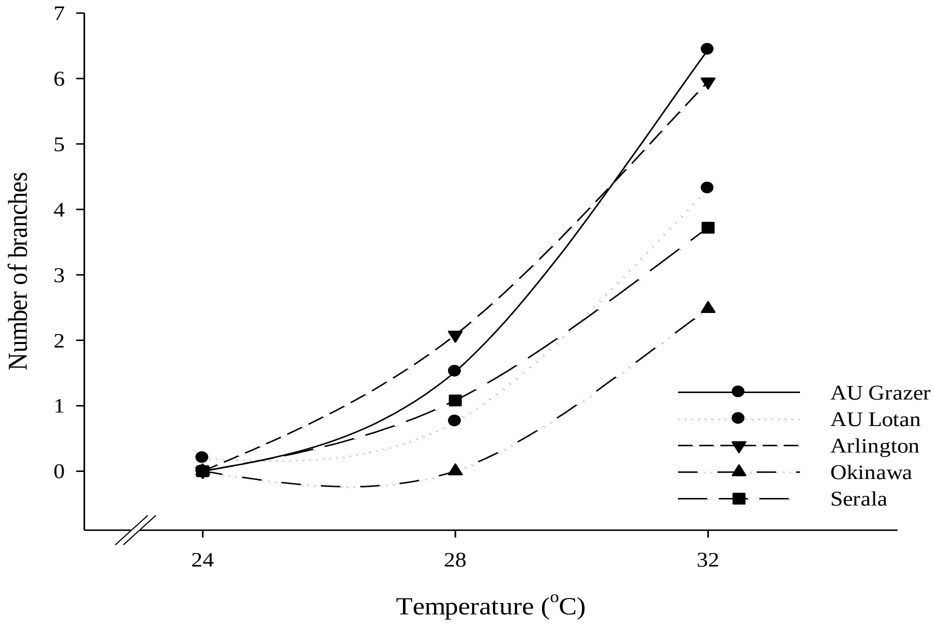

Figure 21: Interaction of cultivars with temperature for the branches of upper portion in experiment 2.

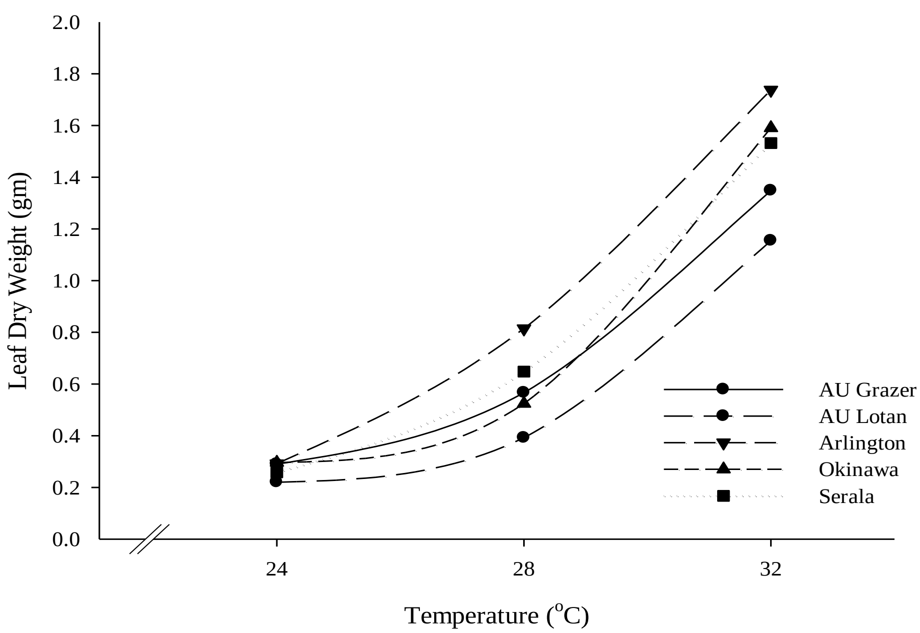

Figure 22: Interaction of cultivars with temperature for the leaf dry weight of upper portion in experiment 2.

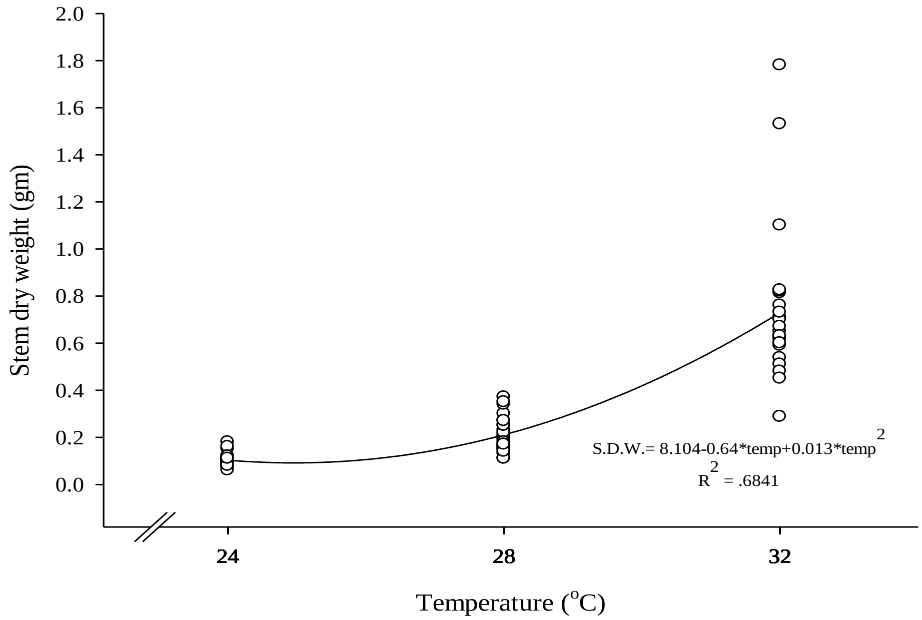

Figure 23: Effect of temperature on the stem dry weight of cultivars for upper portion in experiment 2.

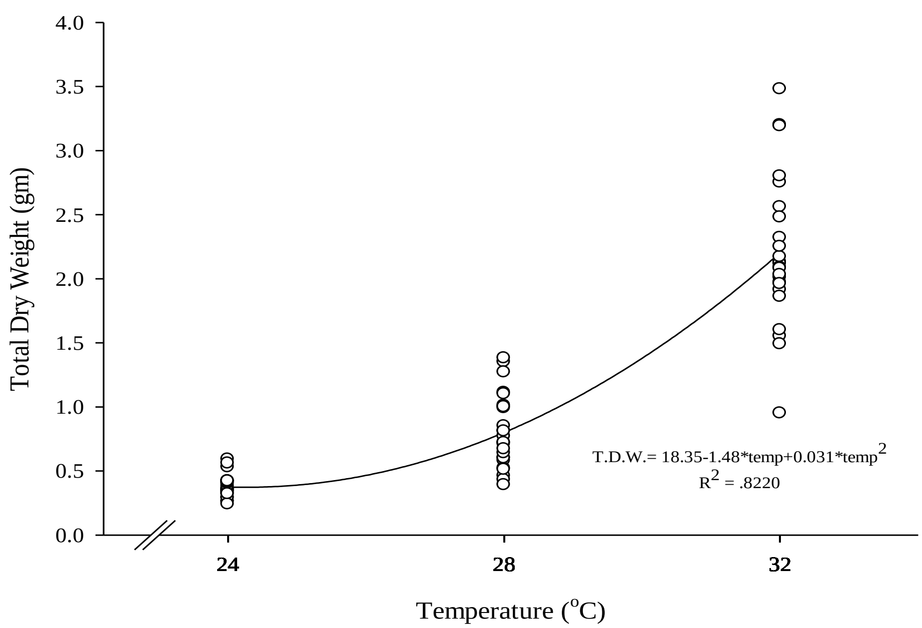

Figure 24: Effect of temperature on the total dry weight of cultivars for upper portion in experiment 2.

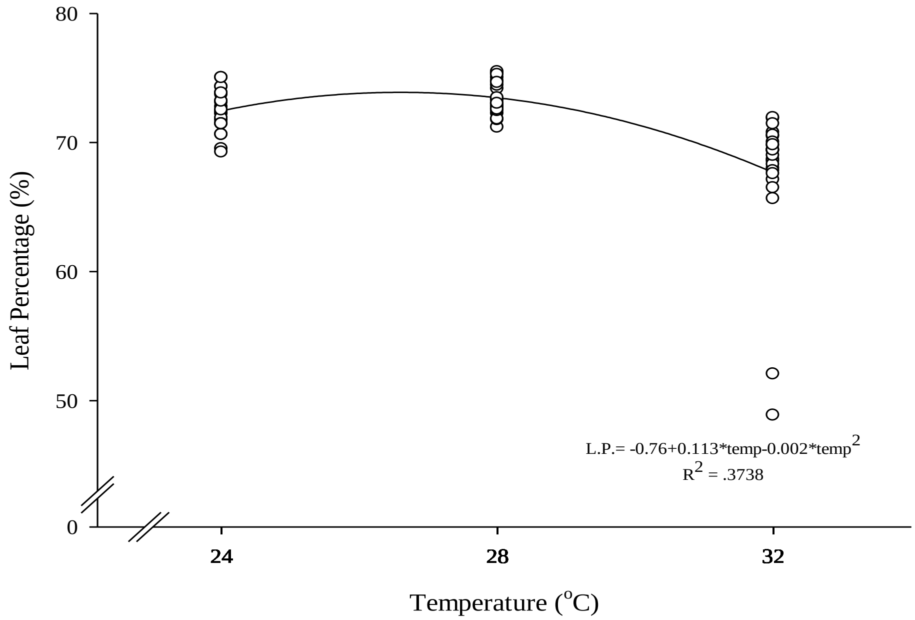

Figure 25: Effect of temperature on the leaf percentage of cultivars for upper portion in experiment 2.

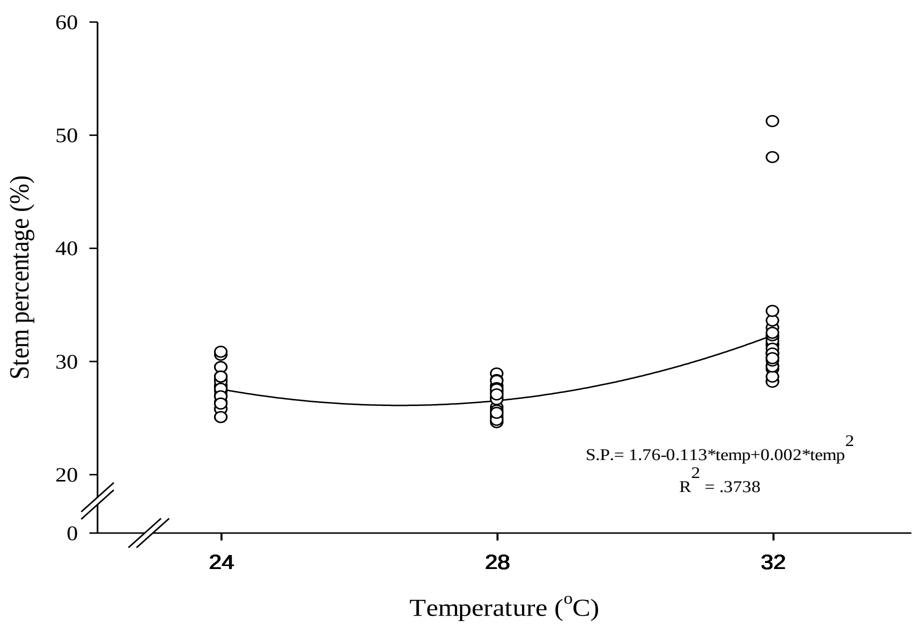

Figure 26: Effect of temperature on the stem percentage of cultivars for upper portion in experiment 2.

