# EFFECT OF DEFOLIATION INTENSITY ON REGROWTH OF TALLGRASS PRAIRIE

By

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EFFECT OF DEFOLIATION INTENSITY

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PRAIRIE

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# CHAPTER I

## INTRODUCTION

In recent years, due to social and economic pressures, it has become necessary to increase forage and livestock yields from rangelands. Improving grazing management is a logical way to increase production. Several investigators have found that total forage production from a paddock can be increased if the paddock is defoliated in such a way as to maintain it in a rapid forage accumulation phase (Donald and Black 1958, Voisin 1959, Youngner 1972). This can be accomplished by grazing the paddock at the maximum rate of growth (Dyer et al. 1979).

Intensive rotational grazing systems allow flexible livestock movement schedules which could enable a grazing manager to defoliate a paddock when maximum growth rate has been attained. Proper management of defoliation schedule is the key to making rotational grazing a viable method of increasing forage production from grass communities. Accurate knowledge of rates of herbage regrowth is necessary for successful planning and implementation of intensive rotational grazing systems. This study was initiated with the objective of determining the effect of defoliation intensity on the regrowth of tallgrass prairie.

The following chapter is an extensive review of the current literature concerning growth of grass swards and rangelands. Chapter III presents the results of the study and is written in a form for immediate submission to the Journal of Range Management.

# CHAPTER II

## LITERATURE REVIEW

The literature concerning growth of herbage following defoliation focuses on the growth of individually defoliated tillers and of defoliated paddocks. Although the response of grass communities is of greater practical importance to grazing managers, the effects of grazing on individual tillers is also discussed because the tiller is the basic unit of a grass community.

Studies which examine the responses of net photosynthetic rate, respiration, carbohydrate allocation, and root expansion within individually defoliated plants and tillers in controlled environments are numerous (Davidson and Milthorpe 1966, Ryle and Powell 1975, Detling et al. 1979, Dyer et al. 1979, Youngner 1979, Painter and Detling 1981, Culvenor et al. 1989). A general consensus of these studies indicates photosynthetic rate initially decreases following defoliation but soon surpasses preclipped rates (Painter and Detling 1981). However, total dry matter accumulation of defoliated plant parts or tillers fails to attain that of unclipped controls because of lower total leaf area (Detling et al. 1979). Current assimilate is rerouted to areas of regrowth rather than to the roots and if defoliation is severe enough stored carbohydrates are mobilized for regrowth (Ryle and Powell 1975, Prins et al. 1989). This will result in reduced root expansion and reduced nutrient uptake. Culvenor et al. (1989) found that rate of shoot growth decreases as severity of defoliation increases. These experiments explain the mechanisms of plant response to defoliation.

Rate of growth changes throughout the growing season (Anslow and Green 1967, Williams 1980). Anslow and Green (1967) constructed a curve of average daily growth rates from various pasture grasses in the United Kingdom. Measurable growth begins in March and rate of growth accelerates rapidly to a peak of 80 to 100 kg DM $ha^{-1}$ $d^{-1}$ in early May. During this stage average daily growth rate is increasing 2.0 kg DM $ha^{-1}$ $d^{-1}$. Following the peak in early May growth rate will decline as rapidly as it increased until it reaches a rate approximately one half of the peak attained in May. Throughout late June and all of July growth rate will slowly recover to a peak in early August that is considerably lower than that attained in the spring. Growth rate will decline to unmeasurable levels in November. If growth is not interrupted by defoliation, Williams (1980) states that growth rates of 180 kg DM $ha^{-1}$ $d^{-1}$ are common on improved pastures.

In Nebraska, Gilbert et al. (1979) found a sigmoid curve existed for dry matter accumulation in ungrazed sandhills prairie. This would indicate a curve of daily growth rate similar to Anslow and Green (1967). In a study of rate of regrowth following clipping of tallgrass prairie, Gillen and McNew (1987) found that maximum rate of regrowth attained after clipping decreased as the growing season progressed (52 - 0 kg $ha^{-1}$ $d^{-1}$ in 1984 and 36 - 16 kg $ha^{-1}$ $d^{-1}$ in 1985), but that the amount of time necessary to reach maximum growth rate did not increase as growing season progressed. This is supported by Morley (1968) and Brougham (1957) from data on improved temperate pastures. Voisin (1959) states that maximum growth rate remains constant as growing season progresses, but the time required to reach this constant maximum growth rate increases with season.

Parsons and Penning (1988) examined the effect of duration of regrowth on average growth rate in a perennial ryegrass pasture being rotationally grazed by sheep. Rest periods of 12-13, 19-23, and 30-34 days were compared. Dry matter accumulation increased throughout the entire measurement period. Average growth rate increased as duration of regrowth was extended from 12-13 to 19-23 days but changed little as the duration was extended from 19-23 to 30-34 days. It was concluded that maximum rate of growth was attained within 19-23 days of defoliation.

Many of the experiments which examine regrowth of entire plant communities involve leaf area index (LAI) as a significant factor affecting regrowth. Leaf area index represents the amount of leaf surface area exposed to light per given area of land (Watson 1947). Amount of forage and LAI are related because forage amount increases with LAI.

Davidson and Donald (1957) stated that the effect of defoliation on a pasture depends upon the LAI prior to grazing and the LAI of vegetation remaining after defoliation. Assuming an infinite growing season all defoliated pastures will achieve the same amount of total dry matter and LAI regardless of severity of defoliation. This implies that severity of defoliation will influence rate of regrowth.

King et al. (1979) conducted an experiment in which regrowth was monitored for perennial ryegrass swards cut weekly (1) and every third week (3) to 2 (L) and 4 (H) cm. The residual weight of total green crop after cutting was higher on swards cut to 4 cm than 2 cm. Although treatment 1H had the highest growth rate it was only significantly different from treatment 3H which had the lowest growth rate. Herbage increase was greatest on the sward cut weekly to 2 cm, but during the first 4 days following cutting a significant weight loss was encountered due to senescence. It was concluded that rate of increase in LAI was more closely related to net canopy photosynthesis than residual LAI.

