Norwegian Journal of Agricultural Sciences

Vol. 8 1994 Nr. 2

Agricultural University of Norway – Advisory Service, Ås, Norway

NORWEGIAN JOURNAL OF AGRICULTURAL SCIENCES
Norwegian Journal of Agricultural Sciences fills a need created by the folding of Scientific Reports of the Agricultural University of Norway and Research in Norwegian Agriculture for a forum for publishing Norwegian research with international interest within the following areas: Aquaculture, Animal Science, Soil Science, Agricultural Engineering and Technology, Natural Resources and Environment, Food Technology, Crop Science, Forestry, Economics and Society Planning.

PUBLISHER
The journal is published by the Agricultural University of Norway, Advisory Service, Moerveien 12, N-1432 Ås, Norway, Norwegian Journal of Agricultural Sciences (ISSN 0801-5341) is published four times a year, each issue containing approximately 100 pages. Four issues comprise one volume. Annual subscription NOK 500,–. Subscribers receive supplement issues free of charge, but these can also be ordered separately through the publisher.

REFEREE
All papers submitted for publication will be sent to one or more competent referees.

CORRESPONDENCE
All Correspondence, editorial or otherwise, should be adressed to Agricultural University of Norway – Advisory Service.

The drawing on the cover is from Kjell Aukrust's *«Guttene på broen»*.

ISSN 0801-5341

N-requirements of cabbage crops grown on contrasting soils II: Model verification and predictions

HUGH RILEY[1] & GUNNAR GUTTORMSEN[2]
The Norwegian State Agricultural Research Stations
[1] Apelsvoll Research Station, Division Kise, Nes på Hedmark, Norway
[2] Apelsvoll Research Station, Division Landvik, Grimstad, Norway

Riley, H. & G. Guttormsen 1994. N-requirements of cabbage crops grown on contrasting soils. II: Model verification and predictions. Norwegian Journal of Agricultural Sciences 8: 99-113. ISSN 0801-5341.

A nitrogen response simulation model developed at Horticulture Research International (England) was used to explain the differences in yields obtained in N fertilizer trials with cabbage grown on soils with high and low water-holding capacity and different irrigation regimes. The model showed that higher N leaching on the sandy soil was responsible, due to both higher irrigation intensity and more rainfall. Simulations showed that split fertilizer dressing was unnecessary on loam soil, but that it was likely to be beneficial on sandy soil. Model predictions of final yields and N concentrations were generally in agreement with measured values, but N concentrations in early season were overestimated. Sensitivity analysis of the model suggested that the parametre used to determine net N mineralisation is of crucial importance in the calculation of nitrogen responses.

Key words: Fertilizer timing, irrigation intensity, net mineralisation rate, nitrate leaching, plant N concentration, potential DM yield, soil type.

Hugh Riley, Apelsvoll Research Station, Division Kise, N-2350 Nes på Hedmark, Norway.

Large differences in cabbage yields and nitrogen concentrations have been found at the same level of nitrogen fertilizer input on soils with contrasting moisture-holding capacities and different precipitation and irrigation regimes (Riley & Guttormsen 1993). Crop responses to nitrogen appeared to be in accordance with the concept of a critical %N concentration in plants which is related to the dry matter mass of the crop, as proposed by Greenwood et al. (1986;1990a;1991).

A simple method is required of calculating crop dry matter production and nitrogen uptake from readily available data, in order to make use of this concept for the practical prediction of crop fertilizer requirements under different growing conditions. This paper examines the suitability of the nitrogen response simulation model proposed for this purpose by Greenwood & Draycott (1989ab), using, where appropriate, the data presented in the previous paper for verification. The model is used to assess possible causes of the differences in N response found in the trials, and to assess the efficiency of alternative fertilizer and irrigation strategies.

MATERIALS AND METHODS

Model description

A detailed description of the model is given by the original authors. Only a brief overview is given here, with sufficient detail to understand the background for results and discussion.

Potential above ground dry matter (DM) production in the absence of N stress is calculated as a function of time from planting and expected yield at harvest, according to equations (1-2). This approach assumes that no constraints are imposed on growth by unfavourable weather conditions.

$$dW/dt = \frac{K_2 \cdot W}{K_1 + W} \tag{1}$$

where W = DM mass (tonnes/ha) on day t, K_1 = DM mass when growth rate is half of maximum, usually assumed to be 1 tonne/ha, and where

$$K_2 = (\ln W_{max} + W_{max} - \ln W_{plant.} - W_{plant.})/(t_{harv.} - t_{plant.}) \tag{2}$$

(W_{max} = potential DM yield and $W_{plant.}$ = DM mass at planting).

K_2 is expressed in units of tonnes/ha/day, and is a measure of growth rate corrected for plant mass (Greenwood et al. 1990b).

The actual growth achieved each day is obtained by modifying equation (1) by a factor which describes the effect of sub-optimal %N in the plant. This factor, whose value may vary between 0 and 1, is the quotient of actual to critical %N in the plant (values which exceed 1 are taken as 1).

Plant %N is calculated from daily growth and N-uptake. The latter is dependent upon (i) the plant's existing N-concentration and (ii) the amount of mineral nitrogen within the root zone. Plant %N is allowed to reach a maximum of twice the critical %N level, at which the apparent recovery of nitrogen is assumed to fall to 30% of the maximum recovery obtainable for the species (around 80% for cabbage). The depth of rooting is assumed by the model to increase as a linear function of DM mass.

The quantity of mineral-N present in the root zone is a function of the balance between that applied as fertilizer or released by net mineralisation and that removed by plant uptake or by leaching. Net mineralisation is calculated as a function of actual soil temperature, in relation to values expected at a given temperature (which may for example be estimated from incubation data).

Redistribution of water and mineral N (ammonium nitrogen is considered in the model to be rapidly convertible to the nitrate form) within the soil profile is calculated for each 5 cm horizon to a depth of 1 m according to the model developed by Burns (1974), in which solute concentration is assumed to equilibrate within each soil horizon before further percolation occurs. Soil water balance is estimated by a calculation of actual evapotranspiration in which the fraction of crop cover is estimated from the crop DM mass.

Input data required to run the model is summarized in Table 1.

Table 1. Input data required for running the nitrogen response simulation model proposed by Greenwood & Draycott (1989 ab)

Weather variables (daily)
Potential (pan) evaporation
Precipation and/or irrigation amounts
Mean soil temperature at 10 cm depth
Soil variables (at start)
Soil moisture-holding capacity in root zone
Maximum rooting depth
Moisture deficit at planting (if known)
Mineral N in root zone prior to planting
Net mineralisation rate at constant temperature
Crop variables (at start)
Dates of planting and harvesting
Potential above ground DM production for whole growth period
DM mass of seeds/transplants
N fertilizer quantities and dates of application
Maximum expected apparent recovery at low N input level

Evaluation of potential growth rate

The suitability of equation (1) was examined using data from Riley & Guttormsen (1993) for cabbage grown with sufficient N fertilizer for optimum yield. Potential yields of above-ground DM of 10 and 20 tonnes/ha were assumed for summer and winter cabbage respectively, on the basis of past experience in southeast Norway (Dragland, pers. comm.) and the DM weight of transplants was in all cases set to 20 kg/ha. A growing season of 148 days was assumed in all cases for winter cabbage, but for summer cabbage two different values were used (77 days in 1990 and 90 days in 1991) because of the colder weather in June 1991, which delayed early growth. The K_2 values derived from equation (2) were thus 0.18 for winter cabbage and 0.21 or 0.18 for summer cabbage.

Sensitivity analysis of net mineralisation rate

A preliminary sensitivity analysis of the various input parametres to the model demonstrated the importance of the constant used to describe the effect of soil temperature on net mineralisation rate, and of the maximum fertilizer recovery rate assumed. Our results (Riley & Guttormsen 1993) have confirmed that 80% maximum recovery is suitable for cabbage, and attention was therefore focused on the former constant.

Model simulations were performed for all eight trials presented in the previous paper, using three different values of the constant for net mineralisation. These were chosen to cover the range (0.1 - 1.5 kg N/ha/day at 15°C) which may be expected in arable soils (Greenwood pers. comm.). Potential DM yields were assumed to be approximately equal to the maximum levels found in either year in the trials. These were 9 and 18 tonnes/ha at Kise (loam soil) and 8 and 16 tonnes/ha at Landvik (sandy soil), for summer and winter cabbage, respectively. Lower values for Landvik were justified by 1-2 weeks earlier harvesting there.

Simulations were performed both without N fertilizer and for three levels of spring application (100, 200 and 300 kg N/ha). All other input data used (soil mineral N in spring, soil moisture holding capacity, rooting depth, weather data and irrigation amounts) were in accordance with measured values.

Simulation of irrigation strategies and fertilizer timing

As previously indicated (Riley & Guttormsen 1993), considerably higher irrigation intensity was practiced in the field trials at Landvik (on sandy soil) than at Kise (on loam soil). Rainfall differences between the sites were relatively small in early and mid season, but conditions later on were wettest at Landvik in both years. There was very high rainfall in June 1991 at both sites.

In order to establish whether soil type, irrigation intensity or rainfall distribution was the most likely cause of the differences in N leaching and consequent N fertilizer response found in the trials, simulations were performed for each trial year, using both sets of soil, weather and irrigation data as follows:

Variable	Simulation no.	1	2	3	4	5	6	7	8
Soil type	(L=loam S=sandy soil)	L	L	L	L	S	S	S	S
Weather data	(K=Kise L=Landvik)	K	K	L	L	K	K	L	L
Irrigation	(M=medium 50/85 mm) (H=high 160/225 mm)	M	H	M	H	M	H	M	H

All simulations were performed using an intermediate level of net mineralisation rate (0.8 kg N/ha/day at 15°C) and assuming a potential DM production of 18 tonnes/ha over 140 days.

In order to evaluate the need for split N applications under average weather conditions, simulations were also performed using mean data of 30 years at Kise, where potential rainfall deficits are 21 mm, 23 mm and 10 mm in May, June and July, respectively, followed by surpluses of 5 mm and 24 mm in August and September. Two irrigation intensities were compared (High = 8 x 20 mm, fortnightly, Medium = 4 x 30 mm, monthly), as well as the effect of partitioning a total application of 200 kg/ha N fertilizer in four different ways:

	At planting	After 3 weeks	After 6 weeks
1	200	0	0
2	125	75	0
3	125	0	75
4	50	75	75

Other input data used were the same as in the above simulations.

RESULTS

Potential growth rate

Calculated and measured values of DM production are shown in Fig. 1. There was reasonable overall agreement in the case of winter cabbage, although the measured development rate deviated somewhat from the calculated rate at certain times, especially early in the season. In the case of summer cabbage, the lower K_2 value gave better agreement with the data from the cold 1991 season, though even then the initial growth rate was overestimated considerably.

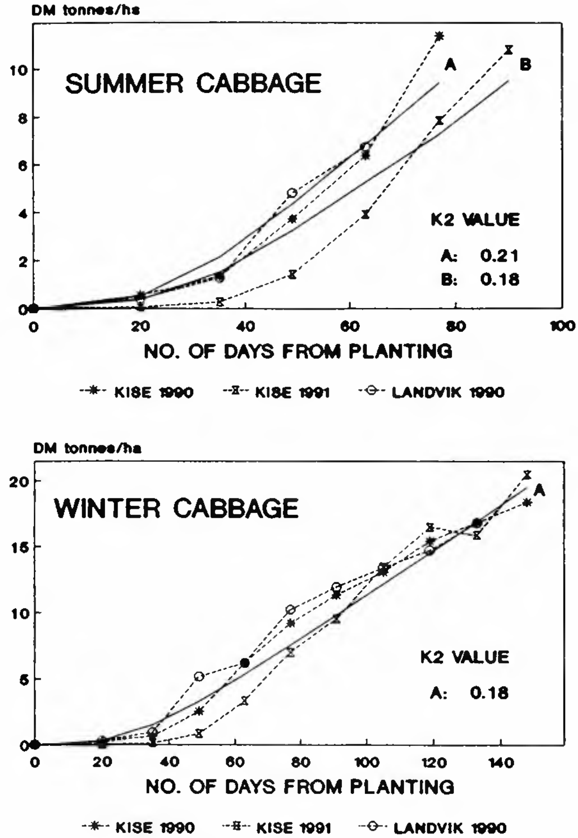


Fig. 1. Potential above ground DM production calculated using equation (1) (solid lines), and values measured in trials with optimum N fertilizer (dashed lines)

Sensitivity analysis of net mineralisation rate

Final DM yields simulated using different rates of net mineralisation are compared with measured values averaged over the last two sampling dates in the field trials (Figs. 2 and 3). There was good agreement between measured and predicted values in both years at Kise, assuming a higher mineralisation rate for summer cabbage than in the case of winter cabbage.

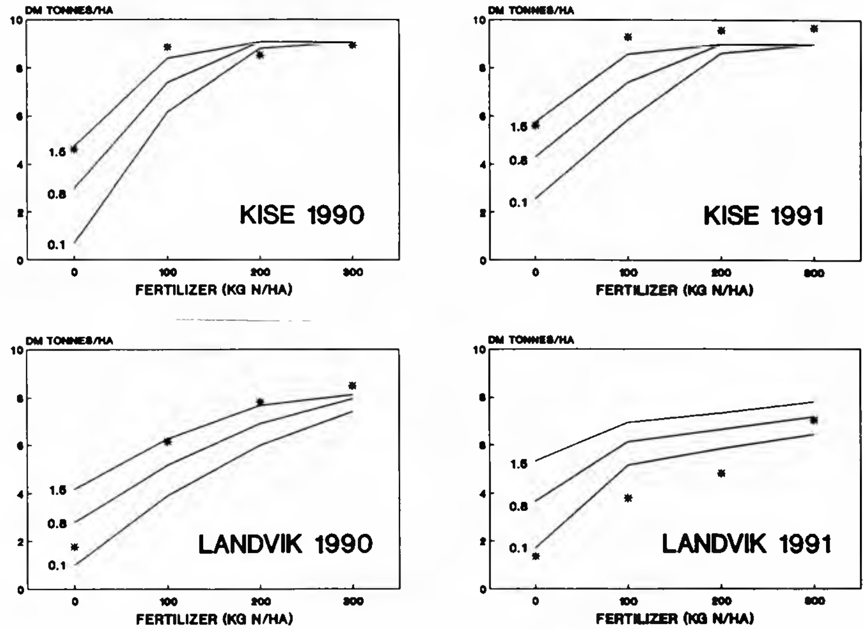


Fig. 2. Total Dm yields of summer cabbage calculated by model (lines) using three levels of net mineralisation rate (kg N/ha/day at 15°C), compared with measured values (*)

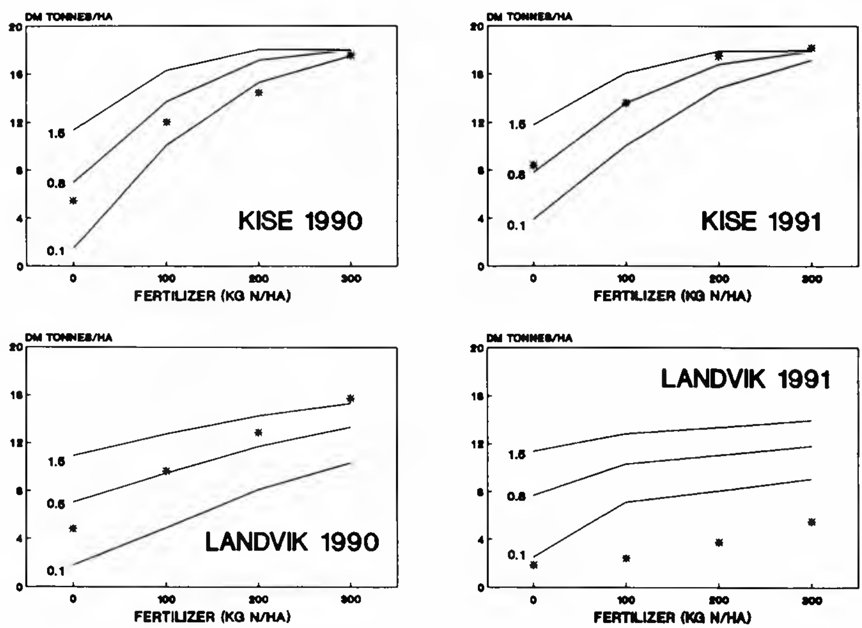


Fig. 3. Total DM yields of winter cabbage calculated by model (lines) using three levels of net mineralisation rate (kg N/ha/day at 15°C), compared with measured values (*)

The same was true to some extent for Landvik in 1990, but the model overestimated the 1991 yields there, even when a very low mineralisation rate was used, especially in the case of winter cabbage. It is possible that the already poor plant growth at this site was further restricted by insect damage or by the lack of other nutrients. Nevertheless the model confirmed that yields were severely limited by N deficiency in this case, and predicted yields were only about 50% of the potential level at the highest rate of fertilizer.

Simulated N leaching to below the maximum rooting depth (40 cm on sandy soil and 60 cm on loam), was in all cases considerably higher from the sandy soil at Landvik than from the loam soil at Kise, and was slightly higher at both sites in 1991 than in 1990. Total N leaching during the growing season is shown in Table 2, for calculations made without fertilizer and with 300 kg N/ha, and fertilizer losses are expressed as percentages of applied. The choice of net mineralisation rate was of relatively minor importance for the level of leaching simulated, possibly because the model showed a very rapid uptake of nitrogen early in the season, as discussed below.

Table 2. Simulated amounts of N leaching from the root zone during the growing season of cabbage crops grown on contrasting soils without N fertilizer and with 300 kg N/ha

			N leaching kg/ha		% of applied
N fert. applied (kg/ha):			0	300	
SUMMER CABBAGE					
	Year	Net min.[1]			
Kise	1990	0.1	0	0	0
(loam soil)		0.8	0	4	1
		1.5	1	10	3
	1991	0.1	31	79	16
		0.8	41	84	14
		1.5	49	93	15
Landvik	1990	0.1	38	181	48
(sandy soil)		0.8	41	186	48
		1.5	45	194	50
	1991	0.1	18	207	63
		0.8	22	223	67
		1.5	24	238	71
WINTER CABBAGE					
	Year	Net min.[1]			
Kise	1990	0.1	0	6	2
(loam soil)		0.8	1	15	5
		1.5	3	25	7
	1991	0.1	32	82	17
		0.8	45	90	15
		1.5	50	97	16
Landvik	1990	0.1	39	227	63
(sandy soil)		0.8	43	234	64
		1.5	49	246	66
	1991	0.1	20	237	72
		0.8	22	254	77
		1.5	29	271	81

[1] Calculations were made at three levels of net mineralisation rate, expressed in kg N/ha/day at 15°C

Plant N concentrations calculated at final harvest were broadly in accordance with the levels measured in the field trials (Figs. 4 and 5). As was the case for DM yields, there was generally best agreement at the highest level of net mineralisation rate in the case of summer cabbage and at the intermediate level in the case of winter cabbage. However, N concentrations calculated by the model during the earlier stages of growth were nearly always higher than those found in practice. Some typical examples of this trend are shown i Fig. 6, using data for cabbage grown in 1990 with 300 kg/ha N fertilizer, calculated using a net mineralisation rate of 1.0 kg/ha/day at 15°C.

The measured values were below the calculated level until late June/early July, when DM mass was approximately 4-5 tonnes/ha. In early June the difference was up to two percent N, equivalent to about 50% of the measured values. The differences between calculated and measured DM mass were relatively small and did not account for the discrepancy. The high nitrate levels found in plants during early growth may be partly responsible, as shown in Table 3 using data from Kise 1990. However, even this does not entirely account for the differences, especially since our investigations suggested that about two thirds of the nitrate may in fact be present in the figures from the Kjeldahl analysis.

Fate of nitrogen applied as fertilizer

Soil mineral N levels in the root zone appeared to decline less rapidly in practice than predicted by the model, as shown in Fig. 7, using data from both sites in 1990. This, together with the high calculated values of plant N, suggests that the model overestimates the rate of nitrogen uptake by plants in early season.

