



COLLECTING

TAPERTIP ONION

(*Allium acuminatum* Hook.)

IN THE GREAT BASIN
USING TRADITIONAL
AND GIS METHODS

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ABSTRACT

As part of a biodiversity assessment and germplasm conservation project, we collected 55 populations of tapertip onion (*Allium acuminatum* Hook. [Alliaceae]) throughout the Great Basin region of the US (Idaho, Oregon, Nevada). Population data from field observations and herbarium specimens were entered into a geographic information system (GIS) to facilitate efficient sampling strategies and maximize the number and diversity of ecoregions represented. Although limited by the quality of source data, GIS-based population location information greatly aided in the organization and time management of the field collection. We collected, measured, and described bulbs. The bulbs will be used in common garden studies and genetic research to evaluate species diversity throughout the region, and develop *in situ* germplasm conservation sites for future rangeland restoration efforts. *Ex situ* collections will also be entered into the National Plant Germplasm System and be available for research, ecological restoration efforts, and germplasm enhancement.

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KEY WORDS

National Plant Germplasm System, georeferencing, field sampling, *in situ* conservation

NOMENCLATURE

USDA NRCS (2005)

Walter Kaiser collecting *A. acuminatum* bulbs in southern Idaho. Photo by RC Johnson

Rangeland restoration using native species is increasingly important for improving habitat quality in arid and semiarid western areas that have been severely degraded by wildfires, invasive annual grasses and noxious weeds, human activity, livestock overgrazing, and mining. The threats to ecosystem health in Great Basin rangelands have led to the loss of both plant and animal habitat. For example, only about 56% of Greater Sage-Grouse (*Centrocercus urophasianus* Bonaparte [Phasianidae]) habitat remains usable since settlement by people of European descent (Schroeder and others 2004; USDI BLM 2005).

Survival and fecundity rates for sage-grouse and other wildlife may depend on habitat quality, which is commonly quantified by the presence of key indicator species (Johnson and Braun 1999). The presence of wild onion (*Allium* spp. [Alliaceae]) and other key shrubs and

forbs are associated with good rearing habitat for sage-grouse (Nelle and others 2000; Miller and Eddleman 2001). Juvenile sage-grouse also depend on forbs and associated insects prior to brood dispersal (Drut and others 1994).

The diversity of forb species in the Great Basin and the limited amount of information concerning seed production, cultivation requirements, and seed transfer zones for many species has impeded the progress of restoration projects with native forbs (Walker and Shaw 2005). In an effort to alleviate the lack of research, federal and state agencies, universities, and private companies are working together as part of the Native Plant Selection and Increase Project (NPSIP) to promote the availability and variety of native plants for restoration efforts (USDA FS RMRS 2005).

The USDA Agriculture Research Service, National Plant Germplasm System (NPGS) is responsible for maintaining genetic diversity of economically important plant species. The Western Regional Plant Introduction Station (WRPIS), Pullman, Washington, as part of the NPGS, maintains approximately 72 500 accessions representing 358 plant genera (2194 species). Of these, 15% are native forb, shrub, and grass genera. The wild *Allium*, garlic (*A. sativum* L.), leek (*A. ampeloprasum* L.), and chive (*A. schoenoprasum* L.) collections (984 accessions, 108 species) are maintained at WRPIS. As part of an *ex situ* program, conservation maintenance of these genetic resources includes storage, regeneration, and distribution of germplasm for research.

Gene banks typically maintain *ex situ* genetic resources of native and cultivated plant material. *Ex situ* collections provide an easily accessed and organized germplasm resource. Alternatively, *in situ* conservation sites, in which populations are identified in natural communities for a given species, allow for the dynamic interplay of adaptation and survival pressures (Pavek and others 2003). Both *ex situ* and *in situ* approaches, however, have advantages

and are strongly complementary, especially for native species. *Ex situ* collections are readily available for research and provide a security backup for areas that may be disturbed or degraded. For native species that are difficult to regenerate *ex situ*, the *in situ* sites provide a source of germplasm from natural plant communities.

Pavek and others (2003) provide guidelines for selecting native plant populations that would be suitable candidates for *in situ* conservation sites using rock grape (*Vitis rupestris* Scheele [Vitaceae]) as a model. Rock grape is a wild North American species used as rootstock to confer grape phylloxera (*Daktulosphaira vitifoliae* Fitch [Phylloxeridae]) resistance to cultivated grape varieties (Cahoon 1996; Pavek and others 2000). They conclude that factors such as inter- and intra-population variation within the geographic range of a species can be used to determine the suitability of a particular population for *in situ* conservation designation.

