8-2019

Explorations and Collaborations on Two Under-Recognized Native American Food Crops: Southwest Peach (Prunus Persica) and Navajo Spinach (Cleome Serrulata)

Reagan C. Wytsalucy

Utah State University

EXPLORATIONS AND COLLABORATIONS ON TWO UNDER-RECOGNIZED NATIVE AMERICAN FOOD CROPS: SOUTHWEST PEACH (*PRUNUS PERSICA*) AND NAVAJO SPINACH (*CLEOME SERRULATA*)

by

Reagan C. Wytsalucy

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Plant Science

Approved:

Brent Black, Ph.D. Major Professor	Daniel Drost, Ph.D. Committee Member
Grant Cardon, Ph.D. Committee Member	Randy Williams, M.S. Committee Member

Richard S. Inouye, Ph.D.
Vice Provost for Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2019

ABSTRACT

Explorations and Collaborations on Two Under-recognized Native American Food Crops: Southwest Peach (*Prunus persica*) and Navajo spinach (*Cleome serrulata*)

by

Reagan C. Wytsalucy, Master of Science

Utah State University, 2019

Major Professor: Dr. Brent Black
Department: Plants, Soils, and Climate

Agricultural production among the Native American populations of the Southwest declined significantly during the twentieth century. Although production of corn, beans, and squash, the three most recognized traditional food crops, remains widespread, knowledge regarding the traditional management of these crops was lost. The loss of traditional knowledge is more pronounced for some of the under-recognized traditional food crops including Southwest peach (*Prunus persica*) and Navajo spinach (*Cleome serrulata* Pursh). Decreased peach production during the late twentieth century left only a few sparse historic peach orchards. There is little to no documentation on importance, cultivation or use of Navajo spinach to the Southwest Native American Tribes. The Navajo, Hopi, and Zuni Nations seek to increase the availability of traditional crops for their original uses, such as for food and wool dye. In order for these Native American communities to revitalize traditional agriculture, information was gathered regarding each of these crops, including: varieties and their characteristics, management practices and the

horticultural basis for these practices, along with uses and cultural significance. Southwest peach orchards were located, seeds and plant material obtained and characterized genetically to test the hypothesis that Southwest peaches are divergent from modern cultivars. Information on peach management was collected by interviewing traditional farmers, evaluating historic orchard location features, and through dendrochronology. Dendrochronology involved collecting tree stumps or cores from tree trunks to evaluate growth rings in order to determine seasonal irrigation practices, age and life span of the orchard trees. Navajo spinach seed was collected from multiple locations and compared. Optimum germination conditions were assessed including requirements for overcoming seed dormancy through scarification, plant hormone addition, and chilling and hydration period. Oral histories were gathered from elders of the Navajo, Hopi, and Zuni Nations on management and use of Navajo spinach; the interviews were translated and transcribed. Information on both Southwest peach and Navajo spinach will be useful to encourage traditional management of these culturally important crops.

(195 pages)

PUBLIC ABSTRACT

Explorations and Collaborations of Two Under-recognized Native American Food Crops: Southwest Peach (*Prunus persica*) and Navajo spinach (*Cleome serrulata*)

Reagan C. Wytsalucy

Agricultural production among the Native American populations of the Southwest declined significantly during the twentieth century. Corn, beans and squash, the three most recognized traditional food crops, remains widespread, but knowledge regarding the traditional management of these crops was lost. The loss of traditional knowledge for Southwest Indigenous Nations was more pronounced for the Southwest peach (*Prunus persica*) and Navajo spinach (*Cleome serrulata* Pursh). The Navajo, Hopi, and Zuni Nations are all seeking to increase the availability of traditional crops for their original uses, such as for food and wool dye. In order to revitalize traditional agriculture for these tribes, information regarding these crops was gathered, including: variety characterization, the horticultural basis for traditional management practices, and cultural uses and significance. Southwest peach orchards were located for seed and plant material collections to characterize their genotype and relate them to modern peach cultivars. Traditional farmers were interviewed on management practices and irrigation strategies to correlate to dendrochronology (tree-ring analysis) techniques. Dendrochronology samples included tree stumps or cores to evaluate ring growth variability, age, and life span of the orchard trees. Navajo spinach seed was collected from Chinle, Arizona for germination studies on overcoming seed dormancy. Information on both Southwest peach and Navajo spinach will be useful to encourage culturally important traditional crop management.

ACKNOWLEDGEMENTS

Funding for this research was provided by the Utah Department of Agriculture and Food Specialty Crop Block Grant program, the Utah Agricultural Experiment Station, Western Sustainable Agriculture Research and Education Graduate Student Grant program (#GW17-060), and by Utah Humanities and Utah Division of State History (#OH18.04). Canyon de Chelly National Monument Park Service approved this research to take place with the residents living within the monument grounds (CACH-2015-SCI-0002). Tribal research approvals were obtained through the Navajo Nation Research Review Board (#NNR-17.270T), the Hopi Cultural Preservation Office (#16-001), and the Zuni Tribal Government (Peach Project approved April 23, 2018). Utah State University Institutional Review Board approved this research for each collaborating tribe (Navajo: IRB-7734; Zuni: IRB-9458; Hopi: IRB-8500). Thank you to all tribal and specialist community members who contributed to this research.

A special thanks go to my committee for their guidance and support. James Frisby and Karen South consistently gave assistance through a majority of research pursuits; thank you for all your assistance. My parents, Roy and Donna Talker, continually gave their time to be a part of this research, serving as guides, labor, and company. I am lucky to have them as my parents! More thanks are needed for my husband, Anthony Wytsalucy, who always supported me through this long road and learning venture. This project would not have been near the success that was accomplished without all of you!

Reagan. C. Wytsalucy

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Several crops are known to be heavily utilized by the Southwestern Native American Tribes including the Three Sisters (corn, beans, and squash), melons, and chili (Kuhnlein, 1981; Park, S, N. Hongu, and J.W. Daily III, 2016). The traditional diet for the Southwestern Tribes included other cultivated crops, such as orchard crops, gathered native foods, and game meat through hunting to supplement protein (Benavides, 1630). Over the recent century, much of the traditional agriculture practices and diet were abandoned due to westernization and the formation of reservations. These dietary changes have prompted many health studies and programs regarding Native American dietary needs and diabetes prevention (Kuhnlein, 1981; Teufel, 1996; Kuhnlein & Receveur, 1996).

Today, about fifty percent of Native Americans of the Navajo (Diné) Nation live in rural parts of the reservation and are 50 to 100 miles from the nearest grocery store. The Diné Nation spans a land area approximately the size of Vermont, New Hampshire, and Massachusetts combined, and within this land area there are only thirteen grocery stores (Moore, Benally, and Tuttle, 2008). About eighty percent of products in these grocery stores are highly processed foods that contribute to obesity rates three times the national average for Diné members (Morales, 2015). A recent study shows one in three residents have diabetes (Morales, 2015, Pettyjohn and Livingston, 2016). Within the Diné Nation, seventy-seven percent of the community is considered to have some level of food insecurity, being labeled as a “food desert” (Pardilla, 2014). Similar studies show that

these circumstances are seen among federally recognized tribes throughout the United States (Jernigan, 2012; Teufel, 1996).

Poverty and malnutrition among Native Americans living on reservations is a high priority focus of the United States Department of Agriculture Food and Nutrition Service (USDA-FNS) and for Native American communities to provide healthy, local food alternatives. The *Food Distribution Program on Indian Reservations* (FDPIR) fact sheet, indicates that $100 million was set aside in FY 2013 to purchase fresh fruits and vegetables and other important fresh food commodities for distribution on reservations (USDA-FNS, 2013). Another initiative to promote healthy food supply is through the Fruit and Vegetable Prescription Program on the Navajo Nation, where low income families can qualify for fresh "food stamps" to use at participating local convenience stores, trading posts, or grocery stores (George, 2017; Shin, et al., 2016). The Navajo Nation passed the Junk Food Tax in 2015, with the hope of generating $2 to $3 million a year to support farming throughout their reservation (Livingston, 2016; Morales, 2015). Other tribes in the Four Corners area have similar desires to support agriculture farms and programs, to preserve religious traditions, and important agricultural practices from previous generations (Singletary, et al., 2014).

The passing on of traditional teachings and cultural practices was hindered over several decades by government efforts to transition Native American Tribes from traditional to modern living practices (Stout, 2012). Among the many traditions and cultural practices lost are agriculture growing, harvesting, and cooking methods (Cleveland, et al., 1997; Guarino, 2015; Norton and Sandor, 1997). Recent needs surveys on promoting sustainable agricultural practices on Native American reservations in

Nebraska indicated that there is a need for local understanding of the history, culture, and socio-economic nuances of the tribes being measured (Hart, 2006). Hart (2006) also indicates that a high priority among Native American peoples, in terms of agricultural improvements, is the preservation of cultural and historical resources (Singletary and Emm, 2007). This brings focus to the need to enhance nutrition and provide a source of income by identifying and re-establishing local-production potential for important and unavailable food sources on the reservations.

Species Background

There is much research and focus on the history, use, and growing methods of the Three Sisters Indigenous crops (corn, beans, and squash), which is largely available to Native American community members. The focus for this study was with two under-recognized but historically utilized food crops of the Southwest Native American Tribes: Southwest peach (*Prunus persica*) and Navajo spinach (*Cleome serrulata* Pursh). There is little to no information on full production methods, uses, or importance for both crops as they pertain to the Navajo, Hopi, and Zuni communities. The following is a brief background and description of use and management practices, and the likely scientific approaches needed to understand potential production for each crop.

Peach Use and Production

For several centuries, peaches were an important crop to the Southwest Native American populations. The Southwest peach has been documented growing in Pueblo communities of the Southwest since the time of early Spanish expeditions into the region

(Benavides, 1630). It was a sustainable, mass-produced food source in the Pueblo and Navajo communities impacted by significant events throughout Diné history (Ferguson, 1996; Jett, 1979; Singletary, et.al, 2014). It is widely believed that the Spanish introduced the peaches to the Pueblo communities and that the Navajo obtained the peaches from the neighboring Hopi Tribe during the early 1700s (Sauer, 1993; Singletary, et al., 2014).

In 1864, in an effort to open territory for western-moving "pioneers," the United States Government worked to isolate the Navajo by creating new reservation boundaries at Bosque Redondo. During this time, Navajo citizens were removed from tribal lands, leading to the Navajo Long Walk, where 9,000 Navajos walked over 300 miles to Bosque Redondo (Jett and Thompson, 1974). The important peach crop was believed to be the sole food source for the remaining 1,000 Navajo continuing to reside in Canyon de Chelly, near Chinle, Arizona. After treaties were continuously broken by both sides, the peaches were subjected to total destruction in Canyon de Chelly. This came after consecutive negotiations (seven ratified treaties) made between Navajo leaders and the United States government to prevent raids by Navajo on adjacent tribes and government posts (Acrey, 1979). Stephen Jett (1974) made a full assessment of Captain John Thompson's report of the destruction of Navajo orchards in Canyon de Chelly along with other food crops, livestock and homesteads. It is estimated in Thompson's report that more than 4,000 fruit trees were destroyed in an effort to starve the Navajo and prevent desertions from Bosque Redono.

Despite these ninetieth century government efforts, the original Southwest peach continues to be grown by the residents of Canyon de Chelly National Monument and other sites in the Southwest. Figure 1.1 exhibits other historical locations identified

throughout the Navajo, Hopi and Zuni lands. One of the most important terrains for peach production was vast canyons near Glen Canyon, Arizona to areas near Navajo Mountain and along the San Juan River (Evans, Woods, and McPherson, 2005; Jett, 1977). Other documented locations include the three mesas in the Hopi Reservation, Keams Canyon, Arizona (formerly known as Peach Orchard Springs), remote areas around the main Zuni Village, and in canyon formations on Navajo lands, near Farmington, New Mexico (Ferguson, 1996; Jett, 1979; Singletary, et.al, 2014). There are additional producing areas within other Pueblo Tribes, but these will not be discussed in detail in this study.

Peaches were grown as an important food source and used as a valuable trade good (Jett, 1979). The fruit was used in many different ways, including harvested unripe and boiled, harvested ripe and eaten fresh, or sun dried and stored for later consumption or for trade. The dried fruit was stewed and then eaten (Jett, 1979). The Navajo and Pueblo Tribes did not use peach management techniques used by Spanish missionaries. Specifically, the tribes rarely used grafting or other methods of asexual propagation, but rather propagated seed from superior plants, developing a sort of landrace (Forde, 1931). In Indigenous orchards, trees were not pruned or thinned, and so selections tended to be quite vigorous in generating fruiting wood in the absence of typical horticultural practices (Jett, 1979). Without crop thinning, the fruit size tended to be small, which likely lent itself to efficient sun drying and fruit preservation. Information available on historic irrigation management has been contradictory. Some sources claim that the trees were irrigated, but some Hopi tribal elders say the trees were not irrigated (Forde, 1931; Jett, 1977). Important, and unknown, information about the Southwest peaches includes: physiological adaption to the harsh desert climate (if any), nutritional benefit from

traditional production practices, genetic origin and structure, and documentation of orchard location and age.

Peach Tree and Fruit Characteristics

Understanding how the Southwest peach population adapted to harsh climates, with little precipitation, may be determined by factors contributing to vegetative growth, fresh and dried peach fruit quality, and shelf life for marketing purposes and have potential benefits for modern growers and users. The Southwest peaches commonly have a stout stature (Travis, 2005) as noted at all Navajo, Hopi, and Zuni historic orchard sites visited in this study. Li, et al. (1989) showed that vegetative growth of peaches can be hindered with water stress in that it reduces water flow and gas exchange for photosynthesis processes, which might be the sole contributor to the Southwest peach's structure (Rahmati, et al., 2015). The common trait of smaller fruit could also be caused by traditional pruning practices, which the Berman and DeJong (1996) and Mitchell and Chalmers (1982) studies determine larger canopies produce larger crop loads and reduce mean fruit weight. Additional outcomes of water stress for a full season has been proven to increase fruit soluble solids and increase flower bud set for years following water stress (Li, et al., 1989; Lopez, et al., 2016).

Commercial peach cultivars have been studied to determine health benefits associated with disease and dietary support and may provide comparative understanding of the nutritional characteristics of the Southwest peaches under the traditional management practices. Purported health benefits of peaches include reduced chronic diseases such as type 2 diabetes, obesity, and heart disease (Ford and Mokdad, 2001; Hu,

2003; Schröder, 2007) This is due to the high content of phytochemicals including polyphenolic compounds, carotenoids, pectin and dietary fiber in peach (Alasalvar and Shahidi, 2013; Alvarez-Parrilla, et al., 2013; Chang, Alasalvar, and Shahidi, 2016). Marketing the Southwest peach as fresh or dried fruit may provide the previously mentioned dietary benefits, including high mineral content, low sugar content, and high levels of potassium (Alasalvar and Shahidi, 2013) as opposed to the common canned fruit supply typical on the reservations today. Peach fruit quality and storage is affected by limited irrigation practices, where fruit from limited irrigation treatments have longer shelf life than from trees provided full amounts of water (Li, et al., 1989). There is an abundance of nutritional benefits from fresh peaches, but dried peaches provide higher nutritional and energy value and longer shelf life than fresh fruits (Alvarez-Parrilla, et al., 2013). In drying fresh fruits, much of the nutritional content increases with the exception of certain vitamins and minerals (Thiamine, folic acid, and Vitamin C) which can break down under heating processes (Alvarez-Parrilla, et al., 2013). The overall methods of growing and marketing the Southwest peach throughout the Southwestern Native American Tribes is anticipated to help reduce chronic diseases at a low cost to rural Native American's to counter current circumstances of high cost, limited availably and short shelf life of healthy foods (Story, et al., 1999).

Peach Genetics and Dendrochronology

Navajo peach culture dates back over 400 years and includes seed propagation and seedling selection. How this history has contributed to the selection of traits important to regional production is not clear. Traits that would contribute to regional

adaptation could also be important in modern peach breeding programs. There is interest in determining how this unique population is related to Old World peaches, which Chen and Okie (2017) have been able to determine for other *Prunus* spp. This information could contribute to gene conservation and possibly to breeding, as has been done with *Pyrus* spp. (Kumar, et al., 2017). Determining relatedness among the various cultivars may also provide information on dispersal pathways among the Native Americans in the Southwest (Sitther et al., 2012; Ward et al., 2013).

Dendrochronology might help correlate historic irrigation practices with historical documentations on orchard management. A majority of work done in dendrochronology studies has focused on dating specimen life spans, forest age, and most recently, climate analysis as it relates to precipitation/drought. There is little to no evidence to support the presence of peaches in the Southwest prior to colonial periods; but the use of dendrochronology may be helpful in determining this. Exploring historic Southwest peach orchards could help determine common site characteristics beneficial for peach production in the Southwest. Depending on sample size and ring count, the Southwest peach dendrochronology collection may also be correlated with various chronologies gathered from the Tree-Ring Society for cross dating, as a majority of early and current dendrochronology work has been accomplished in the Southwest (Ahlstrom, 1985).

Navajo Spinach Use and Production

Native plants were commonly gathered and used by the Four Corners Native American Tribes. One such plant is the Rocky Mountain Bee Plant, *Cleome serrulata* (Figure 1.2). This plant has several common names: stinkweed, stinking clover, skunk

weed, and Navajo spinach. Navajo spinach is called “waá” by the Navajo; “túmi” by the Hopi, and “a’pilalu or ado:we” by the Zuni. Historically, Navajo spinach was a nutritious leafy vegetable in spring, used to color wool or paint pottery and baskets, and seeds were ground for bread or eaten raw (Dunmire, 2004; Pratt, 2017). Navajo spinach commonly grows on open rangelands, in disturbed soils around cultivated fields, and in sandy alluvial washes along streambeds (Winslow, 2014). Wild populations of *C. serrulata* are found throughout the United States and Canada with a large herbarium collection curated by the Intermountain Region Herbarium Network. *C. serrulata* is an annual plant with erect, branching growth habit, and grows about 1.5 m in height (Winslow, 2014). The leaves have three leaflets arranged alternately on the plant. Flowers have four petals, extended stamens, and grow in clusters at the end of elongated stems. The fruit is a 5 cm long pod containing several black or white seeds.

The germination and growth of *C. serrulata* have not been adequately determined for efficient cultivation in any agricultural setting. Determining optimum germination is key to manage production, in order to promote local production leading to reclamation of lost traditions and agriculture practices. Searches of Sustainable Agriculture Research Education and National Institute of Food and Agriculture databases indicate no other research focused specifically on *C. serrulata*. The National Agricultural Library lists four papers, but none are focused on germination or plant growth for *C. serrulata*. An Intermountain Herbarium fact sheet recommends 6-8 weeks of chilling but did not specify *C. serrulata* seed dormancy requirements for germination. Seed companies that sell *C. serrulata* report that chilling, scarification, stratification, and hormonal treatments may promote germination. Since *C. serrulata* is widely distributed throughout colder

areas of North America, this suggests that seed may have dormancy phases, require chilling, and/or have a hard seed coat. Cane (2008) states healthy stands of *C. serrulata* and *C. lutea* can generate >20,000 viable seed/plant to potentially produce thick seedling stands in following years.

C. serrulata germination became of interest at the request of a Navajo tribal official, who stated the population was diminishing in vast areas where the species were previously found growing. Possible reasons for this observation are of interest to determine favorable environmental conditions for *C. serrulata* cultivation. The procedures for utilizing Navajo spinach as a food source, wool dye, pottery paint, and its cultural importance for separate tribes are not described in published literature.

Cleome spp. Seed Germination

Germination studies on other *Cleome spp.* could provide insight to the potential dormancy characteristics associated with *C. serrulata*. Tlig, Gorai, and Neffati (2012) reported that wild populations of *Cleome amblyocarpa,* a related species found in Tunisia, germinated best at 25°C but did not germinate at less than 15°C. They also noted that as soil salinity increased or if soil moisture content decreased, germination percentage and rate decreased. However, no work on seedling growth was undertaken. A series of studies on seed dormancy and germination of *Cleome gynandra* were carried out. Ochuodho and Modi (2005) reported better germination of *C. gynandra* when seeds were subjected to alternating temperatures of 20-30°C in light or 30°C. K'Opondo (2015) defined the temperature requirements of different *C. gynandra* biotypes from around Kenya, and noted optimum germination at temperatures of 35-40°C. Ochuodho and Modi

(2005) collected wild *C. gynandra* and found that germination requirements differed with location of the seed source, suggesting that different ecotypes respond to regionally unique environmental conditions. Kamotho et al. (2014) also noted that wild *C. gynandra* seeds planted by Kenyan farmers had erratic germination, which was due to variable seed maturity. They recommend collecting seed from yellow pods, dry seed to 5% moisture, and store for six months before planting. Onyango (2013) reported on the production and utilization of *C. gynandra* as a leafy vegetable in Kenya. They noted *C. gynandra* is both wild-gathered, but also farm-cultivated and has many local uses not dissimilar to Navajo spinach. The main problems Kenyan farmers encountered were poor stands (germination issues), early flowering, and poor-quality seed for planting. They noted an "urgent need for agronomic research and best practices to enhance production" and "a loss of general knowledge of *C. gynandra* use among the younger generation" (Onyango, 2013). The same issues relate to the agronomic and cultural knowledge of Navajo spinach (*C. serrulata*).

Dormancy mechanisms need to be assessed for *C. serrulata* to ensure consistent uniform germination for commercial production. Seed dormancy mechanisms could include embryo immaturity, seed coat impermeability (physical dormancy), endogenous embryo (physiological dormancy), innate dormancy, or a mixture of these mechanisms. Innate seed dormancy is a mechanism various native plant species utilize to prevent germination during unfavorable conditions (Bradbeer, 1988). Seglias, et al. (2018) studied seed dormancy characteristics for 24 native plant species in the Southwest to assist in restoration purposes to counter climate factors, invasive species, and urbanization effects on native vegetation. They found that physiological dormancy

(hormone, cold stratification, etc.) is the most common dormancy in native plant populations with few species simulating combinational dormancy (physical and physiological). Various physiological dormancy types have been classified into three different levels: deep, intermediate, and non-deep as explained by Finch-Savage and Leubner-Metzger (2006), which may be useful as guidelines for our germination studies in characterizing the physiological dormancy mechanisms of *C. serrulata*.

Temperature and hormones are often factors used to overcome physiological dormancy. Temperature is known to have the following effects on seed physiological processes: 1) combined temperature and moisture fluctuation determines seed deterioration rates, 2) storage temperature can affect the rate of seed longevity and dormancy change, and 3) temperature determines the rate of seed germination when dormancy is no longer present (Roberts, 1988). Physiological dormancy can be lost over time with dry storage, where their level of innate dormancy declines, leading to after-ripening (Murdoch and Ellis, 2000; Probert, 2000). An after-ripening process (reduction in concentration of abscisic acid (ABA) is a possible factor in dormancy release, causing heightened sensitivity to Gibberellins (GA) or the need for GA to break seed dormancy (Miransari and Smith, 2014). The variation in germination for *Cleome spp.* and the characteristics of Southwest native species germination requirements in temperate climates is necessary to optimize Navajo spinach establishment and production.

Revitalize the Peach and Spinach foods in the Southwest

The prevalence and utilization of the Southwest peach and Navajo spinach are diminishing in the Southwest at faster rates than the common native food crops (corn,

beans, and squash). This project is timely as the elders who have the traditional horticultural and cultural knowledge regarding these crops are aging and passing. Thus, collecting and documenting their knowledge is imperative for community history and heritage preservation, and for further scientific and cultural studies on the value of stories to document climate change and historical horticultural practices in the Four Corners area. Along with the reintroduction of healthy traditional nutrition and agricultural heritage practices, this project will also provide a lasting document for the Navajo, Hopi, and Zuni Tribal communities to remember and honor their cultural foodways.

Historical events such as the period leading up to the Pueblo Revolt (1680) and the Long Walk (1860) are periods in Southwestern Native American culture where western influence greatly disrupted the people's heritage. Events such as these create lasting memories and narratives crafted to record the traumatic colonial event; these narratives are passed on to future generations, with the desire to preserve for families and their communities' cultural knowledge and history (Narayan, 2008). These outside events and influences have also hindered traditional teachings over several decades. Among these are traditional agricultural production, harvesting, and cooking methods of Southwest peach and Navajo spinach (Norton & Sandor, 1997; Cleveland, et al., 1997; Guarino, 2015).

Oral histories gathered from elders in the Navajo, Hopi, and Zuni Tribes represent a collection of information on historic events and how these affect current Southwest peach and Navajo spinach uses and importance to past and future generations, including leaders. During an oral history interview, it is common that an elder will provide additional memories aside from addressing interview questions. This information is of

great importance for adding emotion to acquiring basic understanding of general management and use of the Southwest peach and Navajo spinach; thus, building an understanding for the Southwest Native American foodways (Finnegan, 1998). This collection of peach and Navajo spinach use will eventually be utilized to create educational materials for local leaders and youth groups, and to serve as resources for both management and marketing of these agriculture products for the benefit of the Navajo, Hopi, and Zuni Tribes. The benefit to younger generations is to provide awareness of ancestral diets and how the nutrient-rich peach and Navajo spinach has been lost with tribal elders over time. This, along with the previously discussed concern for healthy living, all aim to help preserve tribal heritage (Humphrey, 1988).

Research Objectives

CHARACTERIZING PEACHES GROWN BY NATIVE AMERICANS IN THE DESERT SOUTHWEST (CHAPTER 2)

Objective A. Determine how the Southwest grown peaches are related to modern cultivars.

Objective B. Identify unique fruit characteristics of traditional growing practices to modern practices.

Objective C. Utilize dendrochronology to determine age of trees and management practices.

DETERMINING NAVAJO SPINACH (*CLEOME SERRULATA*) GERMINATION REQUIREMENTS (CHAPTER 3). Learn the germination obstacles for *C. serrulata* cultivation.

SOUTHWEST PEACH CULTURAL IMPORTANCE AND USE TO NAVAJO, HOPI, AND PUEBLO COMMUNITIES (CHAPTER 4). Identify peach crop management practices and community importance from tribal elder oral histories.

FOURTH SISTER: IMPORTANCE AND USED OF NAVAJO SPINACH (*CLEOME SERRULATA*), (CHAPTER 5) Identify the importance and use of Navajo spinach to the Navajo, Hopi, and Zuni Tribes.

LITERATURE CITED

Acrey, B.P. 1979. Navajo History: The Land and the People. Rio Grande Press. Glorieta, N.M.

Ahlstrom, R.V.N. 1985. The interpretation of archeological tree-ring dates. Univ. of Ari., Tucson, PhD Diss.

Alvarez-Parrilla, E., L.A. de la Rosa, G.A. González-Aguilar, and J.F. Ayala-Zavala. 2013. Ch17: Phytochemical composition and health aspects of peach products, p. 309-324. In: F. Shahidi (ed.) and C. Alasalvar. Dried Fruits: Phytochemicals and Health Effects. Wiley, Hoboken, N.J.

Alasalvar, C. and F. Shahidi. 2013. Ch1: Composition, phytochemicals, and beneficial health benefits of dried fruits: an overview, p. 1-18. In: F. Shahidi (ed.) and C. Alasalvar Dried Fruits: Phytochemicals and health effects. Wiley, Hoboken, N.J.

Benavides, F.A. de. 1996. A Harvest of Reluctant Souls: The Memorial of Fray Alonzo de Benavides, 1630. Translated by B. H. Morrow. Univ. Press of Colo.

Berman, M.E. and T.M. DeJong. 1996. Water stress and crop load effects on fruit fresh and dry weights in peach (*Prunus persica*). Tree Physiol. 16:859-864.

Bradbeer, J.W. 1988. Seed dormancy and germination. Blackie, Glasglow and London, U.K.

Cane, J.H. 2008. Breeding biologies, seed production and species-rich bee guild of *Cleome lutea* and *Cleome serrulata* (Cleomaceae). Plant Species Biol. 23:152-158.

Chang, S.K., C. Alasalvar, and F. Shahidi. 2016. Review of Dried Fruits: Phytochemicals, antioxidant efficacies, and health benefits. J. Functional Foods. 21:113-132.

Chen, C. and W.R. Okie. 2017. Characterization of polymorphic chloroplast microsatellites in *Prunus* species and maternal lineages in peach genotypes. J. of Amer. Soc. of Hort. Sci. 142(3):217-224.

Cleveland, D.A., F. Bowannie, Jr., D.F. Erachio, A. Laahty, and E. Perramond. 1995. Zuni farming and United States government policy: The politics of biological diversity in agriculture. Agr. and Human Values. 12:2-18.

Dunmire, W.W. 2004. Gardens of New Spain: How Mediterranean plants and foods changed America. Univ. of Texas Press. Austin, T.X.

Evans, W., S.E. Woods, and R.S. McPherson. 2005. Along Navajo trails: Recollections of a trader, 1898-1948. Utah State Univ. Press, Logan, U.T.

Ferguson, T.J. 1996. Historic Zuni Architecture & Society. Univ. of Ariz. Press. Tucson, A.Z.

Finch-Savage, W.E. and G. Leubner-Metzger. 2006. Seed dormancy and the control of germination. New Phytol. 171:501-523.

