The development of field beans as a crop in Britain

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The plant Vicia Faba *in Britain*

Some of the reasons why the field bean has been cultivated in Britain for a long time may include the following:

(a) It is an erect legume, thus having the advantages of other legumes, such as ability to fix nitrogen and high protein content of grain and leaf, and also being capable of being harvested in a wet climate.

(b) Its pods do not shatter too easily and can be mechanically threshed.

(c) Some varieties have some degree of hardiness and early sowing can allow a complete leaf canopy before the longest days—an advantage for energy absorption. There is some degree of resistance or tolerance to most diseases, though this needs to be improved by breeding.

(d) It is mainly self-fertile and its natural breeding system makes it partly independent of insect pollinators which are not very reliable in Britain. The breeding system is one of 70% selfing and 30% crossing but with crossbreds tending to be more capable of selfing in the absence of insects and so providing a cushioning against seasons unfavourable to insect pollination.

Other legumes are more self-fertile, e.g., peas and some species of *Phaseolus*, but *Vicia* beans are stiffer-strawed than peas or vetches and no comparative trials have shown *Phaseolus* spp. capable of yields greater than that from *Vicia Faba*. Information is needed on such a comparison. Soya beans have produced in some seasons in Britain about the same yield of protein as that obtainable from *Vicia* beans, but in other seasons soya can be a complete failure. No interspecific crosses involving *Vicia Faba* have yet been made, except for some recent reports from the Soviet Union (Zhukova, 1968), so that material available to the breeder is limited to the species. There is, however, a considerable diversity within the species, some of which is already being exploited.

All botanical varieties can be grown in Britain but usually only large-seeded forms (*V. Faba major*) are used for human consumption and medium- and small-seeded forms (*V. Faba equina* and *minor*) for animal consumption. Some degree of hardiness is found in all three botanical groups. However, there are no factors relating to chemical composition that would suggest that smaller-seeded forms are unsuitable for human consumption and in fact all botanical varieties are put to all sorts of uses in various parts of the world. Some examples are summarized in Table 1.

Records of acreages of field beans in England and Wales refer to medium- and small-seeded beans used for livestock feeding. The area of beans cultivated fell steadily from 1870, apart from wartime, until 1963. This was probably due to a fall in the price of imported protein but was accelerated by a reduction in numbers of horses. The rapid rise since 1963 was due to a number of factors: (a) Simazine

Table 1. *Examples of cultivars of the three main botanical varieties (major, equina, minor) of* Vicia Faba *used as winter and spring crops and for human and animal consumption*

	Vicia Faba		
Purpose	Major (large seed)	Equina (medium seed)	Minor (small seed)
Winter sowing	Aquadulce	Throws M.S.	Côte d'Or
Spring sowing	Longpod	Strubes	Maris Bead
Human consumption	Triple White (Britain)	Baladi (Sudan)	Local varieties (India)
Animal consumption	Weir (Holland)	Throws M.S. (Britain)	Maris Bead (Britain)

weed-killer and insecticides were becoming widely used and appreciated by growers, (b) an alternative crop to cereals was needed owing to cereal diseases and yields, (c) some merchants offered contracts for bean growing, (d) the Government provided a subsidy for beans in 1968, (e) improved varieties were becoming available. Now, however, it seems unlikely that the trend will continue upwards at the same rate and reach 500 000 acres in England and Wales by 1972 as was originally expected. Some very low yields were obtained in 1968 and prospects for exports to the continent of Europe have declined considerably.

Beans yield best on heavy soils but apparently, in 1870, 500 000 acres were considered suitable for bean growing. Thus it can be concluded that suitable soil is available, husbandry techniques are available and the plant, though not ideal, is the most suitable grain legume for British conditions. If the grain is what is required nutritionally and there is a demand for it, then further effort could be put into development of the crop. Breeding could be expected to bring about higher yields, earlier maturity, and improvements in resistance to pests and diseases and in self-fertility. Only the prospects for breeding for changes in seed composition, e.g. in protein and amino acid contents, are dealt with in this paper.

Protein content

Clarke (1970), Smith & Aldrich (1967) and Eden (1968) have referred to differences between winter and spring varieties in protein contents and probably the range available within the species is only slightly wider than this, i.e. from about 24% to 35% of the dry matter. There are significant differences within populations as well as between varieties, and most varieties are populations. For example, inbred lines derived from a Cambridgeshire winter bean population were examined by the Chemistry Section of the Plant Breeding Institute and found to vary from 24·4 to 31·4% protein; and inbreds derived from the variety Suffolk Red varied from 26·6 to 33·6% protein. There is therefore a considerable overlap between plants within winter and spring varieties and the possibility of improvement in protein levels is suggested.