Growth rate increases as quantity of light intercepted, due to increased LAI, increases (Black 1957, and Donald and

Black 1958). This is true until a pasture reaches the point of complete light interception when forage production becomes constant. Donald and Black (1958) hypothesized that there is an optimal LAI at which growth rate will be maximized and that pastures defoliated at a high LAI will have a low rate of regrowth compared to pastures defoliated at a low LAI.

Bircham and Hodgson (1984) found results similar to Donald and Black (1958) on paddocks of perennial ryegrass. Paddock 1, which was maintained at a high herbage level (1700-1900 kg OM $ha^{-1}$) for the first half of the growing season, was severely defoliated (700-900 kg OM $ha^{-1}$) and allowed to regrow undisturbed for the remainder of the season. Alternately, paddock 2 was maintained at a low herbage level (700-900 kg OM $ha^{-1}$) for the first half of the growing season and was allowed undisturbed growth the second half of the season. Rates of growth (G) and senescence (S) were higher in paddock 2 than paddock 1. Rate of net production of green material (NP = G - S) for paddock 1 was about 10.0 +/- 6.2 kg DM $ha^{-1}$ $d^{-1}$ while on paddock 2 NP was 33.6 +/- 6.2 kg DM $ha^{-1}$ $d^{-1}$. While it was concluded that NP can be reduced if a paddock of high herbage level is grazed hard, it is not possible to increase NP by manipulating herbage mass under continuous stocking.

Brougham (1955) determined that rate of dry matter accumulation in a short-rotation ryegrass and clover pasture following defoliation forms a sigmoid curve consisting of three phases. Observations of regrowing pasture revealed that average daily growth rate increased soon after defoliation, but eventually became constant before decreasing. While growth rate was constant daily dry matter increase approached 168 lb $ha^{-1}$ $d^{-1}$. This study involved only one defoliation level. Brougham speculated that maximum growth rate coincided with complete light interception by the sward canopy.

Brougham (1957) conducted another study using defoliation treatments of 1, 3, and 5 inches. Regardless of the level of defoliation, a constant maximum growth rate was attained at 95% light interception at 1 inch above the soil surface which corresponded to 1624 kg DM $ha^{-1}$. Although the pastures all attained the same maximum growth rate there was variation in the amount of time necessary to reach this maximum growth rate. Pastures defoliated to 1 inch required more time to reach maximum growth rate than the pastures defoliated to 5 inches.

Bircham and Hodgson (1983) maintained continuously grazed perennial ryegrass paddocks at four herbage levels (500, 700, 1000, and 1700 kg OM $ha^{-1}$). Net production of green herbage (NP) increased with herbage level to a maximum of 75 kg DM $ha^{-1}$ $d^{-1}$ at 1200 to 1500 kg OM $ha^{-1}$ and declined at higher herbage levels. However, NP was within 10% of the maximum from 850 to 1850 kg OM $ha^{-1}$. Although at herbage levels below 850 kg OM $ha^{-1}$ net production of green herbage appears to be reduced significantly, it was concluded that within the range of herbage levels encountered by grazing managers there was little potential for improving productivity by manipulating sward herbage levels under continuous grazing. This conclusion is supported in a similar study by Grant et al (1983) in which NP averaged 31 kg DM $ha^{-1}$ $d^{-1}$ over a range of LAI from 2.3 to 4.7. Hodgson and Wade (1978) found annual herbage accumulation was relatively insensitive to the range of stocking rates likely to be encountered in typical grazing situations.

Aside from work done by Dwyer and Hutcheson (1965), Sims and Singh (1978), Gilbert et al. (1979), and Gillen and McNew (1987) there is little published information on growth rates occurring in the tallgrass prairie. Gillen and McNew (1987) conducted the only study involving regrowth after defoliation. The remaining experiments focused on season-long growth of ungrazed prairie. Although intensive grazing systems are being used in the tallgrass ecosystem there appears to be a gap in experimental data concerning growth rates following defoliation and the parameters influencing growth rates for the ecosystem.

# CHAPTER III

# EFFECT OF DEFOLIATION INTENSITY ON REGROWTH OF TALLGRASS PRAIRIE

## Abstract

Grazing trials were conducted in north-central Oklahoma during 1989 and 1990 to test the hypothesis that live residual herbage level affects the rate of regrowth of tallgrass prairie throughout the growing season. A 1-2 day grazing period on eight treatment paddocks began 26 May (Trial 1), 7 July (Trial 2), and 18 August (Trial 3) of each year. Two replicate paddocks per trial were defoliated to 2.5, 5.0, 7.5, and 10 cm. Live herbage was measured immediately after grazing to determine live residual herbage level and 2, 4, 6, and 8 weeks after grazing to determine live herbage accumulation (LHA). Polynomial regression models were fit to LHA data as a function of live residual herbage level and number of days after grazing. Live herbage accumulation rate (LHAR) was determined from the first derivative with respect to day of each regression equation. Maximum LHAR decreased as season progressed in both years, but the time required to reach maximum LHAR was not dependent upon season. Live residual herbage level was

a parameter in equations describing LHAR in 3 of 6 trials. These results indicate live residual herbage level influences LHAR in some, but not all situations. LHAR of tallgrass prairie following defoliation cannot reliably be predicted by live residual herbage levels alone. Basing management decisions on expectations of LHAR is difficult due to variability in the number and type of parameters influencing these rates.

## Introduction

Intensive rotational grazing involves the rapid rotation of one herd of livestock through a subdivided pasture at intervals decided upon by a grazing manager (Howell 1978, Savory 1978). Timing herd movement to allow sufficient rest periods for major forage species to recover from grazing is critical to the success of rotational grazing (Booysen and Tainton 1978, Howell 1978, Savory 1978). The rate of regrowth of forage species within a rotational grazing system determines the rest period required for forage species to recover from grazing. Because of this relationship knowledge of rates of herbage regrowth and the parameters affecting regrowth is essential to livestock management decisions concerning rest periods in intensive rotational grazing systems.