Finnegan, R. 1998. Family myths, memories and interviewing, p. 177-183. In: R. Perks and A. Thomson (eds.). The Oral History Reader, 2nd. Edition. Routledge, Abingdon, O.X.

Ford, E.S. and A.H. Mokdad. 2001. Fruit and vegetable consumption and diabetes mellitus incidence among U.S. adults. Preventive Medicine. 32:33–39.

Forde, C.D. 1931. Hopi Agriculture and Land Ownership. The J. of the Royal Anthropological Inst. of Great Britain and Ireland. 61:357-405.
George, C., and O. MacKenzie. 2017. Fruit and vegetable prescription program associated with produce purchasing on the Navajo Nation. Window Rock, A.Z. 22 Jun 2018. <http://www.nnhrrb.navajo-nsn.gov/pdf/2017/2017conf_day2/Fruit_Vegetable%20Prescription%20Program%20Associated%20with%20Produce%20Purchangin%20on%20NN.pdf>.
Grossman, Y.L. and T.M. DeJong. 1998. Training and pruning system effects on vegetative growth potential, light interception, and cropping efficiency in peach trees. J. Amer. Soc. Hort. Sci. 123(16):1058-1064.
Guarino, J. 2015. Tribal food sovereignty in the American Southwest. J. of Food Law and Policy. 11:83-111.
Hart, J.G. 2006. Exploring tribal leadership: Understanding and working with tribal people. J. of Ext. 19 Nov 2013. <http://www.joe.org/joe/2006august/a3.php>.
Hu, B. 2003. Plant-based foods and prevention of cardiovascular disease: an overview. Amer. J. of Clinical Nutr. Suppl. 78:544S–551S.
Humphrey, L.T. 1988. "Soup Night": Community creation through foodways, p.53-68. In: T.C. Humphrey and L.T. Humphrey (eds.). "We Gather Together": Food and festival in American Life. Utah State Univ. Press, Logan, U.T.
Intermountain Region Herbarium Network. 2016. *Cleome serrulata* Pursh. SEINet Network Collaboration, Tucson, A.Z. 22 June 2016. <http://intermountainbiota.org/portal/taxa/index.php?taxon=Cleome%20serrulata>.
Jernigan, V.B.B., A.L. Salvatore, D.M. Styne, and M. Winkleby. 2012. Addressing food insecurity in a N.A. reservation using community-based participatory research. Health Edu. Res. 27(4):645-655.
Jett, S.C. 1977. History of fruit raising among the Navajo. Agr. History. 51(4):681-701.
Jett, S.C. 1979. Peach cultivation and use among the Canyon de Chelly Navajo. Economic Bot. 33(3):298-310.
Jett, S.C. and J. Thompson. 1974. The destruction of Navajo Orchards in 1864: Captain John Thompson's report. Ari. and the West. 16(4):365-378.
John, B. 2017. Navajo area audit data. Gallup Indian Medical Center Diabetes Coordinator Meeting. Window Rock, A.Z.
Kamotho, G.N., P.W. Mathenge, R.M. Muasya, and M.E. Dulloo. 2014. Effects of maturity stage, desiccation and storage period on seed quality of Cleome (*Cleome gynandra* L). Res. Desk. 3:419-433.
Kuhnlein, H.V. 1981. Dietary mineral Ecology of the Hopi. J. Ethnobiol. 1(1):84-94.
Kuhnlein, H.V. and O. Receveur. 1996. Dietary change and traditional food systems of Indigenous peoples. Annul Rev. Nutr. 16:417-442.
Kumar, S., C. Kirk, C. Wiedow, M. Knaebel, and L. Brewer. 2017. Genotyping-by-sequencing of pear (*Pyrus* spp.) accessions unravels novel patterns of genetic diversity and selection footprints. Hort. Res. 4(17015):1-10.
Li, S.-H., J. -G. Huguet, P.G. Schoch, and P. Orlando. 1989. Response of peach tree growth and cropping to soil water deficient at various phonological stages of fruit development. J. of Hort. Sci. 64(5):541-552.

Lombard, K.A., S. Forster-Cox, D. Smeal, M.K. O'Neill. 2006. Diabetes on the Navajo nation: what role can gardening and agriculture extension play to reduce it? J. of Rural and Remote Health Res., Edu., Practice and Policy. 6(640):1-16.

Lopez, G., G. Echeverria, J. Bellvert, M. Mata, M. H. Behboudian, J. Girona, and J. Marsal. 2016. Water stress for a short period before harvest in nectarine: Yield, fruit composition, sensory quality, and consumer acceptance of fruit. Scientia Hort. 211:1-7.

Miransari, M. and D.L. Smith. 2014. Plant hormones and seed germination. Environ. and Expt. Bot. 99:110-121.

Mitchell, P.D. and D.J. Chalmers. 1982. The effect of reduced water supply on peach tree growth, and yield. J. Amer. Soc. Hort. Sci. 107:853-856.

Moore, G.R., G. Benally, and S. Tuttle. 2008. The Navajo Nation Quick Facts. Univ. of Ari. Ext. Bul. AZ 147.

Morales, L.L. 2015. The Navajo Nation's Tax on junk food splits reservation. Natl. Public Radio. 08 Apr 2015. <http://www.npr.org/sections/codeswitch/2015/04/08/398310036/the-navajo-nations-tax-on-junk-food-splits-reservation>.

Murdoch, A.J. and R.H. Ellis. 2000. Ch8: Dormancy, viability, and longevity, p.183-214. In: M. Fenner (ed.). Seeds: The Ecology of regeneration in plant communities. CABI Publishing, New York, N.Y.

Narayan. K. 2008. Singing and retelling the past (Conversations with Barre Tolken), p.74-98. In: W. Schneider (ed.). Living with stories: Telling, re-telling, and remembering. Utah State Univ. Press, Logan, U.T.

Norton, J.B. and J.A. Sandor. 1997. Combating desertification with indigenous cultural technology at Zuni Pueblo, New Mexico. Aridlands Nwsl. No. 41. 24 April 18. <https://cals.arizona.edu/OALS/ALN/aln41/norton.html>.

Onyango, C.M., C. Kunyanga, E. Ontita, R. Narla, and J. Kimenju. 2013. Current status on production and utilization of spider plant (*Cleome gynandra*) an underutilized leafy vegetable in Kenya. Genetic Resources and Crop Evolution. 60(7):2183-2189.

Ochuodho, J.O. and A.T. Modi. 2005. Statistical evaluation of the germination of *Cleome gynandra* L. seeds. South African J. of Plant Sci. 22:49-54.

Pardilla, M., D. Prasad, S. Suratkar, and J. Gittelsohn. 2014. High levels of household food insecurity on the Navajo Nation. Public Health Nutr, 17(1):58-65.

Park, S., N. Hongu, and J.W. Daily III. 2016. Native American foods: History, culture, and influence on modern diets. J. of Ethnic Foods. 3:171-177.

Pettyjohn, K., and D. Livingston. 2016. Taking a stand for healthy foods on the Navajo Nation. Dine Community Advocacy Alliance. 09 May 18. <http://ksjd.org/post/taking-stand-healthy-foods-navajo-nation#stream/0>.

Pratt, M.S. 2017. Range plants of Utah. Utah State Coop. Ext., Logan, U.T. 28 Dec 2018. <https://extension.usu.edu/rangeplants/forbsherbaceous/rocky-mountain-beeplant>.

Probert, R.J. 2000. Ch11: The role of temperature in the regulation of seed dormancy and germination, p. 261-292. In: M. Fenner (ed.). Seeds: The Ecology of Regeneration in Plant Communities. CABI Publishing, New York, N.Y.

Rahmati, M., G.H. Davarynejad, M. Génard, M. Bannayan, M. Azizi, and G. Vercambre. 2015. Peach water relations, gas exchange, growth and shoot mortality under water deficit in Semi-arid weather conditions. PLoS ONE. 10(4):1-19.
Roberts, E.H. 1988. Temperature and seed germination. In: S.P Long. and F. J. Woodward (eds) Plants and Temperature. Symposia of the Soc. of Expt. Bio. 42:109–132.
Sauer, J.D. 2003. Historical geography of crop plants: A Select Roster. pp. 117. C.R.C. Press LLC., Boca Raton, F.L.
Schröder, H. 2007. Protective mechanisms of the Mediterranean diet in obesity and type 2 diabetes. J. of Nutr. Biochem, 18(3):149–160.
Seglias, A.E., E. Williams, A. Bilge, and A.T. Kramer. 2018. Phylogeny and source climate impact seed dormancy and germination of restoration-relevant forb species. PLoS ONE. 13(2):1-18.
Shin, S., M. Tsosie, T. Wilmot, E. Piltch, and O. MacKenzie. 2016. The healthy Navajo stores initiative: Program Toolkit. Community Outreach and Patient Empowerment, Gallup, N.M. 28 Dec 2018. <https://docs.wixstatic.com/ugd/0dcff4_918d45d9f8a44b1faf7bd6645fd6aa1a.pdf>.
Singletary, L. and S. Emm. 2007. Strengthening sustainable agriculture practices on American Indian Lands in the Western United States Proc., 23rd Annu. AIAEE Conf., Polson, M.T. J. for Int. Agric. and Ext. Edu. 14(2):82 (abstr.).
Singletary, L. S. Emm, M. Loma'omvaya, J. Clark, M. Livingston, and M. K. Johnson. 2014. Hopi: People of the Land (Sustaining agriculture on the Hopi Reservation). Univ. of Nev. Coop. Ext., Reno, N.V.
Sitther, V., D. Zhang, S. A. Dhekney, D. L. Harris, A. K. Yadav, and W. R. Okie. 2012. Cultivar identification, pedigree verification, and diversity analysis among peach cultivars based on simple sequence repeat markers. J. Amer. Soc. Hort. Sci. 137(2):114-121.
"SoilWeb: An Online Soil Survey Browser." Interfaces to. A. T. O'Geen (ed), Ph. D. University of California, Davis, C.A. 14 Oct. 2013.
Story, M., M, Evans, R.R. Fabsitz, T.E. Clay, B.H. Rock, and B. Broussard. 1999. The epidemic of obesity in American Indian communities and the need for childhood obesity-prevention programs. The Amer. J. of Clinical Nutr. 69:747S-754S
Stout, M.A. 2012. Native American Boarding Schools. ABC-CLIO, LLC. Santa Barbra, C.A.
Travis, T. 2005. Didzétsoh: the peaches of Canyon de Chelly. National Park Service: Sustainability News, p. 18-21.
Tlig, T., M. Gorai, and M. Neffati. 2012. Factors influencing seed germination of *Cleome amblyocarpa* Barr. & Murb. (Capparidaceae) occurring in southern Tunisia. Revue d Ecologie. 67:305-312.
Teufel, N.I. 1996. Nutrient-Health associations in the historic and contemporary diets of Southwest Native Americans. Journal of Nutrition & Environmental Medicine. 6(2):179-195.
Ward, J.A., J. Bhangoo, F.F. Fernández, P. Moore, J.D. Swanson, R. Viola, R. Velasco, N. Bassil, C.A. Weber, and D.J. Sargent. 2013. Saturated linkage map

construction in *Rubus idaeus* using genotyping by sequencing and genome-independent imputation. BMC Genomics. 14(2):1-14.

Williams, R. 2010. Oral History Workshop. Digital Commons at USU Libraries, Logan, U.T.

Winslow, S.R. 2014. Rocky Mountain Beeplant *Cleome serrulata* Pursh. USDA, NRCS-Montana-Technical Note. MT104.

USDA-FNS. 2013. Food Distribution Program on Indian Reservations. Nutr. Program Fact Sheet. USDA Food and Nutrition Service, Washington, D.C.

Figures

Figure 1.1. Map displaying prominent locations of traditional peach growing in the Hopi, Zuni, and Navajo Tribal lands. Image created from Google Earth.

Figure 1.2. Navajo spinach (*Cleome serrulata*) growing along roadside near Bluff, UT. Summer 2016.

CHAPTER 2

CHARACTERIZING PEACHES GROWN BY NATIVE AMERCIANS IN THE DESERT SOUTHWEST

Abstract

Southwest Native American Tribes, such as the Navajo, Hopi, and Pueblo, have grown peaches as an important food source since the early 1600s. Isolated peach orchards in remote canyons and mesa shelves are still tended using traditional methods. The purpose of this study was (1) to locate and characterize these plantings, (2) to understand the genetics of these isolated peach populations, (3) to determine the conditions under which they are grown, and (4) to document how management practices affect tree growth. Four distinct regions with peaches were identified representing lands of three different tribes (Navajo, Hopi and Zuni) and the soils, microclimate, and water availability were documented for each site. Seeds were collected from these isolated populations for genetic analysis. Cores from living trees and dead trees were sampled for tree ring analysis (dendrochronology) to document management and lifespans. Genetic analysis indicates populations from the four different regions are genetically isolated both from modern cultivars and from each other. Documented management practices indicate that trees were not pruned or thinned, and only passively irrigated, and that orchard trees were typically maintained for multiple decades. Dendrochronological analysis confirms the documented management practices. These isolated populations need further characterization for useful traits and should be protected for their unique genetic and cultural significance.

Introduction

Southwest Native American Tribes have continuously grown peaches since at least the 1600s, making them an important food source along with corn, beans, and squash. The Navajo white peach is noted not only for its flesh color but for its small size (Jett, 1977). Peaches were seed propagated over multiple generations, likely forming landraces where plantings were isolated (Marrow, 1996). Historic orchards appear to have been kept isolated from modern cultivars up until the late twentieth century. However, recent efforts have been taken to replant deceased orchards with modern cultivars in annual Earth Day celebrations (Window Rock Navajo Times, 2007). Consequently, seeds from traditional peach varieties and the knowledge of traditional orchard management practices that were previously passed between generations have both become scarce.

Initial expeditions undertaken as part of this project noted possible isolated orchards and individual trees protected from inter-breeding with modern cultivars. Locations of possible historic peach orchards were identified in the Navajo, Hopi, and Zuni Reservations include Canyon de Chelly National Monument; canyons near Navajo Mountain, Utah and Page, Arizona; along the San Juan River in New Mexico; around residences in Hopi, Arizona; and along multiple mesa shelves in Zuni, New Mexico (Bradley, 1973; Evans, Woods, and McPherson., 2005; Ferguson, 1996; Tanner, 1958). These locations are often hidden on mesa shelves or deep in canyons with few access trails. Common characteristics of these locations are co-location with runoff catchment

from mesa tops, or natural waterways including springs and rivers (Ferguson, 1996; Forde, 1931; Hill, 1938; Pawluk, 1995).

Due to the historic practice of seed propagation, and the geographical isolation of these locations, the resulting populations are likely genetically distinct and could have important horticultural traits such as drought and heat tolerance. A genome-wide analysis of peach germplasm was the focus of several recent studies (Bouhadida et al., 2010; Li et al., 2013; Micheletti et al., 2015) but selections from the Native American Southwest (NAS) were not included.

Traditional management practices are different from modern peach growing practices. Trees were primarily seed propagated. During early stages of growth, seedlings were basin irrigated every two weeks, or daily without a basin for successful establishment (Jett, 1979). After establishment, trees subsisted on infrequent irrigation and seasonal precipitation (Forde, 1931; Jett, 1977). Recent research indicated that individual trees from the NAS appear to be more drought tolerant than currently used commercial peaches (Wheeler et al, 2019). Tree training was not existent, and pruning was limited to removal of dead or diseased wood, causing a shrubby growth habit (Jett, 1979). Fruit thinning is not practiced because it is believed to be an act of ending life prematurely (L. Kuwanwisiwma, personal communication; see Chapter 4); thus, impacting fruit size and quality (Minas, Tanou, and Molassiotis, 2018). Harvest occurred from late August to early October. The fruit was eaten fresh and excess fruit sun dried for storage. Dried fruit were rehydrated to make cobblers and jellies or added in stews and other main course dishes (Jett, 1979). Assessment of irrigation practices could be determined through dendrochronological methods along with determining lifespan of

these historic orchards under harsh management conditions. Comparison using dendrochronology are difficult with *Prunus persica*, as the tree-ring literature focuses primarily on forest ecosystems and not horticultural species and cultivars.

The purpose of this research was: (1) to find historic NAS peach orchards, (2) characterize genetic relatedness among NAS sites, and between NAS and modern cultivars; (3) assess fruit quality characteristics of NAS peaches including weight, size, sugar content, and color; (4) determine nutritional content of NAS peach fruit grown under traditional management practices to compare to USDA's standard reference for fresh peaches, and (5) determine orchard age and general irrigation practices by dendrochronology techniques.

Materials & Methods

Plant material

Historic NAS peach orchards were identified in the following locations: Canyon del Muerto, Arizona (CDM) within Canyon de Chelly National Monument; Jayi Canyon near Navajo Mountain, Utah (NMT); Hopi Second and Third Mesas, Arizona (HTM). Characteristics of these locations, including: latitude, site elevation, and soil characteristics, water source and water source elevation, are shown in Table 2.1.

Genetic analysis

Peach germplasm was collected in three regions resenting both Navajo and Hopi tribal lands, with multiple orchards identified in each region: Canyon del Muerto, AZ (CDM-1 and CDM-2; 21 samples); Navajo Mountain, UT (NMT-1; 8 samples); and Hopi

Second Mesa (HTM-2; 7 samples) and Third Mesa in AZ (HTM-3 and HTM-4; 4 samples) (Table 2.1). Individual samples are labeled first by location followed by tree number (eg. NMT-101) in results. Collected NAS peach seed were germinated in greenhouses at Utah State University and transplanted after one growing season to a research orchard in Box Elder County, UT (BE). Young actively growing leaf tissue was collected from 40 accessions, freeze-dried at the USDA-ARS-Forage and Range Research Laboratory and sent to Clemson University for DNA extraction and genotyping. In addition, 20 accessions housed at the Prunus National Clonal Germplasm Repository (NCGR) in Davis, CA representing modern and heirloom cultivars and landraces predominantly from the U.S. were included in the diversity study (Table 2.2).

Genomic DNA extraction, library preparation for Genotyping By Sequencing (GBS; Elshire, et al. 2011), and identification of single nucleotide polymorphism (SNP) markers in NAS and NCGR material followed protocols explained in Bielenberg et al. (2015) using the peach genome v2 (Verde, et al. 2017) as the reference genome (RG). Population structure and SNP diversity analyses followed methods reported in Michelleti et al. (2015). Filtering for missing genotype rates per accession (--mind 0.25) and per SNP (--geno 0.1), for minor allele frequency (MAF>0.05), and linkage disequilibrium (--indep-pairwise 50000 50 0.8) was done in PLINK (version 1.90b6.9; Chang et al., 2015). The filtered dataset was used to calculate identity-by-descent (–genome), create a distance matrix (--distance square 1-ibs), and run principle components analysis (PCA; --pca), Hardy-Weinberg equilibrium (--hardy) analysis and inbreeding (--het) analysis, also in PLINK. Observed (H_o) and expected (H_e) heterozygosity, and the inbreeding coefficient [F coefficient = $(H_o - H_e) / H_T - H_o)$), where H_T = total observations] were

calculated for each accession separately. The H_o, H_e, and F coefficient for the NAS selections were also combined independently from modern accessions by summing the counts from the PLINK output. In addition, a Bayesian cluster analysis was done using fastSTRUCTURE (Raj, Stephens, and Pritchard 2014) with k = 2-12 and default parameters to identify k subgroups of individuals. Results from fastSTRUCTURE were plotted in R (version 3.5.3) as well as a UPGMA phylogenetic tree from the PLINK distance matrix using the aboot function of the poppr package (version 2.8.1; Kamvar, Tabima, and Grünwald, 2014) to distinguish clustered populations.

Fruit quality and nutrition

Fresh fruit samples were taken from traditionally grown fruit at NMT-1 and from seedling Navajo and Hopi peach trees grown at BE and analyzed for fruit characteristics including weight, size, sugar content, and surface color. The NMT-1 orchard had been managed by the same farmers using traditional Navajo practices since the 1940s. The trees at this location are seed propagated and originally planted by progenitors of the current residents, estimated to date back to the late 1800s. The BE orchard contains several seedling selections from Rutger's University (COM-1 and COM-2) and Uzbekistan (COM-3) that were used as modern references. Seedling trees from CDM-1 were also established at this location from 2016-2018. Fruit samples were taken from both the modern and NAS selections at BE. Samples from five different trees were taken at the NMT-1 orchard consisting of white and yellow peaches.

Pits from the same fruit samples, plus additional sources detailed below, were measured for weight and size to relate to archaeological samples predominantly gathered

in New Mexico. The additional seed sources originate from an orchard in Canyon del Muerto, Arizona (CDM-2); HTM-2; and Lovell seed from a commercial nursery source (Sierra Gold Nursery, Yuba City, California). Pits and fruit were weighed, and then length, width and thickness measured with digital calipers. Pit size was compared to archaeological samples found at Navajo, Zuni, and Spanish sites dated between 1600 and the 1900s (Donaldson and Toll, 1982; Moore, Boyer, and Levine, 2004; Post, 2015; Toll, 1986, 1987, 1990). The archaeological samples are collections from Hubbell Trading Post near Ganado, Arizona; Thunderbird Café at Canyon de Chelly National Monument, Arizona; Yamutewa House in Zuni, New Mexico; Navajo Irrigation Project (NIIP) near Shiprock, New Mexico; and various Spanish sites (LA 20237, La Puente, Trujillo House, Menanales, and LA 111322) near Santa Fe, New Mexico (Table 2.4).

Fruit fresh weight and size were measured before sectioning. Fruit length was taken along the suture length, and diameter was measured in two directions (suture to opposite side of fruit, and fruit cheeks perpendicular to the suture) with a digital caliper. Geometric mean diameter (Dg) was calculated based on these three measurements. The fruit was then sectioned into halves with one half weighed without the pit and then freeze dried to determine mesocarp dry matter content. Juice samples were taken from the second fruit half and soluble solids determined using a refractometer. Fruit surface color (lightness, chroma and hue) was determined using a hand-held colorimeter (Konica Minolta CM-2600d). Three color measurements were averaged for each side of the fruit for both over and under color. Fruit quality parameters were averaged across individual fruits for each genotype.

The most commonly known peaches grown by the Southwest Native Americans were white fleshed and free-stone (Evans, Woods, and McPherson, 2005). To understand the potential nutritional benefits of this type of peach grown under traditional agriculture practices, a white, free-stone peach sample was collected from NMT-1 and submitted for a complete FDA food label analysis (Covance Inc. laboratory in Madison, Wisconsin). The nutritional food label report was compared to the USDA standard reference nutritional report for fresh, yellow peaches.

Dendrochronology

Historic peach orchards were sampled across the Navajo, Hopi, and Zuni Reservations. Core samples were taken from both living and dead peach tree trunks and from neighboring trees of other species. A majority of peach tree-ring samples came from dead trees located in older abandoned orchards. Locations included CDM-2, NMT-1 and surrounding orchards near Navajo Mountain, Utah (NMT-2 thru 4); Bacavi Hopi Village, Arizona (HTM-1); and Dowa Yalanne Mountain (ZUI-1) in Zuni, New Mexico. Trees were located on sand to sandy loam soils with pH >7.4 at all locations (Table 2.1).

Dead tree stumps, when available, were cross-sectioned from all listed orchards with cores take from live trees at NMT-1. One incremental core was obtained from each of five live trees representing both apricot and peach. Increment borers were used to sample cores at about 1.2 m above the soil surface. Increment core samples were mounted on wood mounts before sanding to 400 grit. Angers, et. al (2017) found that the death date inferred from tree-rings may differ up to 4 years between tree-ring samples taken near the soil base rather than at breast height. For this study, cross-sections cut

from remaining stump material from dead trees were taken about 30 to 60 cm above the soil surface with a chain saw. This sampling procedure was done in part to account for the multi-stem architecture of traditionally managed peach trees (Jett, 1979). Cross-sections were also sanded to 400 grit prior to ring counting.

A majority of stump samples were heavily weathered. Though we did not test for the carbon break down of peaches (not previously tested), weathering durations are estimated to be from 20 to 50 years depending on orchard location. Increased tree-ring deterioration is estimated to have resulted in nearly 10 outer tree-rings (sapwood tree-rings) potentially worn away once exposed to desert climate conditions after phloem fragmentation (Cornwell et al., 2009). Ring counts were made on visible rings in all samples. Cross-section samples were measured twice and then averaged. The Basal Area Increment (BAI) was calculated for each sample to provide an accurate growth model of annual wood production on an enlarging trunk diameter. To calculate BAI, the tree radius was squared and then multiplied by Pi (3.14) to obtain the area of a circle for each year of ring width increment. The BAI was calculated and plotted for a period corresponding to 5 to 20 years tree age for each region. The Coefficient of Variance (CV) was calculated from the average BAI of each orchard and region (Zuni, Hopi, Navajo Mt., and Canyon del Muerto) to evaluate differences in annual growth due to water availability in order to determine irrigation practices.

Results

Genetic analysis

A final dataset of 56 accessions (from 61), and 2,042 SNPs (from 22,300) was obtained after filtering. The mean observed heterozygosity (H_o) for modern cultivars and landraces was 0.35, ranging from 0.23 to 0.50, and 0.25 for NAS accessions excluding all HTM-3 (HTM-301 to HTM-303) and HTM-207 genotypes with a range of 0.21 to 0.32. The mean expected heterozygosity (H_e) for modern accessions was 0.33 and for NAS without HTM-301-303 and HTM-207 was 0.33. The mean F coefficient for genotypes HTM-301 to 303 was -0.32 and 0.13 for HTM-207. The mean average F coefficient for modern accessions was -0.06, ranging from -0.52 to 0.31 and for NAS was 0.24, ranging from 0.03 to 0.35.

A UMPGA phylogenetic tree with the 35 Navajo and Hopi genotypes and 20 accessions (Figure 2.1) clearly distinguished two main populations, consisting of NAS genotypes (A), and all modern accessions but including four Hopi genotypes (HTM-301 to 303 and HTM-207) (B). PCA analysis further determined differences in the two population clusters showing 5 distinct subgroups of the peach germplasm (Figure 2.2, panel A). They are grouped as follows: NMT-1 and HTM-4 consisting of all Jayi Canyon samples near Navajo Mountain population and one Third Mesa Hopi, AZ genome, CDM-1 and CDM-2 as the Canyon del Muerto population, all HTM-2 samples except HTM-207 population, and accession groups 1 and 2, which are separated in the top clade of the phylogenetic tree (Figure 2.2, panel A). The PCA analysis was further confirmed by the fastSTRUCTURE analysis (Figure 2.2, panel B) which is paired with the PCA plot to

show individual genotype and accession stratification. Similar to the PCA analysis, the number of subpopulations (K) determined by fast STRUCTURE analysis was five (Figure 2.2, panel B), with the eight admixed accessions on the left of the figure.

Fruit quality and nutrition

The NMT-1 white fruit was smaller, less dense, and contained less sugar overall than COM-3 white fruit grown at BE orchard (Table 2.3). Yellow fruit from NMT-1 were larger than NMT-1 white fruit, but consistently smaller, less dense, and contained less sugar than COM-1 and COM-2 yellow fruit grown in BE orchard. White CDM-1 fruit grown at the BE orchard was similar to other fruit collected in the BE orchard overall. Both white and yellow fruit grown at NMT-1 tended to be longer (higher L:D) and had less mesocarp dry matter content than fruit grown in the BE orchard (Table 2.3). NMT-1 grown fruit also had less mesocarp per pit than BE grown fruit. Color varied by location and genotype, with no distinct trend. The NMT-1 genotypes and CDM-1 genotypes tended to have a lighter yellow ground color with a slight blush overcolor.

Pit size appears to be smaller overall for fruit grown in the BE orchard under commercial management conditions than those grown at the NMT-1 orchard with traditional management conditions (Table 2.3). Pits collected from archeological sites were similar in size to NMT-1, CDM-1 and CDM-2 seed (Table 2.3 and 2.4). The HTM-2 seed grown in the BE orchard had the smallest average seed size of all samples. The HTM-2 seed was most similar in size to Yamutewa House archeological collection in Zuni, NM. The NIIP archeological site has many fragmented pits and was indicated to have high variability among pit samples (Donaldson and Toll, 1982).

From the limited sample, it appears that Navajo white fruit grown at the NMT-1 orchard had higher content of calories, fiber, fat, carbohydrates, and minerals than the standard USDA fruit sample (Table 2.5). Protein and sugar content were lower for the Navajo white peach with less total fatty acids than the USDA published standard. This suggests the need for additional research on nutritional value of NAS fruit.

Dendrochronology

Tree age based on total tree-rings for most peach orchards was >50 years. HTM-1 and CDC-2 samples averaged 76 years (Table 2.6). ZUI-1 had the fewest tree-rings out of all locations, 38 years. Values of BAI for each sample region indicate Hopi samples have the most growth and variation between years 5 to 20 (Figure 2.3). Navajo Mountain orchards also had a high BAI, but with less variation in years 5 to 20. Canyon del Muerto orchards had a majority of BAI less than 5 cm^2. The Zuni orchard BAI remained small (>7cm^2) throughout the 5 to 20 year period of the samples collected.

