ROTHAMSTED RESEARCH

Report for 1979 - Part 1

Full Table of Content

General Report

L. Fowden

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GENERAL REPORT

L. FOWDEN

Sir William Gammie Ogg, Director of Rothamsted from 1943 until 1958, died on 25 September at the age of 87. Gammie Ogg came of a long-established Aberdeenshire farming family. He gained early scientific distinction for his study of soils and their classification and, at 39, became the founder Director of the Macaulay Institute for Soil Research. He joined Rothamsted in wartime during the Station's centenary year, when the staff numbered about 180. When he retired 15 years later, he bade farewell to more than 450 colleagues. During these years of rapid expansion, Rothamsted benefited enormously from his enquiring mind, his enthusiasm and organising ability, and his deep experience of practical agriculture. He successfully re-established many of Rothamsted's overseas links that had been stressed or severed during wartime years, and worked tirelessly to ensure that the Manor House was restored and adapted as a residence for young staff and overseas visitors.

Lawes Trust Committee. Sir Gordon Sutherland retired from Committee membership in July having served for 14 years as a Royal Society representative. Fortunately, he will maintain his contact with the Station as a Trustee of the Lawes Agricultural Trust. Professor B. A. Thrush of the University of Cambridge was nominated by the Royal Society to fill the vacancy on the Committee.

Staff. Rothamsted's two Deputy Directors left during the year. F. G. W. Jones retired in November. He had joined Rothamsted in 1956 as Head of Nematology and, during 24 years, had built his Department into a world-renowned centre of nematological research. Recently his personal research was concerned with modelling factors governing field populations of nematodes. He became a Deputy Director in 1971, performing a wide range of tasks with enthusiasm and scientific acumen. I. J. Graham-Bryce transferred to East Malling Research Station as Director at the end of July. He had been Head of Insecticides and Fungicides since 1972, managing the research of the multidisciplinary Department with outstanding skill and developing new strategies for the effective control of crop pests. He was appointed a Deputy Director in 1975 and quickly distinguished himself for his thoughtful, mature approach to complex problems. During the year E. Lester and M. Elliott were nominated Deputy Directors, A. R. Stone succeeded to the Headship of Nematology, and M. Elliott was appointed Head of Insecticides and Fungicides, a Department he first joined in 1948.

Another notable retirement was that of P. S. Nutman, who had completed 40 years as a member of the Soil Microbiology Department. He was appointed to the departmental Headship in 1957. Nutman was an authority on symbiotic nitrogen fixation and his outstanding contributions to knowledge of this subject were recognised by his election to the Fellowship of the Royal Society in 1968. Dr. J. E. Beringer of the John Innes Institute has been nominated Head of Soil Microbiology with effect from April 1980.

Several other members of staff retired after long periods at Rothamsted: these included I. F. Long (appointed to Physics in 1939), W. J. Lessels (Statistics, 1950), Joan K. Foster (Soil Survey, 1953) and A. J. Vernon (Statistics, 1958). Irene J. Covell (Insecticides and Fungicides, 1967) retired in May and, sadly, died in December.

Three scientists gained Individual Merit Promotion to the grade of Senior Principal Scientific Officer: N. F. Janes (Insecticides and Fungicides), D. S. Jenkinson (Soils and Plant Nutrition) and Gillian N. Thorne (Botany). M. Elliott (Insecticides and Fungicides), who was elected a Fellow of the Royal Society in March, was promoted on merit to

https://doi.org/10.23637/ERADOC-1-136

Deputy Chief Scientific Officer but, on becoming Head of Department, he assumed this grade in a personal capacity.

Buildings. The Central Stores were completed and occupied early in the year. The first stage of a major refurbishing of the Ogg building was finished in June and work on the second and final stage is well advanced; completion is expected in spring 1980. Construction of a new single-storey laboratory block for genetic manipulation research commenced in July.

