MAXIMUM GROWTH RATE OF SMOOTH BROME AND MODEL PERFORMANCE OF GROWIT IN KANSAS

by

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INTRODUCTION

There are approximately one million hectares of tame pasture in Kansas, and smooth brome (*Bromus inermis* L.) is considered to be the most important cool-season grass in the eastern third of Kansas (Dicken, 1976).

Since smooth brome is a perennial cool-season grass,it can be grazed in the spring and fall when the native warm-season grasses are not available. It produces vegetative growth during the early part of the season and seed in the long days of early summer. During hot dry periods it is dormant, resuming growth during the cool short days of fall (Newell, 1978; Smith, 1962).

Smooth brome is grown alone and in mixtures with other grasses and legumes. It is used for pasture, hay and erosion control (Walton, 1983). Smooth brome forage quality compares favorably with other cool-season grasses and it is more palatable in the vegetative stage than most species. Under favorable conditions of soil nitrogen availability, the percentage of crude protein is high during early plant growth ranging from 12 % to over 20 % with digestible protein decreasing rapidly with maturity (Newell, 1978; Walton, 1983).

The objectives of this study were 1) to determine the maximum growth rate of smooth brome and 2) to use it as an input parameter in GROWIT, a non-specific crop growth model developed at the University of Kentucky (Smith and Loewer, 1981), to predict forage yields of smooth brome in Kansas.

LITERATURE REVIEW

Growth rate

To obtain a quantitative expression of growth for a plant or group of plants during a given period of time, certain indices are used. These include 1) increase in the length of the stem, root or other organ of the plant, 2) increase in the leaf area, 3) increase in the diameter of the stem or other organ, 4) increase in volume (especially of fruits), 5) fresh-weight increment and 6) the dry weight increment (Meyer et al. 1964).

In studying growth rates (the increment of growth occuring per unit interval of time throughout the life of an organism) an idealized S-shaped (sigmoid) growth curve has been developed. The three primary phases of the curve are the logrithimic phase, a linear phase, and a senescence phase. In the logrithimic phase, the growth rate is initially slow due to the low number of cells in a germinating seed, but the rate continues to increase as more cells are formed. In the linear phase the increase in size continues at a constant rate until the final senescence phase is reached, where a decrease in growth rate occurs as the plant matures (Salisbury and Ross, 1978).

Hunt (1982) reported work done by U. Krensler and co-workers in West Germany in the 1870's where they showed that growth of an annual plant under natural conditions followed a course that is now recognized as typical for many species. Their data showed that with time, there was a increase in mean dry weight per plant in *Zea mays*, similar to perennial plants.

Growth analysis

Growth is analyzed by measuring the total dry weight of the plant (W) and the total leaf area of the plant (A) (Hurd, 1977). Other measures of (W) and (A) such as above ground dry weights, root weights, stem and leaf weights, leaf protein and many other parameters have been recorded which must be clearly defined before a growth analysis formula can be derived.

The attributes of growth of individual plants which are most commonly studied were shown by Hughes and Freeman (1967) to be:

the relative growth rate = $1/W * dW/dt$

the leaf area ratio = A/W

the unit leaf rate = $1/A * dW/dt$

where W = total plant dry weight (mg)

A = leaf area (cm2)

t = time in days

The relative growth rate of a plant (RGR) can be shown as RGR = NAR * LAR where NAR is the Net Assimilation Rate and LAR is the Leaf Area Ratio (Radford, 1967).

Growit model

Modern agriculture has made tremendous progress in raising the productivity of pasture grasses through the use of scientific knowledge and improved technology. Further improvement is sought through advances in plant breeding and the use of simulation models. With the use of these models one can determine deficiencies and predict crop growth. Agricultural practice demands "specific qualitative directives" which are generally obtained through experiments which can be expensive and time consuming. A good and relatively cheaper approach is the use of computer models (van Keulen, 1975). Modelling can be used as a tool to determine the outcome of a certain management decisions and it can also derive solutions for new situations (McKeon and Scattini, 1980).

One such model is GROWIT, a nonspecific plant growth model which is used to predict forage yields on a daily basis. Smith and Loewer (1981) developed this model as part of a larger BEEF (A simulation model for assesing alternate stratergies for beef production with land, energy, and economic constraints) production model developed at the University of Kentucky (Loewer et. al, 1981). GROWIT has been used to simulate vegetative growth of crops such as Coastal bermudagrass (Cynodon dactylon L.), tall fescue (Festuca arundinacea Schreb.), Kentucky bluegrass (Poa pratenis L.), red clover (Trifolium pratense L.), alfalfa (Medicago sativa L.), corn (Zea mays L.) and tobacco (Nicotiana tabacum L.).

Growth prediction is based on:

1) genetic growth potential
2) air temperature
3) latitude
4) leaf area
5) photoperiod
6) rainfall

As a non-specific model, GROWIT is not limited by site, crop, or management techniques (Smith and Loewer, 1981).

In predicting the potential forage growth rate, a function relating maximum growth rate to air temperature is used. A curve is constructed which defines the relationship between temperature and growth rate. The curve consists of two parabolas. The first one describes the growth rate between the minimum and optimum temperatures for growth, the second, describes growth rate between optimum and maximum temperatures for growth.

Daylength is determined from the latitude of the site where the crop is being grown and the Julian day. To describe air temperature as a function of time, the minimum air temperature is assumed to occur at dawn, the maximum at solar noon, and the mean at sundown. No growth occurs between sunset and dawn. Growth is then calculated on an hourly basis.

A 0 to 1.0 multiplier factor used in the model to account for the effects of leaf area on plant growth is described by three dry matter accumulation values. These are the yield per acre necessary to support the maximum growth rate (QQ1), the yield per acre at which shading and senescence cause a decrease in growth rate (QQ2), and the greatest amount of yield per acre that can accumulate (QQ3). Maximum growth rate is maintained between QQ1 and QQ2; reduction in growth increases from QQ2 to QQ3.