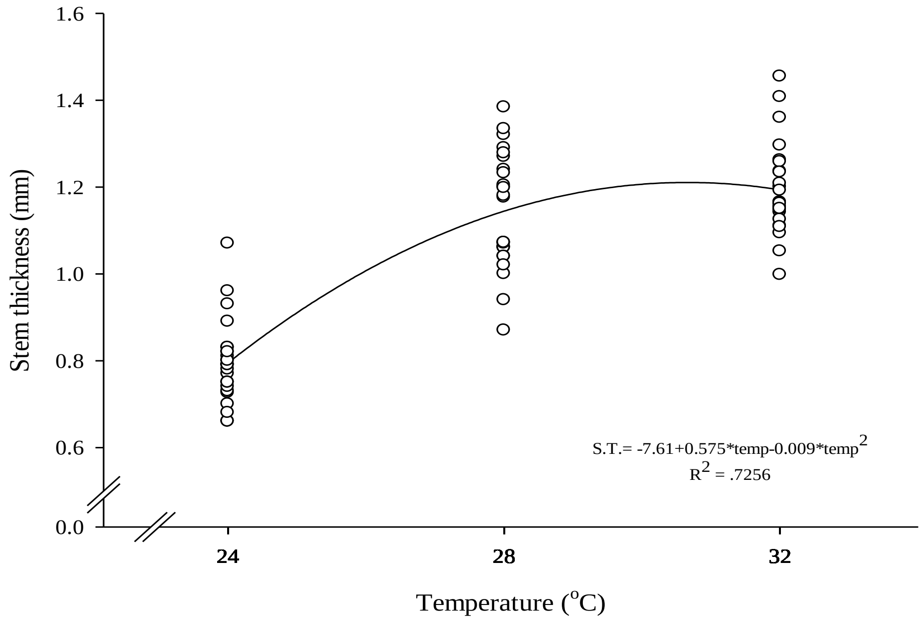

Figure 27: Effect of temperature on the stem thickness of cultivars for lower portion in experiment 2.

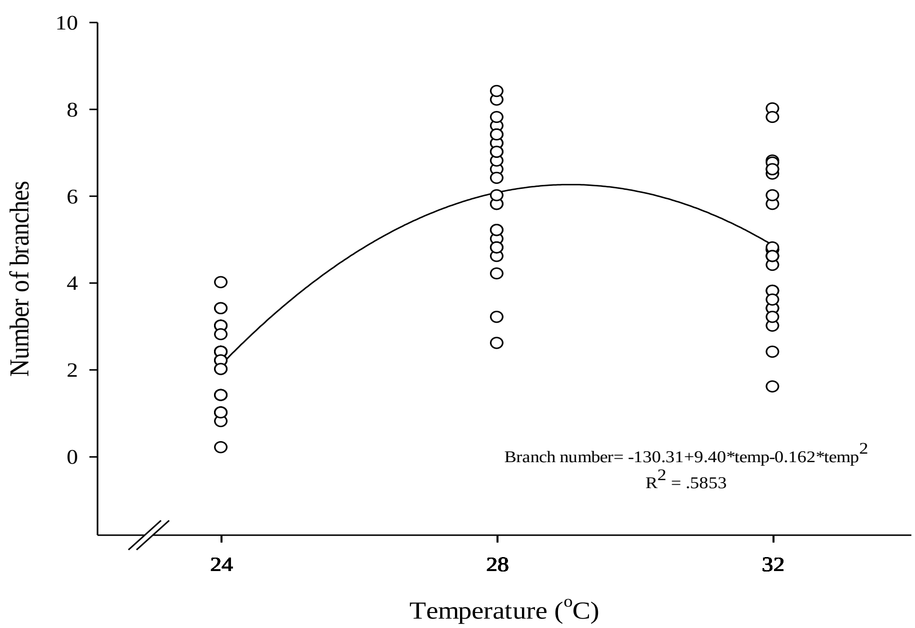

Figure 28: Effect of temperature on the number of branches of cultivars for lower portion in experiment 2.

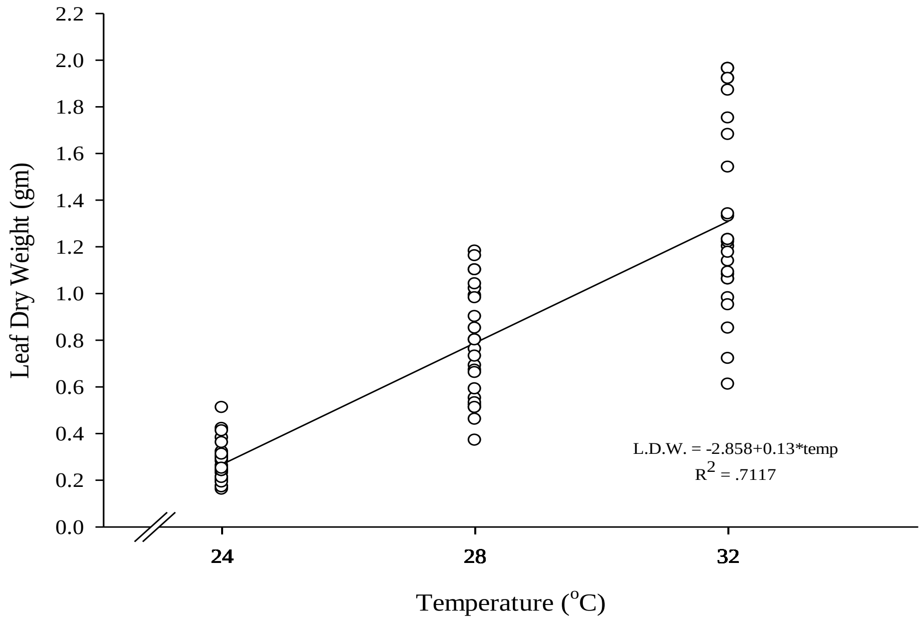

Figure 29: Effect of temperature on the leaf dry weight of cultivars for lower portion in experiment 2.

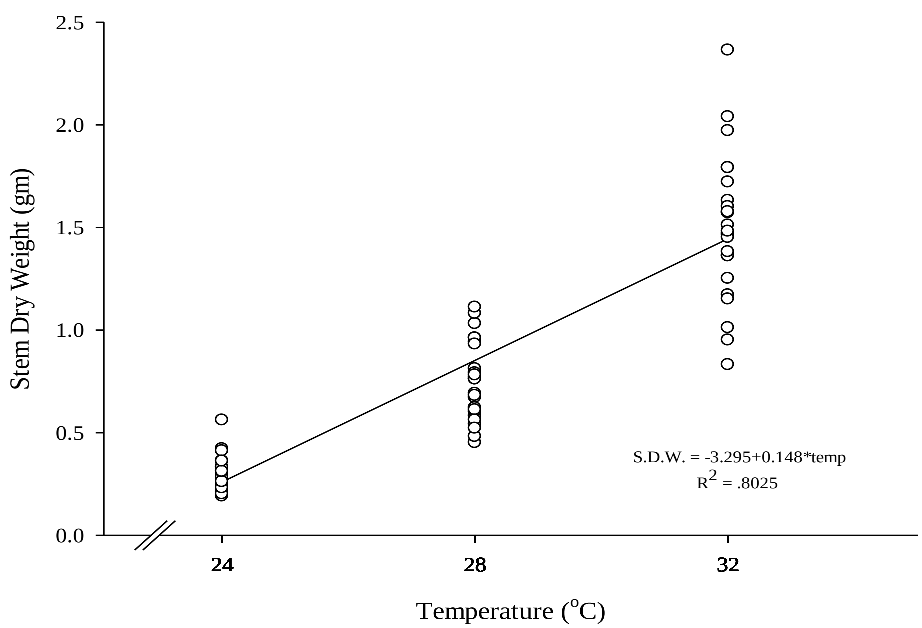

Figure 30: Effect of temperature on the stem dry weight of cultivars for lower portion in experiment 2.

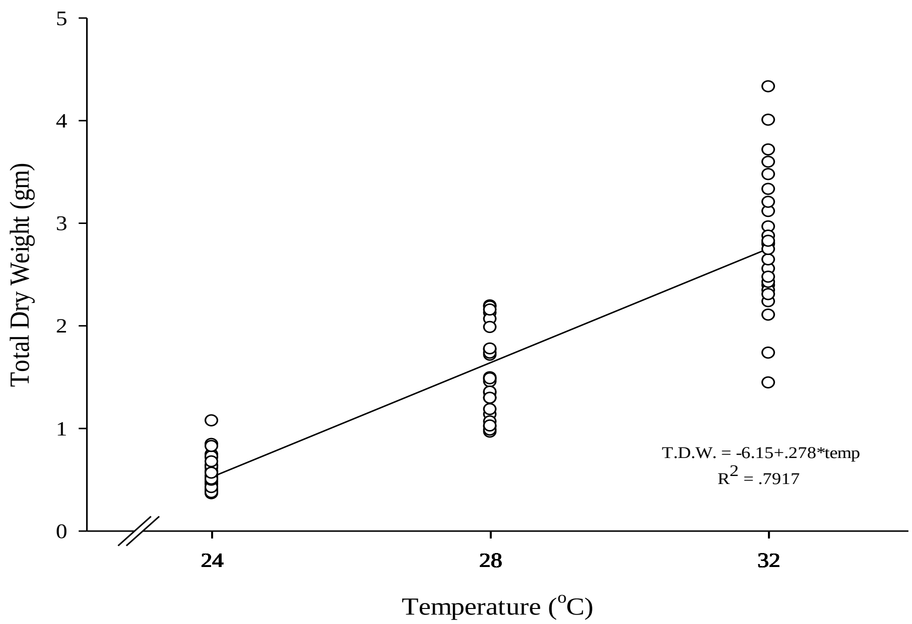

Figure 31: Effect of temperature on the total dry weight of cultivars for lower portion in experiment 2.

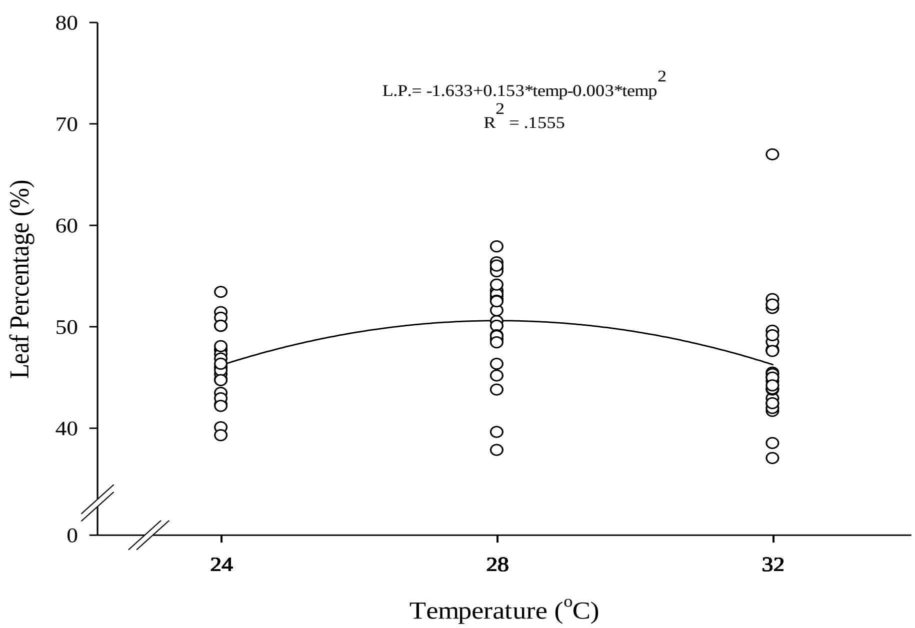

Figure 32: Effect of temperature on the leaf percentage of cultivars for lower portion in experiment 2.

