EUCARPIA FODDER CROPS SECTION

Report of Meeting
held at the Welsh Plant Breeding Station,
Aberystwyth, April 15th-17th 1969.

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PREFACE

Since the formation, of the Fodder Crops Section of the Eucarpia in 1958 the members have met on several occation for discussion of problems concerning the breeding and testing of forage plants.

The section, besides preparing papers for the Eucarpia conferences, has concentrated its activities on working groups and on section meetings, which have been well-attended and have resulted in interesting discussions and valuable personal contacts.

In 1968 the members of the section were kindly invited by Professor P. T. Thomas, Director of the Welsh Plant Breeding Station, to ajourn at his institute in the spring of 1969. The meeting, which was attended by 46 persons, including Professor Thomas and his co-workers, took place on April 15–17. The main subjects were:

1) Physiological aspects of the breeding of fodder crops,
2) Breeding for improved quality in fodder crops, and
3) The OECD-list of International Control Cultivars.

During the meeting Professor Thomas and members of his staff presented the work which is done at the station.

On behalf of the Board of the Section I wish to express our gratitude to Professor Thomas and his staff for their generous hospitality, for the excellent accomodation, for the interesting demonstration of their work, and most stimulating introductory lectures.

This report comprises all papers presented during the meeting. The Board thanks the authors for their valuable contributions.

D.L.F. & F.D.B.
Boelshøj, Jan. 1970.

K. J. Frandsen.
President of the
Fodder Crops Section.

List of Participants

Belgium
Mr. G. van Bogaert

Denmark
Mr. Brian A. Dennis
Dr. K.J. Frandsen
Mr. Jorgen Møller

France
M.J.Y. Blanchet
Professor Y. Demarly
M. Michel Gillet
M.M. Masson

Germany
Dr. E. Lütke Entrup
Dr. E. Farries
Dr. Benno Leitzke
Dr. Christopher Meyer
Dr. Uwe Simon

Ireland
Dr. P.T. Carroll
Dr. M.A. Valle Ribeiro

Italy
Professor Franco Lorenzetti
Professor Adelmo Panella

Netherlands
Ir. G.E. van Dijk
Ir. R. Duyvendak
Ir. J.J. Hintzen
Ir. L.H.J. Korsten
Mr. A.M.M. de Regt

Sweden
Mr. G. Ewertson
Dr. Gösta Julen
Mr. Gunnar Wiren

Switzerland
Dr. Samuel Badoux
Dr. Bruno Nüesch

United Kingdom
Dr. E.W. Bean
Dr. Martin Borrill
Dr. E.L. Breese
Dr. A.H. Charles
Dr. J.P. Cooper
Mr. W.E. Davies
Mr. T.I. Emecz
Dr. C.E. Foster
Dr. D.J. Griffiths
Dr. M.D. Hayward
Dr. J. Hill
Mr. Roy Hughes
Dr. D.I.H. Jones
Mr. A.F. Kelly
Mr. Elfed Lewis
Mr. J. Lewis
Professor P.T. Thomas
Mr. R.J.K. Walters
Mr. N. Young

Words of Welcome

P. T. Thomas

Welsh Plant Breeding Station, Aberystwyth, Great Britain

Dr. Frandsen and Gentlemen,

It is a great pleasure for me to welcome the Fodder Crop Section of Eucarpia to Aberystwyth and to hope that your visit will be both profitable and enjoyable.

I am especially pleased that you have chosen for discussion the problem of quality in herbage as well as those physiolgical characteristics that are important for production, because here at Aberystwyth they are of special interest to us. We must breed plants for animal production and that is why you will find at this Station that the needs of the animal are kept constantly in mind.

Grass, of course, is a complex crop in which differences due to management can over-ride the inherent differences between varieties. Nevertheless it is vitally important that we understand the various interacting factors which collectively determine the efficiency of conversion of solar energy and soil nutrients in a herbage variety – especially when grown as a sward in which there is often intense interplant competition.

Again, varieties produced by the breeder must be well adapted to the environment and consideration must be given, for example, to the degree of winter dormancy which should be introduced into varieties that will give their best performance in any particular region or country.

Then we must consider the intensity of animal production in relation to particular varieties of grass. Perhaps the most spectacular feature of production at high fertility and high concentration of stock is the outstanding performance of the high tillering, persistent and late flowering grasses such as S. 23 perennial ryegrass. With such a variety, it is not difficult for a farmer to produce 1500 galls milk/acre during the growing season. Indeed, if all farmers of Europe produced milk and milk products at this level the grass breeders might well be accused of causing more over-production.

But there are still many problems to be solved especially with production of meat from grass. Success with milk production led many people to consider that the only aspects of real importance were high levels of N_2 and high stocking rate. The botanical composition of the pasture was not really important and clover was a weed.

Using conserved varieties of grasses and clover at specific levels of digestibility you will find from our animal experiments that many factors are important for production – including organic and inorganic constituents as well as physical factors. There is considerable genetic variation for most of these factors and so the pathways for the plant breeder are clearly indicated.

The recent work of *Glen Burton* and his colleagues on pearl millet illustrates well the problems of forage breeding for animal production. A single dwarfing gene was introduced into a variety of millet and the two types were grown together, conserved at the same physiological age, and fed to cattle. The dwarf was found to produce 87% of the yield of digestible dry matter of the tall but at a 6.8% higher digestibility. The voluntary daily intake was 21% more for the dwarf than the tall and the daily live weight gain was 49% more for the dwarf.

Some of the factors which contributed to the net differences in animal production will undoubtedly be fully discussed at this Symposium and I feel sure we shall have a clearer understanding of priorities in the breeding of improved herbage varieties.

Variation in Physiological Characters Influencing Production of Forage Grasses

J. P. Cooper

Welsh Plant Breeding Station, Aberystwyth, Great Britain

The grass crop is basically a means of converting the seasonal input of light energy, water and soil nutrients into herbage of high nutritive value and hence into animal products such as meat, milk and woll. The present paper outlines the input limitations, of both climate and soil, to production of the grass crop, discusses those features of the plant which make for increased physiological efficiency, and suggests how the breeder can improve the efficiency of energy and nutrient conversion by the crop.

Input limitations

The primary climatic limits to production are set by the seasonal distribution of solar energy, but the use of this energy by the crop can be limited by winter cold or summer drought. In the British Isles the input of solar energy shows a tenfold variation from below 50 cal/cm^2/day in December to over 400 cal in June. In fact more than 75% of the total annual energy is received in the 6 months from April to September.

The distribution of temperature follows closely that of solar energy, but with a time lag of 1-2 months. In Aberystwyth, for instance, the coldest months are January and February, each with a mean temperature of 5°C, and the warmest is August with a mean temperature of 16°C. Corresponding figures for Edinburgh are 4°C and 15°C respectively. Since the optimum temperature for both assimilation and leaf growth in many of our temperate grasses and legumes is 20-25°C, outdoor temperatures are usually below the optimum even in mid-summer. Similarly, in most of these forage species, the minimum temperature for active leaf growth is around 5°C, although photosynthesis can continue below this value, Winter production is, therefore, limited by both low light energy input and low temperature.

The other important climatic limitation, particularly in the south–east of England, is water stress in the summer. The water balance is determined largely by the seasonal course of evapo–transpiration and of precipitation, although the water–holding capacity of the soil can modify the amount of stored water available to the plant. Potential evapo-transpiration is influenced mainly by the seasonal energy input, and varies from below 2 cm/month in the winter to over 10 cm/month in summer. Calculations of seasonal water balance, allowing for soil storage, show that for much of the south and east of England water deficits in the summer, are sufficient to affect crop growth in most years.

Even so, in practice, the limitation to total annual production of most British grassland is set by the input of soil nutrients, particularly nitrogen. Most grassland responds steadily to increased nitrogen application, up to over 500 kg N/ha/annum, and the average nitrogen input is well below 100 kg/ha.

Many soil limitations can be remedied by the farmer, either by irrigation or increasing fertilizer input, though it is not always economic to do so, but the seasonal climatic limitations of light and temperature cannot be changed, and can be dealt with only by the selection of better adapted genetic material.

The characteristics needed in a herbage variety will also depend on the seasonal *output* required from the crop in terms of energy and other nutrients, including such mineral elements as calcium and magnesium. The crop may be needed as an energy source, or protein source, or both it may be intended for grazing or cutting, either for feeding direct or for conservation; and if conserved, it may be processed as hay, dried grass, or silage.

Energy and nutrient conversion

The efficiency with which light energy is converted by the crop will depend on the photosynthetic activity of the individual leaves, the rate at which they are expanded, and their arrangement in relation to light penetration into the crop (*Cooper* 1966). The photosynthetic response of the individual grass leaf to increasing light intensities is fairly well-known (*Gaastra* 1962, *Cooper & Tainton* 1968). At low intensities, of about 5000 lux, the leaf can fix about 12–15% of the incoming light energy, but as the light intensity increases the photosynthetic rate becomes limited by other characteristics such as the amount of CO_2 which can penetrate to the active sites in the chloroplasts, and eventually a light saturation level is reached, beyond which further increase in light intensity has no effect on the rate of photosynthesis. In many temperate forage species, including perennial and Italian ryegrass, cocksfoot, and red and white clover the leaf reaches light saturation at about 20,000–30,000 lux. Consequently in the high light intensities of summer, which may exceed 90,000 lux at midday, less than 2–3% of the light energy is fixed by the leaf. In contrast, many sub-tropical grasses, such as *Paspalum dilatatum* and *Cynodon dactylon,* like sugar cane and maize, continue to increase their photosynthetic rates up to light intensities of over 60,000 lux with correspondingly higher maximum photosynthesis. Even within temperate species, however, differences in light saturation level, and hence in maximum photosynthesis, can occur. In perennial ryegrass, for instance, variation of more than 50% in maximum photosynthetic rate between individual genotypes has been reported, associated with differences in the mesophyll structure of the leaf (*Wilson & Cooper* 1967, 1969). Such variation may contribute usefully to increased production during the high light intensities of summer.

The growth of the grass crop will be influenced by the rate of expansion of the leaf surface, as well as by its photosynthetic activity. The optimum temperature for leaf growth of most temperate grasses, including perennial ryegrass, cocksfoot and tall fescue, is about 20–25°C, although for many sub-tropical grasses, such as *Paspalum dilatatum,* it is much higher, 30–35°C. Even in temperate grasses, however, species and varieties differ greatly in their lower temperature limits for active growth (*Cooper* 1964, *Eagles* 1967). Many ecotypes of perennial ryegrass, cocksfoot and tall fescue from Mediterranean environments, where winter is the active growing season, can expand leaves quite actively at 5°C, compared to northern and continental varieties which often become dormant or semidormant; there is, however, little difference in assimilation rate between the two groups at that temperature. This active leaf growth of the Mediterranean material at low temperatures is often associated with lack of frost resistance and the breeder needs to select for an appropriate balance between these characters for his own winter conditions. Conversely, northern varieties of cocksfoot and perennial ryegrass expand leaf surface very actively in the long days and at the high light intensities of summer, while in much of the Mediterranean material leaf expansion is reduced, and a degree of summer dormancy sets in.

The conversion of light energy by the grass crop will also be influenced by the distribution of light down the canopy (*Brovn & Blaser* 1968). Following germination or defoliation, the amount of assimilation, and hence the crop growth rate, are limited by the small amount of leaf surface exposed to light. As the crop grows, the assimilation per unit area of leaf is reduced through mutual shading, although the crop growth rate continues to increase. Eventually a stage is reached where the canopy is large enough to intercept all the light falling on it, and a steady growth rate is achieved.

At the low light intensities of winter the efficiency of a ryegrass canopy in converting the incoming light energy is similar to that of the individual leaf (about 12–15%), since all leaves are exposed to light of well below the saturating intensity. At the higher intensities of summer, however, the dilution of the incoming light over a large leaf area results in more efficient conversion by the capony (5–6%) compared to less than 3% by the individual leaf. This 5–6% conversion corresponds to a crop growth rate of about 200 kg/ha/day (*Cooper* 1966), which is similar to the values calculated by *de Wit* (1965) on theoretical grounds.

The amount of leaf area needed to intercept all the incoming light will differ according to the arragement of leaves in the canopy. In white clover, with flat, horizontal leaflets, all the light will be intercepted by the comparatively small leaf area index of 3–4 (i. e. when there are 3–4

cm^2 of leaf above 1 cm^2 of ground), but in a ryegrass sward with more erect leaves, the same amount of light can be spread over a leaf area index of 7–8 (*Brougham* 1960). Similarly within the ryegrasses, a more erect variety, such as S. 22 Italian Ryegrass, will spread the incoming light over a greater leaf area than will a prostrate type, such as S. 23 perennial ryegrass. The leaf area needed to intercept all the incoming light will also differ with the season, a smaller leaf area being required for the lower light intensities of winter.

Flowering and seed production influence the distribution of dry matter within the plant, and are often accompanied by a decrease in tillering and a cessation of root growth. They are also associated with an increase in fibre content and a reduced digestibility. The seasonal cycle of flowering in temperate grasses, such as perennial ryegrass and cocksfoot, differs with the variety, and is often related to past climatic or agronomic selection.

In a Mediterranean environment, where summer drought is the limiting climatic factor, locally adapted varieties grow actively through the winter, and flowering and seed production must take place in spring before the summer drought begins. By contrast, in a northern or continental environment where winter cold is the limiting factor, local varieties do not produce heads until late spring or early summer, and seed development occurs during the long days of mid-summer. In the maritime clinate of the British Isles, where neither summer drought nor winter cold are severely limiting, a range of early, medium and late flowering varieties have been developed in response to different systems of management. These differences in the date of flowering are based on developmental responses to temperature and photoperiod, which can be measured and selected by the plant breeder (*Cooper* 1961).

Although the fertilizer input, unlike the climatic limitations, is under the control of the farmer, the selection of varieties with the most efficient response to fertilizers is an important breeding objective. It is important to distinguish between varieties which respond well to a particular nutrient in terms of total dry matter production, and those which can take up and concentrate that nutrient in the plant. In perennial ryegrass, for instance, it is possible to select varieties or individual genotypes which accumulate nitrogen and so have a higher protein content, or, alternatively, those which produce a higher total dry matter, often with a lower protin content (*Vose & Breese* 1964). Similarly, large varietal and genotypic differences exist in the accumulation of such elements as sodium and iodine, which may be important in the nutrition of the grazing animal (*Jones & Walters* 1969).

Since the grass crop is grown to feed the ruminant, the availability of the energy and nutrients in the herbage is very important (*Jones & Walters* 1969, *Raymond* 1969). The digestibility of most grasses is high in the spring, but declines steadily after ear emergence; late-flowering varieties, therefore, maintain a high digestibility longer than early flowering ones. Species and varieties, however, also differ in digestibility even in the vegetative stage. Cocksfoot, for instance, is usually less digestible than ryegrass, though some varieties may approach the ryegrass range. Similarly, the proportion of soluble to structural carbohydrate in the herbage, which also differs with the variety, can influence the pattern of fermentation in the rumen and hence the relative value of the herbage for meat or milk production. Variation in protein content, and in such important elements as sodium and iodine has already been mentioned.

Finally, the wide range in energy input, and hence in potential production of the grass crop, between winter and summer means that some form of conservation of summer production is usually necessary; the breeder must therefore pay attention to those physical and chemical features of the crop which make for effective conservation. These may include ease of handling of the cut material, rapidity of water loss and retention of leaf during haymaking, and the optimum soluble carbohydrat/protein balance for fermentation during silage making.

Assessment of genetic variation

Clearly a wealth of variation is available to the breeder in those physiological characteristics of the grass plant which control the seasonal conversion of energy and nutrients.

In order to use this variation in a breeding programme, the breeder needs to know how much of it is heritable and can be fixed by selection, and also what genetic correlations exist between favourable and undesirable characteristics in his breeding material. In perennial grasses, a preliminary assessment of the amount of genetic variation can often be obtained from measurements of clonal replicates, followed by more critical estimates of heritability, derived from parent-progeny regression or the analysis of full-sib families. In perennial ryegrass, such characters as date of flowering, leaf size, and rate of leaf appearance are highly heritable, as shown by heritability values of over 60%, while other important characters such as maximum photosynthetic rate (*Wilson & Cooper* 1969), uptake of nitrogen, and soluble carbohydrate content show lower, though still useful, values of 30–50%. A heritability value of 30% or over, implies rapid and useful response to selection, and in most temperate grasses, which are cross-fertilizing and highly heterozygous, response can continue for several generations. For date of flowering in Irish and Kent perennial ryegrass, for instance, with a heritability of over 70%, response has continued for more than 5 generations, and the extreme early and late selection lines are now well outside the range of the original varieties (*Cooper* 1961). Similar rapid and continued response to selection has been obtained for leaf size and for rate of leaf appearance in both Italian and perennial ryegrass (*Edwards & Cooper* 1963).

