Long-Term Changes in Dry Matter Yield in Variety Trials of Forage Species in Sweden

Magnus A. Halling
Swedish University of Agricultural Sciences, Sweden

The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress
Published by the Kenya Agricultural and Livestock Research Organization

Long-term changes in dry matter yield in variety trials of forage species in Sweden

Halling, M.A.*
*Department of Crop Production Ecology, Swedish University of Agricultural Sciences

Key words: Temperate forage species; variety testing; long-term changes;

Abstract

Using results from official variety testing in Sweden, long-term changes (1964-2018) in total annual dry matter (DM) yield for pure stands of red clover (*Trifolium pratense*) and timothy (*Phleum pratense*) were analysed and compared for two Swedish trial site areas: a central area (59.6-61.5°N) and a southern area (55.5-57.0°N). All trials were managed using a standard protocol, with only minor changes over time. On average for all varieties of timothy in the trials, there was an increase of 91.6 kg ha^{-1} in total DM yield in the first harvest year, probably due to genetically improved varieties, increasing from two to three cuts and a changing climate. For red clover, there was a lower yearly increase of 45.9 kg ha^{-1} in total DM yield in the first harvest year. Four-fold larger variation in red clover yield was seen in the second half of the study period (after 1993) compared with the first, possibly due to a more fluctuating climate, particularly in winter, and more overwintering damage. In timothy, the variation in yield over the entire period was more stable, but still increased by around 80 % in the second half of the period compared with the first. For the most frequently included timothy variety, SW Kämpe II, which was present in trials between 1965 and 2001, total DM yield in the first harvest year (96.8 kg ha^{-1}) was similar to the trial mean over the period for all timothy varieties. For the most frequently included red clover variety, Hermes II (present 1955-1996), total DM yield in the first harvest year increased by 33.2 kg ha^{-1}, i.e., less than the trial mean for that species.

Introduction

In Sweden, forage production from temporary leys in a multi-cut system is the major crop in agricultural areas, especially in northern Sweden. The dominant species in Swedish leys are red clover and timothy, for which breeding and variety testing has long been performed.

Long-term yield data are important when investigating changes in forage crop yields and determining the causes. For example, a study by Niemeläinen et al. (2020) based on over 40 years of data clearly showed that total annual DM yield in variety testing in northern Finland had increased substantially, due to climate change and possibly improvements in breeding and crop management over time. Long-range data series, in some cases dating back to 1955, are available from official variety testing in Sweden (https://www.slu.se/faltforsk).

Methods and Study Sites

Based on the results of official variety testing in Sweden, long-term changes (1964-2018) in total dry matter (DM) yield of pure stands of red clover and timothy were analysed and compared for two trial site areas: a central area (59.6-61.5°N) and a southern area (55.5-57.0°N). Mean total DM yield in the first harvest year for all varieties included in each trial, and in all trials per area and year, was used in the analysis. Two varieties, one of timothy and one of red clover, that were represented in trials in many years during the study period were also analysed for long-term yield changes, using mean DM data for all trial sites. The Department of Crop Production Ecology at the Swedish University of Agricultural Sciences is responsible for official variety testing in central and southern Sweden.

All trials were managed using a standard protocol, with only minor changes over time. The trials were normally undersown with a companion crop annually and lasted for two or three production years. In the central area a two-cut system dominated before 2010, but otherwise three cuts were taken per season. Annual nitrogen fertiliser application rate increased slightly over time at the start of the study period, but after 1997 was 190 kg N ha^{-1} in the two-cut system and 280 kg N ha^{-1} in the three-cut system. Plot size in the trials studied was 15-20 m^2. The first cut of timothy was taken when the control variety was in heading stage, i.e. when half the panicle was visible on 50% of shoots. The first cut of red clover was taken when the first buds were visible on the control variety.

The species data were statistically analysed using calendar year, geographical area and time period as fixed factors in procedure *Mixed model* in SAS Version 9.4 (SAS Institute Inc. 2010). Akaike Information Criterion (AIC) was used to test statistical model fit to the data. The repeated statement in procedure *Mixed model* was used to estimate covariance parameters in different time periods, which enabled comparison of variance. The statement solution gave the slope for a linear regression. The data were divided into two sub-periods at around 1992-93, a breakpoint when a change was seen in the plots.

Results

On average over all varieties of timothy in the trials, there was a yearly increase of 91.6 kg ha^{-1} in total DM yield in the first harvest year over the period, as seen from the slope of linear regression values in Table 1. For red clover, there was a lower yearly increase of 45.9 kg ha^{-1} in total DM yield in the first harvest year. In the whole period, year was significant (Table 1). The interaction between year and area was not significant, meaning that the yield increase trend was similar in the central and southern areas. On dividing the data for red clover into two sub-periods, a four-fold larger variation in yield was seen in the second sub-period compared with the first. This was confirmed by large differences in covariance parameter estimates (Table 2). Dividing the data into two sub-periods gave also substantially lower (better) AIC value in the statistical model, which meant that the statistical model for red clover had a better fit. In this case, year had no significance, meaning that the increase over time was not significant in the two sub-periods. In timothy, the variation in total DM yield in the first harvest year over time was more stable, increasing by around 80% in the second sub-period compared with the first. The improvement in AIC value between the statistical models was smaller for timothy, but the yield increase was significant in both the whole period and the two sub-periods. As seen for red clover, the interaction between year and area was not significant, i.e. the same trend of yield increase was seen in both areas.

