# TECHNICAL NOTES

**U.S. Department of Agriculture** **Natural Resources Conservation Service**

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## Big Pine Paiute Tribe Conservation Field Trial Study

### The Edible Corm Plant, Nahavita, *Dichelostemma capitatum* (Benth.) Alph. Wood: Source Population Adaptation and Vegetative Reproduction Response

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## Background and Objectives

### Background

The underground plant parts harvested historically by the Big Pine Paiute Tribe for foods include bulbs, tubers, and corms (aka "geophytes"). These are often termed "root crops" or "Indian potatoes" in the local vernacular. These underground plant structures provide an important starch and protein component of the Indian diet. "Indian potatoes" gathered by the Big Pine Paiute Tribe include Nahavita (aka bluedicks) (*Dichelostemma capitatum* (Benth.) Alph. Wood ssp. *capitatum*) (Figure 1), and taboose (aka yellow nutsedge) (*Cyperus esculentus* L. var. *esculentus* L.).


**Figure 1. A. Nahavita plants harvested by a traditional tribal digging stick. B. Floral display of Nahavita. C. Nahavita corms. Photos by M. Kat Anderson (A and C), and USDA-PLANTS database (B).**

Some traditional subsistence geophytic plant foods for California Indians from archaeological time to the recent past are declining in abundance in the areas where Indians used to gather them. As an example, Nahavita once covered California valleys and hills with tints of blue and purple, and it was gathered for its edible corm by over half of California's Indian tribes (Anderson 1997; Schmidt 1980).

### Objectives

Little is known about the ecological impacts of indigenous harvesting of Nahavita. Similarly, the feasibility of translocation of Nahavita corms to non-native sites for local management and production for tribal members has not been studied. Native tribes often assert that the moderate removal of underground plant parts can stimulate bulb and corm production, actually increasing the size and density of a population of these plants (Anderson 1997).

In order to address these issues, a Conservation Field Trial (CFT) was installed on the Big Pine Paiute Reservation involving two primary components: (1) collection and documentation of native Nahavita corms from multiple source populations (i.e., accessions); and (2) a replicated experimental study using these source materials to examine impact of transplantation on corm establishment, survival, and productivity. The objectives of the CFT were to determine: 1) whether the quantity and quality of corm and cormlet production of Nahavita are affected by source population genetics; and 2) the degree to which differences in intensity of harvest, with and without replanting of cormlets, have any effect on size of corms and cormlet production.

## Project Sponsors

- Big Pine Paiute Tribe of the Owens Valley, Big Pine Paiute Indian Reservation, Big Pine, CA (BPPT)
- Inyo-Mono Resource Conservation District (IMRCD)
- Natural Resources Conservation Service, Bishop Field Office (NRCS)
- California Plant Materials Center, NRCS, Lockeford, CA (CAPMC)

## Project Cooperators

- Yribarren Ranch, Big Pine, CA (YR)
- Inyo and Mono Counties, University of California Cooperative Extension, Bishop, CA (UCCE)
- Bureau of Land Management, Bishop Field Office, Bishop, CA (BLM)
- US Forest Service, Inyo National Forest, Bishop, CA (USFS)
- Desert Mountain Resource Conservation & Development Council, Ridgecrest, CA (RC&D)
- National Ethnoecology Office, Natural Resources Conservation Service and University of California, Davis, CA (NEO)
- California Native Plant Society, Bristlecone Chapter, Bishop, CA (CNPS)

## Site Information

### Conservation Field Trial Study Site Selection

A common garden site on the BPPT Reservation was selected for the study, immediately north of the Tribal Office and west of U.S. Highway 395 (Figure 2). Specific location information is:

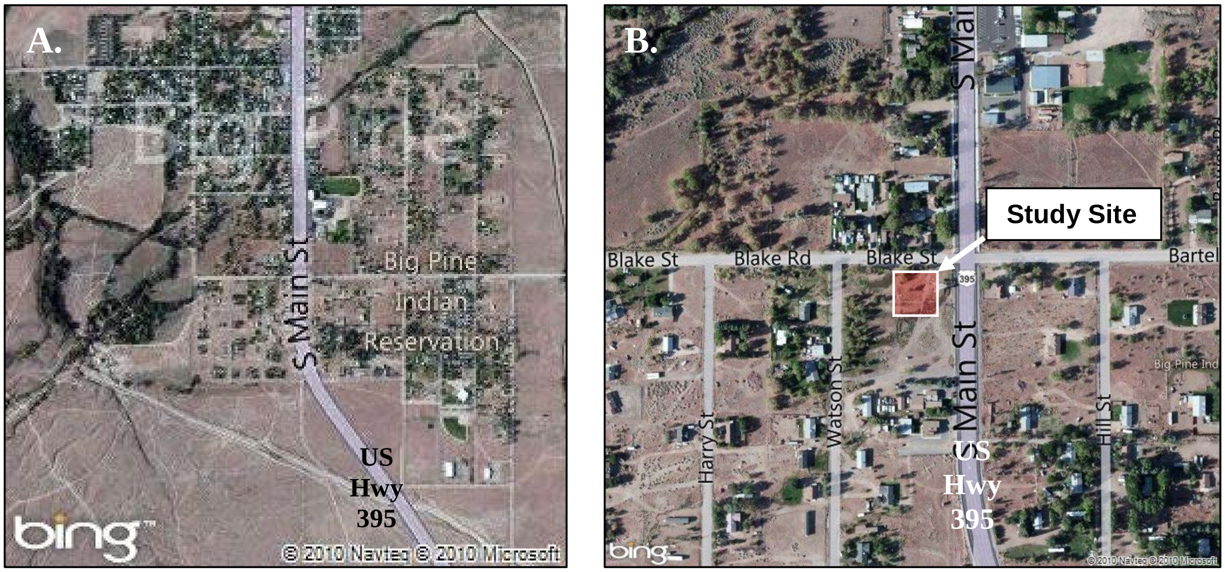


**Figure 2. Study site location, Big Pine Paiute Tribe Conservation Field Trial Study, Big Pine, CA. A. Overview of Big Pine, California and Big Pine Paiute Indian Reservation; B. Specific location of the study site within the reservation.**

Lat / Long: 37.1593ºN, 118.2859ºW
UTM Zone 11: 385823E, 4113318N
HUC: Crowley Lake 18090102

NE ¼ NE ¼, Section 19, T.9S., R.34E.
Elevation: 3,994 feet (1,217 meters)
Big Pine 7.5 minute quad series

### Source Populations and Collection Sites

Nahavita corms were collected from three field sites (Figure 3) to serve as source accessions for testing and comparison of 1) adaptation to BPPT Reservation soils on which future, larger-scale production of corms as a tribal food source would occur; and 2) response to corm harvest intensities in terms of establishment, survival and productivity via traditional tribal digging practices.

Based on extensive field site assessments throughout the Inyo County region, three locales were identified with significant populations of Nahavita corms. These sites were targeted for collection of corms for the CFT study, with collection occurring June 21-22, 2011. Table 1 provides a summary of collection site physical, biological, and ecological parameters for the Nahavita corm accessions.

Corms were collected by digging, using shovels or by hand, with collected corms placed in paper sacks for subsequent measuring and dry storage. A consistent trend among the collection sites was the occurrence of the vast majority of the corms directly under the canopy and in close proximity to the root crown of mature native shrubs. Antelope bitterbrush (*Purshia tridentata*) comprised the predominant shrub canopy for the Buttermilk and Pinyon Canyon sites, while canopies of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) were characteristic for the Symmes Creek site.