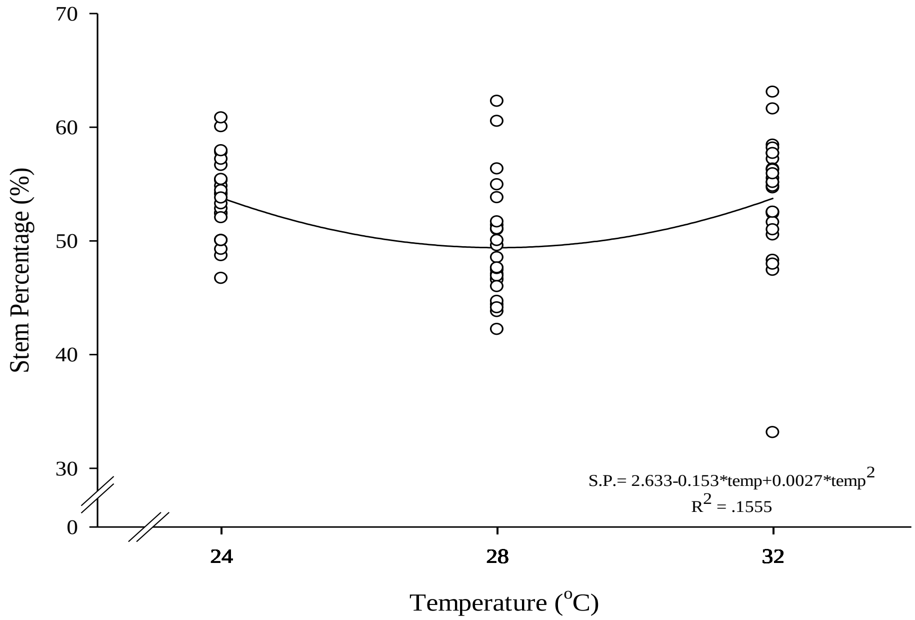

Figure 33: Effect of temperature on the stem percentage of cultivars for lower portion in experiment 2.

III. Genotypic variability among old and new sericea lespedeza cultivars

Abstract

During the last 70 years, breeding programs have facilitated development of sericea cultivars/genotypes with high forage quality and pliable stems. Morphological differences have been observed among these genotypes, but they have not been documented experimentally. Field experiments were conducted in 2008 and 2009 using five cultivars of sericea lespedeza namely Arlington, Okinawa, Serala, AU Lotan, and AU Grazer released in 1939, 1944, 1962, 1980, and 1997, respectively. The study was conducted to compare characteristics of plant parts such as leaves and stems in the canopy and to ascertain the cultivar effects on production and quality traits.

Portion effects were significant ($P < 0.001$) in both years. Cultivar-portion interaction was significant mostly for the first year (2008) for stem dry weight, number of branches, branch stem weight and branch leaf weight for cut 1 and for stem dry weight, leaf dry weight, number of branches and total dry weight for cut 2. Shear force was the only trait for which interaction was significant in second year (2009). AU Grazer was the best or among the best cultivars for plant characteristics important from a production point of view, whereas it was the last ranked or among the last ranked cultivars in terms of characteristics affecting pliability such as stem thickness and shear force. Okinawa was considered as the poorest performer as it had greater stem thickness and required more shear force, though it had a good proportion of leaves as compared to stems.

Introduction

Sericea lespedeza (Chinese lespedeza), a summer perennial legume belonging to Fabaceae family, originated in Eastern Asia (Pieters, 1939) especially Sino-Indian region of Asia (Mosjidis, 1997) and was introduced into the US towards the end of 19th century. During the period of 1930-1940 it was widely seeded for soil conservation in the southeastern US (Pieters et al., 1950) leading to its naturalization to this region (Mosjidis, 1997). This forage legume has deep roots which can extend up to 120 cm or more in the soil (Guernsey, 1970). It has erect stems with leaves all along the striated stems (Mcgraw and Hoveland, 1995; Mosjidis, 1997). The introduced sericea lespedeza plants possessed thick and coarse stems with high tannin content resulting in low palatability and digestibility. Cattle preferred plants with fine and pliable stems (Donnelly, 1954). Fine-stemmed sericea lespedeza plants were found to be nutritionally better than those with coarse stems in a digestion trial with rabbits (Donnelly and Hawkins, 1959).

During the last 70 years, breeding programs have facilitated development of sericea cultivars/genotypes with high forage quality and pliable stems. Arlington and Okinawa were the earliest cultivars released in 1939 and 1944 by the Soil Conservation Service (SCS), North Carolina (USDA-ARS) and SCS, Georgia (USDA-ARS) respectively. Serala, the first variety with fine, pliable stems and more stems per plant, was released in 1962 (Donnelly, 1965). AU Lotan, released in 1980, was the first variety with reduced tannin content but having 85 % dry matter yield to that of Serala (Donnelly, 1981). Subsequently, AU Grazer, released in 1997 (Mosjidis, 2001; Mosjidis and Donnelly, 1989), was the first cultivar tolerant to grazing that was released. These genotypes vary among themselves in terms of yield, resistance to pathogens (Donnelly, 1981), tannin content (Donnelly, 1981) and grazing tolerance (Mosjidis, 2001).

Although, more morphological differences have been observed among these genotypes, they have not been documented experimentally. Forage is a mixture of structures of differing maturity and composition. It was determined that there were differences in composition in different canopy strata in sericea lespedeza. The NDF, ADF, cellulose, and hemicellulose concentration was more at the stem base than top, whereas protein content declined from top to bottom of the plant (Mosjidis, 2000).

The objective of this study was to compare characteristics of plant parts such as leaves and stems in the canopy of five cultivars released in a period of about 60 years. The cultivars studied were Arlington (released in 1939) (USDA-ARS), Okinawa (released in 1944) (USDA-ARS), Serala (released in 1962) (Donnelly, 1965), AU Lotan (released in 1980) (Donnelly, 1981) and AU Grazer (released in 1997) (Mosjidis, 2001) under field conditions.

Materials and methods

Field experiments were conducted in 2008 and 2009 using five cultivars of sericea lespedeza; namely, Arlington, Okinawa, Serala, AU Lotan, and AU Grazer released in 1939, 1944, 1962, 1980, and 1997, respectively. The cultivars were planted in the greenhouse and individual plants space transplanted to the field at the Plant Breeding Unit, E.V. Smith Research Center, Tallassee, Alabama in 2007. Individual plants were placed at 61 cm from each other in a randomized complete block design with 20 plants per cultivar and 4 replications. Each year two cuts were taken.

In 2008, the first cut was on May 27, 2008 and the number of main stems per plant were recorded. Main stems were those that had reached a height of 40 cm or more. The top 30 cm of the plant canopy was divided into two equal portions – upper and lower. After taking branch count from the respective portion, they were removed from the stems. Whole plant material was dried for 48 hours at 60˚C. Leaves were separated from the main stems as well as from the branch stems. Upper and lower 15 cm portion stem and leaf dry weights for main stems as well as branches were quantified and designated as stem dry weight, leaf dry weight, branch stem weight and branch leaf weight respectively. Within a plant, some stems did not reach the height of 40 cm, so they were counted separately and designated as short stems. Second cut was taken on August 07, 2008 and similar traits were measured.

For 2009, first cut was taken on May 18, 2009 and stem count was made. A sample of ten stems from each plant was taken and similar procedure of measuring traits as that of year 2008 was followed. Whole plant data was generated from the plant sample data. Within the plant, the stem count of stems less than 40 cm was taken. Second cut was taken on July 09, 2009 and similar traits were measured.

For both the years, data were taken on 10 randomly chosen established plants within each cultivar and then averaged per cultivar. Plants were harvested leaving stubble of 10 cm above the soil. An outgrowth of 5 cm or more on the stem was considered as a branch. For both cuts in year 2008 and 2009, stem diameters at the bases of both upper and lower portions of the main stems were measured after drying using vernier caliper. Additionally, shear force was measured at the base of the stems using a Stable Micro Systems Texture Analyzer (Model TA-HDi). Stem dry weight and leaf dry weight were added to get total dry weight.

Data were analyzed by year and by cut as a factorial experiment in a split-plot design with cultivars as main plots and portions as subplots. Number of main stems and short stems were analyzed by year and by cut as a randomized complete block design. Data were subjected to analysis of variance using SAS® PROC GLIMMIX. Least square means were used for mean separation at $P \leq 0.05$.

Results and Discussion

CUT 1

Leaf Dry Weight

Analysis of variance showed that main effects of cultivar were not significant in both the years. Portion effects were significant ($P < 0.001$) in both years. Upper portion had 35% less leaf dry weight than lower portion in both the years. Cultivar-portion interaction was not significant in either year. For upper portion, the values for mean leaf dry weight ranged from 4.29 g to 5.85 g and 6.81 g to 9.93 g in the year 2008 and 2009 respectively, but no significant differences were observed among cultivars (Table 8). The mean leaf dry weight of cultivars for lower portion ranged from 6.92 g to 9.20 g in the year 2008. For this portion, AU Grazer had the highest leaf dry weight whereas Serala had the lowest leaf dry weight. Cultivars were significantly different from each other at $P < 0.05$ (Table 9). Though the mean values of cultivars for the lower portion were higher in 2009 as compared to 2008, ranging from 10.95 g to 15.45 g, no significant differences were observed among the cultivars.

Stem Dry Weight

Analysis of variance showed that main effects of cultivar were not significant in both the years. Portion effects were significant ($P < 0.001$) in both years. Upper portion had 55 % less stem dry weight than the lower portion in both the years. Cultivar-portion interaction was significant ($P < 0.08$) only in the year 2008. For upper portion, the values of mean stem weight ranged from 1.44 g to 1.86 g and 2.71 g to 3.73 g in the year 2008 and 2009 respectively but no significant differences were observed among cultivars (Table 8). The mean stem dry weight of cultivars for lower portion ranged from 3.05 g to 4.17 g in the year 2008. For this portion, AU Grazer had the highest stem dry weight, whereas Serala had the least stem dry weight. Cultivars were significantly different from each other at $P < 0.05$ (Table 9). However, the mean values of cultivars for the lower portion were higher in 2009 as compared to 2008, ranging from 6.07 g to 8.08 g but no significant differences were observed among the cultivars.

Number of Branches

Main effects of cultivar were significant ($P < 0.05$) for year 2008 only. Portion effects were significant ($P < 0.05$) in both years. Upper portion had 88% and 95% fewer branches than the lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was also significant ($P < 0.01$) for 2008 only. For upper portion, the mean branch number values ranged from 2.05 to 3.85 and 0 to 9.99 in the year 2008 and 2009 respectively but no significant differences were observed among cultivars (Table 8). The mean number of branches measured on the lower portion of the cultivars for ranged from 12.65 to 30.62 in 2008. In 2009 plants had a much larger number of branches than in 2008. It ranged from 28.47 to 85.56. AU Lotan and AU Grazer had the highest number of branches in 2008 and 2009 respectively. AU Grazer had the second largest number of branches in 2008. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 9).

