Favism is a disease characterized by haemolytic anaemia that affects certain individuals following the ingestion of the broad or field bean, *Vicia faba*. In spite of rather extensive studies that have been made regarding the clinical and biochemical manifestations of favism, the causative principle of favism has not been identified with any degree of certainty. Recent evidence would suggest, however, that perhaps vicine, a nucleoside composed of glucose and 2,5-diamino-4,5-diketopyrimidine, may be responsible for favism, at least in persons genetically susceptible to this disease.

There exists a fairly large category of natural substances that interfere with the utilization of certain minerals and vitamins. As examples, isolated soya-bean protein has been shown to interfere with the availability of such minerals as zinc, manganese, copper and iron as well as vitamin D; raw kidney beans contain a factor that increases the vitamin E requirements of the chick; and linseed meal contains an antagonist of pyridoxine. Only the latter has been identified and has been shown to be 1-amino-D-proline.

The significance of naturally-occurring toxicants in human nutrition is still largely unknown, and they may not in fact pose much of a problem as long as man is able to select a varied diet. But there is the possibility that the prolonged consumption of any one foodstuff may bring to the surface toxic effects that have not heretofore been apparent. It is this sort of occurrence that may be expected to become more commonplace as the shortage of protein becomes more acute, and certain segments of the population are forced to become less discriminating in their choice of life-sustaining foods. By selecting those strains and varieties of plants that are genetically deficient in components of possible toxicity to man, the co-operative efforts of the nutritionist and plant breeder can do much to forestall this problem.

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Factors affecting the limitation of the cultivation of grain legumes in tropical territories

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The apparently simple question 'Why is a crop not grown in an agricultural situation which appears to be ecologically suitable?' is one of those on many tropical food crops that still require an answer. The problem is quite distinct from that with cash crops in that, for the latter, questions of world trade, monetary economics, scale of operation and transport also arise.

For the food crops the search for an answer taxes the skill of the agronomist to the full; here I use the term 'agronomist' in its broadest sense, meaning a student of agricultural science, rather than in the more restricted sense in which it is normally employed in the United Kingdom, where the concept of agronomy relates strictly to field crop husbandry. Further, among the various groups of food crops, answers to questions relating to the grain legumes appear to be more elusive than those for staple food crops such as the cereals, roots and tubers.

The choice of grain legumes for food

Although it may be true that nowadays the provider of food for a household is not consciously influenced by nutritional considerations when choosing a diet, it is difficult to conceive that early Man did not learn nutritional good sense the hard way, on the basis of differential survival. Relics of this drive—perhaps misapplied and in a community or part of the world remote from that in which the original experience was learned—are to be found in the folk-lore associated with food selection and preparation, though they may be so overlaid with dogma and the rites transposed from other aspects of the activity of the community as to be scarcely recognizable for what they are. Nevertheless, we are still able to observe a variety of paired (e.g. Sirinit, Soliman, Van Loo & King, 1965) or triple-crop vegetarian food systems from the Old and New Worlds in which a cereal–legume balanced diet has been developed; and I suggest the hypothesis that these systems, at their zenith, showed a dietary balance which took into account the nutritional requirements of the group over the year, as well as the various other dictates of a part agricultural, part food-gathering system. That is, selection operating at the extended family level favoured nutritionally sound food practices.

In our search for an answer to the problem, I suggest that the starting point is the consideration of food-gathering systems in which animal protein was insufficient to maintain a population throughout the year, and in which the selection pressure (Darlington, 1969), exerted over perhaps thousands of years on a particular human community, was towards a greater dependence on vegetable foodstuffs (Yudkin, 1969) and thus to a recognition of the possible agricultural value of grain legumes (Brothwell, 1969).

Origin of tropical grain legumes as cultivated plants

Phylogenetically, legumes are regarded as having been derived from tropical tree species. Although tree species are used for food, the group with which the agronomist is most concerned for grain products is the tribe of herbaceous species, the *Phaseoleae*. Some of the most comprehensive work on tropical legumes has been that of the Australians (Henzell, 1967), the systematic starting date of their work being 1929 with the establishment of their Plant Introduction Section and the development of the work of the Queensland State Department of Primary Industries. It is to this pioneer work that we are indebted for much information on the ecological requirements of many groups of tropical legumes, and more recently, on their taxonomic association with species and strains of *Rhizobium* bacteria; however, much research has yet to be done.