Demonstrations of research

Subject days featured the Station's research on potatoes. Almost half of the exhibits described disease problems; fungal and bacterial infections were emphasised and the importance of monitoring and control at all stages of crop production was stressed. The role of aphids as vectors of virus diseases is well recognised, and considerable interest was centred on an exhibit illustrating how sticky hairs on potato foliage can reduce aphid movement and the spread of viruses; such hairs are present on certain wild potato species and attempts are being made to introduce the character into commercial varieties. Another main section was devoted to the nematode pests of the crop: the exhibits showed how information about the field populations of the major pest species, and their pathotypes, can be used to develop effective strategies for nematode control involving resistant potato cultivars, crop rotations, and nematicide treatments. The nutrition and physiology of the potato crop formed smaller sections of the Subject Days. The event was again popular with people from a wide cross-section of the agricultural industry, and we were pleased that a large contingent of members of the Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food (MAFF) found the presentations useful in their role as advisers to farmers.

Outside exhibits. Rothamsted scientists contributed to a number of major agricultural demonstrations organised during the year. An exhibit on fungal diseases of the potato seed crop was mounted at the annual conference of the British Crop Protection Council at Brighton. A demonstration describing the measurement and benefit of phosphate residues in the growth of barley was included in the Royal Agricultural Society of England's (RASE) Barley '79 event at Cirencester, and exhibited again at the Royal Show at Stoneleigh. Two other exhibits were displayed at the Royal Show: one dealt with the problem of weed beet and the other with the effects of direct drilling practices on the soil fauna. The Royal Society's Soirées included a demonstration by the Soil Microbiology Department entitled 'Clovers and Fertility', which featured some of the major clover species used in world agriculture and their benefit to the nitrogen economy of agricultural systems; a film produced by the Nematology Department on the stem nematode (*Ditylenchus dipsaci*) and its damaging effects on field beans was shown to Soirée audiences.

Visits and visitors. Lord Porchester, Chairman of the Agricultural Research Council (ARC), paid a personal visit in February to become familiar with aspects of Rothamsted's programme of research. We welcomed him again in June, together with members of the Council, who held a normal business meeting at Rothamsted before visiting research laboratories. During the same week, the Chairman, Board members and senior executives of the National Research Development Corporation (NRDC) visited the Station to discuss research that has been exploited commercially, or that holds potential for future exploitation. Individual visitors from a long international list included the Senior Trustee of the Lawes Agricultural Trust, His Grace the Duke of Northumberland, the Minister

https://doi.org/10.23637/ERADOC-1-136

for Food, Agriculture and Animal Husbandry of Turkey (Mr. M. Yuceler), the Deputy Prime Minister of the Byelorussian Republic of the USSR (Mr. V. A. Goozdez), and Mr. B. D. (now Sir Brian) Hayes and Dr. B. G. F. Weitz, Permanent Secretary and Chief Scientist, respectively, of MAFF. We have received several overseas scientific delegations including groups of crop protection specialists from Hungary and the USSR, seed production specialists also from the USSR, and of plant chemists from the People's Republic of China. More than 50 scientists from 29 countries have worked in Rothamsted's laboratories during 1979; we appreciate the regard shown for Rothamsted by these visiting scientists and students, and hope that the experience they gain whilst here will ultimately benefit agricultural production in many regions.

Members of staff participated in many international congresses and smaller meetings, and only a selection of visits can be mentioned. The Station was represented strongly by J. A. Nelder, J. C. Gower, D. A. Preece and G. J. S. Ross at the 10th International Biometrics Conference in Brazil. K. A. Lord and R. H. Bromilow spent periods at the Biological Institute in São Paulo collaborating in a new programme of pesticide residues research, and A. R. Stone spent 4 weeks in Leningrad working with Russian nematode taxonomists. The Overseas Development Administration (ODA) sponsored visits by E. Lester to Kenya to advise on plant pathology research, by J. M. Day to Trinidad to participate in the final stages of the pigeon pea project, and by L. Fowden to India as a member of a UK delegation attending the 50th Jubilee Celebrations of the Indian Council for Agricultural Research. P. B. Tinker visited several campuses of the University of California as a Regent's Lecturer, M. Elliott and B. J. Miflin attended conferences in Mexico City, and D. H. Rees participated in a seminar on the application of computing to agricultural research in China. Several members of staff are undertaking periods of research in laboratories in the USA and Australia.