Branch Leaf Weight

Main effects of cultivar were significant ($P < 0.01$) for the year 2008 only. Portion effects were significant ($P < 0.05$) for both the years. Branches from upper portion had 84% and 96% less leaf weight than the branches from lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was also significant ($P < 0.05$) for 2008 only. For upper portion, the mean branch leaf weight values ranged from 0.09 g to 0.27 g and 0 to 0.36 g in the year 2008 and 2009 respectively but no significant differences were observed among cultivars (Table 8). The mean branch leaf weight of cultivars for lower portion ranged from 0.54 g to 1.37 g in 2008 and an increase in these values in 2009, ranging from 1.27 g to 3.23 g. AU Lotan and AU Grazer had the highest branch leaf weight in 2008 and 2009 respectively. AU Grazer had the second largest branch leaf weight in 2008. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 9).

Branch Stem Weight

Main effects of cultivar were significant ($P < 0.05$) for year 2008 only. Portion effects were significant ($P < 0.05$) for both the years. Branches from upper portion had 83% and 96% less stem weight than the branches from lower portion in the year 2008 and 2009, respectively. Cultivar-portion interaction was also significant ($P < 0.05$) for 2008 only. For upper portion, the mean branch stem weight values ranged from 0.03 g to 0.09 g and 0 to 0.11 g in the year 2008 and 2009 respectively but no significant differences were observed among cultivars (Table 8). The mean branch stem weight of cultivars for lower portion ranged from 0.17 g to 0.42 g in 2008. These values were higher in year 2009 than year 2008 ranging from 0.40 g to 0.96 g. AU Lotan and AU Grazer had the highest branch stem weight in 2008 and 2009 respectively. AU Grazer had the second largest branch stem weight in 2008. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 9).

Total Dry Weight

Analysis of variance showed that main effects of cultivar were not significant in both the years. Portion effects were significant ($P < 0.001$) in both the years. Upper portion had significantly 41% less total dry weight than lower portion in both the years. Cultivar-portion interaction was not significant in both the years. For upper portion, the mean total dry weight values ranged from 6.07 g to 7.63 g and 9.52 g to 13.22 g in the year 2008 and 2009 respectively but no significant differences were observed among cultivars (Table 8). The mean total dry weight of cultivars for lower portion ranged from 9.96 g to 13.38 g in the year 2008. AU Grazer had the highest total dry weight whereas Serala had the lowest total dry weight. Cultivars were significantly different from each other at $P < 0.05$ (Table 9). Though the mean values of cultivars for the lower portion were higher in 2009 as compared to 2008, ranging from 17.03 g to 23.54 g, no significant differences were observed among the cultivars.

Stem Thickness

Main effects of cultivar were significant ($P \leq 0.05$) only in year 2009. Portion effects were significant ($P < 0.0001$) in both the years. Upper portion had significantly thinner stems (30% and 33% less stem thickness in the 2008 and 2009, respectively) than the lower portion. Cultivar-portion interaction was not significant in either year. For upper portion, Okinawa had the thickest stems in both the years. The mean stem thickness for this portion ranged from 1.22 mm to 1.31 mm and 1.11 mm to 1.21 mm in 2008 and 2009 respectively. However, the differences among cultivars were significant only in 2009 (Table 8). The mean stem thickness of cultivars for the lower portion ranged from 1.70 mm to 1.85 mm in 2008. In 2009, this range narrowed down to 1.67 mm to 1.76 mm. Again, the stems of Okinawa consistently had the thickest diameter in both the years. Cultivars were significantly different from each other at $P < 0.05$ (Table 9) in both the years.

Shear Force

Main effects of portion and cultivar were significant at $P < 0.001$ and $P < 0.05$ respectively, for both the years. Upper portion required significantly 55% and 60% less shear force than the lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was not significant in both the years. For upper portion, the mean shear force values ranged from 19.12 N to 27.23 N and 36.79 N to 49.00 N in the year 2008 and 2009 respectively. Significant differences were observed among cultivars in both the years (Table 8). For lower portion, the mean shear force required to cut down the stems ranged from 43.99 N to 57.10 N in 2008. The stems required higher shear force in 2009 than in 2008, ranging from 90.42 N to 110.06 N. Okinawa required the highest shear force to cut down in both the years. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 9). AU Grazer required the lowest shear force to cut the upper stems in 2008 and 2009 and the second lowest force for the lower stems in 2008 and 2009 (Tables 8 and 9).

Leaf Percentage

Main effects of cultivar ($P < .01$) were significant for 2009 only. Portion effects were significant ($P < 0.005$) for both the years. Upper portion had significantly 11% more leaf percentage than lower portion in both the years. Cultivar-portion interaction was not significant for either year. For upper portion, the leaf percentage ranged from 75% to 77% and 71% to 75 % in 2008 and 2009 respectively. Cultivar differences for this portion were significant only in year 2009 (Table 8). Serala was found to have the highest leaf percentage in 2009 for the upper portion. Average leaf percentage of cultivars for lower portion ranged from 67% to 69% in 2008. Leaf percentage was lower in 2009, ranging from 64% to 67%. Serala had the highest leaf percentage in both the years and the cultivars differed significantly from each other at $P < 0.05$ (Table 9). AU Grazer had consistently the second largest leaf percentage for the upper portion in 2009 and the lower portion in 2008 and 2009 (Tables 8 and 9).

Stem Percentage

Main effects of cultivar ($P < .01$) were significant for 2009 only. Portion effects were significant ($P < 0.005$) for both the years. Upper portion had significantly 24% and 21% less stem percentage than lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was not significant for either year. For upper portion, the stem percentage ranged from 23% to 25% and 25% to 29 % in 2008 and 2009 respectively. Cultivar differences for this portion were significant only in year 2009 (Table 8). Okinawa was found to have the highest stem percentage in 2009 for the upper portion. Average stem percentage of cultivars for lower portion ranged from 31% to 33% in 2008. Stem percentage increased in 2009, ranging from 33% to 36%. Okinawa had the highest stem percentage in both the years and the cultivars differed significantly from each other at $P < 0.05$ (Table 9).

Number of Main Stems

The analysis of variance showed that main effects of cultivar were not significant in both 2008 and 2009. Mean number of stems ranged from 17.51 to 24.20 in 2008. Year 2009 had higher number of main stems than 2008 ranging from 28.57 to 39.05. AU Grazer had highest and the second highest number of main stems than all the rest of the cultivars in 2008 and 2009 respectively (Table 12).

Number of short stems

The analysis of variance showed that main effects of cultivar were not significant in both 2008 and 2009. Mean number of short stems ranged from 0.38 to 0.73 in 2008. Year 2009 had higher number of short stems than 2008 ranging from 2.56 to 3.77 (Table 12).

CUT 2

Leaf Dry Weight

Main effects of cultivar were significant ($P < 0.01$) for 2008 only. Portion effects were significant ($P < 0.05$) for both the years. Upper portion had significantly 27% and 20% less leaf dry weight than the lower portion in the year 2008 and 2009. Cultivar-portion interaction was significant ($P \leq 0.05$) for 2008 only. For upper portion, the values for leaf dry weight ranged from 4.14 g to 6.44 g and 8.75 g to 14.21 g in the year 2008 and 2009 respectively. However, the differences among cultivars were significant in both the years (Table 10). Serala and AU Grazer had the highest leaf dry weight for this portion in the year 2008 and 2009, respectively. The mean leaf dry weight of cultivars for lower portion ranged from 5.39 g to 9.04 g in 2008. These values were higher in 2009 ranging from 10.47 g to 17.33 g. Serala and AU Grazer had the highest leaf dry weight in the year 2008 and 2009 respectively. The lowest leaf dry weight was found for AU Lotan in both the years. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 11).

Stem Dry Weight

Analysis of variance showed that main effects of cultivar were significant ($P < 0.05$) for year 2008 only. Portion effects were significant ($P < 0.001$) for both the years. Upper portion had significantly 51% and 49% less stem dry weight than the lower portion in the year 2008 and 2009. Cultivar-portion interaction was significant at $P \leq 0.005$ for 2008 only. For upper portion, the values for stem dry weight ranged from 1.71 g to 2.55 g and 2.91 g to 4.22 g in the year 2008 and 2009 respectively. However, the differences among cultivars were significant only in 2008 (Table 10).The mean stem dry weight of cultivars for lower portion ranged from 3.49 g to 5.21 g in 2008. These values were higher in 2009 ranging from 5.75 g to 8.26 g. Serala and AU Lotan had the highest stem dry weight in the year 2008 and 2009 respectively. The lowest stem dry weight was found for AU Lotan in both the years. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 11).

Number of Branches

Main effects of cultivar were not significant in either year. Portion effects were significant ($P < 0.07$) for year 2008 only. Upper portion had significantly 70% more number of branches than the lower portion in 2008 while it had significantly 70% less number of branches as compared to the lower portion in 2009. Cultivar-portion interaction was also significant at ($P < 0.08$) for 2008 only. For upper portion, the number of branches ranged from 8.80 to 18.00 and 3.35 to 6.58 in 2008 and 2009 respectively. Cultivars were not significantly different from each other in both the years (Table 10). The mean number of branches of cultivars for lower portion ranged from 3.25 to 16.60 in 2008. AU Grazer had the highest number of branches and the cultivars differed from each other significantly in that year In 2009, the cultivars were not significantly different from each other and the mean values ranged from 11.73 to 22.18 (Table 11).

Branch Leaf Weight

The analysis of variance showed that main effects of cultivar and portion and their interaction were not significant in both the years. Upper portion had more branch leaf weight than lower portion in 2008 while this trend reversed in 2009. For upper portion, branch leaf weight ranged from 0.35 g to 0.82 g and 0.07 to 0.26 g in 2008 and 2009 respectively. The same values of cultivars for lower portion in the two years ranged from 0.10 g to 0.58 g and 0.42 g to 0.79 g respectively. However, the cultivars differed from each other only for lower portion in the year of 2008 where AU Grazer had the highest branch leaf weight (Table 10 and 11).

Branch Stem Weight

The analysis of variance showed that main effects of cultivar and portion and their interaction were not significant in both the years. Upper portion had more branch stem weight than lower portion in 2008 while this trend reversed in 2009. For upper portion, branch stem weight ranged from 0.13 g to 0.26 g and 0.03 g to 0.10 g in 2008 and 2009 respectively. The same values of cultivars for lower portion in the two years ranged from 0.04 g to 0.22 g and 0.13 g to 0.23 g respectively. However, the cultivars differed from each other only for lower portion in the year of 2008 where AU Grazer had the highest branch stem weight (Table 10 and 11).

Total Dry Weight

Main effects of cultivar were significant for year 2008 only. Portion effects were significant ($P < 0.005$) for both the years. Upper portion had significantly 36% and 30% less total dry weight than the lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was significant ($P < 0.05$) for year 2008 only. For upper portion, the mean total dry weight values ranged from 5.85 g to 9.00 g and 11.66 g to 18.43 g in 2008 and 2009 respectively. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 10). Serala and AU Grazer were found to have the highest total dry weight in 2008 and 2009 respectively for this portion. The mean total dry weight of cultivars for lower portion ranged from 8.88 g to 14.25 g in 2008. In 2009, these values were higher, ranging from 16.22 g to 25.58 g. Serala and AU Grazer had the highest total dry weight in 2008 and 2009 respectively. Cultivars were significantly different from each other at $P < 0.05$ in both the years (Table 11).

