BREEDING FOR QUALITY IN COCKSFOOT (DACTYLIS GLOMERATA L.)

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ABSTRACT

Cocksfoot is a very valuable forage grass. However, its palatability and digestibility leave to be desired.

On the basis of data collected from the literature these undesirable qualities are ascribed to:

a. a high lignin content, *b.* an unfavourable K/Ca ratio and *c.* harshness of the leaves through the presence of silicified dentations.

Directions are given for the properties mentioned under *a.* and *b.* A selection method is described for developing non-dentate plants and the results obtained so far are discussed.

INTRODUCTION

Some areas in the Netherlands consist of sandy soils which are sensitive to drought. Crop rotation in the arable tracts is restricted by shortage of water prevailing for some time during the year. Permanent pastures are lacking or they are of a bad quality for Dutch conditions. When it is impossible to irrigate, the fertility of these soils can be improved by regular applications of organic matter in order to enhance the water-storing capacity.

The supply of organic matter is greatly increased by introducing leys in the crop rotation. Grassland maintained for some years accumulates organic matter considerably and its usually enables more livestock to be kept, with the consequent supplementary production of farm yard manure. In addition introduction of leys will be a widening of crop rotation.

In establishing leys on dry soil one is faced with the problem of choosing suitable species. The commonly used grasses – perennial ryegrass, timothy and meadow fescue – demand a moister and more fertile habitat and under dry conditions they are less reliable in production. The species which thrive on these poor and dry soils, mainly some *Agrostis* and *Festuca*-species, are of an inferior quality or are so unproductive that for that reason they are to be considered useless.

Species of somewhat intermediate position are therefore worthy of attention, one of them being cocksfoot, *Dactylis glomerata* L.

Cocksfoot is productive and possesses a fairly important drought tolerance, so that production in summer is relatively high and the total yield is equally distributed over the year. These properties render this grass suitable for leys on dry soils.

LACKAMP (29), on examining 30 indigenous and foreign grass species, found that cocksfoot offered the best prospects for this purpose.

In the Netherlands cocksfoot is recommended for leys on dry soils. In mixtures for permanent pastures this species is not included, because it is too vigorous in competition with other grasses in the mixture, and also because it arouses complaints that cattle sometimes neglect it.

By using on dry soils mixtures in which a late shooting selection of cocksfoot forms the main constituent, the difference in growth-rhythm with other components could be compensated.

However, complaints of low palatability continued and these induced us to search in the literature for information on the palatability of cocksfoot, particularly on the features causing impalatability and on possibilities to remove these by breeding and selection.

We have tried to compare in the first place cocksfoot with perennial ryegrass and timothy, since these grasses are fairly generally used in trials and are also well-known in the Netherlands.

A comparison of data from the literature should of course be made with some restriction since results obtained on a given place and at a given time are not valid in all cases.

Palatability and digestibility

The palatability at a given moment is dependent on many factors (3, 6, 12, 22, 37, 38, 40, 41, 46), factors which may be related both to the grass and to the livestock.

As concerns the grass we may take into account stage of growth, habitat, manuring, moisture content, health, association and time of year.

As concerns the animals, apart from individual differences, species, age and history and sometimes also the choice of other animals play a role.

The time of year has a particular influence on cocksfoot, since in autumn and winter a heavy browning, the so-called winter burning, may occur, reducing the palatability. This can also play a part in spring with the resumption of growth. However, among all these factors determining the palatability at a given moment, there is a constant factor dependent only on the plant species and called intrinsic palatability by Stapledon (41).

It is not surprising that the data in the literature concerning such a property as palatability which is so difficult to determine exactly, are not unanimous. Apart from the palatability, accessibility (12) has an influence, being better for erect growing grasses than for prostrate growing ones.

The investigations of Brüggeman (9) led to the conclusion that timothy and perennial ryegrass are more palatable for cows, calves, foals and sheep. Only hogs preferred cocksfoot. Archibald (3), in a seven-years experiment with cows, found that cocksfoot was less palatable than timothy.

