example of which is given in Table 3. It is clear that the N and soluble carbohydrate fractions suffered most change, although there was even some hydrolysis of the hemicelluloses. The NPN, from a value of 11% of the total N in the grass, rose to 55% in the silage, and the total soluble carbohydrate percentage fell by 91% from the value in the grass. The lactic acid formed during fermentation in this well-made silage amounted to 11·5% of the dry matter, but this compound has a lower energy value than the sugars from which it is derived and may, in addition, be leached from badly protected silage. These results show, I think for the first time, the extent of the hydrolysis of the hemicelluloses, particularly of the major constituent, the xylan.

Conclusion

A significant improvement in our agriculture in the last 20 years has resulted from the wider realization that, when grass is treated as a crop, greatly increased yields of dry matter can be obtained. With skilful management, the higher yields can be accompanied by improved chemical composition and nutritive value. In this paper I have emphasized the great variability in the composition of grasses produced by present agronomic practices and have discussed some of the causes of those variations. The possible nutrient loss that can arise from some of these practices has also been mentioned.

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The effect of soils, fertilizers and environment on the yield and nutrient content of plants: summing-up

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All the subjects discussed at this Symposium bear directly on the fact that there is not sufficient food of high or low nutritive value to satisfy world needs. The yield and composition of plants have been considered in relation to the environment, the soil—and what can be done to the soil in terms of irrigation, fertilizing and manuring—

and in relation to some of the problems of agronomic management, particularly crop conservation which can drastically change plant composition.

Professor Black's paper entitled *The ultimate limits of crop production* compared practical estimates of maximum productivity with theoretical estimates based on the maximum utilization of solar radiation for photosynthesis. Among the many difficulties in such comparisons we have seen that one of the most elusive quantities is the proportion of the gross photosynthesis lost by respiration. Furthermore, light energy does not fall uniformly on leaf canopies and hence it is important that the distribution of light down a crop profile was considered. Theoretical estimates of maximum rates of dry-matter production assume that all photosynthetically useful radiation is used at maximum efficiency. In practice the top leaves often receive light above saturation intensity and there may be very little light reaching the lower part of crop canopies; this, coupled with the fact that older leaves are photosynthetically less active, makes theoretical treatments of the subject difficult. Professor Black's treatment of the relationship between the 'leaf area index' and the crop growth rate is not only important in its own right, but disregard of it can lead to a misinterpretation of the effects of fertilizers. The latter point is exemplified by a quotation from Harper's (1963) report to which reference has been made: 'The drop in tuber yield on plots to which high levels of fertilizer have been applied may be explained by the production of excess foliage which so shades the lower leaves that they cannot produce sufficient carbohydrates to meet their own requirements for respiration'. This fits in with the increased potato yields that have been observed after the inadvertent partial destruction of bulky haulms through the misuse of chemical sprays—a phenomenon that interested some alert growers more than 10 years ago in the eastern counties. As a sequel to the first paper, it seems that we may expect much more attention to be given to the problem of instrumenting crop trials and, in this connexion, we might put out a plea for more measurements of useful solar radiation—not hours of sunshine. If light intensity is the ultimate factor determining the limits of crop production, such a plea seems reasonable.

Turning to the artificially controlled application of water to land for crop production, Dr Olivier discussed *Irrigation as a factor in boosting food and fibre production.* At the same time as stressing the present and future role of irrigation in arid areas, our speaker drew special attention to the merits of supplemental irrigation for increasing production in the immediate future; above all we should remember that 1 ft of water as supplemental irrigation is as effective as about 3 ft of water in arid regions, but for it to be effective we need a reorganization of meteorological observations. Present-day rainfall records make it very difficult, if not impossible, to make appropriate assessments of effective rainfall and thence to assess the supplemental irrigation requirements. For irrigation in arid areas to be effective from the long-term point of view, many factors must be considered. To use the water, which is expensive by any standards, one must have soil that will stand up indefinitely to irrigation. Soils should be surveyed by experts at the beginning so that only suitable soils are used and a watch must be kept so that both water-logging, which arises from reduced permeabilities, and the onset of salinity can be prevented before soils are ruined. In some

countries like Pakistan about 100 000 acres go out of production each year because of reduced soil permeabilities and salinization.

Dr Bould in his paper, entitled *Soil and plant nutrient content in relation to crop yield*, considered various aspects of the inorganic nutrition of plants. However well we may be able to define our soil in terms of nutrient 'intensity' and 'capacity' parameters, we must, to gain real understanding of soil–plant relationships, consider the ways in which plant roots explore soil and make use of nutrient ions. Dr Bould stated that we know too little about what happens in the immediate vicinity of the root. The supply of nutrient ions in the immediate vicinity of the absorbing roots may be rapidly exhausted, particularly when the movement of ions is restrained by soil colloids. The rate at which nutrient ions arrive at the root surface can, therefore, influence the rate of nutrient uptake and subsequent plant growth. These rate-dependent processes are only beginning to be studied in detail. Turning to the plant itself, Dr Bould discussed the question of leaf composition as a guide to the nutrient status of the growing crop. In the hands of experts, in the absence of non-nutritional limiting factors, leaf analysis can be a valuable diagnostic tool, but it does not provide information on the quantitative remedial measures which may be necessary.

In his paper, entitled *Effects of organic manures on soils and crops*, Professor Bunting described how objective field experimentation can apportion the effects of bulky organic manures. The results of a large number of experiments testing the action of organic manures in the presence and absence of inorganic fertilizer showed that the beneficial effects of organic manure could often be almost wholly explained in terms of its content of plant nutrients. On some soils, usually those which are of a fine, sandy texture and easily compacted, the beneficial effects of some bulky organic manures were greater than could be ascribed to the plant nutrients supplied and it seems that the mere presence of certain forms of organic matter, such as rotting straw, so alters the internal geometry of the soil that a more favourable root environment is created.

Under the heading *Composition of grasses in relation to agronomical practice*, Dr Waite dealt with some aspects of the problem of treating grass as a crop. Great progress has been made both in growing more high-quality grass and in using it efficiently; our fifth speaker today has focused attention on the considerable changes in chemical composition which can occur when grass is conserved.

In conclusion I would say that the Symposium has been valuable in that it has given the specialists an opportunity to see how approaches to their own problems are likely to be affected by other developments, and that is surely one of the main functions of a symposium.

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