SOME FACTORS IN CONNECTION WITH HEATING OF HAY [1])

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Summary

During 1953 and 1954 the temperatures in a large number of hay stacks were ascertained over a certain period. The following facts were shown:

1 Heating of hay proved to be promoted by too high a moisture content, large dressings of nitrogen, a high content of clover, young grass, a large volume and a large height of the haystack.

2 The most important factor is the moisture content of the hay.

3 The influence of nitrogen dressing, the amount of clover, the growth-stage of the grass and the size and height of the stacks were generally greater in hay made on the ground than in hay made on racks.

4 Only in a few cases did the temperature of hay made on racks rise above 55° C. Hence not only the danger of fire, but also the damage done by high temperatures to the nutritional value of the hay may be greatly reduced by making hay on racks.

Introduction

Though the yearly loss by fire in the world due to overheating of hay runs into millions of guilders (compare f.i.: Bernstorff 1952, 1954, Browne, 1929, Geering, 1939, Glathe, 1952, Glathe & Bernstorff, 1952, Hüni, 1944, Laupper, 1921, 1924, 1926, Pallmann et al, 1945, Truninger, 1929), the damage done to the nutritional value of hay is much greater (Geering, 1939). Usually it is greatly underestimated. A reduction of quality calls for a greater consumption of hay as has been recorded by Crasemann (1929), Folger (1934) and Frankena (1944). Moreover, feeding-experiments of Call (1928) have shown that more milk and butter-fat are produced by feeding with green hay than with brown hay.

The findings of the government fire-inspection of 15 December 1954 (1954) are summarized for the Netherlands in Table 1.

Table 1 Damage by fire in the Netherlands due to heating of hay

Year	Period	Number of fires	Direct damage
1951	June up to and including September .	97	*f* 715.000,–
1952	June up to and including September .	65	*f* 770.000,–
1953	June up to and including September .	69	*f* 1.074.000,–
1954	June up to and including October . .	35	*f* 308.430,–

[1]) Received for publication October 15, 1955.

In the province of Friesland alone the losses of digestible protein in 1952 caused by heating of hay were estimated at *f* 975.000,–, while the direct damage caused by fire due to heating of hay in that year amounted to *f* 270.260,–. The indirect losses, however, were still greater since the losses of starch-equivalent and dry matter are not included in the calculations.

According to ORTH (1955) the digestibility of the crude protein begins to decrease above 45° C.

When the temperature in the hay stack rises above 50° C not only does the digestibility of the protein decrease, but also the starch-equivalent. An example derived from an investigation of WAHLEN and GEERING (1938) may illustrate this (Table 2).

Table 2 Influence of the temperature in the hay stack on the content of digestible protein and the starch-equivalent (after WAHLEN and GEERING, 1938)

Temperature °C	Decrease of	
	digestible protein %	starch-equivalent %
50	–	5–10
50–60	10–30	5–15
>70	30–80	15–30
>75	100	40–70

Moreover, above 50° C losses of dry matter take place as is shown by the work of HÜNI (1944) (Table 3).

Table 3 Influence of the temperature on dry matter-content (after HÜNI, 1944)

Condition of hay	Max. temp. °C	Loss of dry matter %
No heating of hay	–	0
Normally heated	48	2
Strongly heated	60	14
Very strongly heated	72	17
Overheated	80	29

Above 50° C the losses rise rapidly; BOND (1924) and KINZEL (1926) found a loss of dry matter of 30 per cent in overheated hay, MIEHE (1930) 20 to 33 per cent. Of course, the losses of starch-equivalent, digestible protein, dry matter and also of vitamins not only depend on the temperature reached, but also on the time of exposure to this temperature.

EXPERIMENTAL

Each year the temperatures in the hay stacks on the farms in the North-eastern polder are checked for a certain period to prevent fire and to keep down losses of nutritional value of the hay resulting from heating. In 1953 and 1954 temperatures were checked by 3 and 4 controllers on 426 and 545 farms, respectively, by means of a maximum thermometer placed within a gaugingrod. In these years many data were collected in connection with some factors which influence the temperatures in the stacks.

Just before carrying the hay from the field, samples were taken and were sent in closed containers to the Microbiological Laboratory at Kampen to determine the moisture content. Within 24 hours the figures for the moisture contents were made known to the controllers by telephone, enabling them to decide their attitude to the hay stacks concerned. Because of an accumulation of work at one period it was impossible to take samples of all the hay. In 1953 about 1500 tons of hay were sampled and in 1954 about 3000 tons. Moisture contents of 25 per cent and lower were considered to be good and moisture contents of more than 30 per cent to be dangerous. In the last cases checking of the temperatures began within 5 days after carrying the hay from the field.