Ivins (22) mentions preference of cows for meadow fescue, timothy and perennial ryegrass to cocksfoot, when considering the whole growing season. He points out that for some periods other results may be obtained, while there are also varietal differences. Davies (12) in his grazing experiments with sheep, found that cocksfoot was less palatable than timothy but somewhat better than perennial ryegrass.

On account of its vigorous growth cocksfoot can outgrow other species. This favourable property can be a disadvantage in a mixture as is shown by Scholl and

associates (39) and WIRTZ (49). These authors even are of opinion that cocksfoot under a good treatment is equally palatable as the other species. However, account should be taken of the fact that palatability-differences are dependent on the growing stage. BEAUMONT *et al* (6) state that with plants of 5–10 cm height in their experiments hardly any palatability-differences were found.

The data recorded in the literature and the experience gained by farmers might best be summarized by saying that cocksfoot in a young stage is palatable, but that it looses its palatability more rapidly then other grasses and then looses much of its ability to be grazed, or as was written by DAVIES (12) as far back as 1925: "It is evident, however, that cocksfoot is only palatable when kept fairly closely grazed".

Good palatability is a condition for the uptake of a sufficient amount of food. After that it is the digestibility that determines how much of the food may become effective.

According to the Annual Report 1956/57 (1) of the Grassland Research Institute at Hurley there are indications that cocksfoot is less digestible than perennial ryegrass, although more investigations are needed. VAN DER KLEY and VAN DER PLOEG (27) in comparative grazing experiments found that the percentage crude fibre in older growing grass increased more rapidly in cocksfoot than in perennial ryegrass, while the starch equivalent and the percentage digestible crude protein decreased more rapidly. HOLY (21) found a poor output of cocksfoot hay when compared with that of tall oatgrass.

The quality defects of cocksfoot are therefore a lower palatability and poorer digestibility. As the breeder prefers to base his work on more accurate objectives, it is interesting to consider the question whether there are properties in cocksfoot that influence the palatability and digestibility unfavourably, or reduce its feeding value in other ways. On the basis of the literature mentioned below we presume in this article three factors to be of influence, viz.

a. the high lignin content
b. the cat-ion ration
c. the harshness of the leaves

The lignin-content

According to the traditional analysis of roughage the N-free organic matter is divided into fats, crude fibre and N-free extracts.

In this pattern the crude fibre represents a standard of the indigestible part of the organic matter. However, as the digestibility of this fraction has appeared to be fairly good sometimes, this division does not comply with expectations. CRAMPTON and MAYNARD (11), cited according to PLUMMER (36), have therefore suggested to adopt an analysis based on determination of lignin, cellulose and other carbohydrates in place of the conventional analysis into crude fibre and N-free extracts. These carbohydrates are easily digestible, cellulose takes an intermediate position and lignin is considered indigestible. In addition lignin reduces the digestibility of other components (16, 32, 36).

Other authors do not consider lignin to be entirely indigestible. ELY *et al* (15), in

rations containing cocksfoot hay, found 3.8 % to 16 % as digestibility coefficients of lignin, dependent on the ripening stage of the grass. Lignin derived from young cocksfoot gave the highest coefficients.

SULLIVAN and GARBER (43), in the literature, found even higher figures for the digestibility of lignin, which, as they maintain, may be ascribed to the difficulties of its quantitative determination and of its separation from more digestible substances.

In dealing with data from the literature an attempt is made to use the system designed by CRAMPTON and MAYNARD, but this was not always possible. For practical purposes the conventional system of analysis continues in use because the determinations required in that system can be easily carried out in a series. Also there is a tendency to maintain the applicability of the investigations carried out for a century (18).

PLUMMER (36) found 5.35 % lignin in the dry matter of cocksfoot, against 4.27 % in timothy and 3.34 % in perennial ryegrass. If the lignin and cellulose fractions are taken together, the figures become 41.06 % for cocksfoot, 31.42 % for perennial ryegrass and 31.8 % for timothy. These figures hold for immature plants having few stems.

