Box 11.2 | Rothamsted, the Park Grass Experiment

Most ecological experiments run for short periods of time, owing to practical constraints such as the length of a human career, the short nature of most grants, and in many cases, the duration of PhD research. As a consequence, long-term experiments have been rare in ecology, the Rothamsted experiments being a notable exception. Not only do they illustrate the value of long-term work, but they also provided the impetus for Sir R. A. Fisher's statistical studies that revolutionized thinking about variation in nature, and provided the quantitative arsenal that we now take for granted (Box 10.1). So let us examine these three monumental and intertwined stories, Rothamsted itself, the park grass plots, and Ronald Fisher.

According to Johnston (1994), J. B. Lawes, later Sir John, inherited the Rothamsted estate, which included an old manor house and about 100 ha, in 1822, when he was only eight years old. His father had died, leaving family fortunes at a low ebb. After some time at Oxford, Lawes returned home and had a bedroom at the Manor converted into a laboratory; here he worked on a variety of projects including medicinal plants. He finally took out a patent for the manufacture of superphosphate, and in 1843 starting commercial production at a factory in Deptford, London. On 1 June 1843 he appointed J. H. Gilbert (later Sir Henry), a chemist by training, to assist him in field and laboratory experiments on nutrition of crops and animals. Today some of their experiments continue, and are apparently the oldest continual agricultural experiments in the world. Their partnership continued for 57 years, and together they published some 150 scientific papers and 300 popular articles for farmers.

Gilbert had earned a doctorate at Giessen in Germany as a student of Professor Liebig, a leading figure in the history of plant nutrition, still known for "Liebig's Law of the Minimum." The first edition of Professor Liebig's treatise on agriculture was published in 1840, and it rapidly went through several subsequent editions. Gilbert earned his doctorate in 12 months, returning to England to work at University College London and then in industry in Manchester before moving to Rothamsted. The principal field experiments he established there focused upon agricultural species, turnips (1843), winter wheat (1843), beans (1847), crops in rotation (1848), clover (1849), spring barley (1852), oats (1869), and finally, of most interest to community ecologists, the only experiment involving plants in mixture, the park grass studies of permanent pasture (1856).

Here we shall largely pass over the details of the experiments themselves, particularly the ones on agriculture, except for Figure B11.2(a), which shows the dramatic improvement in yields of wheat through time as fertilizer, herbicides and fungicides were incorporated into agricultural practice.

Fisher was hired at Rothamsted in 1919, nearly a century after the founding of the Statistical Society of London by Adolphe Quetelet in 1834 (Barnett 1994). Although Fisher was at first regarded as flighty, it soon became apparent that he had great ability, and the director of the station, Sir John Russell, concluded that he "was in fact a genius who must be retained." Over his period at Rothamsted, Fisher developed and introduced such essential concepts as factorial design, interaction of main effects, analysis of variance, and blocking to account for the heterogeneity of fields. Figure B11.2(b) shows the layout of the