Orchards within the Navajo Mountain area did not have a CV larger than 50% (Table 2.6). The Navajo Mountain orchards are similar to the HTM-1 orchard, which was said to have only received seasonal precipitation by the grandson of the original HTM-1 planter. The Navajo Mountain orchards have the lowest CV of all orchards sampled. Values of CV were calculated by sample region where CDM-1 had the highest CV (92%) followed by Zuni, NM; Hopi, AZ; and lastly Navajo Mountain, UT. Inter-tree growth comparisons between regions did not show a significant difference between Navajo Mt. sites (all NMT) and Hopi (HTM) at P=0.130 and Canyon del Muerto (CDM) and Zuni (ZUI) at P=0.476 via T-test (Table 2.6).

Discussion

Genetic analysis

Peaches are naturally self-pollinating and can easily develop inbred populations (99.9% homozygous) over a minimum of 6 generations from a single founder individual, and more than 10 generations for populations with more than 50 individuals based on allele frequency (Robertson,1961). In this study, the NAS population structure depicted extensive inbreeding forming subpopulations different not only from modern accessions but also from those in distant tribal regions across the Southwest (Figure 2.1). This seems to be the case with a majority of NAS genotypes since their inbreeding coefficient (F) is 0.24 and they do not cluster with the more heterozygous accessions included in this analysis. The HTM-301 to 303 and HTM-207 genotypes grouping with the heterozygous accessions is assumed to be a result of outcrossing with modern cultivars planted sporadically throughout the Hopi communities neighboring the original peach orchards, which began in the late nineteenth century (Diamond, 2010). The NMT population has been completely isolated from modern cultivars as the current caretakers are traditional Navajo elders that continue traditional management practices (Figure 2.2, Panel A). Both CDM populations are no longer isolated from modern cultivars as nursery material is made available for Navajo youth to rehabilitate their ancestral orchards. The caretakers of both CDM populations continue to practice traditional agriculture and intend to keep their original family seed isolated from modern cultivars.

Fruit quality and nutrition

In this study, like genotypes were not planted in both NMT-1 and BE locations, which limits the ability to determine the contribution of genetic and environmental factors on fruit quality. Modern peach cultivars grown under stressful management practices generally have reduced marketable fruit quality (Lopez, et al., 2016). The NMT-1 site showed active irrigation throughout the life of trees grown in that location based on availability of water and also had a relatively high growth rate based on BAI, suggesting consistently available water. The NMT-1 fruit quality is assumed to be a result of genetic traits and lack of thinning with varying influence from irrigation practices, but as mentioned before, there is no way to separate genetic from environmental factors. The small size of the NMT-1 grown fruit relative to BE grown fruit could result from lower water availability. The mesocarp dry matter content of the NMT-1 fruit ranged from 15.3 to 15.5 and was lower than BE-grown fruit. Lower mesocarp dry matter can be attributed to higher levels of irrigation during the final stage of fruit maturity and ripening (Engin, et al., 2010). Split pits were not observed in sampled fruit, which can result from intermittent irrigation, but is also a function of genetic susceptibility.

Seed from archeological sites were observed to be similar in size to recent fruit collection sites, indicating similarities over time. Hubbell Trading Post collection is similar to NMT-1 seed (Table 2.3 and 2.4), ‘Lovell’, and seed from the twentieth century Navajo Indian Irrigation Project (NIIP) site. Seed size from NIIP was highly variable in size, and this was thought to be a result of stressful growing conditions (Brinkman, 1974). Seed from Thunderbird Café site was similar in width and thickness to CDM-2 site about 16 km away. HTM-2 seed, although grown at BE is similar in size to seed from

the Yamutewa House in Zuni, NM. HTM-2 and Yamutewa House are >110 km apart, but the Hopi and Zuni Tribes were known to have regularly traded (Brody, 1991).

Dendrochronology

There is minimal information that can be utilized on tree-ring variability in fruit trees based on irrigation practices. Instead, we can assume that larger annual growth, as measured by BAI correlates with increased in-season water availability, as has been documented for other woody species. For the NAS peach material, the BAI appeared to be correlated with known irrigation practices for these orchards, as well as ethnographic documentation of orchard irrigation practices from tribal elders (see Chapter 4). Hopi and Navajo Mt. regions had the highest BAI and Zuni and Canyon del Muerto regions the lowest BAI in years 5 to 20 (Figure 2.3). Elders from Canyon del Muerto region and Hopi indicated watering young fruit trees in the first part of their life, which would contribute to a high BAI (Wytsalucy, 2019). However, the NMT location has access to a spring which would provide consistent water availability.

Irrigation is irregularly practiced by caretakers at the CDM-1 location, which is reflected in the higher CV (Table 2.6). Flow from a spring is diverted to NMT-1 orchard during fruit ripening, but not early in the growing season. The NMT-3 orchard likely has access to water from a shallower water table in addition to precipitation, as it is downhill from the main spring source supplying water to NMT-1 resulting in higher CV than other NMT sites (Table 2.6). The NMT-2 orchard has a spring that was dammed for crop irrigation similar to that of NMT-1, but the CV less than NMT-1 and 3 indicating more consistent water availability. The ZUI-1 CV (50%) is similar to Navajo Mt. orchards, but

is said to have never been irrigated due to geography and proximity to natural water sources. The Hopi site (HTM) was said to be irrigated occasionally during drought seasons.

In the most isolated orchards (NMT-2 and 4), the fruit trees lived more than half a century and showed signs of severe sapwood weathering (Figure 2.4). Additionally, missing rings were noted in some samples which indicates additional missing years to the weathered sapwood. Exact age of these samples is speculated to be near 80 to 100 years for the HTM-1 and CDM-2 locations, where deceased trees were sampled (Table 2.6). A live tree cored at the NMT-1 site indicated tree age of 76 years. The deceased Zuni orchard consisted of cross sections showing the shortest life-span at 38 years. The ZUI-1 caretakers never irrigated the trees, but mounded soil around the trunk base annually to generate suckers as renewal growth and increase water retention around the tree.

Conclusion

Additional work is needed to fully characterize the NAS peach germplasm. The inbred Navajo and Hopi populations are particularly isolated. Orchards grown in proximity to modern replants increase the probability of outcrossing, as has been noted to occur with the four Hopi samples. Based on inbreeding estimates of 6 generations (assuming a single founder individual), and dendrochronology age of the existing trees, the isolation period could range from 240-480 years. Further work is ongoing for gathering phenotypic information on each NAS genotype. Additional assessment of fruit and seed pit quality is ongoing to determine differences due to growth location and management strategies.

Literature Cited

Angers, V.A., Y. Bergeron, and P. Drapeau. 2017. Cross Dating Dead Trees: Does Sampling Height Influence Results? Tree-Ring Research 73(1): 24-34.

Bielenberg, D.G., B. Rauh, S. Fan, K. Gasic, A.G. Abbott, G.L. Reighard, W.R. Okie, and C. E. Wells. 2015. Genotyping by sequencing for SNP-based linkage map construction and QTL analysis of chilling requirement and bloom date in peach [*Prunus persica* (L.) Batsch]. Plos ONE 10(10): e0139406.

Bouhadida, M., M.A. Moreno, M.J. Gonzalo, and J.M.A. Segura. 2011. Genetic variability of introduced and local Spanish peach cultivars determined by SSR markers. Tree Genet. and Genome 7(2):257-270.

Bradley, Z.A. 1973. Canyon de Chelly: the story of its ruins and people. Office of Publications National Park Service: U.S. Dept. of Interior. Washington, D.C.

Brinkman, K.A. 1974. Seeds of woody plants in the United States: Agr. Hdbk. 450. U.S. Dept. Arg., Washington, D.C.

Brody, J.J. 1991. Anasazi and Pueblo Painting. Univ. New Mexico Press, Albuquerque.

Chang, C.C., C.C. Chow, L.C.A.M. Tellier, S. Vattikuti, S.M. Purcell, J.J. Lee. 2015. Second-generation PLINK: rising to the challenge of larger and richer datasets. GigaSci 4.

Cornwell, W.K., J.H. Cornelissen, S.D. Allison, J. Bauhuss, P. Eggleton, C.M. Preston, F. Scarff, J.T. Weedon, C. Wirth, and A.E. Zanne. 2005. Plant traits and wood fates across the globe: rotted, burned, or consumed?. Global Change Ecol. 15:2431-2449.

Diamond, D.H. 2010. Origins of Pioneer Apple Orchards in the American West: Random Seedling versus Artisan Horticulture. Agr. History 84(4):423-450.

Donaldson, M.L. and M. Toll. 1982. Analysis of floatation samples and macro-botanical remains: NIIP Blocks VIII and IX mitigation, and X and XI Testing. Castetter Lab. for Ethnobotanical Studies, Univ. of New Mexico.

Elshire R.J., J.C. Glaubitz, Q. Sun, J.A. Poland, K. Kawamoto, E.S. Buckler, and S.E. Mitchell. 2011. A robust, simple genotyping-by-sequencing (GBS) approach for high diversity species. PLoS ONE 6(5):1-10.

Engin, H., F. Sen, G. Pamuk, and Z. Gökbayrak. 2010. Research on the physiological disorders and fruit quality of Cardinal peach. N.Z. J. Crop Hort. Sci. 38(1):39-46.

Evans, W., S.E. Woods, and R.S. McPherson. 2005. Along Navajo Trails: Recollections of a Trader, 1898-1948. Utah State University Press, Logan, UT.

Ferguson, T.J. 1996. Historic Zuni Architecture and Society. Univ. of Arizona Press. Tucson, AZ.

Forde, D. 1931. Hopi Agriculture and Land Ownership. J. of the Royal Anthropol. Institute of Great Britain and Ireland 61:357-405.

Hill, W.W. 1938. The agriculture and hunting methods of the Navajo Indians. Yale Univ. Publ. Anthropol 18.

Jett, S. 1977. History of Fruit Tree Raising Among Navajo. Agricultural History 51(4):681-701.

Jett, S. 1979. Peach Use and Cultivation Among the Canyon de Chelly Navajo. Economic

Botany 33(3): 289-310.
Kamvar, Z.N., J.F. Tabima, N.J. Grünwald. 2014. Poppr: an R package for genetic analysis of populations with clonal, partially, and /or sexual reproduction. PeerJ 2:e281.
Kuwanwisiwma, L. 2016. Hopi Cultural Preservation Director, 1988-2017. Personal communication.
Lopez, G., G. Echeverria, J. Bellvert, M. Mata, M.H. Behboudian, J. Girona, J. Marsal. 2016. Water stress for a short period before harvest in nectarine: Yield, fruit composition, sensory quality, and consumer acceptance of fruit. Scientia Hort. 211:1-7.
Marrow, B.H. (ed.). 1996. A Harvest of Reluctant Souls: The Memorial of Fray Alonso de Benavides, 1630. Univ. Press Colo., Niwot, Colo.
Michelleti, D.M.T. Dettori, S. Micali, V. Aramini, I. Pacheco, C.S. Linge, S. Foschi, E. Banchi, T. Barreneche, B. Quilot-Turion, P. Lambert, T. Pascal, I. Iglesias, J. Carbó, L. Wang, R. Ma, X. Li, Z. Gao, N. Nazzicari, M. Troggio, D. Bassi, L. Rossini, I. Verde, F. Laurens, P. Arús, and M. J. Aranzana. 2015. Whole-Genome Analysis of Diversity and SNP-Major Gene Association in Peach Germplasm. PLoS ONE 10(9):1-19.
Minas, I.S., G. Tanou, and A. Molassiotis. 2018. Environmental and orchard bases of peach fruit quality. Scientia Hort. 235:307-322.
Moore, J.L., J.L. Boyer, and D.F. Levine. 2004. Adaptations on the Anasazi and Spanish frontiers: Excavations at Five Sites Near Abiquiú, Rio Arriba County, New Mexico. Office of Archaeological Studies, Museum of New Mexico. Archaeological Notes 187.
Okie, W.R. 1998. Handbook of Peach and Nectarine Varieties: Performance in the Southeastern United States and Index of Names. U.S. Dept. Agr., Springfield, VA.
Pawluk, R.R. 1995. Indigenous Knowledge of Soil and Agriculture at Zuni, New Mexico. Iowa State Univ. MS Thesis. 16744.
Post, S.S. 2015. Excavations for the NM History Museum (LA 111322): 350 Years of Occupation and Changing Land Use Behind the Palace of the Governors in Santa, Fe, New Mexico. Office of Archaeological Studies, Museum of New Mexico. Archaeology Notes 472.
Raj, A., M. Stephens, and J.K. Pritchard. 2014. fastSTRUCTURE: Variational Inference of Population Structure in Large SNP Data Sets. Genet. 197:573:589.
Roberston, A. 1961. Inbreeding in artificial selection programs. Genet. Res. Cambridge 2:189-194.
Tanner, C.L. 1958. Indians of Arizona. Arizona Highways. 34(8): 4-33.
Toll, M. 1987. Plant materials from the Yamutewa house (LA 9093), Zuni Pueblo. Castetter Lab. for Ethnobotanical Studies, Univ. of New Mexico. Tech. Ser. 206.
Toll, M. 1990. Historic macrobotanical materials from Hubbell Trading Post. Near Ganado, Arizona. Castetter Lab. for Ethnobotanical Studies, Univ. of New Mexico. Tech. Ser. 285.
USDA-ARS. 2019. USDA Food Composition Databases. Natl. Agr. Library. 12 February 2019. <https://ndb.nal.usda.gov/ndb/>.

USDA-ARS. 2019. Germplasm Resource Information Network (GRIN-Global). U.S. Dept. Agr. -Agr. Res. Serv., Washington, D.C. 10 April 2019. <https://www.ars-grin.gov/npgs/gringlobal/sb/home.html>.

Verde, I., L. Dondini, S. Micali, G. Pagliarani, E. Vendramin, R. Paris, V. Aramini, L. Gazza, L. Rossini, D. Bassi, M.Troggio, S. Shu, J. Grimwood, S. Tartarini, M.T. Dettori, and J. Schmutz. 2017. The peach v2.0 release: high-resolution linkage mapping and deep resequencing improve chromosome-scale assembly and contiguity. BCM Genomics 18:225.

Wheeler, W., R. Wytsalucy, B. Black, G. Cardon, and B. Bugbee, 2019. Navajo peach trees have greater physiological resilience to water stress than Lovell peach trees: Precision water stress using automated weighing lysimeters. HortScience 54(5):799-803.

Window Rock Navajo Times. 2007. Earth Day. Window Rock Navajo Times Archives, Window Rock, AZ.

Tables

Table 2.1. Characteristics of locations where Native American Southwest peach seed, fruit, and dendrochronology samples were collected. Locations include Canyon del Muerto, AZ (CDM-1 to 2); various canyons near Navajo Mountain, UT (NMT-1 to 4); Second and Third Mesas in Hopi, AZ (HTM-1 to 4); and Zuni, NM (ZUI-1 to 2). An orchard in Box Elder County, Utah (BE) was used to grow out peach selections for genetic analysis and for fruit.

Location	Latitude	Site Elevation (m)	Soil* pH	EC (dS/m)	Texture	Ann. Precip. (cm)**	Water Source Elevation (m)***
CDM-1	36° 09'	1750	7.8	1.0	Sand	23.1	1748St, Wt
CDM-2	36° 09'	1728	7.8	1.0	Sandy loam	23.1	1725St, Wt
NMT-1	36° 50'	1356	7.6	0.2	Sand	29.7	1369S, 1346St
NMT-2	36° 49'	1388	8.1	1.0	Sand	29.7	1407S, 1376St
NMT-3	36° 50'	1355	8.0	1.0	Sand	29.7	1369Sp
NMT-4	36° 39'	1667	7.5	0.2	Sand	29.7	1762R
HTM-1	35° 54'	1937	7.9	1.0	Sandy loam	33.0	We
HTM-2	35° 50'	1931	7.9	1.0	Sandy loam	33.0	1931R
HTM-3	35° 55'	1938	7.9	1.0	Sandy loam	33.0	We
HTM-4	35° 52'	1740	7.9	1.0	Sand	33.0	1737-1806R
ZUI-1	35° 03'	2101	8.2	0.0	Sand	31.9	2118R, 2195Sp
ZUI-2	35° 0'	2056	7.6	1.0	Sand	31.9	2088R
BE	41° 41'	1366	7.9	1.0	Loam	41.9	We

*Source: USDA-NRCS Soil Survey
**Source: weather.gov
***Water Source Key (Sp= Spring; St= Stream; Wt= Watertable; We= Well; R= Surface Runon

Table 2.2. Peach accessions used for comparison to Native American Southwest peaches, including name and their genome site identifier number (DPRU #), origin and pedigree information where available. OP indicates open pollinated.

Accessions	DPRU #*	Origin	Pedigree**
J.H. Hale	3058	CT, USA	Elberta self
Cardinal	3059	GA, USA	Hale Haven self
RedTop	2775	CA, USA	Sunhigh × July Elberta OP
Elberta	3069	GA, USA	Chinese cling × OP (perhaps × Early Craw)
Chinese Cling	505	China	Landrace
DPRU.520.0003A	520	AZ, USA	N/A
Aguascalientes 6-10	676	Mexico	N/A
KIANG-SI	737	Spain	N/A
Stanwick	1132	Syria	N/A
Golden Queen Improved	1576	New Zealand	Landrace
Yumyeong	1612	South Korea	Landrace Korean Reference
Late Crawford	943	CA, USA	N/A
Cascata	2007	Brazil	(Sunhigh × Redcrest) OP
Boston Red	2141	CA, USA	N/A
Indian Blood Cling	2151	CA, USA	Landrace likely of Blood Clingstone, France
Lola Queen	2159	CA, USA	N/A
Mountain Rose	2163	NJ, USA	N/A
Orange Cling	2166	CA, USA	N/A
Raritan Rose	2171	CA, USA	J.H. Hale × Cumberland
Springtime	2180	CA, USA	(Luken's Honey × July Elberta) × Robin

*Source: USDA-ARS. 2019. GRIN-Global at www.ars-grin.gov/npgs/gringlobal/sb/home.html
**Source: Okie, W.R., 1998

Table 2.3. Fruit characteristics of Native American Southwest peach selections and seedling progeny of modern cultivars. Southwest peach selections (NMT-1) were grown at Jayi Canyon near Navajo Mountain, UT. Modern seedling selections (COM-1 to 3) were grown in Box Elder County, UT along with propagated seed originally collected from Canyon del Muerto, AZ. Fruit characterization for all genotypes include fruit quality, color, and pit size. Fruit flesh color is indicated by white (Wh) or yellow (Ye). Standard Error (SE) was calculated for fruit mass. Geometric mean diameter (Dg) was calculated from fruit length and diameter (L:D) in two directions. Fruit dry matter content (DM) was for the mesocarp. Mesocarp pit ratio is based on fruit fresh weight.

Characteristic of Native American Southwest peach selections							
Genotype		NMT-1	NMT-1	CDM-1	COM-1	COM-2	COM-3
Growth Location		NMT-1	NMT-1	BE	BE	BE	BE
Flesh Color		Wh	Ye	Wh	Ye	Ye	Wh
Fruit Quality							
n		71	18	24	6	6	12
Mass (g)±SE		28.9±1.7	51.6±4.5	71.1±3.7	171±4.7	192±13.1	52.8±2.2
Dg (mm)		37.6	43.6	47.7	63.8	65.8	43.0
L:D		1.05	1.03	0.887	0.852	0.840	0.842
Density (g/cm^3)		1.10	1.19	1.24	1.26	1.29	1.27
%DM-Mesocarp		15.3	15.5	20.2	19.0	23.5	20.2
Mesocarp:pit (g)		6.46	8.69	18.6	21.8	18.7	13.1
SSC (%)		12.5	12.7	16.9	14.6	18.2	16.4
Fruit Color							
Under	*n*	37	12	24	6	6	12
	Lightness	63.8	71.3	70.6	71.5	73.6	77.7
	Chroma	28.9	42.5	38.5	53.1	59.1	42.3
	Hue	65.1	85.2	95.4	74.5	75.6	90.4
Over	Lightness	50.3	74.4	71.8	45.8	65.0	74.3
	Chroma	19.3	46.6	35.7	32.3	50.4	43.1
	Hue	54.3	75.4	81.1	38.6	67.5	81.0
Pit Size							
n		35	18	24	6	6	12
Mass (g)		4.08	5.42	3.67	7.62	9.76	3.85
Length (mm)		28.9	31.4	28.8	35.8	38.4	27.4
Width (mm)		20.1	21.0	22.1	26.5	29.6	21.7
Thickness (mm)		16.1	16.3	15.5	17.7	19.5	16.3

Table 2.4. Pit size of samples from archeological sites compared to recently collected seed. Size measurements are given as length (L), width (W), and thickness (Th). Archeological samples were from various sites in New Mexico and Arizona. Native American Southwest peach selections were grown in multiple locations including Box Elder County, UT (BE); Canyon del Muerto, AZ (CDM-2); Jayi Canyon near Navajo Mountain, UT (NMT-1) during the 2017 and 2018 seasons. Lovell seeds were from commercial nursery in Yuba City, CA (YCA). The original collection location for HTM-2 grown at BE was Third Mesa in Hopi, AZ. Deposit periods with (c.) indicates century.

Archeological seed					
Collection Site	Deposit Period	*n*	L (mm)	W (mm)	Th (mm)
Hubbell Trading Post[1]	late 19th - 20th c.	67	27.9	21.5	15.7
Thunderbird Café[1]	20th c.	4	22.0	23.9	15.8
Yamutewa House[2]	18th - 20th c.	7	24.8	18.0	13.5
NIIP[3]	20th c.	182	26.2	-	-
LA 20237[1]	20th c.	2	24.9	20.4	-
La Puente[4]	1842 - 1912	6	25.7	17.9	14.5
Trujillo House[4]	1750 - 1900	6	25.4	19.2	15.2
LA 111322[5]	17th c.	0.5	23.4	18.8	8.80

Collected seed						
Genotype	Growth Location	*n*	Pit Mass (g)	L (mm)	W (mm)	Th (mm)
HTM-2	BE	5	2.62	24.2	18.0	14.4
CDM-2	CDM-2	15	2.66	25.9	19.6	13.8
NMT-1	NMT-1	15	3.55	29.1	19.6	15.5
Lovell	YCA	15	4.34	27.6	22.9	18.1

Toll, M., 1990[1]
Toll, M., 1987[2]
Donaldson, M.L. and M. Toll, 1982[3]
Moore, J.L., J.L. Boyer, and D.F. Levine, 2004[4]
Post, S.S., 2015[5]

Table 2.5. FDA food label nutrient analysis of Navajo white peach and USDA's standard peach reference. Navajo peach source is from Jayi Canyon near Navajo Mountain, UT (NMT-1).

	Navajo White	USDA Standard**	% Difference
Moisture (g)	42.6	44.4	-4
Ash (g)	0.23	0.215	7
Calories (kcal)	27.1	19.5	39
Protein (g)	0.35	0.455	-23
Total Fat (g)	0.2	0.125	60
Total Carbohydrate (g)	6.81	4.77	43
Total Dietary Fiber (g)	0.951	0.75	27
Total Sugars (g)	4.10	4.20	-2
Minerals			
Calcium (mg)	11.1	3	270
Iron (mg)	0.188	0.125	50
Potassium (mg)	129	95	36
Sodium (mg)	0	0	0
Lipids			
Saturated Fatty Acid (g)	0.0089	0.0095	-6
Monounsaturated Fatty Acid (g)	0.0051	0.0335	-85
Polyunsaturated Fatty Acid (g)	0.021	0.043	-51
Trans Fatty Acids (g)	0	0	0
Cholesterol (mg)	0	0	0

*Value per 50g serving size.
**USDA Food Composition Databases

Table 2.6. Dendrochronology analysis of peach wood samples. Coefficient of Variation (CV) indicates seasonal variation in growth rate. Locations for samples include Dowa Yalanne Mountain in Zuni, NM (ZUNI-1); Third Mesa in Hopi, AZ (HTM-1); Canyon del Muerto, AZ (CDM-2); and four orchards near Navajo Mountain, UT (NMT-1 to 4). CV indicated year-to-year variation in tree growth due to water availability and is used here to compare possible differences in irrigation practices. Values are means of all samples for each region.

Coefficient of Variation by Orchard			
Location	CV	*n*	Max Age (yr)
ZUI -1	50	3	38
HTM-1	44	3	76
CDM-2	92	2	76
NMT-1	45	7	60
NMT-2	43	3	46
NMT-3	51	4	45
NMT-4	45	1	68
Coefficient of Variation by Region			
Zuni	50	3	38
Hopi	44	3	76
Navajo Mt.	37	15	68
Canyon del Muerto	92	2	76
Inter-tree growth Comparison		T-Test ($P \leq 0.05$)	
Zuni vs Hopi			<0.001
Zuni vs Navajo Mt.			<0.001
Zuni vs Canyon del Muerto			0.476
Hopi vs Navajo Mt.			0.130
Hopi vs Canyon del Muerto			<0.001
Navajo Mt. vs Canyon del Muerto			<0.001

Figures

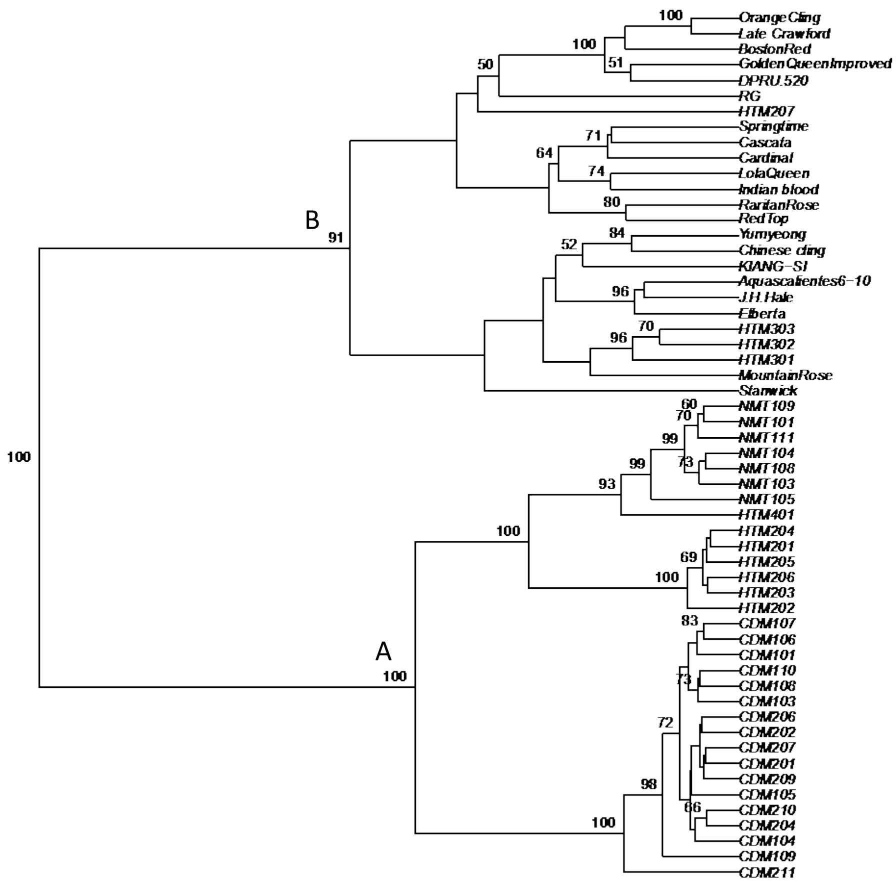

Figure 2.1. UPGMA tree for 20 accessions and 35 Southwest peach genotypes listed by location and tree number (eg. NMT101). Locations include Canyon del Muerto, AZ (CDM-1 to 2); Jayi Canyon near Navajo Mountain, UT (NMT-1); and Second and Third Mesas in Hopi, AZ (HTM-2 to 4).

