ROTHAMSTED RESEARCH

The Soil at Rothamsted

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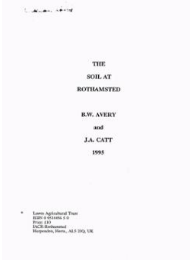

Soil Water Regime

Rothamsted Research

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150-250 t/ha, which was dug from infield 'bell-pits' or from 'dell-holes' on bordering slopes and spread by hand to improve the fertility and workability of the originally acid Batcombe and related soils; this eventually rendered them base-saturated and near-neutral in reaction to depths of 1.5 m or more. Grassland used for pasture or hay, as in Highfield and Park Grass (Fig. 1), was seldom chalked and hence remained at least moderately acid. By the 1950s, reserves of $CaCO_3$ remaining from earlier dressings had in places become exhausted by leaching and the soil had become acid, particularly in plots on Broadbalk and elsewhere receiving annual applications of ammonium sulphate. Except for areas deliberately kept acid, pH (H_2O) values on the cultivated land have since been maintained at around 7.0 by regular liming.

On Broadbalk, continuously cultivated since 1843 or earlier, organic carbon contents in the upper 23 cm of soil vary from around 0.8 per cent in the unmanured plot to around 2.2 per cent in the plot that has received farmyard manure annually. Profiles 19-27 in Broadbalk and Barnfield were located in inter-plot pathways and hence contain less topsoil organic C than adjacent plots. Corresponding values in profiles 18, 28-35, 41 and 42, all in fields not used for long-term experiments but cropped for varying periods before sampling, range from 1.4 to 2.8 per cent. Organic-carbon and pH data on a field-to-field basis, derived from a systematic survey in 1978-79, are given by Johnston *et al.* (1981).

Soil structure

Under woodland or old grassland, the structure of the topsoils is clearly influenced by organic matter content and base status. Thus the very dark coloured surface horizons of the soils that remain calcareous, either naturally or through the retention of added chalk as in Broadbalk Wilderness, are characterized by strongly developed granular or fine subangular blocky peds. In contrast those that are acid are more weakly structured and in extreme cases, typified by the unlimed Park Grass plots that have received regular applications of ammonium sulphate, organic matter has accumulated at the surface to form a discrete *mor* layer and the immediately underlying mineral soil is massive and structureless.

Despite the presence of $CaCO_3$ in varying amounts, structure is markedly weaker in the arable land than in the uncultivated calcareous soils. As a consequence the relatively impermanent aggregates produced by cultivation are apt to slake under the impact of rain, so reducing permeability and promoting the formation of a cap which can set hard and so delay the emergence of seedlings if dry weather follows. These effects are most evident in lighter soils, however, and are mitigated in the silty clay loam topsoils which predominate at Rothamsted by subsequent cultivation under favourable conditions, aided by the restorative action of periodic wetting, drying and freezing. There is accordingly no clear evidence that structural deterioration under continuous arable cultivation has influenced crop yields significantly (Boyd *et al.* 1962), though spring-sown crops may be adversely affected in unfavourable seasons as a result of failure to obtain a satisfactory seedbed.

Soil water regime

The Clay-with-flint subsoils of the Batcombe and Hornbeam series which underlie some 60 per cent of the estate are slowly permeable and hence are periodically saturated with

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water in most years, but are distinctly more permeable than the unaltered Reading Beds clays from which they are largely derived. This can be attributed, at least in part, to long-continued, oxidative weathering as evidenced by the relatively large amounts of 'free iron oxide' in relation to clay that they contain. Thus excess winter rain is eventually disposed of by slow downward movement to the unsaturated Chalk and any water moving laterally over the clay enters the Chalk at the margins of the drift cover or in other places where it is relatively thin.

Water levels in 10 cm diameter dip-wells in a typical Batcombe soil near the southern boundary of Park Grass were recorded at fortnightly intervals over the winters of 1965-6 and 1966-7, both of which were wetter than average. The results (Robson and Thomasson 1977) showed that the subsoil was waterlogged at 70 cm depth for 64 and 80 days *in toto* respectively, and at 40 cm depth for 24 and 30 days, so placing the soil in Wetness Class II (moderately well drained) as defined by Hodgson (1974). Permeability tests using civil engineering procedures at other sites at Rothamsted and Kinsbourne Green (north of Harpenden) have given conformable results that show a clear correlation between the location and intensity of greyish subsoil mottling and the rate of removal of added water from standard-sized holes. Thus it is very much slower in typical Batcombe soils than in unmottled Carstens and Winchester soils (Table 2) that have well fissured clayey subsoils overlying Chalk within 1-1.50 m depth. Except where a plough pan has developed or severe surface compaction occurred, however, they are seldom waterlogged within 40 cm depth for more than a few days at a time and it is only locally, as in Broadbalk and other intensively used land, that pipe drainage has been installed.