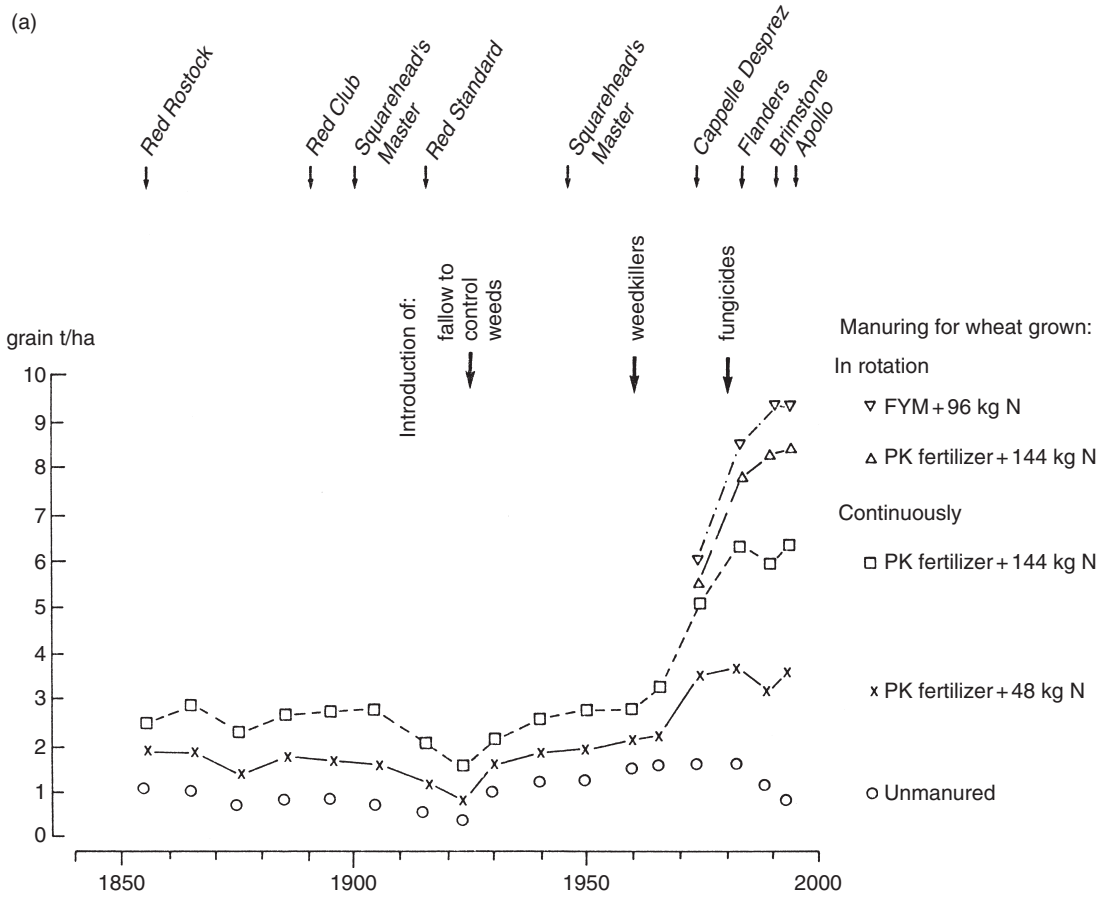
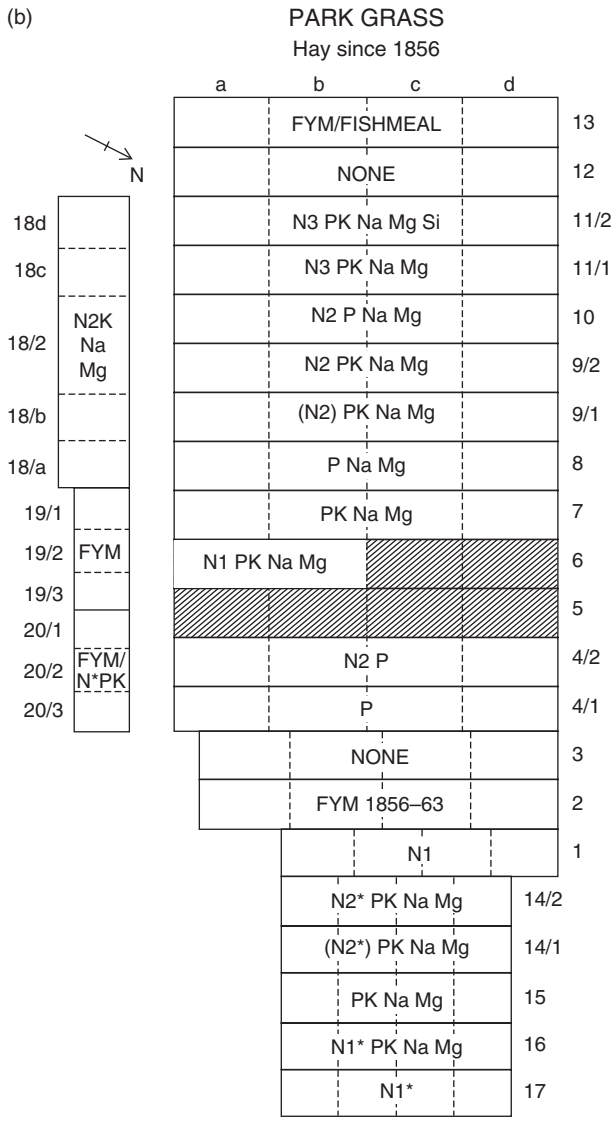