Difficulties may arise, however, from an association between favourable and undesirable characteristics in the breeding material. In ryegrass, selection for large leaves often leads to a slower rate of leaf appearance and vice versa; similarly, selection for extreme early and late flowering can result in reduced male and female fertility. As already mentioned, the active leaf growth at low temperatures of many Mediterramean ecotypes of many grasses is often associated with susceptibility to frost. The possibility of breaking down these unfavourable genetic correlations by further selection will depend on whether the two characteristics are related physiologically, as those of leaf size and rate of leaf appearance, or whether they have simply been selected together in the past.

Breeding objectives

The choice of objectives in the breeding programme requires a knowledge of the seasonal production of existing herbage varieties, and of the extent to which they fall short of their potential energy and nutrient conversion (*Cooper* 1969). Recent studies at Aberystwyth (*Cooper* 1968) and at Wageningen (*Alberda* 1968) show that a number of highly-tillering ryegrass varieties, grown without limitations of water or soil nutrients, and cut to maintain adequate light interception through the year, can provide a dry matter yield of over 20,000 kg/ha/annum, corresponding to over 3% conversion of light energy. Their seasonal production varied greatly through the year reaching a maximum in May and June, but the range in energy conversion was rather less, from about 2% in the winter period to 3–4% in the summer. The frequent harvests, involving 6–7 cuts during the growing season, prevented ear emergence in these late-flowering varieties, and the digestibility was maintained above 75% of all harvests. The crude protin content could be modified by nitrogen application, but remained over 13% in all material, providing an annual yield of crude protein of about 3000 kg/ha. These dry matter yields are much greater than the average production from grassland in Britain which is 6–7000 kg/ha of dry matter, but are approached by a number of intensive grassland farmers using high fertilizer inputs and/or high stocking rates (*Armitage & Templeman* 1964).

In terms of both digestible energy and protein, these potential yields from the grass crop compare favourably with those from other farm crops (*Cooper* 1967, *Holliday* 1966). A good cereal crop, with a grain yield of 50 q/ha, achieves only 0.5% conversion of the annual input of light energy, and a protein yield of below 600 kg/ha, largely because the crop occupies the land for only a portion of the year (the energy inputs of August and September being wasted), and also because the economic yield includes only part of the total dry matter. A potato crop of 50 tonnes/ha, which maintains and active leaf canopy for most of the summer, can convert rather more light energy, over 1%, although here again only part of the total dry matter is used. On the other hand, a sugar beet crop which occupies the ground from April to October, can provide up to 20 tonnes/ha of total dry matter corresponding to over 2% of the annual input of light energy, including 7.5 tonnes/ha of sugar which accounts for 0.8% of the light energy. Although the energy and protein yield from grass is considerably higher than from other field crops, it requires serial harvesting either by grazing or regular cutting, consists of fresh material with a high water content which is difficult to conserve, store and transport, and of course must be processed through the animal. Even so, as an energy source for the ruminant, the margin between grass and a cereal crop is considerable.

Although the potential production of many existing grass varieties is considerably higher than that usually obtained in practice, a yield of 20,000 kg dry matter/ha/annum corresponds to only 2–3% conversion of the annual input of light energy, well below that theoretically possible (*Loomis & Williams* 1963). Future improvement of energy and nutrient conversation by the grass crop may well involve such features as

(i) a higher light saturation level, to make better use of the high light intensities of summer (*de Wit* 1965).

(ii) more effective light distribution down the crop, particularly at high light intensity and a high leaf area index (*de Wit* 1965).

(iii) more active photosynthesis and/or leaf expansion during the low temperatures and low light intensities of winter.

(iv) more efficient uptake and use of soil nutrients, with particular reference to the nutritional requirements of the ruminant (*Jones & Walters* 1969, *Raymond* 1969).

(v) better adaptation to conservation methods, including the optimum soluble carbohydrate/protein balance for silage making.

Selection programmes for many of these characteristics have now been established within existing forage varieties.

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Adaptability to Utilization and Breeding of Cocksfoot for Quality

S. Badoux and J. Caputa

Stations Federales d'Essais Agricoles
Domaine du Chateau de Changins, Nyon, Suisse

Few fodder plants are as much disputed as cocksfoot. In regard to its productivity and resistance to drought, many people consider it as a blessing, but others reject it as a weed.
Cocksfoot has, undoubtly, two important deficiencies:
– it has a questionable quality
– it has shown a poor adaptability to various systems of utilization.
The link between both characteristics is evident. *Rebischung,* the former secretary of our Association and a promoter of cocksfoot in France, used to say: „Recommend it only to people who are already enthusiastic about it", because only those who understand exactly its utilization will get some use from it.

In connection with this problem, we shall use the word quality in a rather restricted sense, linked to the contents of crude protein and fibre. This does not mean that connected problems like the digestibility, the palatability, the K: Ca ratio and the harshness of the leaves have to be neglected. The first point has been investigated in several countries, the others have been reviewed by *van Dijk* (9).

Utilization

The system of utilization is the result of at least 4 different factors: Cutting height, date of the first cut, frequency of cuttings and nitrogen fertilization. All combine to determine the quantity and quality of the fooder. The studies on this point may tentatively be summarized as follows:

Stapledon (22) has already shown that a close cutting will diminish the yield. Several authors (11, 13, 20) have come to the same conclusion. However, they seem to disagree on the optimal cutting height. Furthermore, the quality is modified only in extreme cases (11) due to a change in the leaves to stem ratio. Other results (reviewed by 20) show that the longer the cutting

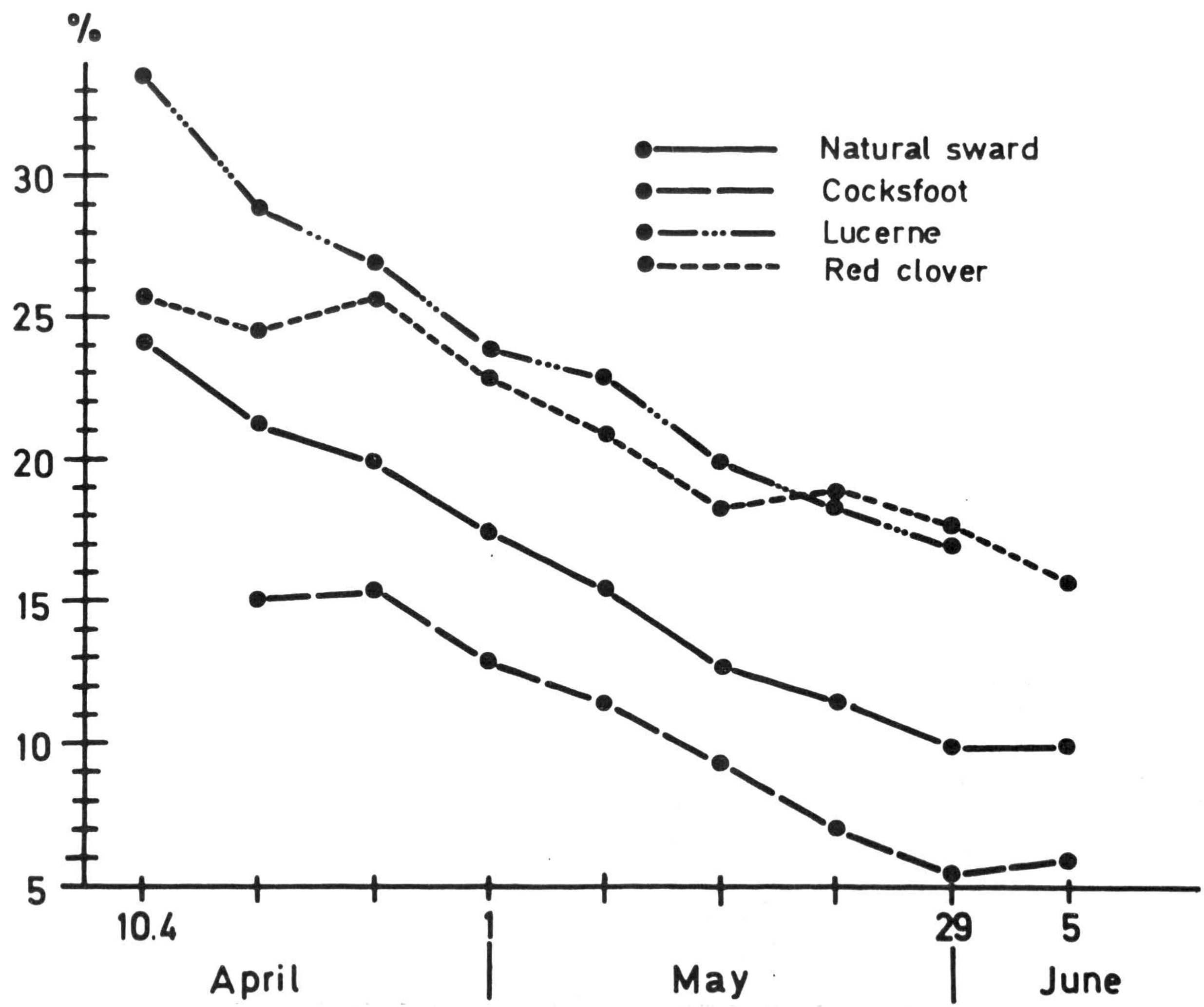

Fig. 1 Crude protein content according to the date of cutting.

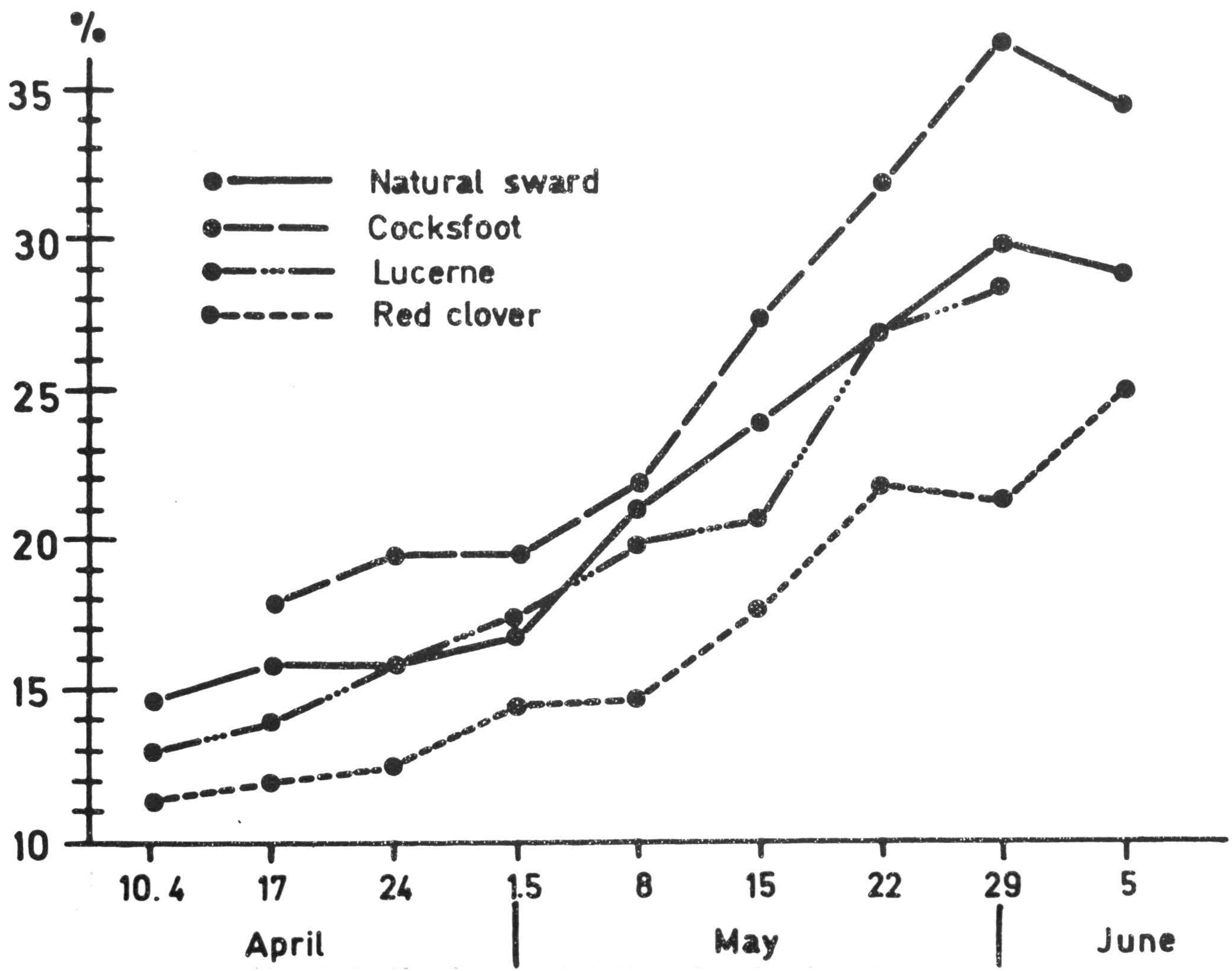

Fig. 2 Crude fibre content according to the date of cutting.

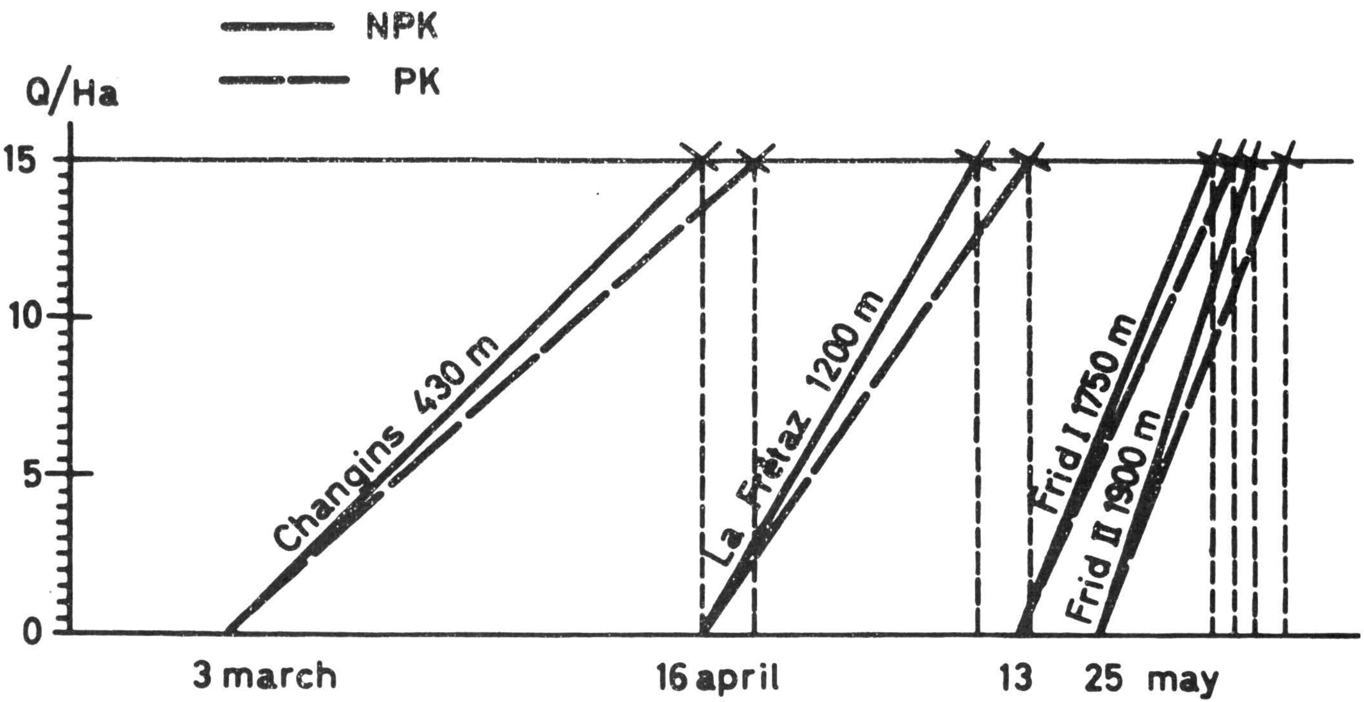

Fig. 3 Growth rate of native sward at various altitudes, between the beginning of growth till the 15 q/ha dry matter level.

interval, the higher the yield. However, the protein content of cocksfoot decreases quickly with senescence, when the fibre content increases (fig. 1 and 2); the digestibility (17) and the palatability (6) becomes less favourable also.