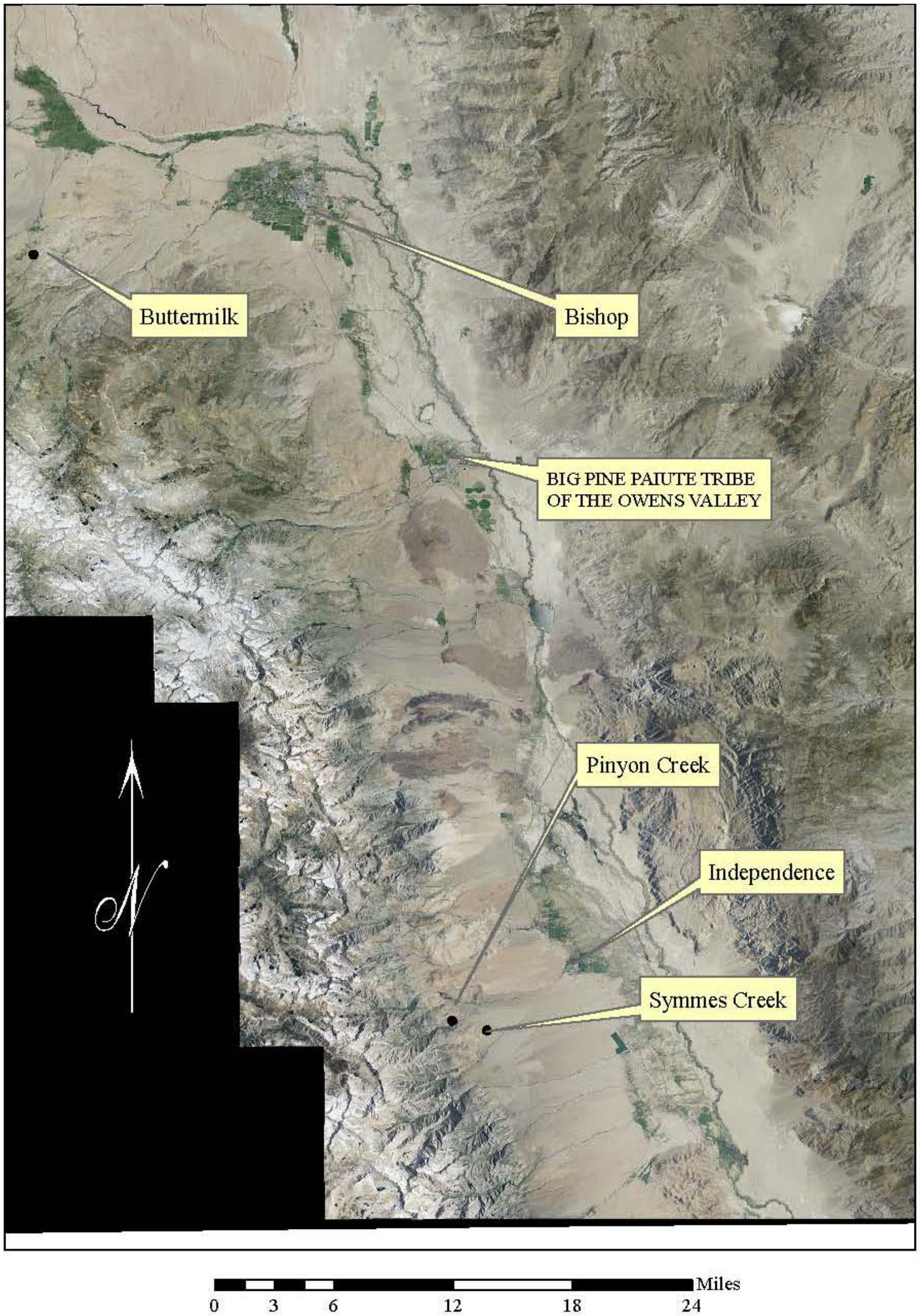


**Figure 3. Ecogeographical collection site locations for Nahavita corms from the three field source populations – Buttermilk, Pinyon Creek, and Symmes Creek - with reference to the regional communities of Bishop, Big Pine (Paiute Tribal Headquarters), and Independence, California. Individual collection site descriptions are summarized in Table 1.**

**Table 1. Summary of collection site physical, biological, and ecological parameters for the Nahavita corm collections (accessions) constituting the Big Pine Paiute Tribe Conservation Field Trial study.**

| | COLLECTION SITE | | |
|---|---|---|---|
| **PARAMETER** | **BUTTERMILK** | **PINYON CREEK** | **SYMMES CREEK** |
| Collection Date | June 20, 2011 | June 21, 2011 | June 21, 2011 |
| County | Inyo 6027 | Inyo 6027 | Inyo 6027 |
| Locale | McGee Creek Drainage, West of Tungsten Hills | Lime Canyon Mouth near Lower Grays Meadow | Symmes Creek Campground near Pinyon Creek Mouth |
| GPS Coordinates (UTM Zone 11) | 359069E, 4131718N | 385266E, 4069577N | 387519E, 4068765N |
| Latitude, Longitude | 37.3214ºN, 118.5906ºW | 36.7650ºN, 118.2855ºW | 36.7580º, 118.2602ºW |
| Legal (Mt. Diablo Meridian) | Section 20, T7S, R31E | Section 33, T13S, R34E | Section 34, T13S, R34E |
| Topographic Quad (7.5’ Series) | Tungsten Hills | Kearsarge Peak | Kearsarge Peak |
| Collection Site Elevation | 6,794 feet (2,071 m) | 5,984 feet (1,824 m) | 5,204 feet (1,586 m) |
| Slope Range | 3-6% | 14% | 7% |
| Aspect | N-NE | NE | SE |
| Annual Precipitation Range | 10-12 inches (25-30 cm) | 8-10 inches (20-25 cm) | 6-8 inches (15-20 cm) |
| Population Size | Uniformly distributed throughout ~160 acres (65 ha); populations aggregated under PUTR cover. | Random distribution; smaller aggregations on ~10 acres (4 ha); populations aggregated under ARTRW8 cover. | Random distribution; smaller aggregations on ~50 acres (20 ha); populations aggregated under ARTRW8 cover. |
| Mean Corm Diameter | 0.57 inch (1.44 cm) | 0.54 inch (1.36 cm) | 0.50 inch (1.27 cm) |
| Mean Corm Weight | 1.45 grams | 1.11 grams | 0.99 grams |
| Mean Corm Depth | 6-8 inches (15-20 cm) | 4-6 inches (10-15 cm) | 4 inches (10 cm) |
| Mean Corm Density: | 100-200 corms per aggregation | 50-60 corms per aggregation | 20-30 corms per aggregation |
| Number collected | 728 | 558 | 453 |
| Mean Number of Stems | None | Rare to None | Rare to None |
| Mean Stem Height | None | 30 inches (76 cm) | 30 inches (76 cm) |
| Mean Canopy Cover | None | 1% | 1% |
| Mean Flower Maturity | Fully senesced | Fully senesced | Fully senesced |

**Table 1 (continued). Summary of collection site physical, biological, and ecological parameters for the Nahavita corm collections (accessions) constituting the Big Pine Paiute Tribe Conservation Field Trial study.**

| | | COLLECTION SITE | | |
|---|---|---|---|---|
| | | BUTTERMILK | PINYON CREEK | SYMMES CREEK |
| **Associated Plant Community [1]** | **Plant Symbol [1]** | | | |
| Antelope bitterbrush (*Purshia tridentata*) | **PUTR2** | 60% | 45% | 15% |
| Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) | **ARTRW8** | 20% | 23% | 75% |
| Mormon tea (*Ephedra viridis*) | **EPVI** | -- | 25% | 3% |
| Rabbitbrush (*Chrysothamnus* spp.) | **CHRYS9** | 13% | T | 1% |
| Spineless horsebrush (*Tetradymia canescens*) | **TECA2** | -- | T | T |
| Anderson wolfberry (*Lycium andersonii*) | **LYAN** | -- | 1% | -- |
| Squirreltail (*Elymus elymoides*) | **ELELC2** | 1% | 2% | 1% |
| Indian ricegrass (*Achnatherum hymenoides*) | **ACHY** | 1% | T | -- |
| Twoneedle pinon (*Pinus edulis*) | **PIED** | 1% | -- | -- |
| California juniper (*Juniperus californica*) | **JUCA7** | -- | T | -- |
| California phacelia (*Phacelia californica*) | **PHCA** | T | -- | -- |
| Cheatgrass (*Bromus tectorum*) | **BRTE** | 2% | 1% | 3% |
| Menzies' fiddleneck (*Amsinckia menziesii*) | **AMME** | T | -- | -- |
| Buckwheat (*Eriogonum* spp.) | **ERIOG** | T | -- | -- |
| Foothill needlegrass (*Nassella lepida*) | **NALE2** | -- | 1% | T |
| Unknown Forbs | **UNK-F** | 2% | 3% | 2% |

[1] **Nomenclature from: USDA, NRCS. 2013. The PLANTS Database (http://plants.usda.gov, 25 August 2013). National Plant Data Team, Greensboro, NC 27401-4901 USA.**

## Vegetation Type

Existing vegetation within the proposed BPPT experimental study footprint (Figure 2) was comprised of exotic annual and perennial grasses and annual broadleaf weeds, with near 100% cover. Dominant species within this plant composition included bermudagrass (*Cynodon dactylon*), cheatgrass (*Bromus tectorum*), wild mustard (*Brassica* spp.), puncturevine (*Tribulus terrestris*), and other minor forb components.

The associated plant community on each of the three field collection sites (Table 1) is characterized by dominance of native shrubs over a mixed native grass and forb herbaceous understory.

Differences in corm size and weight were apparent between the collection sites. Descriptive statistics (MicroSoft Excel™ Descriptive Statistics) for each accession in relation to corm diameter and corm weight are summarized in Table 2. Corms from the Buttermilk collection site were larger in both diameter and weight. However, variability within these parameters was also higher, indicating a wider range of diameters and weights encountered in this accession. In contrast, corms collected from the Pinyon Creek and Symmes Creek sites, while smaller in diameter and weight, were consistently more uniform within a collection site, with smaller ranges and variability.

### Corm Size Stratification

Corms varied in size, depending upon stage of maturity and natural site growth conditions, even within a source population. In order to determine if initial planted corm size influences survival and productivity, corms were stratified within each accession based on evaluation of 1) natural break points between size segments; and 2) adequate sample sizes for each stratification level such that a minimum required number of corms for each treatment combination was satisfied. Stratification break points were similar between accessions, with size classes (based on corm diameter) designated at < 1.0 cm ("small"), 1.0-1.5 cm ("medium"), and >1.5 cm ("large"). Physical assignment of corms to each size classification was conducted using a pre-formed plastic template containing circular holes corresponding to the diameter dimensions for each respective corm size. These size classes were then assigned randomly to each accession / harvest intensity treatment combination.

