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Wageningen

DETERMINATION OF GROSS PRODUCTION CURVES FOR GRASSLAND FROM EXPLOITATION DATA

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1. INTRODUCTION

To know the ways in which grassland production is achieved in actual farming, during two years a grassland administration has been maintained on about twenty holdings in the district of Salland, Overijssel. From exploitation and yield data of the separate fields net production curves could be constructed.

Yield curves for grassland were needed in order to check the results of investigations into the possibility of deriving along mathematical ways the relation between grass yield and growth conditions. Contrary to usual methods, merely connecting final production with one or more growth factors to be studied, using data from experimental fields, the mathematical model is based on biological laws accounting for the flux of ions in liquid and gas towards and within the plants. One of the essential advantages of the mathematical model is, that crop growth is calculated for small time intervals and the influence of yield decreasing conditions, such as insufficient moisture or oxygen supply, can be accounted for on any moment of the process of growth.

Since results of investigations, based upon purely theoretical considerations, ever require careful checking, the yield curves for limiting growth obtained by application of growth formulae had to be compared with production curves representing crop growth under actual farming conditions.

In descriptions of fundamental growth processes, results are mainly expressed as dry matter production of the total plant mass, roots included. In actual net grassland production, however, produced quantities are either given as starch equivalents or digestible crude protein. Consequently attention had to be given to conversion of net

Z.W. = S.E

ds = dm.

starch equivalents production into gross dry matter production. In the following pages starch equivalents will be abbreviated s.e. and dry matter d.m.

2. NET S.E. PRODUCTION OF GRASSLAND

2.1. Exploitation schemes

The net s.e. production of grassland is not confined to growth conditions on the field concerned i.e. soil profile, moisture condition, fertility etc. In connection with rotation systems of grazing and mowing, the length of the intervals between one cycle and the next will be confined by the conditions of all participating fields. This means, the net s.e. production is not exclusively depending on the production capacity of the grassland, but will be defined to a considerable extent by the farmers exploitation techniques. For that reason the returns, i.e. the gross/net ratio, will be particularly a matter of the farmers skill and ingenuity to adapt his exploitation to prevailing non-optimal growing conditions.

Fig. 1a and b show grassland exploitation schemes of two arbitrary Salland holdings in 1969. In table 1 the calculation of the s.e. production of one of the fields of these holdings is given. As an example that field has been chosen, where in comparison with all other parcels of the total number of farms involved, the highest yield was scored.

In this case, exploitation of the field can be considered to exist of six separate cycles viz. mowing for hay making (1), grazing (2), again mowing for hay making (3) followed by three times grazing (4, 5 and 6)) with intervals in between.

Methods of designing optimal exploitation schemes are often based on certain levels of s.e. production called 's.e. supply' of the field required for each separate cycle.

In projects for optimal grassland farming for instance, it is taken as a rule that no mowing or grazing will take place unless a certain amount of dry matter has been produced, that is considered

Table 1. Calculation of net s.e. production; farm 10, field 7, 1969

a. Exploitation cycles	1st	2nd	3rd	4th	5th	6th
b. Nature of cycles	mowing	grazing	mowing	grazing	grazing	grazing
c. Date of cycles	8/6	28/6-3/7	4/8	3/9-10/9	29/10-7/11	7/11-16/11
d. Length of cycles (days)	-	5	-	7	9	9
e. Intervals between successive cycles (days)	20	32	30	49	-	
f. Growth periods	1/4-8/6	8/6-3/7	3/7-4/8	4/8-10/9	10/ 9-7/11	7/11-16/11
g. Length of growth periods (days)	69	25	32	37	58	9
h. Grazing stock (livestock units)	-	13	-	11	10	1.2
i. Net s.e. production (s.e.)	750	444.60	750	526.68	615.60	68.31
j. Acreage of field (ha)	0.50	0.50	0.50	0.50	0.50	0.50
k. Net s.e. prod. (s.e.ha^{-1})	1500	889.20	1500	1053.36	1231.20	136.62
l. Cumulative net s.e. prod. (s.e.ha^{-1}	1500	2389.20	3889.20	4942.56	6173.76	6310.38
m. Mean net s.e. prod. (s.e.ha^{-1}day^{-1})	21.74	35.55	46.87	28.49	21.22	15.17

FARM no 1
Exploitation scheme
(1969)
Mowing and grazing

M=mowing
S=sowing

48=number of stock
– = milking cows
y= yearlings
c = calfs
a b c = joined fields

(no N gifts inserted)