In terms of the crop plants used at the present time, we have drifted—in agricultural evolution—into the second half of the twentieth century using crop species selected by neolithic ancestors, with very little attention being paid by research workers to the question: 'Why do we use the particular species that we do, rather than those of other genera or families?' Such philosophical questions are now being asked by Huxley and others about animal species in domestication (Jewell, 1969; Berry, 1969).

Amongst cultivated food plants the real search for novelty is only just beginning, an important step being the First International Conference on Plant Exploration and Introduction, organized in 1967 by FAO. With cereals the tendency of the research worker has been to concentrate on a handful of genera because of the success achieved by established plant breeders, rather than to search for genera with untapped genetic potential. Our classical cereals were selected because of their suitability to our primitive agricultural methods.

New plant selection should, I suggest, be approached in the awareness of the versatility of modern agronomy and its machines. Some novelty is seen in tuber crop research with the relatively recent series of expeditions to Latin America for potatoes, and the stimulus to collection of yams for non-food purposes. But the pioneer work has hardly started in the development of tropical legume species for the production of novel food crops. This lack of attention to anything but the orthodox tropical legumes is emphasized by Reem (1967), who states: 'Generally, however, the potential role of legumes in increasing food supplies in tropical areas either directly or indirectly has received little consideration'. The major emphasis for increasing food production has been on using greater amounts of fertilizers and supplying the nitrogen requirements from the fertilizer bag rather than through nitrogen fixation by legumes. Evidence is accumulating that a great potential exists for legumes in the tropics in helping materially in the solution of the world's food problems (Aykroyd & Doughty, 1964; Bailey, 1966; Stanton, Doughty, Orraca-Tetteh & Steele, 1966).

An example of the detailed ecological analysis which is possible, and of the need for the study of the various cultivated tropical legume genera, is our own work in Nigeria: systematic study of the indigenous cultivars led to radical changes in our thinking on the agronomy of these crops, and we hope this has wider applications for other areas of the world (Steele, 1964; Kortenhorst & Crowley, 1964).

Ecology of tropical legumes

The most important feature of the wild and semi-cultivated herbaceous species is that they are minor components of ecoseres occurring at the junction of two environments, preferring conditions where the ground has been disturbed by the activities of man or natural agencies. This is illustrated by Nigerian studies of the genus *Vigna*, the cowpea. The tree species of the tribes *Caesialpinoldeae* and *Mimosoidae*, on the other hand, tend to form large tracts often hundreds of miles in extent where they are the sole dominant species.

Practitioners of long-established agricultural systems, into which the cultivars

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related to the wild progenitors have been adopted, recognize this natural attribute of the herbaceous species. The legumes are planted as a very widely spaced inter-crop in the main cereal crop, usually well after the establishment of the cereal crop, and retain the wandering–climbing habit of the wild progenitors.

Introduction into cultivation

This habitat preference has meant that the potential gathered crop was never present in large natural fields, or tight swamp communities (as for the floating rices), as occurs with the cereals, but was disseminated along the interface of the main ecological zones of forest and savanna. This interface can in fact be traced in a broken line right through the Old World, south of the northern tropical desert belt from Senegal through to the Horn of Africa, and then through India and South Asia to the New World. Thus there can be little question of centres of origin. The legumes may be regarded as weeds of the roadsides of the great migratory cattle routes of the nomads by whom their dispersion was no doubt assisted. Botanists, to add to the complication of the location of sites of domestication, have cited as the type specimen of the cultivated form of *Vigna* a plant from Barbados, a locality in which it undoubtedly could not have arisen.

The close homology between the genetic characters of the genera *Phaseolus* and *Vigna* suggests that the former must have been brought into cultivation under conditions similar to those described above (Smartt, 1969).

Legumes diminish in significance in a traverse of the monsoonal forests towards the more regular humid conditions of the equator and, as pointed out by Masefield (1967), grain legumes in the equatorial regions seem to be eaten green, and the climbing forms are also more prevalent. He also notes that the Chinese farmers in Malaya commonly buy their bean and cowpea seed from China rather than save their own. It is certainly true that there is a very short and uncertain dry season on the west side of Malaya and this dwindles to practically nothing towards the southern states of the peninsula, but I suggest that the real reason for this importation is that the Chinese have attempted to bring their whole agricultural complex of intensive vegetable growing and fish farming to Malaya from Canton province of mainland China (Stanton, 1965). There is much less evidence of protein food cropping from the more indigenous Malay-based culture. This culture was essentially coastal and estuarine, and derived its protein from the sea or the river mouths; it was lacking in carbohydrates rather than proteins. Malay communities do not consume vegetables in the same quantity or diversity as the Chinese.