Figure B11.2(a) Yields of winter wheat grown at Broadbalk, Rothamsted, from 1852 to 1990 with fertilizers and with farmyard manure showing the effects of changing cultivars, the introduction of weed control and fungicides, and crop rotation to minimize effects of soil-borne pathogens (courtesy A. E. Johnston, updated from Johnston 1994).

Park Grass experiments. Although the design clearly indicates a desire to study the effects of fertilization, we should now recognize the design as deficient in at least three ways. There is a decided lack of replication to measure variation among plots receiving the same treatment. The design does not appear randomized, similar treatments appearing instead to be adjacent to one another. The design is not factorial for the study of interactions among the treatments. The very fact that most of us can see these inadequacies at once serves only to illustrate how fundamentally Fisher has changed the way we think about the design and analysis of experimental data.

The Park Grass plots themselves continue to be of interest to ecologists (Silvertown et al. 2006); one of the more interesting examples of this work (Silvertown 1980, Silvertown et al. 1994) shows that fertilization consistently led to steady declines in plant diversity (Figure 11.27); in contrast, effects of rainfall were minor. Further, within any plot, there now appears to be some sort of botanical equilibrium at the coarse scale: the relative proportions of three groups (grasses, legumes, and other species) show no trends over recent time. In contrast, however, individual species within each group have continued to fluctuate widely. There thus appeared to be a dynamic equilibrium at one scale, but not the other.

Figure B11.2(b) The layout of Park Grass, Rothamsted, UK. Treatments (every year except as indicated). *Nitrogen* (applied in spring): N1, N2, N3, sulfate of ammonia supplying 48, 96, 144 kg N ha^{-1}; N1*, N2*, nitrate of soda supplying 48, 96 kg N ha^{-1}; (N2), (N2*), last applied 1989. *Minerals* (applied in winter): P 35 kg; K 225 kg; Na 15 kg; Mg 10 kg ha^{-1}; Si silicate of soda at 450 kg ha^{-1} of water-soluble powder; plot 20, rates of fertilization in years when FYM not applied: 30 kg N*, 15 kg P, 45 kg K ha^{-1}. *Organics* (each applied every fourth year since 1905): FYM, 35 tonnes ha^{-1} farmyard manure (bullocks) (1989, 1993); fish meal (about 6.5% N) to supply 63 kg N ha^{-1} (1991, 1995). *Lime*: a,b,c lime applied as needed to maintain pH 7, 6, and 5 respectively; d no lime applied (pH range 3.5 (plot 11/1) to 5.7 (plot 17) (from Barnett 1994).



The Park Grass experiments, and others, continue at Rothamsted. Recognizing the value of this work, many other sites for long-term ecological research have been established over the last few decades. The valuable association of long-term experiments with large tracts of native vegetation also illustrates the close connection possible between systems of protected areas and scientific research. There is a sort of symbiosis here, with the natural areas providing sites for research which otherwise would not be possible and the research providing insight into management and protection of the reserve system. The results of long-term experiments should enliven and enrich future texts on plant ecology, and may be one of the most important and least expected long-term contributions by Lawes and Gilbert.