**Table 2. Descriptive statistics for Nahavita corm diameter and corm weight from the three field collection sites (source population accessions).**

| | CORM DIAMETER (cm) | | | CORM WEIGHT (grams) | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **Buttermilk** | **Pinyon Creek** | **Symmes Creek** | **Buttermilk** | **Pinyon Creek** | **Symmes Creek** |
| **Mean (µ)** | 1.44 | 1.36 | 1.27 | 1.45 | 1.11 | 0.99 |
| **Standard Error of the Mean (SE)** | 0.018 | 0.016 | 0.014 | 0.046 | 0.038 | 0.028 |
| **Median** | 1.4 | 1.3 | 1.3 | 1.2 | 0.9 | 0.9 |
| **Range** | 2.5 | 2.4 | 1.6 | 8.7 | 6.9 | 3.9 |
| **Minimum** | 0.6 | 0.4 | 0.6 | 0.1 | 0.1 | 0.1 |
| **Maximum** | 3.1 | 2.8 | 2.2 | 8.8 | 7.0 | 4.0 |
| **Count** | 728 | 558 | 453 | 728 | 558 | 453 |
| **95% Confidence Level** | 0.035 | 0.032 | 0.027 | 0.090 | 0.075 | 0.055 |

### Soils

#### *Conservation Field Trial Study Site*

Soils for the study site are comprised of the 210 Hesperia-Cartago complex on 0-1% slopes (Soil Survey of Benton-Owens Valley Area, California, Parts of Inyo and Mono Counties; http://soildatamart.nrcs.usda.gov/Manuscripts/CA802/0/Benton_OwensValley_CA.pdf). The majority (65%) of this complex is comprised of Hesperia sandy loam, which is characteristic of the study site. These soils are alluvial in derivation, developing from granitic alluvial outflow onto lower-elevation back slope and tread positions from the Sierra Nevada mountains to the immediate west. This soil provides a growth medium that is typically well drained with moderate available water capacity, low $CaCO_3$ content, and no frequency of flooding or ponding. Irrigated land capability classification is 2s, and the soil series corresponds to the "Loamy 5-8 inch precipitation zone" ecological site association (R029XG017CA).

#### *Source Population Collection Sites*

Additional, site-specific soil sampling was conducted on the Big Pine Paiute Tribal Headquarters study site and the three field collection sites for the Nahavita corm source populations, in order to augment and refine information from the published NRCS Soil Survey. As noted in Table 3, soil samples obtained from the three collection sites (Buttermilk, Pinyon Creek, Symmes Creek) were similar to soil samples obtained from the tribal headquarters study site (analysis by Dellavalle Laboratory, Inc., Fresno, CA). Any differences were considered negligible, however, and within safe and similar plant growth requirements for the Nahavita corms.

As previously noted, a trend among the collection sites was the occurrence of the majority of the corms originating under the canopies of antelope bitterbrush and Wyoming big sagebrush for the Buttermilk / Pinyon Creek and Symmes Creek sites, respectively. It was postulated that this phenomenon resulted from 1) higher soil organic matter accumulated under the shrub canopy overstory as a result of annual leaf fall and decomposition, providing an enriched nutrient and soil moisture retention environment for the corms; or 2) the presence of shrub canopies and root crown bases providing micro-catchment areas for increased Nahavita seed accumulation; or 3) shading effect afforded by this canopy, providing a higher soil moisture environment for corm growth; or 4) some combination of the above. As a result, soils from each of the collection sites were pair-sampled, obtained from under the canopies of bitterbrush and/or Wyoming big sagebrush, and also obtained external to those canopies in open soil areas.

## Methodology

### General

Corm planting and all other aspects of study installation were completed October 3-6, 2011. The study site impacted about 0.04 acres and included buffer / access lanes established between individual plots, between replications, and surrounding the entire study inside the perimeter fence.

**Table 3. Soils analysis of composited samples from the BPPT study site and the three Nahavita corm collection sites (Buttermilk, Pinon Creek, Symmes Creek) (obtained August 16-17, 2011).**

DELLAVALLE Laboratory, Inc.
Chemists and Consultants

**Report of Soil Analysis**

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FAX (559) 268-8174 - (800) 228-9896 - (559) 233-6129

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270 See Vee Lane
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Lab No. 162500
Sampled 8/16/11
Submitted 8/31/11
Submitted by K. Lair
Reported 9/15/2011
Job/Ranch/Site BPPT-CFT
Copy To Kenneth D. Lair kenneth.lair@ca.usda.gov
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Additional e-mail robert.pearce@ca.usda.gov

| No. | Description | % SP[1] | pHs | EC dS/m | meq/l Ca | meq/l Mg | meq/l Na | meq/l Cl | % ESP | T/ac-6" GR Hndbk | lbs/ac-6" Lime Req | +\- Lime Hndbk | mg/l B | mg/kg $NO_3$-N | mg/kg $PO_4$-P | mg/kg K (AA) | mg/kg K $H_2SO_4$ | mg/kg Zn | mg/kg Mn | mg/kg Fe | mg/kg Cu | % OM LOI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Methods | S1.00 | S1.10 | S1.20 | S1.60 | S1.60 | S1.60 | S1.40 | Calc. | 60-22d | S2.50 | 60-23a | S1.50 | S3.10 | S4.10 | S5.10 | SSSA | S6.10 | S6.10 | S6.10 | S6.10 | S9.20 |
| 1 | BPPT-COMPOSITE=0-8" | 22 | 7.2 | 0.54 | 3.7 | 0.9 | 0.6 | | <0.1 | | | - | 0.1 | 2 | 17 | 98 | | 0.1 | 6.4 | 45.5 | 0.6 | 1.06 |
| 2 | BPPT-PINON-PUTR=0-6" | 34 | 7.1 | 2.63 | 16.0 | 5.1 | 0.5 | | <0.1 | | | - | 1.4 | 29 | 28 | 148 | | 1.5 | 25.9 | 15.6 | 0.3 | 2.47 |
| 3 | BPPT-PINON-OPEN=0-6" | 26 | 7.2 | 1.68 | 8.5 | 4.3 | 0.4 | | <0.1 | | | - | 1.2 | 7 | 23 | 265 | | 1.7 | 21.5 | 14.1 | 0.3 | 1.45 |
| 4 | BPPT-SYMMES-PUTR=0-6" | 22 | 7.3 | 0.29 | 1.8 | 0.6 | 0.3 | | <0.1 | | | - | 0.2 | 2 | 11 | 110 | | 1.3 | 8.4 | 11.4 | 0.3 | 0.78 |
| 5 | BPPT-SYMMES-OPEN=0-6" | 24 | 7.1 | 0.40 | 3.5 | 0.7 | 0.3 | | <0.1 | | | - | 0.1 | 1 | 13 | 82 | | 0.6 | 5.8 | 11.4 | 0.3 | 1.87 |
| 6 | BPPT-BUTTERMILK-PUTR=0-6" | 28 | 7.4 | 0.61 | 4.4 | 1.5 | 0.2 | | <0.1 | | | - | 0.6 | 9 | 26 | 170 | | 1.6 | 8.3 | 22.0 | 0.3 | 0.76 |
| 7 | BPPT-BUTTERMILK-OPEN=0-6" | 26 | 6.9 | 0.49 | 2.9 | 1.1 | 0.3 | | <0.1 | | | - | 0.4 | 2 | 12 | 95 | | 1.1 | 6.6 | 20.0 | 0.3 | 20.28 |
| 8 | BPPT-BUTTERMILK-PUTR LITTER | | | | | | | | | | | | | | | | | | | | | 0.51 |

| No. | Description | Ammonium Acetate Extractable Cations mg/kg Ca | mg/kg Mg | mg/kg Na | Ammonium Acetate Extractable Cations meq/100g Ca | meq/100g Mg | meq/100g Na |
|---|---|---|---|---|---|---|---|
| | Methods | S5.10 | S5.10 | S5.10 | S5.10 | S5.10 | S5.10 |
| 1 | BPPT-COMPOSITE=0-8" | 1157 | 70 | 18 | 5.8 | 0.6 | 0.1 |
| 2 | BPPT-PINON-PUTR=0-6" | 1576 | 144 | 37 | 7.9 | 1.2 | 0.2 |
| 3 | BPPT-PINON-OPEN=0-6" | 1107 | 167 | 14 | 5.5 | 1.4 | 0.1 |
| 4 | BPPT-SYMMES-PUTR=0-6" | 586 | 55 | 13 | 2.9 | 0.5 | 0.1 |
| 5 | BPPT-SYMMES-OPEN=0-6" | 848 | 34 | 10 | 4.2 | 0.3 | <0.1 |
| 6 | BPPT-BUTTERMILK-PUTR=0-6" | 996 | 88 | 13 | 5.0 | 0.7 | 0.1 |
| 7 | BPPT-BUTTERMILK-OPEN=0-6" | 447 | 20 | 5 | 2.2 | 0.2 | <0.1 |

[1] **SP (SATURATION PERCENTAGE). Approximate relationship of SP to soil texture as follows:**

