THE EFFECT OF PHOTOPERIOD AND TEMPERATURE ON YIELD IN BEANS

J.H.C. Davis and P. Gniffke[1]

Centro Internacional de Agricultura Tropical (CIAT), A.A. 6713, Cali, Colombia.

SUMMARY

Photoperiod insensitivity in the germplasm collection of beans (*Phaseolus vulgaris*) held at CIAT is found mostly in accessions from higher latitudes. Cold tolerance is found in accessions from the high Andes, but these are all photoperiod sensitive. A break in adaptation seems to occur at about 15°C, between accessions specifically adapted to cool or warm temperatures. Those adapted to cool temperatures tend to have large seeds. An attempt is being made to combine adaptation to growing and yielding at low temperature with photoperiod insensitivity. A number of breeding lines have been selected which combine improved cold temperature tolerance with photoperiod insensitivity (e.g. VRA 81078, VRA 81072). The extent to which production regions of the world can be stratified according to the optimum photoperiod/temperature response required in bean cultivars is being studied in an international phenology nursery organized collaboratively by Cornell University and CIAT.

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[1] Plant breeder and research student from Cornell University, Ithaca, U.S.A., respectively.

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Photoperiod sensitivity in the world germplasm collection of beans (Phaseolus vulgaris) held at CIAT has been found to be related to the origin of the material and its growth habit, most insensitive accessions originating from the high latitudes and tending to be bush types (Growth Habits I and II). Large seeded climbing types, principally from the Andean Region, show the lowest frequency of insensitivity (CIAT, 1977 and 1982). In sensitive materials, higher temperatures increase the delay in flowering (Enriquez and Wallace, 1980), so that the photoperiod response is a more critical factor in warm locations than cool ones.

Any given variety is found to have an optimum temperature and photoperiod at which normal flowering is achieved in a minimum amount of time (Wallace, 1980). Above this temperature flowering may be delayed both by temperature and by increasing photoperiod in sensitive material. Below this optimum temperature, flowering is also delayed. Accessions are found which are specifically adapted to mean growing temperatures as low as 12-13°C, but all are sensitive to photoperiod and most are climbing types from the high Andes. Others are specifically adapted to warm temperature. A sharp break in adaptation seems to occur at about 15°C. (Fig. 1; Hershey et al., 1982).

The seed weights of groups of accessions adapted to different temperatures is shown in Table 1, demonstrating that accessions adapted to cold temperatures generally have larger seeds than those adapted to warm temperatures. In addition, there is an environmental effect of temperature on seed size which operates in the same direction as genetic adaptation, so that the largest seeds are obtained from accessions adapted to cold temperatures and grown at low temperature.

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An attempt is being made to combine adaptation to growing and yielding at low temperature with photoperiod insensitivity. Lights have been placed in the field at the three locations in Colombia shown in Fig. 1, so that the adaptation response to temperature can be studied together with the photoperiod response. A number of breeding lines have been selected which combine improved cold temperature tolerance with photoperiod insensitivity (e.g. VRA 81078, VRA 81072). These do not yet include the maximum level of cold tolerance available in the species, however.

The low frequency of breeding lines obtained to date combining adaptation to high altitudes (cool temperatures) and photoperiod insensitivity is shown in Table 2. Much higher frequencies are available in small black and small red Central American types, and small/medium sized Brazilian types, all adapted to warm temperatures. Some selected breeding lines, representing insensitive and intermediate classes of photoperiod reaction, are shown in Table 3.

Intermediate sensitivity to photoperiod can lead to improved yield under long days, for example in the variety Porrillo Sintético (CIAT, 1977). The extent to which production regions of the world can be stratified according to the optimum photoperiod/temperature response required in bean cultivars is being studied in an international phenology nursery organized collaboratively by Cornell University and CIAT. A first attempt at stratifying regions of Latin America and the Caribbean on the basis of climatic data is shown in Table 4 (from Jones, CIAT, 1979). It is clear that most bean production occurs at a mean growing temperature of 20°C.

The definition of the target environment is of fundamental importance for setting the objectives of an international breeding programme, given that large genotype-environment interactions occur in beans (Voysest, 1982). Photoperiod and temperature are important factors responsible for these interactions. Any division of the total set of environments into more uniform target environments should decrease the potential magnitude of genotype-environment interactions within those target environments and increase the efficiency of genotype selection. Climatic data can be regarded as the most fundamental basis for division, but other factors which are not necessarily related to climate should also be considered, for example diseases and pests, and socio-economic factors including preferences for particular grain types.

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Table 1. The relationship between seed weight and adaptation to temperature in beans. From CIAT, 1979.

Group[a]	Seed weight, mg. 1	2	3
Trial Location[b]			
CIAT-Palmira (24°C)	210	240	320
CIAT-Popayán (18°C)	230	300	310
ICA-Obonuco (12.5°C)	220	380	560

a. Group of 5 accessions which were selected for high yield in: CIAT-Palmira (Group 1); CIAT-Popayán (Group 2); ICA-Obonuco (Group 3). Mean yields for the same groups are shown in Figure 1.

b Location of trial, with mean growing temperature in parentheses.

Table 2. Distribution of photoperiod sensitivity in 1982 EP materials, by grain type and growth habit.