To summarize, it may be concluded that grain legume culture in the tropics is most strongly developed in well-established agricultural systems on the large land masses where there is a strong vegetarian bias in food habits.

Agro-technological and biological considerations

That there are real technical difficulties in the production of grain legumes on a large scale was dramatically emphasized by the ill-fated 'groundnut scheme'. The groundnut, *Arachis hypogaea*, is often classified in crop technology with the oilseeds, but it is an excellent example of the successful spread of a legume culture into areas from which it had previously been excluded only by geographical considerations. Having overcome the geographical barrier it found a natural niche in agricultural systems that were based on its predecessor, the bambarra groundnut, *Voandzeia subterranea*, and, because of its easier processing, its replacement of the earlier traditional crop throughout savanna Africa was dramatic.

Recently, with world supply meeting or exceeding the world demand for vegetable oilseeds, and with the continued shortage of vegetable protein, the rise in the extent and number of the pathological problems associated with the groundnut (e.g.: cercospora leaf spot, 'rosette' virus disease; see Gillier & Silvestre, 1969) and, finally, the hazard created by the occurrence of the mycotoxin aflatoxin on the crop, agronomists have begun a fresh look at Africa's traditional legume, the bambarra groundnut.

The groundnut has not benefitted the nutrition of the peoples of middle Africa to the extent that it might have done, because the great upsurge in its production was primarily to meet the demand for the crop for export.

Return for labour

At present, agronomists are questioning the apparently fundamental inverse relationships between the protein content of a food crop and its yield in dry matter per unit area as seed or tuber. If one considers the total protein in the green matter of the plant then the total protein account is better, and Masefield (1967) demonstrated that the protein yield from green pods of *Phaseolus vulgaris* harvested at 74 days was greater than that from the dry seeds harvested at 105 days. However, he was unable to demonstrate the same relationship for the cowpea. Against this must be set the fact that it is not possible to conserve the green pod, whereas the native farmer has developed methods for the conservation of legume seeds. The bambarra nut takes pride of place for conservability along with some of the more toxic legumes such as the sword bean, *Canavalia*. The labour of harvest of the bambarra nut is much greater and the energy return for energy expenditure is much smaller than for the cultivation of a crop of cassava, *Manihot utilissima* (Johnston, 1963).

During the actual growth of a crop such as the cowpea, there is a problem of protection against both mammalian and smaller predators (Appert, 1964). Depradation can reach high levels when the crop is grown at a high density (Ebong, 1968). This may be illustrated from the results of Booker (1966), who by protecting a crop of cowpeas against insects throughout its growing period obtained a fivefold increase in the crop and a much shorter harvesting period. Booker's experiments arose from observations of breeders who had found it essential to keep the legume culture collection free of pests by a systemic insecticide, as otherwise the pest levels mounted so much during the growing season that the majority of microplots failed to give any yield at all. The native cultivator would not, under these circumstances, be encouraged to grow more of a legume crop than the absolute minimum to balance his protein requirement and possibly to aid soil fertility, though the effect of legumes on fertility at very low planting densities is of doubtful significance.

The wild species of the grain legumes are characterized by having three seed-survival mechanisms, apart from their excellent spring-loaded dispersal mechanism. They are hard-seededness, delayed and staggered germination, and excellent natural camouflage of the seed coat. These characters have been eliminated in the cultivated forms. However, this selection has been at the cost of a sacrifice in agronomic efficiency which still presents problems to the plant breeder selecting for high yield.

Perhaps least obvious of the criteria for selection is the need for the retention of seed-coat colours and patterns in the cultivated and harvested crop. There is evidence to show that the phenolic, flavonoid and organic nitrogenous components that give rise to these coloured substances play important ecological roles in the crop, in addition to providing the basis for the seed-coat patterns. These roles include that of active control of the soil micro-flora and possibly fauna, and effects on the dormancy of the seed. These compounds also give rise to the flavour components and anti-digestive components of the beans when used as human food.

Sociological and technological factors limiting legume consumption

Most communities throughout the tropics recognize one or more of the following characteristics of grain legumes in the diet.

(a) They are difficult to digest and may give rise to stomach upsets or flatulence (Aykroyd & Doughty, 1964).