At a temperature of 55° C the farmer was advised to make a hole in the hay stack since it was known that the content of digestible protein drops markedly at this temperature. At a temperature of 70° C written instructions were given to open up the stack immediately or to turn it over until the temperature was lowered so far that danger of fire no longer was present. At 70° C or at a higher temperature the fire-brigade was also warned.

As far as possible the following data were collected for each hay stack:

a The highest temperature.
b The method of making the hay.
c The date of stacking the hay.
d The moisture content of the hay.
e The rate of nitrogen dressing.
f The amount of clover in the grass (nothing, small or large amounts).
g The growth-stage of the grass.
h The proportions of the hay stack.

Some results obtained in 1953 are already published (van Schreven, 1954).

Experimental results

In the Northeastern polder at least 70 per cent of the hay is dried on racks. Such hay is made by drying the grass for some days on the ground and afterwards by drying it once more for 3 to 4 weeks on special appliances which may for convenience be called racks. The types of racks used are shown in Plates I, II, III and IV. As a matter of fact completing the drying on racks has the advantage of making the farmer less dependent on weather conditions than if the grass is dried only on the ground.

Consequently in most cases the hay stacks in the Northeastern polder are made of hay dried on racks. The other stacks are composed only of hay dried on the ground, or composed of a mixture of hay dried on racks and hay dried on the ground [2]).

Since on the one hand the moisture content is influenced by the method of making the hay and since on the other hand the effect of some factors on the temperature, as for instance, 1) the rate of nitrogen dressing, 2) the amount

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2) For the sake of convenience rack-hay will be further referred to as R-hay, hay dried on the ground as G-hay. If the stacks are composed of both these types the hay will be called GR-hay.

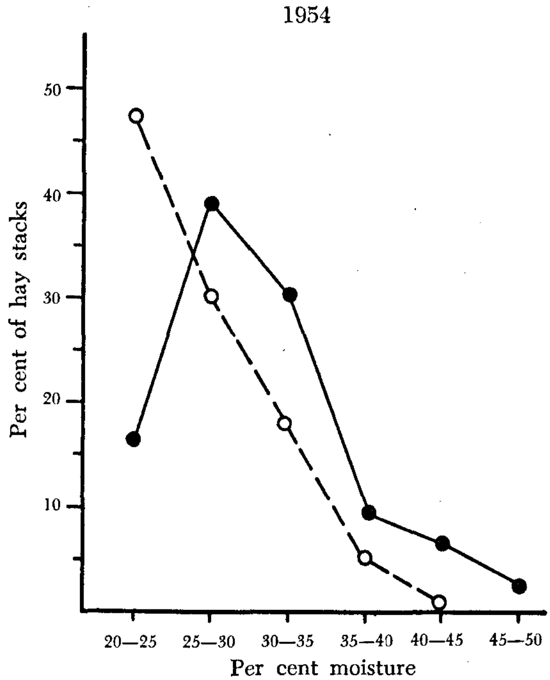
PLATE 1 TRIPOID HAY RACK.

PLATE 2 QUADRUPOID HAY RACK.

PLATE 3 HURDLE RACK OR HAY HUT.

PLATE 4 LONG TUNNEL RACK OF HURDLE.

of clover in the hay, 3) the growth stage of the grass, 4) the height of the hay stack and 5) the size of the stack, may be influenced by the moisture content, the effect of the different factors on the temperature was checked separately for R-hay and for G-hay.



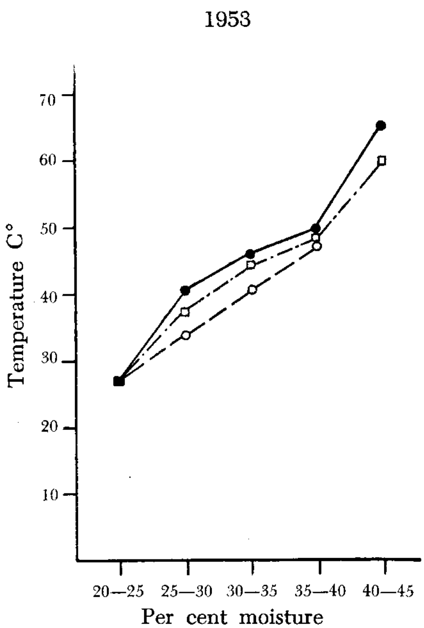
o - - - - o Hay stacks composed of hay dried on racks.
●———● Hay stacks composed of hay dried on the ground.

