Growth of Introduced Temperate Legumes in the Edwards Plateau and South Texas Plains

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Abstract

A study was conducted to evaluate production of 2 temperate, annual legumes at locations where temperature and moisture may seasonally place severe constraints on growth. Arrowleaf (*Trifolium vesiculosum* Savi) and subterranean (*Trifolium subterraneum* L.) clovers were grown at Beeville, in south Texas, and at Brady, 230 miles north of Beeville. Standing crop samples were collected at approximately 2-week intervals, starting 30 days post emergence and continuing to plant maturity during 2 years. Very little growth was made prior to 1 March at Brady in either year or at Beeville the first year. Total production was minimal (<1,500 kg/ha) at Brady. Arrowleaf produced about twice as much standing crop as subterranean at Beeville, 3,900 to 8,800 kg/ha (arrowleaf) versus 2,800 to 4,600 kg/ha (subterranean). No environmental variable showed a close association with growth rate when the data for 2 years and 2 species were included in simple correlations. In stepwise multiple regression equations, daily heat units was the most important variable followed by soil water. Early fall emergence and the development of a supraminimal canopy prior to the advent of growth-limiting winter temperatures had an overriding effect on winter growth as indicated by production differences in the 2 years at Beeville. The study shows that temperate annual clovers can be grown further west in the Southern region than current usage indicates.

Key Words: *Trifolium vesiculosum, Trifolium subterraneum,* arrowleaf clover, subterranean clover, growth rate, climatic factors, temperature, precipitation, soil moisture

Warm-season grasses are dominant on millions of hectares of southern grasslands in areas receiving 450 to 880 mm of rainfall annually while native legumes are either nonexistent or make minor contributions. Improved grasses, introduced extensively into the area, generally require more nitrogen to maintain productive stands than occurs in the current nitrogen cycle. Thus, legumes are needed as a potential source of nitrogen and quality forage on these grasslands.

Murphy et al. (1973) described species and varieties of temperate annual legumes adapted to California ranges receiving from 250 to more than 875 mm of rainfall, largely during the growing season. Williams et al. (1957) described adapted clovers and establishment and management practices for range conditions. Arrowleaf clover (*Trifolium vesiculosum* Savi) originated in the Mediterranean regions (Duke 1981) where most rainfall occurs from autumn through spring. Recently, arrowleaf clover has been used extensively in the high rainfall areas of the southeastern U.S. (Beaty et al. 1963, Hoveland et al. 1970). Duke (1981) describes subterranean clover (*Trifolium subterraneum* L.) as adapted to climates having relatively warm, moist winters and dry summers. Subterranean clover has been used on California dryland ranges (Murphy et al. 1973) and in southern Australia which has a Mediterranean type climate. Reguse et al. (1974) described the developmental morphology of seedling subterranean clover. Reguse and Evans (1977) showed that range site (slope) as well as small modifications in micro relief affected the microenvironment and plant growth. Relatively little research has been done with either species in the western (marginal) area of their adaptation in the southern United States.

The objectives of this study were to determine the production potential of subterranean and arrowleaf clovers at 2 locations which differ in rainfall and temperature, and to quantify climatic constraints to winter and spring growth of these 2 legumes.

Methods

Study sites were located at Beeville (28.5° north latitude) in the South Texas Plains, and Brady (31.5° north latitude) in the Edwards Plateau, Texas. Average annual rainfall is 780 and 625 mm, and average January temperatures are 13° and 9° C for the 2 sites, respectively. Soil on the Beeville site is a Clareville clay loam (fine, montmorillonitic, hyperthermic Pachic Argiustoll), and soil on the Brady site is an alkaline mixed Valera clay loam (fine, montmorillonitic, thermic Petrocalcic Calciustoll). 'Yuchi' arrowleaf clover and 'Mt. Barker' subterranean (sub) clover were used in the study. The seeds were inoculated with the appropriate rhizobia strains using a commercial inoculant sticker and drilled at 1 cm depth on prepared seedbeds at 105 pure live seed per meter row in 5 rows plot^{-1}, 50 cm apart. Plots, 45 m long, were replicated 4 times, in a randomized complete block design. Phosphorus (superphosphate, 20% P_2O_5) was applied preplant by broadcasting on the soil surface at rates of 37 and 73 kg P_2O_5 ha^{-1} at Beeville and Brady, respectively. Planting dates were 11 October 1977 at Brady and 10 November 1977 at Beeville.