Overall nutrient balance was estimated as the sum of measured N recovery in plants at harvest and the simulated N leaching during the growing season, in addition to that from unfertilized plots, expressed as percentages of the fertilizer applied. Data for the plots which received 300 kg N/ha are shown in Table 4. Residual amounts of mineral nitrogen in the soil on these plots were negligible relative to the unfertilized plots.

Uptake plus leaching appeared to account for nearly all the fertilizer applied on the sandy soil (97% on average), but for a somewhat smaller proportion (74% on average) on the loam soil. In the latter case, a proportion was presumably retained within the soil in organic form, probably in microbial biomass.

Simulation of irrigation strategies and fertilizer timing

The effects of simulations using the different data sets for soil type, weather variables and irrigation intensity are summarized in Table 5. The influence of these factors on both N leaching and DM yields may be ranked in the following order:

Soil type > Irrigation intensity > Weather conditions

Fertilizer level was naturally also of importance, and differences between soil types and irrigation regimes were most marked at high levels of fertilizer. The simulations suggest that the main reasons for the differences found between sites in the trials, were the low soil moisture holding capacity and high irrigation intensity used on the sandy soil at Landvik, and that the somewhat higher rainfall there was of less importance.

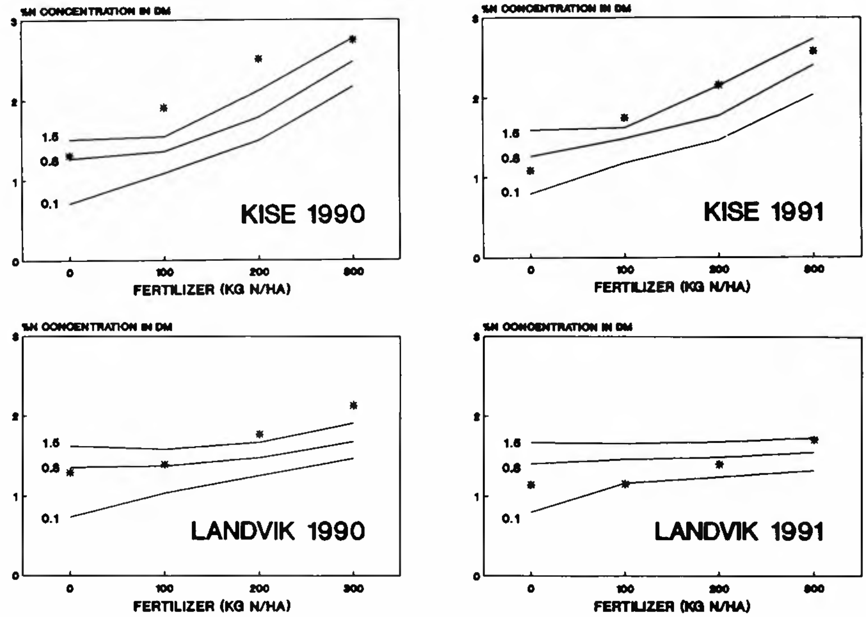


Fig. 4. N concentrations of summer cabbage at final harvest calculated by model (lines) using three net mineralisation rates (kg N/ha/day at 15°C) compared with measured values (*).

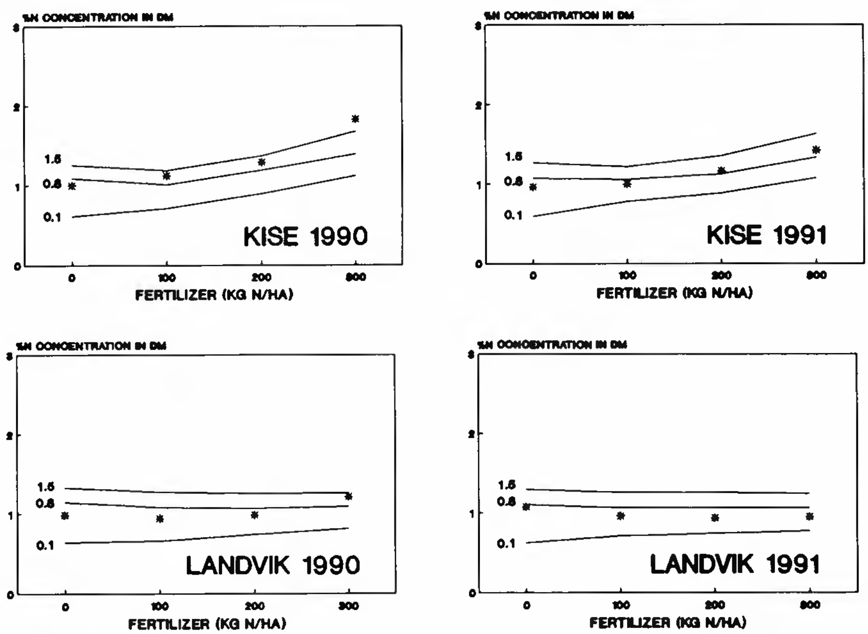


Fig. 5. N concentrations of winter cabbage at final harvest calculated by model (lines) using three net mineralisation rates (kg N/ha/day at 15°C) compared with measured values (*)

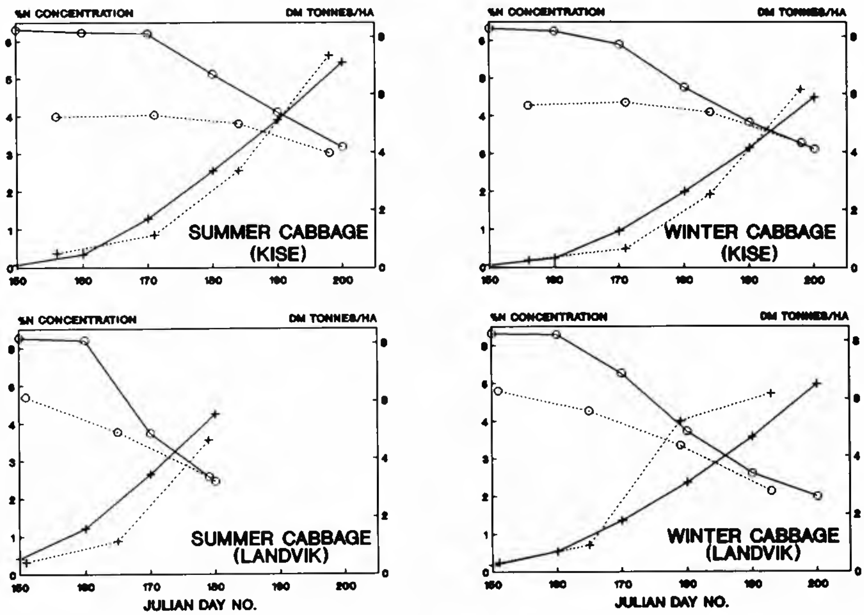


Fig. 6. Comparison of calculated and measured values (solid vs. dotted lines) of %N in DM (o) and DM mass (+) during early development of cabbage grown in 1990 with 300 kg/ha N fertilizer

Table 3. Model calculations of N concentrations in cabbage DM on day 171 (20.6.90) at various levels of N fertilizer, compared with measured values of Kjeldahl N and nitrate N

	SUMMER CABBAGE				WINTER CABBAGE			
N fert. kg/ha	Calc. %N	% of[1] crit.N	Meas. %N	Meas. NO_3-%N	Calc. %N	% of[1] crit.N	Meas. %N	Meas. NO_3-%N
0	2.3	50	2.5	0.1	2.4	50	3.4	0.2
100	5.0	126	3.5	0.4	5.6	132	4.0	0.9
200	6.2	158	3.7	0.6	5.9	139	4.0	1.0
300	6.2	158	4.0	0.8	5.9	139	4.4	1.2

[1] Calculated %N expressed as percentages of the critical %N calculated for relevant DM mass

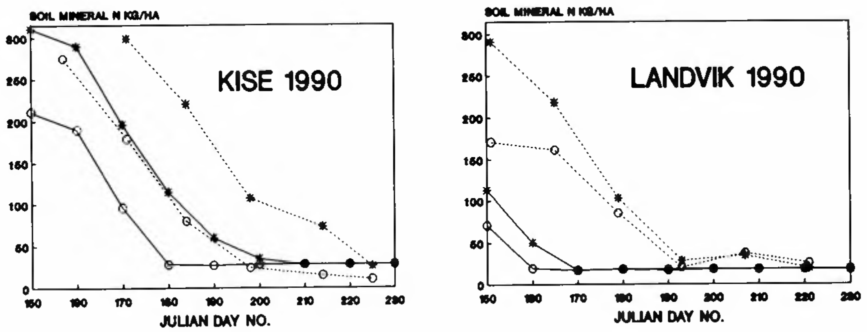


Fig. 7. Model predictions (solid lines) and measured values (dotted lines) of the decline in mineral N in the root zone during early growth of cabbage (means of summer and winter) at two levels of N fertilizer (o = 200 kg N/ha, * = 300 kg N/ha)

Table 4. Apparent recoveries of N fertilizer applied in spring at 300 kg N/ha and additional simulated N leaching during the growing season expressed as percentage of the N fertilizer input

		LOAM SOIL			SANDY SOIL		
		Recovered	Leached	Sum	Recovered	Leached	Sum
Summer cabbage	'90	60	1	61	43	48	91
Winter cabbage	'90	79	5	84	47	64	111
Summer cabbage	'91	62	14	76	31	67	98
Winter cabbage	'91	59	15	74	11	77	88

Results of the simulations performed with average weather data to assess the effect of fertilizer timing are given in Table 6. These simulations suggest that in the case of the loam soil, partitioning had little effect on either leaching or yield level, irrespective of the irrigation intensity used. On the sandy soil, however, leaching losses were reduced by dividing the fertilizer application, particularly where a high irrigation intensity was used. Lower irrigation intensity appeared, however, to be an equally effective means of reducing leaching.

Table 5. Simulated values of N leaching from root zone during the growing season and total cabbage DM production at four levels of N fertilizer, as affected by soil type, weather data (1990-91) from two localitites and irrigation intensity. All results are means derived from the factorial arrangement of 16 simulations

N FERTILIZER	SOIL TYPE		WEATHER DATA		IRRIGATION	
kg/ha	Loam	Sand	Kise	Landvik	Medium	High
			N LEACHING (kg/ha)			
0	20	24	23	21	16	28
100	45	75	57	63	42	78
200	67	129	89	107	71	125
300	95	195	130	160	112	179
Main effect	n.s.		n.s.		$p<0.001$	
Interaction	$p<0.001$		n.s.		$p<0.07$	
			DM PRODUCTION (tonnes/ha)			
0	8.2	8.1	7.6	8.7	8.4	7.8
100	13.1	11.5	12.1	12.5	13.2	11.4
200	16.3	13.8	15.0	15.0	16.1	14.0
300	17.6	15.0	16.4	16.3	17.2	15.4
Main effect	n.s.		$p<0.02$		$p<0.001$	
Interaction	$p<0.05$		n.s.		n.s.	

Table 6. The effect of N fertilizer timing on simulated values of N leaching from root zone during the growing season and total cabbage DM production, for different soil types and different irrigation intensities. All simulations performed using long-term average weather data from Kise, S.E. Norway

	LOAM SOIL		SANDY SOIL	
Irrigation intensity:	Medium	High	Medium	High
FERTILIZER TIMING[1]		N LEACHING (kg/ha)		
200 - 0 - 0	16	24	42	74
125 - 75 - 0	15	23	41	62
125 - 0 - 75	15	23	41	55
50 - 75 - 75	15	23	38	44
		DM PRODUCTION (tonnes/ha)		
200 - 0 - 0	17.5	17.3	16.8	15.8
125 - 75 - 0	17.5	17.3	16.8	16.2
125 - 0 - 75	17.5	17.3	16.8	16.4
50 - 75 - 75	17.5	17.3	16.9	16.7

[1] kg N/ha applied at planting, or 3 and 6 weeks after planting

DISCUSSION

Potential growth rate

All K_2 values used here are close to the level (0.20) generally found for temperate zone crops (Greenwood et al. 1977). Lower values may be expected in crops which are affected by environmental stress, or when senescence occurs before harvest. The effects of drought in cabbage and early senescence in onions have been shown to be examples (Greenwood et al. 1990b).

In the present case, temperature variation early in the growing season may account for the deviations found. Air temperature has been used to calculate the maximum relative growth rate in vegetables by Gysi (1990), who found that temperature was among the most sensitive factors in the modelling of lettuce yield under Swiss conditions. Air temperature has also been used to predict canopy development in the early growth stages of Brussels sprouts (Hamer 1992), in a model which relates potential dry matter production to the amount of intercepted radiation.

Net mineralisation rate

The correct weighting of the factor used to describe net mineralisation has been shown to be crucial for the prediction of optimum fertilizer requirement, but appears to be of somewhat less importance for the prediction of leaching. The fact that a higher weighting gave better agreement between predicted and measured yields of summer cabbage than of winter cabbage suggests that the mineralisation rate relative to temperature may vary at different times in the growing season.

A plausible reason for this is the presence of several organic matter pools in the soil with different turnover rates. This is the assumption normally made in more complex models of nitrogen dynamics (for example Johnsson et al. 1987, Verberne et al. 1990). A simple means of taking into account readily available nitrogen in the previous crop's residues has been suggested in a recent development of the present model (Draycott, pers. comm.), whilst an intermediate basal mineralisation is assumed for the soil.

Nitrogen uptake in plants

The overall uptake of nitrogen in plants seems to have been estimated reasonably well by the model, but the uptakes measured in early season were lower than those calculated by the model, as demonstrated by both plant N concentrations and mineral N levels in the soil. The model may, therefore, in some situations underestimate the risk of leaching, for example under conditions with high rainfall early in the growing season. This may possibly account for the poorer agreement between measured and predicted DM yields of winter cabbage at Landvik in 1991.

The reason for the discrepancy in uptakes could result from an overestimation either of DM growth rate or of %N concentration. The latter alternative seems most likely in the present case. The explanation may lie in the maximum value which N concentrations are allowed to attain in the model, which is set at twice the critical %N. Greenwood & Draycott (1989b) show measured values up to 80% above the critical level in swede, red beet and turnip. Our data for cabbage, on the other hand, has seldom revealed values higher than 50-60% above the critical level, even in heavily fertilized plots with split applications. The use of a lower maximum value may therefore be justified.

Fertilizer timing and irrigation intensity
The simulations support earlier findings (Dragland 1982, 1984), which have indicated that split fertilizer application is unnecessary on soils with relatively high moisture holding capacity. On soil with low water-holding capacity, the simulations suggested that little benefit derives under average weather conditions with moderate irrigation, but that split applications may be beneficial under high rainfall conditions or combined with high irrigation intensity.

The use of a moderate irrigation intensity on sandy soil may be acceptable, since the drought sensitivity of cabbage crops has in Norway been found to be relatively low in the early growth stages (Dragland 1976, Riley & Dragland 1988) and since this crop has shown a relatively high tolerance to withholding irrigation until 50-75% of the soil's moisture reserves are depleted (Riley 1992). Research elsewhere has however suggested that cabbage benefits from a high irrigation intensity (Smittle et al. 1994). More research is required to determine optimum irrigation intensity and fertilizer timing on soils prone to leaching.

ACKNOWLEDGEMENTS

We are grateful to Professor D.J. Greenwood and Miss A. Draycott, of Horticulture Research International, Wellesbourne, England, for many useful discussions and for providing us with the computer program for the N response model used in this work.

REFERENCES

Burns, I.G. 1974. A model for predicting the redistribution of salts applied to fallow soils after excess rainfall or evaporation. J. of Soil Science 25: 165-178.

Dragland, S. 1976. Nitrogen and water requirements in cabbage. Forsk. fors. Landbr. 27: 335-374 (in Norwegian).

Dragland, S. 1982. Timing of N-application to late cabbage. Forsk. fors. Landbr. 33: 27-35 (in Norwegian).

Dragland, S. 1984. Rates and timing of nitrogen application to late cabbage. Forsk. fors. Landbr. 35: 211-216 (in Norwegian).

Greenwood, D.J., T.J. Cleaver, S.H.M. Loquens & K.B. Niendorf 1977. Relationship between plant weight and growing period for vegetable crops in the United Kingdom. Ann. Bot. 41: 987-997.

Greenwood, D.J., J.J. Neeteson & A. Draycott 1986. Quantitative relationships for the dependence of growth rate of arable crops on their nitrogen content, dry weight and aerial environment. Plant and Soil 91: 281-301.

Greenwood, D.J. & A. Draycott 1989a. Experimental validation of an N-response model for widely different crops. Fertilizer Research 18: 153-174.

Greenwood, D.J. & A. Draycott 1989b. Quantitative relationships for growth and N content of different vegetable crops grown with and without ample fertilizer-N on the same soil. Fertilizer Research 18: 175-188.

Greenwood, D.J., G. Lemaire, G. Gosse, P. Cruz, A. Draycott & J.J. Neeteson 1990a. Decline in percentage N of C3 and C4 crops with increasing plant mass. Annals of Botany 66: 425-436.

Greenwood, D.J., D.A. Stone & A. Draycott 1990b. Weather, nitrogen supply and growth rate of field vegetables. Plant and Soil 124: 297-301.

Greenwood, D.J., F. Gastal, G. Lemaire, A. Draycott. P. Millard & J.J. Neeteson 1991. Growth rate and %N of field grown crops: Theory and experiments. Annals of Botany 67: 181-190.

Gysi, C. 1990. Modelling and measurement of the nitrogen cycle in a vegetable field in Switzerland. I. A soil-plant model for the nitrogen cycle. Z. Pflanzenernähr. Bodenk. 153: 181-187.

Hamer, P.J.C. 1992. A semi-mechanistic model of the potential growth and yield of Brussels sprouts. J. of Horticultural Science 67: 161-169.

Johnsson, H., L. Bergström, P.E. Jansson & K. Paustian 1987. Simulated Nitrogen Dynamics and losses in a layered agricultural soil. Agricultural Ecosystems and Environment 18: 333-356.

Riley, H. 1992. Optimalisation of irrigation and N-fertilization. NJF-seminar nr. 211 "Integrated vegetable production", Nyborg, Denmark, NJF - Utredning/Rapport nr. 84: 43-48 (ISSN 0333-1350).

Riley, H. & S. Dragland 1988. Irrigating field vegetables for quality. 2. Effects of drought at different stages of growth. UK Irrigation Association Irrigation News 14: 19-27.

Riley, H., & G. Guttormsen 1993. N requirements of cabbage crops grown on contrasting soils. I: Field trials. Norwegian J. of Agricultural Sciences 7: 275-291. ISSN 0801-5341.

Smittle, D.A., W.L. Dickens & J.R. Stansell 1994. Irrigation regimes affect cabbage water use and yield. J. Amer. Soc. Hort. Sci. 119: 20-23.

Verberne, E.L.J., J. Hassink, P de Willigen, J.J.R. Groot & J.A. Van Veen 1990. Modelling organic dynamics in different soils. Netherlands J. of Agricultural Science 38: 221-238.

Performance of Eruni and Pixy as rootstocks for European plum cultivars in a northern climate

JONAS YSTAAS[1], FINN MÅGE[2], PER HUSABØ[3] & ODDMUND FRØYNES[1]
1) The Norwegian State Agricultural Research Stations, Ullensvang Research Station, Lofthus, Norway
2) Agricultural University of Norway, Department of Horticulture and Crop Sciences, Ås, Norway
3) The Norwegian State Agricultural Research Stations, Ullensvang Research Station, Substation Njøs, Hermansverk, Norway

Ystaas, J., F. Måge, P. Husabø & O. Frøynes 1994. Performance of Eruni and Pixy as rootstocks for European plum cultivars in a northern climate. Norwegian Journal of Agricultural Sciences 8: 115-126. ISSN 0801-5341.

