POPPING BEAN PRODUCTION

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Nuña beans (*Phaseolus spp.*), also called popping beans, are native to Peru and have the unique ability to pop when heated at high temperature. This popping phenomenon is different from how popcorn pops but is similar in that the seed expands and is then eatable. Popping beans may be especially suitable as a snack for children in schools, where pulses must be served at ½ cup per student per week. Nuña beans are not available for production in the U.S. due to a lack of cultivar development and seed availability. Specific challenges for cultivar development include short-day flowering, vining growth habit, and susceptibility to diseases such as bean common mosaic virus (BCMV). Nuña beans could be a new crop for Washington and would be well-suited as a rotation crop as well as for programs such as farm to school. We are evaluating nuña beans for production in northwest Washington and will multiply seed for future studies.

Experimental field site. This field study is planted at Washington State University Mount Vernon Northwestern Washington Research and Extension Center (48°43'24" N, 122°39'09" W, elevation 6 m). The summer climate is cool and humid, with 59 °F average daily temperature, 52 °F average minimum and 73 °F average maximum temperature, and 83% average relative humidity (AgWeatherNet, 2018). In 2019, total precipitation was 9.23 in. from May to September, with 5.24 in. falling in September (Fig. 1). The soil is Skagit silt loam, a fine-silty mixed nonacid mesic Typic Fluvaquents (USDA, 2019), with 6.5 pH, 2.7% organic matter, and is drained with tile.

Seed sources. Sources of seed and 100-seed weight of the 10 entries planted at WSU Mount Vernon NWREC in 2019 are listed in Table 1, and seed are shown in Fig. 1. The entry from Central Bean Company is one of the advanced lines from Colorado (CO49957). Colorado lines have been bred to eliminate photoperiod so should be suitable for our northern latitude, though maturity may be a little late (Ogg, per. comm., 2019). Colorado seed was greenhouse grown, so is considered to be disease-free. Seed of all entries except the breeding lines from Oregon State University were sent to Amjad Ahmad, University of Hawaii, for a similar field study.

Planting. The field was disked twice, on 15 and 20 March, followed by chiseling on 28 March. Fertilizer (16-16-16 plus sulfur; Wilber Ellis, San Francisco, CA) was broadcast applied with a drop-spreader at a rate of 47 lbs of nitrogen per acre, and then incorporated with a cultipacker on 16 May. Rows were marked and seed was hand planted on 22 May. Spacing in the row was 4 in. and rows were spaced 34 in. center-to-center to provide tractor access for cultivation to control weeds (Fig. 3). For weed control, tractor cultivation was done between rows with both a double disc with sweeps (set to move soil away from the crop) and a 2-headed adjustable rototiller. The double disc was used on 6 June [15 days after planting (DAP)] while the rototiller was used on 12 and 28 June (21 DAP and 37 DAP, respectively). Rows were hand weeded in mid-June and early July. To reduce in-row weed pressure, both border rows and entries CO49956, CO49957, PO2, PO3, PO4, PO5 were hilled (2-3 in.) on 8 July (47 DAP) with 10-in. discs mounted on a cultivation tractor (Farmall Cub, Case/IH, Racine, WI). Other entries were not hilled as their semi-vining growth habit caused plants to become entangled in the tractor, pulling them out of the ground.

Although beans grown in the area generally are not irrigated, this study was irrigated to ensure good seed production. The exception was one border row of 'Eclipse' that was not irrigated as a comparison with irrigated 'Eclipse' in the other border row to assess impact of irrigation at this site. Rows were drip irrigated once per week for 3 hours per session, but irrigation was reduced to 2 hours during weeks that precipitation occurred. Irrigation was applied at 3137 gal per hr per acre. Irrigation was halted 7 August to allow plants and pods to dry before threshing.

Plant establishment and growth.

<u>Stand count</u> was measured on 13 and 20 June, and on average was 25 plants per 10-ft row (83% establishment), and ranged from 21 to 29 plants on 13 June, and 20 to 28 plants on 20 June (Table 2). Loss of plants was likely due to birds feeding on seedlings.

