BEAN BREEDING SCALES

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Link to "Standard System for the Evaluation of Beans' from CIAT" provided as Google books - http://www.google.com/books?id=e7144M7teYcC

General disease and pest evaluation scales

The incidence of plants with disease symptoms can be obtained by counting the number of healthy and diseased plants in a plot. The Modified Cobb scale can be used for estimating the amount of leaf area infected by a disease such as bean rust (Table 1).

Table 1. Modified Cobb scale for intensity of infection.

	Description
0	No visible infection
1	1-5% leaf area infected
2	6-10% leaf area infected
3	11-25% leaf area infected
4	26-40% leaf area infected
5	65-100% leaf area infected.

Source: Stavely (1985).

CIAT developed a (1-9) scale for the evaluation of bean germplasm to fungal and bacterial pathogens (Table 2). This is a simple scale useful for screening bean breeding lines.

Table 2. General scale to evaluate the reaction of bean germplasm to fungal and bacterial pathogens.

Rating	Description	Comments
1	No visible symptoms	Germplasm useful as parents or commercial varieties
2 3	Very light symptoms resulting in little or no economic damage	
4 5 6	Visible and conspicuous symptoms resulting in only limited economic damage	Germplasm can be used as commercial varieties or as sources of resistance to certain diseases
7 8 9	Severe to very severe symptoms causing considerable yield loss or plant death	Germplasm in most cases is not useful as parents or commercial varieties

Source: CIAT (1987)

References

CIAT (Centro Internacional de Agricultura Tropical). 1987. Standard system for the evaluation of bean germplasm. Van Schoonhoven, A. and M.A. Pastor-Corrales (compilers). Cali, Colombia. 54 p. http://www.google.com/books?id=e7144M7teYcC

Stavely, J.R. 1985. The Modified Cobb Scale for estimating bean rust intensity. Ann. Rep. Bean Improv. Coop. 28:31-32.

Seed traits

Color

Table 1 . Seed color scale.

Seed color group	Seed color
1	White
2	Cream-beige
3	Yellow
4	Brown-maroon
5	Pink
6	Red
7	Purple
8	Black
9	Others

Source: CIAT (1987)

Size, shape and seed coat patterns

Bean seed size is often reported as the weight (g) of 100 seed. The following symbols can be added to seed color group to indicate the following seed shapes and patterns: kidney (K), mottled (M), striped (R).

Seed brilliance

Bean seed brilliance can be classified as opaque (O), intermediate (I) or brilliant (B).

References

CIAT (Centro Internacional de Agricultura Tropical). 1987. Standard system for the evaluation of bean germplasm. Van Schoonhoven, A. and M.A. Pastor-Corrales (compilers). Cali, Colombia. 54 p. http://www.google.com/books?id=e7144M7teYcC

AGRONOMIC DATA RECORDING – COOPERATIVE DRY BEAN NURSERY (CDBN)

The following were commonly recorded data by the CDBN collaborators. A description of each trait is presented below for ease and uniformity of reporting:

1. **Early Vigor (EV):** Scored on a 1 to 9 scale, where 1=excellent and 9= very poor, within the first three weeks after emergence.
2. **Days to Flower (DF):** Actual number of days from planting to when approximately 50% plants in a plot have at least one opened flower.
3. **Days to Maturity (DF):** Actual number of days from planting to when approximately 50% of plants in a plot have at least one dry pod.
4. **Plant Height (PH):** Recorded in cm from the base of the plant (soil surface) to the top node bearing at least one dry pod with seed.
5. **Growth Habit (GH):** Recorded during flowering and verified when crop is senescing as type I= determinate erect or upright, II= indeterminate erect, and III= indeterminate prostrate.
6. **Lodging (LG):** Scored at harvest on a 1 to 5 scale, where 1 =100% plants standing erect, and 5= 100% plants flat on the ground.
7. **Pod Clearance (PC):** Recorded at harvest as % pods on plants not touching the ground or in contact with the soil surface.
8. **Biomass Yield (BY):** Total plant dry weight recorded at 16% moisture and rounded up to the nearest whole number.
9. **Seed Yield (SY):** Recorded in pounds per acre at 16% moisture and rounded up to the nearest whole number.
10. **Harvest Index (HI):** The ratio of SY/BY expressed in % BY at 16% moisture.
11. **Weight of 100 Seeds (SW):** Weight of 100 randomly taken undamaged seeds recorded in grams at 16% moisture.
12. **Appearance Desirability (AD):** An aggregate value for seed size, shape, color, and brilliance for the respective market class scored on a 1 to 9 scale, where 1= excellent and 9= commercially unacceptable.