The performance of the plum rootstocks Eruni and Pixy using St. Julien A as standard to the cultivars 'Victoria', 'Opal', 'Oullins Gage', 'Mallard', 'Ive', 'Edda', Njøs II and BP 1158 was assessed over seven cropping years at three sites; Ås (eastern Norway), Ullensvang and Njøs (western Norway). Eruni can be characterized as a semi-vigorous rootstock inducing somewhat more vigour than St. Julien A. Trees on Eruni produced higher yields than those on St. Julien A, but produced consistently smaller fruits, while trees on Eruni suckered profusely. The vigour of trees on Pixy was not significantly reduced compared with that of trees on St. Julien A, with the exception of 'Victoria' and 'Opal' at the Ullensvang site. The yield of trees on Pixy was smaller than that of trees on St. Julien A, but yield efficiency was sometimes higher. No reduction in fruit size from trees on Pixy compared with fruits from trees on St. Julien A was observed. 'Victoria' trees on Pixy were more severely damaged in a test winter freeze (-30.8°C) than those on St. Julien A. It is concluded that neither Eruni nor Pixy can be recommended as a better alternative to St. Julien A as a semi-vigorous rootstock for plums.

Key words: Cold hardiness, fruit size, plum, rootstock, suckering, vigour, yield, yield efficiency.

Jonas Ystaas, Ullensvang Research Station, N-5774 Lofthus, Norway.

If plum production is to remain economically viable, more intensive planting systems are required. To obtain biological growth control, precocity, high productivity and superior fruit quality, which are the prerequisites of a successful high density plum orchard, dwarfing rootstocks are needed.

In rootstock trials conducted under Norwegian growing conditions, St. Julien A was recommended as a reliable semi-dwarf rootstock of high yield efficiency with a favourable influence on fruit size and fruit quality (Husabø 1971; Ystaas & Frøynes 1993). Trees on St. Julien A were, however, too vigorous to meet the demands of a successful high density plum orchard. The search for candidates for a true dwarfing rootstock for plums is obviously necessary. In the early 1980s two promising rootstocks, Pixy and Eruni, became available (Webster 1980; Trajkovski & Anderson 1988). Pixy, which was selected at East Malling, England, is a St. Julien type of rootstock of the *Prunus insititia* L. species (Webster 1980). In English trials there was a marked dwarfing effect of Pixy; mature trees on Pixy were half to two-thirds the size of trees on St. Julien A (Webster 1981). Eruni, which was selected at Balsgård, Sweden, from seedlings of open pollinated 'Pershore', belongs within *Prunus domestica* L. (Trajkovski & Anderson 1988), and was first tested as Balsgård Pr 10032 and BPr 32. According to the preliminary results from the Swedish trials, Eruni was considered a semi-dwarfing rootstock (Oldén 1978).

In 1982-83, rootstock trials comparing the performance of Pixy and Eruni with that of the standard rootstock St. Julien A were initiated at three locations (Ås, Ullensvang and Njøs) for several commercially important plum cultivars grown in Norway. The results obtained in these trials are presented in this study.

MATERIALS AND METHODS

Five orchard experiments were established; two at Ås, eastern Norway, on a silty clay loam, one at Ullensvang, western Norway, on a loamy sand of moraine deposits and two at Njøs, western Norway, on a sandy loam.

Ås

In two experiments at the Department of Horticulture and Crop Sciences, Agricultural University of Norway, a comparison was made between the orchard growth and cropping of 'Oullins Gage' and 'Victoria' on the rootstocks St. Julien A and Pixy (Trial 1) and that of 'Victoria', 'Mallard', 'Red Oullins Gage' and 'Edda' on the rootstocks St. Julien A and Eruni (Trial 2). The trees were planted in spring 1982 as maidens without feathers at a spacing of 5 x 3 m. The trees of Trial 1 were arranged in four randomized blocks of three-tree plots, while the arrangement of Trial 2 was four randomized blocks of single-tree plots. The trials were located in two adjacent rows on a hillside facing west. Soil management featured frequently cut grass in the alleyways combined with 1-m-wide herbicide strips along the tree rows. Pruning practice was aimed at adjusting the tree volume to the space allotted each tree. Fruit thinning was practised whenever needed to achieve a normal crop of satisfactory quality.

Trunk girth was measured annually during the cropping period. Blossom density, scores 0-5, was estimated annually. Total yield was recorded in each cropping year and average fruit size estimated from randomly selected samples of 50 fruits. Winter injury caused by subnormal temperatures in February 1985 occurred and an assessment of the health condition of the experimental trees was made (scores 0-5) in the subsequent three years.

Ullensvang

The experiment at Ullensvang Research Station compared the orchard growth and cropping of 'Opal', 'Victoria', 'Mallard', 'Blue Rock' and 'Ive' on rootstocks St. Julien A, Eruni and Pixy. The trees were planted in spring 1983 as two-year-old trees with two to three branches and trained with a central leader as free spindles. The height of the trees was kept at 2.5 m by pruning.

In order to facilitate the management of the trial, each cultivar was planted in a separate row adjacent to the other cultivars. Some soil variation in part of the experimental field located on a hillside facing west, was suited to an experimental design of randomized blocks with single-tree plots and six replicates for two cultivars ('Victoria', 'Ive'). The design used for the other three cultivars was complete randomization with single-tree plots and five replicates.

The trees were spaced 3 m apart in rows 5 m apart. Soil management combined frequently mown grass in the alleyways with 1-m-wide herbicide strips along tree rows. Trunk girth was measured 25 cm above the graft union. The crop of each tree was weighed, and fruit weight was estimated from random samples of 50 fruits per tree at each picking. Soluble solids were determined on samples of 10 fruits from each tree and each picking. Heavy cropping cultivars, such as 'Opal' and 'Victoria', were thinned when needed to obtain an optimal crop load of high quality fruit. The frequency of suckers of the various rootstocks was recorded at the end of the trial.

Njøs

Two experiments at Ullensvang Research Station, substation Njøs, compared the orchard growth and cropping of 'Opal', 'Oullins Gage', 'Edda', 'Ive', Njøs II and BP 1158 on the rootstocks St. Julien A and Eruni (Trial 4), while 'Opal', 'Oullins Gage' and 'Ive' on the rootstocks St. Julien A, Eruni, Pixy and Marianna were included in Trial 5. The trees were planted in spring 1983 as maidens with feathers at a spacing of 5.5 x 3 m. The trees of Trial 4 were arranged in four randomized blocks with two trees per plot. The arrangement of Trial 5 was two randomized blocks with two trees of each cultivar/rootstock combination per plot. The trees were trained with a central leader as free spindles. The height of the trees was kept at 2.5 m by pruning.

Soil management combined frequently mown grass in the alleyways with 1-m-wide herbicide strips along tree rows. Trunk girth was measured annually 25 cm above the graft union and the crop of each tree was weighed annually. Fruit weight was estimated from random samples of 50 fruits per tree. The heavy cropping cultivar 'Opal' was thinned when needed to obtain optimal crop load. The frequency of suckers of the various rootstocks was recorded at the end of the experiment.

RESULTS

Ås

The two trials conducted were located adjacent to each other in the experimental orchard, using plant materials of the same age. Results are presented together whenever possible. No significant differences between rootstocks were found in the vigour of ten-year-old trees of four plum cultivars (Table 1). Trees on Eruni, however, had consistently the largest trunk circumference and trees on Pixy the smallest.

Table 1. Ås: Trunk girth of four plum cultivars as affected by rootstocks at the end of the tenth growing season, mean values

Rootstock	Trunk girth, cm			
	Victoria	Oullins Gage	Mallard	Edda
St. Julien A	27.9	38.5	29.3	27.3
Eruni	32.6	41.1	30.5	30.5
Pixy	25.2	37.6		
LSD, P = 0.05	NS	NS	NS	NS

'Victoria' on St. Julien A and Eruni had a significantly higher cumulative yield per tree than trees on Pixy, (Table 2), whereas the yields of 'Oullins Gage', 'Mallard' and 'Edda' were not affected by different rootstocks. Annual records of flower density of four plum cultivars did not reveal any significant difference between rootstocks (data not presented). When tree productivity was related to tree size, no significant difference in yield efficiency between rootstocks was found (Table 3). Trees on St. Julien A had the largest fruits for all cultivars, but no significant effect on fruit size caused by rootstocks was demonstrated (Table 4). A severe winter freeze in February 1985 (temperature low -30.8°C) inflicted cold injuries on the plum trees. Trees of 'Victoria' on Pixy were the most severely afflicted (Table 5).

Table 2. Ås: Cumulative yield of four plum cultivars over six cropping years, as affected by rootstocks, mean values

Rootstock	Cumulative yield, kg/tree			
	Victoria	Oullins Gage	Mallard	Edda
St. Julien A	137	102	70	26
Eruni	128	108	68	43
Pixy	81	96		
LSD, P = 0.05	40.6	NS	NS	NS

Table 3. Ås: Yield efficiency of four plum cultivars as affected by rootstocks, mean values

Rootstock	Cumulative yield, kg/tree, /trunk cross-sectional area, cm^2			
	Victoria	Oullins Gage	Mallard	Edda
St. Julien A	2.22	0.86	1.03	0.44
Eruni	1.51	0.80	0.91	0.58
Pixy	1.59	0.88		
LSD, P = 0.05	NS	NS	NS	NS

Table 4. Ås: Fruit weight of four plum cultivars as affected by rootstocks, mean values of six cropping years

Rootstock	Fruit weight, g			
	Victoria	Oullins Gage	Mallard	Edda
St. Julien A	38	40	29	34
Eruni	35	37	29	33
Pixy	36	37		
LSD, P = 0.05	NS	NS	NS	NS

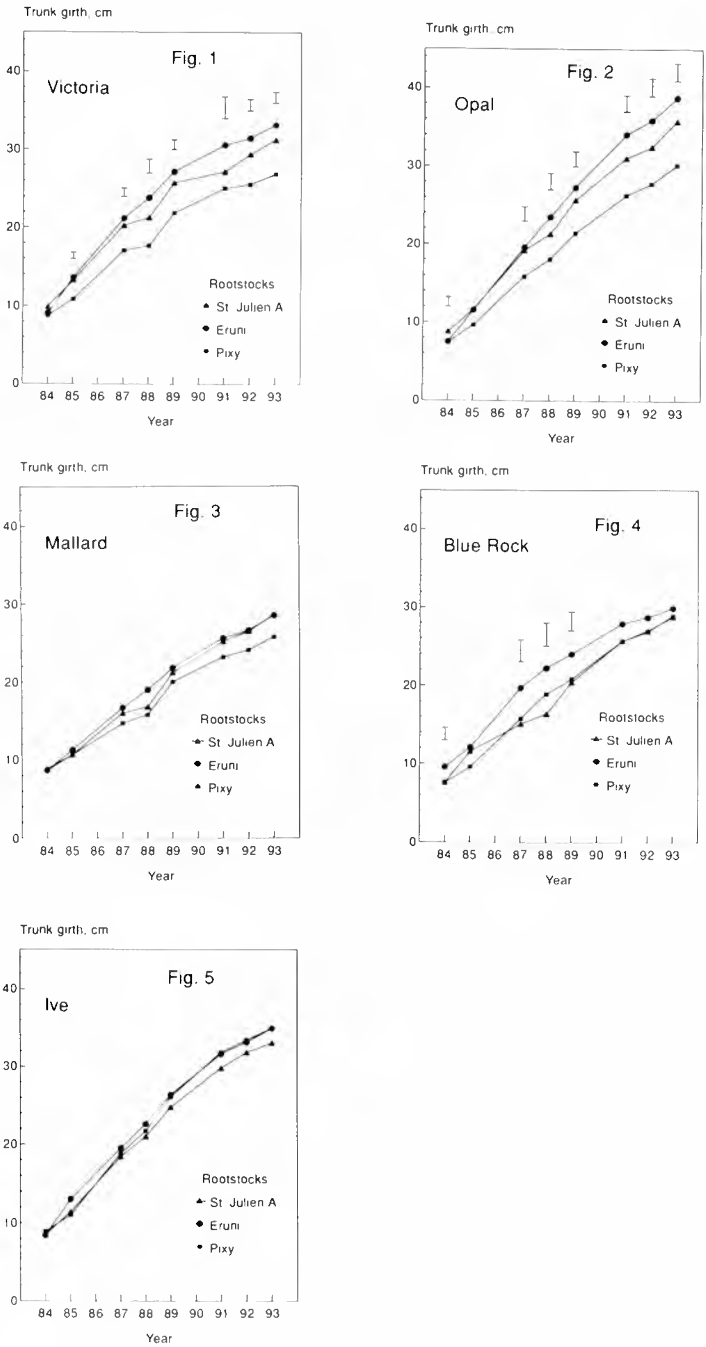
Table 5. Ås: Health conditions of two plum cultivars following a severe winter freeze in February 1985 as affected by rootstocks over three years. Scores of tree health: 0 = dead, 5 = healthy

Rootstock	Victoria			Oullins Gage		
	1985	1986	1988	1985	1986	1988
St. Julien A	4.0	4.9	4.0	4.6	5.0	4.8
Pixy	2.6	2.3	1.8	3.5	4.2	3.9
LSD, P = 0.05	1.3	2.6	1.5	NS	NS	NS

Ullensvang

Tree vigour, represented as trunk circumference of five plum cultivars as affected by three rootstocks over ten years, is presented in Figs. 1-5. Trees of 'Victoria' and 'Opal' were consistently more vigorous on St. Julien A and Eruni than on Pixy (Figs. 1-2). Tree size of the cultivars 'Mallard', 'Blue Rock' and 'Ive' was not significantly affected by rootstocks at the end of the experiment (Figs. 3-5). Trees of 'Victoria' on St. Julien A and Eruni had a significantly higher cumulative yield per tree than those on Pixy (Table 6). For the other four cultivars, no significant effect of different rootstocks was detected. The relationship between cumulative yield and the trunk cross-sectional area at the end of the experiment, denoting yield efficiency, was significantly affected by the rootstocks (Table 7), trees of the cultivars 'Victoria' and 'Mallard' demonstrating the highest yield efficiency on Pixy.

The rootstocks had a significant effect on fruit size (Table 8). Trees of four out of five cultivars produced larger-sized plums on St. Julien A and Pixy than on Eruni. In fruit quality, as measured by the content of soluble solids, no difference was detected among trees of the same cultivar on different rootstocks, even with a trend towards lower concentration for Eruni (Table 9). Suckering presented a problem with all trees on Eruni (Table 10), but much less so with trees on St. Julien A and Pixy.



Figs. 1-5. Trunk girth of the plum cultivars 'Victoria', 'Opal', 'Mallard', 'Blue Rock' and 'Ive' as affected by St. Julien A, Eruni and Pixy rootstocks over ten years in Trial 3, Ullensvang. Vertical bars represent LSD, P = 0.05

Table 6. Ullensvang: Cumulative yield of five plum cultivars over seven cropping years, as affected by rootstocks, mean values

Rootstock	Cumulative yield, kg/tree				
	Victoria	Opal	Mallard	Blue Rock	Ive
St. Julien A	85	57	37	32	41
Eruni	90	54	47	39	47
Pixy	75	35	40	36	37
LSD, P = 0.05	11.1	NS	NS	NS	NS

Table 7. Ullensvang: Yield efficiency of five plum cultivars as affected by rootstocks, mean values

Rootstock	Cumulative yield, kg/tree, /trunk cross-sectional area, cm^2				
	Victoria	Opal	Mallard	Blue Rock	Ive
St. Julien A	1.10	0.57	0.57	0.49	0.48
Eruni	1.04	0.45	0.72	0.55	0.50
Pixy	1.32	0.57	0.76	0.54	0.40
LSD, P = 0.05	0.14	NS	0.14	NS	NS

Table 8. Ullensvang: Fruit weight of five plum cultivars as affected by rootstocks, mean values of seven cropping years

Rootstock	Fruit weight, g/fruit				
	Victoria	Opal	Mallard	Blue Rock	Ive
St. Julien A	38	33	38	24	41
Eruni	36	31	35	24	36
Pixy	38	33	38	24	39
LSD, P = 0.05	1.3	1.9	1.9	NS	2.4

Table 9. Ullensvang: The content of soluble solids in fruits of five plum cultivars as affected by rootstocks, mean values of seven cropping years

Rootstock	Soluble solids, percent				
	Victoria	Opal	Mallard	Blue Rock	Ive
St. Julien A	16.0	14.4	16.7	17.2	17.9
Eruni	15.5	14.4	16.6	17.0	17.1
Pixy	16.1	15.0	16.5	17.1	17.7
LSD, P = 0.05	NS	NS	NS	NS	NS

Table 10. Ullensvang: Root suckering of five plum cultivars as affected by rootstocks, mean values

Rootstock	Number of suckers per tree				
	Victoria	Opal	Mallard	Blue Rock	Ive
St. Julien A	3.2	3.4	7.0	3.4	5.6
Pixy	5.0	3.0	10.0	5.0	8.2
Eruni	20.8	18.6	24.4	22.4	24.4
LSD, P = 0.05	3.6	5.9	3.9	4.4	7.4

Njøs

Tree vigour was significantly affected by rootstocks in two out of six cultivars (Table 11). The largest trees were grown on Marianna and the smallest on Pixy (Trial 5). Trees of all cultivars grew more vigorously on Eruni than those on St. Julien A, although the differences in vigour were statistically not significant (Trial 4). Trees on Eruni of the cultivars 'Ive' and 'Edda' had significantly higher cumulative yield per tree than those on St. Julien A in Trial 4 (Table 12), while trees of 'Ive' on Pixy had the highest yield in Trial 5. Yield efficiency was not affected by rootstocks, with the exception of 'Oullins Gage' in Trial 5, where trees on Pixy had the highest efficiency (Table 13). Fruit weight was influenced by rootstocks; in five out of six cultivars in Trial 4, trees on St. Julien A had significantly larger plums than those on Eruni (Table 14). Fruits of 'Opal' achieved largest size on Marianna, while plums of 'Ive' were larger on St. Julien A than on Pixy. Suckering was more abundant for all trees of six cultivars on Eruni than for those on St. Julien A (Table 15).

Table 11. Njøs: Trunk girth of six plum cultivars as affected by rootstocks at the end of the ninth growing season, mean values

Rootstock	Trunk girth, cm					
	Opal	Oullins Gage	Ive	Edda	Njøs II	BP 1158
Trial 4						
St. Julien A	36.9	38.1	33.8	28.8	32.1	37.3
Eruni	39.2	41.7	38.1	33.3	35.0	38.6
LSD, P = 0.05	NS	NS	NS	NS	NS	NS
Trial 5						
St. Julien A	35.8	36.8	38.3			
Eruni	38.6	43.5	37.6			
Pixy	31.6	34.1	36.9			
Marianna	41.3	43.5	39.5			
LSD, P = 0.05	9.5	5.2	NS			

Table 12. Njøs: Cumulative yield of six plum cultivars over six cropping years as affected by rootstocks, mean values

Rootstock	Cumulative yield, kg/tree					
	Opal	Oullins Gage	Ive	Edda	Njøs II	BP 1158
Trial 4						
St. Julien A	73	35	29	26	44	57
Eruni	74	40	39	40	53	65
LSD, P = 0.05	NS	NS	5.4	13.6	NS	NS
Trial 5						
St. Julien A	71	32	28			
Eruni	81	33	31			
Pixy	60	46	38			
Marianna	85	43	28			
LSD, P = 0.05	NS	NS	6.1			

Table 13. Njøs: Yield efficiency of six plum cultivars as affected by rootstocks, mean values

Roostock	Cumulative yield, kg/tree, /trunk cross-sectional area, cm^2					
	Opal	Oullins Gage	Ive	Edda	Njøs II	BP 1158
Trial 4						
St. Julien A	0.67	0.30	0.31	0.43	0.54	0.52
Eruni	0.61	0.30	0.33	0.45	0.53	0.54
LSD, P = 0.05	NS	NS	NS	NS	NS	NS
Trial 5						
St. Julien A	0.72	0.30	0.24			
Eruni	0.68	0.22	0.27			
Pixy	0.75	0.48	0.37			
Marianna	0.64	0.29	-			
LSD, P = 0.05	NS	0.22	NS			

Table 14. Njøs: Fruit weight of six plum cultivars as affected by rootstocks, mean values of six cropping years

Rootstock	Fruit weight, g					
	Opal	Oullins Gage	Ive	Edda	Njøs II	BP 1158
Trial 4						
St. Julien A	33	47	43	41	43	44
Eruni	30	40	39	39	39	40
LSD, P = 0.05	1.6	3.7	3.3	NS	1.7	2.4
Trial 5						
St. Julien A	30	42	45			
Eruni	29	38	39			
Pixy	29	41	40			
Marianna	33	39	42			
LSD, P = 0.05	2.2	NS	4.3			

Table 15. Njøs: Root suckering of six plum cultivars as affected by rootstocks, mean values

Rootstock	Number of suckers per tree					
	Opal	Oullins Gage	Edda	Ive	Njøs II	BP 1158
Trial 4						
St. Julien A	0.3	0.5	2.7	1.9	0	0.8
Eruni	4.1	2.8	13.8	14.1	8.4	6.9
LSD, P = 0.05	1.9	1.5	4.0	5.6	5.7	3.0

DISCUSSION

The vigour of nine plum cultivars on the rootstock Eruni determined in trials at three Norwegian sites differing in soils and climate indicates that Eruni is a semi-dwarfing rootstock. The trees on Eruni tended to be more vigorous than those on St. Julien A. For most cultivars the difference in vigour between trees on Eruni and St. Julien A was not significant, with the exception of 'Victoria' at the Ullensvang site. The vigour of Eruni induced in the nine plum cultivars included in these trials was in accordance with that suggested by the breeder (Oldén 1978) and the results reported in an earlier Danish trial (Christensen 1975) before Eruni was named.