<u>Growth habit</u> was assessed on 12 July for each entry, following Singh (1991) and Debouck and Hidalgo (1986) (Figs. 4 & 5). Type I determinate bean plant has branches and stems that terminate in flowering points, and Type IA is bush-like whereas Type IB appears vining due to long internode length at the top of the plant. Type II indeterminate bean plant has an upright structure that ends in a short vegetative growing point. Type III indeterminate prostrate bean plant has a prostrate growth habit with more vegetative side-branching and longer terminal growing point. Type IV indeterminate climbing bean plant has vigorous climbing growth.

All nuña bean entries in this study have Type I growth habit, with four entries Type IA and six entries Type IB, and 'Eclipse' dry bean has Type II growth habit (Table 2, Fig. 6). Plant growth habit impacts mechanical cultivation practices as it is not possible to drive down the rows without catching and damaging plants after plants begin to develop vining-type growth. For example we were not able to cultivate the field 8 July onwards (47 days after planting).

<u>Fifty percent flowering</u> was recorded for each entry when half of the plants within the 10-ft data area had at least one open flower. First flowering began on 9 July and 50% flowering occurred from 11 to 18 July, 50-57 DAP (Table 2).

<u>Plant height</u> was measured on 26 July for 10 randomly-selected plants within the 10-ft data area, when all entries had reached 100% flowering. Height was measured from the base of the plant to the top node by straightening the plant (Fig. 7). Plant height was 51 cm on average for all entries, and the range for nuña entries was 29-56 cm while 'Eclipse' was 49 cm on average for irrigated and non-irrigated. To assess the amount of vining-type growth, the length of the longest internode near the top of the plant was measured for 10 randomly selected representative plants within the 10-ft data area (Fig. 8). Internode length was 15.3 cm on

average for all entries, and the range for nuña entries was 11-20 cm while 'Eclipse' was 14 cm on average for irrigated and non-irrigated.

Micronutrient deficiency symptoms appeared on plants in all plots in mid-July. Leaves were bright green with slight bronzing and dark veins (Fig. 9). On 23 July, micronutrient fertilizer (Organic Biolink 0N-0P-1K-2Fe-2Mn-3Zn; Westbridge Agricultural Products, Vista, CA) was applied to all plots as a foliar spray at the label rate of 15 mL/gallon with a 4-gallon handpump backpack sprayer. Walking at 3 mph, a total of 5 gallons of spray mix was applied. Plants were sprayed from both sides of the row to attain good coverage.

Pest identification was done 12 July when black bean aphids (*Aphis fabae*) were found on plants in the field (Fig. 10). Lady beetles were also found on the plants, and as they are known predators of aphids, no pesticides were applied.

Harvest of the 10-ft data area of each entry was by hand on 25 September. It rained much of September (Fig. 1) so that plants/pods did not adequately dry in the field. All entries were sufficiently mature by the end of September, and leaving plants in the field under rainy conditions was leading to pod loss due to sprouting, thus we harvested all entries at the same time. Plants from the 10-ft data areas of each entry were placed in a burlap sack (Fig. 11) and dried at 99 °F for 48 h or until the stems snapped and bean seed moisture content was approximately 12%.

We had expected to combine the remaining plants of each entry that we need for seed multiplication, but plants were not sufficiently dry to combine (our combine also happened to be broken down at this time, but that was a separate issue). Thus we harvested all the remaining plants by hand, placed them in wire orchard bins (1 bin per entry), placed bins in a pole barn with fans (Fig. 12), then using burlap bags we dried the whole plants in the dryer for at least 48 hours such that we were able to get all the plants into the dryer within 4 days of harvest. We have limited dryer capacity and this is a lot of work, so something to consider for production in our region.

Threshing was done by feeding whole dry plants through a chipper-mulcher (Model 500; Roto-Hoe, Newbury, OH, USA) that we had converted to a small-scale standing thresher (Fig. 13) (Miles, 2013). The large debris was removed, and beans were separated from small debris with a small-scale standing cleaner that we built (Fig. 13) (Miles, 2013). Beans were then sorted by hand, and moldy, split and immature beans were removed. The marketable yield and weight of 100 representative beans were recorded for each entry.