The photoperiod growth reduction factor affects growth once daylength decreases to the point XL1 (daylength in hours where decreasing photoperiod affects growth). This factor decreases linearly until a second daylength XL2 is reached where photoperiod is assumed to have no further effect on growth.

GROWIT accounts for reductions in growth resulting from moisture by comparing actual daily rainfall and actual accumulated daily rainfall with normal daily rainfall and accumulated daily rainfall. The user input variables are the actual daily rainfall and normal monthly rainfall. From these variables GROWIT calculates effective rainfall to be used by the crop.

The daily rainfall factor is multiplied by the photoperiod factor, optimum growth rate and leaf area parameters to give a predicted yield in lb/A.

A more detailed explanation of GROWIT logic is given by Smith and Loewer (1981).

MATERIALS AND METHODS

In order to determine the maximum growth rate of smooth bromegrass, a study was initiated at the Agronomy Research Center, Manhattan, Kansas, in 1983.

On 7 March, 1983, the site was cleared by mowing to a 5 cm stubble height and fertilized with 280 kg actual N/ha as ammonium nitrate. Plots measuring 1.2 m wide by 4.5 m long were arranged in a randomized complete block design with four replications, with cutting dates as treatments (Table 1).

Soil moisture content was monitored by tensiometers to a depth of 30 cm (irrigation water was provided by overhead sprinklers) and soil temperature at a 7 cm depth was recorded using a Taylor maximum-minimum thermometer. Climatic data consisting of daily maximum and minimum temperatures and precipitation were obtained from the Kansas State University Physics Department Meteorology Laboratory.

Forage production was measured by harvesting the center 53 cm of each plot. The harvested forage was weighed, anda sub-sample weighing approximately 500 g was oven dried at 65 C for 5 days to determine dry matter content and calculate dry matter yields. These sub-samples were then used to determine crude protein percentage of the forage. The outside rows of the harvested plots were mowed and the forage discarded.

To determine stubble weights, 0.04 m^2 plots of spring residuals were hand clipped, weighed and brought into the lab. The samples were seperated into dead (brown blades) and live tissue (green blades) and weights were obtained.

Table 1. Cutting dates of smooth brome at Manhattan, Ks, 1983.

Treatment	Cutting dats	Previous cut on
1	April 13	
2	April 20	
3	April 27	
4	May 4	
5	May 7	
6	May 10	
7	May 13	
8	May 16	
9	May 19	
10	May 22	
11	May 25	
12	May 28	
13	May 31	
14	June 7	May 31
15	June 14	May 31
16	June 21	May 31
17	June 28	May 31
18	July 5	May 31
19	July 12	May 31

Samples for laboratory analysis were ground in a Wiley mill to pass through a screen with openings 1 mm in diameter (40 mesh) and placed in bottles.

Crude protein was determined colorimetrically using a modified version of the Linder and Harley (1942) procedure. Four ml of concentrated sulfuric acid was added to 0.25 g of ground tissue in an ignition tube. One ml of 30% hydrogen peroxide was added and the mixture was heated over a hot plate until it became clear.

During the digestion process, which usually takes 1 to 2 hours, the samples were periodically removed from the hotplates for cooling and addition of more hydrogen peroxide. Upon completion of digestion, the samples were brought up to volume (50 ml) with deionized distilled water and the resulting solution was bottled.

To 0.5 ml of this solution, 4.5 ml of distilled water was added and mixed. To this solution two color developing reagents (2 ml of solution A and 2 ml of solution B)1/ were added. Following a period of 1.5 to 2 hours to allow full color development, the test solution was read on a colorimeter set at 660 nm and calibrated with known standards, to determine % N. The % N was multiplied by 6.25 to obtain % crude protein.

1/ Reagents
Solution A - In 600 ml distilled water, 85 gm of sodium salicylate was added. Then 0.3 gm of sodium nitroprusside was added and then the solution was diluted to 1.0 liter.

Solution B - In 900 ml of distilled water, 24.0 gm of sodium hydroxide was added. Then 5.0 gm of sodium dichloroisocyanurate was added and the solution was diluted to 1.0 liter.

Since yields increased in a linear manner during the course of the study, a regression analysis was conducted for yield versus date of harvest to obtain the slope of the line to estimate the maximum growth rate of smooth brome.

Computer simulations were carried out at the Kansas State University Computation Center. The GROWIT model, which was obtained from Dr. E. Smith at the University of Kentucky, was used to simulate spring growth for smooth brome using the various parameter values provided by the user.

RESULTS AND DISCUSSION

Field study

Smooth brome accumulated live forage yield in a linear fashion throughout the growing period. Dry matter yields ranged from 560 kg/ha to 7169 kg/ha (Table 2). In a study conducted in Nebraska, spring forage yields ranged from 2800 kg/ha under no N treatment to 10300 kg/ha under the high N treatment (168 kg N/ha in April), (Engel, 1983). Based on eight years of data, 1976 to 1983, an application of 144 kg/ha in late fall to late winter produced approximately 7281 kg/ha forage (Kissel et. al., 1983). In South Dakota, Hanson et. al., (1978) reported total annual yields of 11,802 kg/ha with a split application of 224 kg/ha applied in March and July.

Percent crude protein decreased over the growing period showing a decline in forage quality with maturity. This is in agreement with results of studies conducted by many others such as Newell, (1978) and Walton, (1983) who showed percent crude protein was high during early plant growth and decreased rapidly with maturity.