Trees on Pixy demonstrated some reduction in tree size compared with trees on Eruni and St. Julien A. The dwarfing effect of Pixy was, however, generally smaller than that reported by Webster (1980) and Webster & Wertheim (1993).

Most cultivars tended to crop better on Eruni than on St. Julien A. Generally, the differences in cumulative yield were too small to be statistically significant; at the Njøs site only, two out of six cultivars had significantly higher cumulative yields on Eruni than on St. Julien A. The lowest yields were obtained on trees on Pixy; although the differences in cumulative yield between the three rootstocks were significant only for 'Victoria' at two sites (Ås, Ullensvang). The yield reduction of plum trees on Pixy compared with that of trees on St. Julien A as reported by Webster (1980), Wertheim (1991), Webster & Wertheim (1993) was generally smaller in the present study. This can most probably be explained by the smaller difference in tree vigour between plum cultivars on St. Julien A and Pixy in the Norwegian trials.

Fruit size was consistently better on trees on St. Julien A and Pixy than those on Eruni for the cultivars 'Victoria', 'Opal', 'Mallard' and 'Ive' at Ullensvang. This finding was confirmed by the results at the Njøs site, where fruit size on trees on St. Julien A was superior to that of plums on Eruni in five out of six cultivars. Comparing fruit weights of plums grown on St. Julien A and Pixy, the fruit of most cultivars were commensurate in size; only 'Ive' at Njøs had significantly larger fruits on St. Julien A than on Pixy. This finding was in contrast to the reports by Webster (1980), Wertheim (1991), Webster & Wertheim (1993) who obtained smaller fruits on Pixy compared to St. Julien A.

In addition to fruit size, the content of soluble solids is an important component of plum quality. The plums grown on the three rootstocks met the requirement of the threshold value of 12.5% soluble solids as proposed by Vangdal (1985) for plums of acceptable taste quality. No significant difference in soluble solids of plums grown on different rootstocks was found; even Eruni sometimes tended to have a lower concentration. This is in contrast to the results reported by Webster (1980) who found that plums on Pixy had a higher content of soluble solids than those on St. Julien A.

Suckering, a major problem with many rootstocks (Westwood 1974), was moderate for trees on Pixy and St. Julien A, but profuse for all cultivars tested on Eruni. This represents a considerable disadvantage for orchard management and has to be taken into account when plum rootstocks for commercial orchards are being recommended.

Tree health was affected by a winter freeze at the Ås site, with trees of 'Victoria' on Pixy suffering more serious injury than those on St. Julien A. In the mild winter climate of the two sites located in western Norway, no winter injury occurred. The health condition of the plum trees at these sites was good, irrespective of rootstocks.

In conclusion, the results obtained confirm that neither Eruni nor Pixy is a better alternative than St. Julien A as a rootstock for Norwegian-grown plums. St. Julien A should be recommended as a reliable semi-dwarf rootstock until the results of an international rootstock trial (Salesses 1992) with some fully dwarfing rootstocks to be planted in Ullensvang in 1994 are available.

REFERENCES

Christensen, J.V. 1975. Blommegrundstammen 'Balsgård Pr. 10032'. Tidsskr. Planteavl 79: 446-448.

Husabø, P. 1971. Sort- og grunnstammeforsøk med plommer. Statens Forsøksgard Njøs 1920-1970: 28-59.

Oldén, E.J. 1978. BPr 32 - en klongrundstam för plommon framställd vid Balsgård. Frukt och Bärodling 20: 14-18.

Salesses, G. 1992. Details concerning an international rootstock trial for plums. Chronica Horticulturae 32: 11.

Trajkovski, V. & G. Anderson 1988. BPr 32 Eruni, a plum rootstock produced at Balsgård. Sveriges Lantbruksuniversitet, Balsgård, Verksamhetsberättelse 1986-1987: 25-26.

Vangdal, E. 1985. Quality criteria for fruit for fresh consumption. Acta Agriculturae Scandinavica 35: 41-47.

Webster, A.D. 1980. Pixy, a new dwarfing rootstock for plums, *Prunus domestica* L.. Journal of Horticultural Science 55: 425-431.

Webster, A.D. 1981. Dwarfing rootstocks for plums and cherries. Acta Horticulturae 114: 201-207.

Webster, A.D. & S.J. Wertheim 1993. Comparisons of species and hybrid rootstocks for European plum cultivars. Journal of Horticultural Science 68: 861-869.

Wertheim, S.J. 1991. Results of plum-rootstock trials in the Netherlands. Acta Horticulturae 283: 213-222.

Westwood, M.N. 1974. Performance of prune rootstocks. Oregon Horticultural Society Annual Report 65: 93-95.

Ystaas, J. & O. Frøynes 1993. Performance of five plum rootstocks over 17 years to five commercial important plum cultivars in Norway. Norwegian Journal of Agricultural Sciences 7: 267-274.

Effects of bed height, plant spacing and cultivar on strawberry yield and fruit classification

ROLF NESTBY
The Norwegian State Agricultural Research Stations, Kvithamar Research Station, Stjørdal, Norway

Nestby, R. 1994. Effects of bed height, plant spacing and cultivar on strawberry yield and fruit classification. Norwegian Journal of Agricultural Sciences 8: 127-133. ISSN 0801-5341.

In an investigation of the effects of bed height, plant spacing and cultivar on yield and fruit classification, it was found that the strawberry cultivar 'Bounty' produced a larger fruit yield than 'Korona', and both cultivars produced greater yields than 'Senga Sengana' (SS) as a mean of two years. 'Bounty' had larger and more plentiful fruits in the highest quality classification than the other cultivars. 'Korona' had more rotted fruits than 'Bounty' and 'SS'. Regarding freeze injury of crowns, it was found that 'Bounty' was more freeze tolerant than 'Korona' and 'Korona' more tolerant than 'SS'. Production on a 35-cm-high bed improved the fruit quality, and reduced the percentage of rotted fruits and culls compared with production on a flat bed, while the influence on yield was only a minor one. Increasing the plant density from 3246 to 5495 plants/da increased the yield by 424 kg/da but reduced fruit size, as a mean of all cultivars and two years; no significant interactions were observed between plant spacing and cultivar or plant spacing and year. For effects on yield and all yield components with exception of culls, the interacions between year and cultivar and between year and bed height were significant.

Key words: Bed height, cultivar, plant spacing, strawberry, yield.

Rolf Nestby, Kvithamar Research Station, N-7500 Stjørdal, Norway.

It has previously been shown that plant spacing has an influence on the yield of strawberries (Thorsrud 1964; Nestby 1975; Fournier 1982; Zuzi 1986; Hesketh et al. 1990; Nestby 1992). In addition to increasing the plant spacing within economical limits, cultivar and irrigation techniques have an impact on the optimal number of rows in the bed and on the plant spacing in each row that can be used efficiently (Fiedler 1988; Voth & Bringhurst 1990).

The objective of this experiment was to find ways of improving the cultural systems normally used in Norway. In other countries, systems with high beds are frequently used (Poling & Safley 1986; Voth & Bringhurst 1990), but the main effects and interactions with other factors have not been examined for strawberries in Norway. It was therefore decided that the effects of bed height, cultivar and plant spacing on fruit yield and quality classification in a cultural system should be investigated.

MATERIALS AND METHODS

Experimental design

The experiment was located at Kvithamar Research Station in mid-Norway. Three experimental factors were involved: cultivar, bed height and plant spacing. The bed types were (1) a 35-cm-high bed, and (2) a flat bed; the plant spacings were (1) 3246, (2) 4202, and (3) 5495 plants per decare (hectare/10), and the cultivars were 'Senga Sengana', 'Bounty' and 'Korona'. The experimental design was a split-plot with four replicates. The cultivars were planted on large plots, the bed heights were placed on small plots and the plant spacings on small-small plots. Each small-small plot consisted of 20 plants in a double row with 20 cm between the rows. Plant spacings of 3246, 4202 and 5495 plants per decare represented a 44, 34 and 25 cm distance between plants in each single row respectively. The distance between bed centres was 140 cm.

Growth conditions

The soil type was a poorly drained silt loam with a high content of organic matter, in good nutritional balance except for a relatively high level of P. The plants were drip irrigated in accordance with tensiometer readings. Black plastic was used as mulch. The field was planted on 21 June 1991, and a few plants that did not establish were replaced on 8 July. The cultural practice was in accordance with standard Norwegian methods. The plants were sparyed against *Botrytis cinerea* twice in 1992 and five times in 1993, using half dosage of vinklozolin and benomyl alternately.

Registration

Total yields in kg per decare were recorded in 1992 and 1993. The fruits were harvested with sepals and sorted as Class I and II, rotten fruits and fruit culls, calculated as a percentage of the total yields. The culls mainly consisted of misshapen fruits. Calculation of fruit size was based on the average size of 50 fruits at each harvest, weighed in accordance with the relative size of the yield at each respective harvest. The number of crowns was counted on each plant in June 1992.

Statistical evalution

Main effects of cultivar, bed height and plant spacing, and their interactions were analysed using the SAS Procedure, GLM. Correlation coefficients were calculated using the SAS Procedure, CORR (SAS Inst. Inc., 1992).

RESULTS

Cultivar

The cultivars 'Bounty' and 'Korona' had higher yields than 'Senga Sengana' in each year and as a mean of both years, but the differences were particularly large in 1993 (Table 1). As a mean of two years, 'Bounty' had a larger yield than 'Korona', but of the two 'Korona' had the higher yield in 1992. There were some differences in fruit classification. 'Bounty' had, as an average of two years, the highest percentage in Class I, with 'Senga

Sengana' in second place. 'Korona' had the poorest result mainly because of the high percentage of rotted fruit in 1992. The percentage of fruit in Class II was about equal for all cultivars. 'Senga Sengana' had a larger percentage of culls than the other two cultivars, especially in 1993. The differences in fruit size were small, but 'Bounty' had larger fruit than the others as a mean, and in each of the two years. 'Korona' had larger fruit than 'Senga Sengana' in 1993. The fruits were, as an average of all cultivars, 3.3 g smaller in 1993 than in 1992. There was a significant interaction between cultivar and year for all parameters that were recorded in both years (Table 4).

Table 1. Effect of strawberry cultivars on yield in kg/da, percentage of fruits in Classes I and II, rotten fruits, fruit culls and fruit size in g/fruit, in two years after planting in June 1991

Cultivar	Year	Yield	Class		Rotten	Culls	Fruit size
			I	II			
Senga Sengana	1992	1766	84	2	7	7	13.0
Korona		2364	77	2	14	6	12.6
Bounty		2164	88	2	4	6	13.6
$LSD_{5\%}$		155	2	ns	1	ns	0.5
Senga Sengana	1993	1203	80	5	6	10	9.1
Korona		1980	82	5	8	6	9.7
Bounty		2497	79	6	7	8	10.4
$LSD_{5\%}$		168	ns	1	2	2	0.3
Senga Sengana	Mean	1485	82	3	6	8	11.0
Korona		2172	80	4	11	6	11.2
Bounty		2331	84	4	6	7	12.0
$LSD_{5\%}$		114	2	1	1	2	0.3

Non-tabulated data showed that in June 1992 'Korona' had 6.1 crowns per plant. This was significantly more than for 'Senga Sengana' and 'Bounty', which had 5.4 and 5.2 crowns per plant respectively. The correlation coefficients between number of crowns and yield were low and not significant within each cultivar.

Bed height

There were no significant differences as a mean of two years or in single years (Table 2) in main effect of bed height on yield. On the high bed, however, there was a 5% higher yield in Class I than on the flat bed, as a mean of two years. In the second year there was a higher percentage of fruits in Class II on high beds than on flat beds. In addition, high beds had the effect of reducing the percentage of rotted and culled fruits, but had no significant effect on fruit size. There were significant interactions between bed height and year for all registraions. The only significant interaction between bed height and cultivar was for the percentage of culls (Table 4).

Table 2. Effect of flat beds (F) and 35-cm-high beds (H) on strawberry yield in kg/da, and on percentage of fruits in Classes (CL.) I and II, rotten fruits and fruit culls, in two years after planting in June 1991

Year	Yield		Cl. I		Cl. II		Rotten		Culls	
	F	H	F	H[1]	F	H	F	H	F	H
1992	2061	2136	80	87***	2	2	11***	6	8***	5
1993	1949	1837	79	82***	5	6***	8***	6	8	7
Mean	2005	1987	79	84***	3	4**	9***	6	8***	6

[1] Differences on the 5, 1 and 0.1% significance level, between the two bed heights, are marked *, **, *** respectively, in Tables 2 and 4

Plant spacing

There were no significant interactions between plant spacing and cultivar for either yield or fruit size. The effect of plant spacing is therefore tabulated as a mean of all three cultivars (Table 3). The yield was found to increase with closer plant spacing, mostly from the lowest density to middle level, but also with a distinct increase with the closest spacing. The fruit size was reduced by 0.2 g per fruit for each increment in plant density.

Table 3. Effect of three plant spacings on strawberry yield in kg/da and fruit size in g/fruit on an average of three cultivars and the years 1992 and 1993, after planting in June 1991

Plant spacing	Yield	Fruit size
3246	1762	11.6
4202	2039	11.4
5495	2186	11.2
Mean	1996	11.4
$LSD_{5\%}$	114	0.3

DISCUSSION

Cultivar

It is obvious that under growth conditions similar to those in this experiment, 'Korona' and 'Bounty' will give a yield that is significantly larger than that for 'Senga Sengana'. Such high yields compared with that for 'Senga Sengana' were not achieved for 'Korona', but 'Bounty' had higher yields than 'Senga Sengana' in two out of three locations in Sweden (Sakshaug 1987, 1991). Earlier results from Norway showed that both 'Bounty' and 'Korona' had higher yields than 'Senga Sengana' (Nestby 1987). The large fruit sizes achieved in other experiments with 'Korona' and 'Bounty' compared with 'Senga Sengana' were not achieved in this experiment (Thuesen 1985; Nestby 1987, 1992; Sakshaug 1987), perhaps because the fruit size was reduced as a result of the high fruit yield. 'Korona' had fruits that rotted easily (*Botrytis cinerea*), which is in agreement with Thuesen (1985).

However, in this experiment even using a half dosage of spraying chemicals, the persentage of rot was within an acceptable level. 'Bounty' produced a higher percentage of fruits in Class I than the other two cultivars, and less rotted and culled fruits; valuable features in an integrated production system.

Table 4. Analysis of variance giving F-values and significance levels (SL) of interactions, for yield, yield parameters and fruit size in strawberries, based on data registeret over two years

Parameter	Cause of variation	F-value	SL
Yield	year x cultivar	34.83	***
	x bed height	4.05	*
Class I	year x cultivar	39.25	***
	x bed height	13.41	***
Class II	year x cultivar	6.86	**
	x bed height	7.65	**
Rotten fruits	year x cultivar	45.04	***
	x bed height	8.00	**
Fruit culls	year x cultivar	5.12	**
	cultivar x bed height	3.06	*
Fruit size	year x cultivar	5.38	**
	x bed height	5.79	*

An exceptional long-term black frost, with temperatures below -10°C, began on 10 October 1992, resulting in freeze injury. This condition was probably the main reason for the significant interaction between cultivar and year for all registrations relating to yield, indicating, as observed in the field, that 'Senga Sengana' was more seriously affected than the other two cultivars, and 'Korona' more so than 'Bounty'. The increase in culls in 1993 compared with 1992, especially for 'Senga Sengana', is also an indication of freeze injury. (Campbell et al. 1954).

These results suggests that 'Bounty' and 'Korona' should replace 'Senga Sengana' as cultivars for the fresh market, since they have the potential to produce higher yields and larger fruits.

Bed height

There were several positive effects of bed height, but the antecipated positive effect on yield was suggested only in the first year, when the production on high beds was 75 kg higher per decare than that on flat beds. The following year the effect was reversed, with 112 kg lower production per decare on high beds compared with flat beds, but none of these effects were significant. The interaction between height and year, however, was significant measured on yield and fruit size. This interaction was probably attributable to the black frost in the autumn of 1992. This is in agreement with Boyce & Reed (1983), who showed that the temperature in crowns on 20-25-cm-high beds was lower than that on flat beds, and that the freeze injury was highest on the high beds.

High beds had, however, a positive effect on the quality classification of fruits. The production of Class I fruits was 5% higher than that on flat beds, because high beds reduced the percentage of rotted and misshapen fruits. Another definite advantage of high beds, confirmed in a questionnaire among pickers, was that fruit picking was less laborious than on flat beds.

High beds can be recommended in strawberry production, the only negative aspect being the increased vulnerability to freeze injury, which has to be taken into consideration. In locations where freeze injury occurs frequently, there must be a state of readiness to protect the plants with a rowcover (Boyce & Reed 1983; Boyce et al. 1988; Pollard & Cundari 1988).

Plant spacing

There were distinct differences in yield and fruit size between the three plant spacings. 'Senga Sengana', 'Bounty' and 'Korona' had similar reactions, and there were no interactions between bed type and plant spacing calculated on yield parameters on fruit size. By increasing the plant density from 3246 to 4202 and from 4202 to 5495 plants per decare, the yield was improved by 277 and 147 kg per decare respectively. Earlier experimets with these three cultivars are in accrodance with this result (Thorsrud 1964; Nestby 1975, 1992; Kongsrud 1993). Even though there was a positive effect for the highest plant density in this experiment, results from Nestby (1975) and untabled data from this experiment indicate that 4202 plants per decare are almost the optimal level for 'Senga Sengana'. This experiment indicates similar optimal density for 'Korona'. For 'Bounty', 5495 plants per decare are considered as optimal. These suggested optimal plant spacings should be recommended for cultural systems with double rows on high beds under similar growth conditions to those used in this experiment.

REFERENCES

Boyce, B.R. & R.A. Reed 1983. Effect of bed height and mulch on strawberry crown temperatures and winter injury. Advances in Strawberry Production 2: 12-14.

Boyce, B.R., A.W. Linde & J. Aleong 1988. Effect of delayed mulch removal on yield and harvest date of 'Midway' strawberries. Advances in Strawberry Production 7: 29-31.

Campbell, R.W. & J.C. Lingle 1954. Some effects of low temperature on the flower primordia of the strawberry. Proceedings of the American Society of Horticultural Science 64: 259-262.