Standing crops were measured, starting approximately 30 days after emergence, by harvesting 3 samples per plot, each a 60-cm segment of row (0.3 m^2) at ground level in each of 4 replications at approximately 2-week intervals. Harvested row segments were not re-sampled. Samples were dried at 60° C and dry weights converted to kg ha^{-1}. Growth rate by sample periods (kg ha^{-1} day^{-1}) was calculated as:

$$\text{Growth rate} = \frac{\text{Sample wt. } D_{n+1} - \text{Sample wt. } D_n}{D_{n+1} - D_n \text{ (days)}}$$

where D = date.

Growth rate and rainfall are expressed on a per day basis, in each growth period because growth periods varied in length.

Soil temperature at 75- and 150-mm depths, air temperature, photosynthetic active radiation (radiation), and rainfall were monitored continuously. Radiation was measured as Mol M^{-2} S^{-1} quantum flux density with a LI-COR[1], Inc. 190S Quantum sensor and converted to Mol M^{-2} day^{-1}. Daily maximum and minimum temperatures (°C) were used to calculate accumulated heat units using a base temperature for growth of 5° C (Mederski et al. 1973).

Daily heat unit total = Max. temp. + min. temp./2 − 5.
(minimum temperatures of less than 5° C were set at 5° C).

Soil moisture was measured gravimetrically at 0 to 75 mm, 75 to 150 mm, 150 to 300 mm, and 300 to 450 mm depths each week at Beeville and biweekly at Brady. A soil moisture retention curve was determined for each soil depth based on measurements at −0.03, −0.5, −1.0 and −1.5 MPa tensions. Available soil water (mm) was calculated for each soil depth by the formula: gravimetric water (%)−moisture at −1.5 MPa tension (%) × bulk density × soil depth.