Should you record any other trait or follow another scoring method, please do state so and provide us its details. However, it will be nice if we all use a similar method for data recording.

For other traits including **Seed – After- Darkening (SAD)**; **Cooking and Caning Tests**; response to **Water (WS)**, **Heat (HS)**, **Cold (CS)**, and **Soil Fertility (FS)** stresses; and reaction to disease such as **Anthracnose (ANT)**, **Bean Common Mosaic (BCM)**, **Bean Rust (BR)**, **Common Bacterial Blight (CBB)**, **Fusarium and other Root Rots (RT)**, and **White Mold (WM)**, collaborators are expected to specify the traits (including pathogen race if known) and describe the abbreviations and rating scales used for data recording.

TRAITS EVALUATED IN SNAP BEANS FOR PROCESSING

TRAIT	COMMENTS
Dry seed prior to planting	
White seed color	Anthocyanins from colored seed will influence processed product color.
No obvious defects	Freedom from fish mouth, susceptibility to cracking.
Length: diameter ratio >2:1	Associated with smoother pods.
Germination and Emergence	
Mechanical injury test	Drop seeds 2.6 m onto steel plate placed at 15º angle. Rate for visible cracks and splits. Place mechanically treated seed in moist sterile sand and incubate in the dark at 10ºC for 10 days (no fungicidal seed treatments are applied in this test). Evaluate for percent germination, and defects (ineffective cotyledons, single cotyledons, bald heads and snake heads).
Vegetative growth in the field	
Stand establishment	Percent emerged, defective seedlings.
Days to 50% emergence	
Cotyledon color	Persistent color types may have white cotyledons; normal color is green.
Relative vigor at two weeks	
Reproductive growth in the field	
Days to 50% of plants with at least one flower open.	
Heat susceptibility	Lack of continuous distribution of pods at different maturities when stressed, excessive blanking (lack of seed development) in pods, pollywogs (only seed at distal end of pod developing), fish hooks (extremely curved pods).
Plant architecture	Ideal plant architecture would include thick main stems, short internodes and branches, acute branch angles and pod distribution in upper half of plant.
Lodging	Subdivided into root lodging, and floppy stems and branches.
Maturity	Days to harvest for processing
Concentration of set (Pods similar in maturity)	Pod maturity concentration best evaluated by whether cultivar is still flowering when it has reached harvest maturity. It can be quantified by measuring flowering duration (days to 50% plants finished flowering - days to 50% of plants with at least one flower open).
Ease of pod detachment	Percent of pods breaking at neck vs. pedicle. Some cultivars have the *easy pick* trait where the majority of pods detach at the pedicle abscission zone.
Mechanical harvest ability	Plants strongly rooted, pods accessible to harvester, pods detach singly and easily, correct proportion of vegetation to pods.
Disease evaluation (see BIC Website for disease evaluation techniques)	
Root rots	(*Aphanomyces, Fusarium, Rhizoctonia, Pythium* spp.)
White mold	(*Sclerotinia sclerotiorum*)
Brown spot	(*Psedomonas syringae* pv *syringae*)
Anthracnose	(*Colletotrichum lindemuthianum*)
Common blight	(*Xanthomonas campestris* pv *phaseoli*)
Halo blight	(*Pseudomonas syringae* pv *phaseolicola*)

Bean common mosaic virus	
Bean golden yellow mosaic virus	
Beet curly top virus	
Cucumber mosaic virus	
Post harvest evaluation	
Sieve size distribution	Percent pods graded into one of six sieve classes.
Percent 1-4 sieve	Harvest at 50% 1-4 sieve of full sieve cultivars typically maximizes yield and pod quality.
Total yield (Tons/acre)	
Pod Length (cm)	Short pods (<10 cm five sieve class) are difficult to snip and cut.
Pod Straightness	Straight pods grade more easily, are easier to snip and cut into sections.
Pod Cross Section	Round pods are essential for accurate grading.
Pod Smoothness	Smooth appearance is preferred by processors since bumpy pods suggests over mature pods of low quality and over developed seeds.
Pod Color	Medium to dark green preferred for green beans with a new cultivar blending well with traditional ones. Wax beans should be uniformly yellow, especially in small sieve sizes.
Stringlessness	No pod fiber in sutures should be present.
Interlocular cavitation	No cavities in pod interior between seeds should be present.
Immature seed color	Immature green seed at harvest maturity is required in snap beans compared to immature white seed normally found in dry beans.
Rate of seed development	Slow seed development is preferred although extremes in this trait may result in poor seed production.
Post processing evaluation	
Color intensity	Shade of green meets processor specifications.
Color uniformity	Color from suture to sidewall should be uniform. Suture color should match pod color.
Fiber	Pods should be low in fiber and strings; see Horowitz and Latimer 2005, Official Methods of Analysis of AOAC for method of fiber measurement in snap beans.
Sloughing resistance	Epidermis should not peel away after processing.
Flavor	Varies from processor to processor. Beans should be sweet with a strong “beany” flavor.