Herbage production changes throughout the growing season (Anslow and Green 1967, Williams 1980). Maximum rate of regrowth after clipping decreases as the growing season progresses, but the time to reach maximum net growth rate after clipping does not increase as the growing season progresses (Brougham 1957, Morley 1968, Gillen and McNew 1987). Parsons and Penning (1988) found that maximum net growth rate was attained at 19 - 23 days after grazing regardless of timing of defoliation in the growing season.

Few studies have investigated growth rates in the tallgrass prairie. Several studies have focused on season-long growth of ungrazed prairie (Dwyer and Hutcheson 1965, Sims and Singh 1978, Gilbert et al. 1979). Although intensive grazing systems are being used in the tallgrass ecosystem there is a gap in experimental data concerning growth rates following defoliation and the parameters influencing herbage growth rates for the ecosystem. This study examined the hypothesis that rate of herbage accumulation of tallgrass prairie is dependent upon the amount of live residual herbage remaining after defoliation and the timing of defoliation within the growing season.

## Study Area

The study was conducted on the Research Range of the Oklahoma Agricultural Experimental Station in north-central Oklahoma. Average annual precipitation for the area is 831 mm with 565 mm falling during a 204 day growing season. Average minimum and maximum temperatures range from -4.3°C in January to 34.0°C in August with an overall mean temperature of 15.5°C (Myers 1982).

The soil at the study site is a Renfrow silt loam which is a fine, mixed, thermic, Udertic Paleustoll with a 3 to 5 % west-facing slope. A dense subsurface at 30-40 cm causes the soil to be very slowly permeable (Henley et al. 1987). The area is a Claypan Prairie range site in excellent range condition. Vegetation composition by weight on the study site consists of 33% little bluestem (*Schizachyrium scoparium* (Michx.) Nash), 23% big bluestem (*Andropogon gerardii* Vitman), 22% indiangrass (*Sorghastrum nutans* (L.) Nash), 9% switchgrass (*Panicum virgatum* L.), 10% other perennial grasses, and 3% forbs. Annual forage production on this range site for an average year is 4550 kg $ha^{-1}$ (Henley et al. 1987). The study area was burned and grazed moderately in 1987, and was hayed in early July of 1988 and 1989.

## Methods

During the growing seasons of 1989 and 1990 three grazing trials were initiated each year on 26 May (Trial 1), 7 July (Trial 2), and 18 August (Trial 3). Each trial contained eight 20 X 30m (0.06 ha) treatment paddocks and was conducted on an area not previously used in the study. Treatments were a single defoliation with the intensity of defoliation varying to create a range of residual herbage levels. Stocking densities of 30300, 22700, 15200, and 7600 kg of animal weight $ha^{-1}$ were used to defoliate paddocks to 2.5, 5.0, 7.5, and 10.0 cm during a 1-2 day grazing period. Two pastures per trial were defoliated to each height. Defoliation was imposed with dry cows and yearling cattle. Trials 2 and 3 were moderately grazed at the initiation of Trial 1, and Trial 3 was grazed moderately at the initiation of Trial 2 to present a grazed vegetation environment for all three trials.

Total herbage was measured immediately after grazing to determine residual herbage levels, and 2, 4, 6, and 8 weeks after grazing to determine forage accumulation. Total herbage was measured by hand-clipping 20, 0.1 $m^2$ plots per treatment paddock to ground level. Field weight of each sample was recorded at harvest and samples were oven dried to determine dry weight. Field weight and dry weight of eight samples each of pure live and pure dead plant material were obtained for each sampling date. Live and dead components of total herbage standing crop were calculated based on the moisture content of total, live, and dead plant material (Cooper et al. 1957). Species composition was determined across the entire study in late summer by the dry-weight-rank method using 50, 0.1 $m^2$ plots (Gillen and Smith 1986). Cattle were weighed once each year to facilitate distribution of livestock among paddocks, but no animal response measurements were taken.

Polynomial regression models were fit to live herbage accumulation (LHA) data using the least squares method. Regression models included live residual herbage level, day after grazing, second order exponents of all independent variables, and all possible interactions of independent variables. Initially all possible parameters were included in a model, and nonsignificant parameters were then removed singularly until all parameters remaining in the model were significant ($P<0.05$).

Live herbage accumulation rate (LHAR) is the difference between live herbage growth rate (LHGR) and live herbage disappearance rate (LHDR), i.e., LHAR = LHGR - LHDR (Scarnecchia and Kothmann 1986). An equation describing LHAR was determined from the first derivative with respect to day of each of the regression equations predicting LHA. Values which represent actual live residual herbage levels and day in each trial were chosen for use in the regression equations and curves were plotted to illustrate LHA and LHAR in relation to live residual herbage level and day for 1989 and 1990.

## Results and Discussion

### Weather Conditions

Total annual precipitation for 1989 and 1990 was 940 and 950 mm, compared to a long-term average of 831 mm. Growing season precipitation (April to September) for 1989 and 1990 was 680 and 520 mm, while the long-term average is 565 mm. Precipitation during all trials in 1989 was at least 70 mm above the long-term average, and average temperatures were consistently below normal (Table 1). Precipitation during Trials 1 and 2 of 1990 was 155 and 50 mm below average, respectively. Trial 3 of 1990 experienced slightly above average precipitation. Temperatures exceeded the average for all trial periods in 1990. In summary, weather conditions during the 1989 growing season were much more favorable for forage production than in 1990.

Live Herbage Accumulation

Evaluation of plots of observed versus predicted values indicated a good representation of field data by the regression models. Coefficients of determination for the polynomial regression equations predicting LHA were greater than 0.75, with the exception of Trial 3 of 1989 (Table 2). The amount of variation explained by the regression equations was greatest during the first portion of the growing season, and lowest at the end of the season.

Live herbage following defoliation and maximum LHA for each trial was greater in 1989 than in 1990 even though treatment paddocks were defoliated to the same height each year (Fig. 1 and 2). This resulted in live residual herbage levels approximately 1000 kg ha$^{-1}$ higher in 1989 than in 1990. These differences in live residual herbage level and

LHA are likely due to greater tiller density and leaf area during 1989 creating more forage under a given sward height than in 1990.

