PHYSIOLOGY AS A KEY TO RATIONAL TEA HUSBANDRY

U. Pethiyagoda

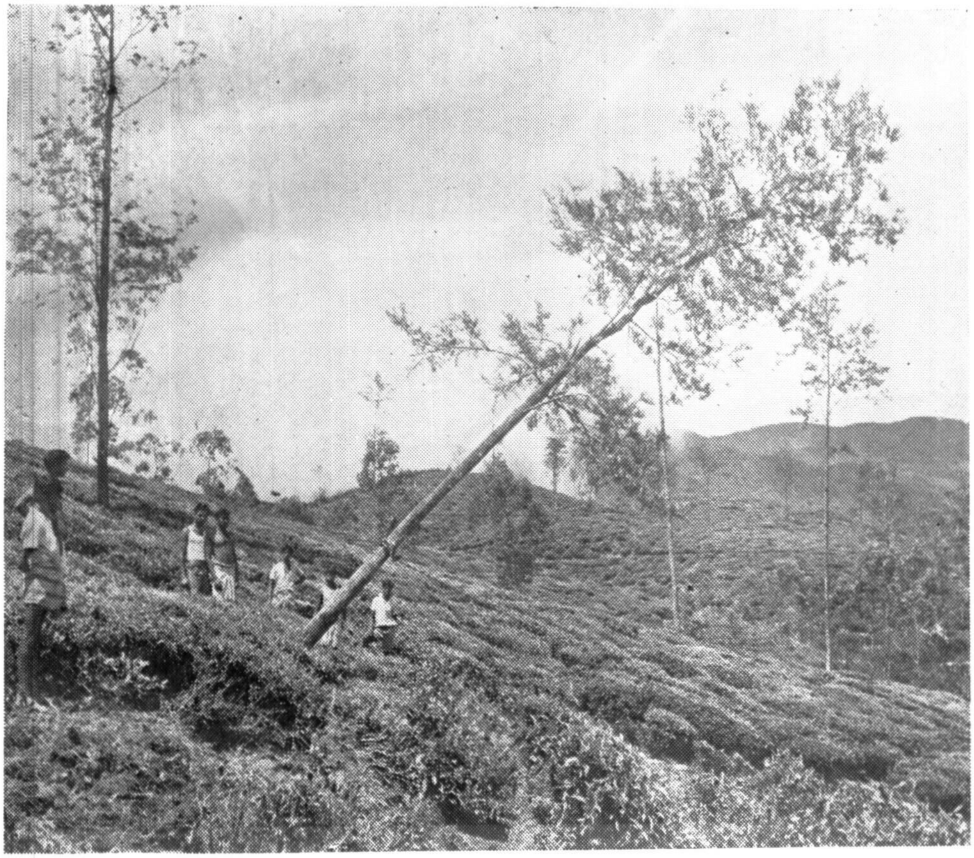
Scientific Agriculture in the modern world stands for much more than just profitable farming. For the most intelligent and productive use of land and crop the activities of the grower must find support and endorsement in the findings of the agricultural scientist. Extensive and intensive cultivation of a crop plant is in a sense an interference with the balance of nature. Such incursions often bring in their train, special problems that are rare to natural biological systems. Once created, these call for the intervention of a wide range of agricultural and scientific disciplines which must apply themselves to the task of maintaining the newly and artificially established equilibria at the optimal level of productivity.

A virile and progressive research institute should display a balance in its organization and pursuits. While remaining alert to its primary responsibility of fulfilling the needs of the industry it serves, it must remain free to organize its activities as it deems will best enable it to perform its functions. In its efforts to see its problems and its objectives in correct focus, it must surely be grounded in its investigations of the behaviour of its subject — in this instance, the tea bush itself. In what way it functions, the manner in which these functions may be turned to human advantage, the resulting ways in which these diversions in turn affect these functions. Physiology is just this — the study of the processes of life. Crop physiology concerns itself largely with not only these vital processes as they are, but the way in which our efforts at organized husbandry change them and the new functional equilibria that are thus established.