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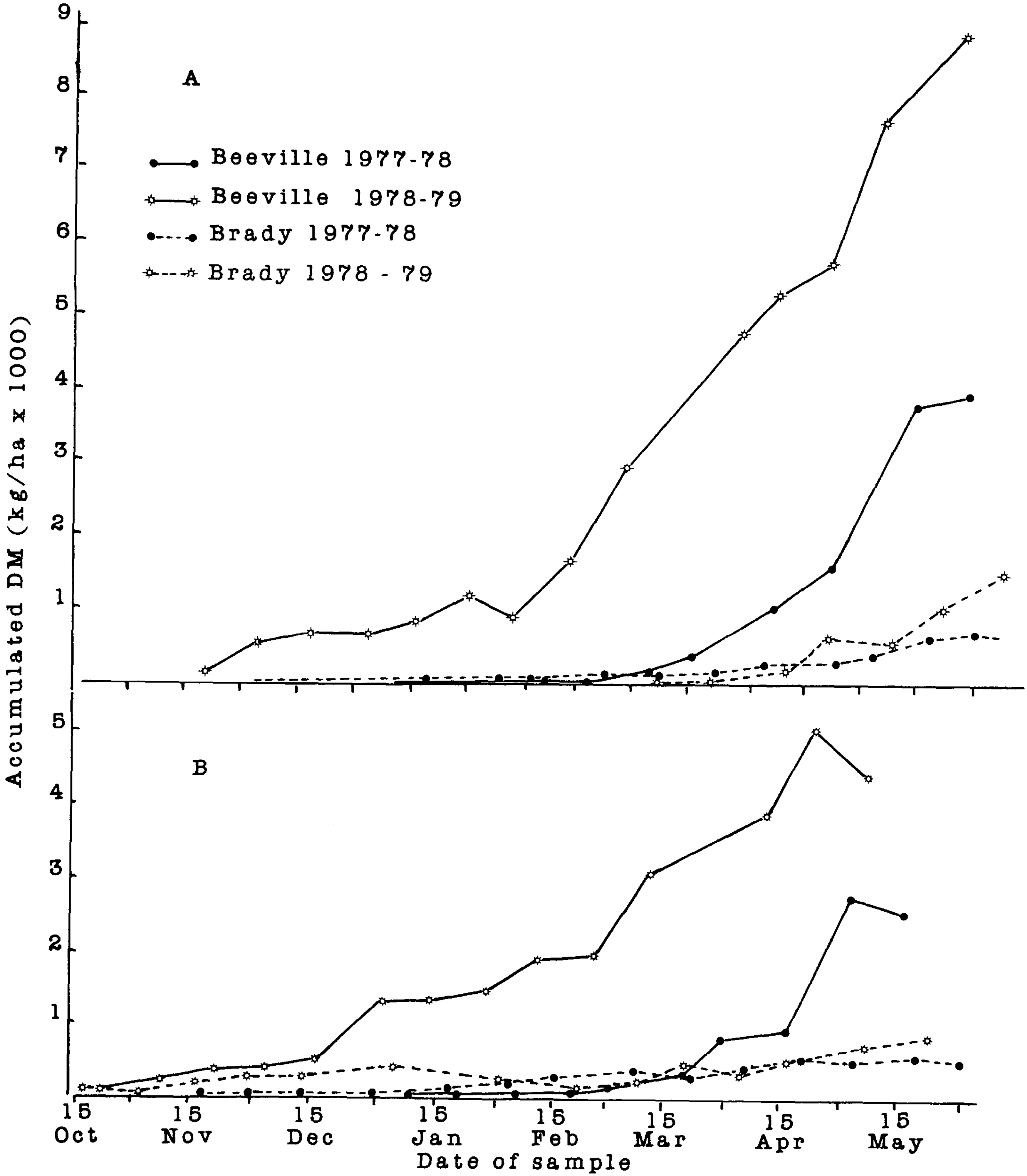

Fig. 1. *Accumulated standing crop of arrowleaf clover (A) and subterranean clover (B) at Beeville and Brady in 2 growing seasons.*

(mm). Available water in the 4 horizons was then summed. It is recognized that all the soil water is not equally available, especially near the permanent wilting point, and that some moisture above the saturation point was included.

Standing crop data were subjected to analysis of variance. Regression analyses (SAS 1982) were used to determine associations between growth rates and various environmental variables.

Results and Discussion

Legumes grew only slightly between fall planting in 1977 and early January at Beeville and mid-November at Brady. It is assumed that early emergence of self-seeded stands at Beeville in 1978 resulted in good winter production in 1978-79 while winter production at the Brady site was low (Table 1). Total production was high at Beeville in 1978–79, exceeding production in 1977–78 by 67 to 125%. These yields exceeded those of kleingrass *(Panicum coloratum)* and Kleberg grass *(Dichanthium annulatum)* (Forsk) Stapf established in the same study in the fall of 1977. Standing crops of these grasses were 1,205 and 950 kg/ha in 1978 and 2,238 kg/ha in 1979, respectively. Minimal winter growth and limited total production at Brady indicated major environmental constraints, probably low winter temperatures and limiting soil water. However, production of 1,000 to 1,500 kg ha^{-1} of a year ha^{-1} of a legume could be very valuable for the Edwards Plateau location where peak standing crops of kleingrass and sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) were 984 and 1,253 in 1979 and 582 and 1,778 kg/ha in 1980, respectively (unpublished data from other components of this study).