Stem Thickness

Main effects of cultivar were significant ($P < 0.005$) for 2009 only. Portion effects were significant ($P < 0.0005$) for both the years. Upper portion had significantly 24% and 21% less stem thickness than the lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was not significant for either year. For upper portion, the stem thickness ranged from 1.03 mm to 1.10 mm and 0.94 mm to 1.05 mm in 2008 and 2009 respectively. Okinawa had the largest stem thickness for this portion and the cultivars were significantly different from each other in both the years (Table 10). The mean stem thickness of cultivars measured for lower portion ranged from 1.37 mm to 1.45 mm in the year 2008. The stems were thinner in 2009 with values ranging from 1.19 mm to 1.33 mm. Again, Okinawa had the largest stem thickness and the cultivars were significantly different from each other in both the years (Table 11).

Shear Force

Main effects of cultivar were significant ($P < 0.06$) in 2009 only. Portion effects were significant ($P < 0.001$) for both the years. Upper portion required significantly 67% and 68% less shear force than the lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was significant ($P \leq 0.06$) for 2009 only. For upper portion, the shear force values ranged from

19 N to 22.75 N and 19.20 N to 23.38 N in 2008 and 2009 respectively, but no significant cultivar differences were observed at $P < 0.05$ for this portion (Table 10). The mean shear force required to cut down the stems of cultivars for lower portion ranged from 63.03 N to 66.78 N and 59.06 N to 77.09 N in 2008 and 2009 respectively. Cultivars were significantly different only in 2009 where Okinawa required the highest shear force among the cultivars tested (Table 11).

Leaf Percentage

Main effects of cultivar were significant ($P \leq 0.05$) only in 2008. Portion effects were significant ($P < 0.001$) for both the years. Upper portion had significantly 15% and 14% more leaf percentage than the lower portion in the year 2008 and 2009 respectively. Cultivar-portion interaction was not significant in either year. For upper portion, year 2008 had less leaf percentage than 2009 with values ranging from 67 % to 71%. These values ranged from 75% to 77% in 2009. Cultivars differed from each other only in the year 2008 for this portion (Table 10). Again, year 2008 had less leaf percentage for lower portion than 2009 with values ranging from 58 % to 63%. These values ranged from 65% to 69% in 2009. Cultivars differed from each other in both the years at $P < 0.05$ (Table 11). Serala had the highest leaf percentage for both the portions in both years. AU Grazer had the second largest leaf percentage for both the portions in 2009.

Stem Percentage

Main effects of cultivar were significant ($P \leq 0.05$) only in 2008. Portion effects were significant ($P < 0.001$) for both the years. Upper portion had significantly 24% and 28% less stem percentage than the lower portion in the year 2008 and 2009. Cultivar-portion interaction was not significant in either year. For upper portion, year 2008 had more stem percentage than 2009 with values ranging from 29 % to 33%. These values ranged from 23% to 25% in 2009. Arlington and Okinawa had the highest stem percentage in 2008 and 2009 respectively. Cultivars differed from each other only in the year 2008 for this portion (Table 10). Year 2008 had more stem percentage for lower portion than 2009 with values ranging from 37 % to 42%. These values ranged from 31% to 35% in 2009. Arlington and AU Lotan had the highest stem percentage in 2008 and 2009 respectively. Cultivars differed from each other in both the years at $P < 0.05$ (Table 11).

Number of Main Stems

The analysis of variance showed that main effects of cultivar were significant at $P < 0.05$ and $P < 0.10$ in 2008 and 2009 respectively. The mean number of main stems ranged from 24.71 to 36.31 and 43.51 to 65.44 in year 2008 and 2009 respectively. AU Grazer had the highest number of main stems and this cultivar had significantly more number of main stems than AU Lotan and Okinawa in both the years. Other contrasts were not significantly different from each other in both years at $P < 0.05$ (Table 12).

Number of short stems

The analysis of variance showed that main effects of cultivar were not significant in both the years. The mean number of short stems ranged from 9.74 to 13.07 and 25.93 to 37.19 in year 2008 and 2009 respectively. AU Grazer and AU Lotan had the highest number of short stems in 2008 and 2009 respectively.

Summary

In summary, as compared to the upper portion of the plant canopy, in the lower portion of the plant canopy all the trait values measured during the growth of plants were higher except for leaf percentage. During regrowth, leaf percentage in both the years and branch stem weight and branch leaf weight in 2008 were recorded more for the upper portion while all other traits were higher for the lower portion.

During growth, for upper portion, cultivars did not differ from each other for leaf dry weight, stem dry weight, number of branches, branch leaf weight, branch stem weight and total dry weight in 2008 and 2009. Additionally, the cultivars had statistically similar values for stem thickness, leaf percentage and stem percentage in 2008. Okinawa had the highest shear force values for both the years. This cultivar also had the highest stem thickness in 2009. Leaf percentage in 2009 was highest for Serala followed by AU Grazer. For lower portion, AU Grazer had the highest values for leaf dry weight, stem dry weight and total dry weight in 2008. Cultivars were statistically similar for these traits in 2009. AU Grazer also had the second highest and highest number of branches, branch leaf weight and branch stem weight in 2008 and 2009 respectively. Okinawa had the highest stem thickness and shear force in both the years. Serala and AU Grazer had the highest and second highest leaf percentage values respectively for this portion.

During regrowth, for upper portion, the response was similar to the growth of plants. AU Grazer had the second highest and highest leaf dry weight, stem dry weight and total dry weight in 2008 and 2009 respectively. Cultivars did not differ from each other for number of branches, branch leaf weight and branch stem weight. For lower portion, AU Grazer had the highest or second highest values for the majority of the traits. Okinawa had the highest stem thickness and shear force in both the years.

Conclusions

AU Grazer was the best or among the best cultivars for plant characteristics important from production point of view, whereas it was the last ranked or among the last ranked cultivars in terms of characteristics affecting pliability such as stem thickness and shear force. Okinawa was considered as the poorest performer as it had greater stem thickness and required more shear force.

References

Donnelly, E.D. 1954. Some factors that affect palatability in Sericea Lespedeza, *L. cuneata*. Agronomy Journal 46:96-97.

Donnelly, E.D. 1965. Serala Sericea (Reg. No. 4). Crop Science 5:605.

Donnelly, E.D. 1981. Registration of AU Lotan Sericea Lespedeza (Reg. No. 11). Crop Science 21:474.

Donnelly, E.D., and G.E. Hawkins. 1959. The effects of stem type on some feeding qualities of sericea lespedeza, *L. cuneata*, as indicated in a digestion trial with rabbits. Agronomy Journal 51:293-294.

Guernsey, W.J. 1970. Sericea lespedeza: its use and management, in: USDA (Ed.), Farmers Bulletin 2245.

Mcgraw, R.L., and C.S. Hoveland. 1995. Lespedezas, in: R. F. Barnes, et al. (Eds.), Forages:An introduction to grassland agriculture, Iowa State University Press, Ames, Iowa. pp. 261-271.

Mosjidis, J.A. 1997. Lespedeza cuneata (Dumont de Courset) G. Don, in: I. F. Hanum and L. J. G. v. d. Maesen (Eds.), Plant Resources of South-East Asia No. 11, Auxiliary plants, Backhuys Publishers, Leiden, The Netherlands. pp. 170-173.

Mosjidis, J.A. 2000. Sericea lespedeza biomass composition for bioenergy in the southeastern USA, 1st World Conference on Biomass for Energy and Industry, Sevilla, Spain. pp. 321-322.

Mosjidis, J.A. 2001. Registration of 'AU Grazer' Sericea Lespedeza. Crop Science 41:262.

Mosjidis, J.A., and E.D. Donnelly. 1989. Registration of 'AU Donnelly' Sericea Lespedeza. Crop Science 29:237-238.

Pieters, A.J. 1939. Lespedeza sericea and other perrenial lespedezas for forage and soil conservation, in: USDA (Ed.), Circ. 534.

Pieters, A.J., P.R. Henson, W.E. Adams, and A.P. Barnett. 1950. Sericea and other perrenial lespedezas for forage and soil conservation in: USDA (Ed.), Circ. 863.

USDA-ARS. National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). Available at: http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1371915 (verified date-June 13, 2010).

USDA-ARS. National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). Available at: http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1088122 (verified date-June 13, 2010)

Table 8: Least square means for upper portion of first cut for years 2008 and 2009

	Upper portion									
Year-Cultivar	Leaf dry weight	Stem dry weight	Number of branches	Branch leaf weight	Branch stem weight	Total dry weight	Stem thickness	Shear Force	Leaf Percentage	Stem Percentage
	---------g----------			------------------g------------------			---mm---	-----N-----	------------%------------	
2008										
AUGrazer	5.85 a	1.78 a	3.85 a	0.27 a	0.09 a	7.63 a	1.22 a	19.12 c	76.58 a	23.42 a
AULotan	4.56 a	1.51 a	2.05 a	0.09 a	0.03 a	6.07 a	1.22 a	22.75 ac	75.14 a	24.86 a
Serala	4.29 a	1.44 a	2.67 a	0.14 a	0.05 a	5.73 a	1.22 a	20.68 bc	75.33 a	24.67 a
Okinawa	5.33 a	1.74 a	2.48 a	0.12 a	0.04 a	7.07 a	1.31 a	27.23 a	75.60 a	24.40 a
Arlington	5.66 a	1.86 a	2.10 a	0.11 a	0.04 a	7.52 a	1.26 a	25.27 ab	75.19 a	24.81 a
2009										
AUGrazer	9.10 a	3.22 a	1.30 a	0.04 a	0.01 a	12.32 a	1.14 ab	36.79 b	73.80 ab	26.20 bc
AULotan	6.81 a	2.71 a	1.03 a	0.03 a	0.01 a	9.52 a	1.11 b	38.64 b	71.99 bc	28.01 ab
Serala	9.93 a	3.19 a	2.78 a	0.07 a	0.03 a	13.08 a	1.13 ab	39.02 ab	74.69 a	25.31 c
Okinawa	9.04 a	3.73 a	0.00 a	0.00 a	0.00 a	12.77 a	1.21 a	49.00 a	70.95 c	29.05 a
Arlington	9.50 a	3.72 a	9.99 a	0.36 a	0.11 a	13.22 a	1.15 ab	38.27 b	71.24 c	28.76 a

Means followed by the same letter were not significantly different according to the t-test on difference of least square means at P = 0.05

Table 9: Least square means for lower portion of first cut for years 2008 and 2009