Fiedler, W. 1988. Dichtere Pflanzungen in der Erdbeerproduction zur Sicherung einer effektiven Flächennutzung. Gartenbau 35: 146-148. (English summary).

Fournier, P. 1982. Expérimentation fraisier a l'ile de la Réunion. Deuxieme partie: Étude de quelques tecniques culturales. Fruit 37: 609-615. (English summary).

Hesketh, J.L., G.W. Eaton & T.E. Bauman 1990. Strawberry runnering and leaf size depend on plant spacing. Fruit Varieties Journal 44: 26-31.

Kongsrud, K.L. 1993. Virkning av plastdekking og planteavstander ved sommerplanting av jordbærsortene 'Senga Sengana', Korona' og 'Bounty'. Norsk landbruksforsking 8: 31-48. (English summary).

Nestby, R. 1975. Effekt av planteavstand, utviding av plantehullet i plasten, tilleggsgjødsling med $Ca(NO_3)_2$ og barjordkultur, på avling og bærstørrelse i jordbær ('Senga Sengana'). Forskning og forsøk i landbruket 26: 63-69. (English summary).

Nestby, R. 1987. Verdiprøving i jordbær ved SFL Kvithamar og Tjøtta i 1986 og 1987. Foredrag/rapport Kvithamar 57b, 15 pp. (In Norwegian).

Nestby, R. 1992. Virkning på avlingskomponenter og kvalitet i tre jordbærsorter av jorddekking med plastfolie, radtype og redusert styrke av soppmiddel mot gråskimmel (*Botrytis cinerea*). Norsk landbruksforsking 6: 173-181. (English summary).

Poling, E.B. & C.D. Safley 1986. Economics of changing from matted row to annual hill system strawberry production. HortScience 21: 1409-1411.

Pollard, J.E. & C.M. Cundari 1988. Over-wintering strawberry plants under rowcovers increases fruit production. HortScience 23: 332-333.

Sakshaug, K. 1987. Sortsförsök med jordgubbar 1981-1985. Swedish University of Agricultural Science, Research Information Centre/Trädgård 329, 20 pp. (In Swedish).

Sakshaug, K. 1991. Sortsförsök med jordgubbar 1984-1989. Swedish University of Agricultural Science, Research Information Centre/Trädgård 59, 17 pp. (In Swedish).

SAS Inst. Inc. 1992. SAS User's Guide: Statistics, 1992 ed., SAS Inc., Cary, N.C.

Thorsrud, J. 1964. Dyrkingsforsøk med jordbær. V. Forsøk med ulik planteavstand til 3 jordbærsorter. Yrkesfruktdyrking 2: 25-27. (In Norwegian).

Thuesen. A. 1985. Vurdering av jordbærsorter 1982-1983. Statens Planteavlsforsøg 87, no. 1805, 4 pp. (In Danish).

Voth, V. & R.S. Bringhurst 1990. Culture and physiological manipulation of California strawberries. HortScience 25: 889-892.

Zuzi, I. 1986. Effect of different techniques of strawberry cultivation on yield and economics. Acta Fytotechnica 42: 215-235. (English summary).

A comparison between meadow fescue and timothy silage
3. Feeding experiments with dairy cows

ASTRID JOHANSEN & LEIDULF NORDANG
The Norwegian State Agricultural Research Stations, Vågønes Research Station, Bodø, Norway

Johansen, A. & L. Nordang 1994. A comparison between meadow fescue and timothy silage. 3. Feeding experiments with dairy cows. Norwegian Journal of Agricultural Sciences 8: 135-153. ISSN 0801-5341.

The feeding value of meadow fescue (MF) and timothy silage (T) was evaluated in three experiments with 80 dairy cows. During two periods silage was fed either restricted or *ad libitum*. Generally, both silages were well fermented although MF slightly stronger than T. This was attributed to the higher buffering capacity of fresh meadow fescue grass. Milk feed units (FEm) estimated from *in vivo* digestibility was 0.873 and 0.858 kg DM^{-1} for MF and T, respectively. Differences in milk yield were generally small but in one occasion energy corrected milk was significantly ($p<0.05$) higher from T. The general milk fat percentage was significantly ($p<0.01$) higher from T (3.95) than from MF (3.80). No significant difference in voluntary intake was found. It was concluded that the feeding value of MF was no less than that of T for dairy cows, even if MF was harvested at a slightly later morphological stage than T.

Key words: Chemical composition, *Festuca pratensis*, milk fat, milk yield, nutritive value, *Phleum pratense*, silage, voluntary intake.

Astrid Johansen, Vågønes Research Station, N-8010 Bodø, Norway

In Norway, and several other countries meadow fescue (*Festuca pratensis* Huds.) and timothy (*Phleum pratense* L.) are the most important grass species sown for forage. Whereas fermentation quality and feeding value of timothy silage is well documented, limited information is available about meadow fescue silage. To examine these questions experiments were conducted at several of the Norwegian State Agricultural Research Stations. These included both ensiling experiments and feeding experiments with sheep and cattle. Ensiling experiments with two harvesting stages and feeding experiments with sheep have been reported by Nordang (1992) and Barvik et al. (1991), respectively. Feeding experiments with bulls are detailed by Johansen & Nordang (1993).

To complete the evaluation of meadow fescue silage feeding experiments with dairy cows were conducted. The main objective of the experiments was to compare the fermentation quality and the feeding value of meadow fescue silage with that of timothy silage. Feeding value of a silage includes both the nutritive value i.e. quantities of energy and nutrients per unit weight, and the voluntary intake. Nylon bag degradation studies and *in vivo* digestibility of the silages either fed alone or with concentrates has been reported earlier (Johansen 1994). In previous feeding experiments net energy values of ensiled forage fed *ad libitum* have been calculated from milk production (Bergheim 1979, Hole 1985, Nordang 1990). However, as feed intake markedly affects milk yield it was difficult to distinguish between the effect of the nutritive value *per se* and the voluntary feed intake. Therefore, the present experiments were designed with two continuously following periods in which the silage was offered either on a restricted basis or *ad libitum*, respectively.

MATERIALS AND METHODS

Feeds

During 1987-89 first cuts from pure sown swards of meadow fescue and timothy were ensiled separately in experimental tower silos (height=6.0 m, diameter=3.5 m) at Bodin Gård, close to Vågønes Research Station, Bodø (67°17'N) for use in three feeding experiments with dairy cows (Expts. 1, 2 and 3). The grass was direct cut using a flail harvester one to two weeks after heading of timothy. In Expt. 1 harvesting of meadow fescue was finished before that of timothy and the grasses ensiled with the inclusion of 3 L 85% formic acid per ton fresh grass. In Expts. 2 and 3 the two grasses were harvested at the same dates and 4 L Foraform (64% formic acid + 6% ammonia, produced by NOFO) included per ton of grass. In Expts. 1 and 2 the weather was dry during the harvesting period but in Expt. 3 it was cold and rainy during most of the harvesting period. Details about the dates of harvest, dry matter (DM) yield and the botanical composition of the swards are given in Table 1. Approximately 130 kg N ha^{-1} was applied to the swards in the spring as inorganic fertilizer. Two commercial concentrates produced by Felleskjøpet Trondheim were used in the feeding experiments; Kunøtt A (Mix A) and Kunøtt C (Mix C). The declared content of digestible crude protein (DCP) was 12.5% for Mix A and 32% for Mix C. Mix C contained 20-25% fish meal while in Mix A the main protein sources were soybean meal, guar meal and rapeseed meal. The ingredient composition of the concentrates is detailed by Johansen (1994).

Table 1. Harvesting dates, dry matter (DM) yield and botanical composition of the swards

	Expt. 1		Expt. 2		Expt.3	
	Meadow fescue	Timothy	Meadow fescue	Timothy	Meadow fescue	Timothy
Year of harvest	1987		1988		1989	
Date of harvest	15.-18.7	19.-22.7	6.-11.7		26.-30.6	
DM yield, t ha^{-1}	5.7	6.3	6.0	6.5	5.6	6.0
Botanical composition (in % of DM):						
Sown grass species	91	93	96	90	84	90
Other grass species	7	5	4	8	14	6
Dicotyledonous weeds	2	2	0	2	2	4

Experimental design

A total of 80 dairy cows in mid lactation of the NRF breed were used in the experiments, including 26 heifers (primiparous cows). A schematic description of the experimental design is shown in Figure 1. During three weeks (preliminary period) all animals were offered restricted amounts of mixed grass silage (mainly timothy). After the third week the animals were randomly allocated to one of two groups and offered either meadow fescue silage (F) or timothy silage (T) in restricted amounts for eight weeks (Period 1). Allocation was based on lactation number, days from calving, milk yield, milk fat content and liveweight. For the last five weeks silage was offered *ad libitum* (Period 2). However, this period in Expt. 2 lasted only four weeks due to lack of silage. The two initial weeks of each experimental period were considered as transition periods and data from these were omitted in the computations.

In Expt. 1 all animals remained in the same group throughout the experiment. In Expts. 2 and 3 each group was sub-divided to give four subgroups at the start of Period 2. In two of the subgroups the animals were offered the same type of silage as in Period 1 (FF and TT) while the other two changed to the other silage (TF and FT). This design was chosen to expose possible carry over effects from Period 1. The allocation of animals into subgroups in Period 2 was based on performance during Period 1, lactation number and days from calving.

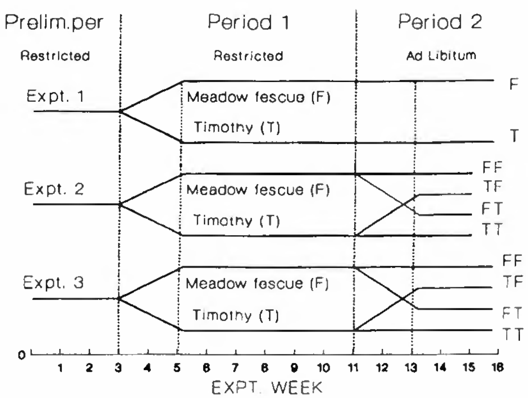


Figure 1. Schematic description of the experiments

Feeding and management

The animals were kept in a tied-stall byre and given silage and concentrates on individual basis. The following management routines were practiced:

	Morning	Afternoon
Concentrate feeding, hours:	6:00 11:30*	15:15 19:00*
Silage feeding, hours:	8:30	15:30
Milking, hours:	6:15	16:00

*) Expts. 2 and 3 only

Silage was offered in two equal portions, morning and afternoon. In Expt. 1 concentrate feeding followed the same routine but in the later experiments concentrates were fed four times a day using an automatic concentrate allocator (Feedmaster). Feed residuals were collected daily at 08:00 h.

In Expt. 1 heifers and cows were offered 6.5 kg and 7.0 kg silage DM daily, respectively. In Expts. 2 and 3 the amounts were 6.0 and 7.5 kg DM. The concentrates were offered according to Norwegian standards (Breirem 1987) assuming the silages to contain 0.74 fattening feed units (FFE) kg DM^{-1}. The heifers were given an extra 0.5 kg Mix A for growth. Mix C was used to meet the requirements for DCP based on a value of 100 g DCP (FFE^{-1}) for silages in Expts. 1 and 3, and 80 g DCP (FFE^{-1}) in Expt.2. Milk yield and liveweight during the preliminary period was used to compute the initial amounts of concentrates. For multiparous cows the amounts were reduced by 0.5 FFE every second week to match the standard rate of decline in milk yield (0.5 kg per week) for cows in mid lactation (Mo 1975, Bergheim 1979). The heifers received constant amounts of concentrates throughout the experiment. During Period 2 silage was offered at approximately 110% of the intake of the previous day. At the start of Period 2 the concentrate feeding was adjusted for all animals to meet the requirements above 6.0 (heifers) and 6.5 (cows) FFE. For Period 2 in Expt. 3 the concentrate feeding became higher than intended (approximately 1.25 FFE) for all animals due to computation errors. All animals were offered 100 g of mineral supplement daily (Norwegian Standard Mixture) and water was freely available.

Sampling and chemical analyses

Samples for chemical analyses of the fresh grass were taken from each trailer load during harvest and mixed to give one sample per field harvested per day. The DM content of the silages were determined every week by drying duplicate samples at 103-105°C for 24 hours. Samples of silage, concentrate and silage refusals were taken every second week for chemical analyses. The samples were stored frozen until analysed at Holt Research Station, Tromsø. All samples were analysed for DM, crude protein (CP, calculated as Kjeldahl-N·6.25), ether extract, crude fibre (CF) and ash, grass samples excepted for which ash not was analysed. In Expts. 2 and 3 neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin (ADL) were analysed in silages and concentrates. In addition, silages were analysed for true protein, ammonia-N and organic acids (formic, acetic, propionic, butyric, valeric and lactic acids) and ethanol. The analytical methods used are described by Van Soest (1963a,b), Van Soest & Wine (1967), AOAC (1980) and Pedersen & Lysnes (1991). For grass samples the buffering capacity was determined using the method of Playne & McDonald (1966).

Milk yield was recorded on four consecutive days, from Monday morning to Thursday afternoon throughout the experiments. Milk samples for milk composition analyses were taken at Monday evening, Tuesday morning and evening and Wednesday morning for all animals. The four samples were analysed separately at the Northern Norway Dairy Laboratory in Harstad. Contents of fat, protein and lactose were determined by using a Foss Electric FMP Combi and weekly weighed means were calculated for all animals. The animals were weighed at two consecutive days at the beginning and end of each period. Within each period the liveweight was recorded once every second week. On three occasions during Period 1 and once in Period 2 rumen fluid samples were collected via the oesophagus. In Expt. 1, 2 and 3 the collection started at 12:30 h, 10:30 h and 12:30 h, respectively. Before preserving the samples with 0.25 ml formic acid (100%) pH was measured. The concentration of acetic volatile fatty acids (VFA; acetic(C2), propionic (C3), butyric (C4) and valeric (C5) acids) and ammonia-N was determined at Department of Animal Science, Agricultural University of Norway.

Calculations and statistical analyses

Silage DM was corrected for losses of volatile substances, assuming that 80% of the VFA and 100% of the ethanol are lost during oven drying at 103-105°C. Estimates of the metabolisable and net energy values of the silages were based on the data from chemical analyses and coefficients of *in vivo* digestibility (Johansen 1993). To calculate the energy values of the concentrates the ingredient composition and the digestion coefficients of Sundstøl *et al.* (1986) were used. Metabolisable energy (ME) was calculated according to Van der Honing & Alderman (1988) and fattening feed units (FFE) as described by Breirem & Homb (1970) using a value number of 80. Milk feed units (FEm) were calculated according to Sundstøl & Ekern (1992). Protein values were estimated as DCP and as amino acids absorbed in the intestine (AAT) and protein balance in the rumen (PBV) as described by Harstad (1992). Rumen degradability (dg) of silage CP was predicted from the equation of Webster *et al.* (1982) relating dg to CP (g kg^{-1}): $dg=100\cdot(CP-22.5)/CP$. For the concentrates CP degradability was calculated from table values for the different ingredients (Skovbo Nilsen 1990). Milk yield was corrected to both 4% fat (FCM) and energy content (ECM) (Sjaunja et al. 1990). Feed utilisation above maintenance was calculated from the difference between total intake and requirements for FFE and FEm to maintenance and growth. The nutritive value of the silage based on milk production was calculated by subtracting the concentrate supply from total requirements (Saue et al. 1978). The requirements of FEm and AAT were calculated according to Sundstøl & Ekern (1992) and Harstad (1992), respectively.

The statistical analyses of the data were performed using the General Linear Model procedure described by SAS (1987). The following covariance model was used to analyse the data from Period 1:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + bX_{ijk} + e_{ijk}$$

where

Y_{ijk} = parameter analysed
μ = general mean
α_i = effect of group (i=F,T)
β_j = effect of lactation number (j=primiparous, multiparous)
b = effect of the covariate Xijk
e_{ijk} = random error

The covariates used were days from calving and milk yield or milk composition in the preliminary period. Interactions were pooled into the random error and nonsignificant covariates ($p<0.05$) omitted from the model. For the data from Period 2 the following model was used:

$Y_{ijk} = \mu + \alpha_i + \beta_j + \sigma_k + (\alpha\beta)_{ij} + e_{ijk}$
where
Y_{ijk} = parameter analysed
μ = general mean
α_i = effect of treatment in Period 1 (i=F,T)
β_j = effect of treatment in Period 2 (j=F,T)
σ_k = effect of lactation number
(k=primiparous, multiparous)
$(\alpha\beta)_{ij}$ = interaction between treatment in Period 1 and Period 2 (ij=FF,TF,FT,TT)
e_{ijk} = random error

In Expt. 1 the effect of treatment during Period 1 was omitted from the model. If no comments are given the tables show LS-means. Significant differences ($p<0.05$) between groups are shown by different superscripts (a and b). Treatment means without superscripts are not significantly different.

RESULTS

Animal health

A total of 13 cows were treated for acetonemia and 10 had clinical mastitis. Most cases of acetonemia occurred in the preliminary period of Expt. 1 (six) and Expt. 2 (five). Two animals from Expt. 1 and one from Expt. 3 were withdrawn from the statistical analyses due to these problems. In Expt. 3 an outbreak of infectious diarrhoea occurred at Bodin Gård during the transition weeks of Period 2 and lasted for about three days. New cases occurred in the last week of the experiment causing feed intake and milk yield to be depressed. For this reason the experiment was stopped. No relation between experimental treatment and health problems was found.

Characteristics of the feeds

The chemical composition of the fresh grass at harvesting is shown in Table 2. In Expts. 1 and 2 DM concentration was lower for meadow fescue than for timothy. In Expt. 3 no such difference between the grass species were seen but the DM concentration appeared to be lower than in the previous experiments. The main difference between the two grass species was the higher buffering capacity for meadow fescue than for timothy.

The DM concentration was less variable for silages than for fresh grass, (Table 3). In Expts. 1 and 2 only small differences between the two silages were seen in DM composition. In Expt. 3 the content of CP and ether extract was higher, while N-free extracts, CF content and cell wall constituents were slightly lower for meadow fescue than for timothy silage.

Table 2. Chemical composition of the fresh grass (Means)

	Expt. 1		Expt. 2		Expt. 3	
	Meadow fescue	Timothy	Meadow fescue	Timothy	Meadow fescue	Timothy
Dry matter, %	19.8	21.7	19.8	24.4	16.6	16.1
In % of dry matter:						
Crude protein	11.8	12.2	14.0	12.4	15.6	14.4
True protein	9.3	9.7	9.1	8.9	10.4	9.6
Ether extract	4.6	4.1	2.9	3.9	3.6	3.2
Crude fibre	30.8	30.2	34.2	32.2	31.1	31.2
WSC[1]	15.7	14.0	13.4	13.0	11.0	9.9
Buffering capacity[2]	42.2	35.8	40.6	32.8	40.6	35.3
True protein, % of CP[3]	78.8	79.5	65.0	71.8	66.7	66.7

[1] WSC=water soluble carbohydrates, [2] mEq (100 g DM)$^{-1}$, [3] CP=crude protein

Table 3. Chemical composition of the silages (Means)

	Expt. 1		Expt. 2		Expt. 3	
	Meadow fescue	Timothy	Meadow fescue	Timothy	Meadow fescue	Timothy
No of samples	4	4	4	4	5	5
Dry matter, %	23.1	22.6	23.5	23.3	21.7	21.1
In % of dry matter:						
Crude protein	11.4	11.0	11.9	12.3	14.4	11.5
Ether extract	4.0	4.0	3.2	3.8	6.9	5.2
Crude fibre	33.7	34.1	36.7	37.3	34.8	36.0
N-free extract	43.8	44.9	41.6	41.0	37.0	41.9
Ash	7.1	6.0	6.6	5.6	6.7	5.3
WSC [1]	5.0	3.7	4.9	4.5	1.9	1.7
NDF [2]	-	-	63.3	64.4	59.9	65.0
ADF	-	-	38.0	38.5	36.3	38.6
ADL	-	-	3.1	3.8	1.9	2.7

[1]WSC=water soluble carbohydrates, [2] NDF=neutral detergent fibre, ADF=acid detergent fibre, ADL=lignin

In Expts. 1 and 2 acetic and lactic acid concentrations were slightly higher in meadow fescue than in timothy silage while true protein content was lower (Table 4). In Expt. 3 the concentration of formic acid was generally low and acetic acid somewhat high compared with the previous experiments. The true protein content was low for both silages but only traces of propionic, butyric and valeric acids were found. In Expts. 2 and 3 the percentage of ammonia-N was high compared with Expt. 1.

