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Particulars.	Units of labour.	Rate. Rs. a. p.	Total expenditure. Rs. a.	Yield in lbs.	Value Rs.
Supervision charges for 7 years.					
1 Manager on Rs. 50 p. m.	...	50 0 0			
2 Fieldmen on Rs. 25 ,,	...	50 0 0			
4 Maistries on Rs. 15 ,,	...	60 0 0			
Total per month Rs. 160					
For 7 years 160 × 84	...		13440 0		
Tools and sundries	...		1000 0		
Land tax @ Rs. 5 per acre per year			1750 0		
			23519 6 or		
			23600 0		
Interest on capital at 6%	...		1516 0		
			25116 0 or		41875
			500 0 per acre.		837
Net profit for 7 years for 50 acres. (Rs. 41875 less 25116)					16759 or 337 per acre.

Note. The cost of building quarters for the Manager, and his assistants and the erection of cooly lines have not been included.

SELECTED ARTICLE

Roots

By H. C. Sampson, C. I. E.

The study of the root systems of crops grown in the tropics and sup-tropics is a branch of agricultural research which has not received the attention which it deserves, in fact, so little information has been published on the subject that one is forced to fall back on inferences rather than to depend on concrete knowledge. This study is more important in the tropics than in temperate regions, because the range of environment is so much greater, and there is no doubt that environment has a considerable influence on the root development and root system of any particular species, or of any cultivated race of a species. For example, the work which has been done at East Malling in examining the root systems of different races of fruit stocks has shown clearly that these vary both with the stock and with the type of soil on which they are grown.

A striking example of the influence of environment on the root system of a species is the case of the Neem tree *(Azadirachta indica)*, which has been introduced into the Gold Coast within the last twenty years. Its native habitat is in India, where it is generally found growing in open country in the drier parts of the country. It is not exacting in the type of soil on which it grows except that it is not seen on deep black cotton soils. Under Indian conditions the tree makes a strong tap root which penetrates vertically into the ground for a considerable depth, and it shows little tendency to form strong branch roots near the surface. In the Gold Coast the tree is now a common feature in roadside, town and village planting, and it is not unusual to see trees where the root system has been exposed by erosion. The most striking feature shown is the tangled mass of stick surface branch roots extending laterally quite close to what must have at one time been the surface of the ground. In fact, one may say that all the common exotic species of trees which are grown in West Africa develop under that environment a shallow root system. This adaptation of the root system to suit a particular environment may explain why it is that trees found useful in

one country as shade for a particular plantation crop may prove quite unsuitable or even harmful in another environment. In some of the West Indian Islands one cannot help admiring the magnificent specimens of rain tree (*Pithecolobium Saman*) which are seen as avenue and savannah trees. In popular accounts of this tree one reads how it closes its leaves when it rains and thus allows the rain to fall on the ground beneath its shade. Certainly in this environment it does not seem to do harm to surrounding vegetation. The same species grown in the drier parts of Peninsular India is, however, a menace to arable agriculture, as there it develops a wide-spreading surface root system which robs the soil of moisture sometimes for a distance of sixty to seventy yards. This makes it impossible to grow rain-fed crops on the area of its root spread, and it is a common complaint of villagers that the tree when planted as a road avenue renders the adjacent land useless for agriculture.

Apparently little has been done to study the root systems of plantation crops in the tropics. If it has, very little literature is available on the subject, and such information as exists deals only with particular environments. The matter is of great importance, especially in the case of plantation crops which are interplanted with shade trees and cover crops; for it seems essential to appreciate what amount of root competition exists between the shade tree and the crop. Of course in some soils this is more important than in others. In heavy soils retentive of moisture and where the rainfall is heavy, such competition may be of actual value, because the roots of the shade tree may assist in draining the soil, thus providing a suitable environment for the roots of the crop. This may explain why it is that shade trees in cacao are advocated in Trinidad whereas in the nearby island of Grenada it is grown without shade.

Information regarding the root systems of plantation crops is often required when laying out experimental plots. A knowledge of the root-spread of individual trees, for example, is essential when laying manurial experiments, in order to decide how many guard rows are necessary between plots. It was a matter of surprise to be told the other day that when the root system of a mature oil palm was exposed, several of the roots extended over 100 feet, while the longest measured 127 feet. This was in a sandy soil with a fairly high water-table, and of course may not represent the root spread of a palm grown on a heavier, deeper and more fertile soil.

Various theories have been expressed on the action of the bush fallow, which is common throughout tropical Africa, where shifting cultivation is the rule, in restoring fertility to the land. The one which seems most important is the deeper root system of the natural tree vegetation which brings up from deeper levels to the surface soil additional amounts of plant food. A striking example of an artificial bush fallow is found in the densely populated region of the Eastern Province of Nigeria. Among the Ibo people, who inhabit the deep sandy soil country of the palm belt, each household has its compound land, but there is also an expanse of communal land. Among many of the clans, however, it is the custom that if one of its members plants up a portion of the common land with a small rosaceous tree called *Acioa Barteri*, he is allowed to crop that area for his own use. An opportunity was given to see the root system of this tree in an area where gully erosion was severe. The gully had been checked by a planted patch of this tree, and the roots of one or two were exposed at the edge of the gully. The tap root went vertically down for a great distance, and there is little doubt it is this deep root system that has established the reputation of this tree for restoring fertility to the surface soil.