There are few examples of crop production that demand such marked alterations of natural tendencies as does the mono-cultivation of tea. Tea is unique among the major perennial crop plants in that the young new growths in the form of tender shoots comprise the produce. In order to achieve optimal production, the tea plant which in its natural state grows to become a tree of moderate size, is treated in various ways to transform it into a low bush of convenient height for the relatively very frequent harvests. The young plant's development is thus deflected by many different types of cultural operations, which though familiar in present day tea culture, are artificial to the normal physiology of the tea plant and thus offer a vast and fascinating field for study.

Of the vital functions of the tea plant, growth is the pre-eminent. Growth is intimately bound with other functions — nutrition, assimilation and respiration. It is associated with and modified by, environment, cultural practices, pests and diseases and its own inherent genetical make-up. The study of the physiology of the growth of tea must concern itself with each one of the above factors and also the manner in which they influence, or interact with one another. Within the vast compass of such a field will be included fertilizer practices, root and leaf function, the effect of light, water, minerals, wind and soil, the impact of such treatments as bringing into bearing, pruning, plucking and shade tree cultivation, the influence of pests and diseases and the methods and materials for their control, and superimposed upon all this, the manner in which the different clones will behave in relation to all of the above factors as they modify the growth of tea. A vast and inexhaustible field, it need hardly be stressed.

High-yielding vegetatively propagated tea



Removing shade trees by winching

Pruning tea

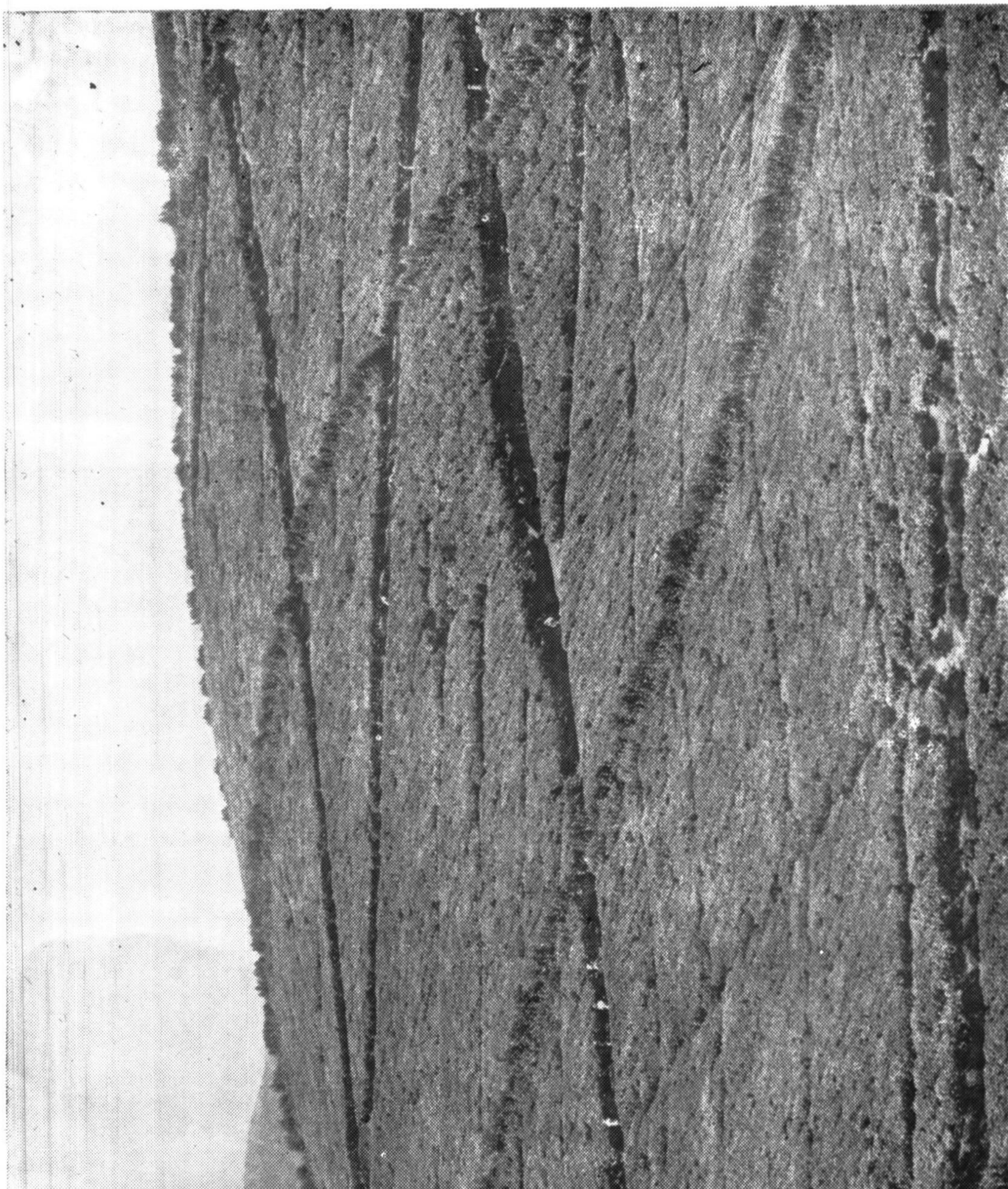
But what is growth ? Perhaps the most adequate practical definition is that growth is the building up of new material with time. This new material is best assessed as dry matter. In complete assessment, such measurements account for the production of new roots, frame, leaves and crop shoots. The last mentioned is what comes as crop — normally the main measure in experiments and a primary concern of the grower. There probably exists an optimal proportion in which the total dry matter produced apportions itself to crop and the more permanent framework of the tea bush. If this were so, a search must be made for the factors necessary to achieve this optimum, resulting both in the avoidance of any hazards of 'over-cropping' and any unnecessary wastage through 'under cropping'. Ideal cultural practices could be striven for, if a sufficiently simple and practical picture emerges. Efficient crop production which may lie at the base of outstanding clonal performance needs to be analysed in order that it may be adapted towards the improvement of genetically less productive populations. Growth analysis as a technique, attempts to understand such situations by analyzing growth into parameters relevant to crop husbandry. A start has been made in the search for such constants by the study of patterns of dry matter accumulation and the ways in which prevalent cultural practices modify this pattern. Translated into practical terms, this could mean a minimizing of the effects of such cultural operations as exert a depressive effect and a maximizing of safe stimulatory influences.