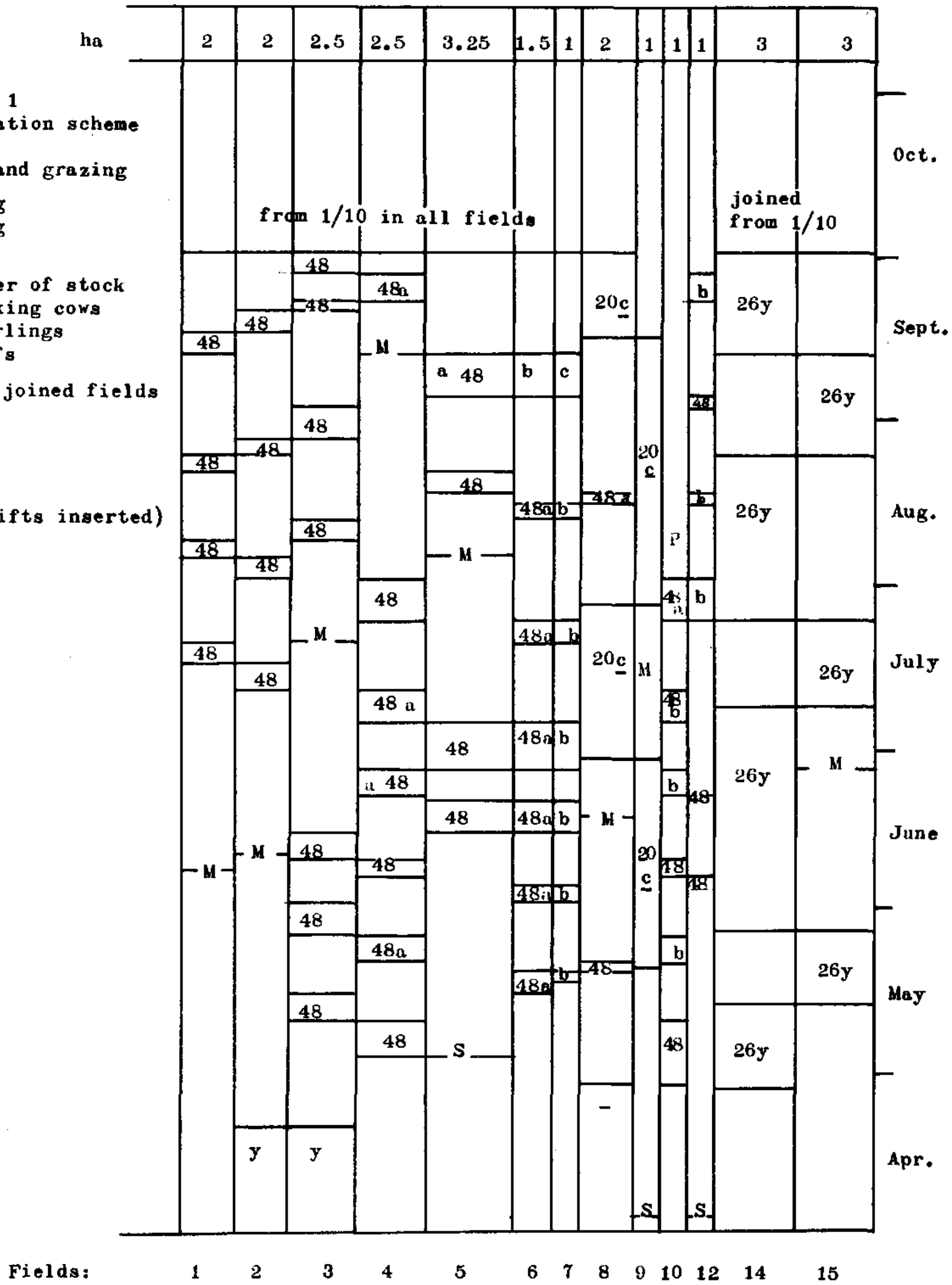


FIGURE 1 a

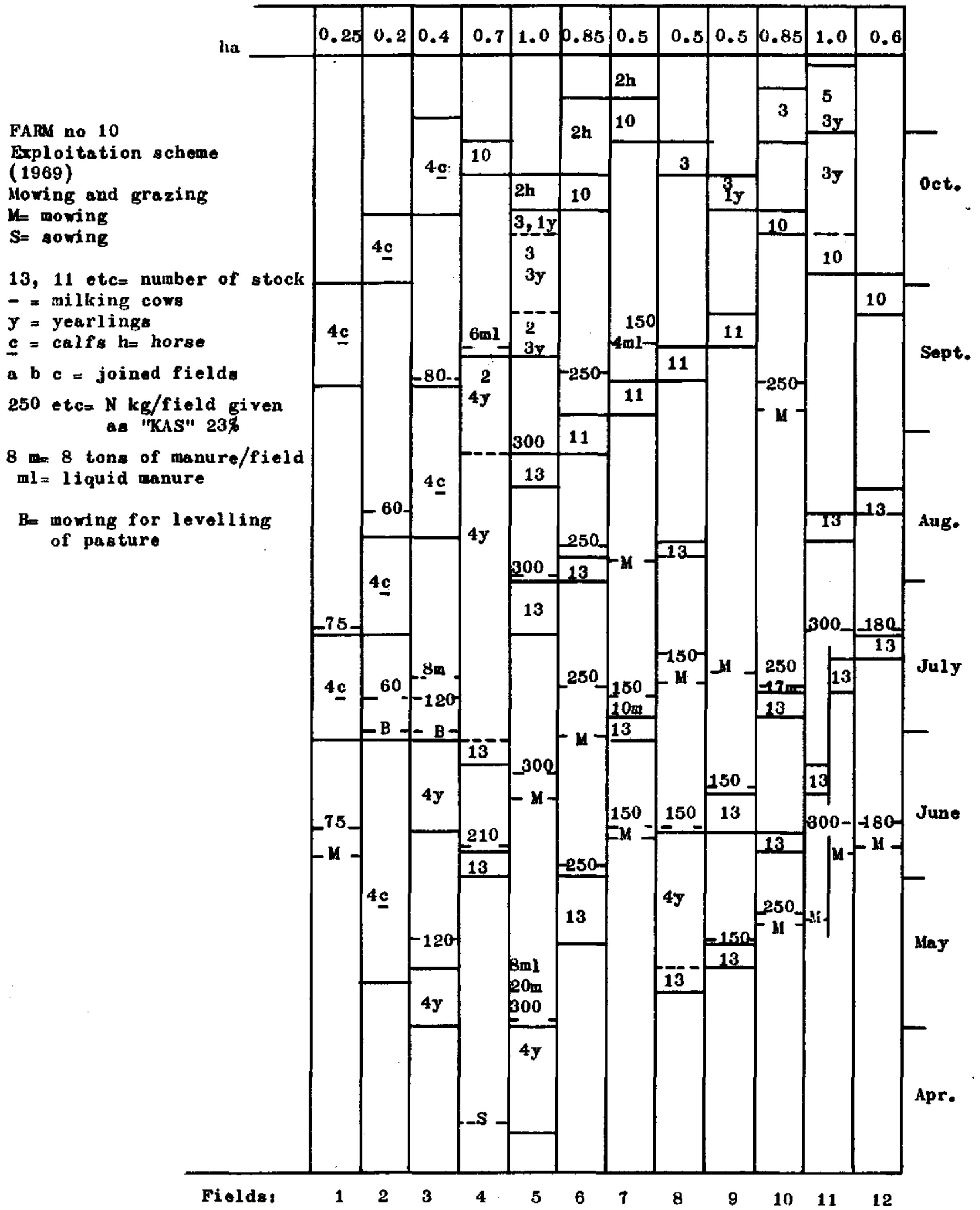

FARM no 10
Exploitation scheme
(1969)
Mowing and grazing
M= mowing
S= sowing
13, 11 etc= number of stock
- = milking cows
y = yearlings
c = calfs h= horse
a b c = joined fields
250 etc= N kg/field given as "KAS" 23%
8 m= 8 tons of manure/field
ml= liquid manure
B= mowing for levelling of pasture
ha
0.25
0.2
0.4
0.7
1.0
0.85
0.5
0.5
0.5
0.85
1.0
0.6
Oct.
Sept.
Aug.
July
June
May
Apr.
Fields:
1
2
3
4
5
6
7
8
9
10
11
12

FIGURE 1b

sufficient to justify the execution of the cycle intended (WIELING, 1973). The length of the intervals between the start of one cycle and the end of the preceding one therefore, is an indication of the production capacity of the field in the course of the growing season under the prevailing growing conditions.

2.2. Mowing

The first cycle (mowing), took place on June 8th. If it is accepted that grass growth starts about April 1st, the first growing period runs from that date to June 8th. This means that it took the grassland 69 days to achieve a s.e. production as obtained on June 8th. The quantity of product harvested has been taken here at 1500 s.e. per ha, which is considered standard for a mean cut (GARMING, 1967). In cases where an estimation of the quantities of hay or silage, either given in number of bales of known weight or calculated from the dimension of the silage pit was obtained, the s.e. production per cut could be established more accurately, using data concerning mean s.e. content of hay and silage provided by the Central Bureau for Fodder in the Netherlands.

2.3. Grazing

The share of grazing in the total net s.e. production has been calculated by multiplying the product of the number of livestock and the length of the grazing period in days by a standard for the daily uptake of starch equivalents per livestock unit, abbreviated $se.lu^{-1}$. This implies a simplification compared with the investigations by the Netherlands Agricultural Extension Service and the Experimental Station for Animal Husbandry in Wageningen a.o., where the net production of grassland is derived more accurately from 'maintenance', that is fodder required for performing the functions of life, from milk production, increase of weight of the stock and number of calfs being born during the grazing season. Results are similarly expressed in starch equivalents according to the standard of 'Geith', and the total production is obtained by simply adding the results of the successive activities.

The reason why this elegant procedure was not followed in our case was, that the aim of the investigations dit not require a suchlike accuracy and moreover, repeated weighing of animals and products would mean a considerable increase in time for the investigation.

The standard for daily uptake of s.e. during grazing, applied in our investigations has been calculated from data of GARMING (1967), which are based on information from the same three groups of experimental farms that served the more detailed analysis described above viz. 'model farms', nitrogen test farms and a sample of farms taken at random for grassland production research in the Netherlands.

It has been found, that for well-producing dairy cows the uptake amounts to 6.84 s.e. per grazing day. This can be checked as follows:

Milking cows and cows in calf with a production capacity of 4000-4750 kg of milk 4 % of fat are reckoned at 1.1 livestock unit (l.u).The annual fodder requirement per l.u. amounts to 2300 s.e. and consequently per dairy cow to 2530 s.e. The grazing season averages 185 days viz. from 1/5 to 1/11 and the fodder requirement during the season amounts therefore to 1265 s.e. which is 6.84 s.e. per grazing day. For other cattle the fodder uptake by grazing then amounts to 6.21 s.e. per day. Conversion factors for livestock units are: calfs under 6 months 0.2, over 6 months 0.4, yearlings, 1-2 years 0.5, heifers over 2 years, in calf, 0.7. These standards have been applied with respect to the 2nd, 4th, 5th, and 6th exploitation cycle. The net s.e. production for each of these grazing periods which is given in the horizontal line indicated by f., is obtained by multiplication of the number of stock converted to l.u. with the length of the period in days and the standard for s.e. uptake. To find the production per ha, results per field have to be divided by acreage in ha. In case several fields have been temporarily united to one grazing lot, which often occurs, it is assumed that participating parcels will be grazed proportionally and the total production may be divided by the total acreage. Actually, however, joining to bigger grazing units often suggests a certain disproportion in a generally low levelled fodder supply of the separate fields and the cattle is supposed to scratch up their required starch equivalents somewhere on the enlarged area. One may trust, however, that scant inaccuracies will cancel out in the average.

2.4. Production periods

Production periods proper, given in table 1 line f, are supposed to start the day after one exploitation cycle is finished and to end at the end of the next. Consequently it is accepted that during grazing the grass will still be growing. Since the rate of grazing, however, will excell the rate of growing, the s.e. supply of the field at the start of the grazing period, added to the production during grazing, is supposed to be finished at the end of that period. Therefore the length of any production period is considered to be the sum of the interval between two successive exploitation cycles and the length of the last one. Definition of the production period is required to get an idea of the mean net production rate during exploitation. The production rate is given in table 1 line m. It should be emphasized beforehand, however, that the net production rate is no standard for growth rate, since growth is similar to gross production i.e. production of total plant mass. Ending a grazing period does not necessarily imply complete consumption of all s.e. supply of the field involved. For the height of the grass in another field to be grazed may induce to remove the cattle to that field before the previous one has been finished. Delay would cause considerable losses as a result of grazing in grass being too high. In this case net production will be decreasing notwithstanding high gross production levels (BOSCH, 1956). Summation of the net s.e. production obtained through the successive exploitation cycles renders the cumulative production curve presented in fig. 2.

3. SHAPE OF THE NET PRODUCTION CURVE

In the series of elaborations of the exploitation data it was found that the shape of the net production curves rather diverges, depending on the succession and the nature of the separate exploitation cycles. Reconstruction of the gross yield from net production curves requires investigation into nature and cause of this phenomenon. In the previously chosen example given in fig. 2, a fluent free hand curve could be drawn through the observations and a satisfying