The organisation and funding of research. Since 1973 the Joint Consultative Organisation (JCO), through the activities of its five main boards and many specialist committees and working parties, has made a detailed review of the national programme of agricultural research and of areas deserving of special emphasis. In autumn 1979, the Minister announced that the JCO would be reorganised and function after April 1980 in a simpler form; it would consist of a single Consultant Board operating in association with *ad hoc* committees convened for limited periods to prepare detailed reports of clearly defined subject areas prior to reviews of MAFF commissions by the Chief Scientist's Group. The present JCO system has enabled scientists at institute level to participate in discussions leading to the formulation of national research strategies; the new system, hopefully, will continue such participation and provide a mechanism for reviewing and fostering areas of basic and strategic research that are not part of MAFF commissions.

The calendar year includes parts of two budgetary years. Late in the financial year ending March 1979, Rothamsted was granted additional funds by ARC for the purchase of a number of items of capital equipment, including a mass spectrometer for ^{15}N work in the Soils and Plant Nutrition and Soil Microbiology Departments. The imposition by Government of strict cash limits to the 1979/80 budget and the failure to provide in full for the agreed increases in salaries has caused a retrenchment in research activity in the second half of 1979. Some vacancies have not been filled, the provision of new equipment has begun to fall behind the replacement needs, and heads of current expenditure have been cut significantly. A provisional cut of almost 5% in Rothamsted's grant for 1980/81 forebodes even greater problems in maintaining research activity, and efficiency, in the future.

For reasons of economy, this *Report* is shorter than those of recent years. Generally, its style is unchanged, but we have introduced a separate section describing aspects of our expanding programme of multidisciplinary experimentation.

https://doi.org/10.23637/ERADOC-1-136 *pp 4*

Weather and crops. All months from January to August were cooler than the long-term averages, and sunshine hours were also less for all months from February to August, with the exception of May. The early months of the year were very wet, and rainfall recorded in the period January to May was 222 mm more than the long-term mean value. These conditions made spring cultivations, sowings and treatments difficult, and crops grew slowly in the cool spring and early summer. Harvest dates for all cereals were later than usual, but combining was done under good conditions. The weather in late August, September and October was particularly favourable and potatoes, beans and sugar beet were harvested in good order, and autumn sowing finished earlier than usual.

Cereals. Many crops of winter wheat suffered during the cold winter and wet spring, but generally they recovered well in the later phases of growth: however, recovery of wheats in the variety experiment planted on Horsepool Lane Close at Woburn was less satisfactory. More winter barley than usual was grown and, where diseases were controlled, some plot yields exceeded 8 t ha^{-1}. Spring barleys were sown late and even then good seed-beds were difficult to obtain; final yields were very variable.

Some very high plot yields were recorded in winter wheat experiments. On Broadbalk, where the variety Flanders was harvested for the first time, the FYM plus fertiliser N plot (with a foliar fungicide spray, also for the first time) gave 8·7 t ha^{-1}, a yield higher than any previously recorded. In a major multidisciplinary experiment studying factors limiting yields of winter wheat (cv. Hustler), the best ever yields at Rothamsted were obtained. The mean of all plots (134 in number) was 9·7 t ha^{-1}, but 16 yielded over 11 t ha^{-1} and one-third gave over 10 t ha^{-1}. In a similar experiment at Woburn, the largest yields from early sown plots irrigated and treated with aldicarb were on average 8·7 t ha^{-1} (maximum 9·4 t ha^{-1}); comparable plots at Rothamsted averaged 11·1 t ha^{-1}.

Very heavy infestations of wheat leaves by aphids built up during July and, rather against expectation, resulted in significant yield losses. Where they were satisfactorily controlled with two applications of aphicide, as in certain treatments in the multidisciplinary experiment, a yield benefit of up to 1·3 t ha^{-1} was obtained.

Potatoes. Planting in the wet spring was restricted to a few suitable days, and so the benefits conferred by an improved temperature control during chitting and by the availability of an automatic planter (for non-experimental crops) were fully realised. The seed crop was lifted early to permit early drilling of 1980 wheat and barley experiments, but good yields approaching 50 t ha^{-1} were obtained. This year fewer potato experiments were conducted; yields from Woburn experiments (all unirrigated) and from experiments (some with irrigation) at Rothamsted fell within similar ranges, but no outstanding yields were recorded.