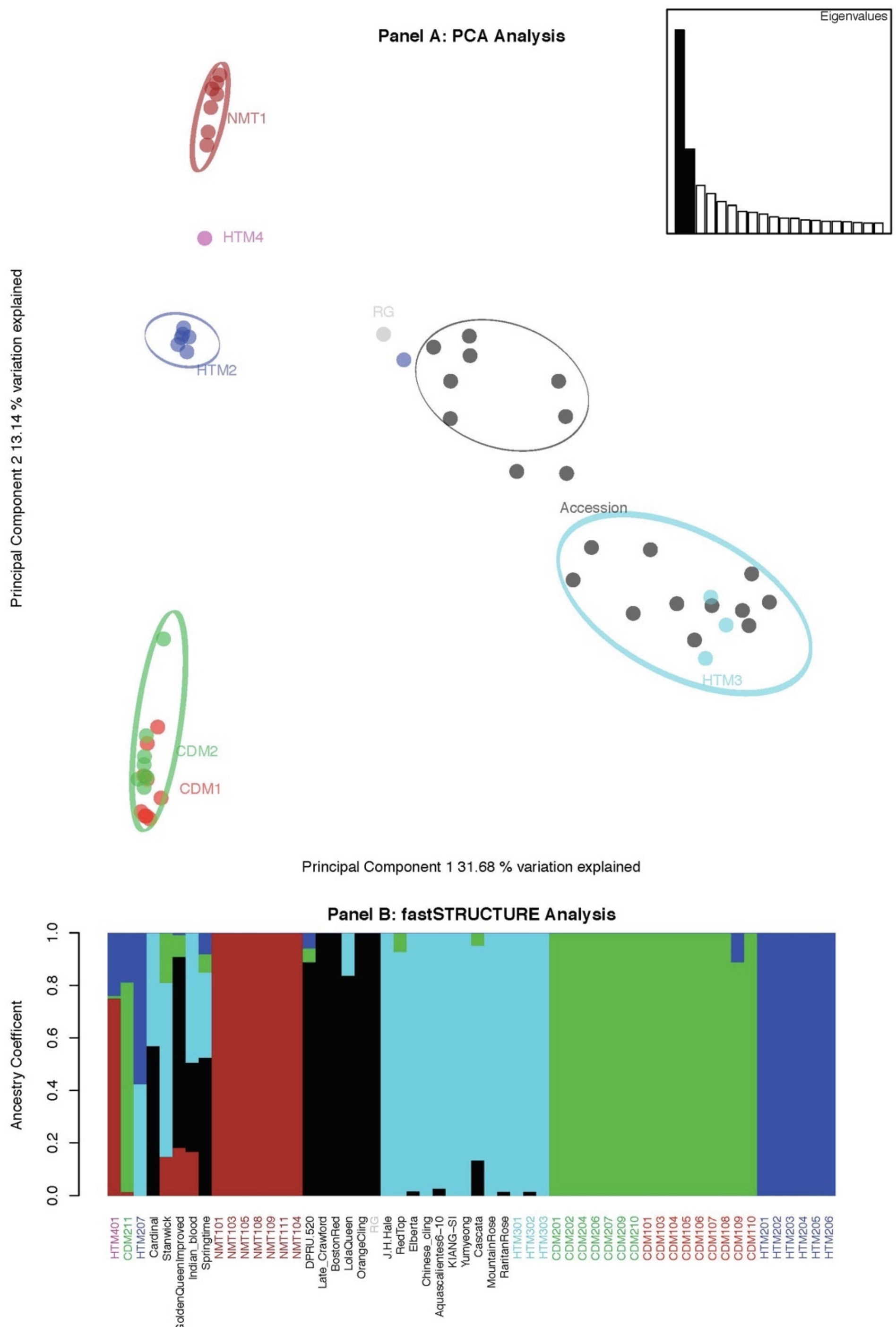

Figure 2.2. Principle component analysis (PCA) including 20 accessions and 35 Southwest peach genotypes. Analysis was done with 2,692 SNPs and each genotype listed by their growth location. Locations include Canyon del Muerto, AZ (CDM-1 to 2); Jayi Canyons near Navajo Mountain, UT (NMT-1); and Second and Third Mesas in Hopi, AZ (HTM-2 to 4). Colors for growth locations in PCA plot coordinate with individual genotypes in the STRUCTURE analysis at K=5. Name for individual genotypes are given first by their growth location then tree number (eg. NMT101).

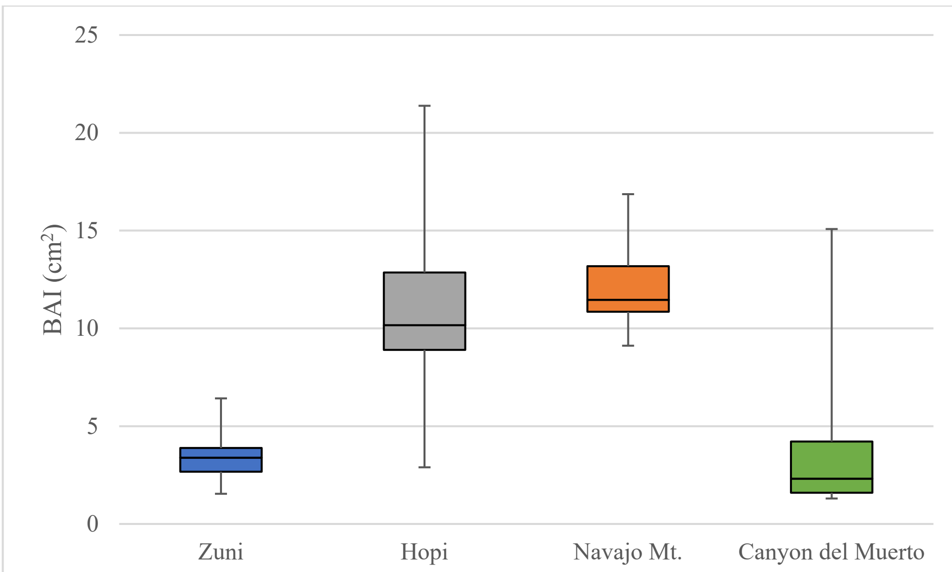

Figure 2.3. Basal area increment (BAI) mean for years 5 to 20 from the sample pith. Values are the means and range for multiple samples from four distinct regions including Zuni, NM; Third Mesa in Hopi, AZ; near Navajo Mountain, UT; and Canyon del Muerto, AZ.

Figure 2.4. Deceased and weathered peach trees near Navajo Mountain, Utah. Summer 2018.

CHAPTER 3

DETERMINING NAVAJO SPINACH (*CLEOME SERRULATA*) GERMINATION REQUIREMENTS

Abstract

Cleome serrulata Pursh (Navajo spinach) germination percentage is highest when seeds are pretreated with gibberellin (GA_{4+7}) and cytokinin (BA) under controlled chilling conditions. Improvements in seed germination treatments is necessary for future field cultivation of Navajo spinach as a native food crop Native Americans in the Four Corners area of the Southwestern United States face serious health challenges due to poor diet and limited availability of nutritious fruits and vegetables. Traditional uses of *C. serrulata* include dye for wool, paint for pottery, and is a nutritional food source often eaten fresh or paired with game meat. *C. serrulata* produces large amounts of pollen for many pollinators, contributes to erosion control, and is occasionally used as forage. *C. serrulata'*s distribution across the United States and Canada (temperate climates) suggests chilling and scarification could improve seed germination. This study applied various combinations of chilling (4- or 8-weeks) at 4, 7, 10 or 20°C (control), scarification with H_2O_2, and hormones (GA_3 or GA_{4+7} and BA) to *C. serrulata* seed grown in Logan, UT (source origin from Chinle, AZ). Initial seed viability for *C. serrulata* seed was 94% via Tetrazolium testing. Seed germination was responsive to both temperature and hormone applications, but not scarification. As chilling temperature increased from 4- 20°C, germination percentage decreased from 50% to less than 2%. Hormone treatments consisting of GA_{4+7} and BA applied prior to chilling for four weeks

resulted in 88% germination. Additionally, the speed of germination (T_{50}) increased with temperature while the spread of germination (T_{10-90}) decreased.

Introduction

Cleome serrulata Pursh (Capparaceae), also known as Navajo spinach, stinkweed, stinking clover, skunk weed, and Rocky Mountain beeplant, commonly grows on open rangelands, in disturbed soils around cultivated fields, and in sandy alluvial washes along streambeds (Pratt 2017; Figure 3.1). It is an important plant for bird and pollinator conservation, rangeland restoration, temporary erosion control, and historically is an important plant in Native American cuisine and culture (Elmore 1944; LBJWC 2018). Wild populations of *C. serrulata* are scattered throughout the United States and Canada, with a major herbarium collection from the Four Corners region of the American Southwest (Intermountain Regional Herbarium Network 2018). Navajo spinach is an annual plant with erect, branching growth habit, and grows up to 1.5 m tall (Iltis 1957; Winslow 2014). The leaves are arranged alternately on the plant and each leaf has three leaflets. Flowers have four petals, extended stamens and grow in clusters at the end of the elongating stems (Figure 3.2). The fruit is a 5 cm pod containing several black and white seeds.

Native American Tribes of the Southwest heavily utilized Navajo spinach. It is called *waá* by the Navajo, *túmi* by the Hopi, and *a'pilalu* or *ado:we* by the Zuni. Navajo spinach has been referred to as the Fourth Sister to the more common Three Sisters of corn, beans, and squash (Hemenway 2009). Recognized as a main food and cultural crop in the Southwest, Navajo spinach draws an abundance of pollinator species, increasing successful fertilization for nearby planted beans and squash (Kuhnlein 1981; Hemenway 2009; Park and others 2016). The Fourth Sister's leaves were eaten fresh during vegetative

growth, or the older leaves were boiled three times before being dried in patties for winter storage (Elmore 1944). The remaining liquid from boiled spinach leaves yields many dyes (light greenish-yellow, light purple, mustard or forest green found on Navajo dye charts) or produced a dried paint paste after evaporating the remaining liquid. The dyes are commonly used to color wool and the rehydrated paste used as the black paint on Anasazi pottery pieces (Bryan 1978; Dunmire 2004). The Navajo credit the Fourth Sister for saving them during food scarcity periods due to drought (Castetter 1935). The fresh or dried leaves, dyes and paint products are still used within the Navajo, Hopi, and Zuni communities, but the practice of making these products are not commonly taught to youth. Youth in these communities often see Navajo spinach as a weed rather than a staple food source that allowed their people to thrive in the desert climate.

Original wild populations of *C. serrulata* have decrease dramatically in the Southwest (oral recollection from tribal members of the Navajo, Hopi, and Zuni Nations). Germination requirements for cultivating the Fourth Sister have not been determined. The Utah State University (USU) Intermountain Herbarium recommends 6-8 weeks of chilling (temperature not specified) and over-seeding to counter poor germination (Piep 2012). *C. serrulata* is widely distributed throughout colder areas of North America (USDA NRCS 2017), which suggests the seed may have physical or physiological dormancy issues which enhance seed longevity and prevent early germination (Baskin and Baskin 2001; Penfield 2017). Tlig and others (2012) reported *C. amblyocarpa*, a related species found in Tunisia, germinates best under hot conditions with temperatures less than 15°C inhibiting germination. Ochuodho and Modi (2006) reported that deep chilling, gibberellins, potassium nitrate, and polyethylene glycol stimulates seed

germination of *C. gynandra* L (related species, Southern Africa). The responses of *C. serrulata* is negotiated to have very poor germination, which may be due to seed dormancy. Seed dormancy characteristics commonly noted in native plants from temperate climates include embryo immaturity, seed coat impermeability, and endogenous embryo dormancy, specific temperature or moisture requirements, or a mixture of dormancy mechanisms (Baskin and Baskin 2001; Penfield 2017).

Improving the germination requirements of Navajo spinach will make it readily available for consumption, utilization within a cultural context, or for rangeland conservation. This study investigated the requirements necessary for *C. serrulata* seed to reach high total germination and uniformity.

Materials & Methods

Detailed germination studies were conducted at USU, to determine the optimum germination requirements for *C. serrulata*. The initial supply of *C. serrulata* seed was collected at Chinle, AZ (36.1544° N, 109.5526° W; elevation 1698 m; 143 average frost-free days) in 2015 (Canyon de Chelly; 2015 seed lot). This seed was used to produce transplants that were then grown to maturity in 2016 at Greenville Research Farm in North Logan, UT (41.7370° N, 111.8338° W; elevation 1405 m; 135 average frost-free days). Mature seed pods were harvested and seeds extracted to provide the seed material used for various germination experiments. Harvested seeds (approximately 500 g; 165 seeds per g) were first air dried, then cleaned to remove additional plant material before cold-dry storage. Wild *C. serrulata* seed contains black (mature) and white (immature;

seeds do not germinate as determined from separate experiments) seeds in mature seedpods.

Tetrazolium Test

A subset of seed was assessed for viability by Tetrazolium test using procedures from Patil and Dadlani (2009). Conditions included 4 replications of 25 mature black seeds. Seeds were first hydrated with distilled water in 250 mL beakers for 24-hours. After hydration, seed were cut longitudinally through the mid-section of the embryonic axis. The cut surface was placed on blotter paper in a 40 mm petri dish, exposed to 1.5 mL of 1% tetrazolium solution and incubated at 35°C for 4-hours. Seeds were then examined under a dissecting microscope to assess viability. Seeds stained a pinkish-red color were counted as viable while white or blood red stained radicals or embryos were considered dead.

General Procedures

C. serrulata seeds were scarified with or without 3% Hydrogen peroxide (H_2O_2), then rinsed with distilled water three times before soaking the seeds in treatment solutions of various concentrations of gibberellins or cytokinins. Five replications of 25 seeds for each treatment were plated in 40 mm petri dishes (filter paper moistened with 1.5 mL water containing 1% Captan® fungicide) before exposure to chilling temperatures for different durations (Phillips, 2007). Petri dishes were wrapped with Parafilm® to help retain moisture.

Chilling Experiments (1 & 2) provided the foundational work for the later Hormone Experiments (1 & 2). In all studies, since seed germination in *C. serrulata* is

relatively slow, germinated seeds were counted at 3-4 day intervals. The resulting data were used to calculate final percent germination, time to 50% germination (T_{50}; measure of germination speed) and the spread or uniformity of germination (T_{10-90}; time interval between the germination of the 10th and 90th seed). The detailed procedures for each germination trial are as follows.

Chilling Experiment 1

Black Navajo spinach (Logan grown) seed were scarified with or without H_2O_2 for 2-hours then rinsed before being soaked in GA_3 (750 ppm; 40% ProGibb®) for 2-hours. The control was no treatment with H_2O_2 or hormone. Seeds (25 per rep; 5 reps per treatment) were plated on filter paper-lined petri dishes and hydrated with Captan® solution. Treated seed were separated into two batches before exposure to chilling treatments (4, 7, 10, or no chilling control of 20°C). The first batch of treated seed were exposed to two, 4-week chilling intervals with a 2-week room temperature (20°C) rest between chilling cycles. Air drying between chilling intervals prevented disease spread to ungerminated seeds and helped determine if initial low germination totals were the result of double dormancy characteristics. After the 2-week rest, seeds were rehydrated with the Captan® solution before beginning the second 4-week chilling cycle. The second batch of treated seed (4-week chilling interval) were hydrated with Captan® and exposed to chilling at the same time the first batch started its second chilling cycle. During the 4- and 8-week chilling periods, seed germination was recorded every 3-4 days. At the end of the chilling periods, the petri dishes were removed from chilling chambers and returned to room temperature for 3 days before assessing the final germination count.

Chilling Experiment 2

Black Navajo spinach (Logan grown) seed were soaked with or without H_2O_2 for 2-hours then rinsed three times before being soaked in GA_3 (750 ppm; 40% ProGibb®) for 4-hours. Peroxide and gibberellin treated seeds were divided into two lots before exposure to chilling treatments (4, 7, 10, or no chilling control of 20°C) as per Chilling Experiment 1. Seeds (25 per rep; 5 reps per treatment) were plated on filter paper-lined petri dishes and hydrated with Captan® solution. Treated seeds were exposed to chilling temperatures for 4- or 8-weeks with the 2-week rest period as per Chilling Experiment 1. Germinated seeds were counted twice per week with the final germination count taken 3 days after removal from chilling treatments.

Hormone Experiment 1

Black Navajo spinach (Logan grown) seed were soaked with or without H_2O_2 for 2-hours, rinsed three times, and then exposed to GA_3 (40% ProGibb®; at 500, 750, or 1000 ppm) or GA_{4+7} and BA (Promalin® at 600 ppm) for 4-hours. After hormone exposure, 25 seeds were plated on filter paper-lined petri dishes, hydrated with Captan® solution, then exposed to three chilling temperatures (4, 7, or 10°C) for 4-weeks. Since few seeds germinated at 20°C (in Chilling Expts. 1 & 2), this treatment was not included. Germinated seed were counted twice per week and again at 3 days after exposure to room temperature at the end of the experiment.

Hormone Experiment 2

Black Navajo spinach (Logan grown) seed were soaked with or without H_2O_2 for 2-hours, rinsed three times, and then exposed to GA_{4+7} & BA (Promalin®), GA_{4+7}

(Novagib 10L®), BA (MaxCel®), or GA_{4+7} + BA (Novagib® + MaxCel®), each at 600 ppm for 4-hours. Seed were then plated into petri dishes (25 per petri dish; 5 replications) and exposed to three chilling temperatures (4, 7, or 10°C) for 4-weeks. Germinated seed were counted twice a week during the chilling period and again at 3 days after exposure to room temperature at the end of the study.

Statistical Analysis

Seed germination numbers from each of the experiments were then used to calculate final percent germination, T_{50}, and $T_{10\text{-}90}$ for the various scarification, hormone, and chilling temperature and duration combinations. The speed of germination (T_{50}) and the spread or uniformity of germination ($T_{10\text{-}90}$) were only calculated for replications with two or more of the 25 seeds germinated. The Least Square Means (LSM) for each treatment combination was then used to determine treatment differences.

The T_{50} and $T_{10\text{-}90}$ were calculated using the approach of Farooq and others (2005) as:

$$T_{50} = t_i + \left[\frac{\frac{N}{2} - n_i}{n_j - n_i}\right](t_j - t_i)$$

where N is the final number of germinating seeds and n_j and n_i are the cumulative number of seeds germinated by adjacent counts at times t_j and t_i, respectively when $n_i < N/2 < n_j$.

The time to 10% and 90% germination were calculated in similar manner and the difference used to express the time interval between the germination of the 10th and 90th of seeds. These parameters (% germination, T_{50} and $T_{10\text{-}90}$) were analyzed using models in which the treatment conditions in each experiment are fixed factors and residuals

modeled with non-constant variations according to treatment. All analysis was performed using PROC GLIMMIX in SAS/STAT 14.3 (SAS Institute Inc., Cary, NC, USA). Significance is specified at 0.05 level**.**

Results

Tetrazolium Test

Seed viability of *C. serrulata* averaged 94% (SE ± 0.04) viable for the Logan grown seed lot used in all studies. Tetrazolium testing was done after all germination experiments were completed (approximately 2-year period).

Chilling Experiment 1

Seeds started to germinate after about 20 days of chilling. Seeds exposed to H_2O_2 plus GA_3 germinate faster and reach a higher final percent germination than seed exposed to H_2O_2 only. Untreated seeds had very low germination percentage. Seed soaked in GA_3 for 2-hours then chilled at 4°C for 8-weeks had the highest final germination percentage (Table 3.1). For chilling temperatures higher than 4°C, seed germination was commonly less than 10% and treatments were not significantly different from each other. Regardless of seed pre-treatment or chilling duration, as chilling temperature increased, final percent germination decreased (Table 3.1).

Due to low seed germination at higher temperatures (10 and 20°C), we were unable to calculate the speed (T_{50}) or spread ($T_{10\text{-}90}$) of germination. Seed scarification and GA_3 treatment had no effect on the T_{50} within the 4- or 8-week germination periods; however, seed germinated faster in the 4-week period compared to the 8-week period

(Table 3.1). In a similar way, the spread of germination (T_{10-90}) was shorter for the 4-week compared to the 8-week chilling period (Table 3.1). In general, the T_{10-90} was longer for seeds chilled at 4 than for seeds chilled at 7°C.

Chilling Experiment 2

Increasing the duration of GA_3 exposure from 2-4 hours improved seed germination compared to Chilling Experiment 1 for all treatments with chilling temperatures of 10°C or colder (Table 3.2). Seeds started to germinate about day 20 of chill cycle for the 8-week chilling period and about day 10 of the 4-week chill cycle (data not shown). Untreated seeds (No Trt) had the lowest percent germination of all treatments. Regardless of pretreatment, as chilling temperature increased from 4-20°C, seed germination percent decreased significantly. Seed germinated at room temperature (20°C; control) always had a low germination percentage that was significantly less than the colder chilling treatments. Due to low seed germination at higher temperatures (10 and 20°C), we were unable to calculate the speed (T_{50}) or spread (T_{10-90}) of germination (Table 3.2). Seed scarification and GA_3 treatment had no effect on the T_{50} within the 4- or 8-week germination periods, however, seed tended to germinate faster in the 4-week period compared to the 8-week period (Table 3.2). In a similar way, the spread of germination (T_{10-90}) was shorter for the 4-week compared to the 8-week chilling period (Table 3.2). In general, both the T_{50} and T_{10-90} was similar for seeds chilled at 4 and 7°C when chilled for 4-weeks but when chilled for 8-weeks, seeds germinated more uniformly at 7 compared 4°C.

Hormone Experiment 1

The interaction between temperature and hormone treatment combinations on mean seed germination was not significant (Figure 3.3). However, as temperature increased from 4-10°C, seed germination decreased significantly (Figure 3.3).

The addition of GA_{4+7} & BA had a significant impact on seed germination. Seed germination percentage with GA_{4+7} & BA application ranged from 61-84% (Figure 3.3). When seeds were treated with different concentrations of GA_3 without GA_{4+7} & BA, *C. serrulata* seed germination was less than 10% and the percent germination was not significantly different from the control (No Trt).

The effect of GA_3 concentration showed that G750 significantly promotes germination over G1000 ($p=0.0007$, data not shown), but had only modest effect when compared to G500 ($p= 0.08$). Scarification with H_2O_2 did not significantly influence seed germination except when combined with highest GA_3 levels (G1000; $p=0.02$) where germination was lower.

However, hormone and scarification pre-treatment and temperature did have a significant interaction on T_{50} and $T_{10\text{-}90}$ (data not shown). T_{50} values tend to be smaller at 10°C (13-20 days) than at 4°C (16-23 days) and 7°C (15-21 days) across all treatments. T_{50} values are also significantly shorter for treatments with GA_{4+7} & BA (16 days) when compared to those without GA_{4+7} & BA (mean; 21 days) at 4°C. As chilling temperature increased, differences in T_{50} for treatments with and without GA_{4+7} & BA were not different. In general, the spread of germination ($T_{10\text{-}90}$) was significantly shorter (8-15 days) at 4°C and increased as temperatures increased (data not shown). Unlike T_{50},

hormone and scarification treatments had no impact on T_{10-90} at 4°C but the spread of germination significantly increased as temperature increased.

Hormone Experiment 2

There is no significant interaction between chilling temperature and hormone treatment on total seed germination. Percent seed germination was significantly greater at 4 and 7 than that at 10°C (Figure 3.3). Seeds treated with GA_{4+7} or GA_{4+7} & BA had higher than 80% germination and the combination of GA_{4+7} + BA +H_2O_2 had a final germination of 92% (Figure 3.3). Hormone treatments without GA_{4+7} & BA and GA_{4+7} had very low germination (7-13%) and these values were not significantly different from the control (No Trt).

The percent germination was not different between GA_{4+7} & BA and GA_{4+7} (p = 0.15, data not shown). Average germination percent with GA_{4+7} & BA alone was 81% and with GA_{4+7} alone was 74%. Scarification with H_2O_2 did not significantly improve seed germination.

There is a significant hormone treatment by temperature interaction for T_{50}. Hormone treatment containing GA_{4+7} & BA or GA_{4+7} germinated significantly faster (T_{50}; 13-16 days) than those without GA_{4+7} & BA or GA_{4+7} (T_{50}; 10-19 days) at 4 and 7 but has no effect at 10°C (data not shown). Seeds germinated faster (lower T_{50} values) as chilling temperature increased when GA_{4+7} & BA and GA_{4+7} are not applied; but when present, there is no significant difference in the speed of germination as temperature increases from 4-10°C. Seed germination T_{10-90} could not be calculated because data for the first 2-weeks of the chilling cycle were not collected.

Discussion

Many native plants have seed dormancy issues that regulate or prevent seed germination. The common dormancies in seed include a simple barrier around the seed that prevents gas exchange or water movement called physiological dormancy (Penfield 2017). Scarification helps break the barrier and permits seed germination. In other plants, the embryo is under-developed, and dormancy exists until the embryo is more mature. This is a morphological dormancy.

Little is known about the germination requirements of *C. serrulata*. Environmental factors such as temperature, light, and moisture all influence germination (Baskin and Baskin 1998). In temperate environments, temperature is one of the dominate signals controlling germination (Penfield 2017). Some species have simple requirements such as cool or cold stratification while other species may require prolonged exposure to unique temperature patterns. Peip (2016) suggested that chilling seed for 6-8 weeks is necessary for *C. serrulata* germination, but no specific temperatures were noted. In this study, Navajo spinach germination exhibited a positive response to moist chilling. Seeds chilled at 4°C had the highest percent germination and as temperature increased, seed germination decreased (Table 3.1). In all studies, germination was very low (< 10%) when seeds were exposed to 20°C (Table 3.1 and 3.2). Cold chilling temperatures (4°C) resulted in slower and non-uniform germination than higher temperature at 7°C. Due to low germination at warmer temperatures (10 or 20°C), neither the speed (T_{50}) or spread ($T_{10\text{-}90}$) of germination was calculable (Table 3.1 and 3.2).

These findings are different from those reported by Ochuodho and Modi (2005) and Tlig and others (2012). Tlig and others (2012) noted that for *C. amblyocarpa*, the best germination percentage and rate of germination was at 25°C but at temperatures above or below this temperature, germination was inhibited. The highest germination percentage of *C. gynandra* L. was achieved in alternating temperatures (20-30°C; 16-8 hours) in the dark (Ochuodho and Modi 2005). They also noted that scarification and GA_3 also improved germination. Both *C. amblyocarpa* and *C. gynandra* L. are erect herbaceous perennial herbs common to many parts of sub-Saharan Africa. In contrast, *C. serrulata* is a small to medium sized annual, occurring generally in more mesic regions, and at higher, cooler elevations (Iltis 1957; Winslow 2014). Many native species found in the Intermountain West region require chilling temperatures to improve seed germination (Baskin and Baskin 2001; Phillips and others 2003; 2010) and *C. serrulata* is no exception.

Peip's (2016) reported necessary chilling recommendation for germination further suggests that the seed coat requires scarification to improve germination or the embryo in *C. serrulata* may need additional time to fully mature. Scarification of *C. serrulata* with H_2O_2 did not improve seed germination in any of the four experiments. This indicates that seed coat impermeability was not a major limitation to seed germination.

Chilling duration (4- or 8-weeks exposure) had a more variable effect on seed germination. In the first experiment (Table 3.1), seed germination improved when seeds were exposed to longer (8-week) than shorter (4-week) chilling periods. However, in the second experiment (Table 3.2), seed germination significantly improved when seeds were exposed to shorter (4-week) chilling periods. Two things could have influenced the

differences between these two studies. First, a commonly noted dormancy breaking process in laboratory settings is dry after-ripening (Penfield 2017). Over time (weeks or months), dormancy is lost while seeds are in dry storage and the change in germination is believed to be associated with ABA catabolism. Since Chilling Experiment 2 (Table 3.2) occurred about 4 months after Chilling Experiment 1 (Table 3.1), the difference in germination response between the 4- and 8-week chilling responses could be due to changes in ABA content. Further studies are required to evaluate this before one can definitively say that ABA plays a significant role in *C. serrulata* germination.

A second explanation for the differences between the 4- and 8-week chilling responses may be associated with the role hormones play in seed germination (Penfield 2017). In Chilling Experiment 1, the two weeks of rest between the two 4-week chill cycles and the addition of GA_3 (2-hour soak) significantly increase seed germination (Table 3.1). However, in Chilling Experiment 2 (Table 3.2), seeds had a longer dry after-ripening period in the laboratory and then were treated with GA_3 (4-hour soak) for longer duration. As a result, this further stimulated seed germination in the 4-week chilling cycles, resulting in high percent germination for the 4-week chill vs. the 8-week chill.

Since gibberellins are known to enhance germination (Penfield 2017), Hormone Experiments 1 and 2 were performed to better understand the role of various hormone dosages and materials on *C. serrulata* germination. While GA_3 appeared to improve seed germination in earlier studies (Tables 3.1 and 3.2), Hormone Experiment 1 (Figure 3.3) showed that GA_{4+7} and BA had a significant positive effect on seed germination while GA_3, even at elevated dosage, did not improve germination. Hormone Experiment 2 (Figure 3.4) helped further clarify if it was GA_{4+7} or BA that improved seed germination.

This study clearly demonstrated that GA_{4+7} was responsible for improved germination since seeds treated with BA germinated at less than 10% and was not significantly different from the untreated control. Additional work is required to understand the mechanism of GA_{4+7} stimulation of seed germination in *C. serrulata*.

Conclusion

The results of these experiments provide new information regarding germination requirements of Navajo spinach, *C. serrulata*. Since *C. serrulata* is found over a wide range of eco-regions, it is necessary to clarify how much of the correlations between the collection site and germination behavior in these species are due to genetics versus environment. Seeds used in these studies were initially collected from wild populations near Canyon de Chelly (Chinle, AZ) but the seed production environment was from plants growing in Logan, UT. Performing the same experiments using seed originating from wild populations throughout the Intermountain West may help separate the role genetics and seed production environment play in seed germination. Understanding the influence of habitat on germination traits in this species may aid in the development of seed source-specific propagation strategies for consumption, utilization within a cultural context, or for rangeland conservation.

While seed viability was high, the finding presented here show that colder temperatures and variable time of exposure have the greatest positive impact on seed germination. As temperature increases from 4-20°C, Navajo spinach seed germination decreased significantly. Adding GA_3 appeared to improved seed germination, however, further studies showed that GA_{4+7} was more effective and pretreating seeds with GA_{4+7}

resulted in greater than 75% germination. Findings clearly demonstrate that chilling duration, gibberellin, and seed after-ripening significantly influence seed germination in the first season after seed harvest. Ideally, *C. serrulata* seed should be treated with GA_{4+7} for 4-hours, dried, and then fall seeded to meet the chilling requirements necessary for higher seed germination and emergence the following spring.