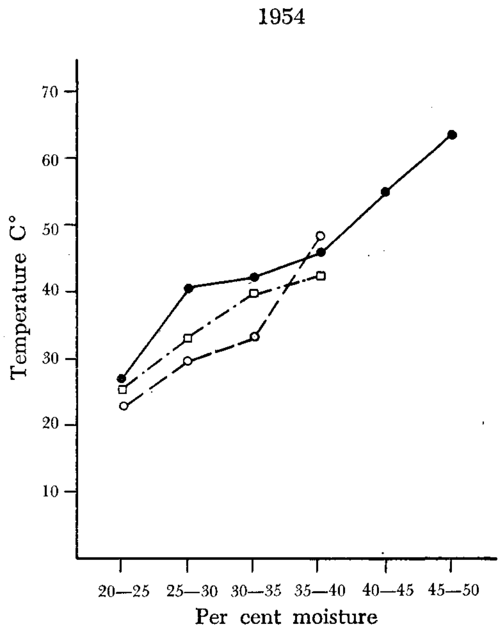
FIG. 1

As may be seen in Figure 1, the stacks which were made of R-hay generally had a lower moisture content than the stacks made of G-hay. In 1954 nearly 50 per cent of the R-hay had a moisture content of only 20–25 per cent, whereas only about 17 per cent of the G-hay had this low moisture content. Moreover about 18 per cent of the G-hay contained 35–50 per cent water and only 6 per cent of the R-hay had a moisture content of 35–45 per cent.

The effect of the moisture content of the stack on the highest average temperatures which were found in 1953 and 1954 is shown in Figures 2 and 3. This relationship follows a straight line curve. It is noticeable that the average temperatures of the stacks composed of G-hay, at any a special moisture content, is in most cases distinctly higher than the temperatures of stacks composed of R-hay. This is especially evident for the moisture contents of 25–35 per cent. Probably this may be attributed to the fact that the R-hay had been pre-fermented to some degree in the period of drying on the racks. Evidently this was most marked at a moisture content of 25–35 per cent. In most cases the highest average temperatures of the stacks composed of GR-hay, belonging to a particular moisture content, lay between the corresponding temperatures of the stacks composed of G-hay and those made of R-hay.

The favourable effect of using racks on the highest temperatures in the stacks becomes convincingly obvious in comparing the Figures 4, 5, 6, 7, 8 and 9.





o - - - - o Hay stacks composed of hay dried on racks.

●——● Hay stacks composed of hay dried on the ground.

□ — · — □ Hay stacks composed of a mixture of hay dried on the ground and hay dried on racks.

FIG. 2 FIG. 3

In Figures 4 and 5 results for 1953 are given of 103 stacks composed of G-hav and of 103 stacks made of R-hay. In most of the R-hay stacks the temperature did not rise higher than 35° C and only in two stacks did the temperature rise above 55° C. Many stacks of G-hay, however, had a temperature higher than 35°, whereas in 20 cases the temperature rose above 55°, amounting to 19.6 per cent of the stacks. The highest average temperature of all the stacks made of R-hay was 32.7° C and of the G-hay stacks 43.2° C.

In 1954 fewer data on G-hay were available than in 1953. In Figures 6 and 7 the data for 63 stacks of G-hay and 63 R-hay stacks (chosen at random) are represented.

In Figures 8 and 9 the results are shown of 273 R-hay stacks and of 84 G-hay stacks. In the stacks represented in Figures 6, 8 and 9 temperatures above 55° C were present in 18.5%, 2.9% and 5.9% of the cases, respectively.

In 1953 it was found that in 14 cases the temperatures in the stacks rose to 60° C or above 60° C corresponding with less than 3 per cent of the total number of stacks. In 13 of these cases the stacks consisted of G-hay. In 1954 also in 14 cases the temperature rose to 60° or above 60° C, viz. in 9 stacks composed of G-hay, in 3 stacks of GR-hay and in 2 stacks of R-hay. In 1953 in 5 cases the temperature rose above 70°, corresponding with less than 1 per cent of the total number of stacks, viz. in 4 cases in stacks of G-hay and in 1 stack of R-hay. In 1954 in 4 cases the temperature was higher than 70°, viz. in 2 stacks of G-hay, in 1 stack of R-hay and in 1 GR-hay stack. However, the fact must be taken into consideration that in both years and especially in 1954 only a small number of the stacks consisted of G-hay.