Sugar beet. Drilling of the crop was seriously delayed by rain and by mid-April, when normally at least 80% of the national crop has been sown, only 7% had been drilled. Despite these difficulties, plant stands were generally better than average. The severe winter and cool, wet spring reduced *Myzus persicae* infestations, and little virus yellows developed. Blackfly (*Aphis fabae*) were more numerous and reached potentially damaging levels in mid-July, but the population then declined rapidly. The wet spring favoured nematode activity and Docking disorder was more prevalent than in any year since 1969; damage, however, was usually slight (anticipated yield losses less than 10%) because of the widespread use of granular nematicides. The soil moisture deficit below the crop at Broom's Barn reached 150 mm at the end of July and, during the dry September, increased again to a maximum of 190 mm; irrigation during July/August produced a considerable yield response.

https://doi.org/10.23637/ERADOC-1-136

The proportion of sugar-beet fields infested by weed beet increased to 24%. A major experiment has been started at Broom's Barn to test a model of the population dynamics of weed beet, and the effects of different levels of seed multiplication, alternative rotations and different cultural techniques will be assessed. Another major new initiative seeks to determine more precisely the relationship between the radiation intercepted by beet foliage and the ultimate sugar yield of the crop; experiments are being conducted at Broom's Barn and at a temperate coastal site in South Wales, where total irradiance is about 20% higher than at Broom's Barn.

Selected research activities

Rothamsted conducts a broad and varied programme of research in the scientific disciplines underpinning agricultural production. It is possible to highlight only a very few of these activities in this general introduction. Items chosen for inclusion relate to topical issues such as those raised by (i) the Report of the Royal Commission on Environmental Pollution: Agriculture and Pollution (Command 7644, published September 1979), or (ii) the continuing need to use capably the nation's land resource; or they are selected because they illustrate progress in inter-institute collaborative programmes, or report novel developments.

Inter-institute collaborative programmes

Yield variation programme. Rothamsted's major contribution to this programme takes the form of a new multidisciplinary experiment to determine the separate and interactive effects of factors limiting the yield of winter wheat crops. The results of the first year of the full experiment at Rothamsted Farm are described elsewhere in this *Report* (p. 17), and an account of a less complex associated experiment, on a different soil type at Woburn, begins on p. 22. It is particularly satisfying that the experiment has given, at this early stage, wheat yields equal to any recorded in Britain and that the treatments associated with these high yields are fully documented.

As part of the inter-institute programme, a Modelling Group has been set up with Dr. J. J. Landsberg (Long Ashton Research Station) as convener. The Group will attempt to develop a simulation model to explore the effects of varying cultural and environmental conditions on the growth and yield of winter wheat. The model will consist of sub-models describing the principal processes governing plant development (biophysical, physiological or metabolic), and should provide researchers with an analytical tool to test hypotheses about how particular processes affect crop growth and yield.

Genetic manipulation programme. The objectives of this work were outlined in last year's *Report* (Part 1, 14). During the first year of experimentation, Rothamsted's effort has concentrated on aspects of the molecular biology of barley storage protein synthesis and on the production of mutant lines of barley resistant to amino acid analogues or combinations of amino acids.

The storage proteins of barley grain and the messenger RNA (mRNA) molecules coding for them are being isolated and characterised. In collaboration with scientists of the Plant Breeding Institute, DNA copies of a mRNA fraction have been produced via reverse transcription and subsequently double-stranded DNA was obtained. We are now seeking to clone this double-stranded DNA material as a prerequisite for future attempts to modify it in ways that will induce it to specify nutritionally improved protein molecules.

An aim of the barley mutant programme is the selection of lines producing increased amounts of certain essential amino acids. So far mutants resistant to the growth-inhibitory

https://doi.org/10.23637/ERADOC-1-136 *pp 6*

effects of aminoethylcysteine (a lysine analogue), of lysine plus threonine, or of hydroxyproline have been obtained. Some of the mutant genes are recessive and some are dominant. As yet only one aminoethylcysteine mutant has been characterised in detail: resistance is attributed to a recessive mutation resulting in a decreased uptake of the analogue, rather than an enhanced synthesis of lysine. However, several mutants selected for resistance to combinations of lysine plus threonine produce seedlings having increased levels of either methionine or threonine. Genes for these types of resistance should prove useful as markers and selective traits in a number of future investigations.