[Information provided by James R. Myers, Oregon State University]

Number of plants necessary to recover a trait

Sedcole (1977) discussed four methods for calculating the needed, with a specified probability, the number of traits needed to recover a trait. A simple and conservative method to estimate (n) the number of plants to be evaluated to recover at least one plant with the trait is as follows:

$$n \geq \log(1-p) / \log(1-q)$$

where p is the probability of recovering at least one plant with the trait and q is the probability of the occurrence of the trait.

References

Sedcole, J.R. 1977. Number of plants necessary to recover a trait. Crop Sci. 17:667-668.

BACKCROSS METHOD **367**

Table 28-1 Total Number of Plants Needed to Obtain Required Number with Desired Genes

		r (Number of Plants to Be Recovered)								
*p**	*q*†	1	2	3	4	5	6	8	10	15
0.95	$\frac{1}{2}$	5	8	11	13	16	18	23	28	40
	$\frac{1}{3}$	8	13	17	21	25	29	37	44	62
	$\frac{1}{4}$	11	18	23	29	34	40	50	60	84
	$\frac{1}{8}$	23	37	49	60	71	82	103	123	172
	$\frac{1}{16}$	47	75	99	122	144	166	208	248	347
	$\frac{1}{32}$	95	150	200	246	291	334	418	500	697
	$\frac{1}{64}$	191	302	401	494	584	671	839	1002	1397
0.99	$\frac{1}{2}$	7	11	14	17	19	22	27	32	45
	$\frac{1}{3}$	12	17	22	27	31	35	44	52	71
	$\frac{1}{4}$	17	24	31	37	43	49	60	70	96
	$\frac{1}{8}$	35	51	64	77	89	101	124	146	198
	$\frac{1}{16}$	72	104	132	158	182	206	252	296	402
	$\frac{1}{32}$	146	210	266	218	268	316	508	597	809
	$\frac{1}{64}$	293	423	535	640	739	835	1020	1198	1623

**p* = probability of recovering *r* plants with the desired genes.
†*q* = frequency of plants with desired genes.
Source: Sedcole, 1977.

Source: Fehr, 1987 Principles of Cultivar Development. Macmillan Pub Co.

Growth habit and development stages

Days to emergence, flowering and maturity should be noted in a field plot when 50% of the plants in the plot have reached a particular stage of development.

Table 1. Growth habit classifications and descriptions of common bean.

Growth habit	Description
Type I	Determinate growth habit Terminal bud reproductive Stems and branches erect or prostrate Terminal guide absent Pods distributed along the length of the stem
Type II	Indeterminate growth habit Terminal bud vegetative Stems and branches erect Terminal guide absent or medium Pods distributed along the length of the stem
Type III	Indeterminate growth habit Terminal bud vegetative Stems and branches prostrate with little or no climbing ability Terminal guide small or long Pods distributed mainly in the basal portion
Type IV	Indeterminate growth habit Terminal bud vegetative Stems and branches twining with strong climbing ability Terminal guide long or very long Pods distributed along the length of the stem or mainly in the upper portion

Source: Singh (1982); Hall (1991).

Table 2. Development stages of the common bean.

Stage	Description
V1	*Emergence*: from the appearance of cotyledons on the soils surface to the unfolding of primary leaves
V2	*Primary leaves*: from the full unfolding of the primary leaves to the unfolding of the first trifoliate leaf
V3	*First trifoliate leaf*: from the full unfolding of the first trifoliate leaf to the unfolding of the third trifoliate leaf
V4	*Third trifoliate leaf*: from the full unfolding of the third trifoliate to the appearance of the first floral bud or raceme
R5	*Preflowering*: from the appearance of the first floral bud or raceme to the opening
R6	*Flowering*: from the opening of the first flower to the expansion of the ovary after fertilization
R7	*Pod development*: from the expansion of the ovary to the elongation of the pod to its full size before increase in seed weight
R8	*Pod filling*: from the beginning of seed weight and size increase to the development of pigmentation of seeds and onset of leaf senescence
R9	Harvest maturity*: from initiation of senescence to complete senescence and drop in seed moisture to about 15%*

Source: Hall (1991).

References

Hall, R. 1991. The bean plant. p. 1-5 *In* R. Hall (ed). Compendium of bean diseases. APS Press. Saint Paul, Minnesota.