Table 1. Accumulated mean standing crop (kg ha^{-1}) of subterranean and arrowleaf clover at Brady and Beeville, Texas in 2 growing seasons.

Locations and Species	1977–78 March 1	1977–78 Season Total[1]	1978–79 March 1	1978–79 Season Total[1]
Beeville				
Subterranean	162 a[2]	2778 a	1961 a	4643 b
Arrowleaf	35 a	3934 a	1639 b	8846 a
Brady				
Subterranean	400 a	630 b	233 a	903 b
Arrowleaf	113 b	965 a	11 b	1500 a

[1]Maximum accumulated dry matter which occurred later at different dates in the 2 years and for the 2 clovers.
[2]Values within a location and date followed by the same letter are not significantly different (>0.05), Duncan's Multiple Range.

Growth of both legume species determined from accumulated yields was slow in midwinter (Fig. 1). Standing crop did not increase between 1 January and 1 March in either year at Brady or in this period in 1977–78 at Beeville. The earlier growth of sub and arrowleaf clover at Beeville in 1978–79 is attributed to earlier seedling emergence and greater seedling vigor of sub clover. Arrowleaf clover seed germination is inhibited by soil temperatures above 20° C whereas sub clover seed germination is less temperature sensitive (Evers 1980). The most rapid growth accumulation generally started between 15 February and 15 March (Fig. 1).

Three major factors that may influence temperate crop growth in a climate involving autumn, winter, and spring periods are temperature, radiant energy, and water. Accumulated daily heat units which reflect to some extent ambient temperature and the effect of radiation on temperature were calculated for the 2 locations by years (Fig. 2).

Daily heat units averaged 5.8 in January–February 1978 at Beeville, versus 8.3 in the same period in 1979. During this period heat units at Beeville exceeded those at Brady by 3 to 4 units with less than 1 unit difference between the 2 years at Brady. The large differences in growth among years and locations suggest relatively small differences in growth-limiting factors may be highly important in stress periods. The amount of standing crop at the beginning of the winter period at Beeville seemed to be an additional factor influencing winter growth. This response indicates the need for high seed production for self-seeded stands for early ground cover development.

Growth rate seldom exceeded 2 to 3 kg ha^{-1} day^{-1} when accumulated daily heat units were below 10. However, factors other than heat units must have been operative in influencing growth rate since some very low growth rates occurred with heat units greater than 10. Simple correlations of the measured and calculated environmental factors (independent variables) with growth rate gave significant coefficients ($P<0.01$) for daily heat units and all temperature measurements. None of the other independent variables gave significant coefficients, and none of the independent variables accounted for more than about 38% of the variability in