Literature Cited

Baskin CC, Baskin JM. 1988. Germination ecophysiology of herbaceous plant species in a temperate region. American Journal of Botany 75(2):286-305.

Baskin CC, Baskin JM. 2001. Seeds: Ecology, biogeography, and evolution of dormancy and germination. Academic Press, San Diego (CA). 666 p.

Bryan NG. 1978. Navajo Native Dyes: Their preparation and Use. Palmer Lake (CO): The Filter Press. 23 p.

Castetter EF. 1935. Ethnobiological Studies in the American Southwest: I. Uncultivated Native Plants Used as Sources of Food. University of New Mexico Bulletin 4(1):1-59.

Dunmire WW. 2004. Gardens of New Spain: How Mediterranean plants and foods changed America. Austin (TX): University of Texas Press. 75 p.

Elmore FH. 1944. Ethnobotany of the Navajo: A Monograph of the University of New Mexico and the School of American Research. Santa Fe (NM): University of New Mexico Press. 50 p.

Farooq M, Basra SMA, Ahmad N, Hafeez K. 2005. Thermal Hardening: A New Seed Vigor Enhancement Tool in Rice. Journal of Integrative Plant Biology 47(2):187-193.

Hemenway T. 2009. Gaia's Garden: A Guide to Home-scale Permaculture. White River Junction (VT): Chelsea Green Publishing Company. 149-150 p.

Iltis HH. 1957. Studies in the Capparidaceae. III. Evolution and Phylogeny of the Western North American Cleomoideae. Annals of the Missouri Botanical Garden 44(1):77-119.

[IRHN] Intermountain Regional Herbarium Network. 2019. SEINet Herbarium Network. URL: http://intermountainbiota.org. (accessed 13 June 2018). Logan (UT): Utah State University.

Kuhnlein HV. 1981. Dietary Mineral Ecology of the Hopi. Journal of Ethnobiology 1(1):84-94.

[LBJWC] Lady Bird Johnson Wildflower Center. 2008. Native Plant Database. URL: https://www.wildflower.org/plants/result.php?id_plant=CLSE (accessed 13 June 2018). Austin (TX): University of Texas.

Ochuodho OJ, Modi AT. 2006. Statistical evaluation of the germination of *Cleome gynandra* L. seeds. South African Journal of Plant and Soil 23(4):310-315.

Park S, Hongu N, Daily III JW. 2016. Native American Foods: History, culture, and influence on modern diets. Journal of Ethnic Foods 3:171-177.

Patil VN, Dadlani M. 2009. Tetrazolium Test for Seed Viability and Vigour. Handbook of Seed Testing 209-249p. URL: http://seednet.gov.in/pdffiles/chapter%2014.pdf (accessed 09 January 2019). New Dehli (India): SeedNet India Portal.

Penfield S. 2017. Seed dormancy and germination. Current Biology 27:R874-R878.

Piep M. 2012. Fact sheet: *Cleome serrulata*. Logan (UT): Utah State University Intermountain Herbarium.

Phillips NC. 2007. Diversity and Adaptation along altitudinal gradients in three Wild Allium spp. native to Utah and implications for Horticultural practices [MSa thesis]. Logan (UT): Utah State University 51 p.

Phillips NC, Drost DT, Varga WA. 2003. Chemical treatments enhance seed germination in Perideridia gairdneri. Acta Horticulturea 618:477-482.
Phillips NC, Drost DT, Varga WA, Schultz LM, Meyer SE. 2010. Germination characteristics along altitudinal gradients in three intermountain Allium spp. (Amaryllidaceae). Seed Technology 32(1):15-25.
Pratt MS. 2017. Range Plants of Utah. URL: https://extension.usu.edu/rangeplants/ (accessed 09 January 2019). Logan (UT): Utah State University Extension.
Tlig, T, Gorai M, Neffati M. 2012. Factors influencing seed germination of *Cleome amblyocarpa* Barr. & Murb. (Capparidaceae) occurring in southern Tunisia. Revue d Ecologie. 67:305-312.
[USDA NRCS] USDA Natural Resources Conservation Service. 2017. The PLANTS database, Version 3.0. URL: http://plants.usda.gov. (accessed 12 June 2018). Greenboro (NC): National Plants Data Team.
Winslow SR. 2014. Rocky Mountain Beeplant *Cleome serrulata* Pursh: A Native Annual Forb for Conservation Use in Montana and Wyoming. Bridger (MT): USDA NRCS, Plant Materials Center. Technical Note No. MT-104. 6 p.

Tables

Table 3.1. Effect of 2 hours of scarification (H_2O_2) followed by 2 hours of hormone (GA_3) treatments before 4- or 8-weeks at various chilling temperatures (4, 7, 10, or 20°C) on final seed germination (%) and the speed (T_{50}) or spread (T_{10-90}) of germination.

	4 weeks			8 weeks		
Temp. (°C)	No Trt	H_2O_2	GA_3+ H_2O_2	No Trt	H_2O_2	GA_3+ H_2O_2
			Germination (%)			
4	20.0^{Abc}	12.1^{Abc}	15.7^{Abc}	8.9^{Ac}	25.4^{Ab}	72.0^{Aa}
7	5.6^{Ba}	6.1^{ABa}	4.3^{Ba}	5.3^{Aba}	8.5^{Ba}	7.8^{Ba}
10	5.6^{Ba}	4.3^{Ba}	3.7^{Ba}	3.7^{Ba}	4.3^{Ca}	5.4^{Ba}
20	3.7^{Ba}	3.7^{Ba}	3.7^{Ba}	3.7^{Ba}	3.7^{Ca}	3.7^{Ca}
			Speed of Germination - T_{50} (days)			
4	19^{b}	21^{Ab}	20^{b}	39^{Aa}	41^{Aa}	38^{Ba}
7	-	23^{Ac}	-	52^{Aab}	34^{Bb}	60^{Aa}
10	-*	-	-	-	-	-
20	-	-	-	-	-	-
			Spread of Germination - T_{10-90} (days)			
4	10^{b}	9^{Ab}	11^{b}	28^{Aa}	51^{Aa}	35^{Aa}
7	-	11^{Aab}	-	20^{Aab}	27^{Ba}	8^{Bb}
10	-	-	-	-	-	-
20	-	-	-	-	-	-

Note: Values with the same uppercase letters (ABC) within each column indicates no seed germination difference due to temperature effects while values with same lowercase letters (abc) within each row indicate no seed germination difference due to treatment effects.

* - due to low seed germination, unable to calculate a T_{50} or T_{10-90} value.

Means separated with Least Square Means (LSM) test. The interaction between seed treatment and temperature was not significant.

Table 3.2. Effect of 2 hours of scarification (H_2O_2) followed by 4 hours of hormone (GA_3) treatments before 4- or 8-weeks at various chilling temperatures (4, 7, 10, or 20°C) on final seed germination (%) and the speed (T_{50}) or spread (T_{10-90}) of germination.

	4 weeks			8 weeks		
Temp. (°C)	No Trt	H_2O_2	GA_3+ H_2O_2	No Trt	H_2O_2	GA_3+ H_2O_2
			Germination (%)			
4	66.4^{Abc}	74.4^{Aab}	84.7^{Aa}	23.2^{Ae}	26.9^{Ade}	48.8^{Acd}
7	46.5^{Aa}	41.3^{Ba}	62.3^{Ba}	4.9^{Bc}	7.6^{Bbc}	14.9^{Bb}
10	17.8^{Bab}	9.1^{Cbc}	24.6^{Ca}	4.6^{Bc}	3.7^{BCc}	3.7^{Cc}
20	3.7^{Ca}	3.7^{Da}	3.7^{Da}	3.7^{Ba}	3.7^{Ca}	3.7^{Ca}
			Speed of Germination - T_{50} (days)			
4	16^{Ab}	17^{Ab}	17^{Ab}	30^{Aa}	32^{Aa}	40^{Aa}
7	14^{Abc}	18^{Ab}	16^{Ab}	7^{Bc}	20^{Bb}	39^{Aa}
10	-*	-	-	-	-	-
20	-	-	-	-	-	-
			Spread of Germination - T_{10-90} (days)			
4	13^{Ab}	16^{Aab}	17^{Aab}	30^{Aa}	32^{Aa}	40^{Aa}
7	15^{Aab}	17^{Aa}	15^{Aa}	7^{Bc}	20^{Bb}	39^{Aa}
10	-	-	-	-	-	-
20	-	-	-	-	-	-

Note: Values with the same uppercase letters (ABC) within each column indicates no seed germination difference due to temperature effects while values with same lowercase letters (abc) within each row indicate no seed germination difference due to treatment effects.

* - due to low seed germination, unable to calculate a T_{50} or T_{10-90} value.

Means separated with Least Square Means (LSM) test. The interaction between seed treatment and temperature was not significant.

Figures

Figure 3.1. Navajo spinach (*Cleome serrulata*) growing near Bluff, UT (2016). Photo credit: Daniel Drost.

Figure 3.2. Navajo spinach (*Cleome serrulata*) indeterminate flower with seed pods grown in Logan, UT (2018).

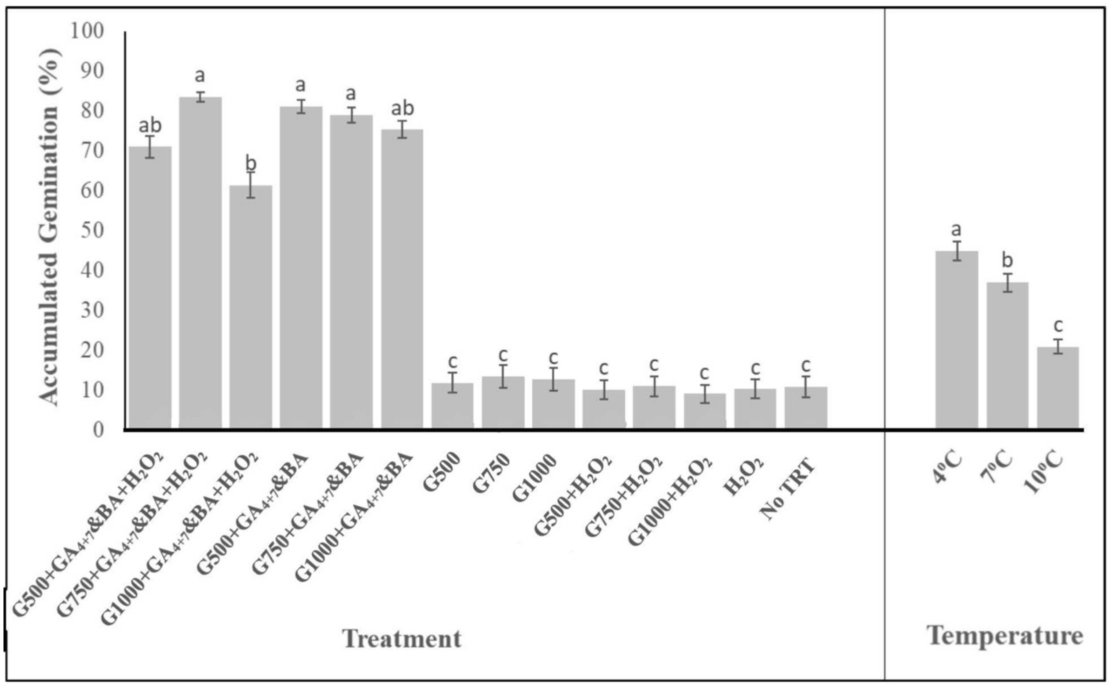

Figure 3.3. Influence of hormones and seed scarification combinations and temperature effects on percent germination (±*SE*).
G500, G750, or G1000 = 40% ProGibb® (GA_3 concentration in parts per million)
GA_{4+7} & BA = Promalin® @ 600ppm
H_2O_2 = 3% Hydrogen peroxide scarification
Values with same letters were not difference due to treatment effects.

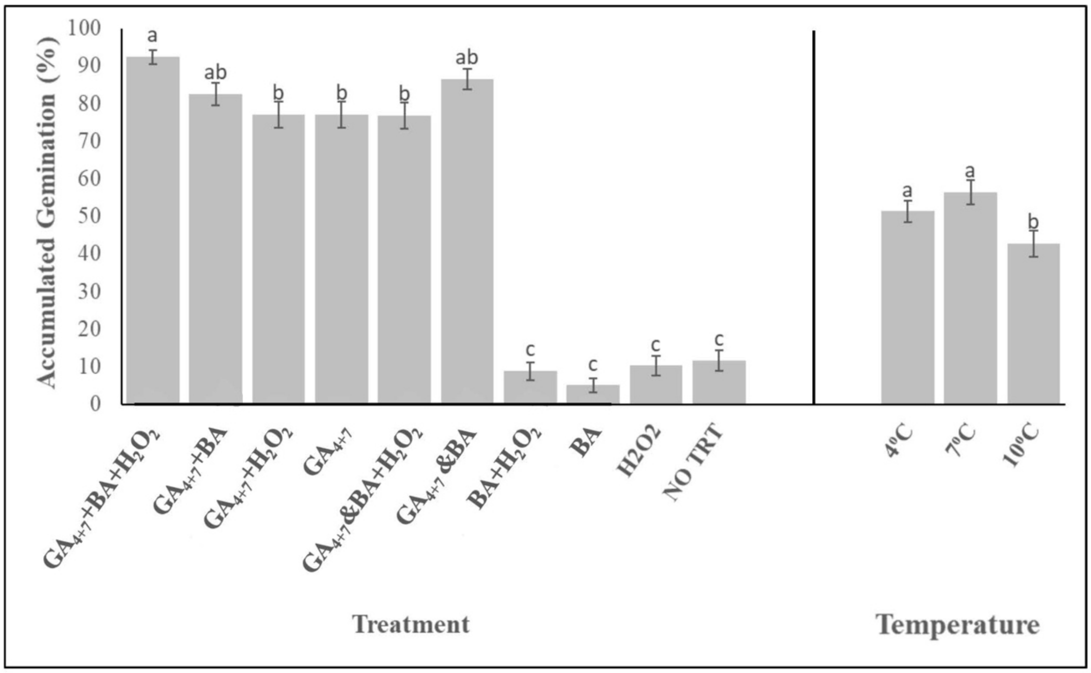

Figure 3.4. Influence of various hormone and seed scarification combinations and temperature effects on germination percent (±*SE*).
GA_{4+7} = Novagib 10L® @ 600ppm
BA = MaxCel® @ 600ppm
GA_{4+7} & BA = Promalin® @ 600ppm
GA_{4+7} + BA = Novagib 10L® + MaxCel® @ 600ppm
H_2O_2 = 3% Hydrogen peroxide scarification
Values with same letters were not difference due to treatment effects.

CHAPTER 4

ORAL HISTORIES AND TRADITIONS RELATED TO THE SOUTHWEST PEACH

Abstract

Southwestern Native American Tribes successfully managed peach orchards for over 400 years. Today, the traditional knowledge for growing peach orchards is being lost when tribal elders, who are the last to poses knowledge of growing traditions and use, die. This study documents traditional peach management practices of written and ethnographic primary materials from Navajo, Hopi, and Zuni elders. Written sources primarily focus on the Navajo of Canyon de Chelly orchard management practices. However, this gathered primary material from elders over the age of 50 suggest orchard management practices to be different not only from commercial orchard practices, but also by tribe. Much of the information obtained suggests the peach orchards are a significant food crop, like corn, also having ceremonial importance. Several members within Southwest Native American communities have expressed gratitude for this projects' contribution to their cultural preservation and its emphasis on providing a sense of cultural reclamation.

Introduction

The Navajo (Diné), Hopi, and Pueblo Tribes all hold claim as descendants of the Anasazi, meaning “the ancient ones” in Navajo. The Diné believe that the Honeycomb Rock People or the Cliff Dwellers People clan (tséńjíkiní) are the closest relatives to the Anasazi, having mixed with the Pueblo clans in distant times (Reichard 1974:62). Yet, there is greater similarity between Anasazi artifacts and Hopi and Pueblo cultural practices today than with Navajo (Brody 1991:81-84). In the Hopi and Pueblo origin stories, there is a belief that the Zuni and other Pueblo Tribes came from the Hopi, and Hopi people being original descendants of the Anasazi (Brody 1991). These stories are passed down through countless generations and provide detailed pathways of these Indigenous peoples’ journeys in the Southwest and their relations to one another.

In addition to artifacts and current cultural practices, food crops of Indigenous people have commonly been a means to map migrations and their effects on modern culture. Today, corn is the most common Indigenous food crop used to map the migration patterns of Native Americans (Maxwell, ed. 1978). On a regional scale, corn is utilized to map and compare ancient stories and artifacts of Southwestern Native American migration patterns. Other food crops and their accustomed social influences represent a potential resource to understanding the origins of Navajo, Hopi, and Pueblo peoples and their relations to one another. An example is the Southwest peach. Since their earliest recorded history, Navajo, Hopi, and Pueblo communities have continuously grown peaches (Benavides 1996 [1630]:48).

Descriptive information of the traditional management practices for peach growing is basic and limited to perspectives of Diné families of Canyon de Chelly. To further understand the uses and cultural importance of the peach to the Southwest Indigenous peoples, ethnographic work was undertaken with elders in various Four Corner's Tribes who actively participated in their local peach growing traditions.

Methods

Several oral histories were collected from elders living within the Navajo, Hopi, and Zuni Tribes to synthesize their knowledge of peach growing and cultural importance within their communities. The ethical intent of creating an oral history collection is not only to gather, preserve, and learn from the information, but with this project, it was also to return the skillsets gathered to the community. The ethnographic work was not intended to exploit the individual providing the information. This, sadly, has been a common occurrence within many Native American communities, where elders' knowledge has been exploited by researchers. Thus, it was very important with this work to ensure that any knowledge gained was returned to the participating individuals, their families, and communities (Toelken, 1998). Although a common ethnographic practice, it is not always exercised (Thompson, 1998).

Therefore, in preparing this project, great work went into building a healthy, reciprocal relationship between the researcher (Wytsalucy) and each interviewee and his/her family in order to gain understanding of one another and for the importance of this work to preserve their heritage. Time was spent talking with the family and interviewee to fully grasp and respect their culture and way of living. On several

accounts, the primary author met with an interviewee several times before recording, with permission, their history. Additional care was taken when transcripts were returned to the families for review and vetting before using the data for associated research and before deposit in specified repositories for preservation. Details of the interview questions are as follows:

- What was your involvement with the peach growing?
- Where was most of the peach growing located on the Reservation before its decline?
- Who did you learn to grow the peaches from?
- Explain the peach planting process. For instance, what was your experience growing, harvesting, and caring for the peaches (farming tools, irrigation, pruning, preservation)?
- Are there any cultural traditions that involve peaches that you are able to share (religious dances)?
- Are there old stories you remember that tell about how we received the peaches? Please explain.

The primary author worked one-on-one with all interviewees with the guidance and support of Randy Williams, Utah State University Fife Folklore Archives Curator and ethnographer. Thus, the remaining narrative is written from Wytsalucy's perspective to learn about Southwest peaches from her elders.

Southwest Peach History

I am Diné, meaning "the people." Along with many of my peers, I grew up somewhat detached from my Diné heritage. And as such, until I started my university pursuits, I was never taught that my people grew peaches. My father, Roy Talker (born 1958), grew up near Navajo Mountain, Utah, in Shonto and Inscription House Canyon in Arizona. As I began my studies in Plant Science, emphasis in Horticulture and Cropping Systems, he told me about our people growing peaches. He explained that when he was young peaches thrived in Shonto Canyon. But, in 1966 when he was 8, rather than acquiring cultural competency with traditional fruit production, he left tribal lands to attend boarding school and soon after participated in the Church of Jesus Christ of Latter-day Saints's Indian Student Placement Program. This displacement from his family home left him detached from his culture, creating for him a struggle to fit into both his native environment and the new society. He recalls that he and other Indigenous students in the placement program were called "red apple," meaning red on the outside, but white on the inside.

During my teen years in Gallup, New Mexico, I learned a few traditional Navajo ways when my father began practicing them in our home. My father worked to relearn many Diné traditional practices. Thus, as I began my journey to do scientific and cultural research with the Navajo peaches my father was my guide and interpreter. He helped me keep my scientific research endeavors ethical and brought to my attention stories taught by his grandparents of how the Southwest Native American nations practiced peach

cultivation many centuries prior to colonialization in the Americas. Using oral histories, I began exploring the centuries' old story of Navajo peaches.

My approach to understand Southwest orchard practices begins after the Coronado Expedition (AD 1540-1542). An observation by Friar Alonso de Benavidas (1996 [1630]:48) provides details of peaches and apricots growing in abundance by the Pueblo Indians and in mission gardens as he traveled into the Southwest from Mexico. Peaches were not seen by Benavidas growing south of the Pueblo communities, except for those previously established in Mexico by the Spaniards (Prescott, Vol. 3 1843:269-270). The early colonial activities prior to Benavidas indicate peaches were introduced into the Southwest ahead of Spanish explorers.

The remnants of the Indigenous Southwest peach orchards and their caretakers are still found today. Mid-nineteenth century peach documentation details the destruction of long-established orchards by government influences consisting of crop destruction, boarding school programs, and present-day cultural loss (Brugge and Correll 1971). The most abrupt documented destruction occurred in 1864 when the U.S. military annihilated Navajo peach orchards, and other crops, in Canyon de Chelly National Monument in an effort to draw the Navajo out of this traditional homeland and force them to relocate to places of containment.

Following on the heels of six broken treaties between the U.S. Government and the Navajo (Brugge and Correll 1971:41), summer 1863, General James Henry Carlton sent Colonel Christopher "Kit" Carson and the First New Mexico Cavalry to relocate the Navajo in Canyon de Chelly to Bosque Redondo (Jett and Thompson 1974). Captain John Thompson wrote that many crops and livestock were destroyed during fall and

winter of 1863 in hopes that the Navajo would come easily. However, many Navajo were able to withstand the cavalry forces, which led to further crop destruction in January 1864. According to Thompson's account of cavalry actions, this final destruction event resulted in over 4000 fruit trees being destroyed and nearly 9000 Navajo walking an estimated 300 miles to Bosque Redondo: known as The Long Walk (Jett and Thompson 1974).

During the Long Walk, some Navajo avoided capture and raided U.S. forts. One of these individuals was my great-grandfather, Hoskinini. Hoskinini fled from the Calvary with his family. The Calvary trailed them for many days until their footprints disappeared at the bank of the San Juan River (Roberts 2015). Through oral tradition, my family has passed down a description of where Hoskinini fled, explaining that it was like an oasis, with many natural springs and waterways, supplying water to yearlong grassy groves. Peaches were present at this location. There were many canyon trails used by these early ones for retreat from the Calvary and invaders wishing to discover their homestead. Jayi Canyon, near Navajo Mountain, Utah, is where my family believes Hoskinini fled to keep his family safe. While there, they grew crops and rounded up the abandoned livestock left from those forced to walk to Bosque Redondo (Figure 4.1). Despite the afflictions faced by those on the Long Walk, when they returned home the people were able to thrive by replanting stored seed and receiving starting flocks of sheep from those, like my great-grandfather, who cared for the land and livestock while they were away (in concentration camps).

Since the Long Walk, other government influences occurred over prolonged periods to undermine peach cultivation. The final agreements in the 7th ratified treaty

between the U.S. Government and the Navajo Nation required, among other things, that all Navajo children receive an education in a boarding school (Brugge and Correll 1971; Stout 2012). The approach of the U.S. Government consisted of Navajo containment in boarding school systems with restrictions on cultural practices, including foodways and the sharing of cultivation practices, such as peach husbandry (Brugge and Correll 1971:41).

Today, many of these children are elders in their communities. Those who avoided the boarding school system and remained on the reservation are the last remaining people in their communities with a near complete knowledge of their heritage, including planting and harvesting knowledge. It is because of these elders that the peach orchards have continued and exist today. With their passing, comes the loss of cultural peach husbandry and many of these orchards once again face destruction. This cultural knowledge annihilation is also affecting the Hopi, where <2% of peach orchards in existence in the 1980s are present today (Singletary et al. 2014:9). Understanding the pathway of the Southwest peach in its adapted climate requires immediate action to preserve the traditional growing practices of and uses by the Southwestern Native American Tribes.

Southwest Indigenous Stories

For centuries, the history of Indigenous peoples has been passed through oral tradition. This verbal tradition provides a primary resource today for documenting Indigenous foodways. For some scholars, this may seem unscientific or too subjective—as the sources are not recorded at time of creation. Oral tradition is recognized by

Indigenous scholars, folklorists, anthropologists, and others, who utilize both written and oral sources to recast Indigenous history, using an Indigenous lens as well as earlier written sources (Kerpel 2014). Thus, to learn the importance and uses of peaches to individual tribes of the Southwest, the following stories from Navajo, Hopi, and Zuni elders provide an alternate perspective for how the peach influenced Southwest Indigenous culture. This work includes elder narratives (histories) on peach trading between tribes, knowledge of the geography of historic orchards, and the imbedded presence of peaches in Indigenous culture, including traditional growing practices and ceremonial importance.

Trading

It is suggested by many scholars that the Hopi received the peaches from the Spanish first and dispersed the seeds to their sister tribes, tying into existing trading routes from Hopi to the Rio Grande River: trading routes starting from Hopi to Zuni and then Pecos Pueblo (Barnes 2009:57). However, Ian Barnes (2009:57) points out major locations of trading between the Native American Tribes of the North American continent. After Choco Canyon was abandoned, the main trading hub was in Pecos as the Rio Grande provided a convenient travel route for the Puebloan people to trade among Indigenous peoples of present-day Mexico. This trading route was not locally available to the Hopi. There are ancient trails from Mexican Indigenous Tribes to the Zuni, as indicated in Coronado's expedition, but these are not considered major trading routes by scholars or Puebloan peoples (Winship 1896).

Many Hopi elders concur with scholars' suggestion that they were the first of the Pueblo Tribes to receive the peaches, trading the seed to neighboring sister tribes. Many Pueblo religious elders teach their youth that prior to colonization, many centuries ago, current Pueblo Tribes diverged from one another (noted from general conversation with many Hopi and Pueblo residents). This orally-documented historic information is corroborated by archeological studies of Anasazi pottery trails (Brody 1991). These trails show the great dispersal and relocation in the 1300s of the Anasazi in Chaco Canyon, Mesa Verde, and the Kayenta districts, that have descendants in the Pueblos today (Brody 1991:82). As written documents and oral traditions do not resonate with one another, further investigation into the pathways of the peach seed trading is needed to provide useful understanding of foodways between Southwest Tribes.

Geography

The geographical location of peach orchards on the Zuni and Navajo Reservations provided protection for the crop from elements and invaders. The term "invaders" could pertain to other Native American Tribes or Spanish colonizers. Many Pueblo members indicated through general conversation that their ancestors were aware of the Spaniards arrival years before they actually came into the Southwest. A letter dated 3 August 1540 from Coronado to the Viceroy states, "They assert that it was said among them more than fifty years ago [est. late-1400s] that a people like us must come, from the direction we have come, and that they [Europeans] would subjugate this whole land" (Flint and Flint, Doc.19 2012:13).This is one of many ancient prophesies that came true and continues to be told today among Southwest Indigenous Tribes. Thus, the Zuni historic peach orchard

sites are located in pocket-land spaces along mesa shelves, often with one trail leading into the orchard. Unless one is led to or spends many days exploring the mesa ridges above the hidden mesa shelves and canyons, the trailheads for the remote places are almost impossible to find (Ferguson 1996). T.J. Ferguson wrote of Zuni orchards:

> Other 'refuge sites' were established in part for peach farming in areas of sandy soil that occurred at the bases and on the sides of mesas in the Zuni River Valley. These agricultural spots were generally located in defensive positions on the tops of elevated landforms like knolls and benches, and they consisted of aggregated complexes of rooms, plazas, and corrals (Ferguson 1996:31).

Historic Navajo orchards were established in canyon lands near Navajo Mountain, Utah, in canyons along river beds near the San Juan River, and the previously discussed Canyon de Chelly National Monument, Arizona. I have traveled to these historic orchard sites for my scientific research and present-day caretakers explain that the orchards have been there for many generations. There is no scientific evidence that other crops were grown in the Pueblo peach orchards; only in Navajo orchard sites where both traditional annual and perennial crops were grown in the same fields (Figure 4.2). In addition to trading and geography of the Southwest peach, there are also management and cultural practices unique to each tribe.

Sipala in Hopi

The Hopi call peaches *sipala*. Working with the Hopi was a privilege. However, because I am Diné, many efforts to help preserve their traditional peach-growing

practices was hindered by years of negative U.S. Government influences on Navajo and Hopi relationships. Thankfully, the former Hopi Cultural Preservation Director, Leigh Kuwanwisiwma, supported my research, and as such, was the only Hopi elder interviewed. Hopi peach-growing practices are very similar to Zuni and Navajo practices. Kuwanwisiwma states:

> Then they [Kuwanwisiwma's ancestors] would plant about ten inches down, like that. They say that the best time to do that was right after the harvest, in the fall. And the peach seeds were fresh, you know, and mature, because that's when they harvested, and when they're ripe and ready, and the seeds (themselves) were mature (Kuwanwisiwma 2017: 2).