Yield was measured for 10-ft row of each entry. All harvested beans were weighed, then beans were sorted and split and moldy beans were discarded, and seed-quality beans were weighed. Total weight of harvested seed was 598 g on average for popping bean entries, and ranged from 451 g (PO5) to 834 g (CO49957-Central Bean) (Table 3). Total weight of 'Eclipse' seed was 866 g on average. Amount of discarded beans ranged from 8-46% for popping bean entries and was 1-3% for 'Eclipse'. Weight of 100 beans was 43 g on average for popping bean entries, and ranged from 36.41 g (PO2) to 55.67 g (CO49957). Weight of 100 beans of 'Eclipse' seed was 20 g on average. For popping bean entries, 1410 seed were harvested on average, and ranged from 1105 (CO49957) to 1779 (CO49956). For 'Eclipse', 4288 seed were harvested on average.

Popping potential or swell ratio will be measured for each entry in January.

Protein Content

This information is provided by Jim Heitholt and Jill Keith, University of Wyoming, and applies specifically to CO49957:

¼ C = 48 popped beans
Weight per seed is 439 mg, ~21 g of dry weight per ¼ C
22% protein on average = 4.6 g protein per ¼ C

Theoretical calculation of protein per ¼ C
700 mL of uncooked seed = 653.2 g
700 mL = 2.96 cup; thus, 221 g of beans per 1 C
221 g x 0.22 (% protein conversion) = 48.6 g protein per 1 C = 12.15 g protein per ¼ C / 2.62 swell rate = 4.64 g protein

Swell ratio
2.62 - that is, 1.0 volume of dry beans converts to 2.62 volumes after popping

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Table 1. Nuñ̃a bean seed sources, seed weight and total number of seed planted at WSU Mount Vernon NWREC in 2019.

Source	Entry/Line	Total Wt (g)	100 Seed Wt (g)	No. Seed
Barry Ogg	1. CO 49956	250.72	53.70	467
Colorado State Univ.	2. CO 49957	250.65	68.85	364
Tom Grebb	1. CO49957	454.25	48.29	941
Central Bean Co., Inc.				
James Nienhuis	1. Nuna 17	241	47.55	507
UW Horticulture	2. Nuna 20	282.08	39.26	718
	3. Nuna 23	332.25	33.96	978
Jim Myers	1. PO2	35.71	34.54	103
Oregon State Univ.	2. PO3	28.59	28.59	100
	3. PO4	32.22	31.88	101
	4. PO5	33.12	32.87	101

Table 2. Stand count of nuñ̃a beans in 10-ft of row 29 days after planting (DAP, 20 June), 50% flowering date and DAP, plant height (cm) and length of top node at 57 DAP, and growth habit type based on observations 12 July at WSU Mount Vernon NWREC in 2019.

	Stand Count		50% Flowering[1]		Plant Ht	Node Lth	Growth
Entry	20-Jun	%	Date	DAP	(cm)[2]	(cm)[3]	Habit[4]
CO 49956	25	83	12-Jul	51	56	17	IB
CO49957	23	77	12-Jul	51	64	17	IB
CO49957 Central Bean	26	87	13-Jul	52	57	16	IB
Nuna 17	25	83	15-Jul	54	68	20	IB
Nuna 20	28	93	11-Jul	50	39	14	IA
Nuna 23	26	87	11-Jul	50	50	12	IA
PO5	24	80	13-Jul	52	40	11	IB
PO4	28	93	13-Jul	52	46	15	IB
PO3	24	80	13-Jul	52	48	15	IA
PO2	24	80	13-Jul	52	44	16	IA
Eclipse (Irrig.)	28	93	18-Jul	57	52	7	II
Eclipse (Non-irrig.)	20	67	18-Jul	57	46	7	II

[1] 50% flowering was recorded when half the plants in the 10-ft data area had at least one open flower.

[2] Plant height was measured for 10 randomly selected representative plants in the 10-ft data area, from the base of the plant to the top node, with the plant straightened.

[3] Node length was measured for 10 randomly selected representative plants in the 10-ft data area, for the longest node near the top of the plant.

[4] Growth habit Types I – IV (Singh, 1991), where IA is bush-type, IB has elongated top internode(s), and Type II is indeterminate but upright, ending in short vegetative growing point.

Table 3. Weight (g) of total beans harvested (included split and moldy beans), seed-quality beans, and 100 beans in 2019 at WSU Mount Vernon NWREC.