It is mostly in the spring, during the generative phase, that the cocksfoot quality has chances to fall below the threshold of tolerance. To avoid this, it is advisable to have an early first cutting (15, 16), just at the beginning of heading. In this way, the nutritive value of the first growth will be better and the ratio first cutting-total yield modified so that the later cuttings are more important. This method presupposes homogeneous cultivars and in the case of grass-legume mixtures, a good harmony between the species.

Nitrogen fertilization is a way of improving the weight and the quality as well. It increases (11) the protein content but does not change the percentage of fibre. This may be due (1) to increase of the leaf area and of the tillering, whereas the number of leaves per stem is not modified.

Physiolgical and morphological characteristics connected with cocksfoot quality

By the use of methods of utilization based on the physiology of the plant, the agronomist will be able to improve the quality of the fodder. Information on the physiology of the growth would also be helpful to the breeder, who must choose among his basic materials according to morphological characteristics which we call „dynamic", because they are steadily changing according to the stage of development.

Date of heading

Cocksfoot may be grown in a pure stand; in this case it will be possible, with a homogeneous cultivar, to get a maximum of fertile and vegetative tillers just reaching the optimal developmental stage at the cutting. More frequently however it will be grown with a legume in order to profit from the advantages of a grass-legume mixture. Using the varietal differences between the dates of heading and bearing in mind the problem of interspecific competition, it should be possible to find balanced combinations. Unfortunately, the spreading of the heading dates in a species varies according to the climatic conditions, mostly with latitude and altitude as already shown by the OECD project in 1956 (12, 19).

In cocksfoot, the interval between the heading dates of the earliest and latest varieties ranges from 46 days in Atlantic conditions to 23 days in Nyon (420 m.above sea level) and to 10 days at La Frétaz (1200 m.) (fig. 3).

As shown by *Caputa* (7), the start of the vegetation is "explosive" at high altitudes. For example, 15 q/ha of dry matter (fig. 4) are harvested 45 days after growth begins in Nyon but only 32 days are required at la Frétaz. So plant development is obviously accelerated. This may have an influence on the protein and fibre contents. Investigations are now being made on this point with cocksfoot, but we have not yet obtained any final conclusions. In any case, utilization of grassland at high altitudes is more rigid and difficult.

Under Swiss conditions, cocksfoot is mostly associated with red clover and lucerne. Native varieties of clover and early lucerne bud about the 25th of May and the first week of June respectively; the latest cocksfoot cultivars are heading about May 22nd, Under these circumstances only the late types of cocksfoot may be used as a growing partner.

However, the late cocksfoot strains may have two shortcomings which should be taken into account in breeding:

– they are slow growing and less competitive against other fodder plants and weeds during the period just after sowing (4); this may be a complication for the mixture with aggressive legumes like lucerne and red clover,

– late types of cocksfoot seem to be poorer in protein and higher in fibre than the early ones. *Sullivan* and *Routley* (32) have shown a negative correlation of –0.86 at heading time and of –0.68 at full flowering between the date at which that stage occured and the protein contents.

Tillering

The physiology of tillering has been intensely studied during the last few years, mostly in connection with the quantity of light and with the temperature as well (23, 14, 15, 18) as with the system of utilization. Under conditions of undisturbed growth, one notes successively an active period of tillering during the autumn, stopping during the winter with a new start in the spring; then from the begining of the generative period the number of tillers will decrease slowly until flowering. Working with the cultivar "Floreal", *Lehmann* (15) in Zürich notes a decrease from 5044 tillers/m^2 to 4488 in 1965 and from 5063 to 3583 in 1966 during the 3 weeks before flowering. This decrease concerns only vegetative tillers, so that the ratio of vegetative to fertile tillers is modified. Tillering influences the quality mostly indirectly by a modification of the ratio of leaves to stems. If, as we shall see later on, the difference in ability to tiller between genotypes is obvious, this change may be important.

The separation of the various parts of the plant

Morphological and anatomical characteristics are easy to observe and to analyse. They may in some cases be connected with factors of quality and be useful criteria of selection. The feed

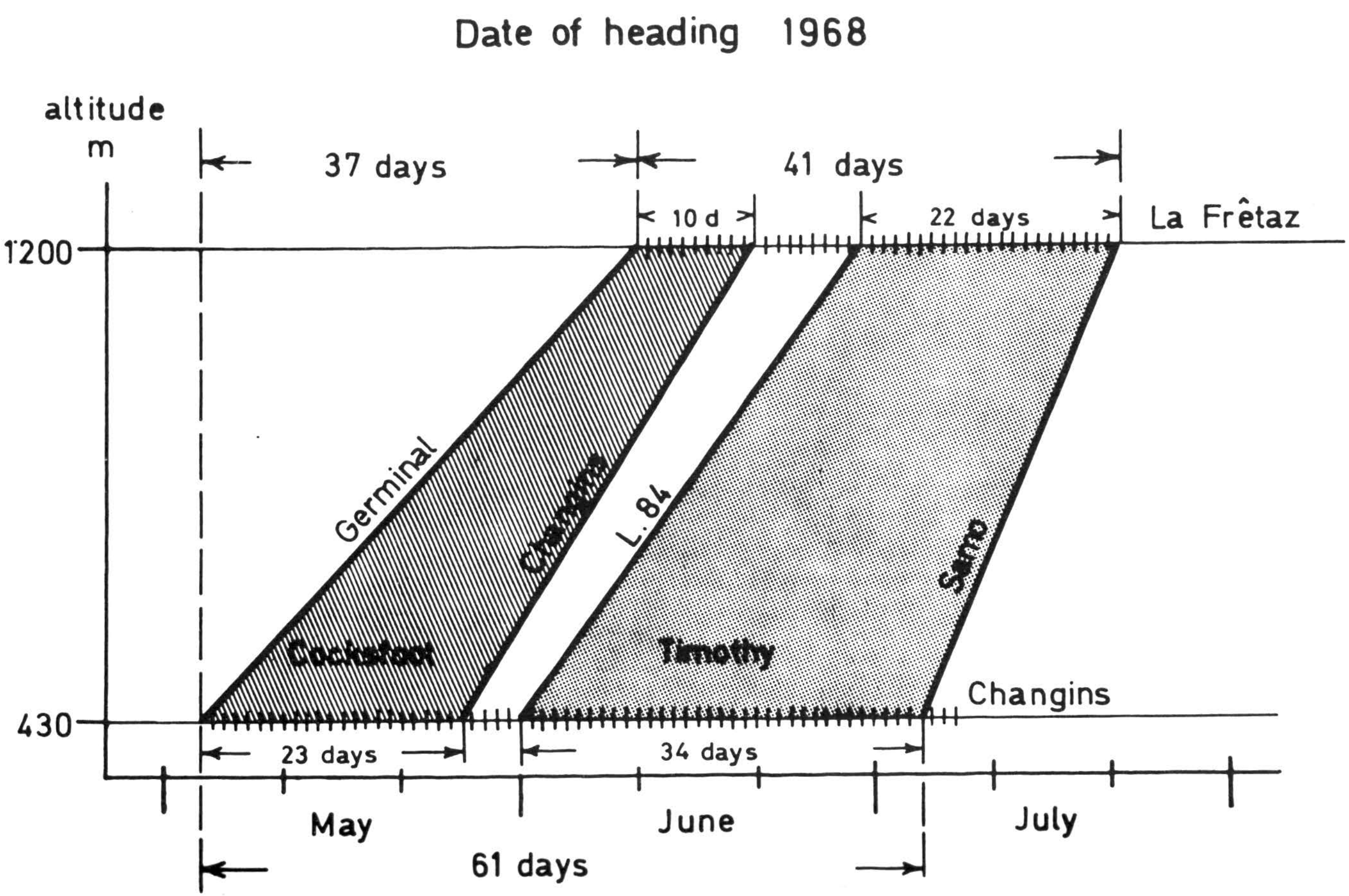

Fig. 4 Range of the dates of heading of cocksfoot and timothy according to the altitude.

Cocksfoot

Beginn of flowering

	Year	Crude Fibre %	Crude Protein %	Protein Digestibility %
Stems	1967	41,6	5,4	79,7
	1968	42,2	5,4	81,4
Leaves + vegetative tillers	1967	31,9	10,4	72,8
	1968	33,5	11,4	79,4
Isolated leaves	1967	34,4	7,2	53,4
	1968	34,9	8,7	62,-

Table 1 Mean crude fibre and crude protein content of various parts of the cocksfoot plant.

<table>
<tr><th>Species</th><th>Year</th><th>Number of cultivars</th><th>Stems (without leaves %</th><th>Leaves on the stems %</th><th>Vegetative tillers %</th><th>Isolated leaves %</th></tr>
<tr><td>Cocksfoot</td><td>1967</td><td>28</td><td>79,0</td><td>11,2</td><td colspan="2">9,8</td></tr>
<tr><td>Cocksfoot</td><td>1968</td><td>28</td><td>74,3</td><td>9,2</td><td>11,7</td><td>4,7</td></tr>
<tr><td>Meadow Fesc.</td><td>1967</td><td>20</td><td>75,5</td><td>8,2</td><td>8,2</td><td>6,0</td></tr>
<tr><td>Timothy</td><td>1967</td><td>26</td><td>75,9</td><td>6,5</td><td>6,5</td><td>4,0</td></tr>
</table>

Table 2 Percentage of the various parts of the plant in cocksfoot, meadow fescue and timothy.

value of the various parts of the plants is different. Stems are poor in protein and rich in fibre (table 1), when the quality of the leaves and vegetative tillers is better.

In comparison to other species cocksfoot has a low stem weight percentage in the first growth (table 2). In the group "isolated leaves" are included the leaves fallen from the base of the stems and decaying tillers which could not be classified in any other category. That is the reason why this material has such a low protein digestibility. For a long time cocksfoot has been bred for a high ratio of leaves to stems. *Fagan* and *Jones* (10) have already noted that the leaves had a better quality. *Bieri* (5) has shown a correlation coefficent of +0.421 between the leaf percentage and the protein content and of –0.452 between the leaf percentage and the fibre content.

However, immature stems and sheaths may be more digestible than leaves. According to *Raymond* and *Terry* (21), the breeding for leafiness might, in some cases, correspond to a selection for low digestibility.

In our material, the digestibility of the protein is somewhat better in the stems than in the leaves. We have also to remember, as shown in fig. 5 drawn from the data of *Lehmann*, that the ratio of leaves to stems has only an instantaneous value, so that it is only possible to compare genotypes or varieties which are exactly at the same stage of development.

Tables 3 and 4 show the means, the standard deviations and the correlations between the dates of heading, the tillering capacity and the ratio of the various anatomic parts of cocksfoot. These data has been collected from the 4 replications of a trial with 28 European cultivars of cocksfoot.

Some characteristics, like the date of heading or the percentage of stems, are relatively stable from one year to the next, but others are varying considerably. The stems were shorter in 1967 after a winter season than in 1968, when, strangely enough, the weight per stem was decreasing with its age. The highest coefficient of variation has been noted on the number of vegetative tillers.

All characteristics studied show a significant coefficient of correlation between the results in these two years. For the leaf weight percentage, the parent progeny correlation calculated by *Cleveland* and others (8) indicates a good coefficient of heritability. This character is correlated with short and light stems, with a late date of heading and with the number of tillers. The number of vegetative tillers itself is highly correlated (+0.879) to the total number of tillers. So tillering may be a valuable criterion of selection.

It should also be possible to increase the weight percentage of leaves attached to fertile stems, although its coefficient of variation is not very high.

The studies on the question of the thickness of the stems in connection with fodder quality show that differences in fibre contents are not related to the thickness of the stems (5) but

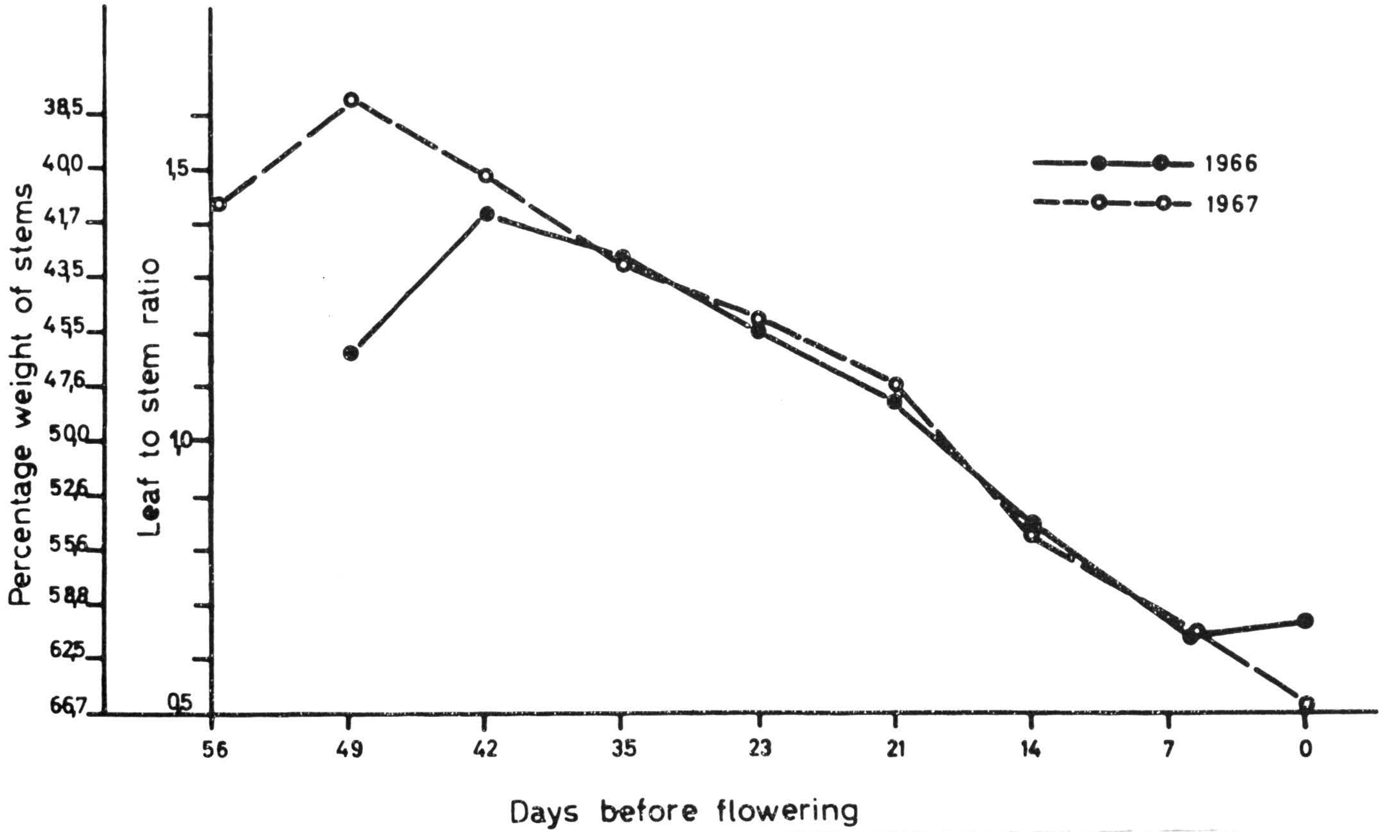

Fig. 5 Modification of the leaf to stem ratio according to the stage of development of „Floreal" cocksfoot.