After the trees were grown a couple of years, then they were transplanted to their permanent locations. Kuwanwisiwma does not recall the peaches ever being watered. Traditional Hopi agriculture does not hold with watering their crops. This goes against Hopi tradition, as they believe watering contradicts their prayers of asking the creator to provide precipitation for their crops, regardless of their lands receiving an average of 15-25 cm of precipitation annually (Singletary et al. 2014).

Pruning was not adopted by the Hopi until recent times, but now it is done prior to blooming. Once the trees are in bloom, thinning is a "cultural no-no," as Kuwanwisiwma states. During a time when a peach farmer from California visited his father's orchards, the farmer began thinning some of the fruit off the trees, to which Leigh and his father reacted, saying "You don't do that! They're our children, you don't do that to them. You let them grow" (Kuwanwisiwma 2017:6).

Harvesting the fruit is again similar to the Zuni and Navajo practices of splitting the peaches and drying them on the rock face. Kuwanwisiwma states:

> During good harvest, after the women folks split open the peaches there would just be piles of seeds, like that [clears throat]. And he would go out to the edge of the mesa where the women folks had peaches drying up. And I remember just the edge of the cliff there: just nothing but yellow, all the way, because that's where the women were. But my grandfather would go over there, and we would go over there, and put the seeds into the buckets (5-gallon buckets), and then we'd take them back. And that's what he would use during the winter, too, as fuel (in the wood stove) (Kuwanwisiwma 2017:5).

Kuwanwisiwma explained how his family would boil the peaches with cinnamon for dessert.

Culturally, the seasonal cycle of the peach blooming and ripening determine the Hopi's Katsina (spring) ceremonies (Singletary et al. 2014). With the limited number of elders interviewed, there is no further information provided on the cultural significance of peaches for the Hopi.

The Hopi Reservation experiences more severe drought conditions than any other Pueblo or Navajo lands. Experts with the University of Arizona's College of Agriculture in Tucson established experiment stations on the Hopi Reservation. These stations were discontinued around 1920 because "the experts admitted they could teach the Hopi nothing about growing food plants suited to the Hopi country" (James 1974:178). It is remarkable to note that peach cultivation was adapted to Hopi agricultural practices, as

the availability of water through either precipitation or irrigation limited adoption of other crops.

Mo:chikwa in Zuni

Mo:chikwa is peach in the Zuni language. It has no relation to the Spanish term for peach: *melocotón,* or the corresponding modern Spanish Mexican term *durazno*. *The Zuni Enigma* by Nancy Yaw Davis suggests that the peaches the Zuni grow may have originated from the Japanese, as the Japanese word for peach is *momo* (2000:167). However, as Davis (2000) and other scientists note, peach DNA testing is required to disclaim current theories of Spanish origins. My research encompassed such DNA testing of several seedling peaches collected in Hopi and Navajo orchards (Chapter 2).

As previously discussed, Zuni villages had "peach orchard villages" away from their main villages that served as "refuge sites" (Ferguson 1991:31). At the end of the nineteenth century, the peach orchard villages were rarely utilized, except during peach ripening for crop protection and processing for storage (Ferguson 1991:35). Today, these orchards are rarely visited or known to community youth. In fact, I found that only a few Zuni elders still knew about the peach orchards and could discuss traditional peach management practices, the location of the historic orchards, or the significance of peach in Zuni culture. Three Zuni elders were willing to be interviewed. They explained personal experiences of growing the Southwest peaches. To my surprise, each elder was only aware of a couple of existing orchards near the village on the mesa shelves. Putting their stories together, I was able to identify at least five orchards with peach trees or the remains of peach trees; which I have shared with the community.

In his interview, Zuni elder, Fred Bowannie (born 1950), told about learning to plant peach trees from tribal member Lygatie "Old Man" Laate, who died in the 1990s. Laate cared for a peach orchard on the North mesa to the Zuni Village called Twin Buttes. Laate showed Bowannie how to prepare a peach seed for planting. He explains, "Old Man Lygatie told us about growing peach tree from seed was that he would freeze it, thaw it, freeze it, thaw it – a couple years, and then crack it open and plant the seed" (Bowannie 2018:6). After this, the seed was planted with the cracked shell in a container with homemade potting media of oak litter, loamy soil, and manure and kept in a warm dark place until it emerged from the potting media layer. Next, the seedling peach trees would be carried up the mesa to be planted; berms were built around each to collect run-off water from the mesa top. Bowannie's account for planting a new generation of peaches in Zuni is the only one out of the Zuni elder's interview.

Thelma Shishie (born 1928) was interviewed with her daughter Lauren Dina Shishie (born ca. 1960s). T. Shishie does not recall planting new trees in the peach orchard her family traditionally cared for at Pia Mesa to the South of the Zuni Village in New Mexico. However, she was told how to start a new tree from seed. Thelma Shishie states, "the trees were already there when my great-great-grandmas grew up. So, I don't know who planted it, how it comes up there" (Shishie and Shishie 2018:9). She echoed Bowannie's recollection, of berm-building around the trees every spring to allow run-off water to collect at the base of the trees and allow suckers to grow out to rejuvenate the tree.

Pruning the fruit trees was only done to remove dead wood material. In summertime, Carlos Laate (born 1962), grandson to Old Man Laate, would occasionally

help his grandfather care for the peach orchard at Twin Buttes, in New Mexico. In his youth, he would prune the dead tree branches and build berms around the trees, like Bowannie and Shishie, for water collection and to obtain suckers to rejuvenate the trees. All three Zuni elders indicated that the peaches were not irrigated. This is most likely due to the fact that the orchard locations are so remote, with shear entryways, that carrying water would not be practical (Chapter 2).

Peach harvest occurred from late summer to early fall. Once the peaches were harvested, they were divided and laid on sandstone near the orchard. Bowannie recollected about Old Man Latte's peach harvesting techniques, "he had a couple of slabs of sandstone rock, which he took ripe peaches, and took out the peach and spread them, and just laid them on top of that rock" (Bowannie 2018:6-7). After harvest, some peaches were eaten fresh, the remaining were dried (traditional preservation method), or canned (adopted practice). Some of the dried peaches were made into preserves to spread on bread and for desserts, such as cobblers.

Perhaps the Zuni's adopted peach growing practices from older origins focused on adapting a tolerance for the harsh Southwest environment, including non-irrigation activities. Looking into the cultural importance of the peaches for the Zuni can shed light on this discussion. During the Zuni winter solstice, the whole village fasts and prays for the start of the new year, known as Shaloko. One of the winter solstice ceremony chants features a prayer for an abundant peach crop in the new year (Bunzel 1992:714). The peach is mentioned with many other traditional food crops, such as corn, beans, squash, yuccas, cactus, forest trees, weeds, wild grasses, etc. Ferguson (1991:31) indicates that the peach orchard villages were likely to be places for ceremonial practices. This

correlates with T. Shishie's knowledge of an existing shrine for the peaches at their orchard on Pia Mesa. Offerings would be made for the peaches to thrive and continue for the nourishment of their people (2018:18). The shrine that T. Shishie describes no longer existed during my 2015-17 visits. Although there are many other shrines that Zuni priests travel to for their offerings, this was a specific shrine for the peaches.

Along with religious connections of peaches in Zuni culture, T. Shishie and L.D. Shishie explained possible peach origins in Zuni. The Shishie home is situated over the main Zuni Village next to the plaza used for ceremonies. For preservation purposes (est. 2000s), the Zuni Tribe remodeled parts of the old village, including the Shishie home. During the remodel, the Shishie's kitchen floor was replaced. During construction a small door was noticed; some of the remodeling team opened the door and descended below the floor, finding a small 1.2 m by 1.2 m room, 1.5 m high. The Shishie family was called to show the discovery. L.D. Shishie states:

> There was like corn grinding things sitting there. And on the side, there's like little dots, like this way, and a basket like this [gesturing]. The peaches, they were sitting there. It's dry, like sit around; and then there's like a little, like a hollow thin, opening like a little refrigerator, kind of – the dry peaches were in there. And they were going to ask if they could take it apart, and I said, 'No, leave it.' (Shishie and Shishie, 2018:22)."

The Shishie family did not allow an archeological excavation stating "that was their treasure" but requested the remodelers to fill the doorway to the subfloor with concrete so all their findings would stay hidden and protected.[1]

Didzétsoh in Navajo

The Navajo often call peaches Diné didzétsoh, meaning "the people's peach." The Diné are considered to be nomadic because they move their families and livestock herds between winter and summer camps in the canyons. Unlike the Pueblo Tribes, they do not live in large communities but are spread across many miles between small family dwellings. The canyon lands in Arizona and Northern New Mexico provided a stable environment for peach growing. The heat from the rocks would radiate through the orchards at night and moderate conditions, including reducing the risk of blossom damage due to cold. Peach growing was practiced continuously throughout Navajo lands and is still evident today in few canyons near Navajo Mountain, Arizona, Canyon de Chelly National Monument, and in a small location near Shiprock, New Mexico.

The Navajo establish new peach trees in a similar way as outlined by the Zuni elders. Diné elder May Gui (born 1936) actively replanted new peach trees in Canyon del Muerto, Arizona, throughout her life. Elder Gui's orchard is one of the last remaining healthy orchards in Canyon del Muerto along with Katherine Paymela (age not given) and Francis Drapper's (born ca. 1930-1940) orchards. Gui demonstrated cracking a Navajo peach pit open to remove the seed for planting. She explained that the peach seeds were planted where ash is thrown out of the house to provide the nutrition needed

[1] The Zuni people remain cautious to outside scholars' and researchers' involvement within their community to preserve cultural identity.

to make the seedling strong. Her niece, Sylvia Watchman, translates, “they used to [start] them during the month of November. And then during springtime, they will grow out in a bunch. And then they always look for places where it’s good for the peaches to grow out” (Gui 2017:2). Alternately, the Tsinnajinni siblings, Rocky (born 1941) and Sarah (born 1954), from Jayi Canyon near Navajo Mountain, Utah, say not to crack the peach pit before planting, as the method will produce a stronger tree once germinated (Tsinnajinni 2018:7).

The canyons the Navajo peaches are grown in have relatively high water-tables. Navajo elders explain how they would irrigate the young trees daily until their roots established in the soil, and then eventually reaching the water table. Sally Tsosie (born ca. 1950s) states, “if the ground is wet, we don’t really have to worry about it; we don’t water it all the time” (Tsosie, 2017:16).

The elders I interviewed, recalled that their grandparents managed the peach orchards without supplemental irrigation, relying on precipitation. Katherine Paymela explains:

> Quite a while back, there was a lot of rain that we received, and we didn’t live this drought world back then, so there was plenty of water. We have spring waters here and there; we didn’t really use. We did use them when we needed them; but now, with the drought, even our spring waters are kind of low” (Paymela 2018:2).

These drought conditions are likely contributing to lower water tables and could increase the rate at which the peach trees are dying off throughout all the orchard sites.

However, Gui describes how the Navajo peaches can grow in sandstone cracks along the canyon walls without management. Gui's niece, Sylvia Watchman translates:

> She [Gui] said when people eat the peaches, they throw the pits out. So, during I guess all this time when it starts to rain, it starts to just, you know, take them here and there, and some of them go in between the rocks. So, now she says that she knows that there's some that grow out in between the rocks, and then some, they go all the way down. And so, they just grow anywhere, because people just throw them out after they eat them (Gui 2017:2).

Pruning is not normally practiced. This was not explained in much detail by any of the Navajo elders interviewed. Harvesting Navajo peaches was explained in detail, as it is the rewarding activity of peach growing. Francis Drapper discusses how the peaches would be split into halves and dried on the flat sandstone near the orchards. After the peaches were dried, they would be stored and made into a cake with corn, rehydrated in stews, preserves, or cobblers.

These management practices are similar to the Zuni peach growing practices. Historians at Canyon de Chelly National Monument believe the Navajo came into contact with peach growing in the canyons in the seventeenth century and that it was the Hopi people who planted the first peach trees in this area, now destroyed by Kit Carson (Bradley 1973:27). Elders that grow peaches in the canyon have been told this by park guides. Sally Tsosie states,

> They don't know exactly, though, who used to live in these canyons. They tell us that they sent out letters all over, what tribe used to live inside the canyon.

> And if a letter had come back in, 'It was us.' Then they would ask the question you are asking me, they could ask them, and that could give them a little idea (Tsosie 2017:9).

However, today many Navajo elders are indifferent to the historians' theories of peaches coming from the Spanish. My father, Roy Talker (born 1958) counters historian theories as his grandfather always told him that "the peaches were there [in the canyons] from a long time ago" (Talker 2017:2), not of Spanish origin.

Talking with Rocky and Sarah Tsinnajinni, they mention being told by a nephew, who is a judge in Kayenta, Arizona, that he "actually found the seed in a cave (like in an Anasazi cave). But they also said that they found corn in the cave" (Tsinnajinni 2018:9). This correlates with the recent finding of the now cultivated Anasazi Bean.[2] Though there is no record of the beans' exact origin, it has been preserved in an Anasazi cave and is now sold as a commodity.

Peach presence in today's culture: Conclusions

Navajo, Hopi, and Pueblo Tribes all hold some claim of originating from the Anasazi. Yet, only Navajo elders claim that peaches came from the Anasazi. Most Zuni tribal members are unsure of exactly where peaches came from, however, they do believe they have ancient origin, possibly tying to the Anasazi, as noted in Zuni elders' interviews. The Hopi agree with many scholars' assertions that peaches have Spanish origins. Though there are differences between the tribes of the peaches' presence in their

[2] Two additional accounts from Navajo members state similar stories of the peach seed being seen in Anasazi ruins. These two accounts will remain off the record with the permission to convey the information, but do not want to be identified.

culture, there is commonality between traditional cultivation, harvesting, food preparation (drying, rehydration in stews) and storage practices. For this reason, these newly documented elders' information on customary cultural activities should be given consideration when interpreting Indigenous foodways and history.

Literature Cited

Barnes, Ian
2009 *The Historical Atlas of Native Americans*. Cartographica Press, London.
Benavides, Alonso de, fl.
1996 [1630] *A Harvest of Reluctant Souls: The Memorial of Fray Alonso de Benavides, 1630*. Translated by Baker H. Morrow. University Press of Colorado, Nitwot, Colorado.
Brody, J.J.
1991 *Anasazi and Pueblo Painting*. University of New Mexico Press, Albuquerque.
Brugge, David M., and J. Lee Correll.
1971 *The Story of Navajo Treaties.* Navajo Historical Publications, Documentary Series No. 1. Navajo Tribe, Windrow Rock, Arizona.
Bunzel, Ruth L.
1992 *Zuni Ceremonialism*. University of New Mexico Press, Albuquerque.
Davis, Nancy Yaw
2000 *The Zuni Enigma*. W.W. Norton and Company, New York.
Ferguson, T. J.
1996 *Historic Zuni Architecture and Society.* The University of Arizona Press, Tucson.
Flint, Richard, and Shirley Cushing Flint (editors, translators, and annotators)
2012 *Documents of the Coronado Expedition, 1539-1542: "they were not familiar with His Majesty nor did they wish to be his subjects"*. University of New Mexico Press, Albuquerque.
Forde, C. Daryll
1931 Hopi Agriculture and Land Ownership. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland* 61:357-405.
James, Harry C.
1974 *Pages from Hopi History*. The University of Arizona Press, Tucson.
Jett, Stephen C., and John Thompson
1974 The Destruction of Navajo Orchards in 1864: Captain John Thompson's Report. *Arizona and the West* 16(4):365-378.
Kerpel, Diana Magaloni
2014 *The colors of the New World: Artists, Materials, and the Creation of the Florentine Codex*. Getty Research Institute, Los Angeles.
Maxwell, James A. (editor)
1978 *America's Fascinating Indian Heritage*. The Reader's Digest Association. Pleasantville, New Jersey.
Prescott, William. H.
1843 *History of the Conquest of Mexico, with a Preliminary View of the Ancient Mexican Civilization, and the Life of the Conquerór, Hernando Cortés, Vol 3*. Harper and Brothers, New York.
Reichard, Gladys A.
1974 *Navaho Religion: A Study of Symbolism.* 2nd ed. Princeton University Press, Princeton.

Roberts, David
2015 "Catch Me If You Can," *Backpacker,* May <https://www.backpacker.com/stories/catch-me-if-you-can>, 19 April 2019.
Singletary, Loretta, Stacy Emm, Micah Loma'omvaya, Janine Clark, Matthew Livingston, Michael Kotutwa Johnson and Ron Oden
2014 *Hopi People of the Land: Sustainable Agriculture on the Hopi Reservation.* University of Nevada Cooperative Extension, Reno.
Stout, Mary A.
2012 *Native American Boarding Schools*. ABC-CLIO, Santa Barbara, California.
Thompson, P.
1998 *The voice of the past: Oral History*. In: R. Perks and A. Thomson (eds.). The Oral History Reader, 2nd. Edition. Routledge, Abingdon, Oxforshire.
Toelken, B.
1998 The Yellowman Tapes, 1966-1997. *Journal of American Folklore* 111(442):381-391.
Winship, George Parker
1896 *The Coronado Expedition, 1540-1542*. Government Printing Office, Washington.

Figures

Figure 4.1. Overlook of Jayi Canyon near Navajo Mountain, Utah (2016). Photo curtesy of Grant Cardon.

Figure 4.2. Navajo peaches growing in Jayi Canyon near Navajo Mountain, Utah. Summer 2018.

CHAPTER 5

FOURTH SISTER: IMPORTANCE AND USES OF NAVAJO SPINACH (*CLEOME SERRULATA*)

Abstract

Southwest Indigenous Americans traditionally traveled great distances to gather native plant resources needed for cultural and ceremonial purposes, including Navajo spinach. Knowledge of these traditional practices is being lost in reservation communities, starting with colonial society restrictions on Native American's cultural practices and as the encroachment of modern society continues. To address the current impact of modern culture, an extensive literature search was completed in conjunction with collecting several Indigenous elders' oral histories about the traditional, historic uses, and current importance of Navajo spinach (*Cleome serrulata*). The interviews consist of descriptions of the native land where the spinach grows, how the plant was harvested, preservation practices, utilization as a food source, and a brief discussion of cultural significance. The collected information will help identify approaches to reintroduce Navajo spinach into Indigenous communities as a common nutritious food source and to preserve tribal elders' knowledge.

Introduction

Throughout recorded tribal history in the Americas, the Three Sisters: corn, beans, and squash were significant food sources for many Native Americans (Johnson and Hook 2007:9). The vernacular name "Three Sisters" is an indicator of the interdependence of the three throughout their lifecycle. Often planted together in one hole, as the crops grow they sustain and support one another (Allosaurus 2007:81-83). There are additional food sources used by Indigenous Americans that are supplied through the natural environment without cultivation, including *Cleome serrulata,* commonly known as Navajo spinach. Toby Hemenway (2001:149-150), a leading writer on permaculture, suggested Navajo spinach as a companion sister, or "Fourth Sister," to the Three Sisters.

Indigenous Americans depended heavily on gathering native species for food and everyday resources: dye, clothes, baskets, and more (Moerman 1998). Traditionally, tribes traveled great distances to surrounding regions to gather and trade these natural resources. This is especially the case with indigenous peoples from the American Southwest, where much of the natural environment is arid desert and resources are scarce and often found over greater distances (Barnes 2009:110). Yet, *C. serrulata* is found over a large land area throughout the United States and Canada (United States Department of Agriculture, Natural Resources Conservation Service 2019). This plant is more commonly known in the Western U.S. as Rocky Mountain Beeplant, but to Southwestern Tribes it is known as wild spinach, or Navajo spinach, after the Navajo people who credit the plant for saving them during starvation periods. Other common names include bee spider flower, beeplant, stink or skunk weed, and stink clover.

Species Background

Navajo spinach is recognized for its multiple conservation uses. It is commonly found growing in sandy, waterway terrains. It provides pollinator habitat and is a common food source for game birds. While helping harvest Navajo spinach seed, Zuni tribal member Anthony Wytsalucy recalled eating dove many times over several years. He notes that "this [Navajo spinach seed] is the seed you find in Mourning doves when you clean them for eating during the fall," inferring that the Mourning Doves must eat a lot of Navajo spinach seed at this time of year. During Reagan Wytsalucy's research, she observed how popular Navajo spinach seeds are by many bird species. In related work to germinate *C. serrulata* seeds for cultivation (Chapter 3), seed was harvested in the fall. A colleague, James Frisby, Plant, Soils, and Climate Lab Technician for Dan Drost (Utah State University Vegetable Specialist) and Wytsalucy observed hand harvested seeds that fell to the ground after one harvest day (estimated to be thousands) were gone the next morning (Frisby, personal communication 2018). This occurred over many weeks of harvesting. The seed disappearance is assumed to be from multiple bird species feeding on the seed supply. Thus, Navajo spinach seed appears to be an important food source for many birds in the fall.

Additionally, Navajo spinach is utilized in rangeland renovation and for conservation cover to help prevent erosion (Winslow 2014). Although livestock are not particularly interested in foraging on *C. serrulata*, they will utilize the plant in cases of drought (personal observation). Navajo spinach is an annual with erect growth, trifoliate leaves (3 leaflets), and can grow up to 60 inches tall (Figure 5.1). It emerges in the early

spring (March-April) and develops woody stems toward the end of its lifecycle in the fall. Once mature in mid-summer, indeterminate nectar-rich flowers are formed, with flowers being both self and insect pollinated. With successful pollination, a long fruit pod is grown to yield numerous seeds for the next growing season. Flower color is used to distinguish between *C. serrulata* and *C. lutea*, a cousin species to Navajo spinach. Navajo spinach has purple-pink and occasionally white flowers, while *C. lutea* has yellow flowers (Figure 5.2). *C. lutea* is not as widespread as *C. serrulata* but does grow in the Western states with *C. lutea* var. *jonesii* found only in Arizona. Though modern society recognizes *C. serrulata* and *C. lutea* as separate species, the Southwest Native Americans did not distinguish between the two, giving them the same name and utilizing them in the same manner.

Methods

As a Navajo tribal member (Diné) growing up in Gallup, New Mexico, Reagan Wytsalucy, the primary author, was not familiar with Navajo spinach until being guided by her father, during 2016-2017, to areas in Northern Arizona and New Mexico where he remembered the spinach growing. The interest in Navajo spinach originated from a Navajo community member who expressed interest in learning the plant's growth requirements, as they no longer saw it growing in the same abundance as in the previous century. In 2015, research began to study Navajo spinach's germination requirements (see Chapter 3). This objective of this research was initially intended to cultivate Navajo spinach as a nutritional local food source and for conservation uses. Additionally, gathering oral histories from elders in the Navajo, Hopi, and Zuni Tribes regarding the

plant's historic uses was done by the primary author to become familiar with the plant and its preferred growing habitat. Interviewees were asked the following questions:

- Why do you think there was a decline in Native American agriculture? Was there a different decline period for the peaches than for general Native American agriculture?
- Did you harvest the Navajo spinach? Please explain how you used the Navajo (Wild) spinach (dye, etc.).

Randy Williams, Utah State University Fife Folklore Archives Curator and ethnographer, guided and supported this work, while Wytsalucy fulfilled the necessary fieldwork for this narrative. Thus, this narrative is written in first person from Wytsalucy's perspective on the following discovery on the cultural importance and uses of Navajo spinach.

Fourth Sister's Lasting History

As with all ethical oral history endeavors, I worked with an expert community scholar, Roy Talker (my father), to guide this work. Talker (Diné) was born in 1958 and grew up in the region surrounding Shonto and Inscription House Canyon in Arizona. In his earlier years he often explored the rural areas in the Southwest. As my research guide across the Southwest Reservations, it was to both our surprise to find *C. lutea*, a plant that he had never seen before having walked most lands in the Southwest.

In a remote canyon near Navajo Mountain, Utah, called Jayi (annunciated similar to ach'ihiyah, meaning armpit because the canyon wall is shaped like an armpit bend) is the location that Talker and I first came across *C. lutea*. Since 2015, the Tsinnajinnii and

Lowe Diné families guided Talker's and my efforts to search for historic peach orchards near Navajo Mountain, Utah (see Chapter 2). Isolated from urban influence, the Tsinnajinnii and Lowe Diné families lived in Jayi Canyon all their lives. They graciously aided my research, sharing their knowledge and crops over the years. During numerous visits to Jayi to talk with the Tsinnajinnii family, we were told of beeplants growing further up the canyon wash, which predominantly grew yellow flowers, but also purple. In late summer 2018, Talker and I traveled into these remote areas to find *C. lutea* and *C. serrulata* growing throughout the canyon wash as the Tsinnajinnii's noted (Figure 5.2).

To understand the abundance of *C. serrulata* and *C. lutea* (Navajo spinach), I also recognized their connection to the Three Sisters from literature searches of ancient Puebloan agriculture. It is interesting to consider why Navajo spinach could be considered the Fourth Sister. In an excerpt from *Gaia's Garden: A Guide to Home-Scale Permaculture*, Hemenway (2001), explores various species and their potential benefit to form guilds for beneficial interactions with the insect world. He explains his reasoning for suggesting Navajo spinach be called the Fourth Sister due its importance within the Southwest environment to draw pollinators to nearby crops:

> I was pleased to learn of this Fourth Sister, as it connects to the web of this guild's beneficial interactions with the insect realm. Part of the strength of corn/beans/squash comes from its tie-in with a non-vegetable domain: that of the symbiotic nitrogen-fixing bacteria carried by the beans. And now by adding a fourth plant to the guild, the web's pattern strengthens further, drawing insects into the network. Lured by bee plant, these nectar-slurpers will pollinate the squash and beans (corn is wind

> pollinated), ensuring good fruit set. By extending the Three Sisters, we've moved into three kingdoms: animal, plant, and bacterial [Hemeway 2001:149].

As mentioned previously, I observed this relationship while growing Navajo spinach seedlings from germination studies (see Chapter 3). Cultivating Navajo spinach in the field created a unique micro-ecosystem within one season, encompassing numerous predator and beneficial insects in an approximate 70 m^2 planting space. Dan Drost, Utah State University Vegetable Specialist, praised the spinach planting for improving the melon and squash yield in his 2018 research plots (Figures 5.3-5.4) (Drost, personal communication 2018).

In recent conversations with Josée Owen, Associate Director of Research, Development, and Technology, Fredericton Research and Development Centre: Agriculture and Agri-Food Canada, she noted that there is a focus on Indigenous food systems at Trent University. She specifically noted how *C. serrulata* was a prominent food source for Canadian First Nation peoples, not dissimilar to Southwestern Tribes (Owen, personal communication 2017). This provides a broader understanding of the importance of Navajo spinach in context to its natural distribution. Insights from Hemenway (2001) and Owen (2017) are important, but only a beginning for understanding the wide variety of uses and importance of this species to Native American foodways and culture.

In the American Southwest, additional evidence of the wide use of Navajo spinach comes from archeologist Winston Hurst's unpublished work. In it he details the Navajo's historic spinach preservation methods: drying the boiled plant material on

canyon walls (explained in more detail in *Waá in Navajo* section). Evidence of this is found at an ancient site in Butler Wash, Utah (north of the San Juan River) where iron has been removed from the canyon wall after recurring processes of drying Navajo spinach in patties on the rock-face for winter storage (Figure 5.5, scientific details from Winston Hurst). Hurst notes that Navajo informants living near Canyon de Chelly National Monument continue to practice this preservation process today. Corresponding with Hurst's information, human coprolites found at Antelope House in Canyon del Muerto, Arizona consisted of "a combination of corn, cottonseed, cactus, wild beeplant (*Cleome serrulata*) and squash" (Dunmire 2004:71). These findings were dated to be from Pueblo II (900-1150 A.D.) and Pueblo III (1150-1350 A.D.) periods, which seems to be a common occurrence in other archeological sites across the Southwest (Fry and Hall 1975; Toll 1984).

With the preluding evidence of the presence of Navajo spinach in indigenous culinary culture, there is great interest to preserve the plant's current uses and gain new insights from Southwestern Tribes regarding current environmental conditions of Navajo spinach. Due to the limited documentation of Navajo spinach throughout the twentieth century, it became extremely important to preserve the remaining knowledge surrounding the significance of Navajo spinach for the Navajo, Hopi, and Zuni Nations. This was done by interviewing tribal elders from each community. The following documented conversations will remain within the tribes and their families; however, the interviewees (and tribal review boards) allow me to share portions of the stories for this research, in detail below.

***Waa'* in Navajo**

Ethnobotanist E.F. Castetter (1935) researched many uncultivated native plants in the Southwest, including how the surrounding tribes utilized them. He details the Navajo's various uses of *C. serrulata*, called *guaco* during this time period, but today commonly called *waa'*, stating:

> The plant is used as food in several ways by the Navajo, who often make a stew of it with wild onions [*Allium* spp.], wild celery (*Cymopterus glomeratus*) and a little tallow, or bits of meat. Morsels of bread are then dipped into the stew and eaten. The young plants are also boiled with the addition of a pinch of salt and eaten as greens. The remnants of these plants are sometimes allowed to dry, and then cooked in the shape of small dumplings with meat or tallow. The young plants are also boiled and pressed out three different times after which they are rolled into balls and eaten; or they may be dried and stored for winter, and when the balls are to be used they are soaked, then boiled with or without mutton. The Navajo claim that guaco has on occasions saved them from starvation [Castetter 1935:24].