So are the gross features of growth studied. At the other end of the spectrum is the cropping unit — the flush shoot. The manner in which it arises, grows and is then harvested are clearly fundamental to the practice of plucking. Studies on this important basic aspect of growth were commenced at the Institute by Bond and Portsmouth. The production of flush shoots exerts a strain on the synthetic functions of the rest of the bush — perhaps also its resources in the form of stored reserves. Simultaneously, there is the production of new synthetic organs in the form of maintenance foliage. How do the relative magnitudes of these conflicting effects compare ? What factors regulate flush shoot size, number and rate of growth ? It is the interplay of such considerations that sum up to determine the cropping capacity and its sustenance in a growing bush. The growth patterns of individual, identifiable flush shoots are studied. Their behaviour is modified by manipulative procedures, both natural and artificial. They are counted, measured and assessed frequently. Their assimilation is studied by the feeding of radio-active tracers, whose incorporation, movements and utilization are followed. These are laborious and intensive studies — academic and abstruse in superficial examination but nevertheless basic to the understanding of the manner in which the crop is produced and this production sustained by the bush. Plucking stimulates more plucking points and so sets in train a process which builds itself up — reflected in the increasing crop as the pruning cycle advances. For a more rational and purposeful evaluation of plucking practices, it is easy to see the need for such basic information on the manner in which flush shoots grow, and once again the way in which environment, other cultural practices and the innate characteristics of the population act on one another. Optimal lengths of plucking rounds, seasonal effects, the ideal severity of the operation among other considerations, will then become amenable to more rational adjustment and not need to develop out of arbitrary and chancy test operations in the field. This is not to be little the importance of field experiementation — which is an ever-important aspect of physiological investigation — but to suggest the need for balanced and mutually supplemented and assisted progress between laboratory and field.