Smooth brome regrowth, shown as yield in days after first harvest (Table 3), ranged from 112 kg/ha to 1255 kg/ha, and percent crude protein decreased as the plants matured. This is in agreement with work done by Kunelius et. al., (1974), who showed crude protein content in aftermath was highest when regrowth interval was shortest.

Parameter values

Estimates of parameter values were obtained either from the literature or personal communication with researchers.

Table 2 . Cutting date, dry matter (D.M.) yield and percent crude protein (% C.P.) of smooth brome in Manhattan, Kansas, 1983.

Cutting date Julian day	D.M. yield kg/ha	C.P. %
103	560	23.6
110	784	26.8
117	1344	26.7
124	2644	21.2
127	3047	20.4
130	3316	19.1
133	4257	18.3
136	4794	16.5
139	5332	16.3
142	5601	15.7
145	6295	14.2
148	6676	13.1
151	7169	13.1

Table 3 . Dry matter (D.M.) yield and percent crude protein (% C.P.) of smooth brome regrowth in Manhattan, Kansas, 1983.

Days after harvest*	D.M. yield kg/ha	C.P. %
14	112	14.8
21	202	20.3
28	493	19.6
35	717	17.1
42	1255	16.5

* Initial harvest May 31 (Julian day 151)

Daily precipitation, maximum and minimum temperatures were utilized (Appendix Table A-1).

The growth rate of smooth brome at the optimum tamperature for herbage growth in a pure stand is not known. The values used in the simulations were determined by conducting a regression analysis on yield versus day of harvest with the slope of the line being the maximum growth rate. The value of 12.53 kg/ha/hr was obtained when the entire growing period was taken into consideration (Appendix Table A-2), and a value of 14.42 kg/ha/hr was obtained when the entire growth period was taken into consideration excluding the first three harvest dates (April 13, 20 and 27), (Appendix Table A-3). In a study conducted at the University of Nebraska in 1982, a rate of 15.83 kg/ha/hr for maximum growth rate of smooth brome was obtained (Engel, 1983). A value of 8.29 kg/ha/hr is used at the University of Kentucky to simulate growth of cool-season grasses (Smith and Loewer, 1981).

GROWIT uses three characteristic temperatures (minimum, optimum, maximum) for a species in order to calculate growth. The three temperatures used to characterize smooth brome herbage growth were 4.4 C (E. Smith, pers. comm.), 22 C (Baker and Jung, 1968 a,b) and 32 C (Baker and Jung, 1968 a,b).

Values representing crop weight able to support full growth rate, weight at which herbage growth is not favored, and maximum weight observed under no nitrogen treatment were required by the model. Values selected for these parameters were 1915, 11199, and 11979 kg/ha (Smith and Loewer, 1981). Other values used were 1347, 3949, and 5600 kg/ha (B. Brown, pers. comm.; Kroth et. al., 1977).

Estimates of stubble weights at the begining of the growth period were difficult to estimate from available literature. To obtain these values, .04 m^2 plots of spring residuals were harvested with 560 kg/ha dry matter and 448 kg/ha of dead growth obtained. Since it was difficult to differentiate between old and new growth, 56 kg/ha was used for each. This number was obtained by dividing the difference in weight between dry matter and dead growth by 2. Other values of 784, 560, 168 and 56 kg/ha of initial amount of dry matter, initial amount of dead growth, initial amount of old growth and initial amount of new growth were also used. These values were used at the University of Kentucky to simulate yields of cool-season grasses (Smith and Loewer, 1981).

Parameter values for estimating smooth brome regrowth were esentially the same, except for the maximum growth rate, which in this study was found to be 2.85 kg/ha/hr. This growth rate was derived by conducting a regression analysis on yield versus days after harvest, with the slope of the line being the maximum growth rate (Appendix Table A-4). A value of 224 kg/ha was used as the amount of dry matter present on the field at the begining of the regrowth period. This value was obtained at the University of Kentucky from a tall fescue regrowth study (E. Smith, pers. comm.).

Sensitivity analysis

Before model evaluation, it was decided to examine the models' sensitivity to selected parameter values. The three parameters studied were the maximum growth rate (Table 4), the QQ values (Table 5), and the stubble weights (Table 6).

As shown in Table 4, changing maximum growth rate from 14.42 kg/ha/hr (combination A) to 8.29 kg/ha/hr (combination B) decreased the predicted yields.

As shown in Table 5, changing QQ2 and QQ3 values (combinations C and E) had no effect on predicted yields, but a change in QQ1 (combination D) did affect predicted yields.

Change in initial stubble weights (combination F and G, Table 6) did have an effect on predicted yields. With an increase in stubble weights there was an increase in predicted yields (Table 6).

Model performance

Selected combinations of parameter values were used to evaluate the model by comparing predicted versus observed yields (combinations H to P, Tables 7 and 8). In all combinations (H to P) the minimum, optimum and maximum temperatures for crop growth were never changed. Combinations H and J had the same maximum growth rate (14.42 kg/ha/hr), different QQ values, and the same stubble weights. Combinations H and J consistently overestimated observed yields (Figure 1).

Combinations I and K had the same growth rate (12.53 kg/ha/hr) but lower than combinations H and J (14.42 kg/ha/hr). Combinations I and K initially overestimated yields, and later in the growing season underestimated yields (Figure 1).

Table 4. Sensitivity analysis for maximum growth rate value.