Table 4. Fermentation characteristics of the silages (Means)

	Expt. 1		Expt. 2		Expt. 3	
	Meadow fescue	Timothy	Meadow fescue	Timothy	Meadow fescue	Timothy
pH	3.9	3.8	4.1	3.9	4.0	4.2
True protein, % of CP[1)]	57	62	60	63	38	39
Ammonia-N, % of total N	4.6	5.2	11.1	9.5	10.4	12.6
In fresh silage (%):						
Formic acid	0.36	0.14	0.30	0.32	0.17	0.15
Acetic acid	0.58	0.36	0.47	0.39	0.60	0.63
Propionic acid	0	0	0.02	0.01	0.01	0.01
Butyric acid	0	0	0.04	0.04	0	0
Valeric acid	0	0	0	0	0	0
Lactic acid	2.08	1.65	1.79	1.53	1.78	1.05
Ethanol	-	-	0.20	0.17	0.18	0.22

[1)] CP=crude protein

Digestion coefficients for silage organic matter (OM), protein degradability and the estimated energy and protein values are shown in Table 5. For the single experiments differences in OM digestibility were not significant but the genrall mean was significantly higher for meadow fescue than for timothy silage (Johansen 1994). The mean protein degradation calculated from the CP content according to Webster et al. (1982) was 81.9% and 80.6% for meadow fescue and timothy silage, respectively. The estimated energy values tended to be higher for meadow fescue than for timothy silage. In Expt. 3 the AAT value was somewhat higher for timothy than for meadow fescue silage but generally the differences in AAT values were small. DCP values were variable and the PBV values low or negative.

Table 5. *In vivo* digestibility of organic matter[1)], crude protein degradability[2)] and estimated energy and protein values of the silages[3)] (Means)

	Expt. 1		Expt. 2		Expt. 3	
	Meadow fescue	Timothy	Meadow fescue	Timothy	Meadow fescue	Timothy
OM digestibility, %	73.8	71.8	72.8	71.6	77.1	75.9
CP degradability, %	80.3	79.6	81.1	81.7	84.4	80.4
Per kg dry matter:						
ME, MJ	10.2	10.0	10.1	10.1	10.9	10.7
FFE	0.778	0.768	0.773	0.768	0.818	0.815
FEm	0.855	0.836	0.848	0.843	0.915	0.896
DCP, g	81	74	81	88	107	81
AAT, g	73	73	73	72	71	75
PBV, g	-12	-15	-6	0	23	-13

[1)] Calculated from *in vivo* digestibility experiments with sheep (Johansen 1994)

[2)] Calculated according to Webster *et al.* (1982): $100 \cdot (CP-22.5) \cdot CP^{-1}$, CP=g crude protein in dry matter

[3)] OM=organic matter, ME=metabolisable energy, FFE=fattening feed untis, FEm=milk feed units, DCP=digestible crude protein, AAT=amino acids absorbed in the intestine, PBV=protein balance in the rumen

The calculated chemical composition of the concentrates (Table 6) was similar to what was found from chemical analyses of composite samples. The difference between FFE and FEm values was negligible and the AAT values were less variable between the mixtures than the DCP values. For Mix C the higher amount of CP produced a larger positive PBV value than for Mix A.

Table 6. Chemical composition, nutritive values and protein degradability (dg)[1] for the concentrate mixtures (Means)

	Expt. 1		Expt. 2		Expt. 3	
	Mix A	Mix C	Mix A	Mix C	Mix A	Mix C
No of batches	2	1	2	2	2	3
Dry matter, %	87.1	90.5	87.4	90.1	87.2	90.5
In % of dry matter:						
Crude protein	18.4	39.8	17.8	40.8	17.7	40.1
Ether extracts	4.6	7.7	4.6	7.8	4.6	7.5
Crude fibre	6.7	7.6	7.7	7.1	7.8	7.4
N-free extract	63.7	33.6	62.1	34.0	63.3	33.4
Ash	5.4	11.3	8.0	10.3	6.6	11.6
Per kg dry matter:						
ME, MJ	12.3	12.5	12.0	12.6	12.2	12.3
FFE	1.09	1.09	1.06	1.10	1.08	1.06
FEm	1.08	1.09	1.05	1.10	1.07	1.07
DCP, g	149	352	14	361	144	353
AAT, g	100	152	97	159	102	162
PBV, g	26	171	24	172	15	161
Protein dg,	0.71	0.57	0.71	0.55	0.68	0.54

[1] Calculated from the ingredient composition (Johansen 1994). Abbreviations; see Table 5

Feed intake

In Table 7 animal data and feeds consumed during Period 1 are shown. The silages were offered in restricted amounts and only minor differences in silage DM intake between the groups were seen whereas the concentrate consumption varied according to yield. In all experiments the cattle in group T was offered higher amounts of Mix A than those in group F (up to 0.4 kg in Expt. 1). In Expt. 2 the amount of Mix C was relatively high compared with the other experiments due to the lower content of DCP in the silages used when computing the concentrate amounts. There were no clear differences between groups in total energy intake. In Expt. 3 group T had a lower intake of DCP than group F, a slightly negative PBV value, but no clear differences in intake of AAT.

Table 7. Animal data and daily feed consumption during Period 1 (restricted feeding) [1)]

	Expt. 1		Expt. 2		Expt. 3	
Groups, Period 1:	F	T	F	T	F	T
No. of heifers	4	4	4	4	5	5
No. of cows	8	8	9	9	8	9
Lactation no.	2.8	2.3	2.5	2.2	2.4	2.0
Days from calving [2)]	94	91	97	102	99	93
Dry matter consumed:						
Silage, kg	7.2	6.9	6.9	6.8	7.0	7.1
Mix A, kg	7.3	7.7	7.4	7.5	7.0	7.1
Mix C, kg	0.1	0.1	0.8	0.8	0.1	0.1
Total FFE	13.6	13.7	14.1	14.1	13.4	13.6
Total FEm	14.0	14.1	14.5	14.5	14.0	14.1
Total DCP, g	1651	1689	1894	1959	1851	1604
Total AAT, g	1263	1277	1347	1339	1224	1276
Total PBV, g	66	131	249	313	399	-13

1) F=meadow fescue silage, T=timothy silage, Other abbreviations; see Table 5
2) At the day of grouping.

The voluntary intake of silage and total feed consumed during Period 2 is shown in Table 8. Both in Expt. 1 and Expt. 2 daily intake of silage DM tended to be higher for animals fed meadow fescue (F, FF+TF) than for those fed timothy silage (T, TT+FT). In Expt. 2 DM intake of meadow fescue silage per 100 kg liveweight also tended to be higher. However, none of these differences were statistically significant. In Expt. 3 silage DM intake was generally lower than in the other experiments and no clear differences between the two silage groups were seen. In Expts. 2 and 3 the following silage DM intake was seen in the subgroups:

	FF	FT	TF	TT
Silage DM intake, Expt. 2, kg day^{-1}	9.9	9.3	8.8	8.5
Silage DM intake, Expt. 3, kg day^{-1}	8.2	8.6	9.4	9.2

In Expt. 2 voluntary intake in groups FF and FT tended to be higher than that in groups TT and TF. In Expt. 3 an opposite, and statistically significant relationship was found.

Animals fed meadow fescue tended to have a higher intake of total energy than those fed timothy silage. In Expt. 1 intake of DCP tended to be and PBV was, significantly lower for group T than for group F. No significant interaction between the subgroups was found for the total feed intake.

Animal performance

During Period 1 there was a tendency for group T to have a slightly higher milk yield than group F. However, the difference was not statistically significant (Table 9). In all experiments the milk fat content was lower for group F than for group T, significantly in Expt. 1 and 3. Generally, corrected milk yields tended to be higher for group T than for group F and, in Expt. 3 the difference of 1.0 kg ECM between the two groups was statistically significant ($p<0.05$). When utilising data from all three experiments in one analysis mean milk yield was 23.7 and 24.0 kg (LS-means) for group F and group T, respectively. The general milk fat percentage was significantly higher for group T (3.95%) than for group F (3.80%).

Table 8. Voluntary intake of silage, concentrates consumed and daily feed intake in Period 2[1)]

	Expt. 1			Expt. 2			Expt. 3		
Groups, Period 2:	F	T	SEM	FF+TF	TT+FT	SEM	FF+TF	TT+FT	SEM
Voluntary intake of silage:									
DM, kg day^{-1}	10.4	9.8	1.5	9.4	8.9	1.6	8.8	8.9	0.8
DM, kg 100 kg LW^{-1}	1.85	1.84	0.26	1.74	1.66	0.30	1.64	1.64	0.19
Concetrate DM consumed per day:									
Mix A, kg	5.1	5.5	1.6	5.7	5.2	1.9	7.1	7.0	1.3
Mix C, kg	0.1	0.2	0.2	0.9	1.0	0.2	0.1	0.1	0.1
Total feed intake per day:									
FFE	13.8	13.8	2.3	14.2	13.3	1.6	15.1	14.9	1.5
FEm	14.6	14.4	2.4	14.9	14.0	1.6	15.8	15.6	1.5
DCP, g	1772	1564	333	1967	1901	233	1842	1790	209
AAT, g	1275	1309	223	1369	1292	152	1394	1388	144
PBV, g	234^b	-70^a	72	340	324	52	99	64	41

[1)] F, FF+TF = meadow fescue silage; T, TT+FT = timothy silage; SEM = standard error of mean. Other abbreviations: See Table 5.

During Period 2 corrected milk yield tended to be higher for animals fed timothy silage than for those fed meadow fescue silage in Expt. 1 and in Expt. 3. In Expt. 2 the relationship between the two silage groups was the opposite. However, none of the differences were statistically significant.

Table 9. Milk yield and milk composition throughout the experiments[1)]

	Expt. 1			Expt. 2			Expt. 3		
Groups:	F	T	SEM	F	T	SEM	F	T	SEM
Preliminary period:									
Milk, kg day^{-1}	25.2	26.1	4.47	27.6	27.4	4.84	23.5	24.3	4.84
FCM, kg day^{-1}	24.7	26.3	3.81	26.6	26.3	4.67	22.7	23.3	4.60
ECM, kg day^{-1}	24.6	26.7	3.84	26.9	27.1	4.50	23.1	23.7	4.51
Period 1:									
Milk, kg day^{-1}	22.8	23.2	2.46	24.8	24.9	2.48	23.1	23.5	1.42
Milk fat, %	3.80^a	4.06^b	0.27	3.79	3.84	0.32	3.80^a	3.96^b	0.22
Milk protein, %	3.21	3.24	0.13	3.35^a	3.48^b	0.14	3.25	3.29	0.06
FCM, kg day^{-1}	22.2	23.2	1.83	24.2	24.7	2.08	22.3^a	23.3^b	1.24
ECM, kg day^{-1}	22.7	23.5	1.89	25.1	25.4	2.28	22.7	23.6	1.26
Groups, Period 2:	F	T	SEM	FF+TF	TT+FT	SEM	FF+TF	TT+FT	SEM
Milk, kg day^{-1}	19.2	19.3	4.07	23.3	21.3	4.23	20.7	21.2	4.56
Milk fat, %	4.04	4.21	0.32	4.04	3.74	0.36	4.10	4.12	0.41
Milk protein, %	3.21^a	3.38^b	0.17	3.60	3.55	0.24	3.43	3.50	0.20
FCM, kg day^{-1}	19.2	19.8	4.11	23.4	20.5	4.45	20.9	21.5	4.40
ECM, kg day^{-1}	19.3	20.7	4.10	24.2	21.4	4.50	21.4	22.2	4.45

[1)] F, FF+TF = meadow fescue silage, T, TT+FT = timothy silage, SEM = standard error of mean, FCM and ECM = fat and energy corrected milk

Figure 2 shows the average milk yield for the groups throughout the experiments. The initial milk yield in Period 1 was not equal for the two groups in any of the experiments, but the differences were not statistically significant. Moreover, the differences seemed to remain throughout Period 1. The average decline of milk yield was 0.64 kg per week in Expts. 1 and 2 whereas 0.28 kg in Expt. 3. The sudden decrease in yield during the second week of Expt. 2 was due to several cases of acetonemia. In the seventh week of Expt. 3 reduced amounts of concentrates were offered due to problems with the automatic concentrate allocator. In weeks 12 and 15 two outbreaks of infectious diarrhoea probably caused the drop in milk production.

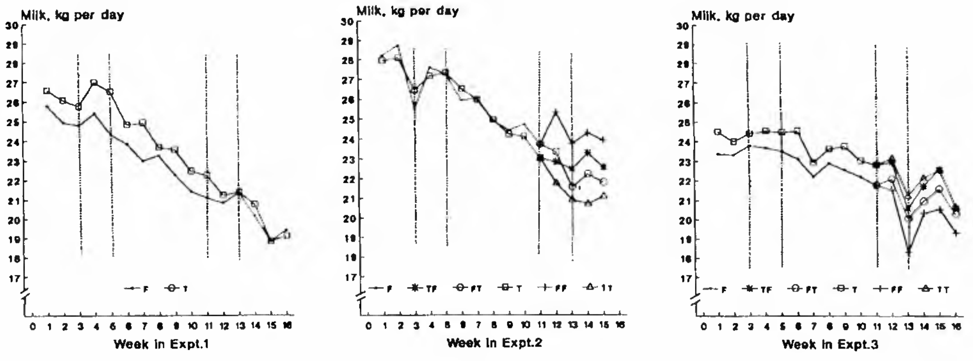


Figure 2. Daily uncorrected milk yield thorughout the experiments for animals fed either meadow fescue (F, FF, TF) or timothy (T, TT, FT) silage (Means)

The initial differences in liveweight were not statistically significant and neither were significant differences in liveweight changes found (Table 10). In Expt. 1 there was a general loss of weight throughout the experiment while in Expt. 2 animals gained weight. In Expt. 3 animals gained weight during Period 1 and was at a steady state or lost weight in Period 2.

Feed utilisation and calculated net energy values of the silages based on milk production during Period 1 are shown in Table 11. No correction for changes in liveweight was made in the computations. In Expt. 1 and Expt. 3 animals consuming timothy silage seemed to have a more efficient feed utilisation than those fed meadow fescue silage. In Expt. 1 the differences in FEm and AAT utilisation and the calculated FEm value were statistically significant. In Expt. 3 the calculated net energy values were higher for timothy silage than for meadow fescue silage. In Expt. 2 no clear differences between the groups were found.

Table 10. Liveweight changes throughout the experiments[1)]

	Expt. 1			Expt. 2			Expt. 3		
Groups:	F	T	SEM	F	T	SEM	F	T	SEM
Preliminary period and Period 1:									
At start, kg	528	513	38	510	509	40	500	516	48
At grouping, kg	532	513	33	508	520	37	501	500	38
End of trans.weeks, kg	531	508	33	517	523	39	503	495	36
End of Period 1, kg	523	501	30	520	530	40	521	501	43
Liveweight gain, g day^{-1}	-205	-106	565	85	173	185	438	156	567
Groups, Period 2:	F	T	SEM	FF+TF	TT+FT	SEM	FF+TF	TT+FT	SEM
At start, kg	523	501	30	521	529	41	510	512	45
End of trans.weeks, kg	561	537	37	532	532	42	535	547	48
End of Period 2, kg	561	530	39	548	554	44	536	543	48
Liveweight gain, g day^{-1}	0	-310	692	800	961	927	54	-151	431

[1)] F, FF+TF = meadow fescue silage; T, TT+FT = timothy silage; SEM = standard error of mean

Table 11. Feed utilisation and calculated net energy values for the silages based on milk production during Period 1[1)]

	Expt. 1			Expt. 2			Expt. 3		
	F	T	SEM	F	T	SEM	F	T	SEM
Feed utilisation above maintenance:									
FFE, kg FCM^{-1}	0.44	0.41	0.04	0.41	0.41	0.03	0.43	0.41	0.05
FEm, kg ECM^{-1}	0.43^{b}	0.40^{a}	0.03	0.39	0.39	0.03	0.43	0.41	0.05
DCP, g.kg FCM^{-1}	63	59	6	66	69	6	72^{b}	57^{a}	8
AAT, g.kg ECM^{-1}	41^{b}	38a	4	40	39	3	40	40	4
Calculated net energy values:									
FFE, kg DM^{-1}	0.667	0.737	0.12	0.756	0.744	0.10	0.732	0.792	0.11
FEm, kg DM^{-1}	0.935^{a}	1.049^{b}	0.12	1.094	1.120	0.12	1.019	1.081	0.15

[1)] F=meadow fescue silage, T=timothy silage, other abbreviations; See previous tables.

Generally, differences in rumen fermentation were small (Table 12) but the proportion between the different acids varied somewhat between the two groups. This caused a generally lower (C2+C4):C3 ratio for group F than for group T during Period 1. In Expt. 3 the difference was statistically significant but during Period 2 an opposite relationship between the two silages was found. Relatively little emphasis should be put on the results from Period 2 which were based on one single collection.

Table 12. Rumen pH, total amount and molar proportion of volatile fatty acids, and concentration of ammonia in rumen fluid, in Period 1 and Period 2[1)]

	Expt. 1			Expt. 2			Expt. 3		
	F	T	SEM	F	T	SEM	F	T	SEM
pH	6.90	6.85	0.15	7.06	7.01	0.18	6.73	6.61	0.17
Total acids, mmol L^{-1}	87.0	86.8	7.32	79.9	80.8	7.62	90.3	91.5	7.62
Acetic acid (C2), %	59.2^{a}	61.1^{b}	2.10	60.9	62.0	2.11	64.2^{a}	66.7^{b}	1.34
Propionic acid (C3), %	19.3	19.1	0.76	20.5	20.5	1.19	19.6^{b}	18.1^{a}	0.76
Butyric acid (C4), %	17.5^{b}	16.0^{a}	1.40	15.5	14.6	1.53	11.0	11.0	1.61
Iso-butyric acid, %	0.93	0.88	0.10	1.01	0.91	0.13	1.15	1.12	0.19
Valeric acid, %	1.71	1.51	0.53	0.90	0.88	0.26	1.61	1.50	0.18
Iso-valeric acid, %	1.35	1.34	0.29	1.08	1.00	0.25	1.74	1.72	0.19
(C2+C4):C3	3.99	4.05	0.18	3.77	3.77	0.26	3.87^{a}	4.31^{b}	0.23
Ammonia-N, mg %	12.7	13.3	2.58	13.9	13.9	3.53	21.8^{b}	19.0^{a}	1.93
Groups, Period 2:	FF+TF	TT+FT	SEM	FF+TF	TT+FT	SEM	FF+TF	TT+FT	SEM
pH	6.79	6.84	0.16	6.77	6.91	0.29	6.66	6.45	0.43
(C2+C4):C3	4.27	4.13	0.42	3.76	3.75	0.26	4.33^{b}	3.89^{a}	0.57
Ammonia-N, mg %	12.8	10.5	3.59	15.1	15.6	4.80	11.4	12.5	3.05

[1)] F, FF+TF = meadow fescue silage; T, TT+FT = timothy silage

DISCUSSION

Feed characteristics

The main difference between the two grass species was the higher buffering capacity for meadow fescue than for timothy. According to McDonald *et al.* (1991) a high buffering capacity may produce an extensively fermented silage with a relatively high concentration of organic acids and ammonia and a low true protein content. In these experiments the content of acetic and lactic acid was slightly higher and true protein lower for meadow fescue silage than for timothy silage. Similar differences between the two grass species and the silages were reported from feeding experiments with bulls (Johansen & Nordang 1993). It should though be remarked that the difference in fermentation quality was small and in Expt. 1 and 2 both silages were considered as well preserved. In Expt. 3 the generally lower DM content in the harvested grasses may partly explain the somewhat poorer fermentation quality of both silages than in Expts. 1 and 2. In Expt. 3 the high percentage of ammonia-N might reflected the low content of true protein. On the other hand, the higher percentage of ammonia-N in Expts. 2 and 3 compared with Expt. 1 was partly attributed to the ammonia present in the additive.