Singh, S.P. 1982. A key for identification of different growth habits of *Phaseolus vulgaris* L. Annu. Rept. Bean Improv. Coop. 25: 92-94.

Additional information concerning growth habit can be found at the following CIAT web site: www.ciat.cgiar.org/beans/growthhabits.htm

Gene pools and hybrid dwarfism

Gepts (1998) reported that the common bean has Andean and Middle American gene pools. Singh et al. (1991) noted that there were different races of common bean within each gene pool. The gene pools and races can be distinguished based on plant and seed morphology and Phaseolin seed protein patterns (Table 1).

Table 1. Principal characteristics of cultivated common bean from the Middle American and Andean gene pools.

Characteristics	Gene pool	
	Middle American	Andean
Shape of terminal leaflet of the trifoliate leaf	Ovate, cordate	Hastate or lanceolate, rhombohedric
Leaf pubescence	Sparce, short	Dense, long
Length of the fifth internode	Short	Long
Pod-bearing inflorescence	Multi-noded	Single-noded
Shape of bracteole	Cordate, ovate	Lanceolate, triangular
Base of the standard	Striped	Smooth
Pod beak position	Placental (dorsal suture)	Between placental and ventral sutures
Seed size	Small, medium	Large
Phaseolin seed protein patterns	S,Sb,Sd,B	C,H,A,T

Singh et al. (1991).

Singh and Gutiérrez (1984) identified two complementary dominant genes (Dl_1 and Dl_2) that can cause hybrid dwarfism in common bean. The dominant Dl_1 allele is found in the Mesoamerican gene pool whereas the Dl_2 allele is found in the Andean gene pool. There are, however, Mesoamerican and Andean bean lines that have the recessive for dl_1 and dl_2 alleles and can be used for crosses between gene pools (Table 2).

Table 2. Bean lines that have the recessive for dl_1 and dl_2 alleles and can be used for crosses between gene pools.

Bean line	Seed type	Gene pool
Opus	Snap bean	Andean
ICA Pijao (indeterminate) 5-593 (determinate)	Black Black	Mesoamerican Andean

Source: Ferwerda (2001)

Shii et al. (1981) reported that the primary abnormal development event associated with hybrid dwarfism was restricted root growth and exogenously applied cytokinin was shown to produce more normal root growth in hybrid dwarf plants. Koinange and Gepts (1992) reported the production of adventitious roots of the lower internodes of hybrid dwarf plants. Hybrid dwarfism is also more severe in higher temperature environments.

Beaver (1993) developed a simple method to produce seed from hybrid dwarfs. The main stems of the hybrid dwarfs were covered with soil above the cotyledonary node. A solution of “Hormex” (0.24% 1-napthaleneacetic acid and 0.013% 3-indolebutyric acid) was applied to the soil at a concentration of 4 ml l^{-1} of water to promote adventitious root growth. Plants were watered frequently to avoid water stress. The hybrid dwarf plants began to grow a few weeks after the main stems were covered with soil. Inspection of plants after the harvest revealed a profuse growth of adventitious roots on the main stem. Kelly (personal communication) was able to avoid hybrid dwarfism by grafting hybrid dwarf scions onto normal stocks.

References

Beaver, J.S. 1993. A simple method for producing seed from crosses hybrid dwarfs derived from crosses between Middle American and Andean gene pools. Ann. Rep. of the Bean Improv. Coop. 36:28-29.

Ferwerda, F.H.. 2001. The investigation of genetic barriers to interspecific crosses between *Phaseolus acutifolius* A. Gray, *Phaseolus coccineus* L. and *Phaseolus vulgaris* L. and the inheritance of resistance of bean golden yellow mosaic virus from *Phaseolus coccineus* L. Ph.D. Dissertation. University of Florida, Gainesville, Florida. 70 p.

Gepts, P. 1998. Origin and evolution of common bean, past events and recent trends. Hortscience 33:1124-1130.

Shi, C.T., M.C. Mok and D.W. Mok. 1981. Developmental controls of morphological mutants of *Phaseolus vulgaris* L.: Differential expression of mutant loci in plant organs. Develop. Genet. 2:279-290.

Singh S.P., Gepts P., Debouck D.G. 1991. Races of common bean (*Phaseolus vulgaris*, Fabaceae). Econ. Bot. 45:379-396

Singh, S.P. and J.A. Gutiérrez, 1984. Geographical distribution of the DL_1 and DL_2 genes causing hybrid dwarfism in *Phaseolus vulgaris* L., their association with seed size, and their significance to breeding. Euphytica 33(2):337-345.