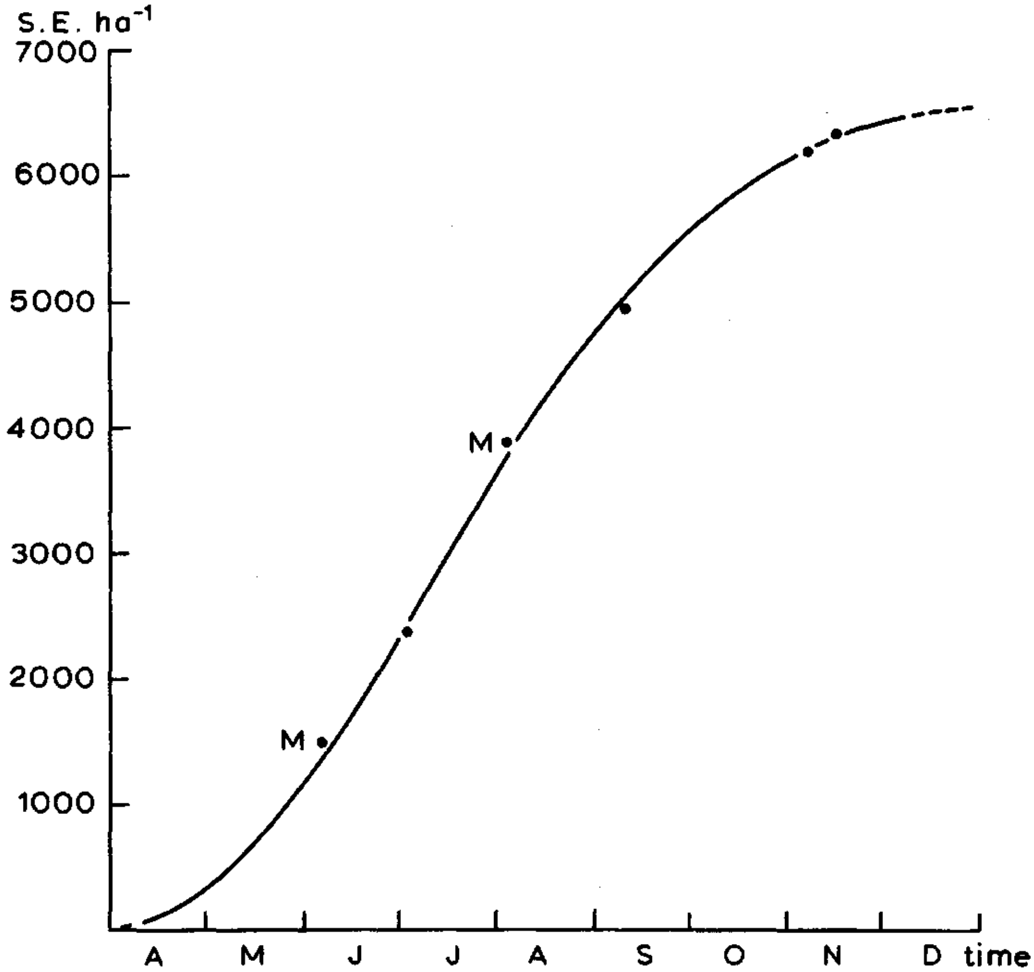


Fig. 2. Cumulative net s.e. production curve; farm no. 10, field 7 (see fig. 1b)

Example of a well producing field in 1969; sandy soil, humic

M = mowing for hay making

S.E. = starch equivalents

N-level = 297 kg/ha

graphical adjustment could be achieved. The reason is that the relatively high production level of this field makes the grazing results with the given favourable intervals to fit well in the curves course. In most cases where mowing and grazing are alternating it will be different. Grassland exploitation by means of grazing only, however, will show a fluent S-shaped course of the net s.e. production almost without any exception. The upwards bend marks the initially slow, then ever faster growth in spring, while the central part, seemingly about straight, represents the maximal production rate in summer, often considered practically constant, though actually the curve is never straight at all. The turning of the curve to a horizontal course in late summer and fall demonstrates the decreasing production rate as a result of decreasing day length and temperature. Examples are given with fig. 3 and 4.

The difference between grassland and arable crops is, that the latter without exception have to be considered annual, no matter whether they are actually of that nature like cereals and potatoes, or in fact perennials like beets, whereas grassland is ever treated as perennial crop. Arable crops, undisturbed growing on, will go through a process of ripening which accounts for the S-shaped bending towards a horizontal asymptote for maximal production. Grassland, however, will be periodically harvested and after each cut will make a new start. The growing process for each separate cycle, however, is never allowed to proceed for beyond the point where ripening starts,since starch as well as protein content are known to decrease rapidly in case the optimal moment for cutting is surpassed.

The decreasing growth rate demonstrated by the bending curves for cumulative net production of fig. 3 and 4, therefore, is no matter of ripening, but merely of regrowth slowing down.

In fact, under conditions of undisturbed growth, ripening of grass would start already in early summer, for instance during the 1st week of June. Before this can happen, however, either grazing or mowing takes place whereafter renewed growth starts. The net production curves of fig. 2 - 4, which have been drawn as fluent, free hand curves are actually built up of smaller parts in which the process of slowly starting growth in spring is repeating itself accelerated

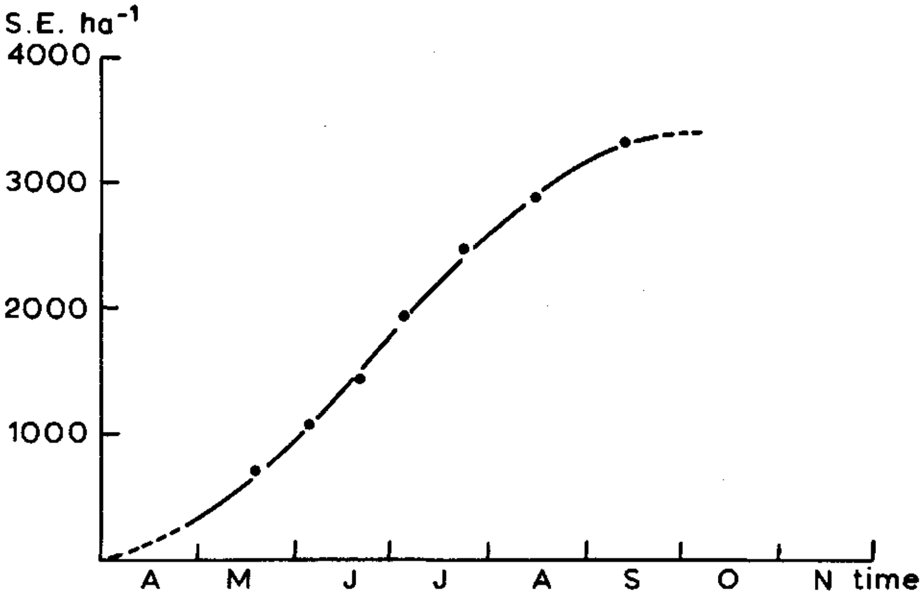


Fig. 3. Cumulative net s.e. production curve; farm no. 1, field 6 (1969), sandy soil.

Example of a field merely being grazed; sufficient moisture supply; stock: milker

S.E. = starch equivalents

N-level = 127 kg/ha; standard S.E. = 3389, actual S.E. = 3318

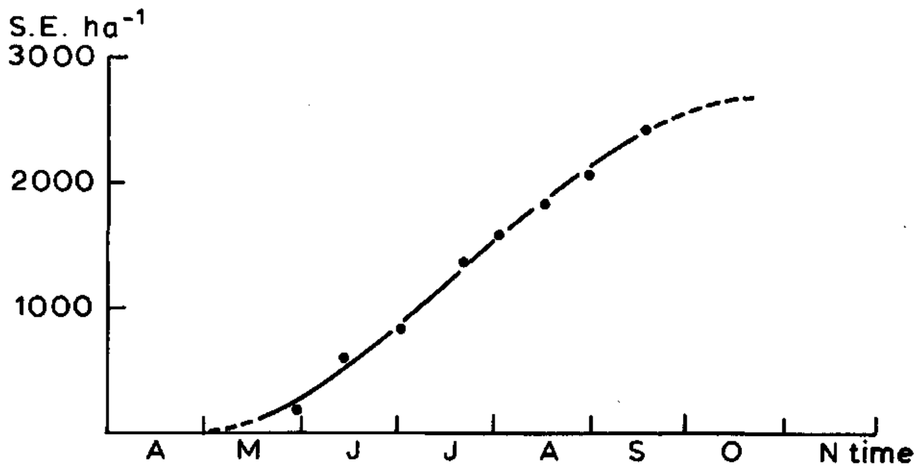


Fig. 4. Cumulative net s.e. production curve; farm no. 2, field 9 (1969), sandy soil.

Example of a field merely being grazed; dry conditions.

Stock: calfs and yearlings

Low production level

N-level = 214 kg/ha; standard S.E. 3984, actual S.E. = 2727 after each operation. The picture therefore would be more according to what actually happens, if drawn as in fig. 5. The reason why these smaller sections never reach the point where the bending towards a horizontal course starts is, that in case of grazing, the grass will be trodden upon and more will be lost as the grass will be higher. In case of mowing, the grass will recover more slowly as it is cut later, i.e. as it is allowed to grow older. Moreover the s.e. content of the product harvested will be decreasing. So there is a double reason for the farmer to avoid intervals becoming to long, and consequently the shape of the separate sections of the growth curve will be as indicated. The trend mentioned is showing very clearly in case mowing as first activity is followed by a number of successive grazing activities under non-optimal conditions. In this case a picture emerges as given in fig. 6 en 7.

The first part of the net production curve takes the shape of a compound interest curve. The growth rate increases gradually according to a growing assimilation potential, created by the increase of total leaf surface, increasing day length and higher temperature. The grass will be mown for hay or silage making before growth will be slowing down as a result of ripening. Regrowth takes place under less favourable conditions, which fact is responsible for the kink in the curve at M. Grazing periods to follow, eventually interrupted by a repeat of mowing, will fit logically in the flattened S-shaped course of the second stage of the production process.