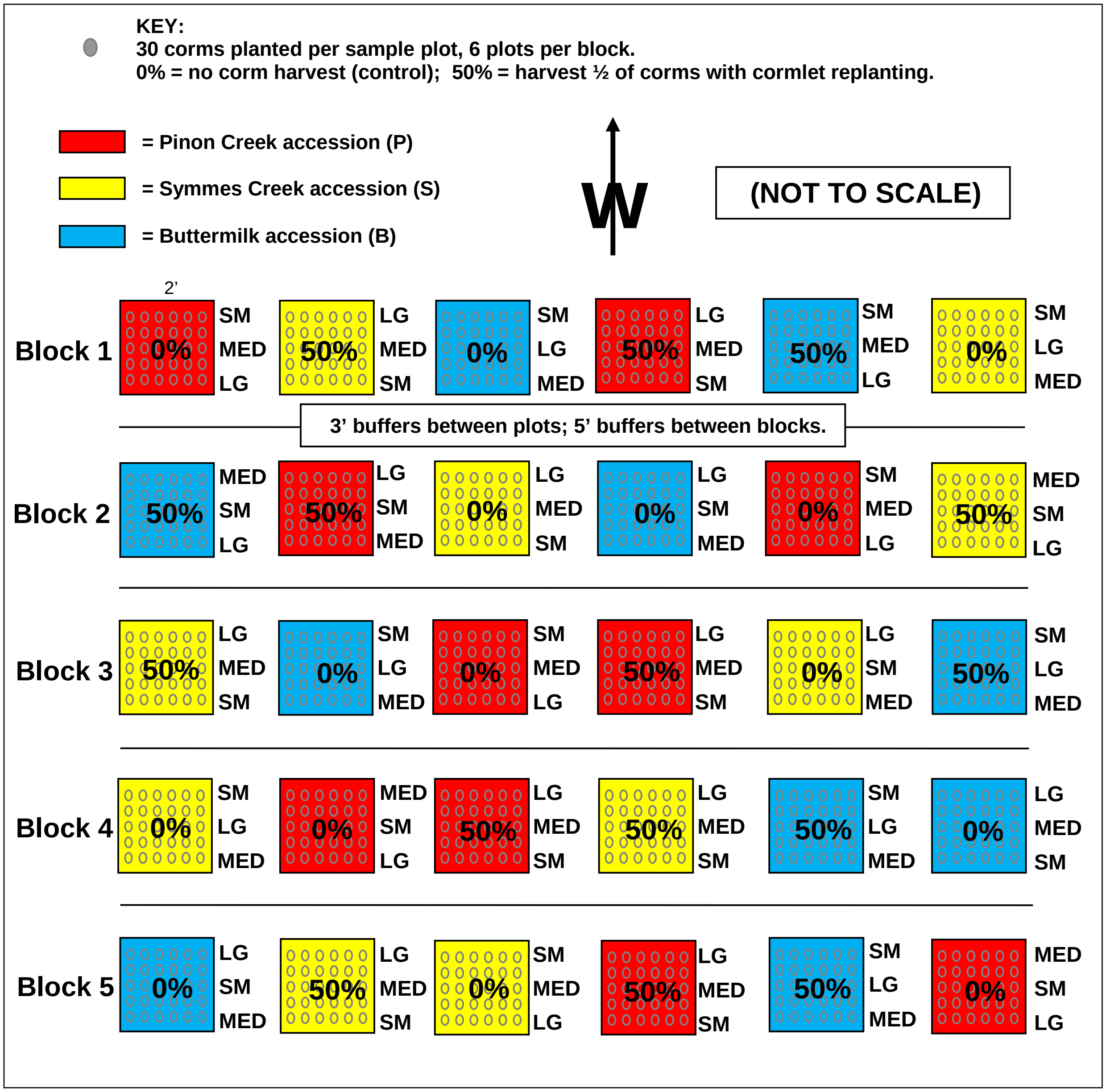
| | |
|---|---|
| **Below 20** | **Sandy or Loamy Sand** |
| **20 - 35** | **Sandy Loam** |
| **35 - 50** | **Loam or Silt Loam** |
| **50 - 65** | **Clay Loam** |
| **65 - 150** | **Clay** |
| **Above 150** | **Typically Peat or Muck** |

## Experimental Design and Plot Layout

Corm planting was applied according to the original experimental design and plot layout depicted in Figure 4. In narrative format, the experimental design corresponded to:

**1st Level, Main plot:** Nahavita Source Population (Accession)

- Buttermilk accession
- Pinyon Creek accession
- Symmes Creek accession




**Perimeter Study Dimensions:**
**East – West: 47 feet**
**North – South: 50 feet**
**Stakes at SW corner of each plot**
**6 rows of 5 corms each per plot = 30**

**Corm Numbers:**
**300 corms per accession – total**
**100 corms per size class per accession**
**60 corms per accession per block**
**2 rows LG; 2 rows MED; 2 rows SM.**

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**Figure 4. Applied experimental design, Nahavita (*Dichelostemma capitatum*) harvest intensity study - Conservation Field Trial, Big Pine Paiute Tribe, Big Pine, CA.**

**2nd Level, Sub-Plot:** Harvest Intensity via Tribal Digging

- 0% corm harvest intensity (control)
- 50% corm harvest intensity with cormlet replanting

**3rd Level, Sub-Sub-Plot:** Planted Corm Size (approximate)

- Small (<1.0 cm)
- Medium (1.0-1.5 cm)
- Large (>1.5 cm)

### Data Analyses

This study incorporated a replicated (5 block) factorial design suitable for ANOVA analyses to evaluate individual accession responses to treatment in terms of survival and productivity, while still accommodating simple demonstration purposes. The analyses were conducted in accordance with procedures described in Gomez and Gomez (1984) and Steel and Torrie (1980), using the Statistix 8 Statistical Package (Statistix™ for Windows Analytical Software, Version 8.1). Fisher's protected LSD test for means comparisons (Steel and Torrie 1980) was used to test for significance of responses between and within treatments.

Data were stratified and analyzed separately by data collection date. Differences between dates were less important than between accessions and between corm size classes (date 4 only). Each potential corm / plant was considered a point sample – thus facilitating a larger sample size overall. Emergence was defined as evidence (presence) of above-ground foliage and/or flowering stem(s) derived from planted corms within each plot. Flowering is defined as presence of a recognizable flowering stem derived from planted corms within each plot.

The null hypotheses tested include:

**$H_{o1}$:** there is no difference in the mean number of planted corms remaining and /or cormlets produced per plot among the three source accessions;

**$H_{o2}$:** there is no difference in the mean number of planted corms remaining and /or cormlets produced per plot among the 0% and 50% harvest intensity treatment levels;

**$H_{o3}$:** there is no difference in the mean number of planted corms remaining and /or cormlets produced per plot among the three planted corm size classes.

## Treatment Methodology

### Mechanical Seedbed Treatments

Mechanical roto-tillage was used for seedbed preparation, in order to maximize uniformity of soil texture, tillage depth, corm planting depth, and soil aggregate size distribution between plots. This seedbed preparation measure also optimized the planting medium in terms of a) initial weed residue removal; and b) enabling a more uniform weed seed germination environment; and c) creating soil surface micro-relief (micro-catchments) to enhance precipitation capture and retention.

### Planting Method

All corms were hand-planted, with a mean planting depth of four inches (10 cm), and each plot consisted of planted 30 corms across the three corm size classes.

### Irrigation Application

Irrigation amounts, timing, and duration were based on meeting minimum evapotranspiration needs of the newly planted corm materials. Irrigation was conducted manually by either hand-set, stationary sprinkler irrigation or individual plot watering by hand. This application rate emulated the long-term mean monthly precipitation received at this locale.

### Climate and Soil Moisture Monitoring

The study site was instrumented with a HOBO MicroStation™ (Onset Computer Corporation, Pocasset, MA) with sensors for precipitation, soil moisture, soil temperature, and ground-level air temperature and relative humidity (Figure 5). Sensors for precipitation, air temperature and relative humidity were mounted at approximately 40-inch (100 cm) height, and soil moisture and soil temperature sensors were buried at approximately 6-inch (15 cm) soil depth.

**Figure 5. HOBO MicroStation™ installed on the Conservation Field Trial - Big Pine Paiute Tribe, Big Pine, CA.**

### Weed Management

Control of secondary weed encroachment following initial removal (pre-installation) was also performed by BPPT. This was accomplished via regular (weekly) monitoring and hand removal (manual grubbing) of weeds. Each plot was weeded when the weeds were immature (small) so as minimize soil disturbance adjacent to the corms during the manual removal process.

### Herbivory Protection

Transplanted corms and emerging stems were protected from rodent digging and/or herbivory by erection of rabbit-proof perimeter exclusion fencing. Additionally, chemical repellent (Plantskydd™) for rodent and other small mammal deterrence was applied post-plant to the complete study area, augmenting the perimeter exclusion fencing.

### Data Collection / Monitoring

The following response data were obtained: 1) number of corms per plot; and 2) number of cormlets per plot; and 3) diameter (size class) of remaining planted corms per plot.

## Results

Upon evaluation of data from the first two data collection periods, it was determined that applying the harvest treatment, as originally designed, was infeasible, based on:

- the relatively small and highly variable survival of corms (as indicated by culm growth) across all accessions and corm size classes; and

- the apparent variability of the soil substrate across the study site. This base resource variability was characterized by substantial and variable degrees of cobble content, presence of old backfill, and accidental (trespass) irrigation.

As a result, the harvest treatment and hypothesis $H_{o2}$ were deleted from the experimental design, resulting in remaining data collection and analysis (retroactive to the first two data collection period) being confined to effects of accession adaptation and corm size class. For the same reason, each plot of the same corm accession then became, in essence, a replication for that accession. This resulted in 10 replications for each accession regardless of original location in the five original design replications.

### 2012 Response Data

The Symmes Creek accession demonstrated highest emergence and survival at the BPPT headquarters study location during early to mid-spring, 2012 (Figure 6). This result is logical in terms of climatic adaptation, as the Symmes Creek accession was closest to the study site relative to elevation and mountain outwash toe-slope position. This superior performance diminished, however, by data collection date 4 (May 4, 2012), resulting in no significant difference from the Buttermilk or Pinon Creek accessions by that date.

