their value for teaching and ecological research. They also noted the potential value of these grasslands, especially those on alluvial soils, as sources of new material for the plant breeder.

The meeting highlighted the problem of managing grassland sites on both field monuments and nature reserves. Many speakers emphasized the value of having clearly defined objectives in management. Although grazing and mowing are the most common forms of management, Mr T. C. E. Wells (Nature Conservancy) suggested that other methods, such as burning, might be used in appropriate cases to reclaim grassland. In view of the cost of maintaining grassland sites, delegates hoped that new mowing machines would be developed for managing small areas of grassland on earthworks and steep slopes. Grassland will be used much more for recreational purposes during the next twenty years, and Mr C. C. Bonsey (land agent, Hampshire County Council) explained that cars, litter, dogs and people are only some of the factors to be considered by county councils producing plans for management. He emphasized the need for more research on these topics.

Archaeology and ecology clearly have interests in common, as Dr M. E. D. Poore (Nature Conservancy), Professor W. G. Grimes (Institute of Archaeology) and Professor R. J. C. Atkinson (University of Cardiff) all noted. They suggested that there should be considerably more collaboration between the two disciplines in both research and management. Increasing public interest in field archaeology and natural history, together with the development of recreational areas, emphasizes the value of close cooperation between those responsible for the countryside.

PHOTOSYNTHESIS

Sugar Cane is Different

from our Plant Physiology Correspondent

TROPICAL and temperate plants seem to differ in important biochemical ways. In 1957, when the classical experiments of Calvin and his colleagues on carbon fixation in green algae led to the formulation of what is known as the Calvin cycle, it seemed as if the principles of photosynthesis had been laid down for all plants. To begin with, it was understandable that there should have been some scepticism about the reports in 1965 by Kortschak, Hartt and Burr (*Plant Physiol.*, **40**, 209) and in 1966 by Hatch and Slack (*Biochem. J.*, **101**, 103) that the Calvin cycle was not a good explanation of photosynthesis in sugar cane and other tropical plants. Gradually, however, it has been accepted that carbon dioxide can be fixed photosynthetically either through the reactions of the Calvin cycle, or by what has become known as the Hatch–Slack pathway. Recently, Baldry, Bucke and Coombs have published evidence that the light reactions of photosynthesis are directly linked to the dark reactions of the Hatch–Slack pathway (*Biochem. Biophys. Res. Commun.*, **37**, 828; 1969).

Photosynthesis is the product of two separate but linked reactions. First, a process in which carbon dioxide is combined enzymatically with an acceptor molecule (dark reaction), and then a process in which light energy from the Sun is used to split water and provide energy and reducing power which are utilized in the reduction of the fixed carbon to sugars, and in the regeneration of the acceptor molecule. According to the Calvin scheme this acceptor is a 5 carbon (5C) molecule, ribulose diphosphate. Carbon dioxide is combined enzymatically with this molecule to yield two 3C molecules of phosphoglyceric acid, which appear as the first measurable products of Calvin type photosynthesis. Kortschak *et al.* and Hatch and Slack, however, found instead the 4C acids malate and aspartate. It seems that the acceptor molecule in this new pathway is the 3C compound phospho-enol pyruvic acid. This combines with carbon dioxide to yield the 4C acid oxaloacetate, a reaction regulated by the enzyme phospho-enol pyruvate carboxylase, perhaps the most effective biological carboxylating mechanism known (D. A. Walker, *Biol. Rev.*, **37**, 215; 1962).

Plants can be placed in two broad categories on the basis of their carbon fixing mechanism. In general, temperate plants have the Calvin type pathway, whereas many tropical and sub-tropical species have the Hatch–Slack or, more correctly, β-carboxylation pathway. Morphological and physiological characteristics of these two groups can be related to the mechanism by which they fix carbon. In particular, photosynthesis in Hatch–Slack plants is very resistant to photosaturation, whereas Calvin type plants reach a maximal level of photosynthesis in quite moderate light.

Baldry *et al.* may have the explanation of this phenomenon. They have examined the influence of light on carboxylation in chloroplasts isolated from sugar cane, the archetypal Hatch–Slack plant. Fixation of radioactive carbon dioxide supplied to the chloroplasts, which are the sites of photosynthesis, did not reach significant levels unless phospho-enol pyruvate was present as acceptor, and then only if the chloroplasts were illuminated. When the first products of photosynthesis were analysed most radioactivity was found in malic acid. Several compounds which inhibit the photosynthetic light reaction were tested, and found to reduce drastically the amount of carbon fixed.

Baldry *et al.* reason that these results are consistent with the fixation of carbon dioxide into pyruvate to yield oxaloacetic acid, which is then photoreduced very rapidly by products of the photosynthetic light reaction to form malic acid. This rapid removal of the first product of photosynthesis could account for the extreme resistance of these plants to photosaturation; the possibility of end product accumulation, and so inhibition, would be minimized. Hatch–Slack plants have several features which promote their efficiency as photosynthetic factories. The leaves of sugar cane, for example, have two types of chloroplast, whereas Calvin type plants have one. Laetsch suggested that this represents a division of labour (*Sci. Prog.*, **57**, 323; 1969). One kind of chloroplast, found in the leaf lamellae, is responsible for the fixation of carbon dioxide and its reduction to sugars. The other kind, found in the cells surrounding the vascular tissues of the leaf, serves as a storehouse for the newly synthesized sugars during the day, and exports the sugars into the vascular system at night.

Observations like these serve to underline the fact that almost all knowledge of plant physiology has been gained from studies of temperate plants; when tropical plants have been studied in similar detail, the textbooks will almost certainly have to be rewritten.