4. RELATION BETWEEN NET PRODUCTION AND GROSS YIELD

With respect to the relation between gross yield and net production, much has been written but no definite solution given so far. By some authors they are discussed as two separate, mutually independent phenomena. BOSCH (1956) notes: 'Net production gives an impression of the quantities harvested, not of the fields production capacity'. For 'production capacity' one may fill in 'gross production'. A definition by WIELING (1972) reads: 'The net production of grassland is the resultant of the cattles production capacity, the

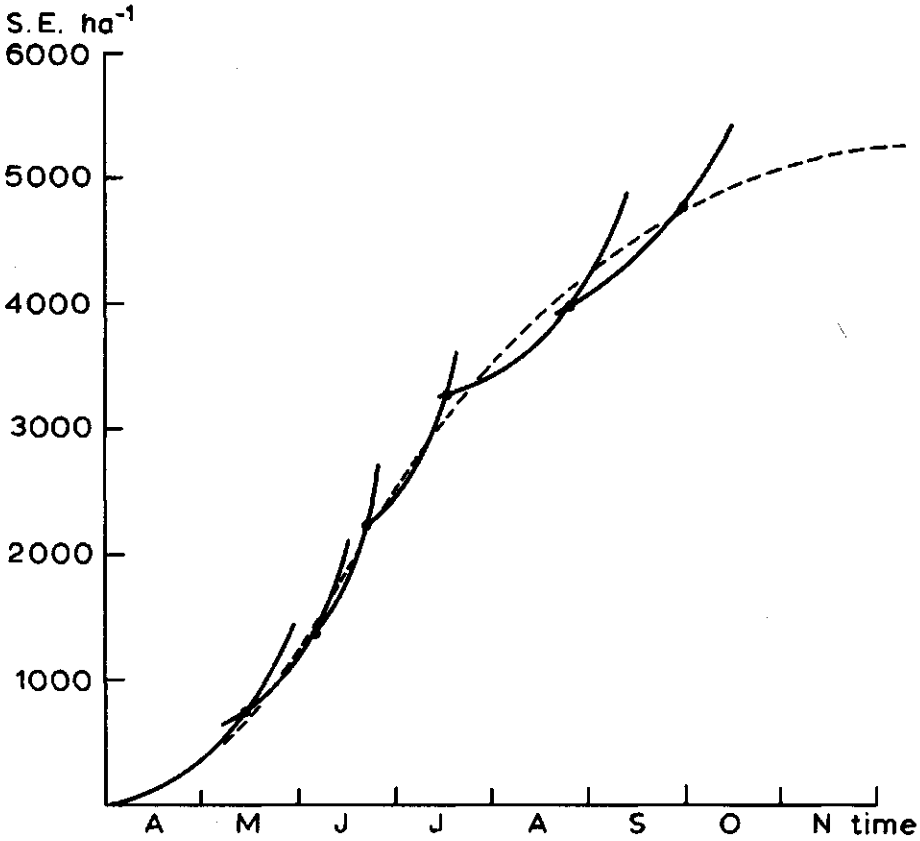


Fig. 5. Cumulative net s.e. production curve; farm 12, field 3 (1969)
Example of a field merely being grazed.
Stock: milking cows
High production level, clayey soil
N-level = 265 kg/ha; standard S.E. 4295, actual 4756
Regrowth is indicated hypothetically by repeated upwards bending.
The influence of decreasing day length follows from the lessening steepness of the successive sections

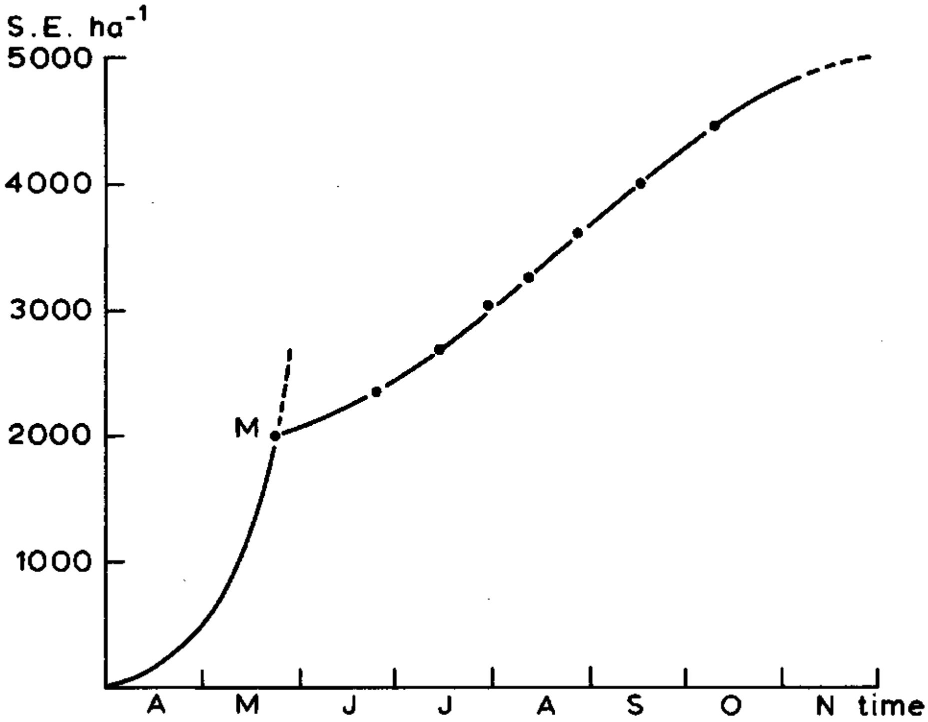


Fig. 6. Cumulative net s.e. production curve; farm no. 2, field 4
Mowing in spring, followed by repeated grazing.
Kink at M, as a result of regrowth

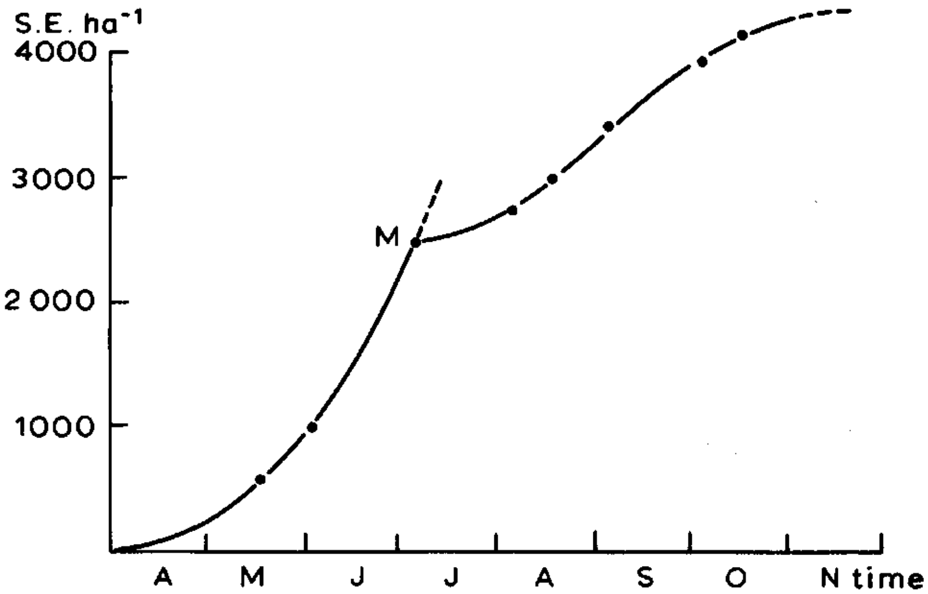
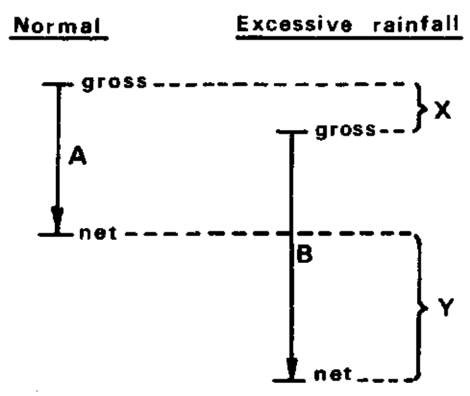


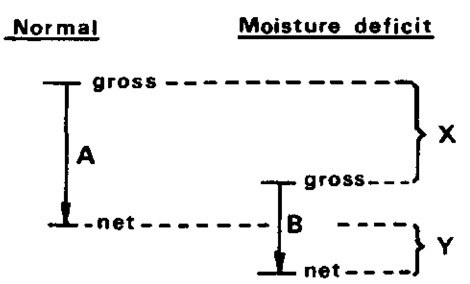
Fig. 7. Cumulative net s.e. production curve; farm no. 2, field 1
Mowing in mid-summer, followed by repeated grazing
Kink at M, as a result of regrowth under less favourable conditions (dry)
Sections beyond M are similar in shape to curves of fig. 2-5

farmers choice with respect to fodder making and his professional skill', Suchlike sentences are based on the experience that ability and adaptability are ever of decisive significance for the feasibility of grassland exploitation. Negation of any relation between gross yield and net production, however, would mean strict denial of the significance of any means of increasing the productive capacity of the field, while yet this is the base for improved farming results, provided that the possibilities of the improvement will be fully utilized. Working systems therefore have to be improved simultaneously.

Gross yield and net production are discussed as separate subjects of growth response also by 'T HART (1960). The author notices: 'Gross production meets less damage with excessive rainfall and more damage with moisture deficiencies than net production'. The interpretation of suchlike sentences might be, that with excessive rainfall the gap between gross yield and net production will be enlarged, whereas a moisture deficit will cause the gap to narrow. This can be schematized as follows:



As a result of wet conditions, gross production will be decreasing much less than net production. Compare x with y. Consequently the gap between gross en net production will increase considerably. Compare A with B.



A moisture deficit makes gross production decrease much more than net production. Compare x with y. Consequently the gap between gross and net production will decrease. Compare A with B.

In this way a clear indication of the relation between gross and net production is given, in spite of the initial denial of such relation.

The reason why, under wet conditions, gross production is decreasing less than net production, is, that grass growth in itself is seldom seriously affected by an excess of water, provided that this will be temporarily, whereas net production will be much lower because grazing and mowing conditions become less favourable (treading).

Under dry conditions, however, grass growth may be seriously hampered, which fact causes gross production to be low. On the other hand, the returns of grazing and mowing will be high in this case, so that net production will be much less affected. The way in which grazing losses by treading have to be accounted for in simulation models for grassland response to non optimal growing conditions will be discussed in more detail in a next paper.