Live Herbage Accumulation Rate

**Season.** Maximum LHAR and the amount of change in LHAR throughout each trial decreased as season progressed in both years. LHAR for Trials 1, 2, and 3 of both years ranged from -40 to 90, -25 to 40, and 1 to 20 kg $ha^{-1}d^{-1}$, respectively (Fig. 3 and 4). Time required to reach maximum LHAR was not dependent upon season. Maximum LHAR was attained on the last day of Trials 1 and 2 of 1989 and Trial 2 of 1990, but in Trial 1 of 1990 maximum LHAR was attained on the first day of the trial. LHAR was not effected by day in Trial 3 of either year. These results support previous findings that maximum net growth rate is dependent upon season while time to maximum growth rate was not dependent upon season (Brougham 1957, Anslow and Green 1967, Morley 1967, Williams 1980, Gillen and McNew 1987, Brummer et al. 1988, Parsons and Penning 1988). These results disagree with Voisin (1959) who believed that maximum net growth rate remained constant as season progressed, but that time to maximum net growth rate increased with season.

Negative LHAR at the initiation of Trial 2 of both years seems to involve season. High herbage levels and above average rainfall (+70 mm) in 1989, and low herbage levels and below average rainfall (-50 mm) in 1990 indicate these two factors are not likely responsible. Defoliation in Trial 2 occurred at a period in the growing season when grasses had began to extend their apical meristems (Vogel 1965). Once the apical meristem is removed new tillers must be generated from basal meristems (Hyder 1972). Anslow and Green (1967) found a natural decline in growth rate at the same period of the growing season during which Trial 2 occurred. It is possible that the removal of the apical meristem and the shock of defoliation at this period of natural growth rate decline may cause LHAR to be negative for a short period, followed by moderate LHAR.

**Live Residual Herbage Level.** Live residual herbage level was a parameter in equations describing LHAR in 3 of 6 trials (Table 3). Low live residual herbage levels and precipitation for Trials 1 and 2 of 1990 compared to similar trials in 1989 may have been factors responsible for live residual herbage level being a significant parameter in LHAR equations for Trials 1 and 2 of 1990. Live residual herbage level and precipitation did not completely explain differences in LHAR for Trial 1 of 1989 and 1990.

Increasing LHAR during Trial 1 of 1989 (Fig. 3) was due to adequate moisture relations, while decreasing LHAR throughout Trial 1 of 1990 (Fig. 4) was due to low precipitation and live residual herbage levels compared to 1989. The fact that LHAR was much higher at the initiation of Trial 1 of 1990 than 1989 cannot be explained by either of these factors.

Higher average daily temperatures at the beginning of Trial 1 of 1990 than 1989 could account for higher initial LHAR in 1990. Although average daily temperature was higher in Trial 1 of 1990 than 1989 (Table 1), the average daily temperatures from a period two weeks prior to grazing until one week after grazing were actually lower in 1990 than 1989. This nullifies any explanation of higher initial LHAR in 1990 than 1989 based on warmer early season growing conditions.

The effect of live residual herbage level on LHAR in Trial 3 of 1989 cannot be explained by defoliation intensity or weather conditions, as both were moderate. LHAR in Trial 3 of 1990 was not effected by live residual herbage level, even though live residual herbage levels were low, perhaps due to the return of normal rainfall conditions.

LHAR increased as defoliation intensity increased in Trial 3 of 1989 and Trial 2 of 1990. Bircham and Hodgson (1983) found that net production (growth - senescence) increased as herbage level increased from 850 to 1350 kg $ha^{-1}$, but as herbage level increased above 1350 kg $ha^{-1}$ net production decreased. All live residual herbage levels for Trail 3 of 1989 and one-half of those in Trial 2 of 1990 were at or above 1350 kg $ha^{-1}$.

LHAR did not increase with live residual herbage levels in Trial 1 of 1990 even though 75% of all live residual herbage levels were below 850 kg $ha^{-1}$, which is a greater severity of defoliation than realized by Bircham and Hodgson (1983), and LHAR might be expected to increase with live residual herbage level. Although LHAR did not increase as live residual herbage level increased in Trial 1 of 1990, less severely defoliated paddocks were able to maintain a more constant LHAR during a period of unfavorable weather conditions than more severely defoliated paddocks.

## Conclusions

The rate of herbage accumulation of tallgrass prairie was effected by the timing of defoliation within the growing season. Maximum LHAR and the amount of change in LHAR throughout a trial decreased as season progressed, but the amount of time required to attain maximum LHAR was independent of season. These findings substantiate the conclusions of several studies (Brougham 1957, Anslow and Green 1967, Morley 1967, Williams 1980, Gillen and McNew 1987, Brummer et al. 1988, Parsons and Penning 1988).

Live residual herbage level was a significant parameter in 3 of 6 equations describing LHAR. Even though LHAR was not affected by live residual herbage level in one half of all trials it must be concluded that live residual herbage level does affect the rate of regrowth of tallgrass prairie in some situations. Live residual herbage level alone does not fully explain live herbage accumulation rates.

Growth of tallgrass prairie following defoliation is influenced by several factors and their interactions, such as season, live residual herbage level, weather conditions, and morphological stage of plants at defoliation. Grazing management decisions based on estimations of live herbage accumulation rates may be difficult due to variability in the number and type of parameters influencing these rates. Further research needs to be directed toward identifying additional factors, such as soil moisture and morphological stage at defoliation, that influence live herbage accumulation rates.

## Literature Cited


Anslow, R.C., and J.O. Green. 1967. The seasonal growth of grasses. J. Agr. Sci., Cambridge. 68:109-122.

Bircham, J.S., and J. Hodgson. 1983. The influence of sward condition on rates of herbage growth and senescence in mixed swards under continuous stocking management. Grass and Forage Sci. 38:323-331.

Bircham, J.S., and J. Hodgson. 1984. The effects of change in herbage mass on rates of herbage growth and senescence in mixed swards. Grass and Forage Sci. 39:111-115.

Black, J.N. 1957. The influence of varying light intensity on the growth of herbage plants. Herb. Abstr. 27:89-98.

Booysen, P. De V., and N.M. Tainton. 1978. Grassland management: principles and practice in South Africa, p. 551-554. In: D.N. Hyder (ed) Proc. First Int. Rangeland Congr.