Year-Cultivar	Leaf dry weight	Stem dry weight	Number of branches	Branch leaf weight	Branch stem weight	Total dry weight	Stem thickness	Shear Force	Leaf Percentage	Stem Percentage
	Lower portion									
	-----------g----------			-------------------g-------------------			---mm---	----N----	-------------%-------------	
2008										
AUGrazer	9.20 a	4.17 a	26.00 ab	1.26 a	0.38 ab	13.38 a	1.74 ab	48.94 cd	68.79 ab	31.21 ab
AULotan	7.25 b	3.48 ab	30.62 a	1.37 a	0.42 a	10.73 b	1.76 ab	50.40 bc	67.49 ab	32.51 ab
Serala	6.92 b	3.05 b	16.32 c	0.59 c	0.18 c	9.96 b	1.70 b	43.99 d	69.40 a	30.60 b
Okinawa	7.75 ab	3.79 ab	12.65 d	0.54 d	0.17 c	11.54 ab	1.85 a	57.10 a	67.13 b	32.87 a
Arlington	8.30 ab	4.05 a	21.33 bc	0.90 bc	0.27 bc	12.35 ab	1.82 a	52.41 abc	67.15 b	32.85 a
2009										
AUGrazer	14.81 a	7.79 a	85.56 a	3.23 a	0.96 a	22.60 a	1.70 ab	93.83 bc	65.77 ab	34.23 ab
AULotan	10.95 a	6.07 a	46.43 bc	1.76 bc	0.55 ab	17.03 a	1.67 b	98.90 bc	64.05 b	35.95 a
Serala	14.11 a	7.05 a	82.60 ab	2.90 ab	0.94 a	21.17 a	1.67 b	103.72 ab	66.54 a	33.46 b
Okinawa	12.99 a	7.30 a	28.47 c	1.27 c	0.40 b	20.29 a	1.76 a	110.06 a	64.05 b	35.95 a
Arlington	15.45 a	8.08 a	75.28 ab	3.01 a	0.96 a	23.54 a	1.76 a	90.42 c	65.43 ab	34.57 ab

Means followed by the same letter were not significantly different according to the t-test on difference of least square means at P = 0.05

Table 10: Least square means for upper portion of second cut for years 2008 and 2009

	Upper portion									
Year-Cultivar	Leaf dry weight	Stem dry weight	Number of branches	Branch leaf weight	Branch stem weight	Total dry weight	Stem thickness	Shear Force	Leaf Percentage	Stem Percentage
	-----------g-----------			-------------------g-------------------			---mm---	---N----	-------------%-------------	
2008										
AUGrazer	5.47 ab	2.45 a	17.71 a	0.63 a	0.26 a	7.92 a	1.04 ab	19.00 a	69.16 ab	30.84 ab
AULotan	4.14 c	1.71 b	13.22 a	0.46 a	0.16 a	5.85 b	1.03 b	22.71 a	70.81 a	29.19 b
Serala	6.44 a	2.55 a	19.75 a	0.82 a	0.30 a	9.00 a	1.08 ab	21.97 a	71.59 a	28.41 b
Okinawa	5.37 abc	2.22 ab	8.80 a	0.35 a	0.13 a	7.59 ab	1.10 a	22.75 a	70.36 a	29.64 b
Arlington	4.92 bc	2.39 a	18.00 a	0.54 a	0.21 a	7.31 ab	1.09 ab	21.19 a	67.02 b	32.98 a
2009										
AUGrazer	14.21 a	4.22 a	4.97 a	0.15 a	0.07 a	18.43 a	0.98 b	20.23 a	77.09 a	22.91 a
AULotan	8.75 b	2.91 a	4.80 a	0.19 a	0.10 a	11.66 b	0.95 b	20.58 a	75.43 a	24.57 a
Serala	12.66 ab	3.55 a	3.35 a	0.07 a	0.03 a	16.20 ab	0.94 b	19.59 a	77.19 a	22.81 a
Okinawa	10.81 ab	3.56 a	4.09 a	0.14 a	0.05 a	14.37 ab	1.05 a	23.38 a	75.09 a	24.91 a
Arlington	10.93 ab	3.51 a	6.58 a	0.26 a	0.08 a	14.44 ab	0.94 b	19.02 a	75.68 a	24.32 a

Means followed by the same letter were not significantly different according to the t-test on difference of least square means at P = 0.05

Table 11: Least square means for lower portion of second cut for years 2008 and 2009

	Lower portion									
Year-Cultivar	Leaf dry weight	Stem dry weight	Number of branches	Branch leaf weight	Branch stem weight	Total dry weight	Stem thickness	Shear Force	Leaf Percentage	Stem Percentage
	----------g----------			--------------------g--------------------			---mm---	---N---	-------------%------------	
2008										
AUGrazer	7.64 ab	5.07 a	16.60 a	0.58 a	0.22 a	12.71 ab	1.41 ab	63.29 a	60.32 ab	39.68 ab
AULotan	5.39 c	3.49 b	16.20 ab	0.54 a	0.19 a	8.88 c	1.37 b	63.43 a	60.36 ab	39.64 ab
Serala	9.04 a	5.21 a	4.14 bc	0.22 ab	0.07 ab	14.25 a	1.39 ab	63.03 a	63.37 a	36.63 b
Okinawa	7.09 b	4.55 a	5.19 abc	0.20 ab	0.07 ab	11.64 b	1.45 a	66.34 a	60.75 ab	39.25 ab
Arlington	6.78 b	4.91 a	3.25 c	0.10 b	0.04 b	11.69 b	1.44 a	66.78 a	57.62 b	42.38 a
2009										
AUGrazer	17.33 a	8.26 a	22.18 a	0.79 a	0.18 a	25.58 a	1.24 b	66.62 b	67.63 a	32.37 b
AULotan	10.47 b	5.75 b	13.06 a	0.50 a	0.13 a	16.22 b	1.21 b	60.89 b	64.93 b	35.07 a
Serala	16.34 a	7.37 ab	19.96 a	0.69 a	0.23 a	23.72 a	1.19 b	59.06 b	68.46 a	31.54 b
Okinawa	13.17 ab	6.62 ab	11.73 a	0.47 a	0.13 a	19.79 ab	1.33 a	77.09 a	66.05 ab	33.95 ab
Arlington	14.51 ab	6.86 ab	11.98 a	0.42 a	0.17 a	21.37 ab	1.22 b	61.89 b	67.75 a	32.25 b

Means followed by the same letter were not significantly different according to the t-test on difference of least square means at P = 0.05

Table 12: Mean number of cultivar main stems and short stems per plant for cut 1 and cut 2 in 2008 and 2009

	Cut 1		Cut 2	
Year-Cultivar	Main stems	Short stems	Main stems	Short stems
2008				
AU Grazer	24.20 a	0.38 a	36.31 a	13.07 a
AU Lotan	19.40 ab	0.45 a	24.71 c	12.83 a
Serala	17.51 b	0.43 a	35.99 a	10.83 a
Okinawa	18.38 b	0.68 a	28.12 bc	9.74 a
Arlington	22.88 ab	0.73 a	32.58 ab	11.23 a
2009				
AU Grazer	37.02 a	2.79 a	65.44 a	31.75 ab
AU Lotan	28.57 a	3.77 a	43.51 b	37.19 a
Serala	35.66 a	3.51 a	59.67 ab	32.37 ab
Okinawa	30.61 a	2.56 a	45.83 b	25.93 b
Arlington	39.05 a	3.30 a	56.70 ab	31.65 ab

Means followed by the same letter were not significantly different according to the t-test on difference of least square means at P = 0.05

IV. Effect of genotype on quality traits in sericea lespedeza

Abstract

During the last 60 years, cultivars of varying morphological and quality traits have been developed in sericea lespedeza. However, the forage quality has not been measured and compared in these old and new cultivars (Arlington, Okinawa, Serala, AU Lotan, and AU Grazer released in 1939, 1944, 1962, 1980, and 1997, respectively). The objectives of this study were to compare the forage quality of these temporally released cultivars and to determine the relationship between plant growth and forage quality. Plants of these cultivars were grown in field in 2007 in a randomized complete block design (r=4) and harvested twice in 2008 and 2009. Only the plants harvested from 2009 were used to measure forage quality. Top 30 cm of the canopy was used and divided into two equal portions. Leaves were separated from stems and dried. The forage quality parameters measured for two cuts were Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), Tannin and Nitrogen using Near Infrared Reflectance Spectroscopy (NIRS).

For both cuts, variation for all the traits across cultivars in leaves and stems of both plant portions was small. Stems had higher NDF, ADF and ADL values whereas leaves had more tannin and nitrogen content for both portions. During growth, AU Grazer and AU Lotan had low to intermediate ADF and NDF values while old cultivars had high values for these traits for upper leaves and stems as well as for lower leaves. For lower portion, stems of different cultivars did not differ from each other for these traits. AU Grazer had high ADL values for both stems

and leaves for upper portion. For lower portion, Okinawa had high ADL values for leaves whereas stems of cultivars did not vary among themselves for this trait. AU Lotan and Okinawa had the highest tannin and nitrogen content respectively for stems and leaves from both the portions.

During regrowth, cultivars behaved similarly for all the traits for upper portion for leaves and stems except for ADF of leaves where Okinawa had the highest ADF values. For lower portion, AU Grazer and AU Lotan had low to intermediate ADF and NDF values for leaves and stems while old cultivars had high values for these traits. Okinawa had high ADL values for leaves whereas values of this trait were similar for stems of cultivars for both portions. Tannin content in leaves and stems of all cultivars was statistically similar for upper portion. For lower portion, only stems of the cultivars differ from each other for tannin content where AU Grazer had the highest values. Nitrogen content was similar in all cultivars for leaves and stems from both portions.

Introduction

Sericea lespedeza is a deep rooted warm season perennial crop which is widely grown in southeastern USA as a pasture, conservation and hay crop. It has several desirable properties such as no fertilizer requirement, drought tolerance and rare occurrence of diseases (Ball and Mosjidis, 2007). Sericea lespedeza forage yields are good (Ball and Mosjidis, 1995) and fresh forage quality assessed in terms of animal performance was found equivalent to that of alfalfa for dairy heifers (Burns et al., 1972). Alternatively, Schmidt et al (1987) reported that forage digestibility of alfalfa was higher than sericea lespedeza, (thus resulting in better beef steer performance), although variability existed among sericea lespedeza cultivars. Sericea lespedeza hay feeding to goats reduced gastrointestinal nematode infection and increased growth rate (average daily gain) as compared to bermudagrass hay (Moore et al., 2008). Sericea lespedeza contains condensed tannins found to be localized in paraveinal mesophyll cells of leaves and perivascular and vascular parenchyma cells of stems, suggesting their role in photosynthate transport (Mosjidis et al., 1990). Based on the tannin content, sericea lespedeza cultivars are known as low and high tannin containing cultivars. Low tannin doesn't necessarily mean all the plants in that cultivar possess low tannin content but on an average the cultivar has lower tannin content than the so called high tannin cultivars (Mosjidis unpublished data).

Extensive research has been conducted to study variation in forage quality factors in low tannin and high tannin sericea lespedeza genotypes. Low tannin sericea lespedeza in different years, locations and harvests consistently gave 25% higher in vitro dry matter digestibility (IVDMD) than high tannin sericea lespedeza (Cope and Burns, 1971). Similar results for digestible dry matter (DDM) of low and high tannin sericea lespedeza plants were obtained using *in vivo* nylon bag technique. Small increase of tannin content in low tannin sericea lespedeza as compared to greater increase in high tannin sericea lespedeza was also recorded between two successive cuttings. However, the data also suggested a tannin threshold (near the upper limit of low tannin group) in relation to DDM (Donnelly and Anthony, 1970). Even though the crude protein percentage was same for both high and low tannin forages, less crude protein in feces was found for steers consuming low tannin sericea lespedeza indicating more digestibility (Donnelly et al., 1971). Differences among low tannin lines and cuttings were found for digestible dry matter, crude protein, and tannin content. However, their interaction was significant for crude protein only. Lines with similar tannin content had different amounts of IVDDM suggesting another factor/factors affecting IVDDM (Donnelly and Anthony, 1983).

Seasonal factors such as temperature and rainfall as well as plant maturity affect the tannin content in sericea lespedeza plants. It was found that tannin content increased with increase in temperature and decrease in rainfall. The oldest plant tissue had higher tannin content than the youngest tissue. Moreover, successive cuts on the same plant material gave higher tannin amount. No relationship was found between tannin content and the height of the plants (Donnelly, 1959).