WILLEMSEN (1965) gives as his opinion that for gross production, precipitation is decisive, whereas for net production it will be temperature. SCHOTHORST and HETTINGA (1972) applied data of the STIBOKA (1970), fixing the ratio between net and gross grassland production at 62 % and 56 % for dry and wet peat soils respectively. Losses of starch equivalent by treading during the grazing under average conditions are estimated by SCHOTHORST (1963) at 40 %. They may vary, however, from 25 % in dry years on slightly humic sandy soils, to 55 % on wet peat soils and humic sandy soils in wet years, gross production then being high. According to this author, grazing losses on slightly humic soils may be put on 35 %. An interesting conclusion reads: 'In case of high gross yields, net production will be high too, the returns, however, will be low. 'The reason is, that ample supply ever tends to less careful management. KOWALIK (1973) reports a similar tendency in Poland, though here it is more a matter of machinery for harvesting leaving behind larger quantities as yields grow bigger.

Fig. 8 shows the relation between gross yield and net production for slightly humic and humic sandy soils in the Netherlands. Data have been extracted from information by SCHOTHORST about a great number of profile types dating from the end of the fifties. The numbers in this figure refer to the years of investigation.

It should be stressed, that in this case the low yield (1959) is caused by a moisture deficit, since 1959 is known to have been a very dry year. Consequently, the 'returns' are relatively high.

In cases where low yields are the result of a moisture excess, low returns will show, especially on humic sandy soils. The relation of figure 8 is valid only for increasing gross yield as a result of increasing moisture supply, since no wet years occurred within the period of investigation (1957-1960). The course of the returns as derived from the adjusted curve of fig. 8, has been drawn in fig. 9. Table 2 gives the s.e. returns adjusted, as well as net production.

The correlation between gross and net production shows up very clearly here. Referring to this kind of data, SCHOTHORST (1963) states that the net production of humic sandy soils of the Mid-Netherlands is lower than that of the slightly humic ones, in spite of a much higher production capacity of the former. The question arises, whether the gross yield of humic sandy soils may be so much higher, however, that in spite of lower returns, the net production too will be higher than that of the slightly humic soils. Such might be the case in relatively dry summers, when the chance of 'treading' on the otherwise wet soils is only small.

Table 2. Returns of grazing; adjusted (constant N-level)

Gross s.e. yield (s.e.ha^{-1})	3500	3750	4000	4250	4500	4750	5000	5250	5500	5750	6000
returns of grazing in percent of gross yield											
Hum.sandy soils	61.5	61.4	61.2	60.6	59.9	59.1	57.8	56.4	54.8	52.9	50.7
Slightly hum.s.s.	79.5	76.6	73.7	70.8	68.2	65.4	62.7	60.3	57.9	55.6	53.3
net s.e. production: (s.e.ha^{-1})											
Hum.sandy soils	2153	2303	2448	2576	2696	2807	2890	3961	3014	3042	3042
Slightly hum.s.s.	2783	2873	2948	3009	3069	3107	3135	3166	3184	3197	3198

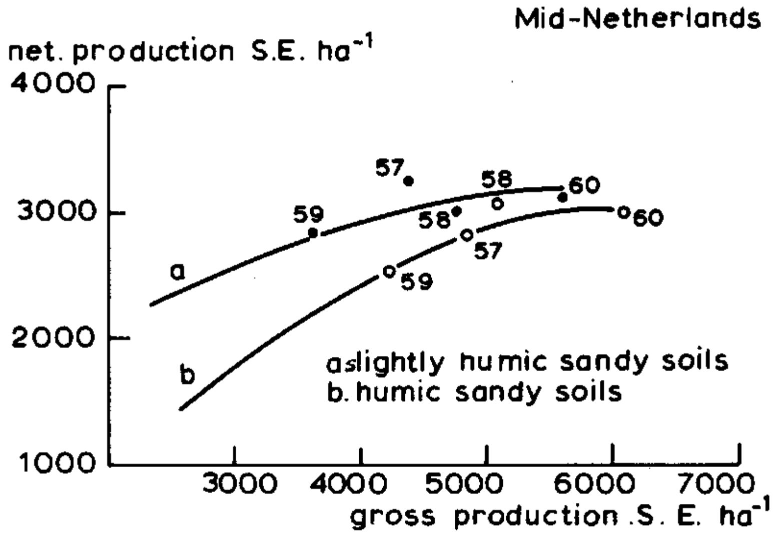


Fig. 8. Relation between gross and net production (data from SCHOTHORST, 1963)

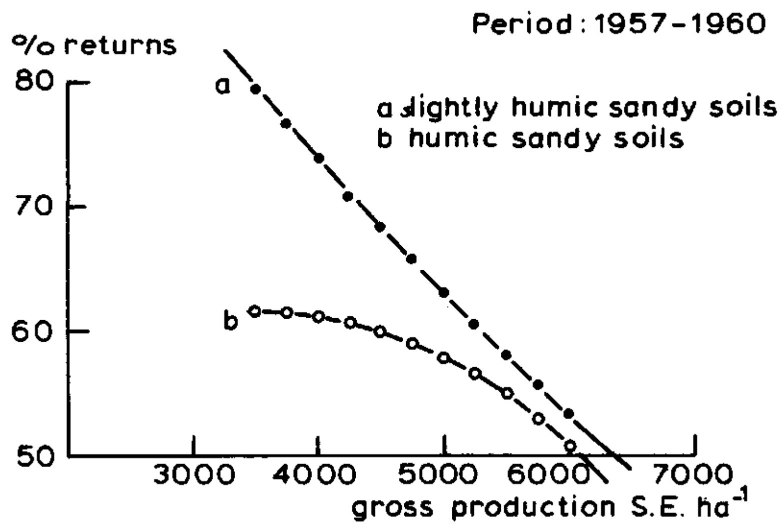


Fig. 9. According as gross production increases, returns will be decreasing
Cause: In case of ample supply, the farmer will be less careful in his management

In the very dry year of 1959, however, this did not show, since humic and slightly humic sandy soils proved to be equally low in gross production. A definite answer to this assumption could not be obtained from one of the other years either.

5. TRANSFORMATION OF NET S.E. PRODUCTION INTO GROSS D.M. PRODUCTION

Information concerning gross/net ratios of t o t a l production will be insufficient to estimate this ratio on any moment of the growth process. Data of table 2 representing total production, therefore, are not allowed to be extrapolated towards lower values as occur in earlier stages of growth. Making these data fit for conversion of the much higher values that are found in the seventies as a result of much higher nitrogen gifts, proves to be impossible either, since net production appear to become constant beyond a certain level of gross production. In other words, here the decrease of the returns is equal to the increase of gross production. According to the data of table 2, this occurs beyond 5750 s.e.ha^{-1} gross production on humic sandy soils, and beyond 6000 s.e.ha^{-1} gross production on slightly humic sandy soils respectively (see framed numbers in table 2).

This simply means, that at the chosen nitrogen level of 70 kg N per ha, to which the original observations of the experimental farms had to be converted in order to obtain comparability to the gross yields of the 'C.I. 203' experimental fields, net production cannot excell 3042 and 3198 s.e.ha^{-1} respectively. The nitrogen level for grassland in our time (1973), however, being about 300 kg ha^{-1} and over, made the net production rise from about 3000-3500 s.e.ha^{-1} in the fifties, to some 4500 or 5000 s.e.ha^{-1} under the p r e s e n t conditions. This is the reason why the data of table 2 cannot be used unconditionally for our transformation purposes. (See third sentence of this paragraph).

The only acceptable way in which to achieve a transformation of the net production curve into the gross production curve is, to convert net s.e. production into gross d.m. production for each separate exploitation cycle successively. The reason why doing so is, that some information is obtained about gross/net and s.e./d.m. ratios for production of grass, either being mown or grazed, on various moments of the growing season. Nothing, however, needs to be said about these ratios on any arbitrary moment between two successive activities, since during these periods of undisturbed growth, such ratios are in fact irrelevant. The actual exploitation cycles therefore, are the steady points in the transformation - technique.

Examples of calculating gross d.m. production from net s.e. production are given in supplement I. For any of the six exploitation cycles, transformation coefficients have been calculated from data about s.e. content in the dry matter of hay and fresh grass on various moments of the growing season and from grazing and mowing losses. Since no information whatever could be obtained about grazing losses as a mere funtion of t i m e, returns of grazing have been considered to be constant throughout the season, viz. a mean 65 % on sandy soils in general. It should be stressed once more, however, that as soon as variation in moisture conditions of the soil are taken into account, returns of grazing have to be varied accordingly.

Of the s.e. content in the dry matter it is known, that it may vary in consequence of age, light intensity, temperature and moisture supply. In late summer and autumn it will be lower than in spring and early summer, mainly as a result of decreasing light intensity and increasing precipitation; see table 3.

Table 3. Mean weather conditions according to data of the Royal Institute for Meteorology in the Netherlands (KNMI)

Months	April	May	June	July	August	September	October
Light intensity cal/cm^2/day	311	396	424	369	318	242	140
Temperature ^{o}C	8.5	12.4	15.5	17.0	16.8	14.3	10.0
Precipitation mm/month	49	52	57	78	89	71	72

The results of calculations, given in supplement I, have been summarized in table 4.

Table 4. Transformation coefficients for gross d.m. production/net s.e. production and gross d.m. production

Closing date of exploitation cycles	8/6*	3/7	4/8*	10/9	7/11	16/11
d.m./s.e.	2.041	1.786	2.174	1.852	1.923	2.000
gross/net d.m.	1.250	1.538	1.250	1.538	1.538	1.538
gross d.m./net s.e.	2.5512	2.7469	2.7175	2.8484	2.9576	3.0760
gross d.m. kg/ha	3827	6270	10 346	13 347	16 990	17 410
adjusted	3842.56	6384.13	9943.02	13 733.80	17 095.03	17 298.06

*mowing; grazing underlined

Since transformation of net production into gross yield is possible only in case a c t u a l quantities of product, being obtained either by mowing or by grazing, are concerned, no fluent transformation curve could be given. A suchlike curve would suggest the possibility of recalculating net production from arbitrary growth levels, occurring somewhere between the closing dates of two successive exploitation cycles. As long as a cycle will not be completed, however, no grazing or mowing will take place, and consequently, transformation of mere growth levels into imaginary net productions is completely without any actual significance.