Hay made on the ground (1953)
(103 hay stacks)

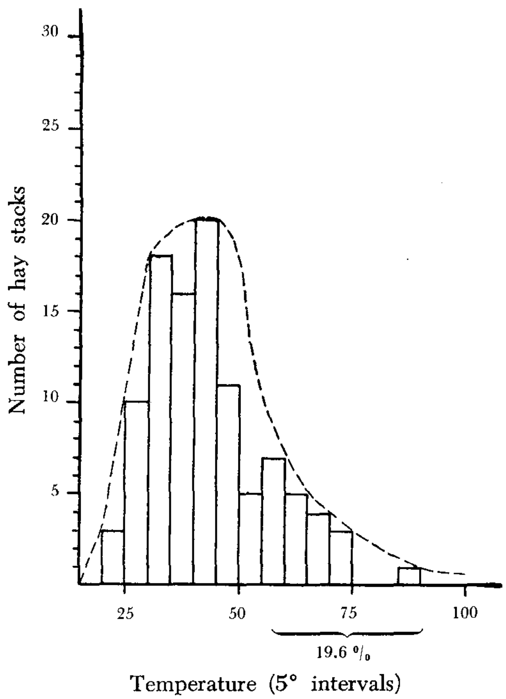


FIG. 4

Hay made on racks (1953)
(103 hay stacks)

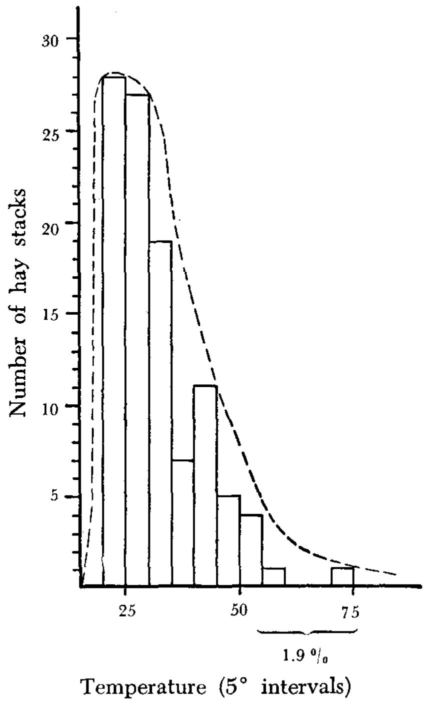


FIG. 5

Hay made on the ground (1954)
(63 hay stacks)

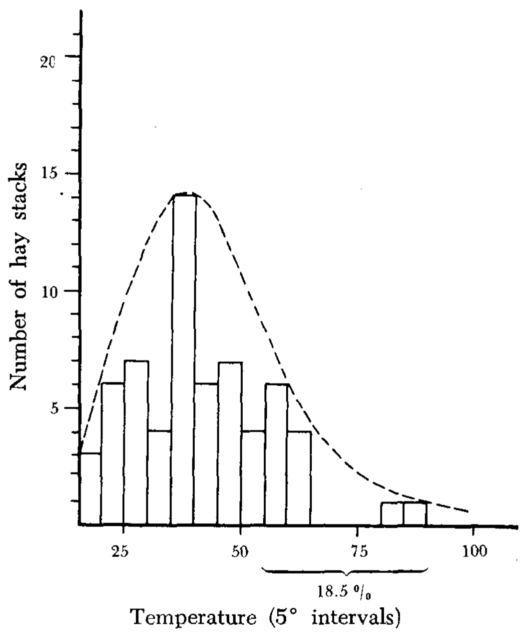


FIG. 6

Hay made on racks (1954)
(63 hay stacks chosen at random)

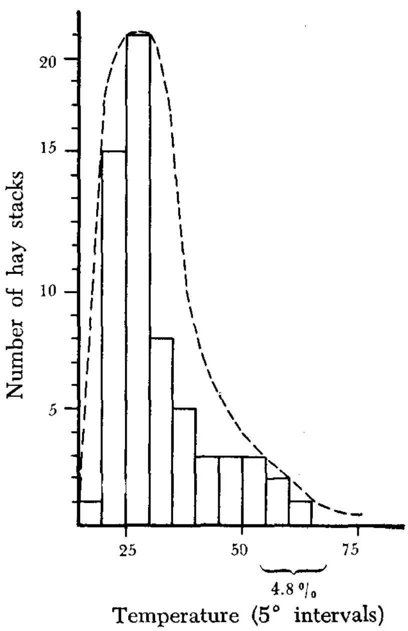
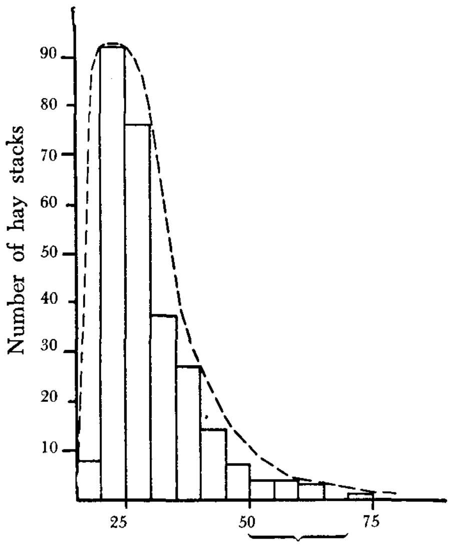