In Bodø meadow fescue usually reaches the stage of heading about a week ahead of timothy (A.Larsen, personal communication). Harvesting dates in these experiments meant that the two grass species were cut at approximately the same stage in Expt. 1 while meadow fescue was slightly ahead of timothy in Expt. 2 and 3. In spite of this, OM digestibility tended to be higher for meadow fescue than for timothy silage in all the experiments. This supported the results from the feeding experiments with bulls (Johansen & Nordang 1993). The differences in OM digestibility were mainly caused by the higher

CF digestibility for meadow fescue than for timothy silage (Johansen 1994). The higher OM digestibility caused the somewhat higher estimated energy values for meadow fescue silage than for timothy silage. However, the difference was lower than what might be expected from the digestion coefficients. This was mainly due to the higher amount of carbohydrates (CF and N-free extract) in timothy silage.

The amount of digestible carbohydrates highly affects the protein values for roughages calculated according to the AAT-system (Kjos 1992). In Expt. 3 the concentration of digestible carbohydrates was higher in timothy than in meadow fescue silage which partly explain the higher AAT value estimated for timothy silage. Moreover, the estimated protein degradability was slightly lower due to the lower CP content in timothy. The estimated protein degradability showed the opposite relationship between the two silages than the effective protein degradability obtained from *in sacco* (Johansen 1994). However, the difference between the two silages was relatively small and the general correlation between estimated and obtained protein degradation good.

For Mix C the estimated nylon bag degradability of CP was lower than the value obtained from *in sacco* measurements (Johansen 1994). The difference may be attributed to the highly variable protein degradability for fish meal (Mehrez et al. 1980) which was the main protein source in Mix C. Due to the low proportion of Mix C in the diets this discrepancy was not considered to affect the present results significantly. For Mix A the predicted protein degradability was in good agreement with the nylon bag measurements.

Animal performance and feed utilisation

It is well known that the digestibility of silages may change when concentrates are supplied to the ration which in turn causes responses in milk production to be less than expected (Huhtanen 1991). Although OM digestibility of meadow fescue was higher than that of timothy when silages were fed alone, Johansen (1994) found no clear difference in OM digestibility between the silage rations when 60% concentrates were supplied on DM basis. Thus, the somewhat higher milk yields in group T than in group F may be attributed to a higher actual net energy intake because of the higher amounts of concentrates consumed.

In Expts. 1 and 2 the decline in milk production during Period 1 was in accordance with the declining level of concentrate offered. However, in Expt. 3 milk yields declined very slowly. This may partly be explained by the higher number of heifers for which the concentrate amounts were not reduced. Moreover, the relatively high OM digestibility for both silages caused a generally high feeding level which also may explain the somewhat higher daily liveweight gain during Period 1 compared with the previous experiments.

The main difference between the two groups was the significantly higher milk fat percentage for animals fed timothy silage than those fed meadow fescue silage during Period 1. Similar effects were also seen during Period 2 in two of the experiments. This may partly be attributed to differences in rumen fermentation. According to Beever & Oldham (1986) the energy partitioning between milk fat secretion and body tissue synthesis may be changed towards the latter at low ratios of rumen acetic and butyric acid compared to propionic acid. During Period 1 the mean (C2+C4):C3 ratio tended to be higher for animals fed timothy silage than for those fed meadow fescue silage. This was partly supported in rumen fermentation studies in sheep fed diets with corresponding silage:concentrate ratios (Johansen 1994).

In all experiments the feed utilisation during Period 1 was in relatively good agreement with the Norwegian Standards for FFE and DCP (Breirem 1987). On the other hand, the consumption of FEm and AAT per kg ECM was lower than the standards given by Sundstøl & Ekeren (1992) and Harstad (1992). In Expt. 1 and 3 the tendency of a more efficient feed utilisation for animals fed timothy silage than for those fed meadow fescue silage was mainly due to the somewhat higher yield of FCM and ECM. Thus, energy values calculated from the milk production ranked the two silages contrary to the estimated values from *in vivo* digestibility. Neither in similar comparisons did (Hole 1985) find the expected response to a higher OM digestibility of silage from smooth meadow grass (*Poa pratensis*) than silage from timothy. Several factors may have caused the inconsistency between estimated and observed energy values for the silages. In the digestibility experiments animals were fed at maintenance level and energy utilisation is altered by feeding level. Besides, energy values estimated from *in vivo* digestibility were obtained from diets with silage fed alone while cows were offered diets with both silage and concentrates. The importance of associative effects between feeds on OM digestibility and thereby the estimated net energy values has already been discussed.

The calculated FFE values were generally lower than those estimated from *in vivo* digestibility. This corresponded well with similar comparisons in previous experiments with dairy cows (Bergheim 1979, Hole 1985, Nordang 1990). It was speculated whether the opposite relationship between estimated and calculated FEm values might be due to the requirements used which are based on data obtained from other breeds than NRF.

Voluntary intake

Among several factors which affect voluntary intake of grass silage OM digestibility, DM concentration and products of silage fermentation are considered to be the most important (Gill et al. 1988, Dulphy & Demarquilly 1990). Besides, concentrate feeding and protein content in the total ration may affect the silage intake (Thomas & Thomas 1989). Despite the slightly poorer fermentation quality of meadow fescue than of timothy silage DM intake tended to be higher from meadow fescue silage in two of the experiments, possibly due to the higher OM digestibility. In Expt. 1 the higher amounts of concentrates offered to the groups TT and FT probably depressed the intake of timothy silage. On the other hand, in Expt. 2 both the concentrate consumption and the voluntary intake of silage were the highest for animals fed meadow fescue. Only minor differences in the protein content between the rations were seen and it was considered as unlikely that differences in voluntary intake were caused by protein shortage. In Expt. 3 the generally lower DM content and the somewhat poorer fermentation quality of the silages may partly explain the depressed intake compared with Expts. 1 and 2. Also the higher amounts of concentrates offered and the infectious diarrhoea probably affected the voluntary intake in Expt. 3.

Unfortunately the voluntary intake was examined during a relatively short period with considerable variation within groups. Carry over effects from Period 1 and the low number of animals in the groups also contributed to the fact that no statistically significant differences between the main groups were found. However, it may be concluded that the feeding value (including both nutritive value and feed intake) of meadow fescue silage was no less for dairy cows than that of timothy, even when meadow fescue was ahead of timothy in morphological stage at harvest.

ACKNOWLEDGEMENTS

These experiments were financed by the Norwegian Agricultural Research Council of Norway (NLVF). The authors are indebted to the staff at Vågønes Research Station and Bodin Gård. Especially, our thanks are expressed to Mr. F.A. Almås and Mr. T. Jensen who were responsible for the practical work with silage making and animal husbandry. The authors also wish to thank Professor F. Sundstøl and Dr. F.L. Mould for reviewing the manuscript.

REFERENCES

AOAC 1980. Official methods of analysis of the Association of Analytical Chemists (W. Horwitz, ed.) 13th ed. AOAC, Washington.

Barvik, K., L. Nordang & A. Våbenø 1991. Surfôr av engsvingel og timotei til sau. Norsk landbruksforsking 5: 225-234.

Beever, D.E. & J.D. Oldham 1986. Nutrient supply and utilization. In: W.H. Broster, R.H. Phipps, C.L. Johnson (eds.): Principles and practice of feeding dairy cows. NIRD Technical Bulletin no. 8: 45-72.

Bergheim, P.I. 1979. The harvesting time of grass for silage in Northern Norway. III. Experiments with dairy cows on silage of grass harvested at different times. Meldinger fra Norges Landbrukshøgskole 58 (3).

Breirem, K. 1987. Fôrnormer. I. Storfe, 1. Mjølkekyr. In: A. Jensen (ed.) K.K. Heje Lommehåndbok for jordbrukere, skogbrukere, meierister og hagebrukere, pp. 186-187.

Breirem, K. & T. Homb 1970. Fôrmidler og fôrkonservering. Forlag Buskap og Avdrått A.S., Gjøvik, 459 pp.

Dulphy, J.P. & C. Demarquilly 1990. Digestibility and voluntary intake of conserved forage. In: G. Pahlow and H. Honig (eds.). Proceedings of a conference on forage conservation towards 2000. Landbauforschung Völkenrode, Sonderheft 123: 408-409.

Gill, M., A.J. Rook & L.R.S. Thiago 1988. Factors affecting the voluntary intake of roughages by the dairy cow. In: P.C. Garnsworthy (ed.). Nutrition and lactation in the dairy cow, Butterworths, London, pp. 262-279.

Harstad, O.M. 1992. Nytt proteinvurderingssystem for drøvtyggere, SFFL Faginfo 13: 555-560.

Hole, J.R. 1985. The nutritive value of silage made from *Poa pratensis* ssp. alpigena and *Phleum pratense*. II. Lactating dairy cows fed silage made from first cut of *Poa pratensis* or *Phleum pratense*. Meldinger fra Norges Landbrukshøgskole 64 (17).

Huhtanen, P. 1991. Associative effects of feeds in ruminants. Norwegian Journal of Agricultural Sciences. Suppl. No. 5: 37-57.

Johansen, A. & L.Ø. Nordang 1993. A comparison between meadow fescue and timothy silage. 1. Feeding experiments with slaughter bulls. Norwegian Journal of Agricultural Sciences 7: 381-399.

Johansen, A. 1994. A comparison between meadow fescue and timothy silage. 2. *In vivo* digestibility experiments and studies on *in sacco* degradation and rumen fermentation in sheep fed silage alone or with different concentrate ratios. Norwegian Journal of Agricultural Sciences 8: 75-90.

Kjos, N.P. 1992. Proteinverdien av grovfôr etter AAT-systemet. SFFL Faginfo 13: 583-587.

McDonald, P., A.R. Henderson & S.J.H. Heron 1991. The biochemistry of silage. Second Edition, Chalcombe publications, Bucks, 340 pp.

Mehrez, A.Z., E.R. Ørskov & J. Opstvedt 1980. Processing factors affecting degradability of fishmeal in the rumen. Journal of Animal Science 50: 737-744.

Mo, M. 1975. Maursyresurfôr av ettårig raigras. II. Fôring med surfôr av westerwoldsk raigras til melkekyr. Meldinger fra Norges Landbrukshøgskole 50 (4).

Nordang, L.Ø. 1990. Barley-fodder rape silage. III. Feeding experiments with dairy cows. Norwegian Journal of Agricultural Sciences 4: 179-193.

Nordang, L. 1992. Ensilering av engsvingel. SFFL Faginfo 13: 148-152.

Pedersen, A. & H. Lysnes 1991. Kort beskrivelse av analysemetoder i bruk ved Kjemisk analyselaboratorium Holt, ved kjemisk analyse i tørt plantemateriale, gras, surfôr, pressaft, husdyrgjødsel o.a. organisk prøvemateriale. Trykk nr. 3, SFL Holt, Tromsø.

Playne, M.J. & P. McDonald 1966. The buffering constituents of herbage and silage. Journal of the Science of Food Agriculture 17: 264-268.

SAS 1987. SAS/STAT™ Guide for personal computers, Version 6 Edition. SAS Institute Inc., Cary, North Carolina, 1028 pp.

Saue, O., L. Bævre & L. Vik-Mo 1978. Evaluation of the energy value of forages by aid of production experiments. Department of Animal Nutrition, Agricultural University of Norway, Reprint no. 470.

Sjaunja, L.O., L. Bævre, L. Jukkarinen, J. Pedersen & J. Setälä 1990. Measurement of the total energy value of milk fat and milk protein. Paper presented at the 27th Session of the International Committee for Breeding and Productivity of Milk Animals. Paris 2-6 July 1990.

Skovbo Nielsen, E. 1990. Fodermiddeltabel. Landsudvalget for Kvæg, Danmark.

Sundstøl, F. & A. Ekern 1992. Det nye energivurderings-systemet for drøvtyggere (FEm-systemet) og nye energinormer. SFFL Faginfo 13: 545-552.

Sundstøl, F., T. Hongslo, O. Herstad & N. Raastad 1986. Fôrverditabell for kraftfôr m.m. 7.utgave, STIL/Fôrvaretilsynet, Oslo.

Thomas, C. & P.C. Thomas 1989. Response to supplementary feeding. In: C.S. Mayne (ed.). Silage for milk production, Occasional Symposium No. 23, British Grassland Society, pp. 49-60.

Van der Honing, Y. & G. Alderman 1988. Feed evaluation systems and requirements. 2. Ruminants. Livestock Production Science 19: 217-278.

Van Soest, P.J. 1963a. Use of detergents in the analysis of fibrous feeds. I. Preparation of fiber residues of low nitrogen content. Journal of AOAC 46: 825-829.

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

Van Soest, P.J. & R.H. Wine 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. Journal of the AOAC 50: 50-55.

Webster, A.J.F., I.P. Simmons & M.A. Kitcherside 1982. Forage protein and the performance and health of the dairy cow. In: D.J. Thompson, D.E. Beever and R.G. Gunn (eds.). Forage protein in ruminant animal production. British Society of Animal Production, Occasional Publications No.6: 89-95.

Possible causes for the changing incidence of adverse flavours and taints detected in milk delivered to dairies in south-west Norway

FERGUS L. MOULD [1] & BJØRN GUNNAR HANSEN [2]

[1] The Norwegian State Agriculture Research Stations, Særheim Research Station, Klepp stasjon, Norway

[2] Rogalandsmeieriet, Klepp Stasjon, Norway

Mould, F.L. & B.G. Hansen 1994. Possible causes for the changing incidence of adverse flavours and taints detected in milk delivered to dairies in south-west Norway. Norwegian Journal of Agricultural Sciences 8: 155-163. ISSN 0801-5341.

A change in the distribution of adverse flavours and taints was observed in milk delivered to dairies in south-west Norway over the period 1986 to 1990. In an attempt to identify possible causes for these, production and management records were obtained from 102 milk producers with known taint problems and 27 "taint-free" producers during 1991-92. The occurence of "bitter" taints was strongly associated with high cell counts, mastitis, milk instability factors and concentrated calving. Poor quality silage offered during milking appeared to be the main source of "feed" taints, although the use of supplementary feeds was also considered. Marginal dietary vitamin E and selenium levels and adverse causal factors related to production of milk containing a high unsaturated fatty acid content were implicated in "oxidative" taints. The causes identified for these taints were in agreement with changes in husbandry observed since 1986 and which continued during the survey period.

Key words: Dairy cow, husbandry, management practices, milk quality, organoleptic survey.

Fergus L. Mould, Vågønes Research Station, N-8010 Bodø, Norway.

The percentage incidence of adverse flavours and taints in milk delivered to Rogaland Dairies increased between 1988 and 1992 to levels higher than those of 1986. In contrast mean values for the entire country declined (Table 1). While this may merely reflect a better detection rate, a reversal in the respective proportions of both "bitter" and "feed" taints was also observed. Over this period average annual yield per cow in Rogaland increased, similar to the rest of Norway, the use of grazed pasture and concentrates declined and the proportion of silage in the total ration increased (Table 2). There has also been a change in the monthly distribution of milk production. Traditionally herds in Rogaland were spring calving to maximise pasture utilisation, however in 1992 6.2 million litres more milk was produced outwith the grazing period (May to September) in comparison to the same period in 1986, despite the total annual production decreasing by

9.0 million litres. To identify probable causes for these adverse flavours and taints and, subsequently, reasons for their changing incidence, an initial investigation of the problem using a field survey technique was conducted. In this, production data and management practices obtained from producers covering periods where milk-organoleptic problems had been identified, were compared with similar data from a group of "taint-free" milk producers.

Table 1. Incidence of adverse flavours by taint group and mean cell counts of milk delivered to dairies in either Rogaland or the entire country (1986-1992)

	1986	1987	1988	1989	1990	1991	1992
% Incidence							
Rogaland	6.8	4.2	3.6	6.1	5.9	7.2	7.6
Norway	6.2	5.1	4.9	4.8	4.4	4.9	4.8
Taint group (Rogaland):							
Bitter	77.5	70.1	73.6	63.0	47.0	36.6	35.4
Feed	3.5	3.9	7.3	11.8	25.4	33.6	31.4
Oxidative	1.3	6.1	4.1	7.1	11.2	8.4	5.2
Miscellaneous	13.9	17.1	11.0	11.4	9.8	13.2	21.7
Sour	3.5	2.5	4.0	6.4	6.2	7.9	5.6
Other	0.3	0.3	-	0.3	0.4	0.3	0.6
Cell counts (000/ml)	230	218	199	182	192	189	188

[1] Source : Rogalandsmeieriet (1991 and 1992)

Table 2. Ration composition by feedstuff (Rogaland 1986-1992[1])

	Year						
	1986	1987	1988	1989	1990	1991	1992
Concentrate[2]	4.08	4.29	4.27	4.24	4.17	3.94	4.27
Roughage[2]	6.52	6.91	6.94	7.11	7.71	7.29	7.10
Silage[3]	51.7	47.3	50.6	48.1	49.0	52.1	52.6
Pasture[3]	40.3	41.0	38.8	32.6	34.3	31.0	28.6

[1] Sources : NOS Agricultural Statistics (1986-1992) and Rogalandsmeieriet (1991 and 1992)
[2] FE cow^{-1} d^{-1}
[3] Expressed as percentage total roughage energy intake

MATERIALS AND METHODS

The survey utilised data collected during 1991-92 from milk producers within the region covered by Rogaland Dairies. Four milk-taint classes were represented by 102 producers, i.e. approximately 55% of those identified to repeatedly deliver taint-contaminated milk. The producers were selected on both the basis of completeness of data and their willingness to take part in the survey. The taint classes - "bitter", "feed", "oxidative" and "secondary" - contained 25, 41, 14 and 22 producers, respectively and are described later. Milk taints were identified by Rogaland Dairies using a standardised organoleptic procedure in which milk samples, obtained at monthly intervals from the farm bulk tank, are held at 4°C for 48 hours prior to being raised to 20°C and examined (smell and taste) by two experienced technicians. This procedure is part of a range of tests, including protein, fat and lactose estimation, endogenous and bacterial cell counts, antibiotic contamination and feezing point analysis, which are conducted to examine milk quality. In addition 27 producers, known to have delivered high quality (taint-free, low cell count) milk for at least the last five years, were included as controls. None of these, so-called "elite" producers, had taints or off-flavours detected during the survey period. All 129 producers were members of the national organisation of dairy advisors ("Kukontrollen") and the majority of the data included were taken from the annual reports prepared for each producer. All milk producers are members of the Norwegian Milk Producers Association (NML), although at present only 85% are also members of "Kukontrollen". These reports provided information on herd structure (including size, age at first calving, calving pattern and interval and replacement policy), milk production and analysis (including fat and protein content and cell counts from individual cows) and health status (treated incidence of ketosis, mastitis and milk fever or other health disorders). In Norway each dairy cow has a health card on which all treatment administered by a veterinary surgeon is recorded. No other person is allowed either to give or record treatment, and it these data that are summarised in the health status section. The "Kukontrollen" summaries also detailed feed offered, in terms of both proportion of the total ration and energy contribution. These data were supplemented with information obtained directly from each producer regarding husbandry and forage production techniques, including conservation and utilisation. Limited feedstuff analyses meant that subjective assessments had to be made to estimate silage quality. The standard of housing and equipment and level of hygiene were also determined subjectively. Disease indices were calculated by dividing the number of recorded incidents treated per year by herd size. Due to the incomplete data, further analysis of neither health status nor disease treatment could be attempted. The contribution of pasture to total energy intake was estimated from milk production requirements less consumption of other feeds. Some of the feed values cannot be considered absolute due to normal feeding practices e.g. allocation of roughage feeds to individual cattle is not normally measured. However, all data were obtained using a similar method, they are therefore representative both in terms of quality and quantity of the feeds offered and the utilisation of different feedstuffs can be compared between groups. The data were analysed using SAS GLM procedures (SAS, 1987) to identify significant differences between the "elite" producers and each of the four taint groups, the hypothesis being that the "elite" group provided a production "blueprint" for taint-free milk and significant differences from this were indicative of possible causal factors. Differences between taint groups were not examined. The most important findings are presented in Table 3 and a difference was considered significant at $P<0.05$. P-values between 0.10 and 0.05 were taken to indicate trends.