Parameter	Combination A	Combination B
Minimum temperature at which crop will grow	4.4 C	4.4 C
Optimum temperature at which crop will grow	22 C	22 C
Maximum air temperature at which crop will grow	32 C	32 C
Maximum growth rate of crop	14.42 kg/ha/hr	8.29 kg/ha/hr
The amount of dry matter in the plant which provides enough leaf area to support maximum growth rate	1347 kg/ha	1347 kg/ha
The amount of dry matter in the plant which is great enough for shading to affect crop growth	11199 kg/ha	11199 kg/ha
Maximum amount of dry matter in the plant above which no growth occurs	11979 kg/ha	11979 kg/ha
Initial amount of dry matter	560	560
Initial amount of new growth	56	56
Initial amount of old growth	56	56
Initial amount of dead growth	448	448

	Predicted Yield kg/ha	
	Combination	
Julian Day	A	B
103	1210	830
110	1850	1189
117	2800	1728
124	3875	2339
127	4299	2580
130	4652	2780
133	5053	2948
136	5435	3091
139	5883	3346
142	6339	3606
145	6845	3894
148	7076	4135
151	7121	4176

Table 5. Sensitivity analysis for QQ values.

Parameter	Combination C	Combination D	Combination E
Minimum temperature at which crop will grow	4.4 C	4.4 C	4.4 C
Optimum temperature at which crop will grow	22 C	22 C	22 C
Maximum air temperature at which crop will grow	32 C	32 C	32 C
Maximum growth rate of crop	14.42 kg/ha/hr	14.42 kg/ha/hr	14.42 kg/ha/hr
The amount of dry matter in the plant which provides enough leaf area to support maximum growth rate	1347 kg/ha	1915 kg/ha	1347 kg/ha
The amount of dry matter in the plant which is great enough for shading to affect crop growth	3949 kg/ha	3949 kg/ha	11199 kg/ha
Maximum amount of dry matter in the plant above which no growth occurs	5600 kg/ha	5600 kg/ha	11979 kg/ha
Initial amount of dry matter	560	560	560
Initial amount of new growth	56	56	56
Initial amount of old growth	56	56	56
Initial amount of dead growth	448	448	448

Julian Day	Predicted Yield kg/ha Combination C	Predicted Yield kg/ha Combination D	Predicted Yield kg/ha Combination E
103	1210	1123	1210
110	1850	1714	1850
117	2800	2657	2800
124	3875	3731	3875
127	4299	4155	4299
130	4652	4508	4652
133	5053	4955	5053
136	5435	5091	5435
139	5883	5533	5883
142	6339	5988	6339
145	6845	6495	6845
148	7076	6982	7076
151	7121	7246	7121

Table 6. Sensitivity analysis for stubble weights.

Parameter	Combination F	Combination G	Days after harvest	Predicted Yield kg/ha Combination F	Predicted Yield kg/ha Combination G
Minimum temperature at which crop will grow	4.4 C	4.4 C	14	851.31	582.48
Optimum temperature at which crop will grow	22 C	22 C	21	963.32	716.89
Maximum air temperature at which crop will grow	32 C	32 C	28	1097.74	851.31
Maximum growth rate of crop	2.85 kg/ha/hr	2.85 kg/ha/hr	35	1097.74	873.77
The amount of dry matter in the plant which provides enough leaf area to support maximum growth rate	1915 kg/ha	1915 kg/ha	42	1120.15	918.52
The amount of dry matter in the plant which is great enough for shading to affect crop growth	11199 kg/ha	11199 kg/ha			
Maximum amount of dry matter in the plant above which no growth occurs	11979 kg/ha	11979 kg/ha			
Initial amount of dry matter	560	224			
Initial amount of new growth	56	56			
Initial amount of old growth	56	56			
Initial amount of dead growth	400	112			

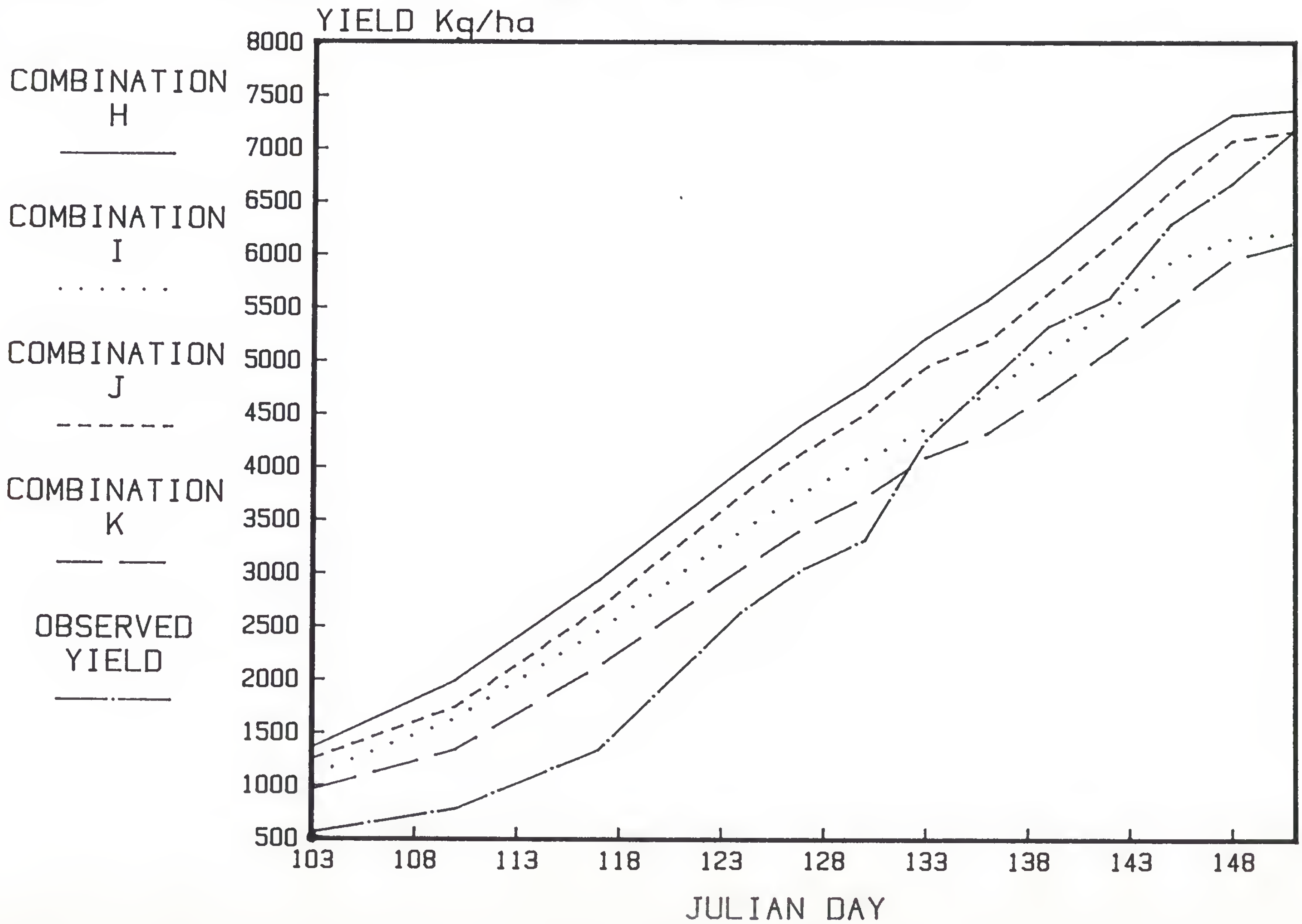
Table 7. Listing of parameter values for smooth brome growth simulations with the GROWIT model.