Group	Grain type	Photoperiod response class[a]					Total number of lines
		1	2	3	4	5	
10000	Small black	15	2	5	8	0	30
20000	Small red	10	3	3	16	1	33
20500	Medium/large red	5	1	2	20	23	51
30000	Small white	7	0	1	2	1	11
30500	Medium/large white	4	1	2	4	1	12
40000	Medium/large Pacific South	7	1	3	5	5	21
40500	Medium/large Mexican	3	0	0	4	10	17
50000	Small/medium Brazil	25	2	9	10	9	55
60000	Black, high altitude	0	0	0	1	4	5
60500	Black, low altitude	0	0	0	0	2	2
70000	Small red, high altitude	0	1	1	3	15	20
70500	Medium/large, high altitude	2	0	0	2	9	13
80000	Med/large colored, high altitude	0	0	0	1	5	6
80500	Med/large colored, low altitude	0	0	1	2	5	8
	Total	78	11	27	78	90	284
	Not classified						20

a. 1 = insensitive; 5 = extremely sensitive.

Table 3. Selected lines from EP 82 representative of the insensitive and intermediate classes of photoperiod reaction.

Grain type and/or region	Photoperiod class[a]		
	1	2	3
Bush			
Small black	BAC 93	BAC 112	Moruna 80
Small red	BAT 1670	BAT 1489	BAT 1516
Medium/large red	BAT 1297	BAT 1620	A 465
Small white	BAC 125	-	EMP 111
Medium/large white	A 491	A 497	A 492
Medium/large Pacific South	BAT 1425	BAT 1322	BAT 1456
Medium/large Mexican	A 407	-	-
Small/medium Brazil	A 386	Carioca 80	A 321
Climbing			
Red	VRB 81047	VRA 81072	VRA 81027
Light colors	-	-	VCB 81004

a. Photoperiod class on a 1-5 scale, where 1 = insensitive; 2 = slightly sensitive; 3 = moderately sensitive; (classes 4 and 5, corresponding to sensitive types, are not shown).

Table 4. A simplified description of the climate types for bean production in Latin America and the Caribbean, from CIAT 1979.

Climate type	Mean temp. °C at flowering	Water balance	Production x 1000 tons.	Example sites
D	26°	Late season stress	262	Veracruz, Mexico
A	23°	Adequate	661	Huila, Colombia
B	23°	Slight excess water	118	Turrialba, Costa Rica
C	23°	Very dry, irrigated	538	Culiacan, Mexico
E	20°	Possible late season stress	1672	Durango, Mexico
F	16°	Moderate deficits	451	Rio Grande do Sul, Brasil
G	13°	Adequate	45	High altitude Andean Region

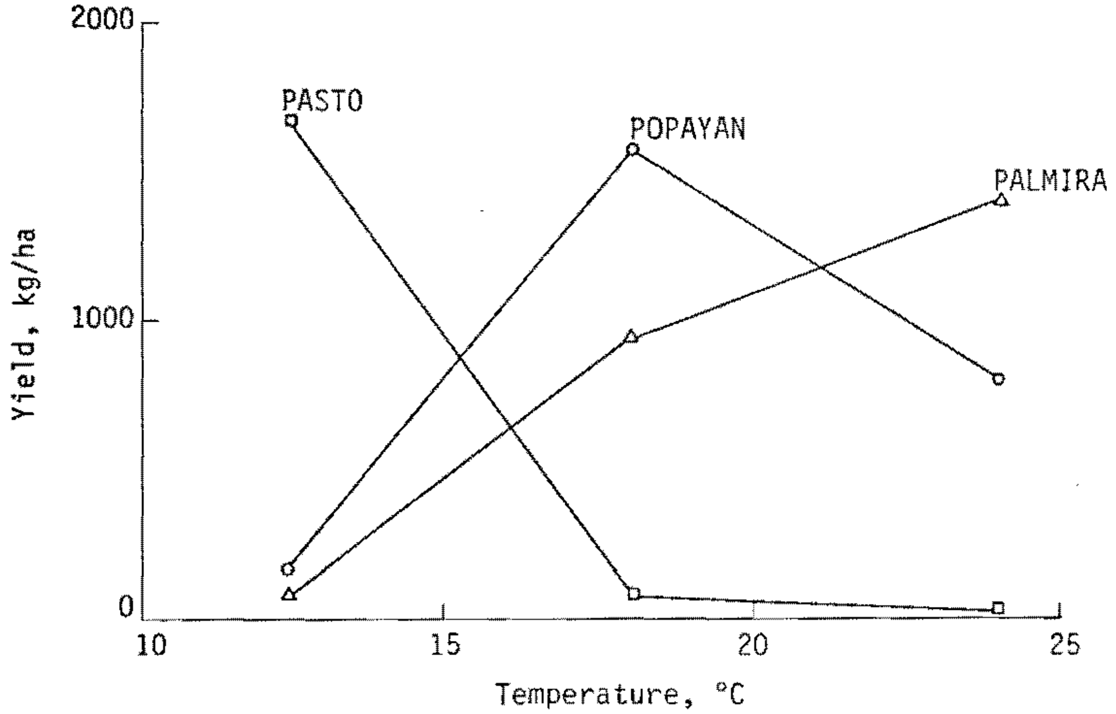

Figure 1. Mean yield of the five highest yielding bean varieties among 180 sown at three altitudes in Colombia, and plotted against the mean growing season temperature. The place names refer to the curve for the mean of the five best varieties at that location. Altitudes: Pasto 2,710 m; Popayán 1,750 m; Palmira 1,000 m.