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THE STORY OF TWO DECADES OF CHEMICAL RESEARCH ON PADDY AND PADDY SOILS IN THE MADRAS PRESIDENCY

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Paddy or Rice (*Oryza Sativa*) being one of the principal food crops of Southern India occupying the largest portion of the cultivated area, was the first to receive the attention of the Department of Agriculture since the commencement of Agricultural Research in this Presidency.

This article deals in popular language, with the investigations bearing on the study of the soil, the crop, the interrelations that exist between soil conditions and crop growth, the mode of action of manures and the influence of manuring on the crop.

The practice of Agriculture in its early days was based almost entirely on the results of accumulated experience. The cultivator had but little idea of the changes taking place in the soil or of the processes controlling the fertility of the land. In consequence, he was often unable to circumvent adverse influences. In course of time, however, it was recognized that the factors involved in crop production were many and varied and the aid of science was invoked with the result that modern agriculture is a fabric built on a scientific foundation based on the labours of an army of investigators in a number of sciences all working in close collaboration with the practical farmer.

It is obvious that plants require food material for their growth and that as they thrive only in the soil, the food must come mainly from that source. The most important of these food constituents, from the point of their absorption by the plant in large quantities, are Nitrogen, Phosphoric acid and Potash. Investigation has shown that all the plant food present in the soil is not in a form capable of being utilized by the growing crop. Plants can take in their food only when it is dissolved in water, and that portion of the plant food in the soil which is not soluble in water, is of little *immediate* benefit to the crop. It is therefore, customary to speak of the '*total*' and '*available*' plant food in the soil, the latter being that portion which is soluble in soil water and which can be at once taken up by the crop. It is thus clear that the '*available*'

plant food in a soil is the factor of chief interest to the cultivator as, other conditions being satisfactory, its amount will within certain limits determine the yield of crops. The *total* plant food is not without interest to the ryot. It is in fact an item of reserve deposit from which small quantities are drawn from time to time. There is, in other words, a slow conversion of insoluble material into soluble plant food for the gradual use of the crop and it is this change which enables soils to go on producing crops for very long periods even though no plant food is added in the form of manure. But if land is continually cropped, there must be a constant drain on the food supply present in the soil, till it reaches a stage of minimum availability.

The yield from an acre of normal paddy crop (3000 lbs. grain and 3000 lbs. of straw) has been found to contain 48 lbs. of nitrogen, 23 lbs. of phosphoric acid and 41 lbs. of potash and these constituents must have come from the soil. If we visualise the soil as a bank, it is obvious that, unless what is withdrawn is returned, the account will soon be overdrawn. But wise Nature has foreseen man's greed and in her infinite wisdom has provided against his sins of commission and omission by setting up in the soil a mechanism for the indefinite supply of the bare minimum requirements, for what is ordinarily termed *the minimum crop production*. So that, if the few pounds of the manurial constituents taken off from the soil are not returned, there will not be a complete cessation of crop growth but there will result crops poor in quality and quantity which means an inferior and insufficient food which in consequence produces a devitalised population falling an easy prey to all sorts of diseases.

It is a matter of great practical importance to ascertain to what extent the loss of plant food has proceeded, what reserves are available, and whether the soil is producing the maximum crop which it is capable of producing under proper management. To this end soil surveys of the more important paddy tracts throughout the Presidency were carried out. Many hundreds of samples, typical of the soils of each tract have been collected and analysed. These surveys have yielded very striking results and show in a very marked manner how very deficient our soils are in certain ways and the large areas which demand immediate manurial treatment. The following tabular statement explains the nature and extent of the deficiency.

No.	Name of tract	Percentage of the soils deficient in	
		Nitrogen	Phosphate
1	Godavari	40	23
2	Kistna	33	55
3	Guntur	80	33
4	Tanjore	87	80
5	Periyar	0	90
6	Malabar	0	90

The surveys have therefore indicated in a very definite manner, the enormous loss in crop production which is taking place throughout the Presidency, owing to the exhausted condition into which the soils have been allowed to fall, either through the ryot failing to appreciate the importance of manures or more usually through his inability to afford the cost of manures. Loss in yield, however, is not the only injury which results from the wide-spread deficiency of phosphoric acid. The results of experiments at Coimbatore have shown very clearly that in cases where phosphoric acid was deficient, not only was the yield reduced, but the composition of the crop was affected. Both grain and straw contained much less phosphoric acid than the crop from properly manured plots and hence the food value of the crop was much diminished.