Various plant parts of sericea lespedeza vary from each other in terms of tannin content as well as other quality characteristics. Cope and Burns (1974) reported that leaves were low in IVDMD and high in tannin as compared to stems when averaged over strains, years, and cuttings while higher values were found for stems for NDF, ADF, Lignin, Lignin/ADF ratio, cellulose and hemicelluloses. IVDMD dropped greatly for stems with successive cuts in contrast to leaves. Stems and leaves of low tannin strain gave higher IVDMD over all harvests as compared to fine-stem and common strain of sericea lespedeza. The fine stem strain was generally lowest in NDF, ADF and lignin. A negative correlation of fiber content and IVDMD was also reported (Cope and Burns, 1974). Likewise, in a more extensive research exploring tannin content within the whole sericea lespedeza plant, low tannin was found in stems, roots and cotyledons. Intermediate amounts were found in senescent leaves and seeds while higher amounts in younger (top) leaves and flowers (Burns, 1966). Even large strata effects on stem NDF, ADF, protein, cellulose and hemicellulose have been measured. NDF, ADF, cellulose, and hemicellulose concentration was more at the stem base than top whereas protein content reduced from top to bottom of the plant (Mosjidis, 2000).

However, forage quality has not been measured and compared in old and new cultivars released over the past 60 years. The objective of this research was to compare the forage quality of old cultivars [Arlington released in 1939 (USDA-ARS, http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1371915), Okinawa released in 1944 (USDA-SCS, http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1088122; C.M. Owsley personal communication), Serala released in 1962 (Donnelly, 1965)], and new cultivars [AU Lotan released in 1980 (Donnelly, 1981) and AU Grazer released in 1997 (Mosjidis, 2001)] and to determine the relationship between plant growth and forage quality.

Materials and Methods

Five cultivars of sericea lespedeza namely Arlington, Okinawa, Serala, AU Lotan, and AU Grazer released in 1939, 1944, 1962, 1980, and 1997 respectively were planted in the greenhouse. The individual plants were space transplanted to the field at the Plant Breeding Unit, E.V. Smith Research Center, Tallassee, Alabama in 2007. Individual plants were placed at 61 cm from each other in a randomized complete block design with 20 plants per cultivar (plot) and 4 replications. Each year two cuts were taken.

Ten random plants were harvested from each plot (cultivar) in the year 2008 and 2009. The number of main stems per plant was recorded. Main stems were those that had reached a height of 40 cm or more. The top 30 cm of the main stems was divided into two equal portions – upper and lower. After taking branch count from the respective portion, they were removed from the stems. Herbage samples of both portions from each plant were dried at 60˚C for 48 hours and then leaves were separated from the stems. Only the plants harvested from the year 2009 were considered for forage quality analysis. Upper and lower 15 cm portion stem and leaves were ground using a cyclone mill to pass through a 1 mm screen. Branch stem and branch leaves were not included for forage quality analysis.

Near Infrared Reflectance Spectroscopy (NIRS) was used for analysis of forage quality parameters. Each sample was packed into ring cups and scanned using a FOSS NIRSystems Model 5000 scanning monochromator. A total of 70 and 60 samples were randomly selected from both the cuts representing leaf and stem plant structures respectively. Calibration equations were generated from the selected samples for quality traits such as Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), Tannins and Nitrogen for leaves and stems separately. R^2 values obtained for leaves for NDF, ADF, ADL, Tannins and Nitrogen are: 0.7964, 0.9063, 0.4405, 0.6625 and 0.2272 respectively. R^2 values for stems for the same traits are: 0.9487, 0.9071, 0.8395, 0.5637 and 0.9823 respectively. All the trait values for each sample were thus obtained using the calibration equations. NDF, ADF and ADL were determined using methods described by Van Soest (Van Soest, 1963). Tannin concentration was determined by modified vanillin-HCl procedure (Terrill et al., 1990). N content was determined by dry combustion in a macro elemental analyzer from Elementar, Americas, Inc. (Mt Laurel, NJ).

Data were analyzed by cut for leaves and stems separately as a factorial experiment in a split-plot design with cultivars as main plots and portions as subplots. Data were subjected to analysis of variance using SAS® PROC GLIMMIX. Least square means were used for mean separation at $P \leq 0.05$.

Results and discussion

Cut 1

Neutral Detergent fiber (NDF)

Analysis of variance showed that main effects of cultivar were not significant for both leaves and stems. Portion effects were significant (P < 0.001) only for the stems. Leaves from the upper and lower portion had equal amount of NDF but the stems from upper portion had significantly (16 %) less NDF than those from the lower portion. Cultivar-portion interaction was not significant for both the leaves and stems. Variation for NDF across cultivars in leaves and stems of both plant portions was small. The mean NDF of leaves and stems for upper portion ranged from 444 to 464 g per kg and 573 to 588 g per kg respectively. Okinawa and Serala had the highest values of NDF for leaves and stems, respectively for this portion. Cultivars were significantly different from each other at $P < 0.05$ (Table 13) for both the plant structures. For lower portion, the NDF values of leaves and stems ranged from 439 to 462 g per kg and 687 to 693 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for leaves only for this portion where Arlington had the highest NDF percentage (Table 14).

Acid Detergent fiber (ADF)

Analysis of variance showed that main effects of cultivar were not significant for both leaves and stems. Portion effects were significant (P < 0.001) only for the stems. Leaves from the upper and lower portion had almost equal amount of ADF but the stems from upper portion had significantly 21 % less ADF than those from the lower portion. Cultivar-portion interaction was significant at $P < 0.08$ and $P < 0.03$ for leaves and stems respectively. Variation for ADF across cultivars in leaves and stems of both plant portions was small. The mean ADF of leaves and stems for upper portion ranged from 246 to 262 g per kg and 408 to 425 g per kg respectively. Arlington and Serala had the highest values of ADF for leaves and stems, respectively for this portion. Cultivars were significantly different from each other at $P < 0.05$ (Table 13) for stems only. For lower portion, the ADF values of leaves and stems ranged from 267 to 280 g per kg and 529 to 533 g per kg respectively. Cultivars were not significantly different from each other at $P < 0.05$ for both leaves and stems for this portion (Table 14).

Acid Detergent Lignin (ADL)

Analysis of variance showed that main effects of cultivar were significant for leaves only. Portion effects were significant ($P < 0.001$) only for the stems. Leaves from the upper and lower portion had almost equal amount of ADL but the stems from upper portion had significantly 17 % less ADL than those from the lower portion. Cultivar-portion interaction was significant at $P < 0.02$ and $P < 0.10$ for leaves and stems respectively. However, there was little variation in ADL content. The mean ADL of leaves and stems for upper portion ranged from 90 to 94 g per kg and 112 to 115 g per kg respectively. AU Grazer had the highest values of ADL for leaves and stems for this portion. Cultivars were significantly different from each other at $P < 0.05$ (Table 13) for both the plant structures. For lower portion, the ADL values of leaves and stems ranged from 94 to 101 g per kg and 135 to 137 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for only leaves for this portion where Okinawa had the highest ADL percentage (Table 14).

Tannin

Analysis of variance showed that main effects of cultivar were not significant for both the leaves and stems. Portion effects were significant ($P < 0.001$) only for the stems. Leaves from the upper and lower portion had almost equal amount of tannin but the stems from upper portion had significantly 42% more tannin content than those from the lower portion. Cultivar-portion interaction was not significant for the leaves as well as the stems. The mean tannin content of leaves and stems for upper portion ranged from 194 to 244 g per kg and 70 to 95 g per kg, respectively. AU Lotan had the highest values of tannin for leaves and stems for this portion. Cultivars were significantly different from each other at $P < 0.05$ (Table 13) for both the plant structures. For lower portion, the tannin values of leaves and stems ranged from 205 to 244 g per kg and 47 to 68 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for only stems for this portion where AU Lotan had the highest tannin percentage (Table 14).

Nitrogen

Analysis of variance showed that main effects of cultivar were significant for stems only. Portion effects were significant ($P < 0.001$) only for the stems. Leaves from the upper and lower portion had almost equal amount of nitrogen but the stems from upper portion had significantly 50 % more nitrogen than those from the lower portion. Cultivar-portion interaction was significant at $P < 0.03$ for stems only. Variation among cultivars for leaves or stems within a plant portion was small. The mean nitrogen content of leaves and stems for upper portion ranged from 27 to 29 and 22 to 24 g per kg, respectively. Okinawa had the highest nitrogen values for leaves and stems for this portion. Cultivars were significantly different from each other at $P < 0.05$ (Table 13) for both the plant structures. For lower portion, the nitrogen values of leaves and stems ranged from 28 to 29 g per kg and 14 to 16 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for the leaves as well as the stems for this portion where Okinawa again had the highest nitrogen values (Table 14).

Cut 2

Neutral Detergent Fiber (NDF)

Analysis of variance showed that main effects of cultivar were not significant for both leaves and stems. Portion effects were significant ($P < 0.05$) for both the leaves and stems. Leaves from the upper portion had significantly 6% more NDF than the leaves from the lower portion. The stems from upper portion had significantly 12 % less NDF than the stems from the lower portion. Cultivar-portion interaction was not significant for both the leaves and stems. Variation for NDF across cultivars in leaves and stems of both plant portions was small. The mean NDF of leaves and stems for upper portion ranged from 447 to 457 g per kg and 611 to 625 g per kg, respectively. Okinawa had the highest values of NDF for leaves and stems for this portion. However, cultivars were not significantly different from each other at $P < 0.05$ (Table 15) for both the plant structures. For lower portion, the NDF values of leaves and stems ranged from 421 g per kg to 436 g per kg and 692 to 717 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for leaves as well as stems for this portion where Okinawa had the highest NDF percentage (Table 16).

Acid Detergent Fiber (ADF)

Analysis of variance showed that main effects of cultivar were significant for leaves only. Portion effects were significant ($P < 0.001$) only for the stems. Leaves from the upper and lower portion had almost equal amount of ADF but the stems from upper portion had significantly 16 % less ADF than those from the lower portion. Cultivar-portion interaction was not significant for leaves and stems. Variation for ADF across cultivars in leaves and stems of both plant portions was small. The mean ADF of leaves and stems for upper portion ranged from 244 to 256 g per kg and 455 to 460 g per kg respectively. Okinawa had the highest values of ADF for leaves and stems for this portion. Cultivars were significantly different from each other at $P < 0.05$ (Table 15) for leaves only. For lower portion, the ADF values of leaves and stems ranged from 244 to 262 g per kg and 538 to 553 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for only leaves for this portion where the highest values of ADF were found for Okinawa (Table 16).

Acid Detergent Lignin (ADL)

Analysis of variance showed that main effects of cultivar were not significant both for leaves and stems. Portion effects were significant ($P < 0.05$) for both the leaves and stems. Leaves and stems from upper portion had significantly 8% and 13 % less ADL than the leaves and stems from the lower portion respectively. Cultivar-portion interaction was not significant both for leaves and stems. Variation for ADL across cultivars in leaves and stems of both plant portions was small. The mean ADL of leaves and stems for upper portion ranged from 86 to 91 g per kg and 124 to 125 g per kg respectively. Okinawa and AU Lotan had the highest values of ADL for leaves and stems respectively for this portion. Cultivars were not significantly different from each other (Table 15) for both the plant structures. For lower portion, the ADL values of leaves and stems ranged from 92 to 98 g per kg and 143 to 145 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for only leaves for this portion where Okinawa had the highest ADL percentage (Table 16).