Characteristics	Year	Mean		s
Date of heading	1967	12,1May	±	6,3 j
	1968	14,5May	±	6,2 j
Number of tillers	1967	219	±	38
	1968	309	±	65
Number of vegetative tillers	1967	45,1	±	18,5
	1968	139,6	±	58,1
Stems weight/Total yield %	1967	79,0	±	4,5
	1968	74,3	±	6,8
Stems weight/Fertile tillers weight %	1967	87,6	±	1,6
	1968	89,0	±	2,1
Stems lenght cm	1967	85,4	±	7,0
	1968	105,0	±	6,2
Weight of one stem g (without leaves)	1967	1,61	±	0,35
	1968	1,07	±	0,2

Table 3 Mean and standard deviation of morphological characteristics in 28 cocksfoot cultivated varieties.

		Date of heading	Number of vegetative tillers	Stems weight/Total yield %	Stems lenght cm	Weight of one stem	Stem weight/Fertile tillers weight %
Date of heading	67 68	0,912					
Number of vegetative tillers	67	-0,019	0,440				
	68	0,507					
Stems weight/Total yield %	67	-0,240	-0,525	0,591			
	68	-0,654	-0,814				
Stems lenght cm	67	0,202	-0,280	0,336	0,440		
	68	-0,022	-0,697	0,709			
Weight of one stem	67	0,023	-0,380	0,628	0,638	0,772	
	68	0,083	-0,600	0,433	0,655		
Stem weight/Fertile tillers weight %	67 68	-0,770	-0,023	0,504	0,366	-0,192	0,673

Table 4 Correlation coefficients between physiological and morphological characteristics of cocksfoot (28 cultivated varieties).

rather to the duration of the development. The late types have more time to build up a larger amount of sclerenchymatous substances. In our experiment, the correlation coefficient between the weight of a stem and the heading date is very low.

A positive but low correlation has also been found by *Bieri* (5) between the contents of chlorophyll and protein and he suggests a selection by visual estimation of the darkness of the green color of the leaves. In our opinion this is valuable only inside a group of genotypes with the same heading dates. If not, this would be in contradiction with the fact that the early types have more protein and are less dark.

Conclusion

In the breeding field we must use methods of utilization corresponding to those which will be in common practice after ten or twenty years. This concerns also the nitrogen fertilization and the date of the first cutting.

The content of protein is only one of the factors which make up the quality of the fodder for animal feed, but it has the advantage of being easily analysed and being correlated with physiological and morphological characteristics. Breeding for high protein content may be combined with the determination of digestibility and of soluble carbohydrates as a way to assess the animal preference (6). Genotypes of cocksfoot, which retain a high protein content in spite of the ageing process, could be of interest.

The creation of a scale of homogeneous cultivars with different dates of heading is one of the ways to overcome the difficulties in utilization due to a rapid loss of quality in cocksfoot. At higher altitudes, however, the differences of heading dates are disappearing.

In the combination with legumes such as red clover and lucerne, only late types are of interest, due to a better growing balance between the partners. They are also more leafy and as shown in a grazing experiment in Nyon, they had a better repartition of the yield during the growing season. However, it will not be easy to destroy the negative correlation between lateness and initial growth on one side, and lateness and protein content on the other side.

The ability to tiller has a high coefficient of variation. This may be of interest when breeding for a grazing type.

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List of Figures

Net Energy Estimation by Determination of the „In Vitro" Digestibility and its Value to Fodder Crop Breeding

C. Meyer

Max-Planck-Institut für Züchtungsforschung, Köln, Germany

For several years many institutes concerned with fodder crop breeding and likewise some commercial breeders have employed the method of digestibility testing developed by *Tilley* and *Terry*, or variations of this method, for selection of better quality by which higher digestibility and higher crude protein content mostly are meant.

In animal nutrition, however, one means by good quality a high net energy content of the fodder. Depending of the purpose of the animal (milk production or fattening), the fodder must contain a specific quantity of net energy in form of crude protein in order to guarantee a correct nitrogen balance. Such a fodder must additionally possess a certain percentage of ballast substances for the maintainance of rumen action. As for the mineral content, I understand that this aspect will be dealt with by another speaker.

Excluding the question of mineral substances, the breeder has to take into consideration the following requirements: the plants should yield a fairly high net energy per unit weight, they must contain adequate crude protein, and the digestibility should not exceed certain limits. The experiments carried out in our institute were intended to show how these requirements can be met by taking account of the percentages digestible organic matter (DOM) and crude protein (CP), and what possibilities may exist for breeding corresponding forage grasses.

The basis of our investigations was previously mentioned in vitro digestibility test, where the test material is digested first for 48 hours in a mixture of rumen fluid and buffer solution, followed by another 48 hours incubation in a hydrochloric acid pepsin solution. From the beginning of our investigations we used this original method, but instead of dry matter we determined the organic matter digestibility, because a highly significant correlation was established between the *in vivo* digestibility and net energy of organic matter, measured in starch equivalents (SE). The experiments were carried out with clonal plants multiplied by division to allow simultaneous *in vivo* investigations. These feeding trials were made by Dr.

Fig. 1: The dependence of DOM on the times of incubation in rumen fluid + buffer solution and in pepsin solution

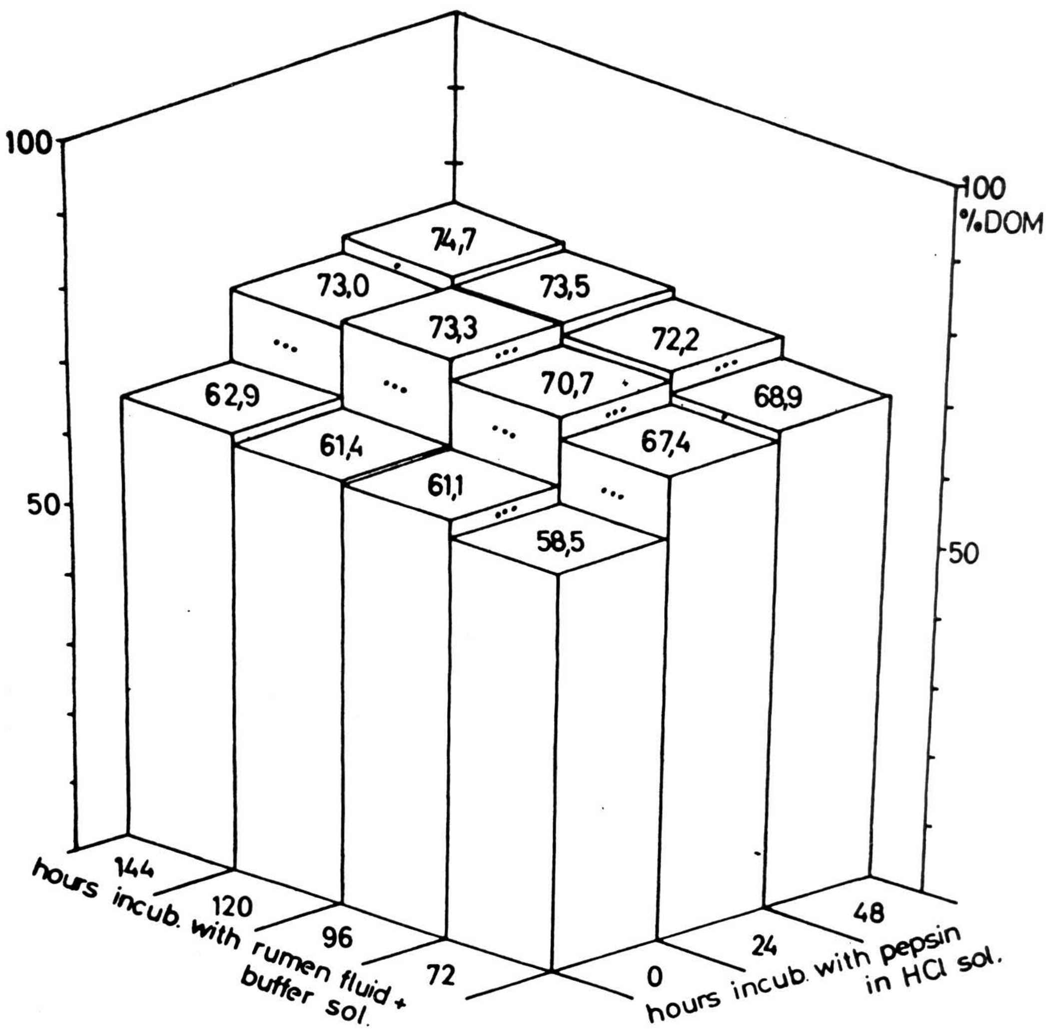

Fig. 2: Correlation and Regression between true und estimated SE values

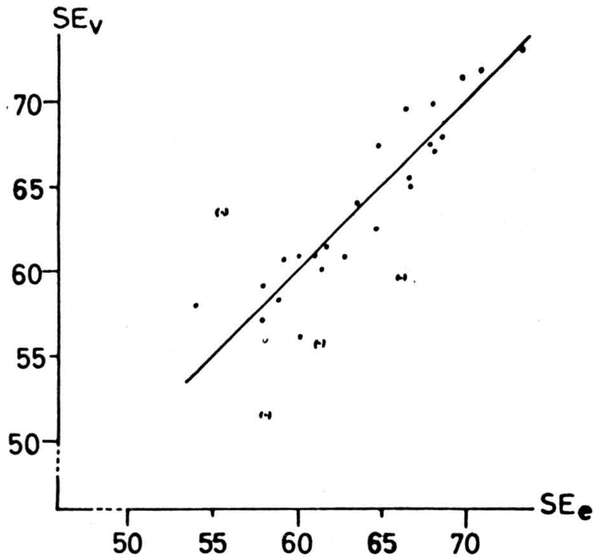

Fig. 3: Correlation and Regression between DCP and CP

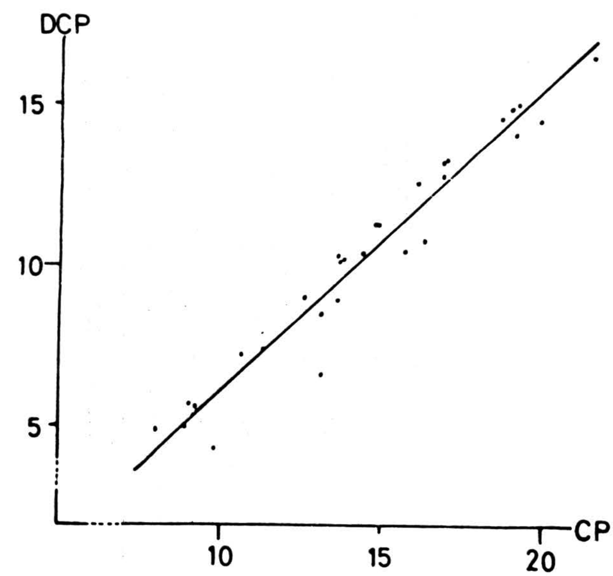

Table 1

Regressions and Correlations between in vivo and in vitro determinations

Combination	Regression	r*)	s*)	No. of samples
DCP x CP	DCP = 0,9301CP - 3,1643	0,974	0,776	29
SE x DOM	SE = 0,9561DOM - 5,6992	0,753	3,577	29
SE x DOM	SE = 1,0076DOM - 9,0446	0,838	2,900	25
SE x DOM and CP	SE = 1,1265DOM + 0,5804CP - 26,3511	0,834	3,109	29
SE x DOM and CP	SE = 1,1914DOM + 0,5890CP - 30,7656	0,934	1,910	25

*) Correlation Coefficient and Standard Deviation are calculated between the in vivo values and the corresponding estimated values

DCP = Digestible Crude Protein)
DOM = Digestible Organic Matter)
SE = Starch Equivalents)
CP = Crude Protein)
in 100 Gram Organic Matter

Farries at the Max-Planck-Institut für Tierzucht und Tierernährung. In the comparison of the in vivo and in vitro digestibility values we found that the in vitro values were approximately 10% lower than the in vivo values, especially in the lower range. The correlation with in vivo determinations was significant, but considerably lower than that described by *Tilley* and *Terry*.

We have heared from Dr. *Julén* that in his trials he had achieved higher digestiblities with a 96 hour incubation in rumen fluid and buffer solution only than with the original method. After confirming this in a test of our own, we conducted a larger experiment with various incubation times in rumen fluid plus buffer, and in pepsin solution. The results of this investigation are to be seen in fig. 1. Three facts were apparent from this experiment. Firstly, at was obvious that the rumen fluid digestion was certainly not complete after 48 hours, because even between the incubation times of 72 and 96 hours a highly significant difference in DOM was established. Secondly, we found a highly significant difference between the treatment with rumen fluid only, and the subsequent pepsin treatment over a period of 24 hours or longer. Thirdly, the experiment shows clearly, that a pepsin digestion of 24 hours was sufficient, because after that time we found no remarkable increase in DOM. Due to these results our standard method has the following incubation times: rumen fluid plus buffer 120 hours, and pepsin in a solution of hydrochloric acid 24 hours. The values achieved with this method are on the average as high as the corresponding in vivo values.

The percentage of DOM of 29 clone samples (first and partly also second cut) was determined using this method, and at the same time the CP of these samples were defined, and compared with the in vivo values for SE, found by corresponding in vivo trials carried out on frozen green material. In table 1 are the calculated regressions, correlations and standard deviations. In 25 cases the difference between the true and the estimated SE-values was between 0 and 4 SE-units, and in 4 samples between 5.5 and 8 SE-units. Therefore, we did the calculations with and without these extreme values. Although the regression equations for this range are almost unchanged, the correlation became better and the standard deviation considerably lower. The results of the latter equation are produced in fig. 2. Similarly, the already well known correlation and regression between digestible crude protein (DCP) and CP are represented in table 1. Fig. 3 shows the corresponding graphic presentations. In all correlations given in table 1 the probability is less than 0.001.

The regressions show, that in the estimation of SE it is necessary to take into account the DOM as well as the CP. When the SE values of two plants or varieties are identical, the CP content, up to certain extreme values, can be adopted as a second selection factor. The range of CP content and DOM in a plant or variety which is to be used as a complete diet for animal nutrition is illustrated in the following example. In table 2, in a very simplified form, the fodder requirements are shown for the production of milk with 4.5% fat, depending on the production capacity of a dairy cow. The potential daily milk production is given in the first column. The second column contains the average organic matter requirements. The third and fourth columns show the necessary absolute amount of DCP and SE. The % DCP which the fodder must contain can be calculated from columns two and three. Similarly, the amount of SE in 100 g organic matter can be calculated from the values in columns two and four. The values achieved from these calculations are given in column five and six. From column five, one can calculate the necessary % CP in the fodder by inversion of the regression equation DCP=0.9301CP−3.1643. These values are given in column seven. Finally, from the values in column six and seven one can calculate the corresponding % DOM values by reversion of the regression equation SE=1.1914DOM+0.5890CP−30.7656. These values can be found in the eighth column. The last column shows the potential milk yield from 100 kg organic matter. The limits for an optimal CP:DOM ratio follow a linear function, namely CP=0.39DOM−12.66. When the CP content exceeds these limits the excess CP is only used as an energy source, and is no longer of special value for production of animal protein. When one considers that all the values given in table 2 are approximate it may generally be said that in the breeding of fodder grasses one should aim at about 80 to 83% DOM and 18 to 20% CP. Values above this DOM range may result in a deficiency of ballast substances which must be adjusted by supplemental feeding of fodder with low digestibility.

The question then is whether or not plants with such a high DOM and CP value can be bred. To solve this problem we investigated the two faktors in 180 commercial varieties and strains of 7 grass species. All samples were harvested approximately 10 days after beginning of head emergency. In fig. 4 the ranges of experimental values within the seven species are given. On the same diagram the marginal slope for the optimal CP:DOM ratio relating to table 2 is described.

With reference to DOM one can assume that a relatively large deviation exists between the single plants of one variety. For example, for 342 individuals of an inbred progeny of *Lolium multiflorum* we found a genetically caused standard deviation of 2.5 DOM units. The other species probably behave similarly. Since *Phleum pratense*, as the species with the lowest average digestibility already reaches 76.7% DOM one can expect that for all investigated seven species selection experiments for attaining the required high % DOM should be successful, particularly for the two Lolium species, whose best varieties are already in that range.

All varieties contain a relatively low CP content. We did not carry out experiments in this direction, but Lackamp has previously demonstrated in his investigations on the heridity of CP content in *Lolium perenne* that a considerable increase can be achieved by breeding, and thereafter 20% CP is recognized as a fairly low value. Therefore, there should not be any restriction to the breeding for higher CP content, particularty as this can be further strongly influenced by appropriate nitrogen fertilization.