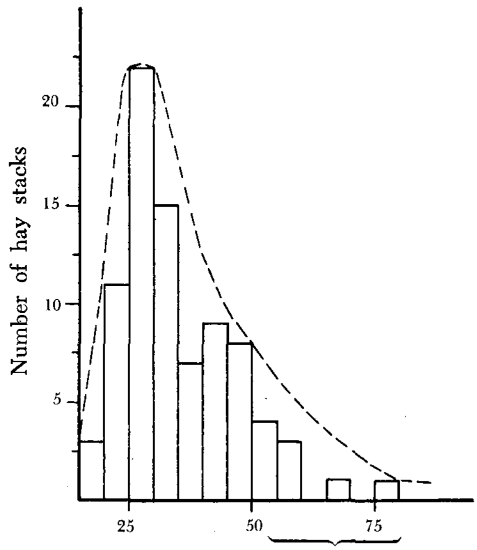
FIG. 7

Hay made on racks (1954)
(273 hay stacks)



Temperature (5° intervals)
FIG. 8

Hay stacks composed of a mixture of hay dried on racks and hay dried on the ground (1954)
(84 hay stacks)



Temperature (5° intervals)
FIG. 9

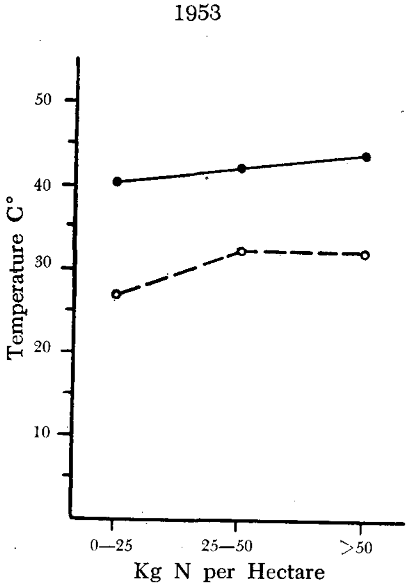
The advantages of R-hay are moreover demonstrated by the fact that according to VAN DER SCHAAF (1953) in the province of Friesland in 1952 in 27 per cent of the stacks the temperature rose above 70° C. In 1953 this percentage was 17.4 per cent. In this province only about 4 per cent of the hay stacks consisted of R-hay. In the Northern and the central clay-region of Friesland where most R-hay is made, relatively the smallest percentage of heating was found.

The effect of increasing dressings of nitrogen is represented in Figures 10 and 11. The influence of nitrogen on the highest average temperatures in the haystacks was very small or practically absent in R-hay, as was clearly shown in 1954. A greater nitrogen influence was present in G-hay.

The influence of increasing amounts of clover in the grass on the highest average temperatures in the hay stacks is shown in the Figures 12 and 13. A markedly greater effect was present in the G-hay than in the R-hay. The greater effect of nitrogen and clover on the temperatures in the G-hay is understandable, since the stacks composed of G-hay generally had a higher moisture content than the R-hay stacks. It should be taken into account that on the one hand the effect of nitrogen on the temperatures in the stacks has been obscured by the presence of clover and on the other hand the effect of clover has been disturbed by dressings of nitrogen, since generally more nitrogen was given as less clover was present.

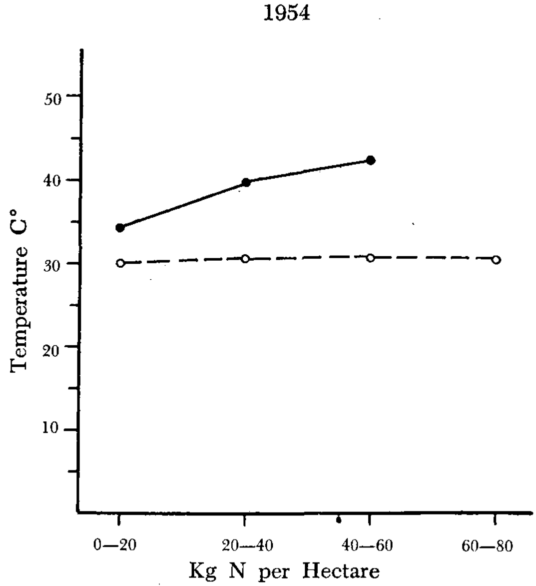
As compared with the influence of the moisture content (Figures 2 and 3) the effect of increasing amounts of nitrogen and clover was much smaller.