Photosynthesis programme. This year ARC decided to support an enlarged programme of research on photosynthetic carbon dioxide fixation and the subsequent partitioning of carbon assimilates in crop plants. Several institutes and three university departments will participate in the first phase of the programme seeking a fuller understanding of the biophysical and biochemical mechanisms regulating the early stages of CO_2 fixation. The Botany Department has traditionally attempted to relate the physiology of photosynthesis with crop growth and, in more recent years, has complemented this approach with biochemical investigations. We plan to increase the biochemical work, initially by undertaking a detailed study of ribulose bisphosphate carboxylase/oxygenase, a key enzyme in both CO_2 fixation and photorespiration processes.

Aspects of soils research

Soil water physics. The new facilities provided for this work are being used to study the flow of water through media composed of particles of dissimilar shape. Meanwhile, a theoretical study has improved our understanding of the hydraulic effects of filter surrounds to land drains. The water table height resulting from a given rainfall depends on the effective radius of the drain pipes; this in turn depends on the size and spacing of the openings through which water enters the drain pipe, and on the shape and thickness of any filter surrounding the pipe. It is clear that the effective radius is more sensitive to changes in the hydraulic conductivity of the filter material than to changes in its thickness; provided the filter surround is much more permeable than the soil, even a thin filter will ensure good control of water table levels.

Soil nitrogen studies. The Royal Commission Report stressed 'the need to ensure that fertilisers are used efficiently so as to minimise nitrate losses and the need to assess carefully the effects, in terms of these losses, of new farming techniques which might find wide application.' The Commission, however, concluded that the anxiety that has been engendered about health risks posed by nitrate in water supplies is not justified on the information at present available. Rothamsted has a long involvement with research seeking to increase the efficiency with which fertiliser N is utilised by the major arable crops of Britain, and recently several new developments have been initiated. Gradually, we are refining a model to simulate leaching of nitrate and other solutes through structured soils which are very widespread and include most soils on Rothamsted farm. The model partitions the soil solution into two phases, one mobile and the other retained, and so allowance is made for 'hold back' of solutes in soil aggregates. The model also allows for equilibration between the phases by diffusion into large peds. It appears to successfully describe movement in heavily structured subsoils, and may be usable for simulating the movement of nitrate through soil into chalk aquifers. An experimental investigation of the movement of nitrate in deeper subsoils, including the chalk layer, at Rothamsted has commenced following the acquisition of a Pilcon drilling rig by the Soils and Plant Nutrition Department: the new programme has developed from earlier studies in

https://doi.org/10.23637/ERADOC-1-136

association with the Water Research Centre, Medmenham. Nitrate leaching is one of several factors governing the nitrogen balance in arable crops. With the aid of the new mass spectrometer dedicated to ^{15}N assay, we have begun a programme to determine more accurately than previously the nitrogen balances for winter wheat and grass, using the Broadbalk and Park Grass classical experiments because their stable levels of soil nitrogen make them particularly convenient for study.

Soil surveys. Last year (*Rothamsted Report for 1978*, Part 1, 15) brief reference was made to the decision to produce a new national soil map at a scale of 1:250 000. This project has progressed satisfactorily in the current year and some 17 000 km^2 of land has been surveyed. Soil types, and their distribution patterns, established in earlier detailed surveys have been confirmed; the national soil series list is being reappraised to eliminate overlapping concepts. As part of its policy to undertake specialised surveys, the Soil Survey have agreed a commission with the National Coal Board which provides for detailed surveys of sites where opencast coal operations are proposed. Knowledge of site characteristics should permit better extraction and reinstatement policies to be formulated and thereby improve land restoration. Each survey will provide information about the ease of soil stripping, susceptibility to compaction when wet, volumes of suitable topsoil and subsoil, unsuitable materials, and suitable replacement soil material.

Mycorrhizal studies. Previous reports have described how endotrophic mycorrhizal infection of plant roots may enhance the uptake of phosphate, especially from soils of low-P status. So far it has not been possible to cultivate the endophytes successfully in the absence of living roots, so material used for soil inoculation must be produced on roots. Last year's *Report* (Part 1, 235) described a preliminary study concerned with the possibility of obtaining relatively clean mycorrhizal roots from plants grown in nutrient film cultures. Now a number of plant species have been successfully infected with five different mycorrhizal spore types using this technique, and current studies are seeking the best nutrient combinations and flow rates to produce optimal infection and production of external mycelium. ODA and NRDC have provided funds to support this research, and work is now directed to the possibility of producing large scale inoculum of consistent quality on lettuce or tomato roots.