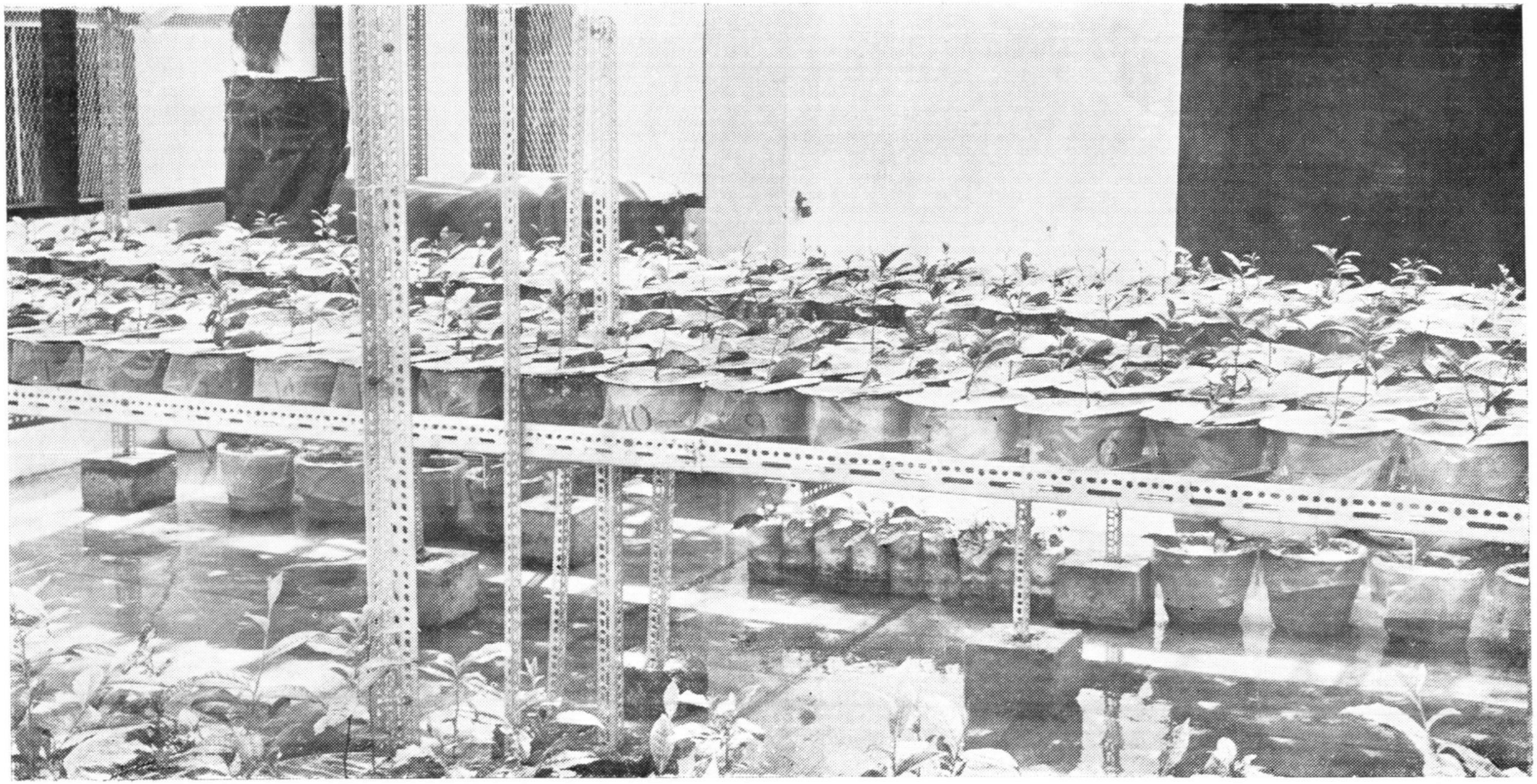
The effects of such cultural factors as shade and pruning may serve as further examples of the approach of the physiologist. Shade, when provided through the interplanting of tea with other tree species, becomes the study of a new type of plant association artificially established. Plants when growing together, exert a number of influences on one another. The larger partner shades and shelters the smaller. They compete, one with the other, for water, nutrients and space — above and below ground. Through the droppings of leaf litter, they affect the organic matter content, water-holding powers and the mineral status of the soil. In a study of such a factor as shade, the physiologist must necessarily combine the agronomic approach (the effects on yield of shading tea) with that of the fundamental scientist (metereology, microbiology, the morphology and interactions between root systems, soil chemistry and physics). It would naturally be impossible to give sufficiently comprehensive coverage to each one of these disciplines. Rather, the approach has to be a synthesis of all lines. Yield is selected as the criterion of performance. An attempt is made to analyse each one of the tree effects and to simulate them by artificial means, singly and in desired combinations. Thus the shade and shelter may be provided by artificial screens or ' trees ', the mulch effects, by bringing in desired amounts from elsewhere and applying them to unshaded tea. The final evaluation of the effects of shade trees on tea will thus consist of purely agronomic observations of their effect on crop production, supported by a synthesis of the individual effects of each environmental amendment and their interactions on one another. This is the synthetic approach.