As may be seen from the data of Table IV the temperature in the stacks is also influenced by the growth-stage of the grass.



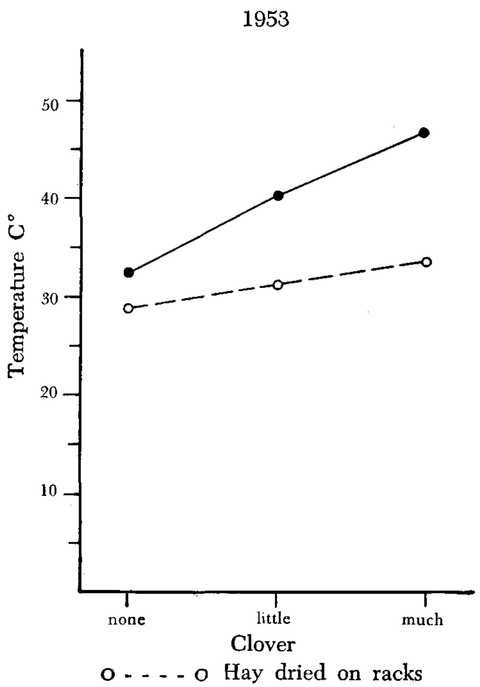
o - - - - o Hay dried on racks

Fig. 10



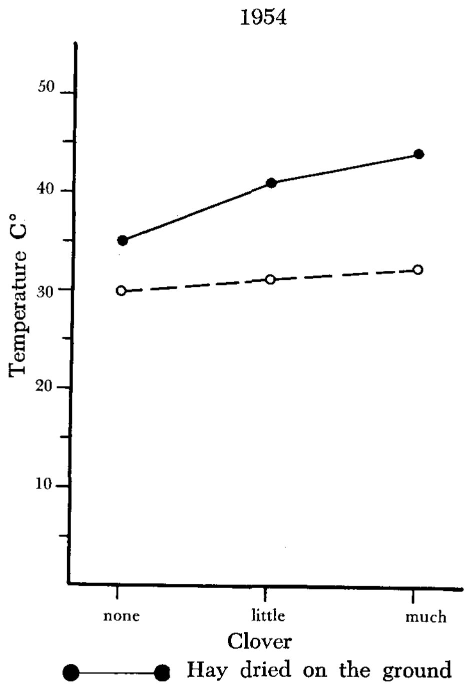
●——● Hay dried on the ground

Fig. 11



o - - - - o Hay dried on racks

Fig. 12



●——● Hay dried on the ground

Fig. 13

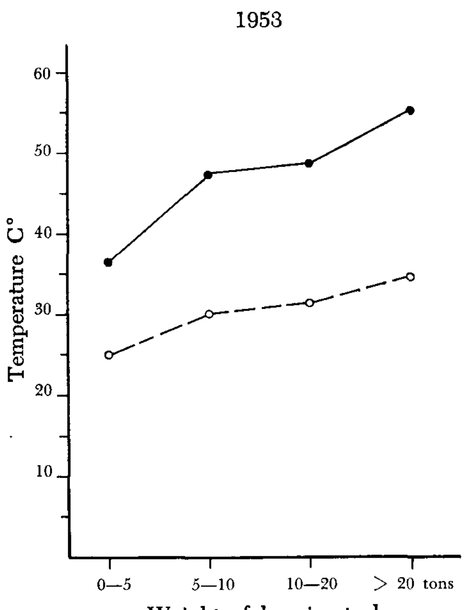
Table 4 Influence of the growth-stage of the grass on the average temperatures in the hay stacks (1954).