NORMAN (31) established a conspicuously high lignin content in young cocksfoot, which as he remarked may be partly due to an erroneous determination, however. The lignin content over the whole period of development was higher than that of ryegrass. The cellulose and lignin content in young cocksfoot was 46 %, in mature plants 58 % of the dry matter. For ryegrass these figures were 29 % and 47 % respectively. In an other publication (30) also this author states that cocksfoot contains a high percentage of structural constituents, even in a young stage.

KIK and STATEN (25) record for cocksfoot a higher lignin and crude fibre content than for tall fescue. ARCHIBALD and BENNET (2) however, state that the crude fibre content of meadow grass and tall fescue is higher than in cocksfoot, though cocksfoot has a higher content than timothy.

In later experiments ARCHIBALD (3) found for cocksfoot 23.0 % crude fibre, for timothy 20.6 %. These determinations were made on grasses in the grazing stage.

ARMSTRONG and THOMAS (4) compared the lignin content of cocksfoot with that of perennial ryegrass and tall fescue. When compared in the same stage of growth little difference was found; cocksfoot in general appeared to compare rather unfavourably with the two other grasses. Only in the seeding stage perennial ryegrass had a markedly higher content than cocksfoot.

PHILLIPS c.s. (34) found no reliable differences in lignin content between cocksfoot and timothy. In the years 1948/49 (34) a significantly higher cellulose content was found in cocksfoot; in later investigations (44) no significant differences between these two grasses were found in this respect. The data obtained by VAN DER KLEY and VAN DER PLOEG (27) have already been mentioned.

From the above it is clear that there is a fairly good agreement in the various data so that the content of poorly digestible organic compounds is higher in cocksfoot than in perennial ryegrass or timothy.

The breeding for a lower lignin content of cocksfoot would be facilitated a great deal if there was a simple lignin determination that could be executed on a large scale.

There is not even a method the reliability of which is generally recognized (26).

Lignin is not a simple well-defined substance, but a mixture of changing composition (26). Lignin is often determined according to the prescription of ELLIS *et al* (14), but this method is too laborious for series work with the equipment of most breeding establishments. Another criticism is that a chemical method only determines the quantity of lignin while the place where lignin is deposited is of consequence.

Apart from chemical methods, botanical methods have been used. STEPPLER (42) coloured the lignin in preparations of stem sections and then projected the coloured sections on a paper wall. The coloured part of the projected cross section was drawn in outline, cut out and its weight compared with the weight of the whole section. The ratio was taken as a quantitative estimate of lignin. A similar method was applied by BIERI (7) to determine the lignified part of the stem.

A drawback of the botanical methods is that they are applied to the stem which does not play a part in the grazing stage. The method would gain in value if there were a good accordance between the lignin-content of the stem and that of the whole plant, also in a young stage.

The foregoing data lead to the conclusion that it is not easy to select directly for a lower lignin content. It is important in this connection that the lignin content of the leaves is significantly lower than that of the stems (35), so that it is possible to approach this character by breeding for a higher leaf stem ratio. In that case a situation is reached as exists in the selection for protein content, whereby the breeders mostly do not determine the protein content but aim at a large contribution of the leaf. As a matter of fact this method is more effective for the hay quality than for the quality of young grass.

Important are also the results of BIERI (7) who found that plants with large stems are richer in crude fibre than those with fine stems so that his advice is to select in plants with fine stems. PIGDEN and HEINRICHS (35) had similar experience with *Agropyron intermedium* (HOST). In 6 clones the lowest lignin content was found in those with the finest stems. However, the percentage of leaves has an even greater influence.

A further question is whether there is a difference in lignin content between plants with stiff leaves and those with drooping leaves. As in cocksfoot there are clear differences in leaf habit (fig. 1) this point is worth investigating especially. A pleasant feature of this character is that it is valid as it applies to plants in the growing stage. Moreover it could be combined with fine stems.