(b) These features can be overcome by boiling, long cooking, washing and removal of the seed coats (Muller, 1967; Zimmermann, Weissmann & Yannai, 1967).

(c) In spite of such processing a bean flavour, or bitterness, may remain in the foodstuff.

(d) Failure to prepare the beans properly for food may lead to serious disorders (Kakade & Evans, 1965; Kakade, Keahey, Whitehair & Evans, 1965; Hintz, Hogue & Krook, 1967).

From these basic observations have arisen a number of superstitions concerning supposed effects of the bean colour and of consumption according to time of year, and taboos to particular age groups or sex groups within the community. This mass of folk-lore has then been a barrier, by transfer of inhibitions, to the acceptance of any other legume crop similar to the land-race crop which produced the original beliefs and taboos.

Because of the geographical and tribal uniqueness of Nigeria, my colleagues and I were able to observe these phenomena operating in a diversity of situations. A full report on this work is in preparation, but a brief account of the cultural mosaic is given by Stanton (1962).

In concluding this note which has concentrated on Africa, the absence of the soya bean is noteworthy. The explanation for this absence is not only geographical, but also biological, sociological and technological. As has been stated elsewhere (Stanton *et al.* 1966), there is no good reason, on the basis of absence of cultural contact, why the soya bean should not have been accepted in Africa. However, there are good reasons arising from all the other factors mentioned.

If soya beans of the wrong eco-type are brought to a new territory, they will fail almost completely owing to the heavy pest and disease burden and the incorrect day-length response. They also require, as is well known, the appropriate strain of *Rhizobium* bacteria for nodulation. Even when these biological factors are overcome, the unusual colour of the bean, its hardness, the problems associated with cooking it and the taste left after all the usual culinary practices have been applied, militate against the crop being accepted. Only after extensive industrial processing and incorporation into the foodstuffs which are known and accepted by the local people can they be induced to eat it, and then only if the ultimate foodstuff incurs no extra financial burden on the consumer.

It must be recognized that the food technological processes by which soya beans are prepared in the Far East are—although operated on a village scale or even by the individual housewife—extremely sophisticated techniques, which have achieved a remarkable conversion of the original material into a highly palatable range of products by careful control of physical, chemical and fermentation conditions (Yokotsuka, 1960; Hesseltine, Smith, Bradle & Ko Swan Djien, 1963). Middle Africa is accepting new skills over the whole field of technology, and I see no fundamental reason why the various highly palatable products of soya-bean fermentation should not become part of the African diet as food technological education expands. Further, I consider that the acquisition of these food technologies might yet lead to the fermentation processes originally developed for oriental foods being tried on traditional African crops, so that Middle Africa will pass yet another milestone of technology in the advance of its own culture.

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The evaluation of the field bean (*Vicia Faba* L.) in animal nutrition

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The field bean (*Vicia Faba* L.) has been gaining increased popularity in Britain over the last few years. This year's crop of 400 000 acres, according to the estimate of the Ministry of Agriculture, Fisheries and Food (although it may only be 300 000 acres, based on the total sale of seed), exceeds the 240 000 acres of 1968 which itself was a far cry from the 67 000 acres of 1964. Its present popularity is mainly due to its value as a break crop, especially where cereal mono-culture is practised. With the present intensity in agricultural production it is unreasonable to think of a crop's economic value in terms of the increased return of the succeeding crops; rather, the bean should be grown as an economic crop in its own right.

The object of this paper is therefore threefold: firstly to examine the analytical composition of the field bean, secondly to assess its potential as a raw material ingredient in animal feeds, and lastly to bring into perspective its value in the feeds of various farm animals and to see if this sheds any light on the direction in which development ought to proceed. Two bean varieties only are considered, Minor's Tic and Throws M.S., representing spring and winter varieties respectively. These make up 70% to 75% of the total acreage of each of the seasonal varieties.

Composition

Consideration will first be given to those three factors which are required to be declared in animal feeds, namely the crude protein, crude fibre and crude oil. Eden (1968), following a survey of bean crops in 1966 and 1967 in Cambridgeshire and the Isle of Ely, found in the majority of the analytical determinations no difference in the composition of spring and winter beans except in respect of crude protein, crude fibre and hence in nitrogen-free extractives which are obtained by difference. Values obtained in our own laboratory in 1967 and 1968 corroborate Eden's findings: the results are shown in Table 1.