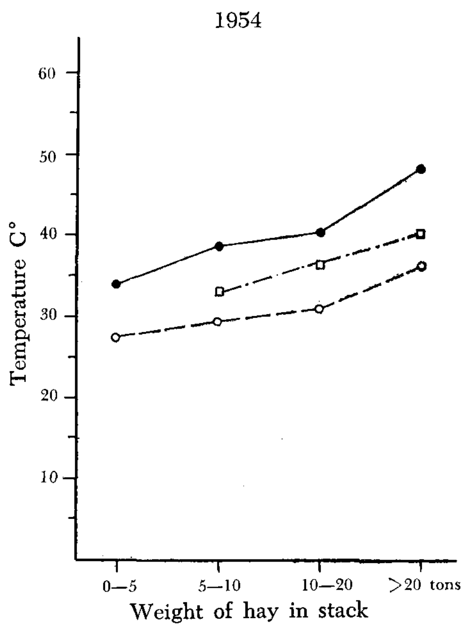
Composition of the hay stacks	Highest average temperatures		
	Young grass	Old grass	Difference
Hay dried on the ground	43.6° (42) [1]	34.0° (5)	9.6°
Mixture of hay dried on the ground and hay dried on racks	39.1° (37)	34.7° (6)	4.5°
Hay dried on racks	34.2° (114)	29.6° (24)	4.6°

[1]) The number of hay stacks concerned is put in brackets.

As in the case with nitrogen and clover the influence of the growth-stage on the average temperatures is most pronounced in the stacks consisting of G-hay.

The effect of the size of the stack on the highest average temperatures found in 1953 and 1954 is shown in Figures 14 and 15. Stacks of a large size tend to have a higher average temperature than stacks of a small size. This effect is somewhat more pronounced for G-hay than for R-hay.

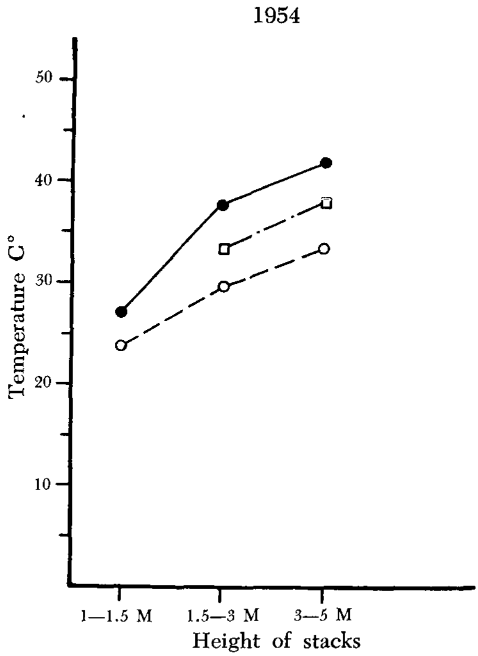




o - - - - o Hay stacks composed of hay dried on racks.
●———● Hay stacks composed of hay dried on the ground.
□—·—□ *Hay stacks composed of a mixture of hay dried on racks and hay dried on the ground.*

FIG. 14 FIG. 15

The relation between the height of the stacks and the highest average temperatures in the stacks, found in 1954, is given in Figure 16. As had been expected, generally a greater effect of the height of the stacks on the temperature is present in G-hay than in R-hay.



o - - - - o Hay stacks composed of hay dried on racks.
●———● Hay stacks composed of hay dried on the ground.
□ — · — □ Hay stacks composed of a mixture of hay dried on racks and hay dried on the ground.

FIG. 16

DISCUSSION

From the data it is apparent that several factors are conducive to heating of hay: too high a moisture content, large dressings of nitrogen, a high content of clover, the use of young grass, a large volume and a large height of the hay stack.

The most important factor is the moisture content. Preferably the moisture content should not exceed 25 per cent, since as long as the water content of the cells is ± 25 per cent respiration of the blades is still possible. As a matter of course mowing during a period of dry weather is the best practice. It must be pointed out that during such weather the product may feel dry very quickly, although the moisture content of the cells is still too high. It is of importance that the moisture content of the cells be low, which may be more easily attained in old grass than in young grass. After mowing, the grass should be spread out as quickly as possible and turned regularly. TRUNINGER (1929) recommends raking the product at the beginning of the evening into small heaps to prevent too great a moistening by dew. In the heaps moisture from the inner parts of the cells is driven off by the disengaged latent heat. The following day the product is spread out again if the weather is favourable and the exuded water will be evaporated quickly.

From the graphs it is clear that making hay on racks is especially favourable to counter excessive heating in the stacks and to prevent temperatures reaching 55° C.

In the first place this is due to the fact that R-hay generally contains less water than G-hay and secondly by the fact that R-hay is prefermented to some extent before it is piled up in the stacks. It is evident that, especially in regions with uncertain weather conditions, it is important to use racks.