Crosses between inbreds with high and with low protein contents, made at the

Plant Breeding Institute, showed that high protein tends to be recessive. In a set of crosses where the parents differed significantly, the mean protein content of the high-protein parents was 30·0%, of the low-protein parents 26·2%, and of the F_1s only 26·7%. The mean difference between F_1s and high-protein parents was significantly greater ($P<0·01$) than the mean difference between F_1s and low-protein parents, and hence dominance of low protein content was inferred. Despite this, much of the variation between crosses could be attributed to the general combining ability of the parents, and this in turn was correlated with the parent values ($P<0·01$). Thus sufficient is known about the inheritance of protein content to allow a prediction of the protein content of an F_1 hybrid.

A high protein content does not necessarily imply low-yielding ability. Correlations of yield and nitrogen content in seven trials tended to be negative but were not statistically significant (Table 2).

Table 2. *Relationship of yield and protein contents in seven trials of field bean varieties*

Trial	Degrees of freedom	Correlation coefficient r
1, inbreds	8	−0·174
2, inbreds	23	+0·197
3, inbreds	28	−0·053
4, inbreds	12	−0·199
5, inbreds	11	−0·291
6, hybrids	15	−0·155
7, hybrids	54	+0·232

Amino acid content

However, a high protein content may mean inferior protein quality. As in cereals, there was a highly significant negative correlation between protein and g lysine/16 g nitrogen. Lysine content of the dry matter increased as protein content increased but not at so fast a rate. The range of genotypes examined was not large enough to judge whether high protein and high lysine can be combined in one variety.

Other amino acids have not been given so much attention at the Plant Breeding Institute as yet, but the Rowett Research Institute carried out a complete amino acid analysis on two Plant Breeding Institute varieties, a hybrid and an open pollinated variety, and the results are shown in Table 3.

The concentration of certain amino acids, per 16 g nitrogen, was significantly lower in 76 × S45 than in Maris Beaver, and the difference was in the same direction for almost all amino acids. 76 × S45 either had more non-protein nitrogen or contained some factor which affected hydrolysis. If 76 × S45 has an inferior quality protein this must, however, be seen in relation to its higher nitrogen content and higher yield of dry matter, as shown in Table 4. 76 × S45 was 6% lower in g lysine/16 g nitrogen but 15% superior in protein content and 28% superior in yield of dry matter. Consequently 76 × S45 still had a 30% advantage over Maris Beaver in yield of lysine per unit area. Differences in lysine content appear to be relatively

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small compared with differences in protein content. Nevertheless, in view of the negative correlation of protein and g lysine/16 g nitrogen, comparison of varieties with equal yield but different protein contents should also include comparisons of lysine and other amino acids, especially if the beans are to be fed to pigs.

Table 3. *Amino acid composition (g/16 g N) of two Plant Breeding Institute field bean varieties*

Variety	Nitrogen	ASP	THR	SER	GLU	PRO	GLY	ALA	VAL
76×S45	4·88	10·6	3·6	4·8	16·3	4·6	4·2	4·1	4·4
Maris Beaver	4·25	11·8	3·8	5·4	17·8	4·6	4·5	4·4	4·8
	*	*		*			*	*	*
	ILEU	LEU	TYR	PHE	LYS	HIS	ARG	MET	CYS
76×S45	4·0	7·7	3·6	4·4	6·8	2·7	9·4	0·6	1·2
Maris Beaver	4·3	8·0	3·7	4·6	7·3	2·9	9·6	0·7	1·1
		*			*				

*Significant difference at $P=0·05$.

Table 4. *Yield and quality of two varieties of field beans*

	Maris Beaver	76×S45	Least significant difference ($P=0·05$)
Yield of dry matter (cwt/acre)	29·5 (100)	37·7 (128)	4·4
Nitrogen (% DM)	4·2 (100)	4·9 (115)	0·15
Lysine (g/16 g N)	7·3 (100)	6·8 (94)	0·59

% of Maris Beaver is given in parentheses.