Entry	T Bean Wt (g)	T Seed Wt (g)	100 Bean Wt (g)	No. Seed
CO49956	802.85	744.82	41.87	1779
CO49957	799.66	615.05	55.67	1105
CO49957 Central Bean	970.66	834.13	50.33	1657
Nuna 17	842.73	576.99	51.75	1115
Nuna 20	582.85	503.21	45.13	1115
Nuna 23	798.17	641.5	42.22	1519
PO2	567.03	514.76	36.41	1414
PO3	532.36	494.44	34.60	1429
PO4	701.12	605.88	35.25	1719
PO5	509.22	450.52	36.21	1244
Eclipse (Irrig.)	824.48	819.27	20.32	4032
Eclipse (Non-irrig.)	938.11	912.08	20.07	4544

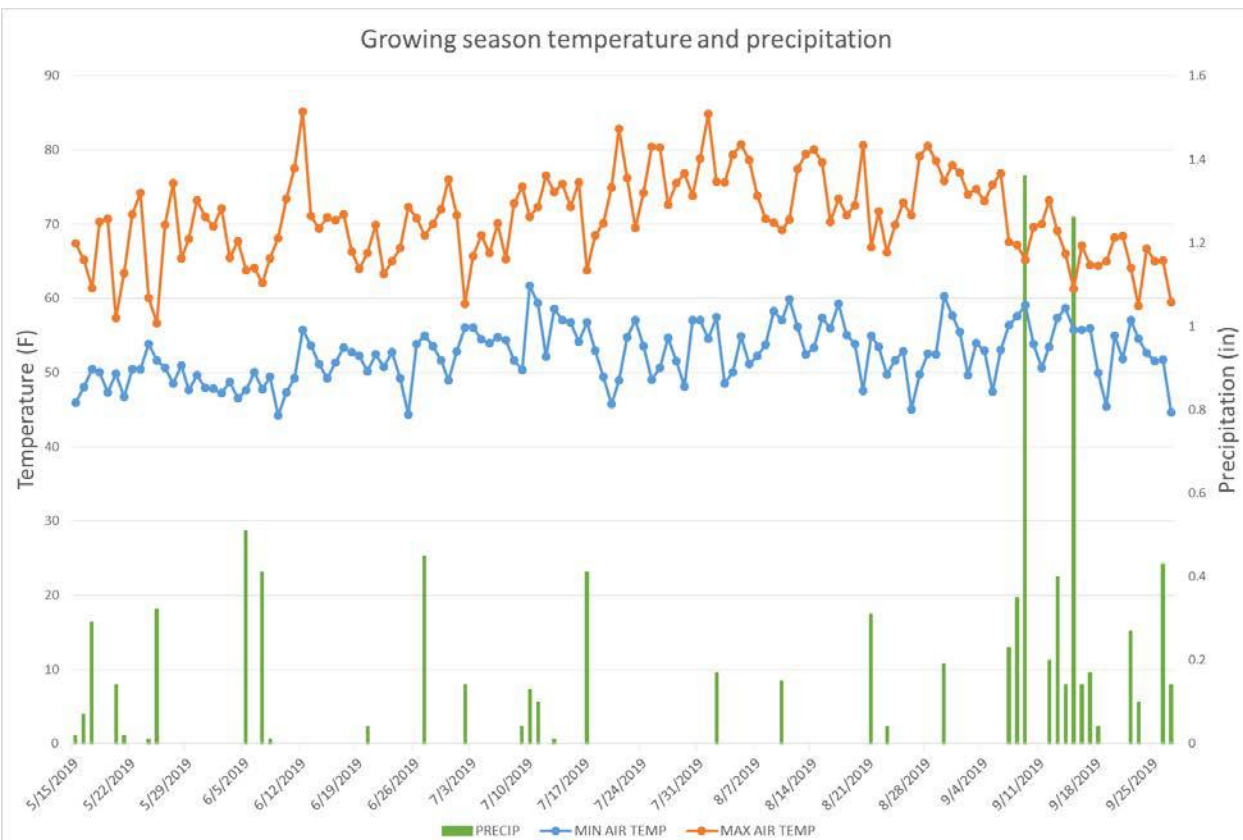

Figure 1. Minimum and maximum air temperature (°F), and precipitation (in.) at WSU Mount Vernon NWREC during the 2019 growing season.