The cat-ion ratio

BOSCH (8) pointed out in his lecture at the European Grassland Congress in 1954 that the ratio K/Na in cocksfoot lies higher than in perennial ryegrass. Later DE VRIES (48) has published figures leading to the same conclusion. A high value of this ratio furthers the incidence of grass tetany (8, 23, 24, 47).

For comparison we have converted some figures from the literature into the ratio K/Ca (table 1).

This ratio cannot always be computed from the data in earlier papers since the

K-content was not always determined. The ratios computed for cocksfoot are clearly higher than in perennial ryegrass, the difference with timothy mostly being smaller.

TABLE 1. RATIO K/Ca IN COCKSFOOT, PERENNIAL RYEGRASS AND TIMOTHY

	BOSCH (8)	DE VRIES (48)[1])	THOMASC.S. (45)[2])	THOMASC.S. (45)[3])	ZÜRN (50) 1st cut	ZÜRN (50) 2nd cut
Cocksfoot	5.52	3.50	2.82	3.44	3.77	3.38
Perennial ryegrass .	3.62	2.09	1.92	2.75	1.73	1.56
Timothy		3.34	2.65	3.28	2.19	2.00

[1]) grazing stage [2]) late vegetative stage [3]) in full bloom

ZURN (5) also records varietal differences in cocksfoot in this respect.

From the investigations of THOMAS *et al* (45) it follows that the ratio mentioned is higher in cocksfoot during the whole period of development of the grasses.

ARCHIBALD and BENNET (2) stated as far back as 1935 that the K- and PO_4-content of cocksfoot is high, the Ca : PO_4 ratio becoming too low.

FUELEMA and BURLISON (17) however found in cocksfoot a high and uniform Ca-content in comparison with *Bromus inermis* and *Poa pratensis*. The mutual ratio of the cat-ions was not determined.

In this connection the results of a recent investigation by ARMSTRONG *et al* (5) are important. In feeding experiments with rats they compared perennial ryegrass, timothy and cocksfoot as a source of calcium. It was shown that calcium from cocksfoot was significantly less available than from the two other grasses. This makes the mineral value of cocksfoot even less favourable. The calcium which according to the above data was present already in an unfavourable ratio is apparently also less accessible (perhaps because of the unfavourable ratio?). ARMSTRONG *et al* also found indications of an inverse proportion between the availability of calcium and the crude fibre content. The latter was highest in cocksfoot.

It is difficult to practice selection for a suitable K/Ca-ratio. Even if the desirable magnitude and the way in which the ratio depends on external circumstances were known, selection could still require a large number of chemical determinations, and this is beyond the possibilities of most breeding establishments. Some rapid methods recommended in the literature gave no satisfactory results in preliminary investigations carried out at our Institute.

Further research is necessary to ascertain how far selection on soils poor in lime offers prospects. Cocksfoot has its natural habitat on calcarious soils. It requires a soil that is rich in lime, though it possesses a relatively low Ca-content. This might be an indication that cocksfoot possesses a poor ability to take calcium from the soil.

By carrying out a breeding programme for cocksfoot on soils that are poor in lime – for which it is also destined in the Netherlands – there is a possibility of selecting a type of cocksfoot which possesses a better capacity to absorb calcium.

Another idea is the breeding of a cocksfoot that is not too aggressive against clover. Cocksfoot has a very detrimental effect on clover; in an old cocksfoot meadow of some

years standing clover hardly occurs. If in a cocksfoot ley a considerable percentage of white clover could be maintained, either through an improved tolerance of cocksfoot or of clover than the mineral-ratio of the harvested product improved considerably: the K/Ca-ratio of leguminous crops is much lower than that of grasses.

Harshness of the leaves

Cocksfoot has sharp silicious dentations, especially along the margins and the midribs of the leaves. These teeth are more vigorously developed and silicified than in other grasses. They cause the margins, particularly of older leaves, to be very sharp, sharp enough to cut the fingers. Presumably this harshness impairs both the palatability and the digestibility.