Parameter	Combination H	Combination I	Combination J	Combination K
Minimum temperature at which crop will grow	4.4 C	4.4 C	4.4 C	4.4 C
Optimum temperature at which crop will grow	22 C	22 C	22 C	22 C
Maximum air temperature at which crop will grow	32 C	32 C	32 C	32 C
Maximum growth rate of crop	14.42 kg/ha/hr	12.53 kg/ha/hr	14.42 kg/ha/hr	12.53 kg/ha/hr
The amount of dry matter in the plant which provides enough leaf area to support maximum growth rate	1347 kg/ha	1347 kg/ha	1915 kg/ha	1915 kg/ha
The amount of dry matter in the plant which is great enough for shading to affect crop growth	3949 kg/ha	3949 kg/ha	11199 kg/ha	11199 kg/ha
Maximum amount of dry matter in the plant above which no growth occurs	5600 kg/ha	5600 kg/ha	11979 kg/ha	11979 kg/ha
Initial amount of dry matter	784 kg/ha	560 kg/ha	784 kg/ha	560 kg/ha
Initial amount of new growth	56 kg/ha	56 kg/ha	56 kg/ha	56 kg/ha
Initial amount of old growth	168 kg/ha	56 kg/ha	168 kg/ha	56 kg/ha
Initial amount of dead growth	560 kg/ha	448 kg/ha	560 kg/ha	448 kg/ha

Table 8. Listing of parameter values for smooth brome regrowth simulations with the GROWIT model.

	Combination			
Parameter	L	M	N	P
Minimum temperature at which crop will grow	4.4 C	4.4 C	4.4 C	4.4 C
Optimum temperature at which crop will grow	22 C	22 C	22 C	22 C
Maximum air temperature at which crop will grow	32 C	32 C	32 C	32 C
Maximum growth rate of crop	2.85 kg/ha/hr	2.85 kg/ha/hr	2.85 kg/ha/hr	2.85 kg/ha/hr
The amount of dry matter in the plant which provides enough leaf support for maximum growth rate	1915 kg/ha	1347 kg/ha	1347 kg/ha	1915 kg/ha
The amount of dry matter in the plant which is great enough for shading to affect crop growth	11199 kg/ha	3949 kg/ha	3949 kg/ha	11199 kg/ha
Maximum amount of dry matter in the plant above which no growth occurs	11979 kg/ha	5600 kg/ha	5600 kg/ha	11979 kg/ha
Initial amount of dry matter	560 kg/ha	560 kg/ha	224 kg/ha	224 kg/ha
Initial amount of new growth	56 kg/ha	56 kg/ha	56 kg/ha	56 kg/ha
Initial amount of old growth	56 kg/ha	56 kg/ha	56 kg/ha	56 kg/ha
Initial amount of dead growth	448 kg/ha	448 kg/ha	112 kg/ha	112 kg/ha

Figure 1. Predicted and observed yields of smooth brome, Manhattan, KS. 1983



Smooth brome regrowth was predicted with combinations L and P (Table 8). All combinations (L to P) had the same growth rate of 2.54 kg/ha/hr. Combinations L and P had QQ values of 1915, 11199 and 11979 kg/ha used to simulate cool-season grass growth in Kentucky (Smith and Loewer, 1981). Different initial stubble weights of 560, 56, 56, and 448 kg/ha were used in combinations L and M while in combinations N and P stubble weights of 224, 56 56 and 112 kg/ha are used. All combinations overestimated yields (Figure 2), however, combinations L and M overestimate yields to a greater extent than combinations N and P. This is probably due to the greater stubble weights in combination L and M.

When looking at differences between predicted and actual yields, the standard errors for combinations H to K ranged from 110.70 to 176.23 kg/ha (Table 9), and 157.57 to 209.47 kg/ha for combinations L to P (Table 10). Combinations H, C and M give significant t tests, with other combinations showing no significance. When dealing with a large range of numbers however, one should consider standard error values when evaluating model performance. Large variability in the predicted yields above and below observed values (combinations I and K) may invalidate the significance of the t test.

Plotting differences between predicted and observed yields for smooth brome, and smooth brome regrowth (Figures 3 and 4 respectively) show trends of possible environmental effects on the model, regardless of combinations used.