Table 1. Statistical details of the four datasets each for timothy and red clover in total DM yield in the first harvest year

Dataset, species, variety	Period, year	Area*	No. of obs.	Yield range, kg DM ha^{-1}	Signif. of year, p-value	Slope of regression	AIC value
Red clover	1967-2018	S, C	91	2581-16140	0.0252	45.9	1649.3
Red clover	1967-2018	S	49	2397-16140	NS	17.9	1631.1
Red clover	1967-2018	C	42	2581-14498	NS	41.3	1631.1
R. clover, Hermes II	1955-1996	S, C	42	5810-11033	0.0238	33.2	-
Timothy	1964-2018	S, C	106	3943-16693	<0.0001	91.6	1774.6
Timothy	1964-2018	S	53	3983-15467	<0.0001	93.1	1772.7
Timothy	1964-2018	C	49	3943-16693	<0.0001	91.0	1772.7
Timothy, Kämpe II	1965-2001	S, C	35	5560-13059	<0.0001	96.8	-

*S = southern Sweden (55.5-57.0°N; C = central Sweden (59.6-61.5°N). NS = non-significant.

The most frequently included timothy variety was SW Kämpe II, which was present in variety testing between 1965 and 2001, a total of 37 years. Its total DM yield in the first harvest year showed a similar increase to the trial mean for timothy over the study period, but with strong significance of year (Table 1). The most frequently included red clover variety was Hermes II, which was present in variety testing between 1955 and 1996, a total of 42 years. Total DM yield in the first harvest year increased by 33.2 kg ha^{-1} for that variety, which was slightly lower than the trial mean for red clover, with year again being significant.

Table 2. Covariance parameter estimates for timothy and red clover varieties tested in southern and central Sweden

Species	Period	No. of obs.	Covariance parameter estimate	Change within species, %
Red clover	1967-1992	51	3089975	100
Red clover	1993-2018	40	12708118	411
Timothy	1964-1993	54	3407080	100
Timothy	1994-2018	46	6106507	179

Discussion

Statistical analysis clearly showed that the yield increase over 37 years in timothy was two- to three-fold larger than that seen over 42 years in red clover. This large difference between the species may have several explanations. It is known that red clover has more problems with winter damage than timothy in the Swedish climate, and it is perhaps also more difficult to increase yield by breeding in red clover than in timothy. The results showed increasing yield variation and a diminishing yield increase over time, mainly for red clover. This could be an effect of much more unstable winters with more frequent fluctuations between cold and warm weather, creating more damage from diseases and physical damage from water and ice. The yield increase in timothy was probably attributable to genetically improved varieties, increasing from two to three cuts and a changing climate. Weather data from the corresponding sites were not analysed, but Niemeläinen et al. (2020) observed a clear increase in temperature in northern Finland over the past 40 years, resulting in a three-fold increase in total DM yield for timothy in the first harvest year. This represented a yearly increase of 156 kg DM ha^{-1}, which is a 71% higher than found for timothy in the present study. One reason could be that their site (Apukka) was at latitude 66.6°N, which is around 6° farther north that the central Sweden area in this study, so temperature had a more dramatic effect. The projected annual yield increase in timothy in Canada for the period 2040-2069 is 15-82 kg DM ha^{-1} (Jing et al. 2014), which is less than the ~92 kg DM ha^{-1} found here for the period 1964-2018. In the Canadian projections, one additional change to the weather effect was going from two to three cuts in the harvest system. This can also be one reason for the increase seen in the Swedish data.

Acknowledgements

Variety testing at Department of Crop Production Ecology, Swedish University of Agricultural Sciences, is acknowledged for giving permission to use trial data. The statistician Johannes Forkman is acknowledged for helping with the statistics

References

Jing, Q., Belanger, G., Qian, B. and Baron, V. 2014. Timothy yield and nutritive value with a three-harvest system under the projected future climate in Canada. *Canadian Journal of Plant Science* 94: 213-222. doi:10.4141/cjps2013-279.

Niemeläinen, O.A., Hannukkala, L., Jauhiainen, K., Hakala, M., Niskanen, X. and Laine, A. 2020. Increase in perennial forage yields driven by climate change at Apukka Research Station, Rovaniemi, 1980-2017. *Agricultural and Food Science* 29: 139-153.

SAS Institute Inc. 2014. [SAS/STAT] software, Version [9.4] of the SAS System for [Windows]. Institute Inc., Cary, NC, USA.