Apart from the Ver valley-floor soils and the Hook series in 'plateau brickearth', the other soil series represented are normally well drained (Wetness Class I), implying that the rooting zone is seldom, if ever, waterlogged. In the groundwater gley soils occupying the lowest parts of Flint and Ver (now made ground) fields and the intervening copse, the water regime was profoundly affected by the installation of the Friars Wash pumping station, some 3 km up-valley, in the early 1950s. Before then the water table is these soils regularly rose into the upper horizons in winter and spring, but by spring 1966, when profile 17 was sampled, it was deeper than 80 cm and the river bed nearby was dry. Following cessation of pumping in 1992, however, the river is now flowing again and the water table correspondingly high.

Except in these few small areas where the summer water table may remain within root range, plant growth over the April-September period, during which monthly transpiration normally exceeds rainfall, is dependent on water stored in the soil. The extent to which crops and grass are affected by drought in an average year depends primarily on the difference between potential transpiration as determined by meteorological factors and the effective available-water capacity of the soil, but is also influenced by rooting habit and growing period. Grass needs most water because of its long growing period with full ground cover, so that the mean maximum potential soil-moisture deficit (PSMD) for grass, estimated as 153 mm at Rothamsted (Hodge *et al.* 1984), is larger than for other crops which do not cover the ground completely in the earlier part of the growing season or, like cereals, ripen before the maximum PSMD is reached. The corresponding effective available-water capacity (AP) of the dominant Batcombe and Carstens soils, derived from water-release measurements, is approximately 135 mm; on this basis PSMD exceeds AP by 18 mm, implying that growth of grass is significantly limited by lack of water in most summers. For winter wheat PSMD is

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estimated as 91 mm, some 44 mm less than AP, so that the crop is unlikely to suffer from drought and Yates (1969) concluded from a review of earlier investigations that wheat yields on Broadbalk were generally larger in dry years.

The deep, nearly stone-free silty soils of the Hook and Hamble series have larger available-water capacities than the Batcombe and Carstens soils and are predictably less droughty on this basis, though an experiment in 1976 on the Hook soil of Little Knott field (Fig. 1) showed that excluding rain from a spring barley crop for 4, 6 or 8 weeks in the main part of its growing season (April 28 onwards) using a mobile shelter decreased grain yield by 17, 29 and 41 per cent, respectively (Woodhead 1977). It is possible, however, that subsurface compaction at this site may have reduced the effective AP by limiting root development.

Of the remaining soils, the most droughty are those in Flint, Scout and Osier Fields that have loose gravelly subsurface horizons of varying thickness, as in profiles 16, 38 and 39. Grass in these areas was severely 'burnt' during the dry summers of 1989 and 1990, even in places where the winter water table is now high. The effective available-water capacity of the shallow chalky soils of the Upton series occurring in parts of White Horse and Drapers Fields is difficult to assess because the shattered Chalk substrate is penetrable by roots to varying depths, but is evidently larger than might be expected because the Chalk itself, unlike other consolidated rocks, is porous and holds considerable amounts of water extractable by plants (Burnham and Mutter 1993).

The Soil-Map Units

Typical Batcombe (139 ha)

This unit, occupying 46 per cent of the mapped area, consists mostly of Batcombe series with a flinty silty clay loam (U.S. silt loam) topsoil containing 18-27 per cent clay and strong brown to yellowish red clay with varicoloured mottling at less than 80 cm depth. The main variations, which can recur laterally within a few metres, are in depth to clay, degree of subsoil gleying and stoniness. In much of the old arable land, including Broadbalk (profiles 20 and 21), the clay is encountered immediately below the topsoil, the clay content of which may locally exceed the 27 per cent limit; elsewhere, as in most of High Field (profiles 2 and 13), a brown friable subsurface horizon similar in texture to the topsoil overlies clay at greater depths, and in variants marginal to the Hook series (profiles 1 and 22) passes downwards into mottled silty clay with few stones. The most gleyed profiles have red, brown and grey mottles within 60 cm depth, the greyest colours occurring on structural (ped) faces and around stones; in the least gleyed, which grade into Carstens soils in places where the underlying Chalk is relatively close to the surface, red mottles and paler brown ped faces are still evident within the same depth, but grey inclusions are rare or absent.

On the sloping land in Black Horse and Bylands fields (profile 34), both surface and subsurface horizons are generally more stony than elsewhere; the boundary between the superficial loamy layer and the clay subsoil tongues downwards to more than 80 cm in places, and the topsoil locally contains enough sand (clay loam rather than silty clay loam) for the soil as a whole to qualify as Hornbeam series (Table 2) rather than Batcombe.

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