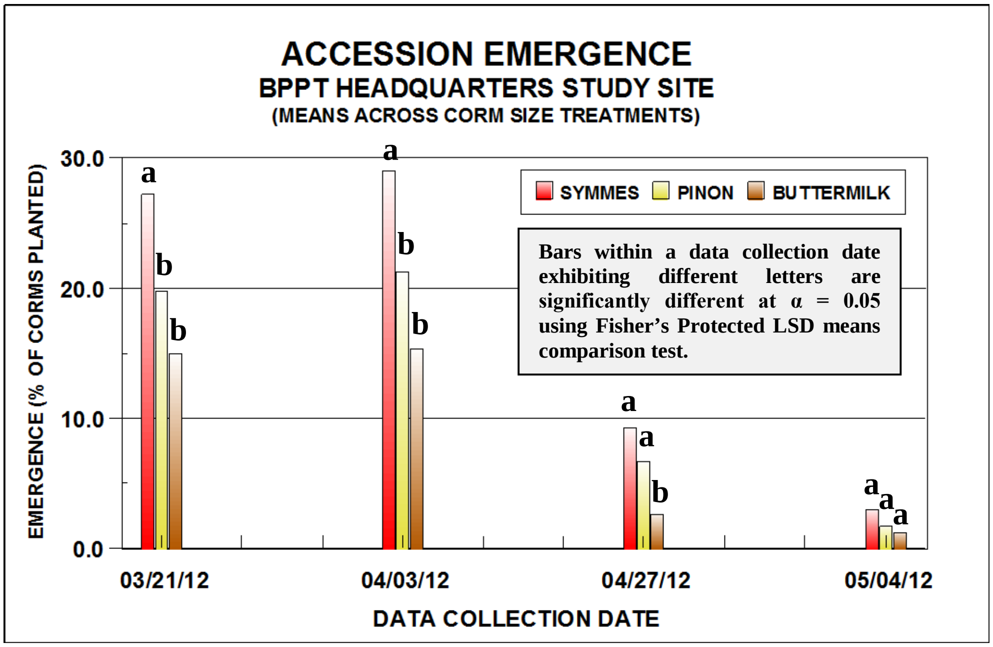



**Figure 6. Comparison of emergence (% of corms planted per plot) for the three accessions of Nahavita (*Dichelostemma capitatum*) at the Big Pine Paiute Tribe headquarters study site, examined across four data collection dates in Spring 2012.**

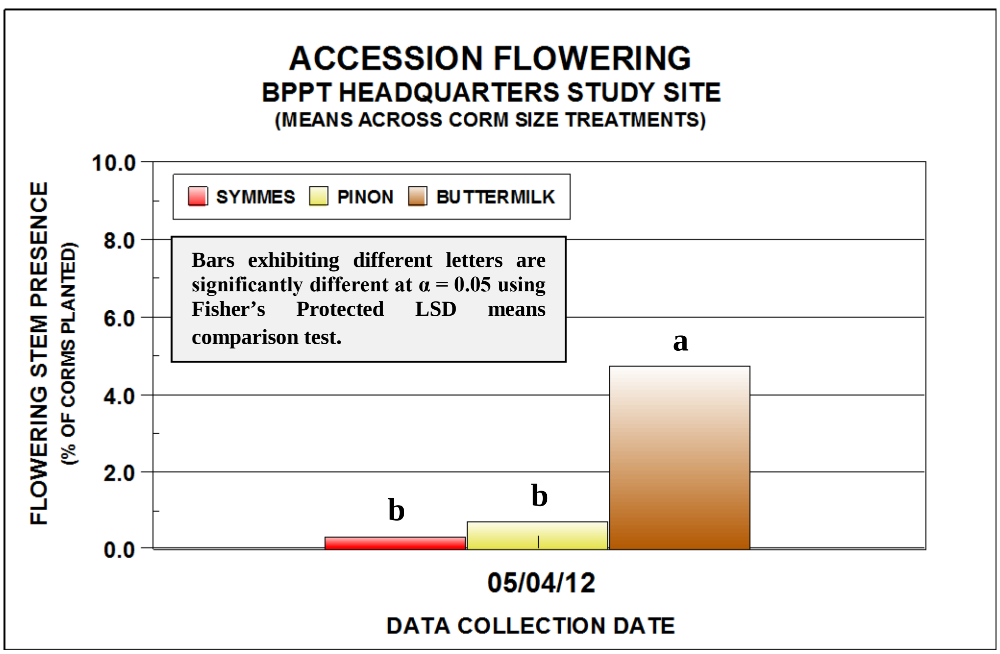



**Figure 7. Comparison of accession flowering (% of corms planted per plot) for the three accessions of Nahavita (*Dichelostemma capitatum*) at the Big Pine Paiute Tribe headquarters study site, examined only for the May 5, 2012 data collection date.**

In contrast, there is mild indication that the Buttermilk accession may be able to produce and/or sustain flower stalks longer into the spring season than the other accessions (Figure 7). This may or may not be an advantage for corm survival, vigor and health going into the next year, dependent upon whether later flower growth adds or detracts from carbohydrate storage and associated vigor in the corm.

Albeit with a very small number of surviving non-dormant plants by date 4 (May 4, 2012), there was no indication that initial corm size exerts any influence on survival during the first establishment year.

### 2013 Response Data

For the 2013 data collections, flowering culms counts were not analyzed because of insufficient population size demonstrating flowering culms during the four 2013 data collection periods.

A limited shade treatment layer using shade fabric (estimated 25% light porosity) was superimposed over the original study experimental design in March 2013 (Figure 8). This treatment was applied only to single, selected plots showing best emergence / survival results for each accession (see green-highlighted plots, Figure 9). This observational treatment was added to simulate shading effect characteristic of natural populations for the source accessions, where the majority of corms were located and harvested directly under shrub (bitterbrush and/or sagebrush) canopies.

Harvesting of selected plots (the same plots as described above for shade treatments, plus two additional plots) was conducted to determine vegetative (cormlet) production from the originally planted corms (Figure 10). The selected plots were excavated using shovels down to 6” (15 cm) soil depth, with the north half of each plot pre-determined for excavation. The excavated soil

**Figure 8. Installation of shade fabric structures for selected plots at the BPPT Nahavita Conservation Field Trial, March 2013, Big Pine, CA.**

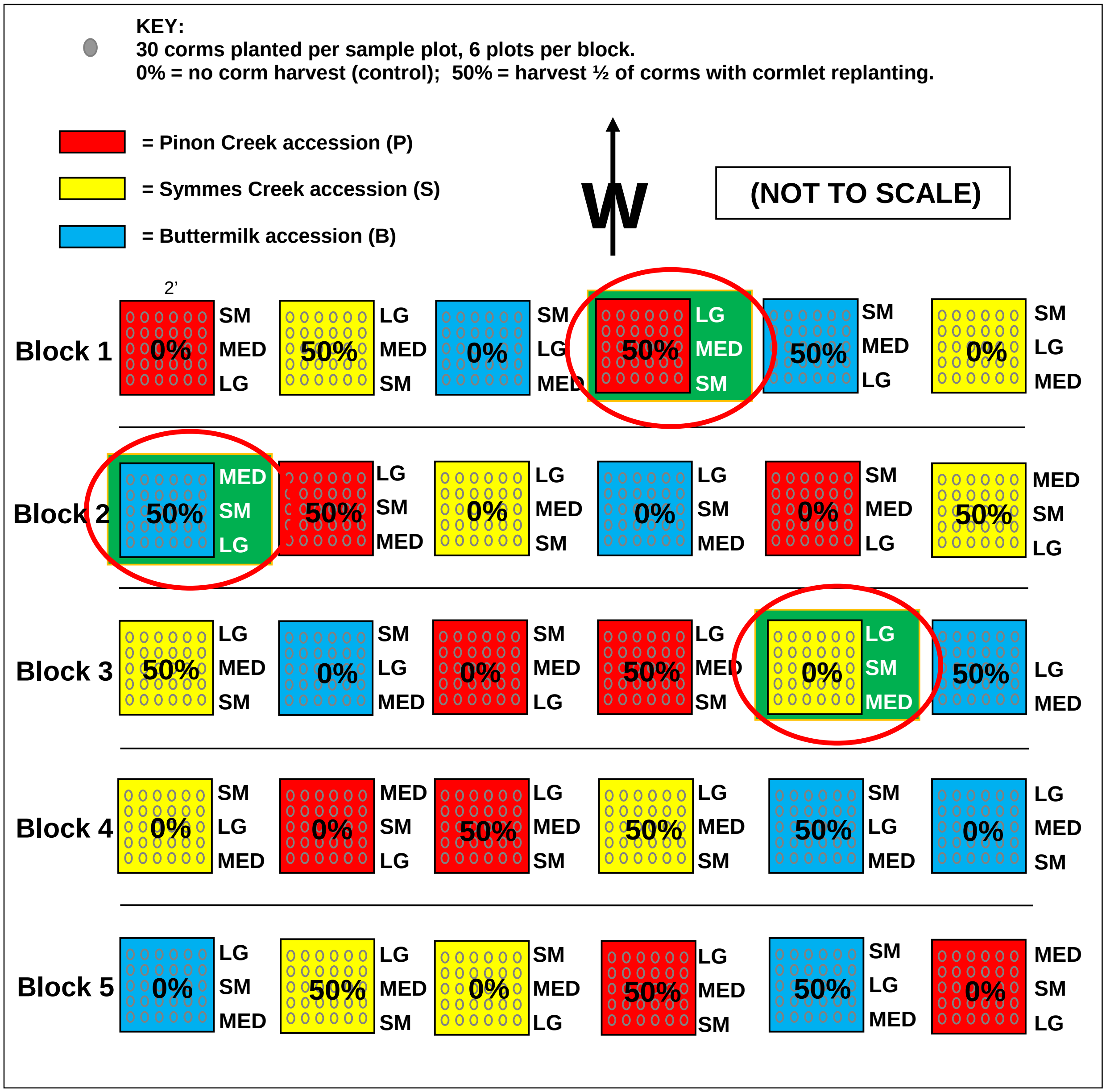



**Figure 9. Overlay of shade cloth treatments on selected plots (green highlight, red circle) of the original experimental design in March 2013, exhibiting maximum emergence of culms and foliage. Conservation Field Trial, Big Pine Paiute Tribe, Big Pine, CA.**

was sieved through a wire mesh screen [0.25 inch (0.6 cm) square openings] with wooden support framework in order to separate corms from soil and gravel material. Cormlets attached to the parent corm, and cormlets unattached but less than 0.25 inch in diameter (i.e., smaller than the original "small" size class of originally planted corms), were counted per plot.