Very often, in the solution of immediate *ad hoc* problems, the approach has necessarily to be analytical. A particular set of circumstances has combined to pose a special problem. Its solution rests in the recognition of the factor or factors responsible. A good instance of such an approach is exemplified by the problem on pruning which had to be faced by the first Plant Physiologist, Tubbs in the early 1930's. Broadly, disconcertingly large numbers of bushes either died or suffered heavy deaths of branches (dieback) after pruning in accordance with practices then prevailing. It was noted that such symptoms occurred more commonly in tea grown at the lower elevations. A comprehensive study was designed by the Plant Physiologist to assess the influence of various types of pruning on recovery at different elevations. The paucity of root carbohydrate reserves at the lower elevations was determined to be the cause of these distressing failures. This long term series of experiments, commenced in 1932, in addition to culminating in the recommendation of ' rim-lung ' pruning as a measure for enhancing recovery and of insuring against deaths and dieback, also furnished much valuable data on post-pruning growth. Two collateral developments from these early observations, were the amendment of cultural practices (*eg* resting, fertilizer applications) so as to offer the best chances for adequate post-pruning recovery, and the intensification of the studies on root reserves, their production and utilization in relation to pruning. The observed beneficial influence of ' lungs ' has also prompted lines of study to evaluate the diversity of functions that leaves are capable of performing — not only the production of carbohydrates but their possible role in the synthesis of other growth factors, both inhibitory and stimulatory in their effects on growth.

This leads us logically to a consideration of the probable functions of leaves. Leaves are the primary centres of many kinds of chemical processes. They are the organs, which by their capacity to receive, absorb and utilize sunlight, function as the sole mechanisms for the trapping of energy to drive the other processes within the plant. Their functions are therefore complex and as yet incompletely understood. The finer features of their chemistry are the province of the Biochemist. However, the sum total of their influence is the balance between products which are beneficial to growth, and those that are inimical. This balance is doubtless conditioned by yet other factors — light conditions, the age and maturity of the leaf *etc.* A complete resolution of all these circumstances, is needless to say, beyond the capacity of a small institution. Nevertheless, at least two practical problems pose themselves. Where does the balance lie for the normal (maintenance foliage) of a bush in plucking ? What are the relative roles of these chemical pathways in the leaves on a ' lung ' retained at pruning ? Are the benefits (or disadvantages under certain



Rested tea rows as experimental shelter belts at St Coombs



Physiological experiments with young tea plants growing in sand circumstances) of lungs, related to these conflicting processes occurring simultaneously ? It is self evident that leaves must be important sources of influences conducive to growth. It may seem disconcerting, but nevertheless fascinating to discover that they can also exert influences detrimental to growth. Three recent observations underline the need to keep the latter eventuality also in mind. If a ring of bark is removed from a leafy branch of tea, normal flushing at the top soon ceases. The barrier to downward transport of foliar products appears to have confined some inhibitor within the branch, causing a stoppage of growth. The same happens in a lung retained at pruning. Similarly, if only half a bush is pruned, the pruned half is considerably slowed down in its recovery and its subsequent cropping. The unpruned half meanwhile continues to grow and yield — at a level much in excess of what it might have been expected to do, had both halves been retained. The third observation relates to the effects of artificially reducing the lower (maintenance) foliage — by stripping off old leaves and small leafy twigs deep within the bush canopy. Drastic reductions of foliage result in only trivial depressions of yield. Now, several explanations are possible for the above three results. Not the least consistent and attractive of these is that leaves (perhaps the more mature ones particularly) exert substantial depressing effects on the growth of young flush shoots. Supporting evidence stems from observations that removal of certain mature leaves on individual freely-growing shoots causes increased extension of the tender regions of stems above them.