Table 3 indicates the SE range of the above mentioned varieties. It shows that as regards to the energy content per unit weight, *Phleum pratense* is the worse species, whereas *Poa pratensis* and *Lolium multiflorum* seem to have the highest energy content.

The possibility of free combination of the two quality factors has also been tested. The partial correlation coefficients between CP, DOM and heading date are produced in table 4. In no case a correlation between CP and DOM could be demonstrated, therefore these factors must be able

Fig. 4: Range of DOM and CP in 180 varieties of 7 species

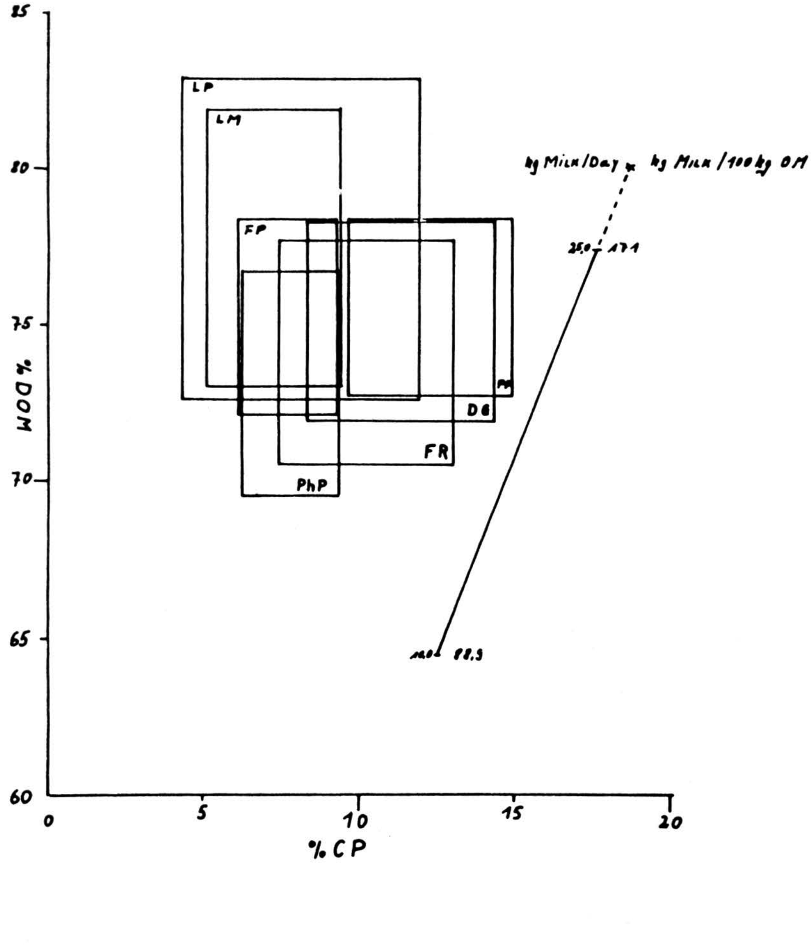

Table 2

The Requirements of a Dairy Cow for the Production of n kgm. Milk containing 4,5 % Fat

kgm. milk	kgm. OM	kgm. DCP	KSE	% DCP	SE/100gm	% CP	% DOM	kgm. milk/ 100kgm OM
10,0	11,250	0,950	6,00	8,44	53,33	12,48	64,41	89
12,5	11,813	1,123	6,75	9,42	57,14	13,53	67,09	106
15,0	12,375	1,275	7,50	10,30	60,61	14,48	69,53	121
17,5	12,938	1,438	8,25	11,11	63,77	15,35	71,76	135
20,0	13,500	1,600	9,00	11,85	66,67	16,14	73,80	148
22,5	14,063	1,763	9,75	12,53	69,33	16,88	75,67	160
25,0	14,625	1,925	10,50	13,16	71,79	17,55	77,40	171

Table 3

Range and distribution of SE in 180 varieties of 7 species

Species	CP-Range	DOM-Range
Dactylis glomerata	8,3 - 14,3	71,9 - 78,3
Poa pratensis	9,6 - 14,9	72,7 - 78,3
Festuca pratensis	6,1 - 9,3	72,1 - 78,3
Festuca rubra	7,4 - 13,0	70,5 - 77,7
Lolium perenne	4,3 - 11,9	72,6 - 82,9
Lolium multiflorum	5,1 - 9,3	73,0 - 81,9
Phleum pratense	6,2 - 9,3	69,5 - 76,7

SE-Range

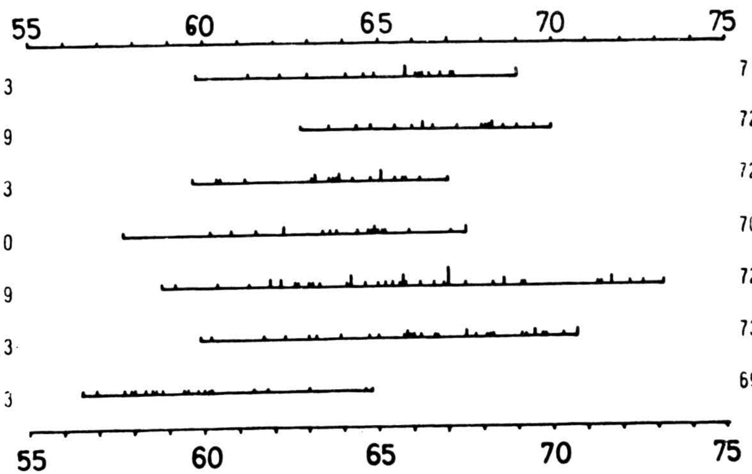

Table 4

Partial Correlation Coefficients between Heading Date (x), CP(y) and DOM (z)

Species	No. of Var.	$r_{xy \cdot z}$	$r_{xz \cdot y}$	$r_{yz \cdot x}$
Dactylis glomerata	19	-0,762***	-0,100	+0,130
Poa pratensis	19	-0,455	+0,430	+0,443
Festuca pratensis	22	-0,685***	-0,121	-0,250
Festuca rubra	21	-0,612**	-0,277	-0,091
Lolium perenne	47	-0,716***	-0,419**	+0,060
Lolium multiflorum	32	-0,545**	-0,796***	-0,285
Phleum pratense	20	-0,388	+0,066	-0,147

to combine freely, at least within the given ranges. To what extent the correlations found between heading date on the one hand, and CP or DOM cotent on the other, are affected by environmental and management factors, must still be investigated.

Beside breeding for quality, high total yield is another important breeding aim, and it should be investigated whether or not a correlation exists between yield and the quality factors. Until now, we had only one experiment with 28 strains of *Lolium multiflorum* at our disposal for this examination. In the first cut the CP content was between 11.2 and 8.5%, the DOM content varied between 84.9 and 76.1%, and the yield was in the range of 6.600 and 5,300 kg organic matter per hectar. In this experiment also there was no correlation to be detected between the three factors CP, DOM and yield, so that within these ranges it should be possible to breed every combination of these factors.

So we take at the moment the following lines in our breeding programmes: First step: Breeding for optimal CP and DOM content. The breeding value of a plant can be expressed in a single figure, namely: $SE_{total} = 0.01 \times \text{yield g} \times (1.1914DOM + 0.5890CP - 30.7656)$. When the SE values are identical, a more favourable relationship between DOM and CP will be included as a further criterion.

Relationship between morphological characters and protein content in lucerne

Uwe Simon

Bavarian State Plant Breeding Institute, Weihenstephan, Germany

Introduction

Protein content is certainly one of the constituents of forage quality, and lucerne is known as one of the protein richest forage legumes. *Panse* (1942) and *Sachs* (1953) reported the great variability of this character. It has been suggested, therefore, to improve the protein content by selection.

Prior to the selection it would be necessary to determine the content by chemical analysis. This is an expensive and lengthy procedure if a large number of samples is to be analysed. However, if a close relationship of easily distinguishable visible plant characters and protein content exists, much of the chemical analysis could be dispensed with.

One of the morphological characters which seem to be useful in this respect is leafiness, because the foliage of lucerne contains about twice as much protein as the stems (*Heuser* 1931).

Several authors like *Sachs* (1953) believe that also dark green leaf colour indicates a higher protein content than light green colour.

Material and methods

Nineteen selected clones of lucerne were classified according to plant height (tall : low), width of leaflets (broad : narrow), and leaf colour (light green : dark green).

The clones were planted in a five times replicated randomized blocks design on 1 X 1 m plots, the distance between plants being 12.5 cm which simulates a normal field stand of lucerne according to *Davies* (1963). The plantings were made in May 1963. The crude protein content of the whole plants was determined by the Kjeldahl-method from four cuts in the following year. Part of the data has been reported elsewhere (*Simon* 1969).

Results

Comparing tall with low growing clones the following results were obtained (table 1).

Table 1. Plant height and protein content in lucerne

	Crude Protein Content % in Cut			
Type of Growth	1	2	3	4
Tall	21.15	17.94	19.92	24.03
Low	20.69	19.11	20.98	25.70
Tall-Low	0.46	-1.17^{+}	−1.06	-1.67^{+}
in %	2	−6	−7	−7

The difference in protein content in the first cut is small and not significant. In later cuts, however, the low growing types contained consistently about 7% more crude protein with differences in the second and fourth cut being significant at the 5% probability level.

The results of the comparisons of width of leaflets are shown in table 2.

Table 2. Width of leaflets and protein content in lucerne

Width of leaflets	Crude Protein Content % in Cut			
	1	2	3	4
Broad	21.31	18.63	20.78	24.94
Narrow	20.47	18.08	19.70	24.33
Broad-Narrow	0.84	0.55	1.08	0.61
in %	4	3	5	3

Although it appears that the broad-leafed types are generally richer in protein in every cut, the differences are small and not significant.

Table 3 gives the results of the comparisons of light green and dark green types.

Table 3. Leaf colour and protein content in lucerne

Leaf Colour	Crude Protein Content % in Cut			
	1	2	3	4
Light-green	21.32	18.18	19.82	24.15
Dark green	20.72	18.57	20.70	25.06
Light-Dark	0.60	–0.39	–0.88	–0.91
in %	3	–2	–4	–4

Dark green types appear to contain a little more protein in the regrowth, but the differences are small and never significant.

Finally, the association between protein content and green matter yield was investigated. The calculated regression and correlation coefficients are summarized in table 4.

Table 4. Regression and correlation of protein content and green matter yield in lucerne

Coefficient	Cut			
	1	2	3	4
b_{yx}	–0.75	–0.23	0.001	–0.04
r	–0.86	–0.67	0.009	–0.45

In three of the four cuts a negative regression and correlation between protein content and green matter yield was observed. Although none of the coefficients is significant, it is concluded from these figures that it would be difficult to select for higher protein content without lowering the green matter yield.

Discussion

The characteristics leaf colour and width of leaflets were not significantly associated with protein content. These findings are in agreement with those of *Åkerberg* and *Hackbarth* (1937), *Panse* (1941) and *Heinrich* and *Troelsen* (1965). The close relationship between dark leaf colour and high protein content which was cited by *Daniel* (1967) for several grass and legume species does apparently not apply to lucerne.

The only significant relationship between morphological characteristics and protein content was observed in the aftermath of lucerne plants of different types of growth. Low growing types contained significantly more protein content than the tall ones. This may be explained by the general observation that low growing lucerne plants are generally leafier than the tall types, and it is well known that the leaves contain more protein than the stems. *Heinrichs* (1966) found more crude protein in varieties with more Medicago falcata (prostrate) in their genetic background than the M. sativa (erect) varieties.

On the other hand, the low growing types are usually not as productive as the taller growing types in Central Europe (*Demarly* 1967, *Simon* unpublished). This raises the question about the practical aspects of increasing the protein content in lucerne by selection. The data in fact suggest a negative though not significant correlation between protein content and green matter yield which would make it difficult to select for higher protein content without lowering the green matter yield.

Very similar results were obtained by *Lackamp* (1965) in perennial ryegrass, and this author expresses the opinion that high protein content is not only correlated to low productivity but is also its cause.

Although the variability of protein content in lucerne is large (*Panse* 1942, *Sachs* 1953, *Heinrichs* 1966), it's heritability is low (*Panse* 1942).

From these findings and considerations it seems doubtful wether a breeding program aiming foremost at the improvement of the protein content in lucerne would be successful.

Summary

No significant relationship between leaf colour and width of leaflets and protein content in lucerne was found. A negative correlation was obtained in the aftermath of different plant types, low types containing more protein than tall ones. The implications of these finding on the breeding of lucerne for higher protein content are discussed.

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Relations Between Quality and Yield in Lucerne

Guy P., Genier G. and Procheron Annie

Station d'Amelioration des Plantes Fourrageres, Lusignan, France ce

This article does not pretend to be exhaustive, it only brings together a few reflections that have come up in the course of our work of selection at Lusignan.

One of the difficulties often encountered with a breeding programme lies in the synthesis of different objectives, sometimes contradictory, which leads to the definition of the composite picture of the desired plant, or better the desired population. Yield and quality are an example of these objectives pursued simultaneously. A good knowledge of their relationships is useful to the plant breeder.

Dry matter yield is an objective characteristic; it is defined in relation to the plant without ambiguity. Quality is more difficult to grasp, although just as objective: for this it is enough to call to mind the variation of crude fibre. In other respects, quality is sometimes defined in relation to the plant (nitrogen content) and often by an interaction plant – animal (intake, digestibility): The criterion of quality is thus transformed into several elements defined in function of the plant, the conditioning (conservation, crusting, presentation . . .) and the animal (poultry, cattle . . .).

Influence of morphology:

A lucerne plant is made up of stems and leaves, parts which have a very different function and composition. Table 1. *Arnault* 1968.

The stems accumulate a considerable part of the harvested dry matter carbohydrates. The leaves photosynthetic organs, contain the greater part of protein.

Let us consider what happens in spring or after a cutting. The total amount of leaves increases very rapidly to reach a maximum (early in May at Lusignan) before the recognized stage for cutting is reached, the amount of stems, on the contrary, continues to increase. The appearance of new leaves is compensated by loss of the oldest ones. For some time before cutting, the lucerne-field is thus turned into a manufacture of stems. It is advisable to note besides that flowering results in a modification, a regression of the shape and size of the leaflets. The amount of leaves/hectare is defined firstly by the conditions of environment (light?), the state of growth and development (photoperiod?) and finally in a more minor way by the genotype. It follows that the amount of leaves is a stable characteristic, not highly sensitive to the climat of the year, depending more especially on the vegetative cycle considered. The production factors (climatic conditions, soil, genotype . . .) particularly modify the amount of stems, as is shown in Table II, *J P Bessac* 1967 and Table III.

Dry matter yield and nutritive value of fodders:

It is evident from what has been said above that all the factors which contribute to an increase in yield cause at the same time an increase in the amount of stems, and a lowering of the leaf to stem ratio and thus a reduction in the nutritive value of the lucerne. Table IV summarizes the correlations between these different factors.

There is always a negative correlation between the factors of production and the factors of nutritive value. Does there remain in these conditions a possibility of selection? Let us consider the seven varieties out of the fourteen studied which have a production equal or superior to Du Puits and to the flemish population, and we find that for these seven varieties:

nitrogen content	varies from	2,28 to 2,69 %	that is	0,4 %
digestibility	" "	55 to 60 %	"	5 %
leaf/stem ratio	" "	0,42 to 0,56 ;	"	0,14

This gives us an order of greatness of the variability that the plant-breeder has at his disposal.

Is it possible to concentrate the effort of selection more on digestibility, the very point of lucerne, than on protein content? That is the question.

Yield in dry matter and nutritive matter per surface unit?

Literature on the subject does not give much data, so we shall return for an example to the results of the same trial with fourteen varieties. Let us establish the correlations between the total dry matter yield (1st cutting) and its leaf and stem components.

Yield	Leaves	Stems
total lst c.	+0,57	0,90⁺⁺

Let us likewise determine the correlations between annual dry matter yield, amount of digestible dry matter and amount of nitrogen produced per hectare.

	Digestible dry matter yield	Nitrogen yield
Dry matter yield		0,61^{+}

We have seen before that the variability at the plant breeder's disposal was less than the genetic variability, as the result of or biological antagonism between yield and quality. We now find something much more useful to the plant breeder: a positive correlation between the total dry matter yield on the one hand, and the amount of leaves, amount digestible dry matter and amount of nitrogen produced per surface unit, on the other hand.