In fig. 10 the calculated gross d.m. production of the successive exploitation cycles is cumulatively plotted and a free hand curve drawn through the points.

In the table of Supplement II values are compiled of $\sum$ net production in s.e.ha^{-1} (column 4), net production rate in s.e.ha^{-1}day^{-1} (column 5) $\sum$ gross d.m. production in kg ha^{-1} (column 6) and gross d.m. production rate in kg ha^{-1}day^{-1} (column 7). In fig. 11 the curve for the gross d.m. production rate is drawn.

It should be stressed, that the relation between gross and net production, following from the two production curves of fig. 10, is valid only for the field taken as an example. For any other field, the transformation has to be executed once more, since the shape of

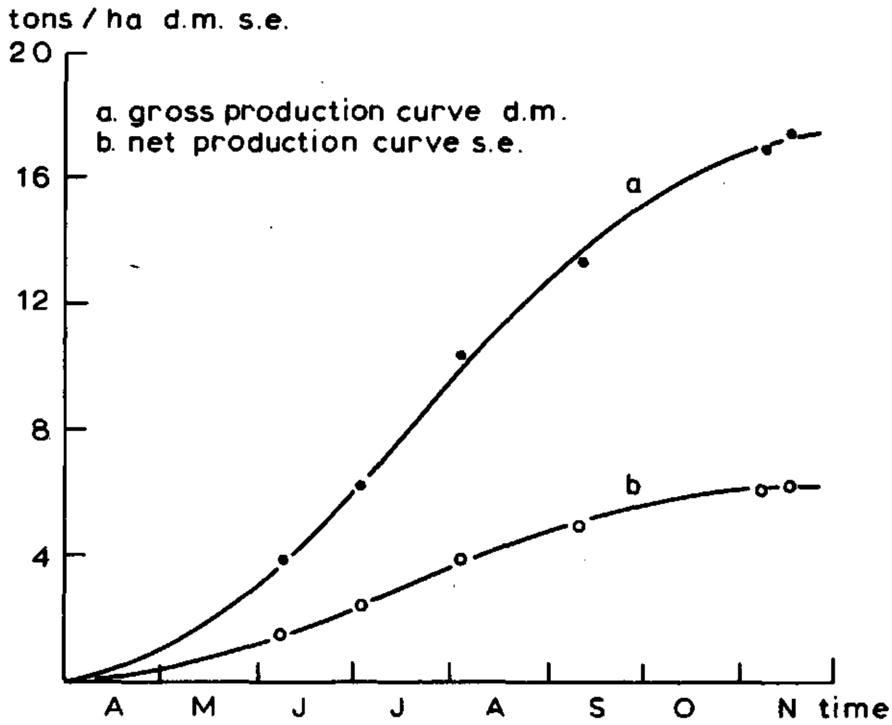


Fig. 10. Cumulative gross d.m. production as derived from net s.e. production according to transformation coefficients of table 3
Through the points a free hand curve has been drawn (a)
Salland farm no. 10, field 7; slightly humic sandy soil, sufficient moisture supply.
Exploitation: 1969. Scheme: see fig. 1b

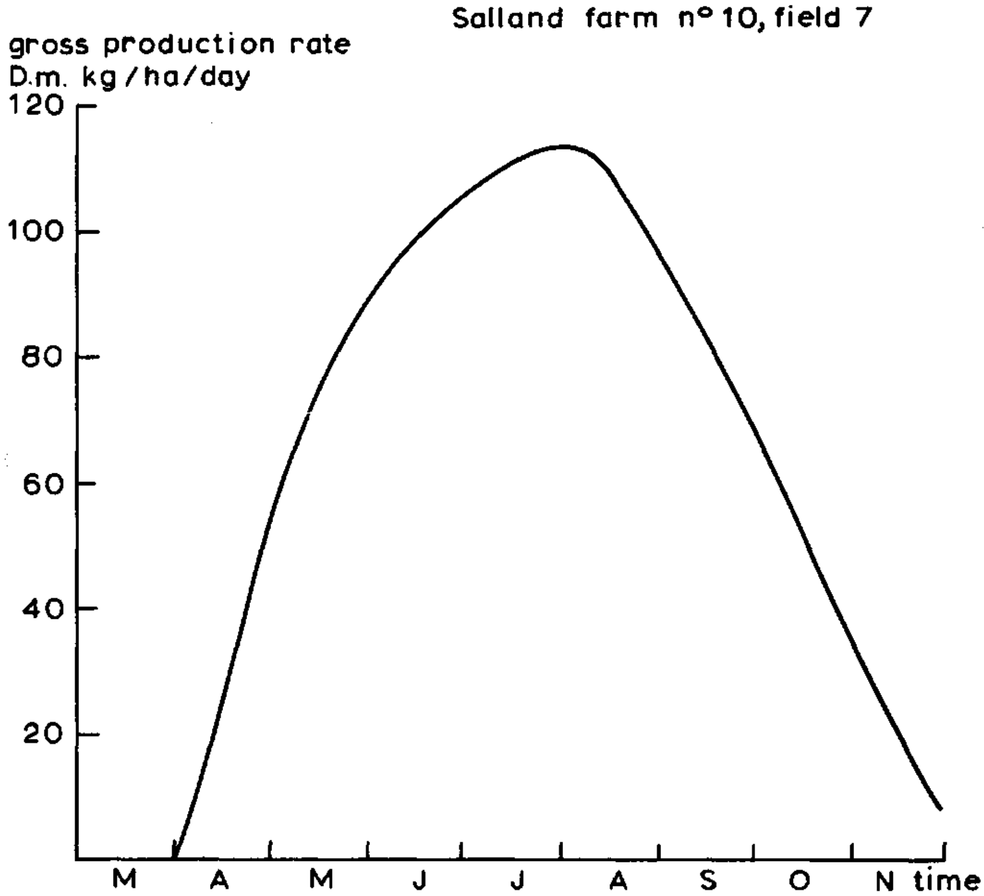


Fig. 11. Gross d.m. production rate, reconstructed from cumulative gross d.m. production curve of fig. 10.
Production rate does not exceed 112 kg d.m./day, roots excluded

the cumulative gross production curve depends on the exploitation sequence and the moment at which the separate cycles are completed.

As shown in the previous pages, the most common sequence in grassland exploitation in Salland is mowing, eventually preceded by one or two grazing cycles and followed by a number of cycles that may be continued till far into October or even November, depending on weather conditions. A sequence also often met, is mowing without preliminary grazing, followed by a single, or by repeated grazing cycles, interrupted by a second mowing. Many other sequences can be thought of and in fact any variation may occur depending on prevailing conditions and personal choice of the farmer with respect to exploitation techniques.

6. FURTHER CONSIDERATIONS CONCERNING RECONSTRUCTION OF GROSS D.M. YIELDS FROM NET PRODUCTION DATA

In case the first exploitation activity will be mowing, transformation of the first stage of the net production curve renders no complications. Nearly the complete upperpart of the grass, present at the moment of mowing will be actually harvested, except a small quantity consisting of stubble. After settling mowing losses, the gross yield, i.e. the total amount of grass produced, can be reconstructed from the quantity of hay harvested.

In case of preliminary grazing, however, it will be different. After settling grazing losses with net production found by multiplication of number of livestock, number of grazing days and standard of s.e. consumed per l.u. day^{-1}, a gross production is found of which no certainty can be obtained whether it is a reliable measure for the *actual* production of the field.

The reason is, that in spite of the fact that in the field being grazed, the grass supply may not completely be finished yet, the condition of the grass on some other field of the farm may force the farmer to remove his cows to this latter field in order to prevent grazing losses caused by grazing in grass being too high.

In such cases the *actual* gross production of the former field has clearly been higher than could be calculated from data of net production based on information about exploitation. The amount of grass that is left behind in the field in consequence of premature removal of the grazing stock, is not included in gross production derived from net production data of this field, and may therefore be called the 'neglected part of the production'.

This neglected part, however, will be automatically accounted for in the next cycle, provided this will be mowing, as it will be part of the total grass supply of the field at that time.In case no mowing follows, however, the actual gross production, and consequently the course of the curve between beginning and end of the total period of successive grazing cycles after mowing will be in doubt. In case it is assumed that the last grazing cycle will be continued untill the grass supply of the field, then available, will be completely finished, the total net production may be considered a safe base for calculation of the total gross production.

7. REFERENCES

BOSCH, S. The determination of pasture yield, Neth. Journ. of Agr. Sc. (1956).

CENTRAAL VOEDERBUREAU IN NEDERLAND. Voedernormen en Voederwaarden (1962).

GARMING, R.W. Handleiding voor het opstellen van begrotingen voor gemengde bedrijven op zandgrond. P.A.W. publ. 31 (1967).

HART, M.L. 'T. De opbrengst van grasland op stikstof proefbedrijven, Stikstof nr 25 (1960).

KOWALIK, P. Personal communication (1973).

R.L.V.D. Het rendementsonderzoek, Resultaten van . . . . . in Lochem (1958).

SCHOTHORST, C.J. Beweidingsverliezen op diverse graslandgronden, Landbouwkundig tijdschrift 75-15 (1963).

——— en D. HETTINGA. Het effect van polderpeilverlaging in een proefobject in de Alblasserwaard, ICW nota 697 (1972).