In his research from the early twentieth century, Castetter describes how Navajos prepared the Fourth Sister, which is similar to how their posterity prepares *waa'* today. Although knowledge of the use of *waa'* throughout the twentieth century was had by many tribal members, today only elders have the knowledge and practice to prepare *waa'* as a food source. In interviews with Navajo elders, I learned the most common way *waa'*

was utilized was by harvesting the young plant or leaves before the flowers were formed, boiling it, then removing the water (repeating this process up to three times) before forming it into the rolled balls, as Castetter explained. Other than with meat, the elders did not specify other dishes that *waa'* was served alongside.

There is, however, an additional preservation process done by Navajos living near Canyon de Chelly National Monument, where they would take the pressed *waa'* cakes and throw them at the rock walls of the canyon, letting them dry in the sun for storage. This information comes from Sally Tsosie (born ca. 1950s) and Mae Gui (born 1936), both residents of Canyon del Muerto. This modern-day practice by Navajo elders validates archeological findings by Hurst. Sally Tsosie noted:

> I believe that when we don't have any vegetable[s] and that, like green beans, corn, then they collect those [*waa'*], boil it over and over until it does not come up real fast. So, my grandmother would boil it two, three times – I don't know exactly how many times she would be doing that [to] get the bitterness out.
>
> And then she gets a handful and throw[s] it against the wall, and it sticks to the wall. And that's how she dried them. And you still can see those marks on the wall at Standing Cow [Pueblo III Ruin in Canyon del Muerto, Arizona]. And then when it's dry, they just get a spatula, [and] collect it off the wall [Tsosie 2018:10].

When talking with Katherine Paymela, a Navajo rug weaver from Canyon del Muerto, Arizona, she indicated, "Waa' is one of our best foods that we have, that we gather." (Paymela, 2018:7) Ms. Paymela generally eats traditional foods and particularly

enjoys fresh *waa'* harvest. She also utilizes boiled *waa'* to produce a light-yellow dye for her wool, which can be seen on many Navajo wool dye charts.

Along with being a food source (both fresh and preserved) and as a dye, *waa'* has medicinal properties. Medicine man Francis Drapper (born ca. 1930-1940), who serves the Canyon del Muerto community, explained what his mother taught him about the uses of *waa'*, including cooking various dishes and foods, and also how these practices imparted Navajo ways. This included many practices such as sand paintings, prayer songs, praying to the crops, and knowing many natural medicines and combinations of these medicines to formulate healing, including for bad dreams, illnesses, preventing pregnancies, and cleaning the body. Specifically for *waa'*, he is the only elder from the three tribes (and many other Southwest Native Americans I spoke with) who explained *waa's* medicinal properties. He shared that it helps sooth insect bites (mosquito, ant, etc.). I took the initiative to try *waa's* medicinal properties on a recent mosquito bite and the result was reduced inflammation and no itch after applying a pressed *waa'* leaf to the bite. Mr. Drapper also used *waa'* in combination with other natural medicines for healing purposes, which he did not explain in detail.

Tumi in Hopi

The Hopi call wild spinach *tumi*. Being Diné, my time working with Hopi to preserve the knowledge of the wild spinach was hindered by years of politically-motivated tension between Hopi and Navajo caused by repeated U.S. government influences. Leigh Kuwanwisiwma, the previous Hopi Cultural Preservation Director, was an advocate for research to benefit the Hopi people. He was very supportive of my efforts

to preserve oral traditions and was the only Hopi member to participate in an interview. Leigh indicated that his family and other Hopi collect the *tumi* leaves and dry them on screens or other material good for drying, without boiling them. They would store the dried leaves and take bunches to incorporate into dishes or boiled for a plain spinach dish. Kuwanwisiwma's family's use of *tumi* is marginally similar to Castetter's (1935) account of the Hopi people's variety of ways to utilize *tumi* in their cuisine. Of this Castetter (1935) wrote:

> Among the Tewa of Hano and the Hopi, the plant is of sufficient economic importance to be listed in songs with the three main cultivated plants, corn, pumpkins, and cotton. The plant is used in a variety of ways. It is gathered in mid-summer and boiled for a long time to counteract the alkaline taste and then eaten much as we eat spinach…The Hopi boil and eat the young leaves and flowers; also boil the young plants with green corn [Castetter 1935:24].

Had circumstances been better between the Hopi and Navajo, perhaps more knowledge of Hopi elders would be preserved to tell a variety of ways *tumi* is still used similar to Castetter's account.

***Ado:we* in Zuni**

Ado:we is what the Zuni call wild spinach. Much of the preparation for preserving the spinach is similar to Hopi and Navajo ways. Castetter (1935:25) mainly relays the way the Zuni enjoyed eating the spinach, "with corn (on or off the cob) strongly flavored with chili." Zuni elder Thelma Shishie (born 1928) and her daughter Lauren Dina Shishie

(age not given) still enjoy eating the spinach this way. Fred Bowannie, Zuni elder (born 1950), also gave a personal account of how his mother would prepare *ado:we*:

> Mom would take an old cast iron kettle – probably a good three or four gallon, a big one like that (spreads hands about two feet apart) – and maybe pick about two or three gunnysacks of that spinach. And then she will put it in there with salt, and a little bit of sugar, and just boil it and boil it for almost eight hours, [and] keep adding water…
>
> She would take a basket and put that spinach and dump it, and [the] juice would just ripple. But she would use [the] juice, and also make stew out of it…She'd put it in a pot, she'd cut up meat. But mostly I liked it when it was rabbit, fresh-killed rabbit: cut it up, put it there, corn, a little bit of flour, spinach. Make it into a nice, thick paste. It's good…eat it as a chip, or you can rehydrate it in the stew…when she wanted to spread it out, she'd put on salt, and cover it [with a] window screen [Bowannie 2018:8].

In addition to eating ado:we, many Pueblo peoples utilized it as the primary black pottery paint: often found on Anasazi pottery (Adams et al. 2002). Among all elders interviewed, Carlos Laate (born 1962) is the only individual that knew of these old pottery practices; making paint from *ado:we* and other native plants to create his own traditional Zuni pottery. He provided a detailed account of making the pottery paint:

> For the painting process of using the wild spinach, you just have to cook the spinach first, and then drain the water out (the liquid), and then

> you re-boil it [the spinach] again, and just keep boiling it, and boiling it until the water evaporates and the spinach water comes to a tar state, it gets real black, real, real heavy. And then once it gets to that point, you…scrape it from the bottom of whatever you're boiling it…and let it all dry out, let it get hard.
>
> And then once you want to mix some paint, you just take off a piece (or cut off a piece), put it back in [a] jar and then re-soak it: re-soak it, rehydrate it, and then mix it up. Once it's all dissolved you use it as paint. And if you want to make it darker, use hematite for the color black.
>
> And once you accomplish that and you start painting on your pottery, it will be like a brownish color first, but once you fire it, it will turn black. So, that's how I found out when I started mixing wild spinach with the hematite. There are several methods of mixing paints that I use.
>
> So, I kind of experimented with the wild beeweed and then the wild spinach and then yucca fruit that's been boiled down. So, I chose to use yucca fruit – it works for me. But it has the same thing that you would use with the wild spinach, it's just got a different color: it would have a real dark, black color; but sometimes it comes out real dark, dullish black color. It's almost like a permanent marker color: real dark [Laate 2018:10-11].

Amongst the versatile uses of the Fourth Sister, there are also cultural/religious uses to many Pueblo Tribes, including Zuni. This information has been shared through many accounts, but out of respect for keeping these practices private, I will not describe

them here. To build understanding on these practices, the spinach is one of the clan groups, such as corn or sun clan, etc., which the clan practices are those to be protected from being shared with outside members. Precedence for this attitude is found in folklorist Barre Toelken's work with Navajo medicine man Hugh Yellowman. Folklorist Randy Williams wrote:

> In 1998, he [Toelken] wrote the seminal 'The Yellowman Tapes, 1966-1997,' wherein he discusses his rationale for returning his fieldwork tapes to the Yellowman family, fearing someone might use them out of season or in culturally dangerous ways. Although criticized by some for this move, he held strong to his decision. He wrote, 'folklorists stand to learn more and do better work when scholarly decisions are guided by the cultures we study even when taking this course causes disruptions in our academic assumptions' [Williams 2019].

The Promise of Tomorrow

Talker's familiarity with remote areas across the Southwestern United States allowed him to describe population changes of predominant species, including Navajo spinach, throughout these areas. In the late twentieth century, the Fourth Sister's distribution apparently covered much of the sandy areas in valleys, covering roadsides and near washes, not always in close proximity to waterways. Today, this rarely occurs. Several elders from Zuni concur with this assessment and presume it could be an effect of less precipitation for consecutive periods.

Reduced precipitation is a common topic associated with climate disruptions, resulting in smaller native plant populations that are then also affected by higher

temperatures. The lack of precipitation and access to water, the elders note in their interviews, has also affected the interest to farm in these communities. Other possible reasons for reduced distribution may include overgrazing, erosion, or human influence by over-harvesting.

In the instance that narrower distribution continues to be the norm, there will continue to be reduced Navajo Spinach use by tribal members, thus preventing the passing of knowledge to younger generations. Climate change may also influence distribution as precipitation patterns change, but modern conveniences have also hindered interest for Navajo, Hopi, and Zuni to learn tribal heritage specifically associated with agriculture and use of their surrounding environment. Carlos Laate from Zuni notes:

> The wild spinach was very useful in the old days, but right now, nobody hardly knows how to cook that wild spinach…and what they would use it for. The new generation that's coming up – people don't really, I guess, want to work outside to harvest any of the plants. So, every time when they say…it's very delicious, but nobody hardly [uses] the wild spinach anymore.
>
> People just don't understand how important that is – that was our meal of the day. When we went out and get the wild spinach and cook the wild spinach. And you can't hardly see anybody doing that anymore. And it's just store-bought spinach that they [eat] [Laate 2018:10].

To bring light to current issues facing the Fourth Sister, there is a desire by elders, USU Extension, and the author to ignite interest in Indigenous youth by sourcing native plants as a common food in their communities. With movements

like Farm to Table and increasing interest in cultural cuisines, there is the possibility of promoting local interest in the Fourth Sister. I have begun working with White Mountain Apache Chef Nephi Craig, to produce a modern outlook of utilizing the Fourth Sister in its many forms by tying in traditional practices. Chef Craig is the Nutritional Recovery Program Coordinator and Executive Chef at the Rainbow Treatment Center and Café Gozhóó in the White Mountain Apache Tribe, Arizona. He uses his profession to heal people in his community from generational disturbances caused by centuries of colonial intervention. With Chef Craig, I find there are many possibilities to expand local knowledge for traditional foods and self-sustainability into cultural education and restorative healing through workshops to introduce indigenous foodways to Indigenous peoples and others.

Conclusion

In spite of everything that Navajo spinach faces from climate variability, lack of use, and limited knowledge for use and storage with elders, the Fourth Sister continues to be beneficial to multiple populations by providing pollinator habitat and environmental stability. It was my privilege to learn from present-day elders about the traditions surrounding Navajo Spinach, some going back to Anasazi times. Though many elders and their ancestors relied on the Fourth Sister's abundance in nature, it is my desire to preserve and share this information to the next generation of Navajo, Hopi, and Zuni members, revealing the importance of Navajo spinach historically and culturally to indigenous Southwest US peoples; and for its benefit to the fertilization of their plantings.

Successful scientific efforts to germinate the Fourth Sister will shed light on cultivation practices for personal garden and restoration purposes.

Literature Cited

Adams, Karen R., Joe D. Stewart, Stuart J Baldwin
2002 Pottery Paint and Other Uses of Rocky Mountain Beeweed (*Cleome serrulata* Pursh) in the Southwestern United States: Ethnographic Data, Archeological Record, and Elemental Composition. *The Kiva* 67:339-362.

Allosaurus
2007 North Carolina Native American Legends and Folklore: The First Americans! Electronic document, http://digital.ncdcr.gov/cdm/ref/collection/p249901coll37/id/25289, Accessed February 21, 2019.

Barnes Dr. Ian
2010 *The Historical Atlas of Native Americans*. Chartwell Books Inc. New York, New York.

Castetter Edward. F.
1935 Uncultivated Native Plants Used as Sources of Food. Ethnobiological Studies in the American Southwest 1. *University of New Mexico Bulletin* 4:1-59.

Dunmire, William W.
2004 *Gardens of New Spain: How Mediterranean Plants and Foods Change America*. University of Texas Press. Austin.

Fry, Gary and H. J. Hall
1975 Human coprolites from Antelope House: Preliminary Analysis. *The Kiva*. 41:87-96.

Hemenway, Toby
2001 *Gaia's Garden: A Guide to Home-Scale Permaculture*. Chelsea Green, White River Junction, Vermont.

Johnson, Michael, Richard Hook
2007 *Encyclopedia of Native Tribes of North America*. 3rd. ed. Firefly Book, Buffalo, New York.

Moerman, Daniel E.
1998 *Native American Ethnobotany*. Timber Press, Portland, Oregon.

Toll, Mollie
1984 Archaic and Historic Botanical Materials from Cerrososo Canyon Sites, Northeastern New Mexico. *Castetter Laboratory for Ethnobotanical Studies*. Technical Series 129.

United States Department of Agriculture, Natural Resources Conservation Service
2019 *Cleome serrulata* Pursh. *The PLANTS Database.* February 21, 2019. https://plants.usda.gov/core/profile?symbol=clse.

Williams, Randy
2019 Barre Toelken: 1938-2018. *Folklore*. 130(2):25.

Winslow, Susan R.
2014 *Rocky Mountain Beeplant (Cleome serrulata Pursh): A Native Annual Forb for Conservation Use in Montana and Wyoming*. United States

Department of Agriculture, Natural Resources Conservation Service. Electronic document, https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/mtpmctn12314.pdf, Accessed February 21, 2019.

Figures

Figure 5.1. *Cleome serrulata* along roadside on the Navajo Reservation. Photograph courtesy of Donna Talker and used with permission.

Figure 5.2. *Cleome lutea* flowers from population in Jayi Canyon, Arizona near Navajo Mountain, Utah.

Figure 5.3: *Cleome serrulata* flowers with multiple pollinators. Taken in Logan, Utah.

Figure 5.4. *Cleome serrulata* growing in row plantings next to melon planting at Utah State University's Greenville Research Extension Farm, Logan, Utah. Photograph courtesy of James Frisby and used with permission.

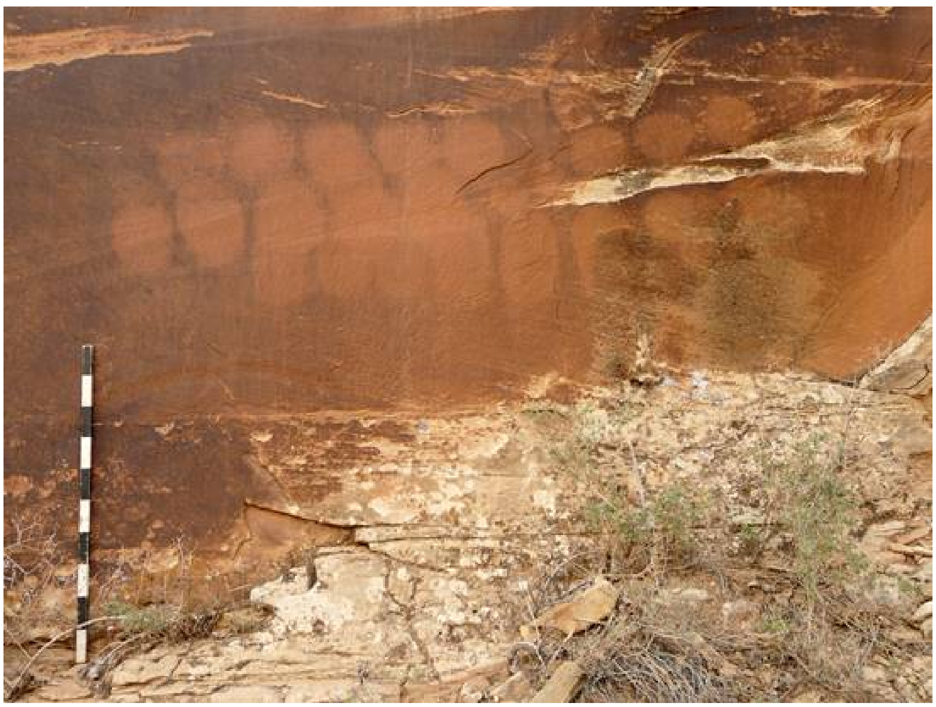

Figure 5.5. Archeological find by Winston Hurst displays iron removal from Navajo spinach (*Cleome serrulata*) drying process into patties for long-term storage. Photograph courtesy of Winston Hurst and used with permission.

CHAPTER 6

CONCLUSION

Southwestern Native American Nations are concerned about the current health crises of their people and with the reduction of cultural competencies, traditionally learned through oral teachings of their youth. The approach taken through this project was to address these issues through exploration of underutilized crops. This exploration included scientific and ethnography research approaches focused on two crops: Southwest peach and Navajo spinach.

Characterization of the Southwest peach was done through mapping of historic orchard sites genotyping plants from these locations, evaluating fruit quality parameters, and dendrochronology of wood samples from these locations (Chapter 2). The Southwest germplasm is inbred subpopulations with no close relationship to modern accessions. The peach fruit quality is likely influenced by management practices as much as genetic factors. However, management practices are still speculated to affect fruit sugar content, size, and dry matter content. The isolated inbred populations identified here resulted from generations of selection under unique environments and may yield important traits that could be useful for modern fruit production.

Navajo spinach seed successfully germinated under controlled environment conditions (Chapter 3). Optimal germination requirements include, pre application of GA_{4+7} and BA plant hormones at 600 ppm followed by hydration and chilling at 4 to 7°C for a minimum of four weeks. Though field trials were not done, there is future collaboration in progress to address environmental factors on these controlled

germination results. Additional studies with multiple seed locations were done in addition to experiments outlined in Chapter 3, as preliminary investigation to future field trials.

The collection of oral histories from elder's from the Navajo, Hopi, and Zuni Tribes provided new details of unique management practices dissimilar to modern orchard growing practices and by tribes (Chapter 4). The irrigation practices are consistent with dendrological data discussed in Chapter 2. Additionally, the peaches have ceremonial importance to the Hopi and Zuni Tribes. The peach is culturally imbedded along with all other traditional food crops giving reason to speculate it has been grown in the Southwest years prior to Spanish arrival. Further investigation done in Chapter 2 could support this speculation.

The importance of Navajo spinach was documented for the Navajo, Hopi, and Zuni Nations (Chapter 5). Information from elders provided further understanding from published documents of how Navajo spinach was and is utilized and incorporated into each communities' foodway heritage. The interviews also helped to supplement information from written sources on indigenous cuisine, religious significance, and medicinal properties of the Navajo spinach. This information is not only a helpful resource to the Native American communities, but also for promoting Navajo spinach as a food commodity.

Overall, this study has provided a foundation for a lifetime career of research focused on cultural preservation and potential horticulture methods for preserving crops. Much of this work will be utilized in educational outreach endeavors with participating Southwest Native American communities.

APPENDIX

APPENDIX A

VALIDATING GROWING CONDITIONS AT CANDIDATE ORCHARD SITES AND SELECTING SOUTHWEST PEACH SEEDS ON RESERVATION LANDS IN THE FOUR CORNERS

Abstract

Southwest Native American farmlands in New Mexico and Arizona have recently been abandoned resulting in diminished knowledge of agricultural practices. To encourage reestablishment of this knowledge, site characterization for fruit production was done on Southwest Native American lands, as the Southwest Native Americans successfully grew fruit crops. Much of the current soil identification is unknown throughout the Southwest Native American Reservations except for urban areas. Climate data is also localized to urban areas, but detailed temperature data profiles are unavailable from potential agricultural sites. A thorough review of archival soil and climate data was collected in the Four Corners region for a small number of candidate production sites. Four of ten locations were selected for further soil and water analysis and climate monitoring to verify archival data sources for orchard establishment, specifically Southwest peaches. Southwest peach pits were gathered from several locations and germinated for preserving the isolated peach crop for future reestablishment. Establishing orchards on Southwest Native American Reservations is anticipated to provide local grown food, bring back lost traditions, and educate future generations about agriculture.

Introduction

Site characterization of soil, water, and climate have not been recently recorded for a majority of Southwest Reservation farm steads. Thus, this study determined the current potential of four candidate fruit growing sites. Exploration and characterization of potential fruit growing sites across the Navajo and Zuni Reservations was done between 2014-2016. This was done in conjunction with finding remnants of historic Southwest peach growing sites for reproduction and to preserve traditional management practices. Like most traditional food crops, the peaches have become scarce with the communities' adaption to modern culture. The few remaining Southwest peach orchards are still found growing with Navajo, Hopi, and Pueblo Tribes. Propagating the Southwest peaches is important to these Southwest Tribes' heritage and historic diet. The following objectives were focused on to further understand current growing conditions for orchard crops on the Navajo and Zuni Reservations:

1) Evaluate the value and relevance of regional sources of soil, water, and climatic data necessary to selecting orchards sites with long-term, sustainable production potential.
2) Provide impetus for increased attention to higher intensity soil, water and climatic data collection important to revitalizing sustainable agricultural production on reservation lands, where needed.
3) Educate Native American peoples in reservation lands on the establishment of their own sources of nutritionally important produce that is often expensive and unavailable to them.

4) Locate productive orchard sites to collect propagation material to be utilized in future fruit characterization analysis and genotyping.

Methods

Funding was provided by Utah State University's (USU) Undergraduate Research and Creative Opportunities Grant. In order to facilitate fieldwork on tribal lands and with their community members, Institutional Review Board (IRB) approvals were obtained through USU, and the Navajo Nation. Tribal approval was obtained before receiving USU IRB approval.

This project was implemented with the help of Dr. Cardon, Soil Extension Specialist at USU. Thorough investigation of existing soil and climate data was undertaken for ten sites surrounding reservation lands. Primary sources include print and digital soil survey data made available by the USDA Natural Resources Conservation Service (through the SoilWeb user interface developed by the Soil Resources Lab at the University of California, Davis) and Utah Climate Center's current and archival climate databases for the study region. Remote HOBO temperature dataloggers were installed at the four candidate sites (Zuni, New Mexico; property near Gallup, New Mexico; Shonto, Arizona; and Many Farms, Arizona) to capture diurnal fluctuations in temperature at 1.2 m above the soil surface for three years. Temperature data was collected to capture the optimal growing season in each area, and to relate to archival climate history results.

Review of existing soil data was followed by visits to the four candidate sites. At least three soil samples were taken from each candidate area. For each soil sample, a coring probe was used to collect several sub-samples within the designated area (Figure

A.1). The samples were then mixed to provide a composite sample that was analyzed in the USU Analytical Laboratory. An additional soil sample and three water samples were taken in Many Farms. The first two taken from an irrigation canal, supplied by the local reservoir, and the third from the community's well water supply. Of the water samples taken from the canal, one sample was taken before canal reeds and the other after the canal reeds to determine salinity differences as the reeds filter the water.

An observation well was placed about 9 m away from a seep at Shonto to determine the water table. A soil probe was used to extract a maximum soil profile of five feet. A 1.3 cm PVC pipe was inserted into the extracted soils' place to prevent the surrounding soil from cavitating and easy measuring. The date and water table depth were recorded once in the spring and again in late summer of 2015.

In addition to site characterization, historic orchards were identified by the assistance of tribal community members. Collected peach pits were vernalized in moistened peat moss for two months before being planted in potting soil and grown out at the USU Research Greenhouse in Logan, Utah. Communication and education were done with local residents in the selected areas by attending board meetings, providing updates on research data pertaining to their areas, and supporting their agriculture foundation.

Results

Archival climate data analysis determined average frost dates, and maximum and minimum temperatures for a 30-year period. The growing period from archival data is shorter than recent data and temperatures tend to be warmer than the 30-year average

(Table A.1 and A.2). The selected Arizona sites have longer growing periods than the New Mexico sites (Table A.2).

Three of the four selected sites (Many Farms excluded) had exceptional soil and water properties for future cultivation. The initial Many Farms soil and water samples were 20.8 dS/cm and 2880 µS/cm respectively (Table A.3). This Many Farms site poses a concern from the reservoir's salinity issues from irrigation over a 30-year period. However, Many Farms High School FFA program utilizes the community water supply and is willing to support a peach orchard for education benefit. The additional soil analyses from Many Farms High School soil had a pH pf 7.59 and salinity of 11.08 mS/cm (Table A.4). The additional water analyses still had higher salinity in the canal before reeds (2.78 mS/cm) but was reduced after canal reeds (0.781 mS/cm) (Table A.4). Many Farms community well water was modest on salt (0.763 mS/cm). The water table depth at the Shonto observation well was checked June 16, 2015 was 1 m deep and on Aug 9, 2015 it was 4.5 m (data not shown). The water table is low enough to not be of concern for peach production. Peach pits were collected from two families in Canyon de Chelly, Arizona, and from two families in Hopi, Arizona. Seeds will potentially be collected from some families near Navajo Mountain, Utah. Peach pits were not found in Zuni, however, there is an orchard on a mesa shelf near the Zuni Village that has two trees growing and can potentially be used for bud grafting.

Shonto and Many Farms Chapters were notified on the soil, water and climate analysis for their areas (Figures A.5). Formalizing arrangements to use Many Farms High School farming grounds for orchard test plots were made. Continuing communication with local chapters for Shonto and Many Farms is ongoing as they continue to develop

and strengthen their agriculture programs. Shonto Chapter has begun working with Engineers Without Boarders to develop their lands for agricultural production.

Conclusion

Three of the four sites have potential for successful agriculture production. Further soil analysis needs to be done in Many Farms to characterize non-saline soils throughout the community. Continual participation in Chapter meetings will provide opportunities for agriculturally based learning environments and help ensure trust and support for future projects done in their communities. This research is a foundation for genotyping propagated peach pits gathered in this study.

Tables

Table A.1. Climate history from late 1900s of three locations on Navajo and Zuni Reservations.

Location	Climate History 30 Yr. Average Min(°C)	Max(°C)	30 Yr. Absolute Min (°C)	Max (°C)	Average Freeze Dates Spring	Fall
Shonto, AZ	-18.2	36.9	-28.3	40.6	24-Apr	24-Oct
Many Farms, AZ	-21.9	38.0	-35.6	40.0	3-May	16-Oct
Near Zuni, NM	-22.8	37.3	-35.6	40.6	19-May	9-Oct

*Utah Climate Center, climate.usu.edu.

Table A.2. Climate analysis of four locations on the Navajo and Zuni Reservations.

Location	Year	Spring Frost	Fall Frost	Growing Period	Annual Min (°C)
Shonto, AZ	2014	14-May	3-Nov	172	-12.6
	2015	17-Apr	6-Nov	202	-16.0
	2016	18-Apr	20-Oct	184	-18.8
Many Farms, AZ	2014	14-May	3-Nov	172	-12.4
	2015	17-Apr	6-Nov	202	-14.2
	2016	2-Apr	-	-	-
Zuni, NM	2014	15-May	3-Oct	140	-18.1
	2015	10-May	13-Oct	155	-17.6
	2016	31-May	16-Sep	107	-30.3
Near Gallup, NM	2014	15-May	12-Oct	150	-21.3
	2015	10-May	27-Oct	169	-18.3
	2016	1-May	24-Sep	145	-21.0

Table A.3. Soil and water analyses for four locations on the Navajo and Zuni Reservations. Spring 2014.

	Soil Quality		Water Quality	
Location	Soil pH	Salinity EC (dS/m)	Water EC (μS/cm)	SAR Adjusted
Shonto, AZ	8.20	0.39	287	0.25
Many Farms, AZ	8.40	20.5	2880	10.6
Zuni, NM	7.80	1.70	543	0.99
Near Gallup, NM	7.00	0.44	577	1.45

Table A.4. Soil and water analyses for various locations in Many Farms, Arizona. Spring 2015.

Sample	pH	Salinity EC (mS/cm)
High School Soil	7.59	11.08
High school Well	7.77	0.763
Before Reeds	8.79	2.78
After Reeds	7.80	0.781

Figures

Figure A.1. Wytsalucy gathering soil with soil probe for site characterization at location near Gallup, New Mexico. Spring 2014. Photo curtesy of Grant Cardon.

Figure A.2.Wytsalucy with Canyon del Muerto resident who provided Southwest peach pits for this project. Spring 2015. Photo curtesy of Grant Cardon.

Figure A.3. Canyon del Muerto Southwest peach pit planting by Reagan Wytsalucy with the help of James Frisby. Utah State University Research Greenhouse in Logan, Utah. Spring 2015. Photo curtesy of Karen South.

Figure A.4. Germination of Canyon del Muerto Southwest peach pits in Utah State University’s Research Greenhouse in Logan, Utah. Spring 2015.