Figure 2. Predicted and observed yields of smooth brome regrowth. Manhattan, KS. 1983

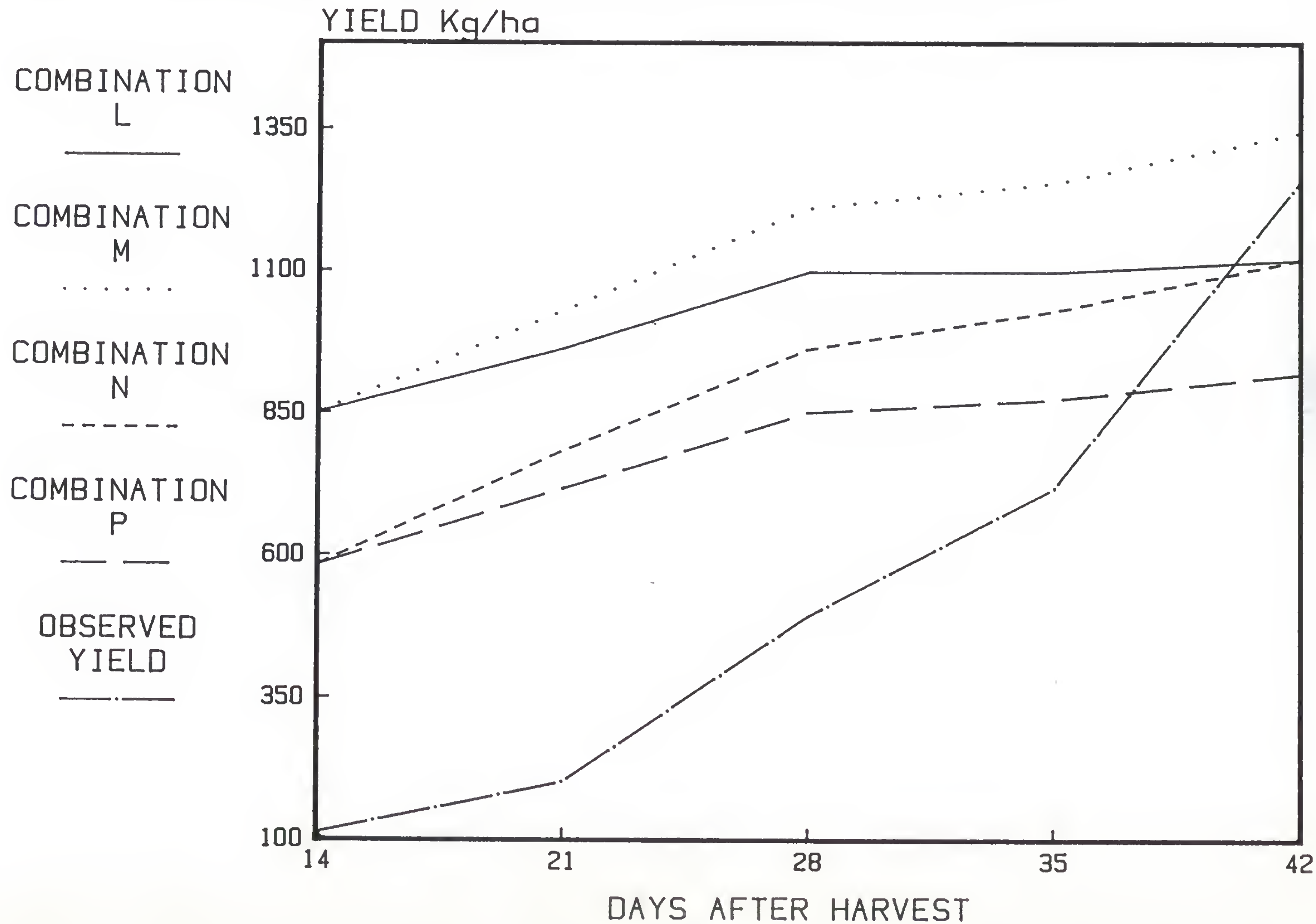


Table 9. Modelled yield versus observed yield of smooth brome, (Predicted yield - Observed yield), kg/ha.

Cutting date	Yield difference (kg/ha) Combination			
Julian day	H*	I*	J*	K*
103	807	538	695	403
110	1210	851	963	560
117	1591	1120	1322	784
124	1344	761	1097	403
127	1366	717	1098	381
130	1456	761	1187	403
133	963	112	694	-157
136	784	-89	403	-470
139	672	-247	313	-627
142	873	-112	493	-493
145	672	-358	314	-761
148	650	-515	403	-717
151	202	-963	0	-1053
$\bar{d}$	968.46	198.15	690.92	-103.38
$\bar{sd}$	110.70	176.23	113.69	169.94
t	8.74	1.12	6.08	-.6

* See table 7

Table 10. Modelled yield versus observed of smooth brome regrowth, (Predicted yield - Observed yield), kg/ha.

Days after Harvest**	Yield difference kg/ha Combination			
	L*	M*	N*	P*
14	739	739	471	471
21	761	828	582	515
28	605	717	470	358
35	381	538	313	157
42	-135	89	-135	-336
$\bar{d}$	436.50	548.50	307.75	201.75
$S\bar{d}$	209.47	164.74	157.57	196.17
t	2.08	3.33	1.95	1.03