Brougham, R.W. 1955. A study in rate of pasture growth. Aust J. Agr. Res. 6:804-812.

Brougham, R.W. 1957. Effect of defoliation on regrowth of pasture. Aust. J. Agr. Res. 7:377-387.

Brummer, J.E., R.L. Gillen, and F.T. McCollum. 1988. Herbage dynamics of tallgrass prairie under short duration grazing. J. Range Manage. 41:264-266.

Cooper, C.S., D.N Hyder, R.G. Petersen, and F.A. Sneva. 1957. The constituent differential method of estimating species composition in mixed hay. Agron. J. 49:190-193.

Culvenor, R.A., I.A. Davidson, and R.J. Simpson. 1989. Regrowth by swards of subterranean clover after defoliation 1. Growth, non-structural carbohydrate and nitrogen content. Ann. Bot. 64:545-556.

Davidson, J.L. and F.L. Milthorpe. 1966. Leaf growth in Dactylis glomerata following defoliation. Ann. of Bot. 30:173-184.

Davidson, J.L., and C.M. Donald. 1957. The growth of swards of subterranean clover with particular reference to leaf area. Aust. J. Agr. Res. 9:53-73.

Detling, J.K., M.I. Dyer, and D.T. Winn. 1979. Net photosynthesis, root respiration, and regrowth of Bouteloua gracilis following simulated grazing. Oecologia. 41:127-134.

Donald, C.M., and J.N. Black. 1958. The significance of leaf area in pasture growth. Herb. Abstr. 28:1-6.

Dwyer, D.D., and H.L. Hutcheson. 1965. Growth rate of four range grasses in North Central Oklahoma. Oklahoma Exp. Sta. Bull. B-683.

Dyer, M.I., J.K. Detling, D.C. Coleman, and D.W. Hilbert. 1979. The role of herbivores in grasslands, p. 255-295. In: J.R. Estes. R.J. Tyrl, and J.N. Brunken (eds), Grasses and grasslands: systematics and ecology. Univ. Oklahoma Press, Norman.

Gilbert, W.L., L.J. Perry, Jr., and J. Stubbendieck. 1979. Dry matter accumulation of four warm-season grasses in the Nebraska sandhills. J. Range Manage. 32:52-54.

Gillen, R.L., and R.W. McNew. 1987. Seasonal growth rates of tallgrass prairie after clipping. J. Range Manage. 40:342-345.

Gillen, R.L., and E.L. Smith. 1986. Evaluation of the dry-weight-rank method for determining species composition in tallgrass prairie. J. Range Manage. 39:283-285.

Grant, S.A., G.T. Barthram, L. Torvell, J. King, and H.K. Smith. 1983. Sward management, lamina turnover and tiller population density in continuously stocked Lolium perenne dominated swards. Grass and Forage Sci. 38:333-344.

Henley, J.R., R.D. Gelnar, and R.E. Mayhugh. 1987. Soil survey of Payne County, Oklahoma. USDA, SCS.

Hodgson, J., and M.H. Wade. 1978. Grazing management and herbage production, p. 1.1-1.12. In: Proc. British Grassland Soc. Winter Meeting.

Howell, L.N. 1978. Development of multi-camp grazing systems in the Southern Orange Free State, Republic of South Africa. J. Range Manage. 31:459-465.

Hyder, D.N. 1972. Defoliation in relation to vegetative growth, p.305-317. In: V.B. Youngner and C.M. McKell (eds), The biology and utilization of grasses. Academic Press, New York.

King, J., W.I.C. Lamb, and M.T. McGregor. 1979. Regrowth of ryegrass swards subject to different cutting regimes and stocking densities. Grass and Forage Sci. 34:107-118.

Morley, F.H.W. 1968. Pasture growth curves and grazing management. Australian J. Exp. Agr. Anim. Husb. 8:40-45

Myers, H. 1982. Climatological data of Stillwater, Oklahoma 1893-1980. Oklahoma Agr. Exp. Sta. Res. Rep. P-821.

Painter, E.L., and J.K. Detling. 1981. Effect of defoliation on net photosynthesis and regrowth of western wheatgrass. J. Range Manage. 34:68-71.

Parsons, A.J., and P.D. Penning. 1988. The effect of the duration of regrowth on photosynthesis, leaf death and the average rate of growth in a rotationally grazed sward. Grass and Forage Sci. 43:15-27.

Prins, A.H., H.J. Verkaar, and M. Van Den Herik. 1989. Responses of Cynoglossum officinale L. and Senecio jacobaea L. to various degrees of defoliation. New Phytol. 4:725-731.

Ryle, G.J.A. and C.E. Powell. 1975. Defoliation and regrowth in the graminaceous plant: the role of current assimilate. Ann. Bot. 39:297-310.

Savory, A. 1978. A holistic approach to ranch management using short duration grazing, p. 555-557. In: D.N. Hyder (ed) Proc. First Int. Rangeland Congr.

Scarnecchia, D.L., and M.M. Kothmann. 1986. Observations on herbage growth, disappearance, and accumulation under livestock grazing. J. Range Manage. 39:86-87.

Sims, P.L., and J.S. Singh. 1978. The structure and function of ten western North American grasslands. IV. Comparative transfers and energy flow within the ecosystem. J. Ecol. 66:983-1009.

Vogel, W.G. 1965. Stem growth and apical meristem elevation related to grazing resistance to three prairie grasses. Proc. IX Grassl. Congr. 9:345-348.

Voisin, A. 1959. Grass productivity. Philosophical Library, Inc., New York.

Watson, D.J. 1947. Comparative physiological studies on the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. Ann. Bot. 11:41-76.

Williams, T.E. 1980. Herbage production: grasses and leguminous forage crops, p.6-69. In: W. Holmes (ed), Grass: its production and utilization. Blackwell Scientific Publications, London.

Youngner, V.B. 1972. Physiology of defoliation and regrowth, p.292-303. In: V.B. Youngner and C.M McKell (eds), The biology and utilization of grasses. Academic Press, New York.