Table 3. Difference in production and management parameters between elite producers and taint groups

			Taint			
Variables		Elite	Bitter	Feed	Oxid.	Misc.
Herd size		18.8	18.3	15.7	16.1	18.9
Mean age (years)		3.80	4.29***	4.07*	3.77	3.90
Replacement rate (%)		50.9	39.7*	44.1+	48.9	42.0+
Age 1st calving (months)		25.8	25.8	25.2	25.7	25.8
Calving interval (months)		12.2	12.4	12.2	12.3	12.4
Calving (%) :	Jan-Apr	31.2	53.5**	48.9**	38.6	45.6+
	May-Aug	37.1	30.6	27.4+	27.5	30.7
	Sep-Dec	31.6	16.0**	23.8+	33.8	23.7
Milk (%) :	Jan-Apr	34.6	26.3***	29.9*	31.3	29.0*
	May-Aug	33.2	42.2**	40.1**	36.6	39.3**
	Sep-Dec	32.2	31.5	30.0	32.1	31.7
Fat-corrected milk (kg)		6836	6078***	5892***	6687	6030***
Milk fat (%) 3.96		3.88	4.00	3.94	4.00	
Milk protein (%)		3.22	3.20	3.20	3.20	3.20
Cell count ('000/ml)		126	214***	197***	155	172*
Disease :	Mastitis	0.45	0.31*	0.26*	0.35	0
	Milk fever	0.11	0.08	0.07*	0.08	0.07+
	Ketosis	0.12	0.10	0.10	0.13	0.09
Diet % :	Pasture	17.0	20.7	22.5+	18.7	23.4+
	Concentrate	36.2	31.7*	29.8***	34.1	31.9+
	Silage	34.0	33.9	33.8	32.5	35.7
	Fresh grass	3.3	4.8	4.5	5.3	4.5
	Brassica-forages	6.6	6.5	4.0	6.7	1.4*
	By-product feeds	1.0	1.3	2.1	0.8	1.8
Feed energy (FE 100kg FCM^{-1})						
	Total	64.3	69.3**	70.8***	64.1	68.8*
	Pasture	10.8	14.2	15.9*	12.2	16.3*
	Concentrate	23.2	21.6	20.8+	21.7	21.9
	Silage	21.9	23.5	23.6	20.8	24.5+
Concentrate	: kg d^{-1}	4.3	3.6**	3.4***	4.0	3.6*
	: max kg d^{-1}	11.0	9.1**	8.4***	9.2*	8.9**
	: allocations d^{-1}	3.3	2.6**	2.2***	2.6*	2.5**
Usage %	: ≤12% CP concentrate	33.4	69.2	67.5	42.9	45.5
	: >12% CP concentrate	66.6	30.8	32.5	57.1	54.5
	: min-vit supplement	31.6	23.8	17.2	9.1	20.0
	: wilted silage	53.8	34.6	35.1	35.7	22.7*
Silage	: quality [2]	1.00	0.84	0.63***	0.89	0.86
	: appearence[2]	1.00	0.84	0.57***	0.79	0.76*
	: before milking (%)	48.1	42.3	48.7	64.3	54.5
	: during milking (%)	3.7	26.9*	33.3**	14.3	45.5***

Table 3. contd/.

Variables		Taint			
	Elite	Bitter	Feed	Oxid.	Misc.
Additive (%) : Formic acid	77.8	61.5	52.5*	64.0	59.1
: Foraform [3]	22.2	23.1	22.5	14.3	22.7
: Microbial [4]	0	7.7	10.0	14.3+	4.5
Hygiene (housing) [2]	0.95	0.74	0.67*	0.91	0.66*

Significance of difference between elite producers and taint groups
+ P<0.10, * P<0.05, ** P<0.01 and *** P<0.001
[1] : Defined in text; [2] : 1 = good, 2 = poor; [3] : Norsk Fôrkonservering A/S;
[4] : Apothekerns Laboratorium a.s./ Ewos)

RESULTS AND DISCUSSION

When interpreting the results from such a survey a number of problems occur. Multiple causes for the same taint result in vastly different production or management variables occurring within a taint group, while some milk taints could be placed in more than one group. There are also occasions where associated variables appear initially to be disparate. For example the "elite" producers were found to have both a significantly (P<0.001) lower cell count but a higher mastitis index than the other producers. From this it is assumed that the "elite" producers are not only more adept at identifying and treating mastitis but also in preventing high-cell count milk from entering the bulk tank. The reverse, a high cell count but low mastitis index, suggests that a number of mastitis incidents are either not observed or remained untreated.

Bitter taints

These milk taints included those described as harsh, bitter or salty. The herds in this group, in comparison to the "elite" herds (Table 3), were low yielding, composed of older cows, with a low annual replacement rate and slightly extended calving interval. A number of possible causes for these taints were identified. Firstly the milk had a significantly (P<0.001) higher mean cell count (214,000 ml^{-1}) than the "elite" herds (126,000 ml^{-1}) and, as cell counts above 250,000 ml^{-1}) are generally considered as indicative of mastitis (Lindström et al, 1981), this suggests, despite the low mastitis index, that a high proportion of cattle in this group were mastitic. High cell count milk is known to be less stable as both endogenous and bacterial lipases cause an increase in the free fatty acid (FFA) content (Holmes and Wilson, 1984). Rancid, bitter flavours are usually detected with FFA levels above 1.3 meq. $100g^{-1}$ milk lipid (NML, 1987). Mastitis can also produce a salty taste due to increased milk sodium, chlorine and serum protein levels (Whittemore, 1980). The close relation between the decreased occurrence of bitter taints and the reduced incidence of mastitis (lower cell counts) before and during the survey period (Table 1) further implicates the involvement of mastitis as a causal factor for these taints. Herd age may also have an effect as both cell counts and milk serum protein increase with age. A bitter taint is also associated with milk produced towards the end of the lactation period, but this does not normally cause a problem if the calving pattern is spread. In this taint group, however, calving was concentrated with 51.3% of these occuring during the period January to April and, correspondingly, the proportion of milk produced during this period lowest (26.3%). These values were both significantly different from the elite group and higher and lower, respectively, than those observed for any of the groups during any period. It has also been established that energy deficient diets are associated with an increased incidence of bitter flavours in milk due to the disruption of the lipoprotein membrane surrounding the milk fat globule (Ekern et al, 1977). While energy levels appear sufficient it is interesting to note that this taint group had the lowest inclusion rate of "high" protein concentrate (+12% crude protein) offered either alone or in combination compared with all other groups, and especially the "elite" group. Disruption can also occur if milk freezes during chilled storage (NML, 1987), however this could not be confirmed with the available data.

Feed taints

These taints generally result from contamination of milk by feed flavours either directly (air-borne) or via the blood /milk barrier following ingestion of material (e.g. fishmeal) or from digestive by-products. The producers in this taint group had the smallest herds with the lowest yields ($P<0.001$) (Table 3). They utilised a greater proportion of pasture and fresh grass and offered a significantly ($P<0.001$) lower proportion of concentrate feed compared to the elite group, partly replacing it with brassica forage crops and by-product feeds. However poor ensiling techniques resulted in silage of significantly lower ($P<0.001$) quality compared to the "elite" group. Three causes for feed taints were implicated. Silage was offered during milking by 33.3% of the producers in this group, significantly ($P<0.01$) more in comparison with the elite group (3.7%), resulting in air-borne contamination of the milk. The problem was enhanced by both the poor quality of silage offered and the lower ($P<0.05$) standard of hygiene. Diets deficient in energy have produced flavours classified as "feed" taints, although it is not considered that this occurred here. Direct air-borne taints (McDonald et al. 1988) or fermentation end-products of the glucosides found in brassica and crucifera crops have also been identified as causal factors (NML, 1987). However, due to the low levels offered, it is unlikely that they had any observable effect.

Oxidative taints

In terms of production and management parameters this group was similar to the "elite" producers except that herd size, age and milk yield were lower and the incidence of ketosis highest (Table 3). Oxidative taints, often associated with milk which has been exposed to sunlight, result from the autolysis of unsaturated fatty acids to aldehydes and ketones. This most commonly occurs in antioxidant deficient milk or where the fat globule membrane has been physically or chemically disrupted. The vital rôles of vitamin E and selenium, as "antioxidants" preventing this reaction are well documented (e.g. Charmley et al, 1993). Milk from high yielding cows, those offered a high level of concentrates or cows in their first or second lactation, contains a high proportion of unsaturated acids, and is therefore less stable and more prone to oxidation (NML, 1987). All these production factors were present in this taint group and the vitamin E / selenium status of these herds has, therefore, to be suspect. Soils in Norway are deficient in selenium (Wu and Låg, 1988) and as a result animal production based on domestic feeds will always be exposed to the risk of marginal or deficient selenium levels (Øvernes, 1993). A survey conducted in early 1992 found that the average blood selenium levels in Norwegian dairy cows was low (16 $\mu g\ ml^{-1}$). In addition about 15% of the cattle were below the accepted marginal level of 10 $\mu g\ ml^{-1}$ and lower than average levels were found in Rogaland (Øvernes, 1993). While fresh forages are high in vitamin E, feedstuffs such as hay, concentrate and root crops all contain low levels (Hakkarainen and Pehrson, 1987; Frøslie et al. 1989). Poor quality silage, especially produced from late-cut, stemmy material is also low. During hay production vitamin E content falls rapidly and losses of up to 90% have been recorded (McDonald et al. 1988). Wilting grass prior to ensiling over an extended period under adverse conditions, will probably have a similar effect. The producers in this group used a low pasture input, offered brassica forage crops, and had both the highest proportion and daily allocation of concentrate of all the taint groups. No difference in the type of concentrate offered was found. In comparison with 32% of the "elite" producers, only 10% of the producers in this group utilised a vitamin-mineral supplement, the lowest inclusion rate of all the taint groups. The combination of these factors would suggest that these diets were deficient or at least marginal in vitamin E / selenium and was the probable causal factor in the production of oxidative taints.

Secondary taints

This group contains those milks in which taints and adverse flavours caused by a wide range of factors including those associated with poor animal and housing hygiene, chemicals, detergents etc. are placed. Due to both the range of possible causes and wide variation of production and management variable within this group (Table 3), no single factor could be determined. It is also very possible that a number of taint incidents should have been classified in one of the other groups. Poor hygiene was identified on a number of occasions but it is more appropriate that the factors responsible for these taints are investigated on an individual incident basis.

CONCLUSIONS

The causal factors identified for the "bitter", "feed" and "oxidative" taints are in agreement with husbandry changes observed since 1986. Improved husbandry has resulted in reduced cell counts and the distribution of milk production has altered from pasture-dominated to confined feeding and an increase in silage utilisation. This was reflected in the decreased incidence of "bitter" taints and the increased occurence of "feed" taints especially where ensiling techniques were poor. "Oxidative" taints appear to be related to factors affecting the level of unsaturated fatty acids in milk and the provision of adequate dietary vitamin E and selenium. This survey should be considered as an initial investigation of the problem of milk taints, as it indicates a number of areas for further research. In particular the link between milk yield, concentrate usage, dietary vitamin and trace element levels, the degree of milk fat saturation and oxidative taints; the relationship between feed-taints and silage quality, where detailed feed analysis is required and the interaction between mastitis, production diseases such as ketosis and lactation phase in the production of bitter flavours.

ACKNOWLEDGEMENTS

The authors are indebted to the staff of Rogaland Dairies for collecting the field data and those producers who allowed their production records to be used in this survey.

REFERENCES

Charmley, E., J.W.G. Nicholson & J.A. Zee 1993. Effect of supplemental vitamin E and selenium levels and control of oxidised flavour in milk from Holstein cows. Can. J. Anim. Sci. 73: 453-457.

Ekern, A., O. Skrøvseth, & H.N. Astrup 1978. Innvirkningen av fôringa på kvaliteten av leverandørmelka. Symposium om melkeråstoffeets kvalitet, 13.-14. nov. 1978, Norsk Meieriteknisk Forening. Stensiltrykk nr. 89. NLH, Ås.

Frøslie, A., U. Nymoen, & L. Bævre 1989. Vitamin E i noen norske grovfôrslag og kraftfôrråstoffer. Norsk landbruksforsking 3: 233-239.

Hakkarainen, J. & B. Pehrson 1987. Vitamin E and polyunsaturated fatty acids in Swedish feedstuffs for cattle. Acta Agric. Scand 37: 341-346.

Holmes, C.W. & G.F. Wilson 1984. Milk Production from Pastures, 319 pp. Butterworths, Wellington, New Zealand.

Lindström, U.B., H. Kenttämies, J. Arstila & B. Tuovila 1981. Usefulness of cell counts in predicting bovine mastitis. Acta Agric. Scand. 31: 199-203.

McDonald, P., R.A. Edwards & J.F.D. Greenhalgh 1988. Animal Nutrition, 4th Edn., pp 543. Longman Group Ltd, England.

Norske Melkeprodusenters Landsforbund. 1987. Lukt-smaksfeil i leverandørmelk, pp 32. Oslo, Norway.

Norwegian Official Statistics, Agricultural Statistics 1986-1992. Oslo, Norway.

Rogalandsmeieriet Årsmelding og Rekneskap 1991 & 1992. Klepp stasjon, Norway.

SAS 1987. SAS Institute Inc. SAS/STAT Guide For Personal Computers, Version 6 Edition. SAS Institute Inc., Cary, NC. pp 1028.

Whittemore, C.T. 1980. Lactation of the Dairy Cow. pp 94. Longman Group Ltd, England.

Wu, X. & J. Låg 1988. Selenium in Norwegian farmland soils. Acta Agric. Scand. 38: 271-276.

Øvernes, G. 1993. Selenium supplementation in ruminants. Norw. J. Agric. Sci. Suppl. 11: 199-203.

NORWEGIAN JOURNAL OF AGRICULTURAL SCIENCES

INSTRUCTIONS TO AUTHORS

THE MANUSCRIPT

The manuscript shall be typewritten on one side of the paper only. It shall be double spaced and have margins of at least three centimetres. Each of the following elements of the manuscript shall begin on a new page: (1) the title, (2) abstract, (3) the text, (4) summary, (5) list of references, (6) tables, (7) figure legends.

The pages shall be numbered consecutively beginning with the title page.

Articles will usually be organized as follows: (1) introduction, (2) materials and methods, (3) results, (4) discussion and (5) summary. Up to three grades of headings can be used to divide up the text. Articles must not exceed 20 manuscript pages, and two copies should be submitted to the managing editor.

TITLE PAGE

The title page shall contain:

1. A precise but brief title. A subtitle may be used, but also this should be brief.
2. A short title of not more than 40 letters and spaces for use as a running headline.
3. The full names of all authors.
4. The name and adress of the institution and/or departments in which the research was carried out. Names of institutions shall be in English.

ABSTRACT AND KEYWORDS

Use only keywords listed in Agrovoc. The abstract must not exeed 150 words, corresponding to 10 lines in print. The abstract shall briefly describe the purpose/question of the experiment/research project, the method, results and the principal conclusions drawn. Use only standard abbreviations in the abstract.

Do not use more then 10 keywords and list them alphabetically. Indicate the name and adress of the author to whom correspondence, proofs and offprints should be sent.

ACKNOWLEDGEMENTS

Acknowledgement shall be made only to persons who have contributed substantially to the results of the research. Authors are responsible for ensuring that individuals named are recognized as being identified with the results and conclusions described in the article.

TABLES

Each table shall be typed double spaced on a separate sheet of paper. They shall be numbered consecutively with Arabic numerals and have a concise descriptive heading. Abbreviations in tables shall be explained in footnotes, using the following symbols in this order: [1]), [2]), [3]), [4]), [5]).

Avoid horizontal and vertical rules (lines) in tables. Tables shall be self explanatory as far as possible without the reader having to refer to the text.

FIGURES

All illustrations, line drawings as well as photographs, shall be considered as figures. Figures shall be numbered consecutively with Arabic numerals. Letters, numerals and symbols must stand out clearly and be in relation to each other. Make sure they are large enough to take reduction. Before preparing line drawings the author should decide wether they are to be of 1 column, 1½ columns, or 2 colums width so that lettering, etc., after reduction, will be the same size on all drawings. Photographs should be submitted as near to their printed size as possible. If enlargement or reduction is significant in an photograph, the scale should be given on the back and not in the legend. The legend should make the general meaning comprehensible without reference to the text. Figure legends shall be typewritten together on one or more sheets of paper.

REFERENCES

Reference indicators in the text will follow the Harvard style, with the author's name and the year of publication: Høeg (1971), or (Høeg 1971). The text reference indicator to a work by two authors is given by naming both authors: Oen & Vestrheim (1985) or (Oen & Vestrheim 1985). If three or more authors, the text reference indicator is given by adding et al. to the first named author: Aase et al. (1977) or (Aase et al. 1977).

In the list of references authors' names are listed alphabetically. Two or more works by the same author are listed chronologically and if published in the same year must be distinguished by the appendage a, b, etc. after the year of publication. The corresponding appendage must also appear in the text indicator.

Høeg, O.A. 1971. Vitenskapelig forfatterskap. 2. utg. Universitetsforlaget, Oslo. 131 s.

Oen, H. & S. Vestrheim 1985. Detection of non-volatile acids in sweet cherry fruits. Acta agriculturae scandinavia 35: 145-152.

Strømnes, R. 1983. Maskinell markberedning og manuell planting. Landbrukets årbok 1984: 265-278.

Uhlen G. 1968. Nitrogengjødsling til ettårig raigras. Jord og avling 10(3): 5-8.

Aase, K.F., F. Sundstøl & K. Myhr 1977. Forsøk med strandrøyr og nokre andre grasartar. Forskning og forsøk i landbruket 27: 575-604.

Notice that:

- Only the first named author's initials and surname are inverted.
- The ampersand symbol is used between author's names.
- The date after the author's name is the year of publication.
- The issue number is given in parentheses after the volume number and only in cases where each issue of a particular volume begins on p. 1.
- A colon is used before page numbers in journal articles.
- The year of publication suffices where the volume number is missing.
- In references to a book, the name of the publisher and the place of publication are given after the title of the book. If more than one edition of a book has been published, the edition used must be indicated. The number of pages should be given.
- It is recommended not to abbreviate the titles of periodicals, but in cases where this has nevertheless been done, abbreviations should be in accordance with the World List of Scientific Periodicals and/or BUCOP British Union Catalogue of Periodicals.

ABBREVIATIONS

Use standard abbreviations where available, otherwise abbreviations given in the text should be explained at their first mention. Quantities and units of measurement shall be in accordance with «Systéme International d'Unites« (SI).

PROOFS

Page proofs will be sent to the author for proofreading. They should be read immediately and returned to the journal's editorial office. Printer's mistakes should be marked with a blue pen and any possible changes made by the author against the manuscript in red. The second proof will be checked at the editorial office.

OFFPRINTS

An order form for offprints, plus price list, will be sent to authors along with the first proofs. The author(s) will receive 50 offprints free of charge. This form should be filled out and returned with the first proofs to the editorial office.

Norwegian Journal of Agricultural Sciences
Vol. 8 1994 No. 2

Content Page

NLH-Fagtjenesten, Moerveien 12, 1430 Ås, Norge
Agricultural University of Norway, Advisory Service, Moerveien 12, N-1430 Ås, Norway

Indre Smaalenenes trykkeri A/S, Mysen