Tannin

Analysis of variance showed that main effects of cultivar were not significant for both the leaves and stems. Portion effects were significant ($P < 0.001$) only for the stems. Leaves from the upper and lower portion had almost equal amount of tannin but the stems from upper portion had significantly 26% more tannin content than those from the lower portion. Cultivar-portion interaction was not significant for the leaves as well as the stems. The mean tannin content of leaves and stems for upper portion ranged from 280 to 302 g per kg and 108 to 115 g per kg respectively. AU Grazer had the highest values of tannin for leaves and stems for this portion. Cultivars were not significantly different from each other at $P < 0.05$ (Table 15) for both the plant structures. For lower portion, the tannin values of leaves and stems ranged from 268 to 296 g per kg and 85 to 95 g per kg respectively. Cultivars were significantly different from each other at $P < 0.05$ for only stems for this portion where AU Grazer had the highest tannin percentage (Table 16).

Nitrogen

Analysis of variance showed that main effects of cultivar were not significant for both the leaves and stems. Portion effects were significant ($P < 0.001$) for leaves as well as the stems. Leaves from the upper portion had significantly 2% less while the stems from the upper portion had 40 % more nitrogen than the leaves and the stems from the lower portion respectively. Cultivar-portion interaction was not significant for both the plant structures. Variation for nitrogen across cultivars in leaves and stems of both plant portions was small. The mean nitrogen content of leaves and stems for upper portion ranged from 25.3 to 25.6 g per kg and 16.7 to 17.0 g per kg, respectively. Cultivars were not significantly different from each other at $P < 0.05$ (Table 15) for both the plant structures. For lower portion, the nitrogen values of leaves and stems ranged from 25.5 to 26.2 g per kg and 11.7 to 12.5 g per kg, respectively. Cultivars were not significantly different from each other at $P < 0.05$ for the leaves as well as the stems for this portion also (Table 16).

Summary

For first growth (cut 1), variation for all the traits across cultivars in leaves and stems of both plant portions was small. Stems had higher NDF, ADF and ADL values than leaves whereas leaves had more tannin and nitrogen content than stems for both portions. For the upper portion, AU Grazer and AU Lotan had lower NDF and ADF values for leaves and stems than the old cultivars. AU Grazer had higher ADL values for both stems and leaves than the other cultivars.

For the lower portion during first growth, AU Grazer and AU Lotan had lower NDF and ADF values for leaves than old cultivars. Okinawa had high ADL values for leaves. Stems of different cultivars did not differ from each other for NDF, ADF, or ADL for this portion. Also, cultivars had similar values for tannin and nitrogen content. AU Lotan and Okinawa had the highest tannin and nitrogen content for stems and leaves, respectively, from both the portions.

For regrowth (cut 2), variation for quality traits among cultivars for leaves or stems within a plant portion was small again. All the trait values during regrowth were similar to that of growth (cut 1). Cultivars behaved similarly for all the traits for upper portion for leaves and stems except for ADF of leaves where Okinawa had the highest ADF values. For lower portion, AU Grazer and AU Lotan had lower ADF and NDF values for leaves and stems than old cultivars. Okinawa had high ADL values for leaves whereas values of this trait were similar for stems of cultivars for both portions. Tannin content in leaves and stems of all cultivars was statistically similar for upper portion. For lower portion, only stems of the cultivars differ from each other for tannin content where AU Grazer had the highest values. Nitrogen content was similar in all cultivars for leaves and stems from both portions.

Conclusion

Variability was little among the cultivars for all the traits measured. Leaves had more tannin and protein than the stems, while stems had more fiber content than the leaves. New cultivars had less fiber than the old cultivars, but higher tannin content. Nitrogen (protein) content was higher in Okinawa than the rest of the cultivars for growth, but during regrowth all cultivars had similar protein content.

References

Ball, D., and J. Mosjidis. 2007. Sericea Lespedeza: A Pasture, Hay, and Conservation Plant, Alabama Cooperative Extension System, ANR-1318.

Ball, D.M., and J.A. Mosjidis. 1995. An objective look at sericea lespedeza, Proceedings of the 51st southern and pasture forage crop improvement conference, Blacksburg, Virginia.

Burns, J.C., R.D. Mochrie, and W.A. Cope. 1972. Responses of dairy heifers to crownvetch, sericea lespedeza, and alfalfa forages. Agronomy Journal 64:193-195.

Burns, R.E. 1966. Tannin in sericea lespedeza, Georgia Agricultural Experiment Station Bulletin 164.

Cope, W.A., and J.C. Burns. 1971. Relationship between tannin levels and nutritive value of sericea. Crop Science 11:231-233.

Cope, W.A., and J.C. Burns. 1974. Components of forage quality in sericea lespedeza in relationship to strain, season, and cutting treatments. Agronomy Journal 66:389-394.

Donnelly, E.D. 1959. The effect of season, plant maturity, and height on the tannin content of sericea lespedeza, *L. cuneata*. Agronomy Journal 51:71-73.

Donnelly, E.D. 1965. Serala Sericea (Reg. No. 4). Crop Science 5:605.

Donnelly, E.D. 1981. Registration of AU Lotan Sericea Lespedeza (Reg. No. 11). Crop Science 21:474.

Donnelly, E.D., and W.B. Anthony. 1970. Effect of genotype and tannin on dry matter digestibility in sericea lespedeza. Crop Science 10:200-202.

Donnelly, E.D., and W.B. Anthony. 1983. Breeding low-tannin sericea. III. Variation in forage quality factors among lines. Crop Science 23:982-984.

Donnelly, E.D., W.B. Anthony, and J.W. Langford. 1971. Nutritive relationships in low and high tannin sericea lespedeza under grazing. Agronomy Journal 63:749-751.

Moore, D.A., T.H. Terrill, B. Kouakou, S.A. Shaik, J.A. Mosjidis, J.E. Miller, M. Vanguru, G. Kannan and J.M. Burke. 2008. The effects of feeding sericea lespedeza hay on growth rate of goats naturally infected with gastrointestinal nematodes. Journal of Animal Science 86:2328-2337.

Mosjidis, C.O.H., C.M. Peterson, and J.A. Mosjidis. 1990. Developmental differences in the location of polyphenols and condensed tannins in leaves and stems of sericea lespedeza, Lespedeza cuneata. Annals of Botany 65:355-360.

Mosjidis, J.A. 2000. Sericea lespedeza biomass composition for bioenergy in the southeastern USA, 1st World Conference on Biomass for Energy and Industry, Sevilla, Spain. pp. 321-322.

Terrill, T. H., W. R. Windham, J. J. Evans, and C.S. Hoveland. 1990. Condensed tannin concentrationin sericea lespedeza as influenced by preservation method. Crop Sci. 30:219-224.

USDA-ARS. National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). Available at: http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1371915 (verified date-June 13, 2010).

USDA-ARS. National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). Available at: http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1088122 (verified date-June 13, 2010)

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Off. Anal. Chem. 46:829-835.

Table 13: Least Square means of cultivars for upper portion for cut 1 by plant structure

	LEAVES					STEMS				
Cultivar	NDF	ADF	ADL	TANNIN	N	NDF	ADF	ADL	TANNIN	N
	-------------------------g per kg-------------------------					---------------------------g per kg---------------------------				
AUGrazer	453.7 ab	254.8 a	94.3 a	239.7 ab	27.5 ab	583.3 ab	421.1 ab	114.7 a	84.7 ab	21.5 b
AULotan	444.2 b	245.9 a	92.4 ab	243.6 a	27.4 b	575.6 ab	408.4 c	112.3 b	94.5 a	21.5 b
Serala	459.6 ab	258.7 a	90.3 b	219.1 ab	27.6 ab	588.4 a	425.2 a	113.6 a	71.5 b	22.0 b
Okinawa	464.2 a	255.9 a	93.3 a	194.2 b	28.5 a	573.2 b	410.3 bc	111.9 b	69.6 b	24.0 a
Arlington	460.0 ab	261.9 a	92.7 ab	233.6 ab	27.4 b	574.7 b	413.6 bc	113.2 ab	85.1 ab	22.0 b

Table 14: Least Square means of cultivars for lower portion for cut 1 by plant structure

	LEAVES					STEMS				
Cultivar	NDF	ADF	ADL	TANNIN	N	NDF	ADF	ADL	TANNIN	N
	-------------------------g per kg-------------------------					------------------------g per kg-------------------------				
AUGrazer	449.0 ab	266.8 a	98.6 ab	230.2 a	28.1 ab	693.2 a	532.8 a	136.5 a	59.9 ab	14.8 b
AULotan	439.0 b	268.5 a	96.9 b	243.6 a	27.8 ab	691.9 a	529.3 a	136.1 a	68.4 a	13.9 b
Serala	453.9 ab	269.2 a	94.2 c	219.8 a	27.9 ab	690.4 a	531.1 a	135.2 a	46.7 b	14.9 b
Okinawa	454.2 ab	276.3 a	100.6 a	205.1 a	28.8 a	688.6 a	532.8 a	135.9 a	50.3 b	15.9 a
Arlington	462.0 a	280.0 a	98.5 ab	231.9 a	27.6 b	687.0 a	529.1 a	136.4 a	60.4 ab	14.6 b

Table 15: Least Square means of cultivars for upper portion for cut 2 by plant structure

	LEAVES					STEMS				
Cultivar	NDF	ADF	ADL	TANNIN	N	NDF	ADF	ADL	TANNIN	N
	-------------------------g per kg-------------------------					-------------------------g per kg-------------------------				
AUGrazer	446.7 a	244.1 b	86.3 a	302.4 a	25.3 a	610.9 a	454.8 a	124.5 a	115.1 a	17.0 a
AULotan	447.3 a	251.0 ab	87.4 a	281.4 a	25.6 a	622.0 a	460.3 a	125.2 a	110.3 a	16.7 a
Serala	449.3 a	244.0 b	86.2 a	280.4 a	25.4 a	618.9 a	458.4 a	124.0 a	108.8 a	17.0 a
Okinawa	456.8 a	256.3 a	90.5 a	285.5 a	25.5 a	625.3 a	456.7 a	123.7 a	112.4 a	17.0 a
Arlington	456.0 a	250.4 ab	87.9 a	276.8 a	25.6 a	615.4 a	456.7 a	125.0 a	108.4 a	17.0 a

Table 16: Least Square means of cultivars for lower portion for cut 2 by plant structure

	LEAVES					STEMS				
Cultivar	NDF	ADF	ADL	TANNIN	N	NDF	ADF	ADL	TANNIN	N
	-------------------------g per kg-------------------------					-------------------------g per kg-------------------------				
AUGrazer	421.0 b	244.9 b	92.6 ab	295.5 a	25.6 a	691.5 b	538.3 a	142.9 a	98.5 a	12.5 a
AULotan	424.4 ab	260.0 a	97.5 a	276.8 a	26.2 a	703.5 ab	541.8 a	142.9 a	94.2 ab	12.0 a
Serala	422.0 b	243.8 b	91.8 b	280.9 a	25.5 a	699.6 ab	541.5 a	143.1 a	94.9 ab	12.1 a
Okinawa	436.1 a	262.4 a	98.0 a	271.1 a	25.8 a	717.2 a	552.4 a	145.0 a	92.0 ab	11.7 a
Arlington	431.5 ab	254.3 ab	96.0 ab	268.3 a	26.0 a	708.2 ab	553.1 a	145.3 a	84.6 b	12.0 a