APPENDIXES

# APPENDIX A

# TABLES

Table 1. Weather data for each trial, Precip = precipitation two weeks prior to and during trial, Max = average maximum daily temperature, Min = average minimum daily temperature, Daily = average daily temperature.

| | | | Temp | | |
|---|---|---|---|---|---|
| Trial | Year | Precip | Max | Min | Daily |
| | | mm | ----- | °C | ----- |
| 1 | 89 | 376 | 28 | 17 | 23 |
| | 90 | 148 | 30 | 18 | 24 |
| | Avg | 303 | 30 | 17 | 23 |
| 2 | 89 | 280 | 31 | 19 | 25 |
| | 90 | 155 | 33 | 21 | 27 |
| | Avg | 205 | 33 | 21 | 27 |
| 3 | 89 | 276 | 28 | 15 | 23 |
| | 90 | 224 | 33 | 19 | 26 |
| | Avg | 185 | 31 | 18 | 24 |

Table 2. Coefficients of polynomial regression equations for live herbage accumulation, L = live residual herbage level, D = day after grazing, $R^2$ = coefficient of determination. All regression terms significant at $P<0.05$.

| Trial | Year | $b_0$ ($10^2$) | $b_1L$ | $b_2L^2$ ($10^{-4}$) | $b_3D$ ($10^{-1}$) | $b_4D^2$ | $b_5L*D$ ($10^{-2}$) | $b_6L*D^2$ ($10^{-3}$) | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 89 | 5.23 | 0.72 | | 0.38[1] | 0.58 | | | 0.88 |
| | 90 | -0.40 | 0.76[1] | | 10.35 | -1.39 | -7.34 | 1.25 | 0.82 |
| 2 | 89 | 3.91 | 0.87 | | -1.12[1] | 0.45 | | | 0.77 |
| | 90 | 6.91 | 2.83 | -5.64 | -1.07 | 0.54 | -1.16 | | 0.90 |
| 3 | 89 | 2.73 | 0.84 | | 3.24 | | -1.31 | | 0.53 |
| | 90 | 3.10 | 0.56 | | 1.59 | | | | 0.79 |

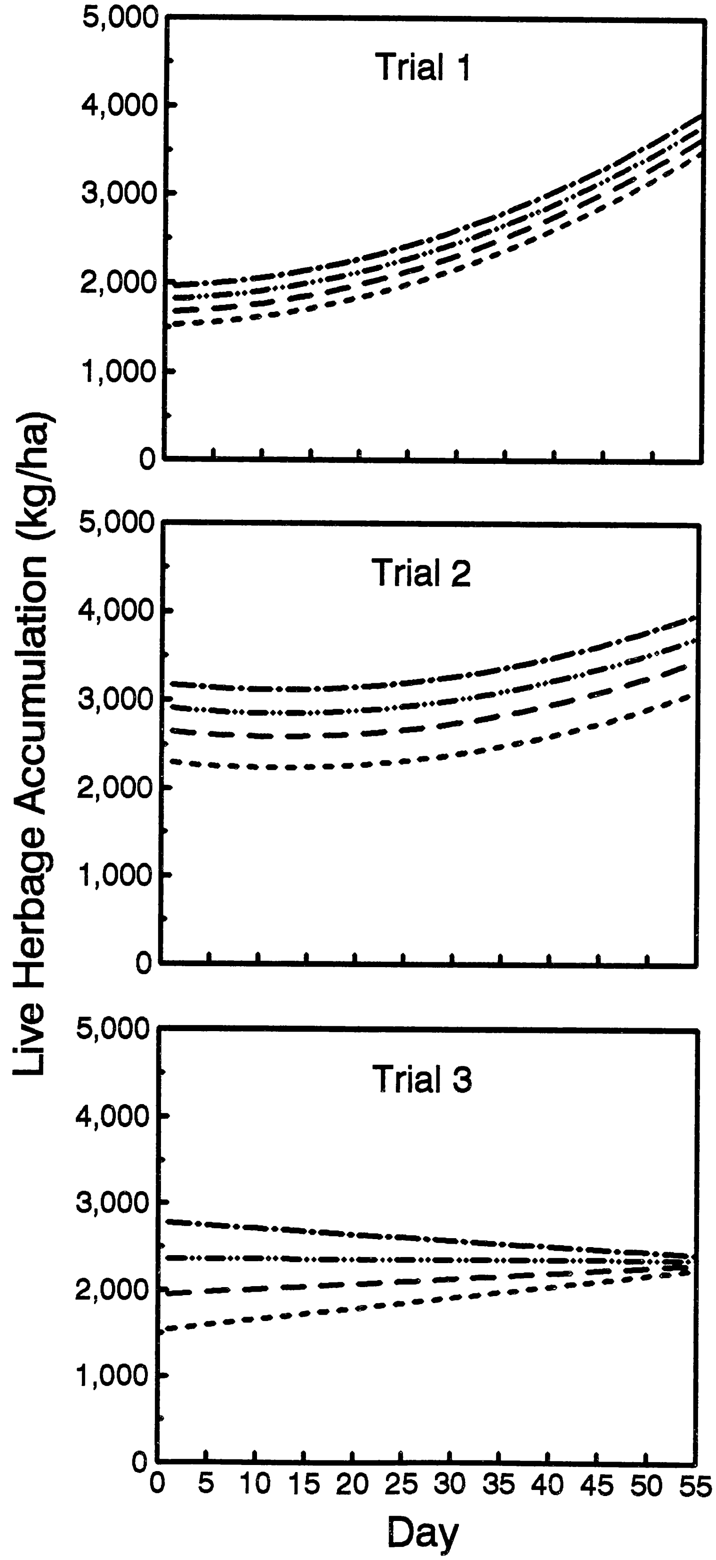
[1]Not significant at $P<0.05$, included because higher order terms were significant.

Table 3. Coefficients of live herbage accumulation rate equations derived from regression equations for live herbage accumulation, L = live residual herbage level, D = day after grazing.