* See table 8

** Initial harvest May 31

Figure 3. Predicted - observed yield of smooth brome. Manhattan, KS. 1983

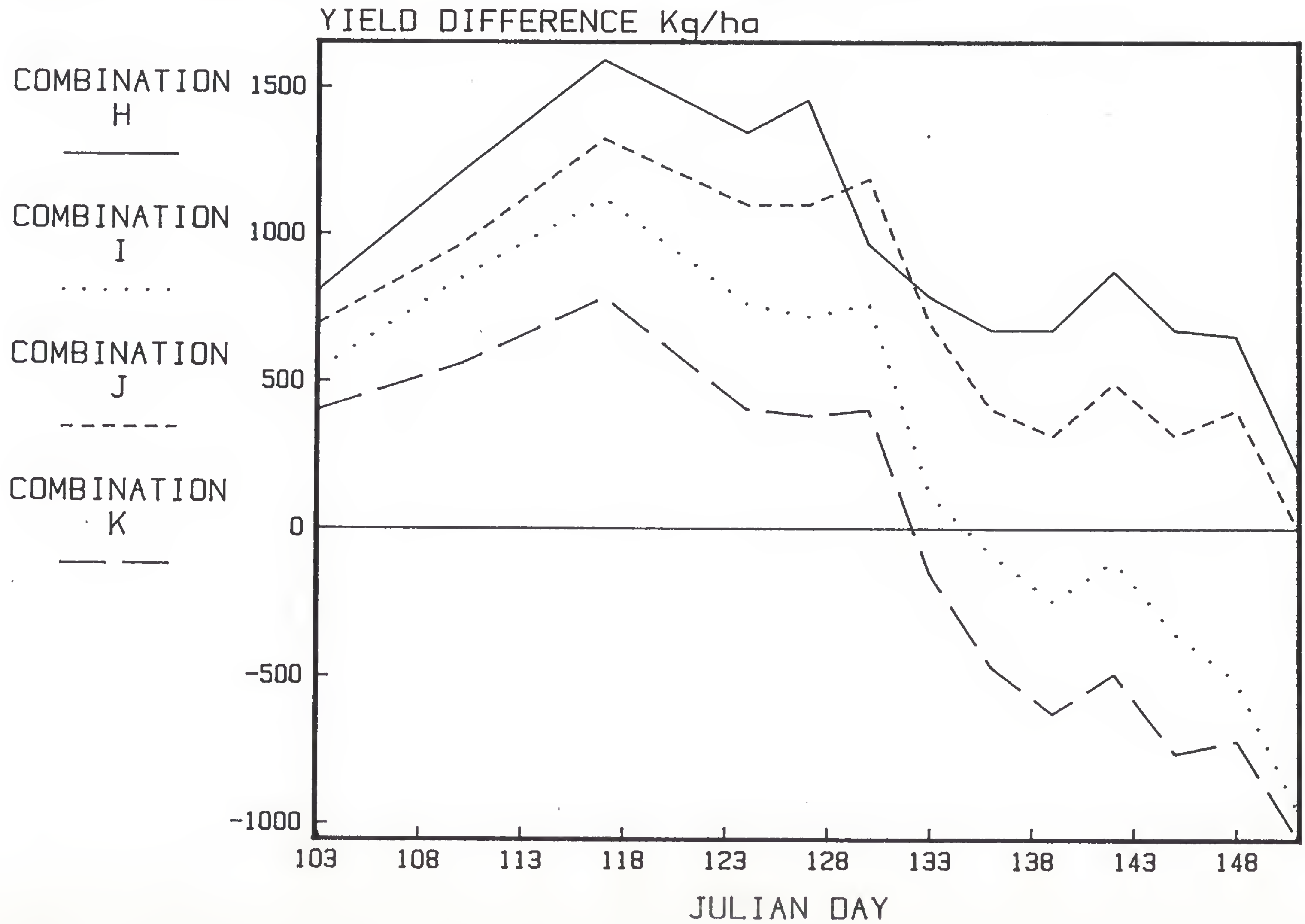
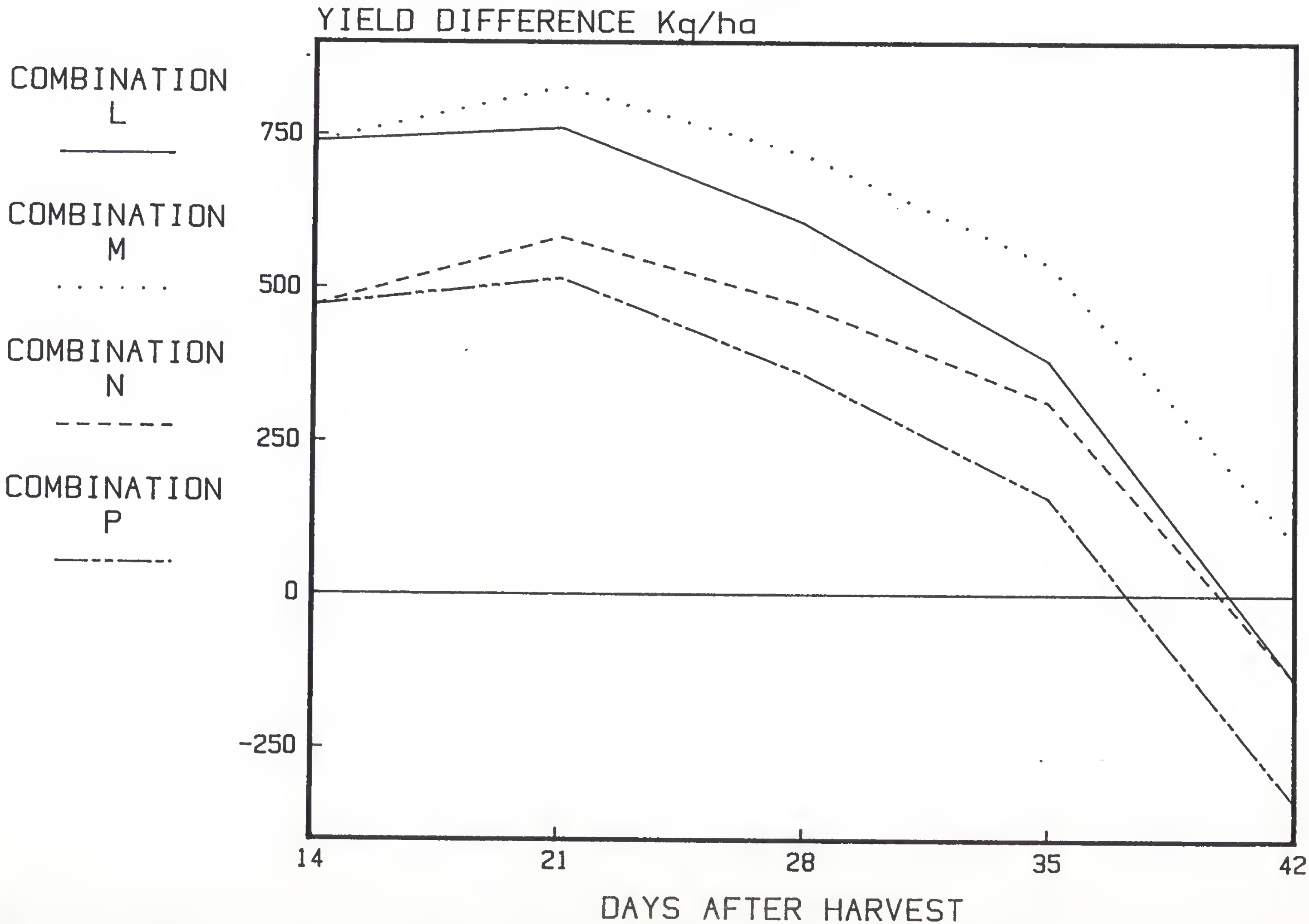