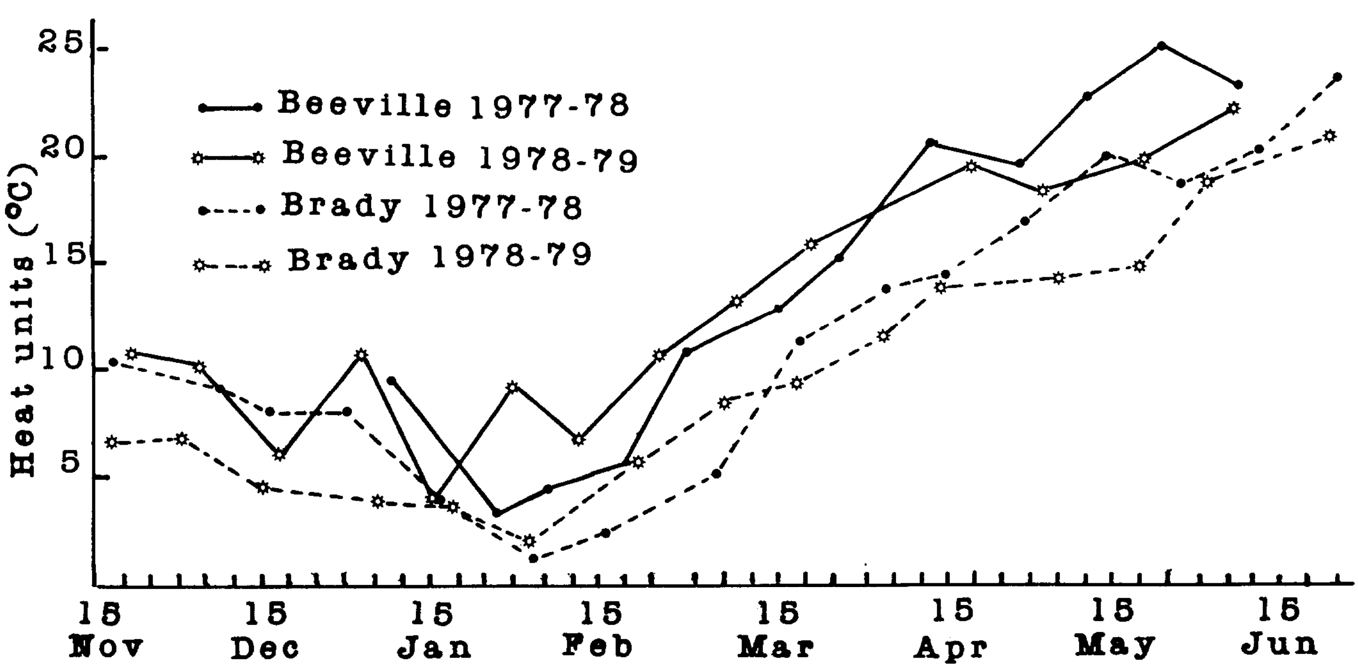

Fig. 2. *Accumulated heat units at Beeville and Brady in 2 growing seasons.*

legume growth rates.

Based on the lowest interrelationships of independent variables, and the simple correlation coefficients, the independent variables of heat units, radiation, rain, and soil water were used with growth rate data for individual species within years at Beeville in stepwise regression procedure for improving R^2. Growth rates at Brady of sufficient magnitude to show relationships occurred for only a few weeks in the spring thus allowing insufficient numbers for reliable analyses.

Heat units was the most important single independent variable (based on a 1 variable model) in 3 of the 4 data sets in a 4 variable multiple regression model. Radiation and rain were each significant in 1 of the data sets. Maximum R^2 values ranged from 0.68 and 0.92. Obviously, other factors must have accounted for appreciable growth responses. When all of the data for both years and both species were included in 1 data set, a 4-variable model best fit the data giving an R^2 of 0.49, heat units and soil water being statistically significant variables.

Growth obviously requires not only light but also the interception of that light by leaves capable by carrying on photosynthesis under climatic conditions suitable for photosynthesis and growth. One of the problems of evaluating growth rate in the field with fall planted crops is that ground cover and leaf area are inadequate to intercept and use a high proportion of available light during much of the fall and winter at the same time that temperature is also likely to be the most limiting to growth. Plots with different ground cover and leaf area may respond differently to environmental conditions. These conditions lead to poor regression relationships when data for 2 or more species differing in rate of initial development, or 2 or more years in which rate of early development differ, are included in the same data set, and relatively low R^2 even if the values are significant.

While these studies were conducted in areas where temperate legumes have not been used, presumably because of limited rainfall, the data indicate growth is mediated more by temperature and light than by soil water. If seedling emergence is delayed, whether from late planting or dry soil, until average maximum daily temperatures are below 15° C or average daily accumulated heat units are below 10, the amount of winter growth will be negligible. The low production level at Brady appeared to be due more to the lower temperature than to the amount of water available for growth. Spring growth follows the expected pattern of an annual crop with growth rate generally increasing both as the environmental conditions for growth improved and as the amount of plant material to intercept light increases. The total production levels at Beeville, comparable to or higher than those of adapted warm season grasses, indicate that both species are well adapted to the climatic conditions encountered at that location.

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