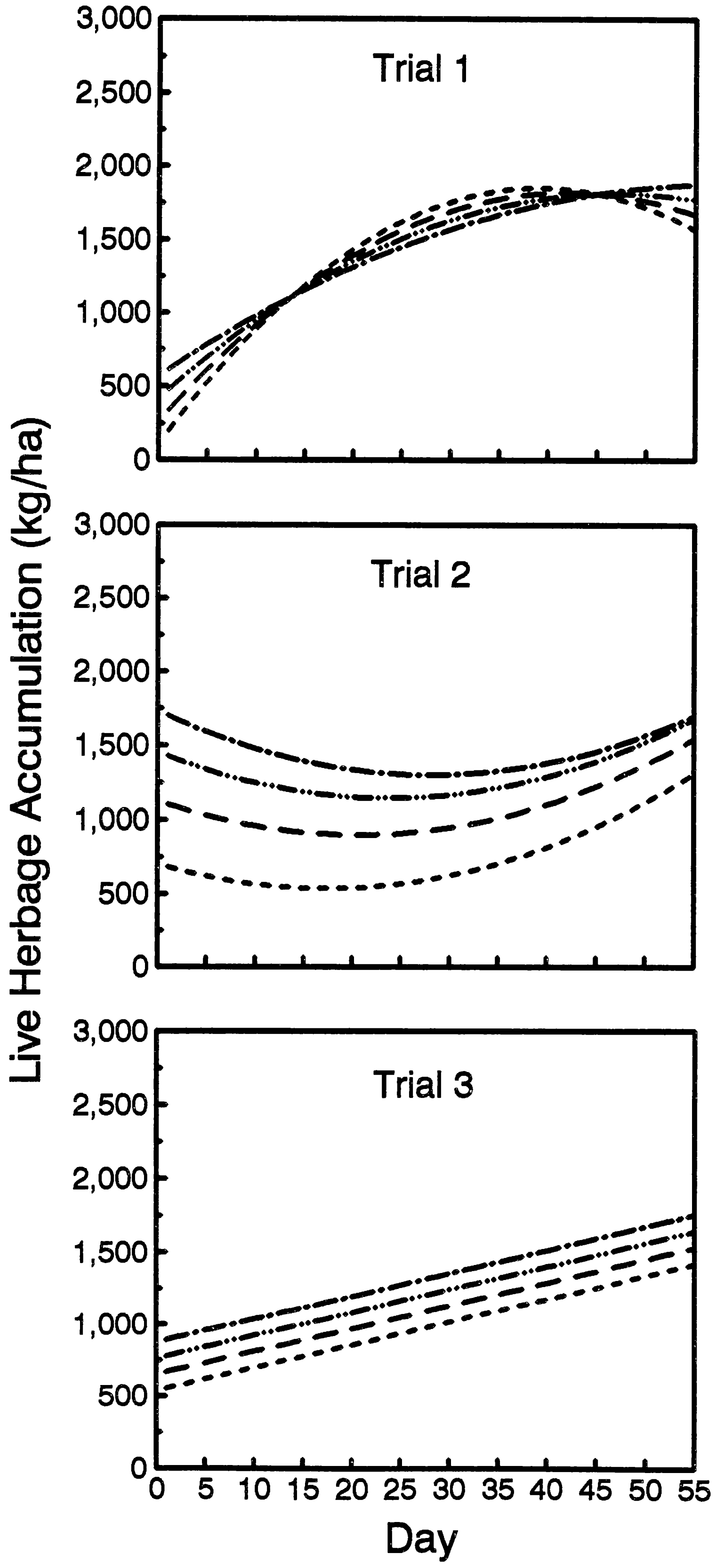
| Trial | Year | $b_0$ ($10^{-1}$) | $b_1L$ ($10^{-2}$) | $b_2D$ | $b_3L*D$ ($10^{-3}$) |
|---|---|---|---|---|---|
| 1 | 89 | 0.38 | | 1.16 | |
| | 90 | 10.35 | -7.34 | -2.78 | -2.50 |
| 2 | 89 | -1.12 | | 0.90 | |
| | 90 | -1.07 | -1.16 | 1.08 | |
| 3 | 89 | 3.24 | -1.31 | | |
| | 90 | 1.59 | | | |