Figure 4. Predicted - observed yield of smooth brome regrowth. Manhattan, KS. 1983



CONCLUSIONS

Field study

Maximum forage yield of smooth brome under the environmental conditions present in Manhattan, Kansas in 1983, with 280 kg N/ha, was 7169 kg/ha with a mean growth rate of 173 kg/ha/day. The mean growth rate of smooth brome regrowth was approximately 33.60 kg/ha/day.

Model

Using the best available crop parameter values in several combinations, GROWIT was unable to consistantly predict observed yields. The performance of the model could be improved by making better estimates of parameter values. This however, might lead to unrealistic parameter values in order to fit the data.

Rate of dry matter accumulation greatly affects forage yields, and manipulating this value can result in better performance of the model.

GROWIT uses a maximum growth rate value in lb/A/hr to construct daily growth curves. Once the simulation is initiated, this rate cannot be changed. It is well documented that growth rates do change during a growing season. GROWIT makes these changes through changes in environmental parameters which affect dry matter accumulation.

Stubble weights, another parameter evaluated in this study were difficult to define. Cutting reduces the weight of the crop left in the field and affects the plants ability to accumulate dry matter; the model is sensitive to this parameter.

Since the model consistently overpredicted forage yield during the early part of the growing season, a solar radiation parameter should be considered. The model assumes adequate sunlight for photosynthesis. However, clouds interrupt photosynthetic activity and in some cases it may be virtually zero.

To improve crop growth predictions, plant physiological processes must be studied in more detail. Parameter values need to be adjusted for different environmental conditions and fertilization schedules. More documentation is needed to obtain values suitable for a wide range of conditions, making GROWIT truely a non-specific crop growth model.

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APPENDIX

Table A-1. Climatic data for Agronomy Research Farm, Manhattan, KS. 1983

Month	Temperature C		Precipitation (cm)		Irrigation	
	Average Max.	Average Min.	Average	Total	(cm)	Dates
March	11.39	1.28	6.3	8.15	—	—
April	14.22	3.22	8.72	11.79	—	—
May	20.83	9.06	14.94	14.22	—	—
June	26.91	15.70	21.31	0.58	2.54, 5.08	2, 21
July	34.95	21.74	28.34	1.42	2.54, 2.54	5, 8

Table A-2. Regression analysis for growth rate of smooth brome. (Growing period Julian days 103-151)

Source	d.f.	Mean Square	Equation	r^2
Model	1	26096.63	$Yield_{(day)} = 150.37x - 15735.37$	0.97
Error	11	60.19		

Table A-3. Regression analysis for growth rate of smooth brome. (Growing period Julian days 124 to 151)

Source	d.f.	Mean Square	Equation	r^2
Model	1	9978.82	$Yield_{(day)} = 172.93x - 18865.25$	0.99
Error	11	10.12		

Table A-4. Regression analysis for smooth brome regrowth.

Source	d.f.	Square	Equation	r^2
Model	1	447.66	$Yield_{(day)} = 2.85x - 374.87$	0.91
Error	3	10.59		

MAXIMUM GROWTH RATE OF
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ABSTRACT

Using computer models to predict crop performance under different environmental conditions and management practices is gaining popularity. One such model is GROWIT, a non-specific crop growth model developed and tested at the University of Kentucky.

An important parameter value required by the model is the maximum growth rate of the crop being evaluated. Since smooth brome (Bromus inermis L.) has a dominant role in grazing systems in Northeast Kansas, this study was designed to determine the maximum growth rate of this cool-season grass and to use GROWIT to predict forage yields under Kansas environmental conditions.

With a 3 and 7 day harvest schedule, the maximum growth rate of smooth brome in 1983 in Manhattan, Kansas, was 14.42 kg/ha/hr (12.83 lb/A/hr) if early growth was excluded (Julian days 103-127), and 12.53 kg/ha/hr (11.15 lb/A/hr) for the entire growing period. Using this growth rate and other parameter value combinations, forage yields were simulated.

The GROWIT model consistently overestimated or underestimated actual yields, indicating a need for further studies to obtain more accurate parameter values for use in the model, or to develop~~e~~ sub-routines that would consider such factors as solar radiation and leaf area index.