WIELING, H. Personal communication and papers to be published (1973).

——— Opbrengstbepaling van grasland; weidebouw, voederwinning en conservering cursus 1972 Deel II: Produktie en gebruik van grasland (1972).

WILLEMSEN, W. Zeventien jaar netto Z.W. opbrengst van het grasland op de voorbeeldbedrijven. Stikstof nr 47/48 (1965).

——— De netto opbrengsten van grasland; weidebouw, voederwinning en conservering, cursus 1972 Deel II, Produktie en gebruik van grasland (1972).

CALCULATION OF GROSS DRY MATTER PRODUCTION FROM EXPLOITATION DATA

1st cycle: The first cycle was m o w i n g (see table 1) and took place June 8th. Net production of hay amounted to 1500 starch equivalents per ha. The s.e. content of hay that is made in early summer, amounts to 49 % in the dry matter. Consequently 1500 s.e. ha^{-1} means a dry matter production equal to 100/49 . 1500 = 3061.22 kg d.m.ha^{-1} n e t. Losses in hay making are taken at a mean 20 % of gross production. Therefore a net d.m. production of 3061.22 kg ha^{-1} will be equal to a gross production of 100/80 . 3061.22 = 3827 kg d.m.ha^{-1}. The transformation coefficients that can be applied for calculation of gross d.m. production from net s.e. production in this first stage of growth follow from the s.e. content in the dry matter of hay and the losses in hay making as given above: These data are valid for this first cycle only.

Transformation coefficient d.m./s.e. = 100/49 = 2.041 (a)
Transformation coefficient gross/net d.m. = 100/80 = 1.250 (b)
Transformation coefficient gross d.m./net s.e. = a x b =
= 2.55125 (hay)

2nd cycle: The second cycle was g r a z i n g and took place from June 28th - July 3rd. Net production of grass, according to chapter 2.3, amounted to 889.2 starch equivalents per ha (see table 1).

The s.e. content of fresh grass amounts to 56 % in the dry matter in spring and early summer (information from the Institute for Animal Husbandry in the Netherlands). Consequently 889.2 s.e. ha^{-1} means a dry matter production of 100/56 . 889.2 = 1588 kg d.m. ha^{-1} net.

Estimation of the net production of this field in case of exclusive grazing: 4500 - 4750 s.e. ha^{-1}. According to table 2, returns of grazing will then amount to a mean 65 % on lightly humic sandy soils. Therefore a net d.m. production of 1588 kg ha^{-1} will be equal to a gross produc-

tion of 100/65 . 1588 = 2443 kg d.m. ha^{-1}.
Transformation coefficients for d.m./s.e. and gross/net d.m. can be derived in a similar way as done for the 1st cycle.

d.m./s.e. = 100/56 = 1.786 (a)
gross/net d.m. = 100/65 = 1.538 (b)
gross d.m./net s.e. = a . b = 2.74687 (grazing)

For the next cycles the explanation will be schematized

3rd cycle: M o w i n g; date: Augustus 4th. Net production 1500 s.e. ha^{-1} (hay) (see table 1).
S.e. content of hay made in August will be a little lower than in spring and has been put therefore on a hypothetical 46 % in the d.m.
Net d.m. production = 100/46 . 1500 = 3261 kg d.m. ha^{-1}
Losses in hay making are similar to those of 1st cycle i.e. 20 %.
Gross d.m. production = 100/80 . 3261 = 4076 kg d.m. ha^{-1}
Transformation coefficients d.m./s.e. = 2.174 (a)
Transformation coefficients gross/net d.m. = 1.250 (b)
Transformation coefficients gross d.m./net s.e. = a . b =
= 2.7175 (hay)

4th cycle: G r a z i n g; date: 3/9-10/9. Net production = 1053.36 s.e. ha^{-1} (see table 1).
Due to decreasing day length and temperature the s.e. content of fresh grass in late summer will be less than in spring or early summer and has been put therefore on 54 % in the d.m.
Net d.m. production = 100/54 . 1053.36 = 1951 kg d.m. ha^{-1} (net)
Since no information could be obtained about grazing losses as a function of time, returns of grazing are considered constant viz. 65 %.

Gross d.m. production = 100/65 . 1951 = 3001 kg d.m. ha^{-1}
Transformation coefficients d.m./s.e. = 1.852 (a)
Transformation coefficients gross/net d.m. = 1.538 (b)
Transformation coefficients gross d.m./net s.e. = a . b =
= 2.84838

5th cycle: G r a z i n g; date: 29/10-7/11. Net production = 1231.20 s.e. ha^{-1} (see table 1).
S.e. content in the d.m. according to decreasing day length 52 %.
Net d.m. production = 100/52 . 1231.20 = 2368 kg d.m. ha^{-1} (net).
Returns of grazing = 65 %. Gross d.m. productie = 100/65 . 2368 = 3643 kg d.m. ha^{-1}
Transformation coefficients d.m./s.e. = 1.923 (a)
Transformation coefficients gross/net d.m. = 1.538 (b)
transformation coefficients gross d.m./net s.e. = a. b. =
= 2.95757

6th cycle: G r a z i n g; date: 7/11-16/11. Net production = 136.62 s.e. ha^{-1} (see table 1).
S.e. content in the d.m.: 50 %. Net d.m. prod. = 100/50 . 136.62 = 273 kg d.m. ha^{-1}.
Returns of grazing = 65 %.
Gross d.m. productie = 100/65 . 273 = 420 kg d.m. ha^{-1}
Transformation coefficients d.m./s.e. = 2.00 (a)
Transformation coefficients gross/net d.m. = 1.538 (b)
Transformation coefficients gross d.m./net s.e. = a . b =
= 3.0760

1-2	3	4	5	6	7
date	days	net se prod ∑	net se prod rate	gross dm prod ∑	gross dm prod rate
October					
1	184	5573.30	23.10	15 356.11	67.53
2	185	5596.05	22.75	15 422.71	66.60
3	186	5618.43	22.40	15 488.38	65.67
4	187	5640.50	22.05	15 553.11	64.73
5	188	5662.20	21.70	15 616.91	63.80
6	189	5683.55	21.35	15 679.78	62.37
7	190	5704.55	21.00	15 741.71	61.93
8	191	5725.20	20.65	15 801.55	60.84
9	192	5745.50	20.30	15 860.45	58.90
10	193	5765.45	19.95	15 918.41	57.96
11	194	5785.05	19.60	15 975.42	57.01
12	195	5804.30	19.25	16 031.48	56.06
13	196	5823.15	18.85	16 085.87	54.39
14	197	5841.60	18.45	16 139.17	53.30
15	198	5854.65	18.05	16 191.38	52.21
16	199	5877.30	17.65	16 242.51	51.13
17	200	5894.55	17.25	16 292.54	50.03
18	201	5911.45	16.90	16 341.02	48.48
19	202	5928.00	16.55	16 388.55	47.53
20	203	5944.20	16.20	16 435.12	46.57
21	204	5960.05	15.85	10 480.73	45.61
22	205	5975.55	15.50	16 525.38	44.65
23	206	5990.70	15.15	16 568.48	43.10
24	207	6005.50	14.80	16 610.61	42.13
25	208	6019.95	14.45	16 651.78	41.17
26	209	6034.05	14.10	16 691.99	40.21
27	210	6047.80	13.75	16 731.24	39.25
28	211	6061.20	13.40	16 769.52	38.28
29	212	6074.25	13.05	16 806.84	37.32
30	213	6086 95	12.70	16 843.20	36.36
31	214	6099.30	12.35	16 878.59	35.39

1-2	3	4	5	6	7
date	days	net se prod ∑	net se prod rate	gross dm prod ∑	gross dm prod rate
November					
1	215	6111.30	12.00	16 913.02	34.43
2	216	6122.95	11.65	16 945.88	32.86
3	217	6134.25	11.30	16 977.70	31.88
4	218	6145.20	10.95	17 008.68	30.92
5	219	6155.80	10.60	17 038.60	29.96
6	220	6166.05	10.25	17 067.63	28.99
7	221	6175.95	9.90	17 095.03	27.40
8	222	6185.50	9.55	17 121.46	26.43
9	223	6194.70	9.20	17 146.93	25.47
10	224	6203.55	8.85	17 171.43	24.50
11	225	62.12.05	8.50	17 194.95	23.52
12	226	6220.20	8.15	17 217.51	22.56
13	227	6228.00	7.80	17 239.10	21.54
14	228	6235.45	7.45	17 259.70	20.60
15	229	6242.55	7.10	17 279.38	19.68
16	230	6249.30	6.75	17 298.06	18.68

Supplement II

Net and gross productions and production rates (Farm no. 10; field no. 7)

1-2 date	3 days	4 net se prod Σ	5 net se prod rate	6 gross dm prod Σ	7 gross dm prod rate
April					
1	1	0.2	0.2	0.515	0.515
1	2	1.-	0.8	2.575	2.060
3	3	2.4	1.4	6.179	3.604
4	4	4.4	2.-	11.328	5.149
5	5	7.-	2.6	18.022	6.694
6	6	10.2	3.2	26.260	8.238
7	7	14.1	3.9	36.300	10.040
8	8	18.7	4.6	48.143	11.843
9	9	24.-	5.3	61.788	13.645
10	10	30.-	6.-	77.238	15.450
11	11	36.75	6.75	94.617	17.379
12	12	44.25	7.50	113.926	19.309
13	13	52.50	8.25	135.167	21.241
14	14	61.50	9.-	158.338	23.171
15	15	71.25	9.75	183.440	25.102
16	16	81.75	10.50	210.474	27.034
17	17	93.-	11.25	239.438	28.964
18	18	105.-	12.-	270.333	30.895
19	19	117.75	12.75	303.159	32.826
20	20	131.25	13.50	337.929	34.770
21	21	145.50	14.25	374.619	36.690
22	22	160.50	15.-	413.239	38.620
23	23	176.25	15.75	463.791	40.552
24	24	192.75	16.50	496.273	42.482
25	25	210.-	17.25	540.687	44.414
26	26	228.-	18.-	587.032	46.345
27	27	246.75	18.75	635.307	48.275
28	28	266.25	19.50	685.514	50.207
29	29	286.50	20.25	737.652	52.138
30	30	307.40	20.90	791.494	53.842