The earliest – and unfortunately the only fundamental investigation into this character was carried out by HOLY (21) in Germany in 1907. He experimented with sheep which were given hay in their rations. One group received cocksfoot hay and another group tall oat-grass hay.

The cocksfoot ration yielded a remarkably bad output compared with tall oat-grass, which could not be explained by the chemical composition of the two grasses. HOLY (21) explained this result by pointing to the heavy silicification of cocksfoot which he described in details. From his experiments it is clear that these heavily silicified parts are not broken down during the digestion process and actually block the digestion of other plant parts.

They also injure the mucous membranes and glands of the digestive organs.

As far as we know no further feeding experiments of this subject have been made.

Harshness of the leaves is often mentioned as a character reducing the palatability of a grass. DAVIES (12) includes harshness of the leaves in the secondary factors influencing taste. He presumes that cocksfoot in a mature stage is avoided by the animals for this reason.

STAPLEDON (40) states that leaves with strongly serrated or barbed margins are not palatable and will be neglected as long as more favourable herbage is available. Trials at Aberystwyth have shown that sheep evinced a decided preference for plots consisting of cocksfoot strains with the barbs reduced to a minimum.

As it is easy to ascertain the presence of dentations by touching with the fingers or by observation with a magnifying glass, selection for absence of this character offers good prospects. A favourable feature in this connection is that the silicic-acid content of cocksfoot is not higher than that of other grasses, as was shown by BIERI (7).

LACKAMP (28) mentions differences in silicic-acid content in cocksfoot seedlings and he advises selection based on this character. In our opinion the improvement of cocksfoot to a lower SiO_2-content is not more imperative than in other fodder grasses.

EXPERIMENTS

Breeding work on cocksfoot at the Foundation for Agricultural Plant Breeding started with some 4,000 plants derived from grasslands in the Netherlands and 2,000 plants from commercial seeds (13). There were big differences in harshness among the plants, which is in accordance with the experience of many others (7, 10, 20, 28).

FIG. 1. STIFF-LEAVED (LEFT) AND DROOPING (RIGHT) PLANT OF COCKSFOOT

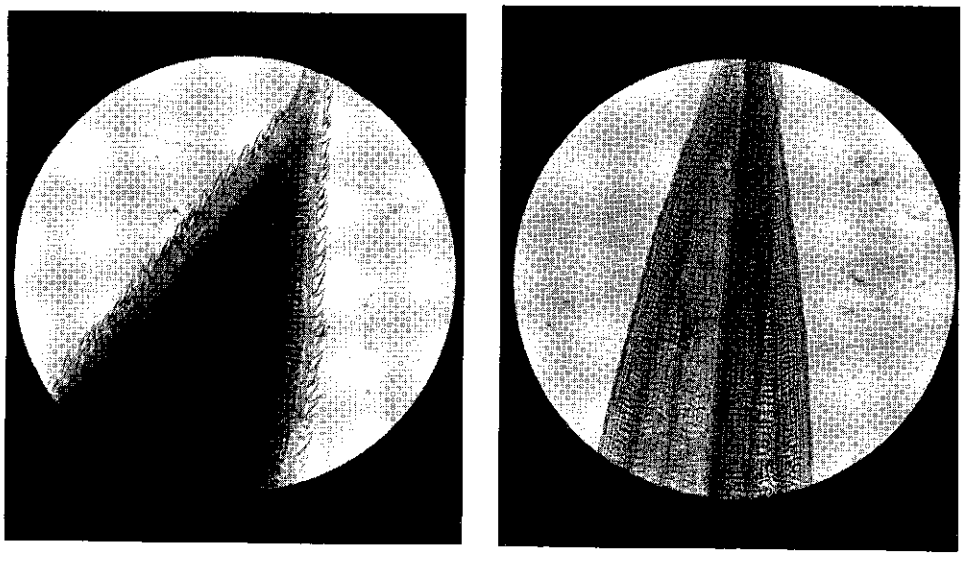

FIG. 2. ENLARGEMENTS OF DENTATED (LEFT) AND NON-DENTATED (RIGHT) LEAVES OF COCKSFOOT

However, in the initial material not a single plant was found that was entirely free from dentations.

