Open access • Journal Article • DOI:10.1017/S0021859600027714

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Published on: 01 Oct 1976 - The Journal of Agricultural Science (Cambridge University Press)

Topics: Vicia faba and Pollination

J. agric. Sci., Camb. (1976), **87**, 395–399
Printed in Great Britain

Pollination as a factor limiting the yield of field beans (*Vicia faba* L.)

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(*Received* 29 *January* 1976)

SUMMARY

Self-pollinating and cross-pollinating by hand samples of flowers in field bean crops usually gave an increased set of seed compared with control flowers left to be pollinated naturally. Hence, insect pollination of field bean crops is often inadequate. In large fields of more than 12 ha the seed yield was greater by plants near the edge than near the centre. Fewer pods were produced from nodes at the upper than the lower parts of a stem, and they contained fewer seeds which were of a smaller size.

INTRODUCTION

A commercial crop of field beans consists of about one-third hybrid plants and two-thirds inbred plants (e.g. Sirks, 1923; Hua, 1943; Fyfe & Bailey, 1951; Fyfe, 1954; Rowlands, 1958). The flowers of hybrid plants are able to set seed from autopollination and their progeny is produced predominantly by self-fertilization. However, flowers of inbred plants have some mechanical barrier to autopollination that is absent in hybrid flowers and although self-fertile do not set seed unless visited by insects. As a result of this about half their progeny are from cross-fertilization (Drayner, 1959).

It might be expected, therefore, that although the autofertility of the hybrid plants would ensure a fair crop under conditions of poor pollination, insect pollination could improve the yield by pollinating the inbred plants. Furthermore, seed produced under conditions of poor pollination would produce a crop still more in need of insect pollination.

Experiments in which plots of field beans have been caged to exclude or contain pollinating insects have demonstrated that insect pollination increases yield by about a third (e.g. Riedel & Wort, 1960; Scriven, Cooper & Allen, 1961; Watts & Marshall, 1961; Cooper, 1964; Free, 1966), the amount depending, of course, on the proportion of plants that have grown from self-fertilized and cross-fertilized seed.

We have now attempted to discover to what extent yield of commercial crops is limited by insufficient pollination.

METHOD

Observations were made in 1970 and 1971 on 30 and 7 crops, respectively, of spring-sown field beans. Field size varied from 2 to 40 ha in 1970 (mean 11 ha) and from 4 to 16 ha in 1971 (mean 9 ha).

During flowering in 1970, 30 plants near the centre of each field and 30 plants 10 m from the edge of the field were labelled and metal plant rings put below the lowest node and above the highest node that had two or more flowers open. The plants were allocated in order into three treatments in which all the open flowers (about 12) between the plant rings were either (*a*) self-pollinated by depressing the keel to push the pollen plug on to the stigma, or (*b*) cross-pollinated by depressing the keel and brushing the exposed stigma with pollen from three or more flowers of other plants, or (*c*) not pollinated by hand and left to be pollinated naturally. Just before the crop was harvested the entire plants were removed. From the treated section of each plant, the lower part that flowered before the treated section (pre-treatment section) and the upper part that flowered after the treated section (post-treatment section) the pods and seeds were counted and the seeds were weighed.

The method used in 1971 was similar except that each of the 30 plants used in the centres and edges of the fields received all three treatments. The open flowers on three adjacent flowering nodes on each plant were (*a*) self-pollinated by hand, (*b*) cross-pollinated by hand, or (*c*) not pollinated by hand, respectively, equal numbers of each treatment

Table 1. *Pod and seed production in the centre and edge of fields*

	Location of plants in field			
	1970		1971	
	Edge	Centre	Edge	Centre
Mean wt. (g) per seed	0·30	0·30	0·36	0·32
Mean no. seeds per pod	2·47	2·39	3·30	3·23
Mean no. pods per node	1·62	1·68	1·90	1·84
Mean no. seeds per plant	18·30	18·59	32·82	33·48

Table 2. *Number of crops in which the seed production of flowers self-pollinated and cross-pollinated by hand exceeded that of control flowers*

	1970 (30 crops)		1971 (7 crops)		1970 and 1971 (37 crops)	
	Self-pollinated flowers	Cross-pollinated flowers	Self-pollinated flowers	Cross-pollinated flowers	Self-pollinated flowers	Cross-pollinated flowers
Edge of field	17	20	4	6	21	26*
Centre of field	19	19	7**	7**	26*	26*
Edge and centre of field	36	39**	11*	13**	47*	52***
Mean of edge and centre of field	19	20	6	7**	25*	27**

* $P < 0{\cdot}05$; ** $P < 0{\cdot}01$; *** $P < 0\,001$,

being allocated to nodes in each of the relative positions.

RESULTS

The average yield of plants at the centres and edges of the fields were similar (Table 1) and such differences as occurred were not consistent. Thus plants near the edges of 15 of 30 fields in 1970 and 3 of 7 fields in 1971, had more seeds per plant than those near the centres of the fields. However, field size appeared to influence the result as there were more seeds per plant at the edges than the centres of 9 of 10 fields more than 12 ha in size compared with 10 of 27 fields less than 12 ha in size ($P < 0{\cdot}01$). There were no other significant differences associated with field size.