Figure A.5. Wytsalucy presenting research to Shonto Chapter Officials in Shonto, Arizona. Spring 2014. Photo curtesy of Grant Cardon.

APPENDIX B

DETERMINING SEED GERMINATION REQUIREMENTS OF THE ROCKY MOUNTAIN BEE PLANT, *CLEOME SERRULATA*

Abstract

Native American Tribes in the Four Corners area are predominantly known for farming and gathering. Numerous native plants were gathered and used as food, such as the Rocky Mountain Bee Plant, *Cleome serrulata*. Wild populations of *C. serrulata* are scattered throughout the Four Corners area. There is interest within the Navajo communities for increasing the availability of native species, including *C. serrulata*, for traditional uses, such as food, pottery and basket making, and dye. Local production of *C. serrulata* for Native American Tribes will help reclaim lost traditions and agriculture practices. Minimal research has been done to determine *C. serrulata*'s germination and growing condition requirements. This study focused on physical and physiological traits preventing *C. serrulata*'s seed germination. Two germination trials were done involving 3 seed sources (Commercial, Chinle, Az and Zuni, NM) chilled for 4 weeks at 4, 10 or 20°C and scarification with or without sandpaper. Colder chilling temperatures increased germination over all while room temperature 20°C did not support seed germination. Scarification with sand paper didn't appear to improve germination. Additional methods of scarification are needed to determine benefits to germination.

Introduction

Traditional uses of *C. serrulata* include food source, medicine, and dye (Prendusi, n.d.). Young *C. serrulata* are harvested before maturity and cooked in stews (provide a source of Vitamin A and Calcium) or made into a tea to reduce fevers or minor illnesses. The seeds were ground to make bread or are commonly eaten raw. Hard-boiling mature plants produced a black dye to paint pottery and for dyeing baskets while a lighter boil will produce a yellowish-green dye for wool.

C. serrulata's wide distribution throughout North America and Canada suggests that seed may have a dormancy phase, like many native species. Several seed dormancy characteristics include embryo immaturity, seed coat impermeability, and endogenous embryo dormancy, or a mixture of dormancy mechanisms. In order to increase the native population of *C. serrulata*, or cultivate for agriculture production, optimum germination conditions need to be determined through a series of germination tests.

Objectives for this study include:

1) Learn optimal growing treatments for *C. serrulata* for greenhouse production and for native regions.
2) Determine if *C. serrulata* can be cultivated for mass production for Native American use.

Methods

C. serrulata seed was gathered near Chinle, Arizona and Zuni, New Mexico in Aug 2015. Commercial seeds of *C. serrulata* purchased from Great Basin Seed Company

served as our control. *C. serrulata* seed has a mixture of black and white seed. The white seed is thought to be immature, and thus, was separated from black seed to be tested separately. Cleaned seed were divided into 5 replications of 25 seeds for the various germination tests. Since fewer seeds were collected at the Zuni site, 4 replications per treatment were tested.

Treatments imposed on the 3 seed sources (Commercial (G), Chinle (C), Zuni (Z) included scarification and chilling (Phillips, 2007). Scarification occurred with #200 grit sand paper to the seed coat. Treated seeds were plated 47 mm petri dishes with sterile filter paper. Seeds were then moistened with 1.5 mL of 1% Captain® solution before chilling for 4 weeks at 4 or 10°C. After chilling all seeds were set at room temperature (~20°C) for two days before taking a final germination count. Additional Captan® solution was added to petri dishes as needed. Seeds were monitored for germination every 2-3 days for four weeks. Average percent germination and T_{50} (time for 50% of seed to germinate) was calculated to assess the speed of germination for each treatment.

Germinated seeds were planted in a well-draining, sandy potting media and grown at Utah State University's Research Greenhouse in Logan, UT for 8 weeks. During their vegetative growth, plant samples were periodically evaluated but no specific growth measurements were made as differences in growth were not evident.

Results

In Trial 1, the 20°C treatments did not germinate except for one seed in one replication, which produced the 6 days to 50% germination in the G seed (Table B.1). The Z seed also had slow germination as indicated by a higher T_{50} value. Chilling at 4°C

in both G and C seed resulted in lower T_{50} values than seeds chilled at 10°C (Table B.1). Lower T_{50} values indicate that chilling at 10°C speeds up germination than those chilled at 4°C. The influence of scarification on the speed of germination was inconsistent. The Z and all 20°C treatments had few seeds germinate (less than 3%) if any. Chilling G and C seeds at 4°C have greater germination than seeds chilled at 10°C (Figure B.1). Scarification treatments show some benefit to germination rates in the C 4°C trials (Figure B.1), but scarification did not improve germination for C seeds at 4°C. There was no difference between treatments with or without scarification for either the G or C seed at 10°C (Figure B.1 and B.2).

Similar to Trial 1, Trial 2 chilling at 4°C resulted in slightly longer T_{50} germination times than 10°C treatments. G seed chilled at 10°C had longer T_{50} values than what was recorded in Trial 1. Z seed consistently had poor germination in Trial 2. The final germination percentage and germination response curves in Trial 2 were very similar to those produced in Trial 1 for seeds chilled at 4°C (Figure B.3). Chilling at 4°C resulted in greater final percent germination for C seed. Scarification treatments show some benefit to germination at 4°C for G seed, but not for C seed (Figure B.3). The C seed germinated better overall than G seed at 4°C treatment in Trial 2 (Figure B.4). Generally, at 10°C, germination percentage was lower and more variable.

Conclusion

These preliminary germination trials suggest *C. serrulata* seeds require chilling for at least 4 weeks to germinate. Colder chilling treatments (4°C) resulted in higher germination percentages but a slower speed of germination (high T_{50}). While seeds

pretreated at 10°C had a lower percent germination but a faster T_{50}, this suggests there is an optimal chilling requirement for *C. serrulata*. Seed collected near Zuni may have been immature which likely lead to poor germination results. Tetrazolium staining will be done on the remaining Zuni seed to determine viability. The benefits of scarification were inconclusive and thus warrant additional application of other scarifying methods. These methods could include acid treatments or various plant hormones to determine if it will yield higher germination rates. There may be other environmental factors contributing to poor germination based on where the seed was collected. Germinated seed are being planted to harvest more seed for future germination trials (Figure B.5). Further work on seed germination requirements of the *C. serrulata* are warranted.

Literature Cited

Phillips, Nathan C. 2007. Diversity and adaptation along altitudinal gradients in the three wild *Allium* spp. native to Utah and implications for horticultural practices. PhD Dissertation. Utah State University.

Prendusi, Teresa. n.d. Rocky Mountain Bee Plant (*Cleome serrulata*). USDA Forest Service. (www.fs.fed.us/wildflowers/plant-of-the-week/cleome_serrulata.shtml)

Tables

Table B.1. *Cleome serrulata* time to 50% germination (T_{50}; speed of germination) after chilling at 4, 10, or 20°C with or without scarification (Scar).

Treatment	Commercial (Days)	Chinle (Days)	Zuni (Days)
Average T_{50} Trial 1			
4°C	16.5	15.6	29.0
4°C + Scar	14.8	14.2	-
10°C	11.7	10.7	12.0
10°C + Scar	11.6	12.4	-
20°C	6.0	-	-
20°C + Scar	-	-	-
Average T_{50} Trial 2			
4°C	17.9	12.3	-
4°C+ Scar	15.8	15.2	-
10°C	14.9	11.6	10.0
10°C+ Scar	18.5	14.2	27.0
20°C	-	-	-
20°C + Scar	-	-	-

Figures

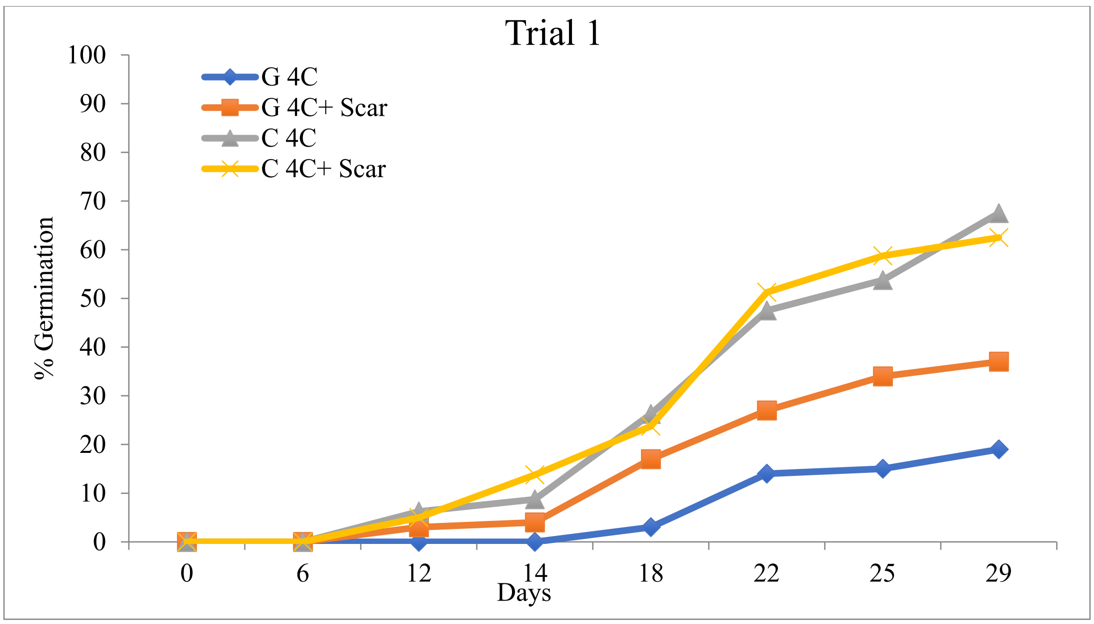

Figure B.1. The influence of chilling *Cleome serrulata* seeds at 4°C and seed scarification on the time course of seed germination for seeds from Commercial (G) or Chinle (C).

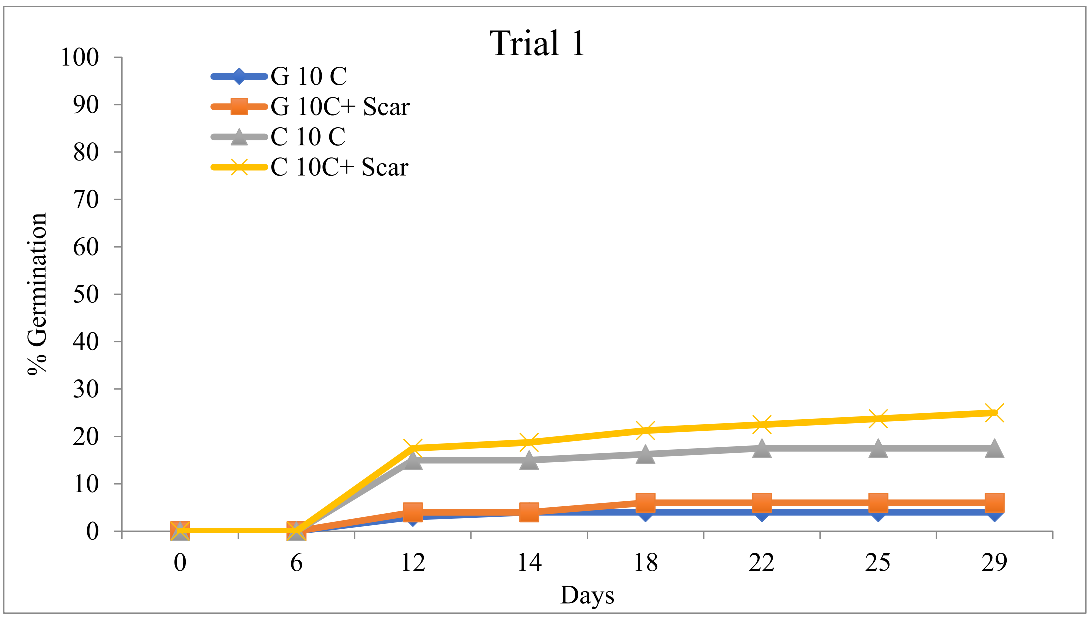

Figure B.2. The influence of chilling *Cleome serrulata* seeds at 10°C and seed scarification on the time course of seed germination for seeds from Commercial (G) or Chinle (C).

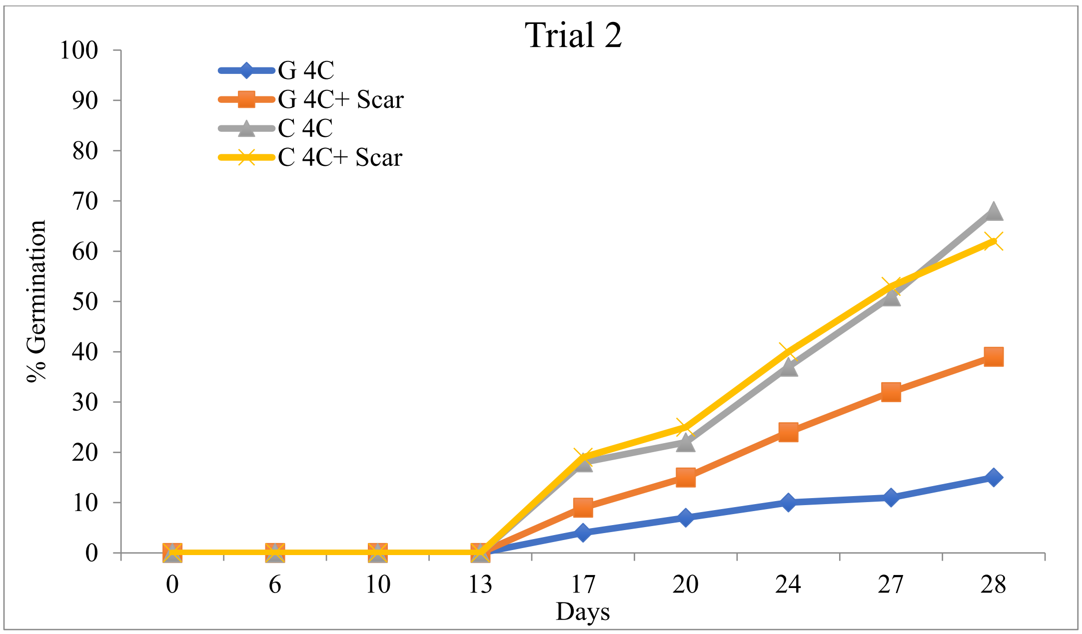

Figure B.3. The influence of pretreating seeds at 4°C and seed scarification on the time course of seed germination for seeds from Commercial (G) or Chinle (C).

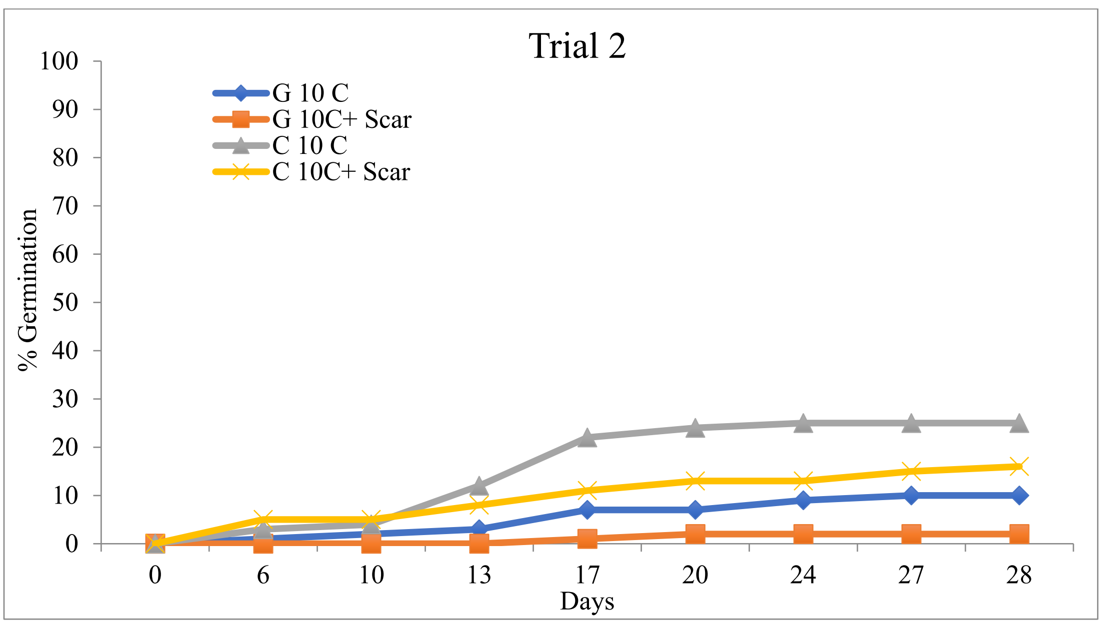

Figure B.4. The influence of pretreating seeds at 10°C and seed scarification on the time course of seed germination for seeds from Commercial (G) or Chinle (C).

Figure B.5. *Cleome serrulata* growing from germination Trials 1 and 2. Transplants are growing at Utah State Universities Research Greenhouse in Logan, UT. Spring 2015.

APPENDIX C

PEACH PROJECT ORAL HISTORIES

Interviewee: Francis Drapper; Navajo Nation (Figure C.1)

Interviewee Age: Est. 1930s

Place of Interview: Francis Drapper Residence; North Rim, Canyon de Chelly National Park, Arizona

Date of Interview: 16 June 2017

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 9 October 2018

Transcript Proofed by: Reagan Wytsalucy, 7 January 2019

Interview Deposit: Navajo Nation Human Research Review Board; Window Rock, Arizona

Brief Description of Contents: Reagan Wytsalucy interviews Mr. Francis Drapper regarding his knowledge on the Navajo peach, as well as the native Navajo spinach (waa'). Mr. Drapper talks about lots of his memories and experiences growing up raising peaches, vegetables and sheep. He shares lots of his cultural Navajo knowledge.

Interviewee: Katherine Paymela; Navajo Nation (Figure C.2)

Interviewee Age: Est. 1950-1960s

Place of Interview: Canyon del Muerto; Canyon de Chelly National Park, Arizona

Date of Interview: 23 August 2018

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 3 October 2018

Transcript Proofed by: Reagan Wytsalucy, 7 November 2018

Interview Deposit: Navajo Nation Human Research Review Board; Window Rock, Arizona

Brief Description of Contents: Reagan Wytsalucy interviews Katherine Paymela, member of the Navajo Nation. Ms. Paymela participates in farming, including the Navajo peach (Figure C.3). She talks about her knowledge and experience regarding the Navajo peach, as well as the native spinach (waa’).

Interviewee: Mae Gui; Navajo Nation (Figure C.4)

Interviewee Age: Est. 1930s

Place of Interview: Chinle Nursing Home; Chinle, Arizona

Date of Interview-Tape 1: 23 June 2017

Date of interview-Tape 2: 23 June 2017

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 8 October 2018

Transcript Proofed by: Reagan Wytsalucy, 6 January 2019

Interview Deposit: Navajo Nation Human Research Review Board; Window Rock, Arizona

Brief Description of Contents: Mae Gui talks about her memories and knowledge regarding growing, harvesting and preserving the Navajo peach, as well as the Navajo spinach.

Interviewee: Rocky Tsinnajinni (Figure C.5); Sarah Tsinnajinni; Navajo Nation

Interviewee Age: Rocky born 1941; Sarah born 1954

Place of Interview: Tsinnajinni Residence; Jayi Canyon, Arizona near Navajo Mountain, Utah

Date of Interview: 20 June 2018

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 2 October 2018

Transcript Proofed by: Reagan Wytsalucy, 7 January 2019

Interview Deposit: Navajo Nation Human Research Review Board; Window Rock, Arizona

Brief Description of Contents: Reagan Wytsalucy interviews Mr. Rocky Tsinnajinni, and his sister, Sarah Tsinnajinni; Mr. Roy Talker translates (Navajo to English). They talk about their knowledge and memories regarding the Navajo peach (Figures C.6-C.8), it’s history and location, as well as the native spinach (waa’).

Interviewee: Roy Talker, Navajo Nation (Figure C.9)

Interviewee Age: Born 1958

Place of Interview: Roy Talker Residence; Gallup, New Mexico

Date of Interview: 8 June 2017

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsaluc

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 30 September 2018

Transcript Proofed by: Reagan Wytsalucy, 7, November 2018

Interview Deposit: Navajo Nation Human Research Review Board; Window Rock, Arizona

Brief Description of Contents: Reagan Wytsalucy interviews her father, Roy Talker. Mr. Talker shares his knowledge, memories, and experiences of and with the Navajo peach, as well as the wild Navajo spinach (waa'). Mr. Talker speaks of his perspective on the history of the Navajo people, as well as his belief that science is limited when it comes to understanding the history of people (Figure C.10-C.11).

Interviewee: Sally Tsosie, Navajo Nation

Interviewee Age: Est. 1950s

Place of Interview: Thunderbird Trading Post Restaurant; Chinle, Arizona

Date of Interview: 26 July 2017

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33- 3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 7 October 2018

Transcript Proofed by: Reagan Wytsalucy 5 January 2018

Interview Deposit: Navajo Nation Human Research Review Board; Window Rock, Arizona

Brief Description of Contents: Ms. Sally Tsosie reminisces about her memories growing up, helping her grandparents grow food and with house chores, before going off to school (around age ten). She talks about her knowledge of how to grow the Navajo peach, as well as how to nurture, harvest and preserve the crop for eating. She also talks about her knowledge of the native spinach (waa') – how and where it was harvested, how it was processed and also how it was preserved.

Interviewee: Leigh Kuwanwisiwma, Hopi Nation

Interviewee Age: Est. 1950s

Place of Interview: Hopi Cultural Preservation Office; Kykotsmovi Village, Arizona

Date of Interview: 20 June 2017

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 8 October 2018

Transcript Proofed by: Reagan Wytsalucy, 7 October 2018

Interview Deposit: Hopi Cultural Preservation Office; Kykostmovi, Arizona

Brief Description of Contents: Mr. Leigh Kuwanwisiwma shares his knowledge and experiences surrounding the Hopi peach, including cultivating, germinating, pruning, harvesting and storing the peach (Figure C.12). He talks about what he knows about the history of the peach in Hopi culture and life. Mr. Kuwanwisiwma also talks about his knowledge surrounding the native spinach, or Rocky Mountain Bee plant.

Interviewee: Carlos Laate, Zuni Nation

Interviewee Age: Born 1962

Place of Interview: Airport Inn Hotel, Salt Lake City, Utah

Date of Interview: 13 October 2018

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 22 October 2018

Transcript Proofed by: Reagan Wytsalucy, 7 November 2018

Interview Deposit: A:shiwi A:wan Museum; Zuni, New Mexico

Brief Description of Contents: Mr. Carlos Laate recounts his memories of planting and harvesting food with his parents in Zuni. He talks about his knowledge and experience tending to and taking care of peach trees and orchards, something he learned from his father, as well as harvesting and preserving peaches. He shares his knowledge on the wild spinach that grows: how and when it is harvested, how it is utilized as food and paint, as well as how it stored.

Interviewee: Fred Bowannie; Zuni Nation (Figure C.13)

Interviewee Age: Born 1950

Place of Interview: Fred Bowannie Residence; Zuni, New Mexico

Date of Interview: 15 August 2018

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 7 October 2018

Transcript Proofed by: Reagan Wytsalucy, 6 November 2018

Interview Deposit: A:shiwi A:wan Museum; Zuni, New Mexico

Brief Description of Contents: Mr. Fred Bowanie talks about his life experiences with farming and gardening local crops, including Zuni peaches and native wild spinach. He talks about the ways in which he remembers harvesting, preserving and eating these foods. He shares his knowledge of the local landscape and history.

Interviewee: Thelma Shishie; Lauren Dina Shishie; Zuni Nation

Interviewee Age: Thelma born 1928

Place of Interview: Thelma Shishie Residence; Zuni, New Mexico

Date of Interview: 19 August 2018

Interviewer: Reagan Wytsalucy

Recordist: Reagan Wytsalucy

Recording Equipment: Voice Memos app on iPhone SE Version 12.0.1; RadioShack 33-3013 Microphone

Transcription Equipment used: Express Scribe with PowerPlayer foot pedal.

Transcribed by: Susan Gross, 29 September 2018

Interview Deposit: A:shiwi A:wan Museum; Zuni, New Mexico

Transcript Proofed by: Reagan Wytsalucy, 6, November 2018

Brief Description of Contents: Thelma Shishie (and daughter, Lauren Dina Shishie) talk about their memories and knowledge associated with the old peach orchards their family attended to historically, as well as the wild spinach (ado:we) they traditionally harvested, preserved and utilized (Figure C.14-C.15).

Figure C.1. Francis Drapper at his residence on Canyon de Chelly North rim. Summer 2017.

Figure C.2. Katherine Paymela at her orchard in Canyon del Muerto. Summer 2018.

Figure C.3. Katherine Paymela's peach orchard in Canyon del Muerto. Summer 2018.

Figure C.4. Mae Gui at Chinle, AZ community nursing home. Summer 2017.

Figure C.5. Rocky Tsinnajinni at his residence in Jayi Canyon. Summer 2018.

Figure C.6. Tsinnajinni orchard and field overlook next to their residence in Jayi Canyon near Navajo Mountain, UT. Summer 2017.

Figure C.7. Tsinnajinni peaches and corn. Summer 2018.

Figure C.8. Camp site at Tsinnajinni residence at Jayi Canyon near Navajo Mountain, UT. Summer 2018.

Figure C.9. Roy Talker at his home in Gallup, NM. Summer 2019. Photo curtesy of Donna Talker.

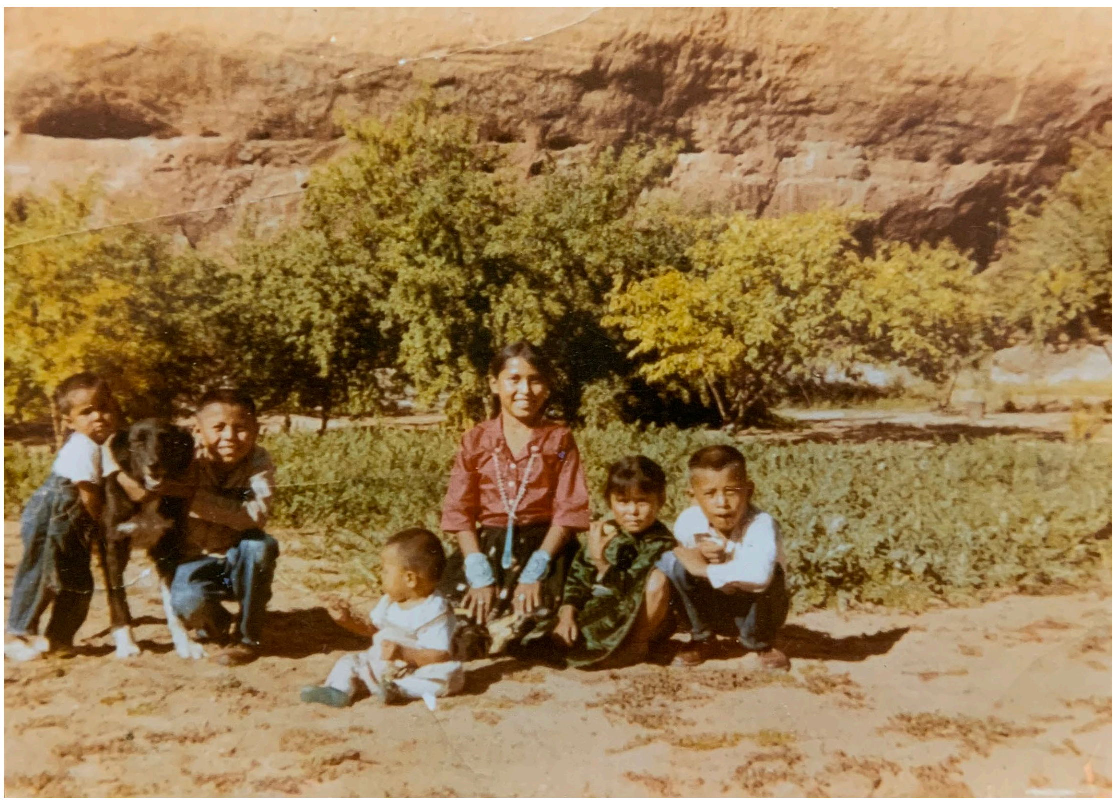

Figure C.10. Roy Talker (far left) with his siblings at their family garden and orchard in Shonto Canyon, AZ. Photo credit to Church of Jesus Christ of Latter-day Saint missionary. Summer 1961.

Figure C.11. Apricot tree with Roy Talker standing near at Inscription House Canyon, AZ. Summer 2018.

Figure C.12. Peach tree next to Leigh Kuwanwisiwma's house in Bacavi, AZ. Summer 2016.

Figure C.13. Fred Bowannie at his residence in Zuni, NM. Summer 2018.

Figure C.14. Pia Mesa peach orchard overlooking Zuni Village, NM. Spring 2016. Photo curtesy of Grant Cardon.

Figure C.15. Anthony Wytsalucy and Grant Cardon walk down narrow pathway from into Pia Mesa peach orchard. Spring 2015. Photo curtesy of Brent Black.