Examining large numbers of mature plants by touching is time-consuming and unpleasant work in the long run. However, it is also possible to examine the character in fairly young seedlings and this enables the work to be done during the winter months.

The experiments were carried out in the following way:

Seeds were sown in a heated glasshouse in winter and the seedlings were examined after about eight weeks. By moving the leaves along the fingers or by using a magnifying glass this procedure could be carried out quite speedily. In total more than 10,000 plants were examined. The selection yielded 880 seedlings which were judged as being less harsh, even though they still possessed clearly visible silicic-acid teeths. These seedlings were planted in the open field in the spring and were reexamined later when mature.

After this second assessment 220 plants remained that were smoother than the others. These plants were then compelled to selfing by bagging 10 inflorescences per plant before flowering. Of these bagged inflorescences 150 gave some seed, the yields varying widely. Some selfings produced a few seeds only, from others hundreds of seedlings were obtained.

In one of these inbred families four plants were found which after examination with the fingers and with the magnifying glass appeared to be free from dentations. In the open pollinated progeny of the parent plant one other plant was found with the same character. Later this mother plant has been allowed to produce seed once more, both by selfing and open pollination, in order to ascertain the segregation ratio. It appeared that among 236 I_1 seedlings there were 11 without dentations. In 266 offspring derived from open pollination only one seedling of this type was found. It is also important to know the chance of finding in random initial material mother plants that after selfing segregate plants without dentations. Continued inbreeding in other families so far has produced no results, but investigations are being continued.

The five plants resulting from the first examination were again assessed in a mature stage. With strong magnification some vestigial dentations were seen; however, they were smaller than the serrations which are found on nearly all cultivated grasses.

Although for practical purposes the result certainly may be called sufficient, the selection has been continued. The progeny obtained by mutual pollination of these 5 plants was carefully examined with strong magnification. Through particular circumstances only a small quantity of seed was harvested in the first year, although in the next year it was shown that the seed production of these plants may be normal. From an offspring of 608 plants 260 individuals were isolated which had an even smoother surface than the five parent plants (figure 2). In the meantime these plants have produced seed which is still to be examined.

In principle harshness of the leaves in cocksfoot can be eliminated entirely by selection.

HERTSCH (20) has also recorded the existence of smooth-leaved cocksfoot plants and ZIJP (51) too describes such plants. The latter author applied X-rays and then subjected his material to inbreeding.

Discussion

In order to provide a guide to the possibilities of selecting for palatability and high digestibility of cocksfoot, we have combined the data scattered in the literature. Further research will have to test the above mentioned selection methods for their efficiency. The actual value of softness of the leaves against harshness should be ascertained, while data should also be gathered concerning the inheritance.

Improvement of a particular characteristic has sense only when the other good qualities are not lost. Therefore more knowledge is desirable on the possible relation between such properties as drought tolerance and lignin content or harshness. Many of these problems remain to be solved or are insufficiently known in the present state of our knowledge about the subject.

Samenvatting

Veredeling op kwaliteit bij kropaar

Kropaar is een zeer waardevol gras. De smakelijkheid en verteerbaarheid laten echter te wensen over. Op grond van literatuurgegevens worden als oorzaken hiervan genoemd:

a. een hoog ligninegehalte,
b. een ongunstige K/Ca-verhouding,
c. ruwbladigheid door kiezelzuurtanden.

Voor de verbetering van de onder *a* en *b* genoemde eigenschappen worden richtlijnen gegeven. Een selectiemethode ter verkrijging van niet ruwe planten wordt beschreven.

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