On the question of leaf function, a whole new problem surrounds the functions of the mother leaf in the development and early stages of growth of individual cuttings. If one is to rely on more than the green fingers of the nursery staff, it is clearly imperative that nursery practice be based on a logical understanding of the physiology of growth of the young plant. The role of the mother leaf in the processes that regulate callusing, rooting and shoot growth must be basic to such an understanding — for cuttings devoid of their leaf fail to strike. Further, the possession of more than one leaf does not appear necessary or increasingly beneficial.

It is unnecessary to labour the point that the development of the concept and techniques of vegetative propagation must rank second to none among the past achievements of the physiologists in its impact on the progress of the industry. Commencing with the pioneering work of Tubbs and Kehl, the popularization of clonal planting has dramatically changed the limits of potential productivity of tea. By this single development, cropping capacities of outstanding clonal tea have far surpassed those of the best seedling tea. How did this all begin ? Primarily, from the observation that a seedling field clearly consists of individual bushes varying vastly in appearance. Yield records of individual bushes convincingly demonstrated that variability in appearance was closely matched by variable performance. This not merely in respect of yield but also in regard to quality. A large proportion of the crop was contributed by a relatively small percentage of the population. Vegetative propagation is a means of multiplying a promising bush without any alteration of its genetic make-up ; that is, without the admixture of characters that is inherent in propagation by seed. Successful establishment of outstanding clonal lines thus reduced itself to evolving reliable means of selection, and successful methods of propagation. In the earliest years of the development of this subject, both requirements were placed on a sound footing — achievements which called for much fundamental statistical and physiological investigation. The outstanding success of this line of work stands as tribute to the pioneers within and outside the Institute, who by their labours helped to transform the near failures of the early days into the striking successes that are so commonplace today.

Outstanding potentials of new clones for growth and yield introduces the need for a re-examination of standard cultural operations. It is to be expected that such special populations may deserve and require special types of treatment and will pose special problems. Clones demonstrably differ in their capacity to withstand drought and other adverse climatic factors, their growth forms and their reactions to cultural practices like pruning. The importance of recognizing any fundamental physiological differences that can account for these differences is twofold. Firstly, such findings will greatly simplify the problem of tailoring field operations to suit the requirements of specific clonal progency being cultivated. Secondly, such keys to future performance will reduce the burden of establishment of clonal lines. The selection, propagation and comprehensive testing of a clone is at present inherently time consuming. If it becomes possible to use some measurable criterion in a potential mother bush or young nursery population, as a reliable index of future performance, the whole process can be shortened. Presently, we possess information on the long term performance of several of the more popular clones. The search for measurable characteristics which can be associated with performance could therefore be profitably pursued. Such attempts were made by Visser but these failed to yield conclusive pointers. The use of such characteristics as ' pubescence ' and ' phloem index ' as indicators of quality in North India and the evolution of the ' Chloroform test ' for testing fermentation capacity are such attempts at correlations for quality. The search for similar parameters for cropping potential by the application of growth analysis techniques, to young nursery plants of clones of known performance is being actively pursued.

In the activities of a research scientist in an agricultural research organization, the emphasis must necessarily lie in studies directly relevant to crop management. In order to obviate the development of an entirely empirical approach to agricultural practice, however, most institutions are sufficiently broad based in their organization to include the more basic approaches to their investigations. It is also in recognition of the difficulties of drawing a firm line between the so-called fundamental and applied forms of research that such disciplines as Biochemistry and Physiology are represented in the Tea Research Institute of Ceylon, established " for the purpose of research into and investigation of all problems and matters relating to tea ". A firm foundation of basic knowledge is a vital tool in the hands of a researcher working on his particular problems, however practical they are. Most of his activities are often necessarily of a type designed primarily to *test* — for instance, one fertilizer treatment against another, one type of cultural practice against another, one agricultural chemical against another or one manufacturing procedure against others. At one stage or another he faces the need to understand the primary effects of his operations or innovations. For this may easily indicate to him either more effective or more economical methods for reaching his goals. In answering the questions of *why* ? and *how* ? he must turn to the types of studies designed rather to *learn* than to *test*. The practical services to the industry will probably flow most directly from testing studies but much time, effort and money could often be saved by the application of fundamental knowledge relevant to each particular problem. The importance of the collateral and mutually assisted development of these two aspects of research activity is widely recognized as the way to the optimal utilization of the effort and finances expended in the acquisition of materials and trained men for research. It is comforting to see that the Tea Research Institute of Ceylon has, and continues to build its efforts on a firm foundation of basic knowledge. This has paid rich dividends and will continue to do so as long as this happy balance is maintained in its endeavours. The industry demands and deserves the best. The trained scientific worker while constantly mindful of his obligation to furnish the industry with findings of practical importance, must be tolerated if he occasionally seeks the exhilaration of scientific discovery. This is not only of benefit to himself but also to the industry he serves. It is the good fortune of the Physiologists that their studies often take them to those areas in which such possibilities abound. There lies their own fulfilment and their best use to the tea industry.