APPENDIX B

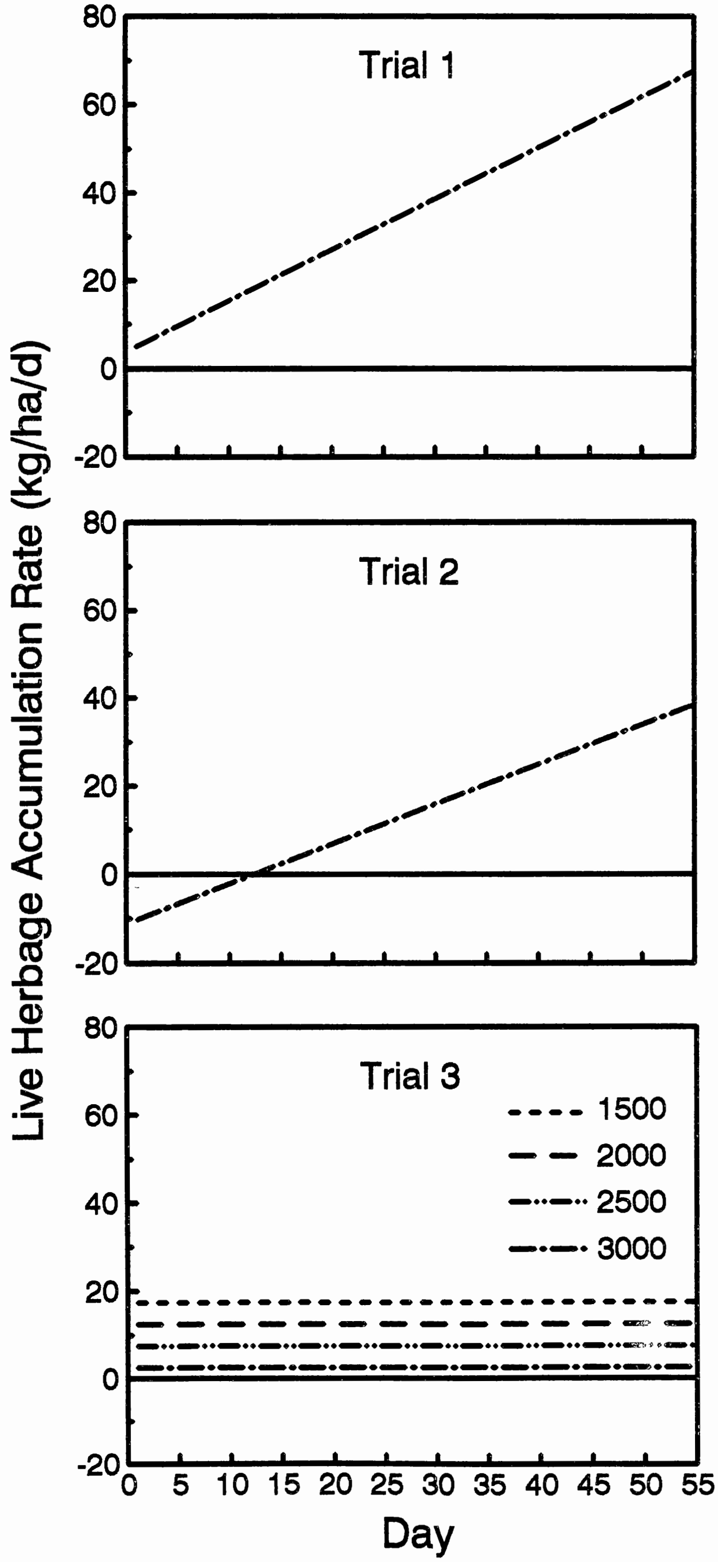
FIGURES

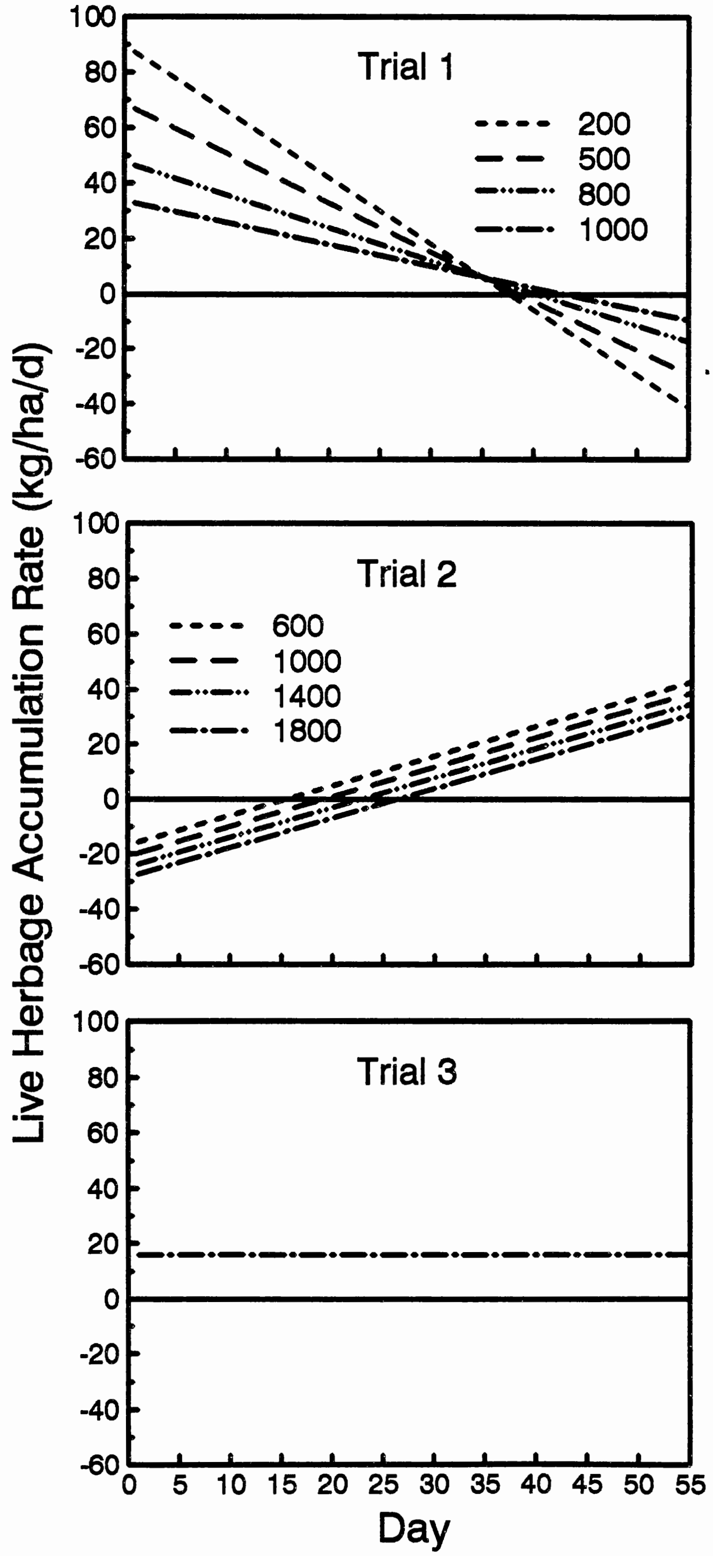


Trial 1
Trial 2
Trial 3
Live Herbage Accumulation (kg/ha)
5,000
4,000
3,000
2,000
1,000
0
0 5 10 15 20 25 30 35 40 45 50 55
Day



Trial 1
Trial 2
Trial 3
Live Herbage Accumulation (kg/ha)
3,000
2,500
2,000
1,500
1,000
500
0
0 5 10 15 20 25 30 35 40 45 50 55
Day


Trial 1
Trial 2
Trial 3
1500
2000
2500
3000
Live Herbage Accumulation Rate (kg/ha/d)
Day
80
60
40
20
0
-20
0
5
10
15
20
25
30
35
40
45
50
55


Trial 1
200
500
800
1000
Trial 2
600
1000
1400
1800
Trial 3
Live Herbage Accumulation Rate (kg/ha/d)
Day
100
80
60
40
20
0
-20
-40
-60
0
5
10
15
20
25
30
35
40
45
50
55

VITA

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