**Figure 10. Excavation and harvest of corms and cormlets from selected plots, at the BPPT Nahavita Conservation Field Trial, May 2013, Big Pine, CA.**

### Climate Summaries

Climate trends during the project period, including long-term monthly and annual precipitation and temperature at the corm wildland collection sites, are depicted in Figure 11. Precipitation received during the 2012 calendar year at the BPPT study site was significantly below (47% of) the long-term mean monthly and annual precipitation for the Big Pine, CA locale. This deficit was particularly evident in comparison to long-term precipitation means for the source population locales – i.e.,

- 59.1% of the long-term mean annual precipitation, as derived from the Independence, CA WRCC/NOAA weather station (044232), as an approximation for the Symmes Creek and Pinon Creek accessions; and

- 25.1% of the long-term mean annual precipitation, as derived from the Bishop Creek Intake 2, CA WRCC/NOAA weather station (040819), as an approximation for the Buttermilk accession.

Air temperatures also varied from long-term mean temperatures as recorded at the WRCC/NOAA weather stations cited above. Mean monthly and annual air temperatures in 2012 for the BPPT study site were higher than Big Pine and Independence long-term means, with 2012 BPPT study site mean annual air temperature 110% and 106% above those reference locales, respectively. Mean annual BPPT study site *soil temperature* in 2012 ($59.4^{o}$ F) was 102% of the long-term mean annual *air temperature* ($58.0^{o}$ F) for the Big Pine locale.

In general, irrigation was applied to the planted corms on a weekly to by-weekly basis (for approximately one minute per plot for hand-watering of individual plots; or for approximately one hour duration to all plots simultaneously by sprinkler) during extended periods when natural precipitation was absent or minimal. Soil moisture at the BPPT study site was erratic in relation

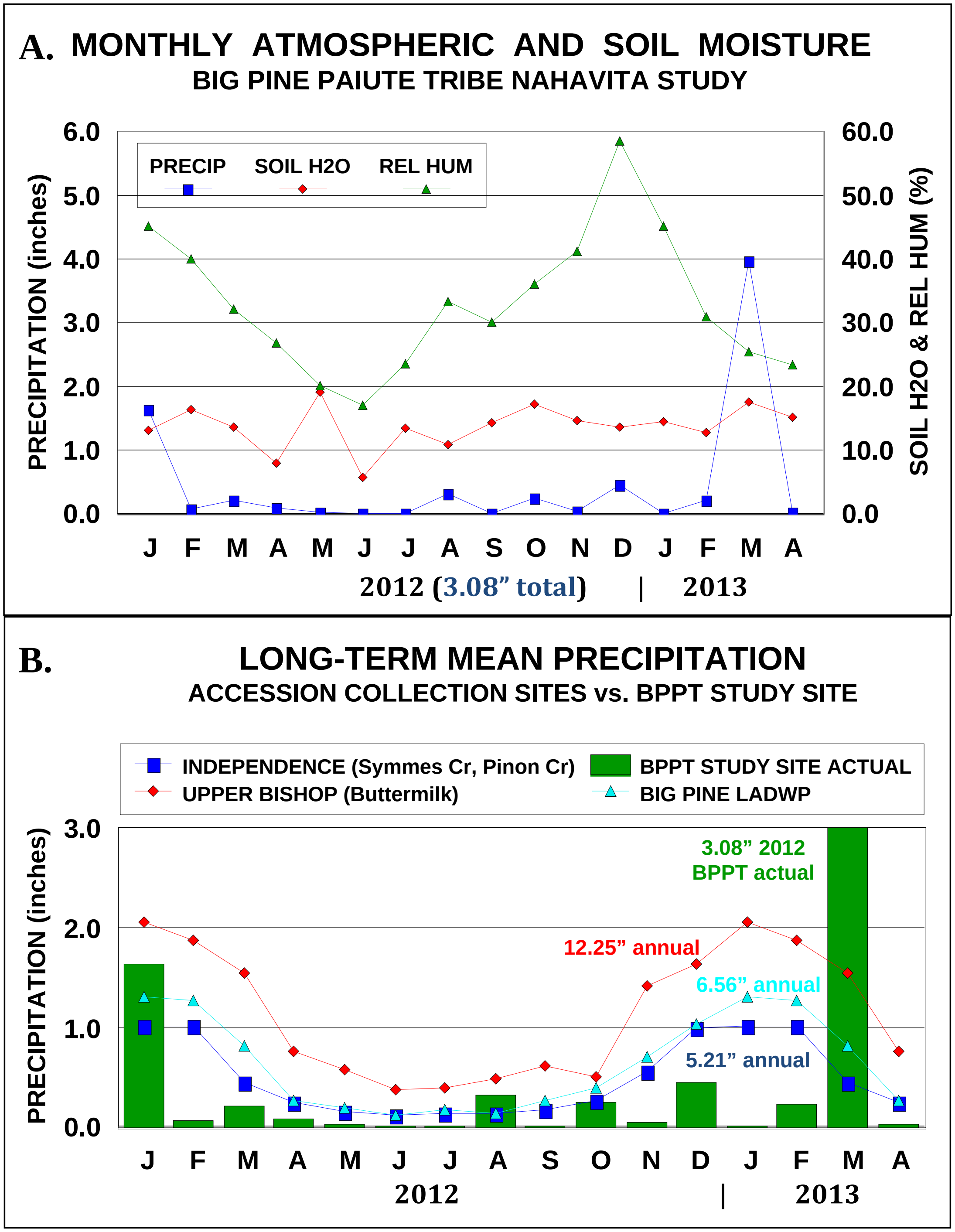



**Figure 11.** A. Monthly atmospheric and soil climatic variables at the BPPT study site. B. Long-term mean precipitation at the corm accession collection sites vs. the BPPT study site, Big Pine Paiute Tribe, Big Pine, CA. Accession location climatic data derived from the WRCC / NOAA weather stations at a) Independence, CA (044232) approximating the Symmes Creek and Pinon Creek accession sites; and b) Bishop Creek Intake 2, CA (040819) approximating the Buttermilk accession site.

to precipitation received. Irrigation effects are evident, particularly where soil moisture increased in chronological correspondence to significant decreases in precipitation and an extended drought period (February 2012 – February 2013). As a joint effect of irrigation and precipitation, soil moisture at the study site averaged 13.3% (volume basis, $m^3/m^3$) across the 2012 calendar year.

### Accession Adaptation

The mid-March to early-April 2013 emergence / survival values were used as best indicators of study site adaptation for 2013 data interpretation (Figure 12).

While the Symmes Creek accession indicated higher emergence and survival during the 2012 monitoring dates, the Pinon Creek accession approaches or equates with the Symmes Creek accession during the 2013 evaluations (including the 12/07/12 monitoring date) (Figure 12). Statistically, emergence results for these two accessions suggest equal adaptation at the study site by the second growing season. The Buttermilk accession continues to display significantly reduced survival / adaptation to the headquarters study site, rarely attaining greater than 60% of the survival values for the other two accessions. On this basis, hypothesis $H_{o1}$ was rejected.