The practical utility of the investigations mentioned above is obvious. With the aid of these soil analyses it has been found possible to ascertain the manurial needs of the areas and that of the paddy crop with the result that the nature of action of manures began to be investigated. The results of a large number of experiments in the field and in the pot-culture house spread over a number of years have shown that all the natural and artificial nitrogenous manures are more or less beneficial to paddy but that they are more economical when applied in conjunction with bulky organic manures. Of the latter class of manures, green manures are preeminently suited to paddy crop. The results of the manurial experiments may be briefly described in numerical values comparing the relative merits of the different systems of manuring with that of green manure, taking the value of green manure as the unit of standard.

No.	Manure applied	Relative efficiency
1	No manure	0·33
2	Phosphate alone	0·50
3	Nitrogen alone	0·70
4	Nitrogen + phosphate	0·90
5	*Green Manure*	1·00
6	Green manure + Phosphate	1·20
7	Green manure + Nitrogen	1·33
8	Green manure + phosphate + Nitrogen	1·60

Potash is not included in the investigations as our soils are generally well supplied with this constituent.

The numerical values mentioned above refer to the results of pot cultures. The results of field trials are of a similar order.

These experiments show that of the three most important manurial constituents, namely, nitrogen, phosphoric acid and potash, the last named does not appear to be necessary except perhaps in rare cases or where it is indicated to counteract disease. Nitrogenous and phosphatic manures are in general need and are responded to by the crop when applied singly or together, but their effect when combined is better. Phosphatic manures have been found to stimulate the assimilation of nitrogen which would otherwise not be utilized and also to enrich the composition of the crop in this constituent thus enhancing the *nutritive* and *seed* value of the grain.

It is seen that artificial manures are not as efficient as green manure for paddy and that the efficiency of either class of manure can be considerably improved by combining them. This raises the question as to the proportion in which artificials and green manures should be used. In so far as the Coimbatore soils are concerned, it would appear that a mixture of two-fifths of artificial nitrogen and three-fifths of organic nitrogen make a suitable combination for paddy. Larger dressings of green manure appear to render supplements of artificial nitrogen like sulphate of ammonia ineffective.

The study of the soil conditions and the nutrition of the paddy plant with special reference to the practice of green manuring marks a distinct advance in our knowledge of the nature of action of green manure under puddled and swampy conditions.

Paddy in this Presidency is generally grown under swampy conditions and in a puddled soil throughout the growing season, and yet no general system of cultivation holds good for all tracts, so that it cannot be said that the system adopted in one locality holds good in another. In South Malabar, the general practice is to plough the lands in the dry season with excellent results, but this practice introduced into the deltaic tracts resulted in failure. Green manuring is found beneficial in one area, but when tried in another the crop fails. In some places water may be run on to fields and puddling and manuring done weeks before the crop is planted, but in other districts the custom is to put in the green manure just before transplanting. These and other mutually opposed facts make it essential that the conditions governing the growth of paddy should be closely studied in order to obtain, if possible, some common basis capable of explaining them before any improvements in paddy cultivation can be considered.

Since green manure undergoes putrefactive fermentation when buried under water, it was considered that an examination of the soil gases would make an opening to the problem. The first investigation showed that the normal fermentation of green manure in swamp paddy soils leads to the production of different gases and that the introduction of a crop into the field modifies the proportion in which some of the gases are produced and inhibits the production of others. The soil conditions are found to be anaerobic in character and therefore, nitrification is impossible and the nitrates produced during the period when the soil was dry are quickly denitrified. Under these conditions, therefore, the nitrogen required by the crop is obtained in the form of ammonia and probably form other nitrogenous organic compounds produced by the anaerobic decomposition of the proteins in the green manure.

Certain substances formed as a result of this decomposition are toxic to the crop and should be removed in the drainage water or should be destroyed by prolonged decomposition before seedlings are transplanted.

A more detailed study of the soil gases has revealed the fact that the gases escaping through and at the surface of the water in the paddy fields, are different from those that are present in the

soils themselves and consist mostly of oxygen and nitrogen as against marsh gas, hydrogen, and carbon dioxide that are formed *in* the soil. A certain relationship was also noticed between the evolution of oxygen and the presence or absence of crop, and pot experiments have clearly shown that the effect of the crop is to diminish the evolution of oxygen. This means that the evolved oxygen is absorbed by the crop for its growth. A careful examination of paddy roots of different types has shown that the roots of paddy do not resemble those of typical aquatic plants, but are similar to those of ordinary dry-land crops and as such require oxygen to be healthy and strong. The supposition is, therefore, correct that the oxygen is used up by the crop for aerating its roots.