In the case of arable tropical and sub-tropical crops little information is available. Weaver has described the root systems of several sub-tropical crops

which are grown in the United States, but it is felt that much more local research is necessary to gain knowledge regarding particular environments and particular races of cultivated crops.

The monocotyledons include all the cereal crops as well as such crops as onions, ginger, etc. The peculiarity of all such crops is that they do not form a tap root. Their roots are more or less ephemeral and if damaged they die, but can be rapidly replaced by freshly formed roots. All cereal crops are for this reason capable of being transplanted, and in some cases this is the normal agricultural practice, the seedlings being raised in a seed-bed and subsequently pulled out and transplanted. Swamp rice is generally grown in this way, at any rate in the more developed rice-growing areas. The seedlings are pulled out when they have reached a certain age and most of the roots formed in the seed-bed are broken. They are further damaged by beating the butts of the bundles of seedlings against a stake stuck in the ground. In some places the seedlings which are tied in bundles, are stacked in small heaps in the field with all the roots facing outwards, and they are left in this way for two or three days for the roots to wither. Thus the transplanted crop has to start and make an entirely new root system.

The sorghum crop in India is considered to be the most drought-resistant of all cereals, and one presumes therefore that it has a deeper root system than other grain crops. There is however, a considerable difference in this repect between varieties. One variety known to the writer, it is claimed, can mature its crop provided there is sufficient moisture in the ground for the crop to germinate and form a *braird*. For the rest of its moisture requirements it is dependent on dew and on moisture in the deeper soil. The question of drought resistance in West Africa is not so clear, because, though there are numerous varieties they all appear to be long duration ones occupying the ground for six to seven months, while in India the time of maturity is considerably less than this, and there are also short duration varieties to suit districts having a short rainy season. The root systems, however, of the Indian and the West African varieties appear to be different, though this may be due to environment, since the rains are generally heavier in West Africa and the soils as a rule have a lower pH value. Local agricultural practice in the black cotton soils of India spaces the plants about 6 inches apart in rows about 14 inches apart. In West Africa the crop is grown on ridges 3 to 3½ feet wide, and the plants are spaced about 1½ feet apart in the row. Thus in West Africa each plant has nearly ten times the surface area that the plants have in India. This certainly seems to point to a difference in the root systems of the cultivated races of sorghums in these two regions.

In the drier parts of West Africa, where the rainfall is less and the rainy season shorter, the grain Pennisetums form the most important cereal crop whereas in India these are not considered to be as drought-resistant as sorghum. This again may point to a difference in the root system, though it must be remembered that many of the early sown West African Pennisetums are comparatively short-duration crops.

In the case of sugarcane, both Venkataraman and the workers at the East Indian Sugar-cane Station at Barbados have shown that there exist marked differences in the root system of different seedling varieties of sugar-cane, and it is on such differences that new varieties are selected for trials in other environments. These differences in seedling cane varieties are, however, on rather a different footing from races of cereals owing to the complex hybrid origin of the present-day seedling canes.

Apart from cultivated grass crops, recent work in Uganda has shown the value of a grass fallow where elephant grass (*Pennisetum purpureum*) is deliberately planted prior to allowing the land to go out of cultivation. It is claimed that this not only restores the texture of the soil but also its fertility, and one wonders how deep the roots of this grass penetrate to bring up from below fresh supplies of plant food. In Northern Nigeria experiments of a similar nature are being made with *Andropogon gayanus*, which judging by the way the grass can remain green in the dry season, has, one suspects, a deep root system, thus enabling it to restore fertility to the surface soil.