This result is essentiel: The plant breeder can thereby improve simultaneously the yield in dry matter and in useful elements: digestible matter, protein . . .

Conclusion –

It seems than that plants with high yield potential give a forage mass in which the amount of leaves reaches a slightly higher level, but are above all, capable of producing more stems, that is, producing more dry matter, nitrogen, digestible matter . . . although the nutritive value of the product is often lower. This leads us to a general conclusion: whether variation is due to genotype, place or year the dry matter yield is in positive correlation withthe amount of useful elements (leaves, digestible matter, proteins . . .) but in negative correlation with the content of these same elements (criteria difining quality).

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	Date	Nitrogen content	Digestibility
Leaves	2/5	4,6 %	75 %
	1/6	4,6 %	75 %
Stems	2/5	2,5 %	66 %
	1/6	2 %	54 %

Table I: Nitrogen content and "in vitro" digestibility of stems and leaves at two different dates.

	Year	1st cutting	2nd cutting	3rd cutting	Annual total
Amount of stems	1965	3,26	2,39	1,28	6,93
	1966	4,56	3,02	1,64	9,22
Amount of leaves	1965	2,22	1,68	1,29	5,19
	1966	2,07	1,74	1,32	5,13

Table II: Influence of year and cutting on the production of stems and leaves.

Genotype	Total dry matter yield	Stem yield	Leaf yield
1	8,0	5,5	2,6
2	7,9	5,8	2,5
3	7,2	4,9	2,3
4	7,2	5,0	2,6
5	7,1	4,7	2,0
6	6,9	4,0	2,3
7	6,9	4,4	2,5
8	6,8	3,9	1,9
9	6,8	4,8	1,9
10	6,7	4,6	2,2
11	6,4	5,4	2,4
12	6,3	3,9	2,1
13	6,2	4,3	2,0
14	5,8	3,3	2,2
Variation	2,2	2,5	0,7

Table III: Yield of the first cutting in tons of dry matter per hectare. The amounts of stems and leaves have been estimated by sampling of two blocks.

	Dry matter yield	Nitrogen content	Digestibility of dry matter	Leaf/stem ratio	Extreme variat. of characteristic
Dry matter yield	1	–0,87++	–0,64+	–0,56	5,9 à 8,0 T/ha
Nitrogen content		1	+0,42	+0,65+	2,28 à 3,19 %
Digestibility of dry matter			1	+0,35	55 à 62 %
Leaf/stem ratio				1	0,42 à 0,66

Table IV: Correlation between characteristics of production and of quality (1st cut 1967. 14 varieties).

The Problem of Assessing Quality in the Breeding of Forage Plants

D. I. H. Jones and R. J. K. Walters

Welsh Plant Breeding Station, Aberystwyth, Great Britain

Forage plants are grown primarily as a feed for the ruminant, their nutritional attributes are therefore of importance and require consideration in plant breeding programmes. Before quality assessment can be meaningfully incorporated into such programmes, however, it is necessary to recognize the importance of the various qualitative components influencing animal production, and to relate these to the various physical and chemical characteristics of forage plants. Priorities may then be decided and the potential improvement through breeding assessed.

The assessment of quality from animal production experiments

The nutritive attributes or defects of forage plants may be directly assessed in a comparative feeding trial. Relatively few attempts have been made to evaluate forages by this means, although comparisons have been made of meat and milk production from varieties of cocksfoot and perennial ryegrass (1, 2, 3, 4). The results show superior production from ryegrass, attributed to its higher organic matter digestibility and, in most instances, to a higher level of feed intake.

Miles, Walters & Evans (5) have noted wide differences in the weight gain of steers offered artificially dried grass varieties, all conserved at the same level of organic matter digestibility (Table 1). Their results emphasize the importance of taking into account voluntary intake as a qualitative criterion; thus, steers offered S. 51 timothy showed significantly lower intakes and lost weight over the duration of the experiment. There were also indications of differences in the efficiency of utilization of the digested organic matter, e. g. steers offered S. 37 cocksfoot gained weight at a significantly higher rate than those offered S. 24 perennial ryegrass, despite a similar level of feed intake.

In this respect, the low protein content of ryegrass may have been significant. In a subsequent experiment, where digestibility and protein contents were similar, no significant differences were noted between S. 37 cocksfoot and S. 24 perennial ryegrass but gain and intake were again significantly lower on S. 51 timothy.

Table 1. Mean voluntary dry matter intake (DMI) and liveweight gain (LWG) of cattle offered single variety grass feeds at similar levels of digestibility

	Grasses				S.E. of differences and level of significance
	S.24	S.22	S.37	S.51	
	L.p.	L.i	D.g.	Timothy	
% DOMD (in vitro)	68.5	68.5	68.5	68.7	–
% CP	6.6	7.3	9.7	6.0	–
DMI (g/day/kgW 0.73)	75.2	78.3	80.1	63.9	$\pm 2.28^{+++}$
LWG (g/day)	411	471	761	–16	$\pm 115.4^{+++}$

after Miles, Walters & Evans (5)

Table 2. Effect of mineral supplementation on lambs offered different varieties of timothy

	Grass			
	S.352		S.48	
Feed composition				
% DOMD (in vitro)	66		66	
Na (% in DM)	0.04		0.05	
Co (ppm in DM)	0.11		0.12	
Animal responses	–M	+M	–M	+M
Mean DM intake (g/day)	988	1077	1008	998
Mean gain (g/day)	98	153	97	86

–M = unsupplemented
+M = supplimented with Na (1g/day) and Co. (0.1 mg/day)

after Patil & Jones (6)

The levels of essential mineral elements may also influence animal performance. *Patil & Jones* (6) have reported differences in intake, liveweight gain and wool characteristics of lambs feeding on artificially dried grass varieties. Copper and cobalt were found to be deficient in certain grasses, and there was evidence that the availability of these elements needs to be considered in addition to their content. Thus supplementation with a mixture of sodium and cobalt salts significantly increased the liveweight gain of lambs offered S. 352 timothy, but tended to decrease gain in those offered S. 48 timothy, although the levels of sodium and cobalt were almost identical in the two grasses (Table 2).

It appears from these results that a comprehensive appraisal of quality in fodder plants must take account of differences in (a) voluntary intake, (b) digestibility and (c) levels and availability of essential dietary constituents, such as protein and mineral elements. The next section examines the extent to which existing techniques permit such an appraisal on a scale suitable for screening breeding material.

Techniques for the evaluation of forage quality

The measurement of digistibility and voluntary intake *in vivo* is clearly not a suitable technique for screening material in a breeding programme. Attention is therefore being given to the development of laboratory techniques which will predict these components with sufficient precision. The two stage *in vitro* digestibility of *Tilley & Terry* (7) provides a convenient and accurate method of assessing the relative digestibility of grasses, good correlations being obtained between *in vivo* and *in vitro* values (8).

Techniques for predicting voluntary intake are also being developed. It is becoming apparent, for example, that the low intake of certain grass varieties may be related to a high content of cell wall materiel. *Osborn* (9) has attributed the low intake of S.48 timothy to its high content of digestible fibre. Close correlations have been established between voluntary intake and cell wall contens (10), energy expenditure in milling (11) and particle size distribution after maceration (12).

We are currently examing the use of some of these techniques on a wide range of grasses of known voluntary intake. Table 3 shows simple regressions and correlation coefficients for volunary dry matter intake on digestibility, protein content and some physical characteristics. It is apparent that the precision intake from any one of these parameters is limited when applied to a wide range of grasses.

Voluntary intake of feed has also been related to rate of cellulose digestion *in vitro* (13) and rate of dry matter digestion *in vitro* (14). This technique has been examined by *Patil* (15) in studies on the genetic variation in herbage with respect to animal production. *Patil* finds the low intake of S. 51 timothy by lambs to be related to a high content of cell wall material, a

Table 3. Correlation coefficients and regression equation of voluntary intake various parameters for a range of grass varieties and species

Parameter	Regression equations	Residual S.D.	r
% dry matter digestibility in (in vitro)	DMI = 1.32 DMD – 22.2	± 3.6	0.94+++
% organic matter digestibility in (in vitro)	DMI = 1.41 DOMD – 18.1	± 4.0	0.89+++
% crude protein	DMI = 1.64 CP – 50.6	± 6.0	0.79+++
Particle size	DMI = 34.9 PSI – 36.2	± 8.7	0.74+++
Milling energy	DMI = 90.0 – 57.6 MR	±10.2	–0.62++
Density (volume: Weight)	DMI = 135.6 – 1.34 D	±10.0	–0.63++

slow rate of digestion *in vitro* and a slow rate of passage *in vivo*. It appears that intake in this grass may be limited by a slow rate of breakdown of feed which consequently occupies the digestive tract for a longer period. Differences in rate of digestion could be clearly detected after 12–24 hours, and a measurement of dry matter digestion over this period may provide a useful index of digestible material, a technique similar to that suggested by *Crampton* (16) for predicting the nutritive value index. Techniques of this obviously warrant further attention in relation to developing screening procedures in plant breeding, as they offer a single measure of two of the important components of quality, viz. digestibility and voluntary intake.

The introduction of automated analytical techniques permits the analysis of protein and most mineral elements to be undertaken on a scale suitable for screening purposes. Analytical problems remain, however, for several of the minor elements of particular nutritional interest, e. g. iodine, cobalt and selenium. In assessing the adequacy of forage minerals, the total content of an element may not, however, be a nutritionally acceptable measure if its availability is low. More fundamental work is obviously required before this problem can be resolved.

In the light of current nutritional knowledge and with the techniques available, a screening procedure could be envisaged which would involve an estimate of (a) digestibility by an *in vitro* method, and (b) intake by a measurement of rate of digestion *in vitro*, of cell wall contents or of physical characteristic. Alternatively, it may be possible to estimate digestibility and intake on the basis of the rate of dry matter or cellulose digestion (*in vitro*) in a single digestion of

12–24 hours. At a later stage in the breeding programme, plants would be screened for nitrogen and mineral content. It appears that, at present, mineral inefficiency arising from poor availability can only be detected by animal experimentation and this could only be attempted in the final stages of evaluation.

Variation in nutritional characteristics
Voluntary intake

Although the voluntary consumption of dry matter by the ruminant is in general related to the digestibility of the feed (*Blaxter et al.* 17), several exceptions have been observed. The results quoted in Table 1, for example, show the low intake of S. 51 timothy at the same level of digestibility as ryegrass and cocksfoot varieties. *Minson et al.* (18) have similarly noted the low intake of S. 48 timothy while *Miles et al.* (unpublished data, W.P.B.S.) have noted several divergencies in the expected intake-digestibility relationship among grass varieties. At any given level of digestibility, the intake of cocksfoot varieties, such as S. 345, was high and of timothy varieties low.

The application of laboratory techniques for predicting voluntary intake will permit a detailed investigation of its variation between species, varieties and genotypes. *Patil* (15), for example, has shown that there is an appreciable variation in the rate of digestion of timothy varieties at similar levels of digestibility, considerable genotypic variation was also indicated.

Digestibility

There is considerable evidence of both inter- and intraspecific variation in *in vitro* digestibility. *Dent & Aldric* (19), *Walters et al.* (20) and others, have studied this variability and have shown, for example, that the level and seasonal pattern of digestibility varied according to species and variety, in first growth, the digestibility of a variety was characteristically associated with its stage of maturity. At comparable growth stages cocksfoot varieties were lower in digestibility than ryegrass varieties, while later heading varieties of each species were less digestible at ear emergence than early flowering ones.

In first growth, most of the variation in *in vitro* digestibility between varieties at a given date is a reflection of differences in growth stage and gross morphology (20). Over 80% of the variation in digestibility found within species of cocksfoot, perennial ryegrass, tall fescue and meadow fescue can be attributed to growth stage, leaf and stem content and proportion of dead material (Tabte 4). Differences between species, and also between varieties in regrowth, could only be partly accounted for by these variates. It was concluded that, in primary growth, the dominating influence of flowering largely overshadows the potential intrinsic variation in digestibility. It follows that in elucidating genetic variation in digestibility in first growth, data on growth stage and proportion of components is required. It is evident that selection for digestibility based on a single date of sampling will simply result in a late flowering variety.

Table 4. Multiple regression equations for the prediction of dry matter digestibility (% DMD) on growth stage (GSI), % leaf (L), % stem (S), % dead material (B) in grasses

	Regression equation	Residual S.D.	% of variation included (R^2)
Perennial ryegrass	DMD = 68.6 –0.86GSI +0.33L –0.05S +0.02B	±2.42	92
Cocksfoot	DMD = 74.8 –0.052GSI +0.39L –0.21S –0.28B	±3.42	89
Timothy	DMD = 70.8 –0.47GSI +0.11L –0.02S –0.14B	±2.27	80
Tall fescue	DMD = 72.4 –1.38GSI +0.17L +0.09S +0.09B	±2.09	96
Meadow fescue	DMD = 90.9 –0.04GSI +0.04L –0.09S –0.07B	±2.03	96

Selection at a comparable growth stage will, on the other hand, result in an earlier heading variety. In each case the most digestible plants will probably contain a higher proportion of leaf or a lower proportion of dead material. Increasing digestibility without changing heading behaviour may therefore imply either (a) increasing the proportion of leaf or decreasing the proportion of dead material or (b) selecting for a higher digestibility of the leaf and stem portions.

Protein and mineral content

A difficult problem in assessing the extent of inter-and intra-specific variation in chemical composition is created by the dominating effect of stage of growth on the content of most nutrients. Thus the content of protein and most minerals declines as the plant matures. Wide variation can therefore be shown when comparisons are made at the same harvesting date for varieties which differ substantially in their heading date. Several methods of comparison may be used viz. (a) by date, (b) at the same stage of growth (c) at the same level of digestibility (d) at the same yield of dry matter. Taking protein content as an example, Table 5 shows that while later heading varieties are higher when compared by date, earlier heading varieties are higher at ear emergence or at similar levels of digestibility.

When assessing the extent of variation in protein content, it is therefore important to specify the basis of comparison. The choice of a suitable basis will obviously need to take account of the utilization system envisaged for the varieties being compared. Thus varieties intended for

Table 5. Protein (NX6.25) content of cocksfoot and ryegrass varieties compared (a) at the same date in primary growth (b) at ear emergence and (c) at 70% in vitro dry matter digestibility

	% in D.M. (a)	(b)	(c)
Cocksfoot			
S. 345	13	20	20
S. 37	14	14	14
S. 143	20	15	19
Ryegrass			
S. 24	12	14	11
S.321	15	12	10
S. 23	17	13	11

conservation would be most logically compared at a certain level of digestibility or at a certain level of dry matter yield. Similarly, varieties intended for grazing must be compared under a frequent cutting system.

Similar considerations apply to comparisons of several mineral elements. Magnesium, phosphorus, copper, cobalt and iodine, for example, decline markedly as the plant matures. Differences in certain of these elements have been established between species and varieties, iodine content, for example, has been shown to be a strongly inherited characteristic (21). Other elements, such as sodium, do not vary consistently with growth stage. ap *Griffith & Walters* (22) have shown consistent inter-and intra-specific variation in sodium content independent of growth stage.

The levels of certain major and minor elements found in grasses would appear to be nutritionally inadequate when compared with the recommended requirement of livestock (22). Table 6, for example, compares the content of some essential minerals of grass species with the estimated requirements for sheep and cattle. Mineral deficiencies may therefore well prevent the efficient utilization of the high energy available in many of our existing grass varieties. While it may be possible to supplement the diet in the form of additives, *Patil & Jones* (6) report evidence suggesting that supplementation of high sodium grasses with salt may impair the performance of lambs.

Table 6. Mineral content of grasses and estimated nutritional requirements for animal production

Mineral	% in DM				ppm in DM	
	P	Ca	Na	Mg	Cu	Co
Grass						
S. 37 cocksfoot	0.29	0.25	0.75	0.09	6.6	0.08
S. 24 ryegrass	0.25	0.25	0.60	0.09	4.5	0.11
S. 170 tall fescue	0.20	0.27	0.42	0.17	6.4	0.13
S. 51 timothy	0.17	0.28	0.03	0.08	5.5	0.08
Estimated requirement						
Cow producing 20 kg milk/day	0.42	0.52	0.15	0.15	10	0.10
Sheep gaining 200 g/day	0.25	0.50	0.07	0.06	5	0.10

Agricultural Research Council (22).