The influence of the moisture content proved to be much greater than the effect of increasing dressings of nitrogen. FRANKENA (1934) has pointed out that not only is the nitrogen content of the grass raised by large dressings of nitrogen, by which the danger of heating is increased, but also the yields and moisture contents are increased so that drying takes place more slowly and consequently the farmer will be more dependent on the weather conditions. Moreover as a result of the greater yields the stacks are often made larger and higher. FRANKENA (1939, 1941) has shown that the protein content decreases with moving at a later growth-stage of the grass. This is coupled with an increasing crude fibre content.

Early mowing, therefore, ensures a high content of easily digestible constituents and there is therefore a greater danger of heating.

According to 'T HART (1941) the effect of early mowing in order to get a fodder with a high protein content often is nullified by over-heating. Protein-rich material is conducive to excessive heating and losses of 20 %digestible protein are possible.

Hay with a high content of protein is not only nutritious for cattle, but if sufficient moisture is available it is also a good substrate for microbes which are also responsible for causing the temperature to rise. PALLMANN et al (1945) found in cases of the same methods of hay-making with similar conditions and moisture contents (30 %) that hay with clover showed much more symptons of heating than hay without clover. According to BOULENAZ and CAPUTA (1951) the botanical composition of the hay may influence the moisture content, for instance the presence of many succulent weeds, and it may also affect the content of protein if protein-rich material, as for instance clover, is present.

Though high temperatures have been recorded by several investigators in relatively small hay stacks, there is a greater chance of higher temperatures in large high stacks than in small low stacks as is clearly shown in the Figures 14, 15 and 16.

As a matter of fact it is much better to spread the hay over several small stacks than to put all the hay in one big stack. If the farmer is forced to make large stacks because of limited space, it is advisable to divide the stack in two or more sections with an interspace of some centimetres.

In such sections less close packing of the hay takes place than when the same amount has been put up in one stack and better air circulation and cooling of the hay are possible.

Of course the temperature in the stacks is greatly influenced by the time spent in building it. VAN DER SCHAAF (1954) recommends not more than 1 m of settled hay per hay stack per week. In this way it will take at least 36 days for making a stack with a height of 6 m.

From the Figures 4 up to 9 it is clear that the use of special appliances is important in preventing heating. The influence of nitrogenous dressings, the amount of clover, the growth-stage of the grass, and the size and height of the stack are shown to be generally greater in G-hay than in R-hay.

In the stacks consisting of R-hay only in a few cases did the temperature rise above 55° C. Hence not only the danger of fire, but also the damage done by high temperatures to the nutritional value of the hay may be greatly reduced by making hay on racks.

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"1954 VENEZUELAN RICE PROGRAM"

Preliminary Technical Report

JOSEPH R. ORSENIGO

The above-mentioned report was published in June, 1955, by the IBEC Research Institute as an account of the experiments performed in 1954 at the Hacienda Palo Gordo, Acarigua.

On studying this very bulky report, 429 pages long, the reader's original interest will very soon give way to deep disappointment and amazement at the way in which time, money and labour have been illspent, in carrying out a relatively small programme of tests.

The present writers have, however, taken the pains to struggle through the entire book, to enable them to form a just idea of its value.

If the report is viewed from the standpoint of the agricultural statistician, the following comments can be made :

1 The work is not really a scientific publication but a detailed record, in which almost all data concerning the tests have been filed. For this reason the whole is indigestible and tiring to read, the more so because the same remarks are repeated over and over again at different places in the book.

2 Generally speaking, the conclusions reached do not give a logical picture of what has been learned from experiment. The conclusions consist of a summary of a number of significant and non-significant differences in which virtually no connecting thread of basic principle is discernible. The results of trials are only valuable if it is possible to interpret them in agricultural terms.

3 Some of the very large number of tables could be dispensed with because they contain no information ; certain of them comprise only one figure, which is thus repeated in every place in the table.

4 The trials seem to have been extraordinarily imprecise – in some cases so imprecise as almost to be pointless. In rice, this can be seen from the coefficients of variation which, in properly performed trials, ought to be in the neighbourhood if 10 %. In the present trials coefficients are met with of 35 %, 41 %, 61 % and 76 %, which appear to be abnormally high, even if the trials were laid out in an extensive way. On the other hand, the number of parallel plots has not been increased – a measure which would have been highly desirable in such a case.

5 One wonders whether, in conjunction with the previous remark, there is any point in meticulously determining the yield per trial plot down to grammes.

6 What purpose is served by including a report with tables filling 24 pages on trials which have obviously failed ?

From the standpoint of the agriculturist, the following criticisms can be made :

a What was the purpose of this series of trials ? Why does the introduction say nothing about the object it was hoped to achieve by them ? Is the series correlated with an already existing agricultural system, or has such a system yet to be developed ? Is the object