The principal dicotyledonous crops of the tropics belong to the family of the Leguminosae. The value of such crops in mixed croping and in rotations has often been stressed on account of their being able to fix atmospheric nitrogen with the aid of symbiotic bacteria living in their roots. With few exceptions tropical pulse crops are grown as mixed crops. Recent work in this country has shown, in the case of pastures, that the grasses among which legumes are grown can make use of the nitrogen from the roots of the legumes, and it is probable that tropical cereals, among which pulses are grown can do likewise. It is not clear whether, in the tropics, the nitrogen fixed by a leguminous crop in one season will remain available in the soil for the benefit of cereal and other crops of the next season. Experiments conducted by the Nigerian Department of Agriculture where *Mucuna aterrima* has been grown as a green manure show that there is no appreciable difference in the yield of the succeeding maize crop on plots where Mucuna crop has been ploughed in and on plots where this has been burnt on the ground. One imagines therefore, that value of the green manure crop largely lies in the fact that it has brought up from below supplies of mineral plant food, which are thus available for the succeeding crop. This is partly borne out by the fact that the pH of the plots where the Mucuna was burnt is higher than that of the plots where it was turned in. The fact that Mucuna has been most successful in areas where the lateritic subsoil is fairly near the surface suggests that its root system is comparatively shallow. In Northern Nigeria experiments are being carried out in restoring fertility with pigeon pea (*Cajanus cajan*) grown as a biennial. The fact that the plant can survive through the intensely dry season suggests that it has a deep root system. Ducker, in Nyasaland, states that the roots of the pigeon pea will penetrate a lateritic pan. In the Sudan several leguminous crops have been tried as rotation crops for cotton, and *Dolichos lablab*, agriculturally has been found to be most suitable, though, owing to its harbouring pests which damage cotton, its use has had to be restricted. This suggests that its roots can tolerate, even if they cannot penetrate, the alkaline subsoil. Another leguminous plant whose roots can penetrate an alkaline pan is *Sesbania aculeata*, and possibly other species of Sesbania may behave in the same way.

The groundnut is a legume which is generally grown as a pure crop, though sometimes it is interplanted among cereals. It is extremely drought-resistant, remaining green and fresh till it commences to ripen its pods. It is a crop suited to lighter classes of land, and its drought resistant qualities have made it a valuable asset to the light red soil districts of tropical India. On such soils it is generally considered an exhaustive crop, and yields decrease rapidly after three or four years' cropping unless the land is manured. In West Africa the crop has been extensively grown for many years and recently it has been reported that the older groundnut areas are not giving the yields that they formerly did. Considering that manuring is hardly known in West Africa, it is rather surprising that the land has not shown signs of exhaustion before this, and one can only suggest that this is due to the type of subsoil commonly found and the depth to which the roots penetrate. The red soils of India generally lie

directly on the parent rock and thus have no reserves on which to draw, while in West Africa a lateritic subsoil usually occurs.

The root system of Asiatic cottons is quite different from that of the upland cotton of the New World. The former are much more slender and penetrate much more deeply into the soil, and the tap roots of seedlings which have made only one leaf have been traced to a depth of 18 inches in black cotton soils. It is possibly because of this deeper and therefore more drought resistant root system that in French West Africa Indian cottons have been introduced into the dry north as a rain-fed crop. The variety is known as Budi and is stated to be a cross between two Indian cottons—Karunganni of the Tinnevelly district and the Garo Hills cotton. But even the Upland cotton has a much deeper root system than some other crops, and in Nyasaland it is generally stated that tobacco always does well after a cotton crop, presumably because the latter has replenished the supplies of mineral plant food near the surface.

It is unfortunate that there have been several years of low prices for tropical primary products; for at such times agricultural departments are expected to produce quick results, and no one can say that the study of root systems is not a tedious and often an expensive business. It is hoped, therefore, that when and if the prices of primary products improve more attention may be given to the study of the root systems of crops in the colonies. *The Empire Cotton Growing Review*, 16: (1939) 165—170).

ABSTRACTS

Value of Refined Coconut Oil and Butter Fat. R. S. Harris and L. M. Mosher *Food Research* 5: 183.

Experimental rats were maintained on a diet consisting of extracted skimmilk powder (72 percent), extracted brewer's yeast (three percent) supplemented with vitamin A, vitamin D, and iron. These diets were abnormal in only one respect, that is, they contained an abnormally large proportion of fat. The animals were observed as to the effects of these two diets on weight increase and food consumption. Groups were guillotined after 15, 30, 60 and 90 days on the diets, and body tissues were studied histologically. Results were compared with those on rats maintained on a standard stock ration which served as control. Animals on the butter fat diet consumed a slightly larger but possibly insignificant, amount of diet but increased in weight much less rapidly than the animals on the coconut oil diet. The superior weight increase of the rats on the coconut oil diet was not adipose tissue, for the body and liver tissues of the groups contained essentially the same amount of fat (alcohol–ether extract) and true lipid (petroleum ether extract of the alcohol—ether extract). The investigation is being extended to determine whether the weight increase was due to increase in muscle tissue. The animals on both the butter fat and the coconut oil diets developed a slight fatty infiltration of the body and liver cytoplasm. This was shown by the increased amounts of fat and of true lipids and by histological examination. This fatty infiltration was equally intense in the coconut oil and butter fat groups. There was no evidence of pathological tissue changes in any animal in any group. These results indicate that butter fat and coconut oil even when fed at rather high levels in a complete diet, are equally harmless to rats and presumably to man. (Author's abstract).

Rice and Beri-Beri. It is over twenty-five years since Eijkman and his coworkers clearly demonstrated the connection between the consumption of highly milled rice and beri-beri, but, according to statistics collected by the League of Nations, the habit of using highly milled rice is increasing, and in 1937 the intergovernmental committee pointed out that the economic and other factors