In most crops hand-pollinated flowers set more seed than control flowers (Table 2). Any advantage of cross-pollination over self-pollination was not great. The mean amounts of seed produced by the different treatments is given in Table 3. Much of the increase in set of the hand-pollinated sections was maintained in the yield of the plant as a whole, and, in 1971, plants with self- and cross-pollinated flowers produced more seed than control plants in 19 and 20 fields, respectively.

In general, flowers on the part of the plant that was hand-pollinated, and earlier flowers lower on the stem, produced more seeds per pod, more pods per node and larger seeds, than flowers that were produced later (Tables 4 and 5).

DISCUSSION AND CONCLUSIONS

Because hand-pollination increased the flower set of many crops it is apparent that they were being inadequately pollinated. This may be overcome by importing colonies of honeybees or growing the crops in areas in which bumblebees are abundant. Bond & Pope (1974) found that the amount of crossing in field bean crops was associated with the suitability of the site for bumblebees. However, as pointed out by the Ministry of Agriculture, Fisheries & Food (1970) the number of bumblebees and other wild pollinators is unlikely to be adequate for large fields.

Bond & Pope (1974) also found that in general more crossing occurs in small than in large fields, and a higher proportion of cross-fertilized seed survives at their centres than at their edges due to mortality of self-fertilized embryos; they suggested that the critical size of field requiring extra bees is between 12 and 32 ha. The greater seed set near the edges than the centres of our large fields (over

Table 3. *Effect of self-pollinating and cross-pollinating by hand on pod and seed production in* 1970 *and* 1971. *The percentage increase compared with control plants is given in parentheses*

Treatment	Mean no. of pods per node of treated section			Mean no. of seeds per treated section			Mean no. of seeds per plant		
	Control	Self-pollinated	Cross-pollinated	Control	Self-pollinated	Cross-pollinated	Control	Self-pollinated	Cross-pollinated
1970									
Edge of field	1·93	1·95 (1·0)	2·00 (3·6)	8·55	9·23 (8·0)	9·16 (6·1)	17·55	18·79 (7·1)	18·54 (5·6)
Centre of field	1·78	1·93 (8·4)	1·97 (10·7)	8·29	8·76 (5·7)	9·48 (14·4)	17·80	18·42 (3·5)	18·47 (3·8)
Edge and centre of field	1·82	2·02 (10·9)	2·01 (10·4)	8·37	8·88 (6·1)	9·21 (10·0)	17·51	18·02 (2·9)	18·28 (4·4)
1971									
Edge of field	—	—	—	6·18	6·38 (3·2)	7·02 (13·6)	—	—	—
Centre of field	—	—	—	5·99	6·58 (9·8)	6·72 (12·2)	—	—	—
Edge and centre of field	—	—	—	6·08	6·48 (6·6)	6·87 (13·0)	—	—	—

Table 4. *Number of crops in which the seed and pod production of the pre-treatment flowers and the treated flowers (hand-pollinated) exceeds that of the post-treatment flowers*

	1970 (30 crops)		1971 (7 crops)		1970 and 1971 (37 crops)	
	Pre-treatment flowers	Treated flowers	Pre-treatment flowers	Treated flowers	Pre-treatment flowers	Treated flowers
Wt. (g) per seed						
Edge of field	23**	17	6	6	29***	23
Centre of field	24**	20	6	5	30***	25*
Mean of edge and centre of field	23**	20	6	6	29***	26*
No. of seeds per pod						
Edge of field	24**	26***	7**	6	31***	32***
Centre of field	22*	27***	5	6	27**	33***
Mean of edge and centre of field	24**	27***	5	7**	29***	34***
No. of pods per node						
Edge of field	25***	30***	6	7**	31***	37***
Centre of field	25***	30***	6	7**	31***	37***
Mean of edge and centre of field	27***	30***	7**	7**	33***	37***

* $P < 0{\cdot}05$; ** $P < 0{\cdot}01$; *** $P < 0{\cdot}001$.

Table 5. *Seed and pod production by early, treated and late flowers*

	1970			1971		
	Pre-treatment flowers (early)	Treated flowers	Post-treatment flowers (late)	Pre-treatment flowers (early)	Treated flowers	Post-treatment flowers (late)
Mean no. of seeds						
Edge of field	7·18	8·79	2·02	5·28	19·56	7·96
Centre of field	7·14	8·64	2·40	3·75	19·30	10·74
Edge and centre of field	7·16	8·71	2·21	4·51	19·43	9·35
Mean wt. (g) per seed						
Edge of field	0·35	0·32	0·30	0·36	0·36	0·34
Centre of field	0·32	0·30	0·28	0·35	0·33	0·29
Edge and centre of field	0·34	0·31	0·29	0·35	0·34	0·31
Mean no. of seeds per pod						
Edge of field	2·62	2·52	2·12	3·38	3·31	3·08
Centre of field	2·52	2·55	2·04	3·23	3·52	3·03
Edge and centre of field	2·57	2·54	2·08	3·30	3·41	3·05
Mean no. of pods per node						
Edge of field	1·83	1·92	1·13	2·04	1·98	1·55
Centre of field	1·92	1·85	1·21	1·70	1·95	1·66
Edge and centre of field	1·87	1·89	1·17	1·86	1·96	1·60

12 ha) probably reflects the greater abundance of pollinators near the edges, and emphasizes the need for more pollinating insects in such circumstances.

We are grateful to Dr D. A. Bond of the Plant Breeding Institute, Cambridge, for helpful discussion and encouragement.

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