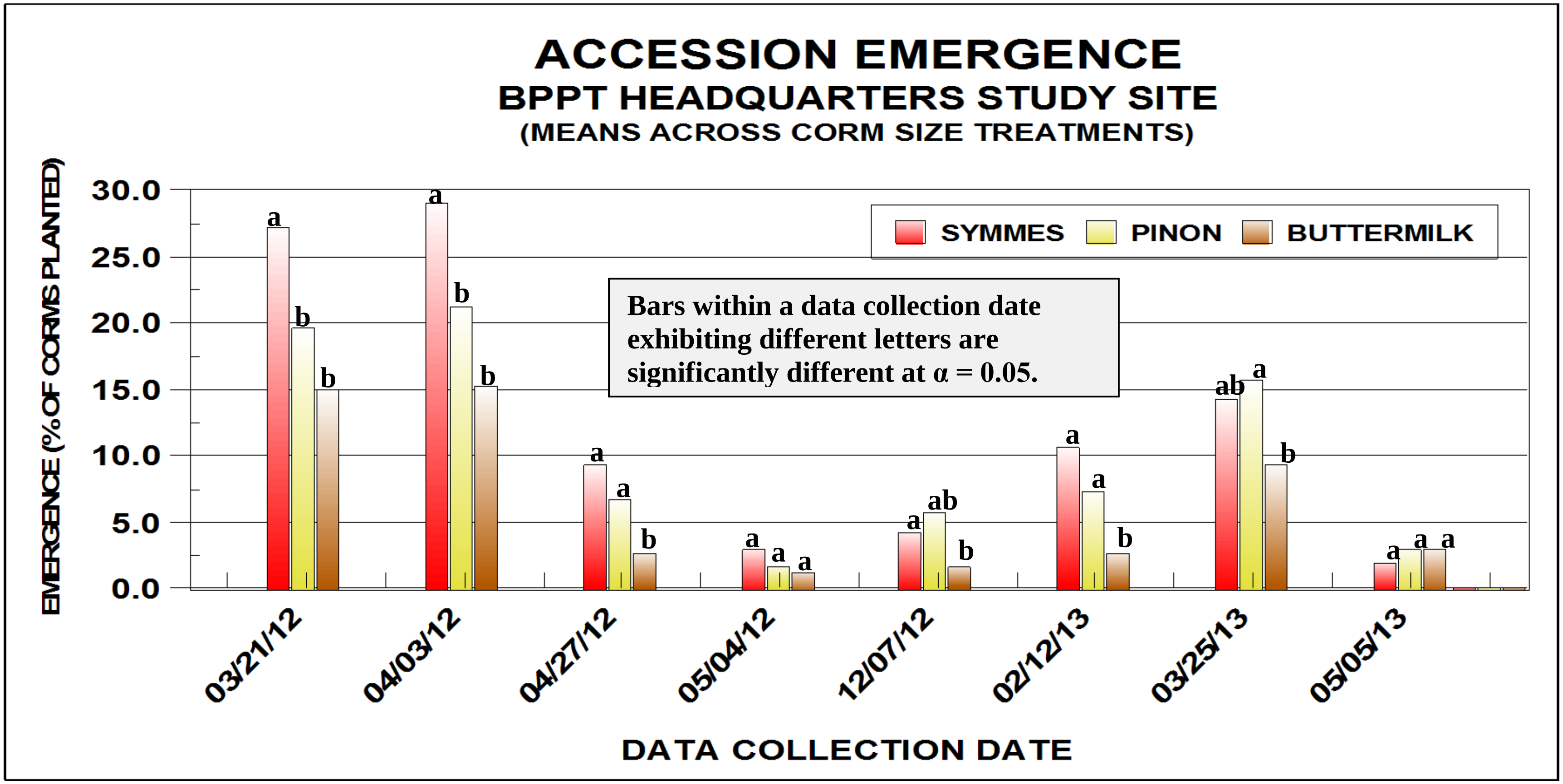
In contrast, general observations again suggest that the Buttermilk accession continues to consistently exhibit more flowering stems at multiple monitoring dates. Surviving accession population sizes were too small to permit valid statistical analysis for flower production.

### Corm Size Differentiation

Factorial ANOVA for data collection dates 12/07/12 through 05/05/13 revealed no significant differences between corm size classes for essentially all accessions and across all dates, in similarity to analyses for the earlier dates. Data were analyzed within accessions for corm size effect, again with no significant differentiation detected within all three accessions. As such, corm size data were then pooled for subsequent analysis of accession adaptation only in order to provide comparison of accessions with a more robust analysis (i.e., higher degrees of freedom). The absence of corm size differentiation is largely considered a factor of the low survival of all corms across all accessions, introducing high variability among plots that likely tended to mask any potential corm size treatment effects. On this basis, hypothesis $H_{o3}$ was accepted.

### Vegetative Reproduction (Cormlet) Performance

In March 2013, portions of plots across all corm size classes and source accessions showing no emergence of corms were randomly sampled via soil excavation (Figure 13). This excavation was conducted to determine if corms were still present and/or exhibiting indications of viability within the original planting zone (approximately 4” deep) in the absence of above-ground foliage or culms. No corms of any size were found within plot portions where above ground culm growth was not present.




| | 03/21/12 | 04/03/12 | 04/27/12 | 05/04/12 | 12/07/12 | 02/12/13 | 03/25/13 | 05/05/13 |
|---|---|---|---|---|---|---|---|---|
| SYMMES CR. | 27.2 | 29.0 | 9.3 | 3.0 | 4.3 | 10.7 | 14.3 | 2.0 |
| PINON CR. | 19.7 | 21.3 | 6.7 | 1.7 | 5.7 | 7.3 | 15.7 | 3.0 |
| BUTTERMILK | 15.0 | 15.3 | 2.7 | 1.3 | 1.7 | 2.7 | 9.3 | 3.0 |

**Figure 12. Comparison of emergence for the three accessions (Symmes Creek, Pinon Creek, Buttermilk) of Nahavita (*Dichelostemma capitatum*) at the Big Pine Paiute Tribe headquarters study site. Data examined across eight monitoring / data collection dates (from Spring 2012 to Spring 2013). Emergence (survival) values for dates 03/21/12 through 05/04/12 are taken from the 2012 response data (above).**

Few plots exhibited above-ground foliage and/or flowering culms as of late May 2013 - primarily

**Figure 13. New cormlets still attached to the parent (planted) corms, BPPT Nahavita Conservation Field Trial, May 2013, Big Pine, CA.**

the shaded plots (see Figure 9), plus two additional plots with reduced above-ground growth compared to the shaded plots. For these select plots, the north half of each plot was excavated to determine cormlet production, as described above. The observational findings (not statistically analyzed because of insufficient sample size) are summarized in Table 4.

**Table 4. Cormlet production in May, 2013 on selected plots, BPPT Nahavita Conservation Field Trial, Big Pine, CA.**

| | PARENT CORM SIZE | | | | | |
|---|---|---|---|---|---|---|
| | Large | | Medium | | Small | |
| ACCESSION | Parent | Cormlets | Parent | Cormlets | Parent | Cormlets |
| **Buttermilk** | 2 | 6 | 1 | 0 | 0 | 0 |
| **Symmes Creek** | 2 | 3 | 0 | 0 | 2 | 0 |
| **Pinon Creek** | 6 | 6 | 1 | 0 | 0 | 0 |

Corms that were equal to or less than 0.125 inch (3.175 mm) were designated as "cormlets".

During the digging process, recovered cormlets (whether attached or detached from the parent corm) were re-planted, again emulating common practice by California Indian tribes.

### Shade Effects

Observationally, addition of shade appeared to extend the life of viable flowering culms for the three accessions, compared to non-shaded plots. Essentially all culms produced and retained viable flowers under shade, whereas rarely did flowers remain on culms in non-shaded plots by late May 2013. Additionally, all inflorescences produced seed pods containing viable seed (average 4 pods per plant) in shaded plots, while non-shaded plots exhibited rare pod and seed formation. As noted above, this observational treatment was intended to simulate shading effect characteristic of natural populations for the source accessions, where the majority of corms were collected directly under predominantly bitterbrush and/or sagebrush canopies, depending upon accession collection site.

## Discussion and Recommendations

### Suitability of the BPPT Headquarters Study Site

The BPPT study site exhibited inherent soils and environmental limitations that likely reduced Nahavita corm survival (March 2013 mean of 15.0% for the Symmes Creek and Pinon Creek accessions; 9.3% for the Buttermilk accession – as based on above-ground foliage and/or culm presence). These limitations also adversely affected productivity since planting. These limitations include:

- Significantly larger component of coarse fragments and/or cobbles than those occurring naturally at the accession collection sites. Although the fine material component of the BPPT study site planting medium was sandy loam, in similarity to the accession collection sites, the skeletal (rocky) nature of the soil resulting from high cobble content introduced adverse factors affecting the growth medium –

    - Increased water infiltration and deep percolation, resulting in poor water-holding capacity;
    - Inability to properly prepare the soil to adequate depth via tillage, thereby reducing planting bed friability and tilth.
    - Difficulty in weeding the inter-plot buffer spaces using mechanical means; forcing manual (hand) roguing of weeds.

  The coarse, cobbly soil composition was further compounded by apparent addition of overlain cobbly, coarse-sandy, compacted fill material on at least the northern one-third of the actual study plot site.

- The BPPT headquarters site is at sufficiently lower elevation than the accession collection sites, such that environmental factors such as mean monthly and annual precipitation, air temperature, and soil temperature were not optimally conducive to survival of transplanted corms from higher elevations without supplementation by planned regular irrigation, and possibly shading.

- Difficulty in providing a dependable irrigation supply and scheduled application that met plant needs on a weekly basis in relation to precipitation patterns, particularly during non-peak precipitation periods. Accidental trespass water from adjoining field areas over only portions of the study site was also an occasional problem.

- Possible absence of native mycorrhizal fungi commensally associated with Nahavita corms in wildland sites. Introduced perennial and annual grass vegetation dominated the study site prior to study installation and associated disturbance, which likely maintained some mycorrhizal component in the soil. However, the skeletal / mineral nature of the study site soil, and the absence of native vegetation, may preclude or reduce presence of mycorrhizae that are / may be host-specific for Nahavita corms.

These cumulative limitations (singly or in combination) posed a significant restraint on developing planting beds (as expansion and larger-scale application of this research) that can produce sustainable populations of Nahavita. These limitations must be addressed in terms of potential siting of either additional research or larger-scale production beds in the future.

### Accession Performance

Both 2012 and 2013 results are consistent with expectations that lower elevation source populations of the selected accessions would exhibit greater adaptation to the headquarters study site. However, even with better adaptation for the Symmes Creek and Pinon Creek accessions, second growing season results indicating generally less than 15% survival suggest that environmental adaptation factors at the study site need further refinement and investigation (see constraints above; recommendations below).