Conclusions

Considerable variability in nutritive characteristics is available for exploitation by the breeder. It is clear, however, that several problems require elucidation before a fully comprehensive evaluation of herbage quality can be envisaged within a breeding programme. In particular, improved screening techniques are required for predicting characteristics such as voluntary intake which is known to severely limit animal production from certain varieties. Several techniques show promise, but all require more rigorous testing against forages of known intake before they can be confidently recommended in a selection programme. Animal experimentation is also revealing hitherto unrecognized limitations to production from existing varieties e. g. with regard to mineral content and availability. It appears that at present animal experimentation is a necessary adjunct to breeding for quality.

The inter-relationship of nutritive components with stage of growth and management also poses problems of evaluation. This underlines the necessity for clearly defined objectives in breeding for quality i. e. it is necessary to pre-determine the system of utilization of the proposed variety. Selection and evaluation can then be carried out under the appropriate conditions.

More information is required in several respects before the potential benefits from quality breeding of forage plants can be realized. Refinement in the techniques of evaluation will, however, enable the breeder to plan a more comprehensive breeding programme for nutritive attributes in the future.

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Quality requirements of the animal on fodder crops

E. Farries

Max Planck Institut für Tierzucht und Tierernährung, Mariensee, Germany.

For the quality evaluation of fodder crops and their qualification for ruminant nutrition three points are important:

1. Green fodder is not feed if the animal does not eat it, i.e. if the botanical composition of the sward does not meet the requirements of the animal in palatability.

2. Furthermore, the concentration of nutrients and minerals is of great significance to meet the requirements of the animal for performance. In this point not only the quantity of the different ingredients is important for utilization by the animal, but much more the quality of all nutrients and minerals.

3. For the production of winter feed from grassland some ingredients are of special importance for the fermentation of the silage so that losses are as low as possible and the silage is of a high nutrient concentration.

Doubtless it will not be possible to meet all the animal's requirements by means of breeding or nutrition of grassland, because the genetical conditions cannot be varied at will. In the following report I will try to discuss some important points which significantly influence the quality of grassland products.

1. The palatability of roughage is an important factor in evaluating the productive capacity of grassland. It is not yet clear which of the different ingredients of the plants influence the palatability most. Extensive experiments by *Lampeter* (1967) have demonstrated that there are some grasses, present in a normal sward, which animals like to eat more than others. In this experiment 30 dairy cows were grazing on an experiment plot divided into 5 parts, each of which was, grown over with a different type of grass.

It was investigated how often and how much the animals grazed on each of the 5 plots.

The plot with *Festuca pratensis* was grazed most frequently, followed by *Lolium perenne, Phleum pratense, Agrostis gigantea* and *Dactylis glomerata*. The palatability of a mixture of the most preferred grasses corresponded to the average.

In order to produce the greatest amount of milk possible a high intake of green feed on the pasture is necessary. Therefore the botanical composition of the sward has to be considered.

2. The palatability of grassland products also depends on the content of nutrients and minerals. In this respect the proportion of crude protein and crude fibre is of special importance. This proportion between the different types of grasses is variable and furthermore depends mostly on the stage of maturity at the time of grazing. Grass rich in crude fibre is not only eaten less, but also its nutritive value is much lower than that of grass with low crude fibre content.

The nutrient content of grass, cut from the same pasture with 7 days intervals beginning with the time of first grazing, showed no variation in the content of organic matter, NFE, ash and crude fat over a period of four weeks. However, the crude protein content decreased from 24.2% i. d. m. at the beginning to 14.1% at the end of experimental period. In the same period the content of crude fibre increased from 16.8% i. d. m. up to 27.3%. As a consequence of this variation in crude protein and crude fibre content a remarkable decrease of nutrient digestibility takes place.

Even though there was no variation in organic matter and NFE, depending on the stage of maturity, the digestibility of these two ingredients decreased significantly. The digestibility of crude protein decreases by about 10 – 15%, while in crude fibre there is a decrease in the last part of the experimental period only. It is quite evident that the content of crude fibre has a great influence on the digestibility of nutrients. For the digestibility of the crude fibre itself the relation of cellulose to lignin is of great importance. Only a very small portion of lignin is digestible, while cellulose is highly digestible. The higher the share of lignin is, the lower is the digestibility of crude fibre. In a more advanced stage of maturity the share of lignin increases and it consequently follows that the digestibility of crude fibre and all other nutrients decreases.

Therefore the nutritive value depends mainly on the stage of maturity. Within the experimental period of 4 weeks the nutritive value decreased from 190 g digestible protein in more than 700 s. e. to 110 g digestible protein in about 575 s. e.

Even though the ruminant needs a certain amount of crude fibre to keep up the normal function of the rumen, it is very important to have a high concentration of nutrients for a high productivity of roughage.

This is the reason why, from the point of view of nutrition, it of great importance to produce roughage with a crude fibre content as low as possible.

The influence of the composition of the sward on the nutritive value of the more mature grass is also evident from the results of the following experiment.

Grass was cut at the same stage of maturity from two pastures, which where extremly different in the composition of the sward. One of these pastures was on a well cultivated ground, the other was often flooded by a small river during spring.

The crude nutrient content was not so different between the two materials; crude protein was about 1% i. d. m. lower, crude fibre about 5% higher in the grass from the flooded pasture.

The differences in the digestibility of all nutrients were more than 20%; this holds true also for crude fibre. That means that it was not only an effect of the higher crude fibre content, but the quality of the nutrients themselves was much lower than in the control material.

Corresponding with these results there was a great difference (up to 20–25%) in the nutritive value of both materials. This was not in fresh grass only, but also in hay.

As a result with the same intake of 15 kg dry matter of both materials, cows can produce 6–7 kg more milk with green fodder from the pasture with the high nutritive value.

These results show that there are important differences in the nutritive value of green fodder. These differences depend not only on the type of grass, but also on artificial fertilization and management of pasture.

There is no doubt that we can increase the productivity of the grassland by means of artificial fertilization, especially by nitrogeneous fertilizers. But we know that by this method the botanical composition of the sward is influenced in an unfavourable way. The various types of clover and almost all herbs disappear with increasing nitrogen fertilization. But this is of great importance for the mineral content of the grass, because clover and herbs are rich in minerals, especially Ca and Mg.

This is the more unfavourable as the content of some minerals in roughage is too low anyway. This is true especially for Mg and Na, while the content of K is always high enough or even too high. This may be shown by some results of grass analyses from North Germany.

Only 20–25% of all samples have a content of Mg higher than 0,2% i. d. m.; of the samples with a crude protein content lower than 15% only about 5% contain more than 0,2% Mg. We know that in certain grassland districts there is always a lack of Mg, so that the animals cannot meet their requirements for maintenance and milk production if they are mainly fed with grass. Therefore in these districts a sickness called hypomagnesaemia often appears. Each year this causes a lot of losses among dairy cows, especially animals with a high milk yield. It is not evident whether this sickness depends only on the content of Mg, or if the content of crude protein and K as well as some environmental factors such as temperature, humidity and wind may be of influence too.

Na is the second, very important mineral for animal nutrition, which is always present in insufficient amounts in green fodder.

Here the conditions are just the opposite. 90 % of all samples had a K-content of more than 2.0 % i. d. m., thus the K intake often is higher than 400 – 800 g/day. Whether this high K-intake is of influence on hypomagnesaemia is not yet proved definitely. But is is proved, that with increasing excretion of K in the urine, the excretion of Na increases too. However, by physiological regulation of the excreting mechanism the excretion of Na in the feaces is greatly decreased, so there cannot be a total deficiency in the organism.

Not only is the quantitative amount of minerals eaten important for the supply, but more so is the utilization of the different mineral compounds. In this point there are great differences between the minerals. The results of an experiment by *Kemp* (1967) show a digestibility of K in grass of about 89 %, for Na 85 %, Ca 30 %, P 27 % and Mg about 17 %. That means especially for Mg, that besides a very low content of Mg in grass its utilizibility is the lowest of all minerals. Therefore the deficiency becomes more and more serious.

This observation of different utilizibility must depend on the form of combination between anions and cations in the plant. Basic research work in this field of investigation has been done by *Günther* (1967). According to his results the utilizibility of P decreases in the sequence Na – Ca – K and Mg – phosphate, in the same course from mono – to triphosphate. The utilization of Ca- and Mg- minerals is much better, if they are combined with organic acids instead of inorganic ones. Therefore it would be of great interest to study the form of mineral bindings in the plant material.

In connection with the mineral supply of our animals there is another problem, which depends on special ingredients in the plant. Some plants, for example alfalfa and the leaves of different beets, have a remarkable content of oxalic acid. Part of the Ca in the plant is combined with oxalic acid to form insoluble Ca-oxalate. Furthermore, the free oxalic acid in the plant may block part of the free Ca in the whole ration, thus the utilizibility of the complete fodder Ca becomes lower.

Part of the Ca-oxalate may be broken down by the rumen micro-organisms in the presence of sufficient amounts of Mg, so that Ca becomes available to the animal. I think it would be very interesting for plant breeders to produce varieties of plants poor in oxalic acid.

3. A major problem is the quality of fodder crops for conservation purpose in order to get a winter feed with high nutritive value.

The methods for conservation are drying and ensiling; perhaps deep freezing will be a method for the future. During the drying process there is a decrease of water content, so that the dry matter increases to 85 %. At the beginning of this process there is a loss of soluble carbohydrates by respiration. Beyond a dry matter content of more than 30 – 40 %, parts of the plant material are lost by handling the drying material. This loss is mainly depending on climatic factors and causes not only a loss in soluble ingredients but also in protein, which is mainly located in the leaves of the plants.

By the different drying methods the total losses in dry matter can increase to 40 % of the fresh weight. Furthermore the nutritive value of dry matter in the final product is always lower than in fresh grass, so that the total losses in nutritive value can increase up to 50% and more. These variations of the nutritive value are mainly depending on management, and not so much on the plant material itseelf. Therefore the farmers must use a method which keeps losses as low as possible.

In opposition to the drying of fresh plants the composition of the material is very important for the ensiling process. The basis for the conservation is the formation of organic acids, especially lactic acid, acetic acid and butyric acid. These organic acids are formed from soluble carbohydrates, for example sugar. The main problem is to save the nutrients from the fresh materials, this means to keep the losses as low as possible. The transformation of plant ingredients into organic acids is not possible without any losses, but the size of the losses is very different for the individual acids.

If sugar is transformed into lactic acid, only 4 % of the energy is lost, into butyric acid the losses increase to 24% and into acetic acid even up to 38%. This demonstrates that it is very important to have lactic acid fermentation, which can only be secured when a high amount of solubie carbohydrates is present. This is especially important in materials with a high crude protein content, such as grass and clover, but not so much in maize or sugar beet leaves, because both materials have either a very low crude protein content or are very high in sugar content.

At the beginning of the fermentation process there is a lot of oxygen in the material and the pH is about 7 – 6. Lactic acid fermentation starts at a pH of 4 – 3. At the beginning one must take care to remove all oxygen, which is combined with respiration of carbohydrates. Therefore the 0_2 might be pressed out of the material by mechanical means in order to keep the losses as low as possible. This is followed by a decrease of pH, so that the acetic acid producing micro-organisms can develop. As shown, this process is combined with very high losses, but the pH decreases more and more until conditions are favourable for butyric acid production. If the pH reaches about 4, lactic acid production begins.

The formation of lactic acid is only possible, if at this stage of fermentation a sufficient amount of soluble carbohydrates is still present. Otherwise the fermentation stops at the stage of butyric acid production and in this case the silage is not stable; this means that the fermentation always begins again, so that a great deal of the nutrients are transformed into butyric acid with a high loss of energy.

This pool of soluble carbohydrates is especially important if the material is high in protein, as protein is strongly basic and therefore causes a high pH so that it is difficult to decrease the pH in the material.

It has been proved that the anount of lactic acid increases with the sugar content.

That is the reason too why in the ensiling management of grass we use the method of prewilting the fresh material more and more in order to concentrate the plant fluid and increase the sugar content. For the ensiling of plant material with a high content of protein, such as grass, we need a sugar concentration of at least 3 % in fresh material in order to have a lactic acid fermentation with low nutrient losses.

Summarizing, it must be stated that the botanical composition of our pasture plants must be in good relation to the taste of the grazing animals. Furthermore, the content of valuable ingredients must be high, the content of crude fibre as low as possible, because the ruminants do not need more than 18 – 20 % of crude fibre in the ration in order to meet their requirements for rumen function. Within the crude fibre fraction the share of lignin must be low.

The content of Na and Mg is too low in all fodder crops except in beets, and it is very important to increase these minerals by breeding or by artificial fertilization.

Last but not least, it is of great importance in the conservation of green fodder that there should be a high content of soluble carbohydrates, such as sugar, in order to reach a lactic acid fermentation with as little loss as possible.

Some Selection Criteria for Quality in Tall Fescue and Cocksfoot

J. Jadas-Hecart, M. Gillet and C. Mousset.

Station d'Amelioration des Plantes Fourrageres, Lusignan, France

In the International grassland Congress in Sao Paulo, in 1965, we presented a communication on palatability of tall fescue: it was stated that leaf flexibility was a heritable character, and that palatability depended at least partly on it. This work was continued, and a study of heritability of nitrogen content in tall fescue and cocksfoot was undertaken. We briefly summarize the results here.

I – Selection Criteria for Palatability in tall Fescue

Several workers have selected for palatability by grazing spaced plants nurseries by means of animals. *R. C. Buckner* has succeeded in this way, in building a palatable cultivar: Kenwell. But this method is very difficult to work with. We have tried to find criteria bound to palatability, and easier to select for. Flexibility of leaves was such a character, and selection for it has allowed us to obtain a new palatable variety, which will soon be registered on the french "List of Cultivars".

This work was continued by searching for other characters bound to palatibility, not only for pasture, but also for zero grazing. In the latter, such external characters as vigour, height, growth habit etc. are not likely to play any role more. It is interesting to know if the animals still chose, and in this case, if they do it in the same way as in pasture.

This work was made several times; we report here the last one.

1) Material and methods

39 clones with similar earliness but widely different in leaf flexibility vere put in a spaced plant trial in summer 1965. There were 2 replications, each plot including 6 plants of the same clone.

They were grazed 4 times by sheep, on 16th Nov. 1965, 19th July, 7th Sept. and 7th Nov. 1966; they were in a vegetative condition: The first cut, with stems, was not submitted to grazing, as we had noticed that at this stage, slight earliness differences, or number of reproductive tillers, may completely alter the results. The number of animals was such that about half the forage was grazed in 12 hours. On the day before, several external characters were noted, as also leaf flexibility. The clones with rusts, stems etc. able to prejudice palatability, were not taken into account. On the day after, the intensity of grazing was eye-estimated as percentage of intake.

In 1967, zero grazing was studied with a circular sheep-fold, outside which were hooked up 78 little troughs. Three times (26th June, 17th August and 10th Oct.) the grass of the former clones, which was in a vegetative condition, was chopped in pieces about 10 cms long. The same amount of green matter of each was distributed in the troughs. There were 2 replications. Samples were taken for analysis of dry matter content, in vitro digestibility, and the "fibrosity index" defined by *M. Chesnot* as the electric energy necessary to grind a given amount of dry forage in standard conditions.

The day before grazing, the same characters as the year before were noted.

The number of sheep was such that about half the forage was eaten in 12 hours. After grazing, the remaining grass was weighed and sampled for dry matter content analysis.

2) Results

The correlation between grazing intensities at different dates are not good; they allow us to group the "summer pastures" (19th July and 7th Sept. 1966) on one hand the "autum. pastures" (16th Nov. 1965 and 7th Nov. 1966) on the other hand. The zero grazings cannot be grouped together.

Summer pastures

Palatability seems to be correlated with 3 main characters: fibrosity index, length of leaves and flexibility.