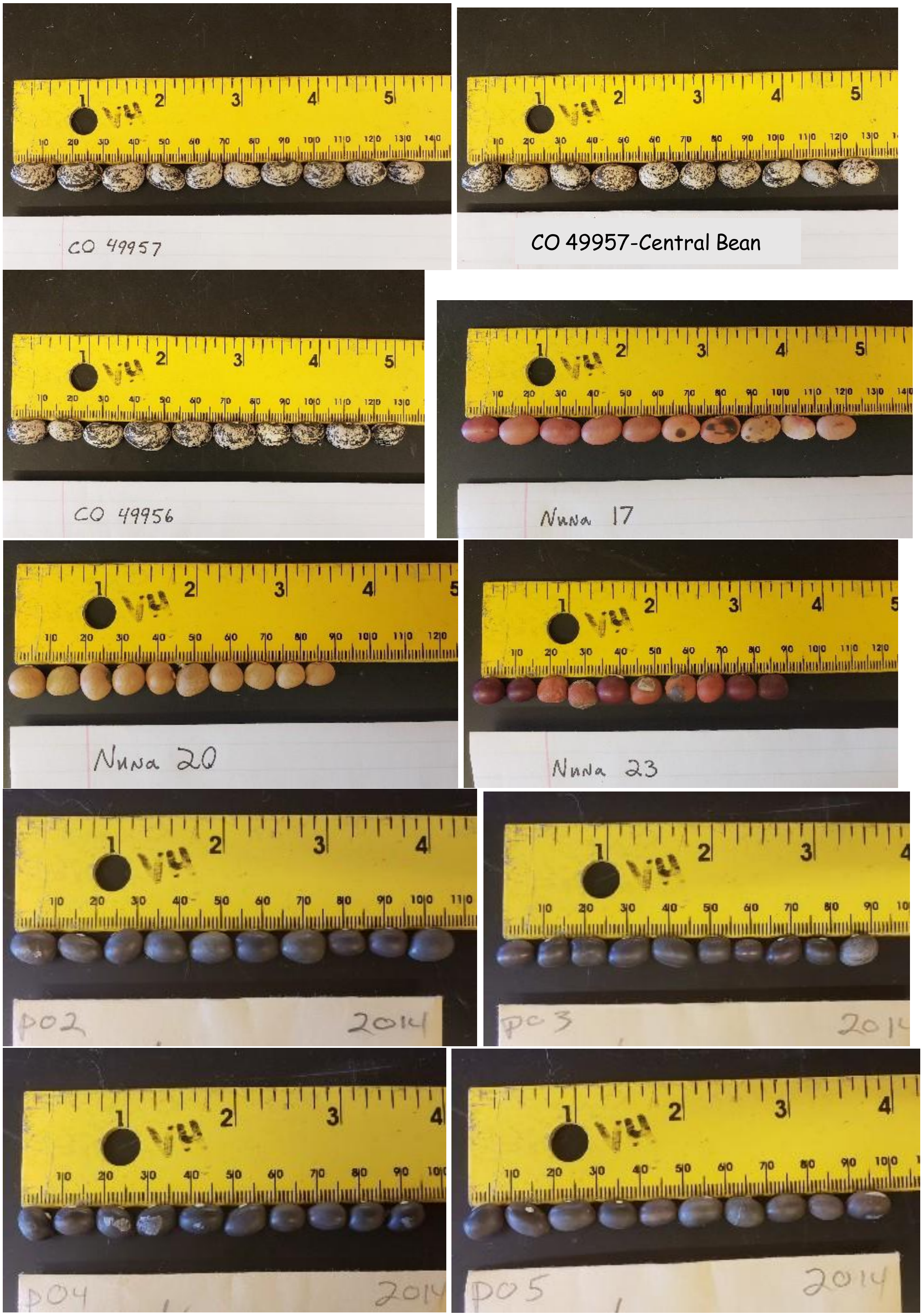

Figure 2. Seed of each advanced nuña bean breeding line planted at WSU NWREC in 2019.

Figure 3. Nuña bean plots on 28 June, 23 July and 25 September at WSU Mount Vernon NWREC.