Observations that the Buttermilk accession continues to consistently exhibit more flowering stems at multiple monitoring dates suggests that this potential for possible new seedling recruitment via sexual reproduction may tend to compensate for the reduced corm survival of the Buttermilk accession over time at the headquarters study site. Whether later flower growth affects carbohydrate storage and associated over-wintering vigor in the corm needs further study.

Of additional note is that the Buttermilk accession also appears to support vegetative cormlet reproduction better than the other two accessions (2:1 ratio compared to approximately 1:2 and 1:1 ratios for the Symmes Creek and Pinon Creek accessions, respectively). There is insufficient data because of the low corm survival rates to assign any significance or basis for this finding, other than simple observational value based on a total of 14 parent corms harvested (shaded plots primarily) out of an original transplant number of 900 for the overall study.

### Potential for Sustained Cormlet Production

As summarized in Table 4, cormlet production is achievable for all three accessions, even in the context of the first growing season (2012) being extremely dry and warm. This suggests that established, transplanted corm populations could be sustained via vegetative reproduction under optimal management (i.e., in the absence of site environmental constraints as discussed above). Based on the minimal data available, these accessions could apparently sustain an ongoing harvestable population of corms, using the vegetatively-produced cormlets for immediate re-planting to initiate (or augment and sustain) the crop in future years. Eventual fate of re-planted cormlets was not determined in this study, having been first re-planted in May 2013. Similarly, seed was collected from all seed pods that were produced on flowering culms; thus, no seedling recruitment at the study site was / will be studied.

## Soils Adaptation

### *Source Population Collection Sites*

It inhabits a wide variety of plant communities including vernal pools, coastal strand, mixed evergreen forest, chaparral, valley grassland, desert scrub, coniferous forests, oak woodlands, montane scree, and on the fringe of coastal salt marsh and redwood forest (Encyclopedia of Life 2015).

As noted previously, site-specific soil sampling was conducted on the three field collection sites for the Nahavita corm source populations. As noted in Table 3, soil samples obtained from the three collection sites (which were similar to those obtained from the tribal headquarters study site) consisted primarily of sandy loam textures.

In summary (see previous description for details), these soils are alluvial in derivation, developing from granitic alluvial outflow onto lower-elevation back slope positions from the Sierra Nevada Mountains. These soils are well drained with moderate available water capacity, and low $CaCO_3$ content. These sandy loam soil characteristics would be considered adequate or recommended plant growth edaphic guidelines for the Nahavita corms, particularly for populations originating from Sierra Nevada east slope ecogeographical positions. In agreement with recommendations from other literature sources, it prefers soils with good to excellent drainage, at low- to mid-elevations. (Harlow and Jakob 2003, Payne Foundation 2015, Leon 2015).

### *Additional Considerations*

As previously noted, the vast majority of the collected corms originated under the canopies of antelope bitterbrush (Buttermilk / Pinyon Creek sites) and Wyoming big sagebrush (Symmes Creek site). It was postulated that this phenomenon resulted from 1) higher soil organic matter accumulated under the shrub canopy overstory as a result of annual leaf fall and decomposition, providing an enriched nutrient and soil moisture retention environment for the corms; or 2) the presence of shrub canopies and root crown bases providing micro-catchment areas for increased Nahavita seed accumulation; or 3) shading effect afforded by this canopy, providing a higher soil moisture environment for corm growth; or 4) some combination of the above.

This is also in agreement with literature on bluedicks occurrence, which generally observe that bluedicks often establish and perform best when growing out of (i.e., from under or through the canopies of) or adjacent to low, loose-textured shrubs such as *Rosa*, *Berberis*, and

*Arctostaphylos* spp. On nutrient-poor, rocky or gravelly soils, bluedicks usually benefits from support by close-neighboring grasses and low shrubs (Harlow and Jakob 2003, Payne Foundation 2015, Leon 2015). However, following fire, other authors have observed that Nahavita plants vigorously flower in the resultant open environments that may derive increased soil nutrients from the released ash as well as from temporarily reduced competition from adjacent shrubs. Grasslands that have been burned may exhibit thousands of plants where none have appeared in recent years (Anderson and Roberts 2006, Wikipedia 2015).

It is theorized that seed micro-catchment, moisture conservation, and/or shading effect are therefore important factors promoting the occurrence of Nahavita corms in these canopied environments. These factors may also have a significant role in how planted corms emerge and survive at remote planting sites. Continued presence and viability of emerged culms in the shaded plots (including persistence of flowering culms) - in comparison with much reduced culm presence in all other, non-shaded plots - suggests that shading may play a major role in facilitating increased survival, emergence, and productivity of planted corms.

Bluedick populations also require periodic disturbance to maintain and increase their populations; therefore, indigenous harvesting regimes may help maintain populations. Populations that become overcrowded and show reduced vigor can be divided and separated (Bryant 2015, Wikipedia 2015, Anderson 2005, 1997, Anderson and Rowney 1998, Fowler 1986, Peri and Patterson 1979, Murphey 1959, Hulse 1935, Steward 1933).

## Planting Rate

### *Propagation by Corms:*

The primary source of information on field (i.e., non-nursery) propagation of Nahavita corms is found in the ***USDA-NRCS Plant Guide for bluedicks*** (Anderson and Roberts 2006), from which most of the following recommendations are taken (except where noted otherwise). In general, plant the larger corms [greater than 0.25 inch (0.6 cm) in diameter] down to 3-4 inches (7.5 – 10.0 cm) deep, and smaller corms 1-2 inches (2.5 – 5.0 cm) deep in well-drained soil. This recommendation is in keeping with the findings of this study at BPPT, in which the establishment performance of larger corms (generally greater than 1.5 cm in diameter) was superior (see Table 4).

Initial corm spacing at time of planting is recommended to be 1.0 inch (2.5 cm). However, other authors recommend corm spacing to be at least 12 inches (30 cm) apart (Leon 2015). To minimize intra-specific competition and optimize nutrient and moisture uptake, particularly in natural field planting situations with shrub cover, the latter spacing is recommended by this report's authors.

### *Propagation by seed:*

Since only corm transplanting and subsequent vegetative reproduction were studied, no data is available from this study regarding recommended seeding rates for this species. However, the

NRCS Plant Guide for bluedicks (Anderson and Roberts 2006) partially addresses this aspect of bluedicks' re-establishment, summarized as follows:

Seeds sown in the fall usually readily germinate and do not need special treatment. If sown at other times of the year, the seeds may need one month's stratification. Scatter seeds and rake them lightly into the soil in full or partial sunlight. Plant the seeds at a depth which equals the width of the seeds. Protect the seed from animals and cold, dry winds, and from weed competition.

Water the seeds after planting, and water them again when the surface is becoming dry to the touch. The seedlings should be watered through the spring. The plant commonly occurs in Mediterranean climates exhibiting winter monsoonal regimes. Therefore, supplemental irrigation (where possible) should emulate these conditions in frequency, amounts, and temporal patterns as closely as possible.

Upon corm transfer to more remote field sites following 24 months of in-situ initial establishment and growth, scatter the corms to provide an appearance of "natural" distribution. After one bloom, the plants should be well established so that they don't need to be weeded or watered unless it is a dry winter.

## Summary of Recommendations

In summary, recommendations for future research and/or larger-scale production bed planting of Nahavita corms at the BPPT, as an expansion of this current research, include:

- ✓ Continued use and evaluation of the Symmes Creek and Pinon Creek source populations of Nahavita, given their consistently exhibited superior performance at the BPPT locale.

- ✓ Location of site(s) with soil characteristics having greater similarity to the source population, corm collection sites, to serve as the growth medium for corm transplants (with consideration of logistics involved for tribal access, irrigation, shading, maintenance, and harvest); OR

- ✓ Incorporation and ongoing use of shade structures (whether shade fabric or structural shade lathing) to emulate shrub canopy shading as typified in natural source population corm collection sites.

- ✓ Improvement of irrigation supply and delivery system(s), enabling regular and dependable irrigation of planted corms during the initial establishment phase (1-2 years after planting).

### Proposed Future Research

Seed from senescent plants on the study site were hand-collected by Margaret Smither-Kopperl, Manager of the California Plant Materials Center (CAPMC) at Lockeford, CA for further on-center common garden trials. These will be greenhouse-propagated in Spring, 2013 and then out-planted to the field in Fall, 2013 for evaluation. Demonstration trials (or experimental trials, if funding and time permit) will be conducted in greenhouse and field out-planting site(s), evaluating environmental factors potentially affecting germination and growth, respectively, including soil texture, soil moisture, shading, and soil organic matter content.

Proposed test hypotheses in greenhouse and field applications at BPPT and the CAPMC relating to future treatment comparisons involving evaluation of:

- Physical shading vs. ecological / biological association of corm accessions with host-specific shrub species.
- Moisture capture and conservation (via irrigation) in relation to shrub canopies (real or simulated).
- Soil organic matter content and retention in relation to shrub canopies (real or simulated).
- Harvest intensity in established and quantified populations (planting beds) in relation to corm survival, foliage and culm emergence, and cormlet production (per the original intent and experimental design for the current study).
- Mycorrhizal inoculation vs. no inoculation (perhaps with concurrent analysis of native wildland soils from source population corm collection sites for mycorrhizal presence, and if possible, species-host identification and specificity).

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