The fibrosity indices were measured three times but only the year after. Those taken on 17th August and 10th Oct. were significantly negatively correlated with each other and with summer palatability "in situ" in 1966: Respectively $r = -.4^{+}$ and $r = -.7^{++}$

The *length of leaves* is one of the characters which express the fact that sheep prefer to graze a low sward than a high one. In other experiments, the best character happened to be the height of plants, or sometimes their "vigour" (amount of grass present). This may depend on the fact that the tips of vertical leaves are more or less upright or bent according to their length, numbers etc. The correlation between length of leaves and summer palatability is $r = -.63^{++}$

For *flexibility* it is only $r = +.55^{++}$. Clones with flexible leaves are all palatable, but those with hard leaves are not all unpalatable. We may explain this if we look after the correlation between flexibility and fibrosity index: flexible clones have all low fibrosity indices, but hard ones may also be little fibrous. Flexibility is thus likely to act only through fibrosity.

Autumn pastures

At these grazings, all clones were rather flexible, the differences between them being small and unsignificant. This character does not play any role.

On the other hand, the animals choose far less between clones than they do in summer.

Only two characters are in correlation with this palatability: the fibrosity index measured in October 1967 ($r = -.39^{+}$) and the width of leaves, the narrow ones being never well grazed ($r = .38^{+}$).

Mean palatability in pasture

Only one character remains in good correlation with the mean palatability of all pastures: the fibrosity, as measured in October 1967 ($r = .62^{++}$).

Zero grazing

Sheep choose between genotypes in zero grazing as well as in pasture, for at each grazing there are significant differences between clones. Of course, length and width of leaves don't play any role, but it is more astonishing that also fibrosity does not have any influence at all.

On the contrary, flexibility becomes an important character, more or less linked with palatability in all grazing, particularly on 17th August. For this time the correlation is $r = .54^{++}$, it is $r = .49^{+}$ for the mean palatability of the three grazings. Here, unflexible clones are no more palatable.

The in vitro digestibility had a slight influence on the first grazing ($r = .45^{+}$) but not on the two others.

The mean palatability in zero grazing is in correlation with the mean one in pasture ($r = .43$). This may be due to the negative correlation between fibrosity and flexibility.

3) Conclusion

We are not able to explain why the animals choose according to different criteria from one time to another. We cannot claim to have found all of these criteria: some unflexible but unfibrous and short-leaved clones are nevertheless neglegted by the sheep, for instance.

But with leaf flexibility we find a good character to select for: flexible genotypes are generally palatable in zero grazing, and, because they are not fibrous, they are also palatable in pasture.

Some unflexible ones may be good in the latter condition, but not in zero grazing.

On the other hand, flexibility is quite easy to note rapidly.

II – Heritability of Nitrogen Content in Cocksfoot and tall Fescue

Analysis of nitrogen content were made on spaced plants of the selection nurseries, in July 1968 for tall fescue, in September and November 1968 for cocksfoot. The plants were in a vegetative condition. There were lines at various levels of inbreeding, and the parent clones.

All correlations between parent and offspring of consecutive generations were between .60 and .77, all highly significant.

With cocksfoot we have calculated the correlation between the two cuts, for the same clones. They were .50 with the mother plants, .61 with the lines.

With tall fescue, some I_3 lines were analysed per individual plant. The differences between lines are significantly larger than within lines, but only when we compare lines from different I_1 ancestries. The difference between lines from the same I_1 ancestry are not significantly larger than within lines.

Nitrogen content is thus a fairly heritable and faithful character, easy to select for. Such a selection is still efficient after one generation of inbreeding, but rarely after two, although this happens in some families. There remains to know if these conclusions are still worthy when we compare genotypes of equal yields.

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International Control Cultivars

A. Kelly

National Institute of Agriculture Botany, Cambridge, Great Britain.

During the 8th International Grassland Congress at Reading, U. K. in 1960, the O. E. C. D. (O. E. E. C. as it then was) arranged a meeting of the participants in the E. P. A. Projects 209 and 210 – international trials with cultivars of lucerne and grasses and clovers respectively. These trials were reported in O. E. E. C. Documentation 23, 1960 series.

One point made by several participants at that meeting was that it is difficult to compare the results of trials at widely differing localities. Terms such as "early heading", "late heading" were found to have little meaning as between one country and another.

It was proposed that the inclusion of internationally agreed control cultivars in national trials could provide reference points for the description of new cultivars under test. These international control cultivars might be expected to be used in much the same way as a centimetre scale in a photograph – however much the photograph is enlarged or reduced in size, the centimetre scale still provides a reference point to the height or length of the object which has been photographed.

The Advisory Group for the O. E. C. D. Herbage Seed Scheme met in November 1960 and discussed this question. It was agreed that the use of internationally agreed control cultivars in national cultivar trials might give more meaning internationally to cultivar descriptions. (See E. P. A./AG(60)43). This matter was reported to the Annual Meeting of Designated Authorities for the O. E. C. D. Herbage Seed Scheme in March 1961, and it was agreed that the project should be recommended to O. E. C. D. for action (E. P. A./AG(61)16).

During 1961, two cultivars from each of the more important herbage species were selected. The basis of selection was: –

(a) A medium early and a medium late cultivar to cover as far as possible the flowering range of the species.

(b) Well established cultivars having a reliable source of seed, likely to continue without change for several years to come.

(c) Reasonably winter hardy cultivars able to survive under most climatic conditions.

The cultivars selected were: –

Dactylis glomerata	Floreal
	Frode
Festuca pratensis	Mimer
	S.53
Lolium perenne	Steinacher
	Sceempter Weidetype
Phleum pratense	Øtofte A III
	Heidimij
Trifolium pratense	Kuhn
	Merkur

Later, Lolium perenne Steinacher was replaced by Aberystwyth S.24, and Phleum pratense Øtofte A III by Topaz Øtofte. In addition, the following were added:

Festuca arundinacea	Aberystwyth S 170
Lolium multiflorum	R. v. P.
	Prima Roskilde
	Million (Westerwold)
Medicago sativa	du Puits
	Tuna
Trifolium repens	Aberystwyth S. 184
	Blanca R. v. P.

The O. E. C. D. made several attempts to collect data about how these cultivars were being used, but precise information was sent by very few countries. The observations had been made by very different methods and so the information about the international control cultivars was difficult to compare as between one country and another. The lesson here was that if it is desired to compare data about a control cultivar obtained in one country with data obtained in another, it will be necessary to standardise the technique.

In some instances, however, it was possible to use the data to predict the behaviour of cultivars. In 1963 and 1964 the controls of Phleum pratense were used in Cambridge and in Ottawa, the cultivars under test being different in each centre.

	1963		1964		Mean or prediction of heading order
	Ottawa	Cambridge	Ottawa	Cambridge	
+Topaz Øtofte	0	0	0	0	0
Climax	3	–	2	–	2.5
Scotia	–	1.7	–	3.7	2.7
Drummond	8	–	9	–	8.5
+Heidenij	17	13.7	20	18.7	17.3
S. 48	–	16.7	–	21.4	19.0

These same cultivars were all in another trial at Cambridge. The results from this test were: –

	1963	1964	Mean
+Topaz Øtofte	0	0	0
Climax	0	3	1.5
Scotia	3	3	3
Drummond	10	8	9
+Heidenij	28	24	26
S. 48	27	27	27

Such instances were, however, rare, and in many cases the data have been so incomplete as to make it impossible to draw any valid conclusions.
There are thus the following questions for Eucarpia to consider:–

1. Is the concept of the international control cultivar the best way to achieve better international understanding of cultivar descriptions, or are there alternatives which should be considered?

2. If it is agreed that it is desirable to continue with the international control cultivars, how best can this be organised so as to provide a better understanding of the behaviour of the chosen cultivars over a wide area, and descriptions of new cultivars which can be readily understood?

Report on the replies to a questionnaire concerning the International Control Cultivars.

By Gösta Julén

Swedish Seed Association, Svalöv, Sweden.

At the annual meeting in 1968 the representatives of the designated authorities for OECD:s scheme for the varietal certification of herbage seed and cereal seed moving in international trade accepted a report with a revised list of international control cultivars. It was noted in the report that Italy and Portugal had suggested that the names of additional cultivars of special interest to Southern Europe might be added to the list. This proposal was accepted by the meeting and it was agreed that countries should be invited to submit names of additional species and cultivars of which *Vicia sativa* should be one. It was also agreed at the meeting that Eucarpia should be asked to submit a list. As a consequence of this a request from OECD was put forward at the meeting of the Fodder Crops Section of Eucarpia held in Milan in October 1968, that the Section should assist in the establishment of a revised list of International Control Cultivars of Fodder Crops. It was decided that the existing list should be sent to all members of the section and the members be asked to give their comments on the cultivars included, and make their suggestions on alterations and additions.

With reference to this a copy of the existing list was distributed to the section members together with a questionnaire which should be completed and returned to the secretary. The members were asked to indicate for each variety on the list, if they thought that this variety was suitable or not as a control cultivar. If they had no definite opinion there were asked to indicate "no comments". If they regarded the variety as not suitable they were asked to give the reason for thid. They were also asked to suggest new suitable control cultivars and to give their justification for their suggestion. These suggestions could relate either to species already included in the list or to other fodder crop species which they thought ought to be included in the list. About 115 questioners were sent out, 36 replies have been received.

The replies received have been summarized in Table 1. As can be seen the majority of those, who have sent in their replies have indicated "no comments" on existing control cultivars. That means that they do not have any decided opinion onto whether the variety is suitable or not. Most of those had a definite opinion think that the varieties on the existing list are suitable and only in very few cases the existing varieties on the list have been regarded as "not suitable". Still fewer have given any reason why they regard a variety as "not suitable". The remarks made about the different varieties are included in Table 1. One gets the impression that those who were not satisfied with the existing list, are dissatisfied, not because the varieties on the list are unsuitable as control cultivars, but because they miss good varieties well known in their own countries and used there as standard varieties. It is also clear that especially breeders in extreme areas find that there is not sufficient variation among the cultivars included in the list to meet the requirements under certain conditions, i.e. not being sufficiently winter-hardy for Scandinavia, not drought resistant enough for arid areas or not being able to a normal development under Mediterranian conditions. Finally it seems rather common that these control cultivars are regarded not only as a neutral yard-stick but specifically selected varieties with high agriculture value with which their own new ones will have to compete. These different ideas are clearly reflected in the large number of new varieties suggested to be included in the list and the justifications given for their inclusion. In the following list of suggested varieties the names and country of origin of the cultivars are given and also the reasons why they have been suggested. In some cases the same variety has been suggested by several people and the number of persons, suggesting a variety is also indicated in the list.

Suggested varieties	Justification	No. sug.
Dactylis glomerata		
Holstenkamp, Germany		2
Daprime, France	Ear emergency much slower than in other varieties	1
L 22, Italy	Mediterranean type	2
Monegros, Spain	Dry land variety for arid zones	1
Aberystwyth S 143, U.K.	Late variety	1
Barenza, Netherlands	Late type	1
Aries, France	Early type	1
Festuca arundinacea		
Manade, France	Very early, 'common in the Mediterranean area	4
Ludion, France	Late type	1
Festuca pratensis		
Dr. V. Schmieder, Germany		1
Kentucky 31, U.S.A.		1
Bergamo, Italy	Outstanding, late variety	1
Sequano, France		1
Fero, Danmark	Early type	1
Svalöf's late, Sweden	Very uniform, good winterhardiness	1
Rossa haytype, Netherlands	More competitive in mixtures	1
Steinacher, Germany	Very good in western Europe	1

Lolium multiflorum	
Tetila, Netherlands	Tetraploid
Tiara, Netherlands	Very productive
Sceempter, Netherlands	Better than Roskilde
var. Vesterwoldicum	
Billion, Netherlands	Tetraploid
Tewera, Netherlands	Tetraploid
Lolium perenne	
Aberystwyth S.23,U.K.	Alternative to Sceempter, which has changed.
Odenwälder, Germany	
L 17, Italy	
Odstein, Germany	Medium early type
Splendor, Netherlands	Medium late type
Reveille, Netherlands	Tetraploid
Petra, Netherlands	Tetraploid
Viva, Sweden	Very winterhardy
Glasnevin leafy, Ireland	Mid-season variety
Hora, Netherlands	Very productive
Splendor, Netherlands	Pasture type, Persistant as dipl. Rust resistant as tetr.
R.v.P. Hay-pasture, Netherl.	Medium late type
Taptoe, Netherlands	Tetraploid
Phleum pratense	
Landsberger, Germany	
L.84, Italy	
Timo, Netherlands	(Syn. Mommersteg Tussentype) Late type
Pecora, France	Very common in France and U.K.
Aberystwyth S 352, U.K.	
Aberystwyth S 48, U.K.	Late type
Sceempter weidetype, Netherl.	
Medicago sativa	
Triesdorfer, Germany	
Polesana Maliani, Italy	
Florida L 99/100, Italy	
Orchesienne, France	
Vernuile, France	Persistant, resistant to Verticillium

YT-1, Spain	Dry land variety for arid zones	1
Europe, France	Very productive	1
S. Pastore, Italy	Mediterranean type	1
Sabina, Italy	Mediterranean type	1
Trifolium pratense		
Lembkes, Germany		1
L 69, Italy		2
Tetri, France	The most promising French tetraploid variety	1
Weitetra (Syn. Tetra) Sweden	Tetraploid	1
Triel, France	Early, Flamande type	1
Red Head, Netherlands	Tetraploid	1
Ulva, Sweden	Tetraploid, typical late clover	1
Renova, Switzerland	Early, persistant type	1
Mattenklee	Resistant, early type	1
Alpilles, France	Early, high production	1
Disa, Sweden	Good representative for the N. European late type	1
Trifolium repens		
N.F.G. Giant, Germany		1
Ladino Espanso L 107/66 Italy		2
Morsö, Denmark		1
Ladino (no variety)		1
Kivi, Sweden		1
Cran, France	var. giganteum, good results	1
Lena, Sweden	The same type as S 184, but much more winterhardy	1
Tamar, Netherlands	Very high production	1
Lodigiant, Italy	Large leaved type	1
Milka, Denmark	Most used in W. Europe	1

In the request from OECD on the advised list it was also asked for suggestions on varieties of fodder crop species not already included in the list. These suggestions are compiled in the following list.

Suggested cultivars	Justification
Poa pratensis	
Ötofte Norma, Denmark	
Festuca rubra	
Ötofte Rubina, Denmark	
Koket, Netherlands	var. commutata
Novorubra, Netherlands	var. rubra rubra
Trifolium hybridum	
Tetra, Sweden	Tetraploid, high yielding
Vicia sativa	
VM-46, Spain	Resistant to low temperature
Svalöf's Süsswicke, Sweden	
Pisum arvense	
Violetta, France	
Lupinus lutheus	
Sulfa	
Lupinus angustifolius	
v. Sengbusch Mücheberger, Germany	
Grünfutter Süsslupine	
Lupinus albus	
Pfluga Ultra, Germany	
Multolupa	High yield, high protein content
Brassica napus (fodderrape)	
Gartons Ealy Giant. U.K.	
Nevin	Resistant to some races of clubrot
Brassica oleracea (marrow stem cale)	
Cannells, U.K.	

Table 1.

Species and varieties	No comment	suitable	Not suitable	Remarks
Dactylis glomerata				
Floreal	21	15	1	Too fine
Frode	21	15	1	Disease suseptible
Festuca arundinacea				
Aberystwyth S. 170	21	15	0	
Festuca pratensis				
Aberystwyth S. 53	22	14	0	
Mimer	22	13	1	
Lolium multiflorum				
R.v.P.	21	14	1	
Prima Roskilde	25	9	2	Other varieties are better
Million	25	9	2	Not drought resistant
Lolium perenne				
Aberystwyth S. 24	17	15	1	Not winterhardy. Not drought resistant
Sceempter weidetype	19	12	1	
Phleum pratense				
Heidemij	25	9	2	Not stable enough. The variety has changed
Topas Øtofte	26	10		
Medicago sativa				
du Puits	12	25		Late growth – not withstanding
Tuna	18	17		
Trifolium pratense				
Kuhn	18	17		Not winterhardy under Scandinavian cond.
Merkur	14	19	1	Too late under French conditions
Trifolium repens				
Aberystwyth S. 184	17	16	1	Not winterhardy enough
Blanca R.v.P.	23	10	1	The variety will be replaced on the market

I have given here a report on the replies I have received from the section members concerning the list of control cultivars. I have not made any effort to make up a revised list on bases of the suggestions. It will be up to the members participating in this meeting to discuss the matter and I hope that we will be able to come to some conclusion about that and about further action which must be taken for the full utilization of the list of control cultivars.