The evolution of oxygen has been traced to a film of algae commonly seen on the surface of paddy fields and this film is found to contain bacteria which oxidise hydrogen and marsh gas with production of carbon-dioxide. The carbon of this gas is utilized by the algae for their food liberating oxygen which dissolves in the soil water and aerates the roots.

If the oxygen dissolved in the surface water is to aerate the roots, the water charged with oxygen should be capable of reaching the root zone, and this is possible only if there is drainage; so that drainage is an important factor. If the soil is badly drained, the oxygenated water cannot enter the soil and consequently aeration would be restricted to the surface layers.

On the other hand, in well drained soils, the aerated water would penetrate deeper into the soil. Consequently it appears reasonable to presume that the better the drainage, the deeper would be the aeration and therefore a proportionately increased cropping. If this is the case aeration can be promoted by a thorough periodical draining of the soil.

Actual experiments have shown that this is not the case. The mere draining of the soil is inadequate for the purpose. The simple system of slow movement of water through the soil and therefore, through the root range has been found to be most beneficial for the crop. The reason for this has been found to be that the water percolating through the soil is strongly charged with oxygen and therefore supplies plenty of it to the roots; whereas, the simple admission of air into the soil by thorough draining would yield only a weak solution of oxygen.

The best results are obtained with a moderate amount of drainage and too slow or too rapid drainage would result in decreased cropping. The reason for this has been traced to the fact that the development of the film which is responsible for the supply of oxygen occurs best under moderate drainage conditions. Thus the most efficient drainage in paddy soils is not the quickest but one that permits the surface film to maintain its full activity.

The practical aspect of these investigations from the point of view of the South Indian ryot is that the relationship of green manure to the aeration of roots is of the greatest importance and that, apart from all other considerations of manurial value or its influence on the texture of the soil, one of the most important functions of green manuring with reference to paddy soils lies in promoting the activity of the surface film which is responsible for the proper aeration of the roots. We have also learnt that green manuring does not always give good results on all soils and that when drainage is deficient the toxins produced during the decomposition of the green manure affect the growth of the crop adversely and that, therefore, green manuring should not be adopted as a universal practice but should be undertaken after careful consideration. The universal practice of puddling paddy soils has been understood and this knowledge has led to the conclusion that drainage can be controlled by means of puddling and that this is easily at the command of the ryot.

Another very important practical indication of these investigations is that growing a green manure crop in a field to which it has to be subsequently applied as green manure, is not advantageous as the nitrogen is largely dissipated as gas and as the crop had taken its nitrogen originally from the soil, it involves a distinct loss of nitrogen.

The work on paddy soils and the nutrition of the paddy plant has so far been considered. The work on the dietetic value of rice which forms the main food of a large section of the people of South India will now be considered. This investigation had its origin in a collaborative work of the Chemical section with the Deficiency Diseases Inquiry into the relationship existing between rice and *Beri-beri* in India.

The problem of the relationship of rice to *Beri-beri* will not be specifically discussed here but certain aspects of the defects of polished white rice will be briefly considered.

Fashion is so contageous that even the poorest man is anxious to use highly polished spotless white rice if he could only secure it. It is no exaggeration to state that the opulence and the extent of refinement of a man is partly measured by the quality of the rice he uses. Little do we know what valuable nutrient materials are lost in the polishing. The greater the polish, the greater is the loss. The fats, proteins, mineral salts and vitamins are stored in the outer, dirty brown or red coating of the rice grain, and during the process of polishing these nutritive constituents are lost and all that remains is mostly starch.

Analyses in the laboratory and feeding trials with pigeons have shown that raw, milled, unpolished rice is the most nutritious while raw, milled, highly polished rice is the least nutritious. Parboiled rice comes midway between these two extremes. Parboiled and milled rice, in the unpolished stage is not so nutritious as raw, milled and unpolished rice; but even when it is polished, boiled rice possesses a higher nutritive value than the corresponding raw polished rice.

Washing of rice just before cooking has also been found to deprive rice of a good deal of its most nutritious ingredients. The effect of draining rice after cooking should also be similar.