Crop protection research. In their report, the Royal Commission write (para. 8.10) 'We accept that the continued use of pesticides is essential to maintain food supplies and that much care is taken by manufacturers, and through the existing control machinery, to ensure safety in use and to minimise adverse environmental effects. We are concerned, nevertheless, about the scale of pesticide use.' They proceed to recommend that future research should (i) place greater emphasis on the development of new techniques to improve the efficiency of pesticide application, (ii) expand knowledge of the factors determining the incidence of diseases and pests and on the measurement of economic threshold levels, (iii) develop strategies to delay the onset of resistance to insecticides in insects, and (iv) seek to apply the concepts of integrated control. These recommendations mirror the Station's general philosophy concerning crop protection practices, and many of the established and newer aspects of our research programme are especially relevant to the Commission's proposals. For instance, we initiated a programme to apply the concepts of integrated control to pests of cereals at North Farm, Sussex, in association with scientists at the Glasshouse Crops Research Institute and the Game Conservancy. We are also continuing an assessment of *Sitona* weevil damage of field beans to relate population levels to resulting yield losses, and extending our survey of the factors affecting the levels of fungal and bacterial infections of the potato crop at all

https://doi.org/10.23637/ERADOC-1-136

stages of production in the hope that disease development during tuber storage may eventually be predictable.

Factors influencing the scale of pesticide use. Ideally, farmers spray crops with pesticides only when the yield benefit exceeds the economic cost of spraying, but a degree of insurance spraying happens—to be safe rather than sorry! Monitoring of aphids using suction traps or of pea moths using pheromone (sex-attractant) traps, both developed at Rothamsted, seeks to alert farmers to potentially damaging insect populations in particular localities, and so to give them confidence to withhold pesticides until clearly needed. This year possible sex attractants for the male diamond back moth have been tested as baits in traps. Preliminary results suggest that the pheromone traps were more effective than traditional light traps in catching moths; and eventually we hope to develop a sensitive, yet practical, method for monitoring populations of this pest damaging cruciferous crops, especially in countries with warmer climates than Britain.

Several other options exist for reducing the amount of pesticides entering the environment. The development of spraying systems designed to increase the efficiency with which pesticide chemicals reach the target organisms is clearly important, and low-volume, controlled droplet size equipment should make a significant contribution to this problem. Electrostatically charged spray application systems, one type of which is being developed jointly by Sheffield University and Rothamsted, should ensure better penetration and more even deposition of pesticide chemicals to crop foliage. This is especially important with highly active compounds, such as the photostable pyrethroids. These synthetic pyrethroids stemmed from a basic study seeking to relate chemical structure to insecticidal activity of pyrethrin-type compounds, and this project continues to seek principles by which this class of insecticides might be further improved in selectivity and in intrinsic activity whilst retaining the desirable environmental properties of involatility in air and rapid degradation in soil.

Resistance of insects to insecticides. This is one of the most intractable problems facing insect control. Our ability to control many important agricultural, medical and veterinary pests is increasingly threatened by the development of resistant populations. The situation is particularly grave because it is generally agreed that crop protection and public health pest control must continue to depend on pesticides.

Surveys of potato and cereal aphids and of houseflies have shown resistant populations to be unexpectedly widespread in Britain, and so have emphasised the need for a broadly-based approach to the problem of resistance. Loss of control arises through the occurrence and selection of a resistant genotype in insect populations following treatment with insecticides. In *Myzus persicae*, resistance is associated primarily with multiple copies of a structural gene for an esterase with a broad substrate specificity which hydrolyses many ester-type insecticides; this is a unique demonstration of gene duplication in whole organisms. In formulating strategies to delay the development of resistance, an investigation now supported by the Leverhulme Trust, the newer synthetic pyrethroids provide an excellent opportunity to avoid past mistakes. We then regret the tendency developing to control houseflies and other domestic pest insects with the photostable pyrethroids, for appropriate use of the earlier less stable pyrethroids (resmethrin and bioresmethrin) would probably delay onset of the anticipated build-up of resistance to the stable compounds.

https://doi.org/10.23637/ERADOC-1-136 *pp 9*