Table 1. A key for identification of the principal growth habits of dry beans, *Phaseolus vulgaris* L.

a Growth habit	b Terminal bud	c Growth	d Stem and branch strength	e Terminal guide	f Climbing ability	g Pod load distribution	Examples
Type I	Repro-ductive	Deter-minate	Strong, upright	Absent or small	Absent or weak climber	Along the length	Sanilac, Canario 101, Calima, Pompadour Checa, Alubia Cerrillos INTA
Type II	Vegeta-tive	Indeter-minate	Strong, upright	Absent or small twining	Absent or weak climber	Along the length	Midnight, Porrillo Sintético, ICA Pijao, Jamapa, Rio Tibagi
Type III	Vegeta-tive	Indeter-minate	Weak, open or prostrate	Small or medium, twining	Weak or facultative climber	Concentrated in the basal portion	Pinto UI114, Flor de Mayo, Zamorano 2, Carioca, Cocacho
Type IV	Vegeta-tive	Indeter-minate	Very weak, twining	Very large, twining	Strong climber	Along the length or concentrated in the upper portion	Garbancillo Zarco, San Martín, Cargamanto, Bola Roja, Caballeros

NOTE: 1. For growth habit identification the first evaluation needs to be made during flowering and the final evaluation 3 to 4 weeks later.

2. The type of terminal bud separates growth habit I (reproductive) from other three indeterminate types (vegetative). The strength of stem and branches separates type II (strong and upright) from other indeterminate growth habits (weak, prostrate or twining). It is the combination of characters e, f, and g which separates type III from growth habit IV. For evaluation of the latter two types varieties need to be grown with and without support.

3. Types I, II and III do not require support and their grain yield is much higher in monoculture than with intercroppping.

Figure 4. Bean growth types I-IV from Singh (1991).

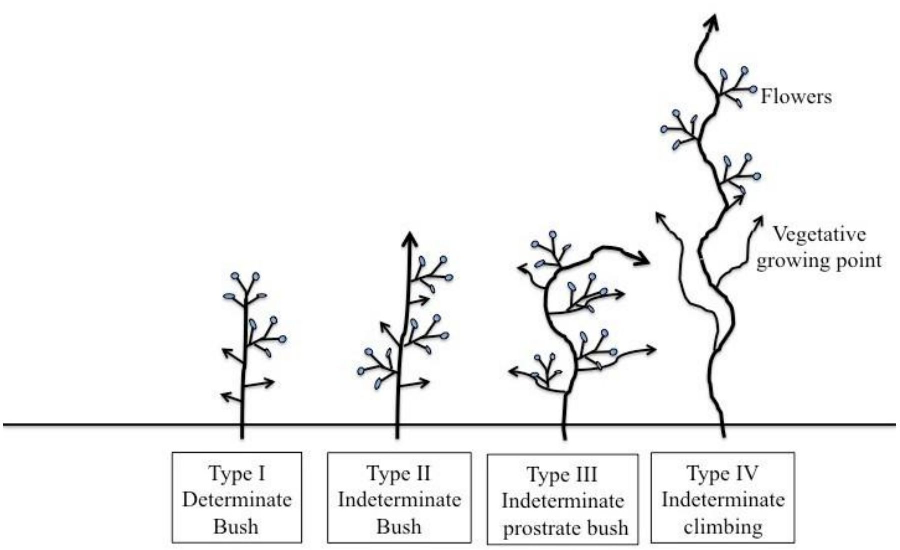

Figure 5. Four primary dry bean growth habits. Diagram adapted from *Morphology of the Common Bean Plant* (*Phaseolus vulgaris*) (Debouck and Hidalgo 1986).

Figure 6. Nuña beans with Type IA (left) and Type IB (center) growth habit, and 'Eclipse' dry bean with Type II growth habit (right), at WSU Mount Vernon NWREC on 12 July.

Figure 7. Measuring plant height of nuña beans (left) and 'Eclipse' (right).

Figure 8. Measuring the length of the longest internode near the top of the plant on 26 July.

Figure 9. Nuña bean plants showing possible symptoms of micronutrient nutrient deficiency: dark veins with bright green leaves, and slight bronzing of leaf tissue.

Figure 10. Black bean aphids on underside of nuña bean leaves (left) and lady beetle, a known aphid predator, on neighboring leaf (right).

Figure 11. Whole nuña bean plants harvested from data area (10-ft row) of each plot by cutting plant at the soil line and placing in a burlap bag.

Figure 12. Whole nuña bean plants bulked for remainder of each plot and drying in wire bins with fans in a pole barn at WSU NWREC for no more than 4 days after harvest (left). Burlap bags filled with plants from each plot drying in ovens (99 ^{o}F) at WSU NWREC for at least 48 hours.

Figure 13. Small-scale thresher (left) and seed cleaner (right) used at WSU Mount Vernon NWREC.