1-2 date	3 days	4 net se prod Σ	5 net se prod rate	6 gross dm prod Σ	7 gross dm prod rate
May					
1	31	328.95	21.55	846.980	55.486
2	32	351.15	22.20	904.141	57.161
3	33	373.95	22.80	962.846	58.705
4	34	397.35	23.4	1023.10	60.254
5	35	421.35	24.0	1084.93	61.83
6	36	445.35	24.5	1148.02	63.09
7	37	470.85	25.-	1212.39	64.37
8	38	496.35	25.5	1278.05	65.66
9	39	522.35	26.-	1345	66.95
10	40	548.85	26.5	1413.29	68.29
11	41	375.85	27.-	1482.87	69.58
12	42	603.35	27.5	1553.75	70.88
13	43	631.35	28.-	1625.92	72.17
14	44	659.75	28.4	1699.12	73.20
15	45	688.55	28.8	1773.36	74.25
16	46	717.75	29.2	1848.64	75.28
17	47	747.35	29.6	1924.95	76.31
18	48	777.35	30.-	2002.30	77.35
19	49	807.75	30.4	2080.68	78.38
20	50	838.55	30.8	2160.10	79.42
21	51	869.75	31.2	2240.65	80.55
22	52	901.35	31.6	2322.34	81.59
23	53	933.35	32.-	2404.87	82.63
24	54	965.75	32.4	2488.54	83.67
25	55	998.55	32.8	2573.26	84.72
26	56	1031.75	33.2	2659.03	85.77
27	57	1065.25	33.5	2745.57	86.54
28	58	1099.05	33.8	2832.91	87.34
29	59	1133.15	34.1	2421.03	82.12
30	60	1167.55	34.4	3009.40	88.91
31	61	1202.25	34.7	3099.64	89.70

1-2 date	3 days	4 net se prod Σ	5 net se prod rate	6 gross dm prod Σ	7 gross dm prod rate
June					
1	62	1237.25	35.-	3190.13	90.49
2	63	1272.50	35.25	3281.27	91.14
3	64	1308.-	35.50	3373.07	91.00
4	65	1343.75	35.75	3465.53	92.46
5	66	1379.75	36.-	3558.79	93.26
6	67	1416.-	36.25	3652.71	93.92
7	68	1452.50	36.50	3747.30	94.95
8	69	1489.25	36.75	3842.56	95.26
9	70	1526.25	37.-	3938.49	95.93
10	71	1563.45	37.2	4034.95	96.46
11	72	1600.85	37.4	4131.95	97.00
12	73	1638.45	37.6	4229.49	97.54
13	74	1676.25	37.8	4327.57	98.08
14	75	1714.20	37.95	4426.06	98.49
15	76	1752.30	38.10	4525.14	99.08
16	77	1790.55	38.25	4624.63	99.49
17	78	1828.95	38.40	4724.54	99.91
18	79	1867.50	38.55	4824.87	100.33
19	80	1906.20	38.70	4925.62	100.75
20	81	1945.05	38.85	5026.98	101.36
21	82	1984.05	39.-	5128.77	101.79
22	83	2023.20	39.15	5230.98	102.21
23	84	2062.50	39.30	5333.83	102.85
24	85	2101.95	39.45	5437.11	103.28
25	86	2141.55	39.60	5540.83	103.72
26	87	2181.30	39.75	5644.99	104.16
27	88	2221.15	39.85	5749.45	104.40
28	89	2261.10	39.95	5854.21	104.76
29	90	2301.15	40.05	5959.29	105.08
30	91	2341.30	40.15	6064.90	105.61

Supplement II (continued)

1-2 date	3 days	4 net se prod Σ	5 net se prod rate	6 gross dm prod Σ	7 gross dm prod rate
July					
1	92	2381.55	40.25	6170.73	93.92
2	93	2421.90	40.35	6277.32	106.49
[3]	94	2462.35	40.45	6384.13	106.31
4	95	2502.85	40.50	6491.14	107.01
5	96	2543.40	40.55	6598.34	107.20
6	97	2584.00	40.60	6705.74	107.40
7	98	2624.65	40.65	6813.33	107.59
8	99	2665.35	40.70	6921.11	107.78
9	100	2706.10	40.75	7029.09	107.98
10	101	2746.85	40.75	7138.51	109.42
11	102	2787.60	40.75	7248.04	109.53
12	103	2828.35	40.75	7357.67	109.63
13	104	2869.10	40.75	7467.41	109.74
14	105	2909.85	40.75	7577.25	109.84
15	106	2950.60	40.75	7688.38	111.13
16	107	2991.35	40.75	7799.65	111.27
17	108	3032.10	40.75	7911.05	111.40
18	109	3072.80	40.70	8022.47	111.42
19	110	3113.45	40.65	8133.89	111.42
20	111	3154.05	40.60	8248.58	112.69
21	112	3194.69	40.55	8357.31	112.73
22	113	3235.10	40.50	8472.08	112.77
23	114	3275.50	40.40	8584.76	112.68
24	115	3315.30	40.30	8697.34	112.58
25	116	3356.-	40.20	8810.51	113.17
26	117	3396.10	40.10	8923.59	113.08
27	118	3436.05	39.95	9036.47	112.38
28	119	3475.85	39.80	9149.13	112.66
29	120	3515.50	39.65	9261.58	112.45
30	121	3555.-	39.50	9375.60	114.02
31	122	3594.35	39.35	9489.44	113.84

1-2 date	3 days	4 net se prod Σ	5 net se prod rate	6 gross dm prod Σ	7 gross dm prod rate
August					
1	123	3633.55	39.20	9 603.11	113.67
2	124	3672.60	39.05	9 716.60	113.49
3	125	3711.45	38.85	9 824.78	113.18
[4]	126	3750.10	38.65	9 943.02	113.24
5	127	3788.55	38.45	10 055.45	112.93
6	128	3826.80	38 25	10 168.57	112.62
7	129	3864.85	38.05	10 280.89	112.32
8	130	3902.70	37.85	10 392.89	112.00
9	131	3940.35	37.65	10 505.37	112.00
10	132	3977.80	37.45	10 617.54	112.17
11	133	4015.05	37.25	10 724.42	111.88
12	134	4052.10	37.05	10 840.99	111.57
13	135	4088.95	36.85	10 952.25	111.26
14	136	4125.60	36.65	11 061.97	109.72
15	137	4162.05	36.45	11 171.36	109.39
16	138	4198.30	36.25	11 230.41	109.05
17	139	4234.30	36.00	11 389.00	108.59
18	140	4270.05	35.75	11 497.11	108.11
19	141	4305.55	35.50	11 602.60	105.49
20	142	4340.80	35.25	11 707.57	104.97
21	143	4375.80	35.00	11 812.03	104.46
22	144	4410.55	34.75	11 915.98	103.95
23	145	4445.05	34.50	12 014.42	103.44
24	146	4479.30	34.25	12 120.49	101.57
25	147	4513.30	34.00	12 222.02	101.03
26	148	4547.05	33.75	12 322.51	100.49
27	149	4580.55	33.50	12 422.45	99.94
28	150	4613.30	33.25	12 521.85	99.40
29	151	4648.80	33.00	12 619.31	97.46
30	152	4679.55	32.75	12 716.21	96.90
31	153	4712.05	32.50	12 312.54	96.33

1-2 date	3 days	4 net se prod Σ	5 net se prod rate	6 gross dm prod Σ	7 gross dm prod rate
September					
1	154	4744.30	32.25	12 408.29	95.75
2	155	4776.30	32.00	13 003.48	95.19
3	156	4808.00	31.70	13 097.47	93.99
4	157	4839.00	31.40	13 190.75	93.28
5	158	4870.50	31.10	13 283.31	92.56
6	159	4901.30	30.80	13 375.16	91.85
7	160	4931.80	30.50	13 466.28	91.12
8	161	4962.00	30.20	13 556.18	89.90
9	162	4991.90	29.90	13 45.54	89.36
[10]	163	5021.50	29.60	13 733.80	88.26
11	164	5050.80	29.30	13 821.51	87.71
12	165	5079.30	29.00	13 908.49	86.48
13	166	5108.50	28.70	13 942.69	84.20
14	167	5136.90	28.40	14 076.13	83.44
15	168	5165.00	28.10	14 158.81	82.68
16	169	5192.80	27.80	14 240.73	81.92
17	170	5220.30	27.50	14 321.89	81.16
18	171	5247.50	27.20	14 401.24	79.35
19	172	5274.40	26.90	14 479.81	78.57
20	173	5301.00	26.60	14 557.61	77.80
21	174	5327.30	26.34	14 634.63	77.02
22	175	5253.30	26.00	14 710.87	76.24
23	176	5379.00	25.70	14 786.33	75.46
24	177	5404.40	25.40	14 861.02	74.69
25	178	5429.50	25.10	14 934.93	73.93
26	179	5454.30	24.80	15 008.05	73.12
27	180	5478.80	24.50	15 080.40	72.35
28	181	5502.95	24.15	15 150.72	70.32
29	182	5526.73	23.80	15 220.12	69.40
30	183	5550.20	23.45	15 288.58	68.46