Well-tended VP tea in up-country Ceylon

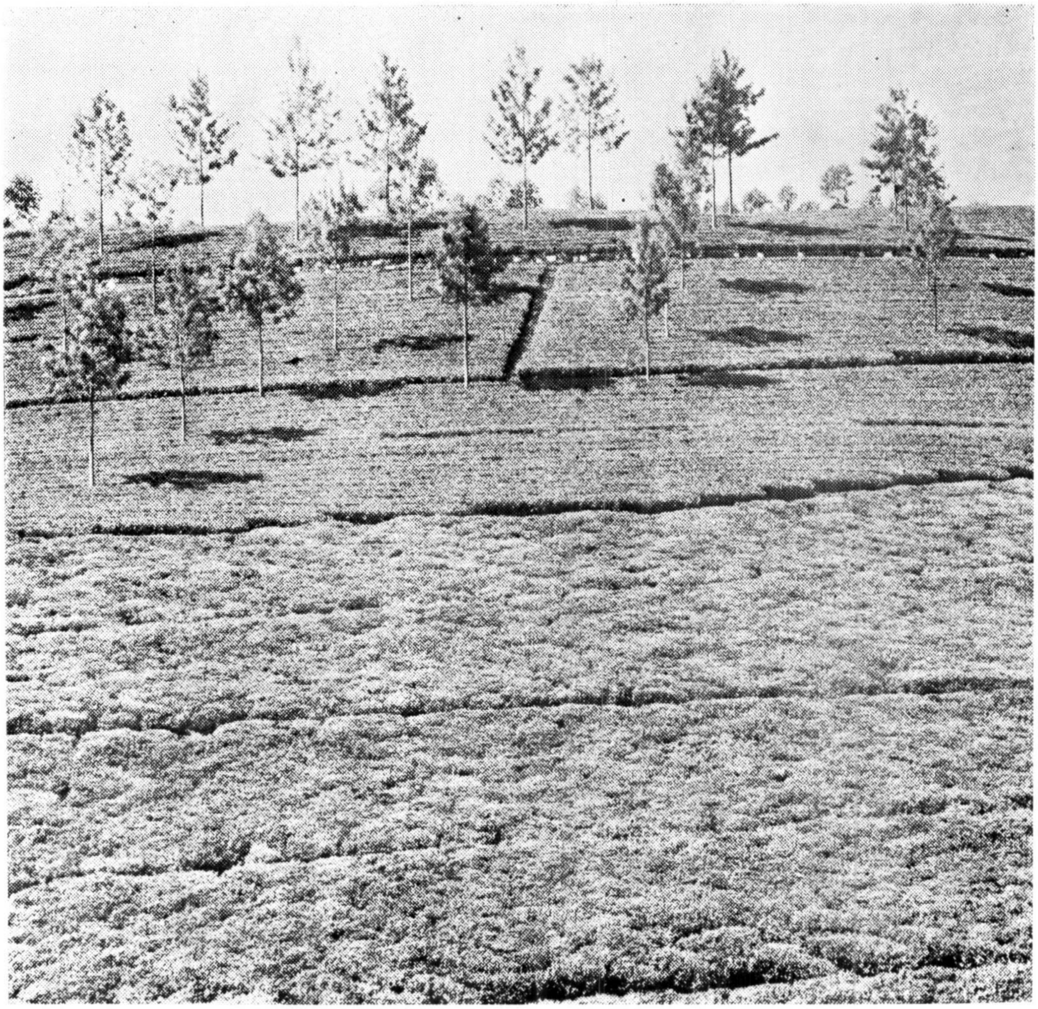


FIGURE 1 — *Above* — Contour planted clonal tea
Below — Row planted seedling tea