Digestibility

Using in vitro methods of estimating digestibility as applied to forage crops, it was shown that bean seeds had a significantly higher digestibility than barley grains (Table 5). The difference between winter beans (represented by 76×S45) and spring beans (represented by Strubes and Maris Bead) was not statistically significant, but this result, together with others that just failed to show a significantly higher digestibility in winter than in spring beans, suggests that further comparison should be made. It might be expected that, given a constant thickness of seed coat, large-seeded varieties would have a higher digestibility than small-seeded varieties: the proportion of seed coat or husk, which corresponds approxi-

Table 5. *Protein content and digestibility of grain from a trial which included field beans, barley and peas*

	76×S45 (winter bean)	Strubes (spring bean)	Maris Bead (spring bean)	Maris Badger (barley)	Minerva Maple (peas)	Least significant difference ($P=0·05$)
Protein (% of dry matter)	27·1	28·8	30·8	15·8	28·1	1·3
Organic matter digestibility (%)	84·0	81·7	82·4	77·8	82·0	2·9

mately to the indigestible fraction, is about 12% of the dry weight of the bean. However, no results have yet been produced to support this hypothesis: the small-seeded Maris Bead was as digestible as the larger-seeded Strubes (Table 5).

Future developments

Undoubtedly the quality of the beans produced will become increasingly important if the bean crop becomes established alongside cereals in British farming. There may also be some changes in utilization with more emphasis than at present on human consumption and industrial uses. There may be more attempts to utilize the whole plant, and in this connexion some values obtained at the Plant Breeding Institute may be relevant. As with whole-crop cereals, whole-crop beans have given about double the yield of dry matter expected from grain only. Protein content was halved (from 30% to 15%), but the digestibility of organic matter was not reduced by half, only from 82% to 60%. Thus the yield of digestible organic matter was increased from 2500 kg/ha to 4400 kg/ha in spring beans; 7500 kg/ha was obtained from whole-crop winter beans. The stage of growth which would give maximum digestibility and protein content was determined by periodic sampling. Most winter varieties had reached maximum digestibility and protein content at about the end of July when pods formed a high proportion of the dry matter. Later cutting would reduce conservation costs because of the rapid increase in dry matter after this date, but there would be a loss in digestibility. Some varieties were more suited to whole-crop conservation and others to grain yields. The economics of whole-crop beans have not yet been assessed but a high-quality product will be necessary to offset the high cost of seed.

Other possible developments in bean breeding

Self-fertile varieties. These would make field beans independent of insect pollination. Also, although the indeterminate growth habit (whereby more flowers are produced than the plant can bear pods) allows some plasticity in response to different environments, there would be less need for this in self-fertile varieties.

F_1 hybrid varieties. These are also self-fertile but require bees for pollinating the male-sterile parents which are normally grown in blocks alternating with fertility-restoring lines. This method of seed production would increase seed costs to the grower but F_1 hybrids have shown advantages in yield over the best open-pollinated varieties of between 10% and 30%, and the performance and quality of a hybrid is to a large extent predictable from that of its parents.

Whatever improvements in varieties may be introduced there will be stricter control over the multiplication of seed stocks. A seed certificate scheme for field beans was introduced in 1969 and plant variety rights are likely to be extended to include field beans in the near future. These schemes should result in a more uniform and reliable product than at present, and as such they may aid nutritional evaluation of field beans as well as being an incentive to breeders. What breeders mainly want to know is whether they are measuring the most important characters of the plant affecting grain quality. Are protein, amino acid, digestibility and energy values enough in themselves, or have full-scale animal feeding tests to be carried out before a variety can be evaluated? It is hoped that in return breeders can provide nutritionists with a diversity of plant material which can be used to help to answer these questions.

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Concluding remarks

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The symposium has revealed that plant breeders are concerned with a number of problems of purpose when considering the objectives of their long-term programmes of plant improvement. A plea has been made to us as nutritionists to define what we think are the desirable nutritional attributes of crop plants, so that guide lines can be established for the improvement of the quality of crops. It has been only too apparent that it is of little value for nutritionists to attempt this without providing precise and preferably non-destructive methods of assessment of quality, which could be readily applied to the thousands of genetic isolates with which plant breeders deal. The symposium has also shown that nutritionists are reluctant to make precise specifications to which plant breeders could adhere during the period of many years which must elapse between the inception and completion of a breeding programme. As one discussant said: 'The guide lines at present, if they exist at all, are extremely fuzzy round the edges'.

Such reluctance arises for several reasons. Understandable caution is one, for, as Dr Kodicek reminded us, a programme of breeding maize rich in nicotinic acid was rendered rather useless once the role of tryptophan in the aetiology of pellagra was discovered, and the fact that the nicotinic acid in cereals is normally unavailable was recognized. Again, as Dr Carpenter pointed out, contexts of value change. The success of chemical and microbiological synthesis of amino acids on a commercial scale already implies that investment in the breeding of lysine- or methionine-rich grains could in retrospect prove as pointless as the view we would at present take of breeding grains rich in calcium. Supplementation of nutritionally inadequate grains may well prove a more sensible solution than attempts to produce a completely adequate nutritional package from every plant. We are not certain about the