The genus *Allium* is a member of the Alliaceae family and contains 500 to 600 species occurring mainly in the Northern Hemisphere (Kamenetsky 1993) with 84 species native to North America (Stearn 1992). Seven *Allium* species are currently grown commercially throughout the world including common onion (*A. cepa* L.), garlic, leeks, and chives. The Food and Agriculture Organization (FAO) reported in 2003 that common onion production was 52 550 metric tonnes (57 926 tons), surpassed only by tomato and cabbage in the vegetable and melon category (FAO 2003). Commercial and wild *Allium* plants have been used throughout history as a vegetable flavoring, are rich in carbohydrate, and full of vitamins and minerals (Augusti 1990).

Garlic is historically the most important *Allium* species utilized for medicinal properties, but other species have also received attention (Goldman and others 1995). Some traditional folk remedies involve the use of garlic as an antiseptic, diuretic, earache treatment,



Figure 1. *Allium acuminatum* collected at Roland Road (Owyhee County, Idaho) showing umbels, scapes, and bulbs.

Photo by Walter Kaiser

and for relief of arthritic and inflammatory pain (Augusti 1990). Wild *Allium* species have been reported by many early medical writers in Greece, Persia, and Arabia as a remedy for colds, neuritis, depression, fever, and dyspepsia (Kamenetsky 1993). Many of the North American *Allium* species also have been used medicinally. Meadow garlic (*Allium canadense* L.) is reported to prevent worms and colic in children, and shortstyle onion (*A. brevistylum* S. Wats) as a wash for carbuncles (Moerman 1998). Wild leek (*A. tricoccum* Ait.) is reported to have similar virtues as garlic (Foster and Duke 2000). Exploration of additional medicinal and nutraceutical values of wild *Allium* species, exotic and native, may be enhanced with expansion of the public *Allium* germplasm collection.

For this project, we chose to collect tapertip onion (*Allium acuminatum* Hook.; Figure 1) for germplasm conservation and potential future use in rangeland reclamation and restoration. *Allium acuminatum* is a perennial herb native to North America that grows throughout most of the western US and western Canada (USDA NRCS 2005). It has a large range compared with many of the North American native *Alliums* (Hellier 2000). Although other native *Allium* species occur in the Great Basin, *A. acuminatum* was selected because of its wide range, abundance, and possible association with quality sage-grouse habitat.

COLLECTION PROTOCOL

Possible collection site locations were obtained from a variety of sources including the University of Nevada-Reno Herbarium, field observations by USDA Forest Service and Bureau of Land Management personnel, and collection data from a 2004 preliminary field study. Information was organized into a spreadsheet for field use and entered into a geographic information system (GIS)-based map to aid in collection planning.

Personal observations and historical herbarium collection location data were converted into latitude and longitude in decimal degrees (DD.DDDD) for use in ArcMap® (ESRI 2005). Many of the locations from herbarium specimens were recorded in the form of Public Land Survey System (PLSS), also referred to as Township/Range/Section. These data were converted into coordinates (decimal degrees and Universal Transverse Mercator [UTM]) by means of an online conversion application provided by the Environmental Statistics Group at the University of Montana (Gustafsun and Wefald 2001). This conversion places the site coordinates in the center of the 1-mi square section indicated by the PLSS data.

The GIS data from Omernik Ecoregions and our possible collection sites were joined in order to identify *A. acuminatum* populations located in unique ecoregions (Minami 2000). This procedure allowed us to prioritize collection sites and maximize the probability of collecting plants that may have adapted to special or rare environments. Level III and IV Omernik Ecoregions geospatial data are available for most of the conterminous US on the Environmental Protection Agency website (US EPA 2005). Although other classifications are available, Omernik Ecoregions were chosen because of the ease in obtaining the data needed to create our preliminary collection site maps. Other ecoregion classifications, such as Bailey (1976) and Hargrove and others (2000), will be considered when investigating the influence of environment on phenotypic and genotypic variation of the germplasm collected in this study (Jones 2005).

Collection site data previously recorded from handheld global positioning system (GPS) units or general site directions were checked for accuracy using online US Geological Survey topographic quadrangle maps (1:24 000–1:250 000). Herbarium data that provided only road names and (or) mileage were assigned coordinates from online digital maps (Topozone.com® 2004).

GIS applications were used to examine sample collection data and elevation. Collection date and elevation aided in planning field work, so that bulb collection occurred when *A. acuminatum* was flowering. This timing was essential for field identification of populations because *A. acuminatum* umbels and scapes become difficult to see after flowering and seed set.

Once *A. acuminatum* was identified in the field, the population size and area (m²) were estimated. Sites separated by a minimum of 16 km (10 mi) from other *A. acuminatum* populations were considered individual populations. Forty to fifty bulbs were collected from across the population area. Only populations of 250 or

more individuals were collected to minimize the long-term impact on a given site. In practice, most populations significantly exceeded 250 plants (Figures 2 and 3). A large screwdriver was used for digging bulbs by removing soil surrounding the scape until the bulb was exposed (Figure 4). Although bulbs were occasionally damaged, this method resulted in less habitat disturbance than using a hand shovel. Bulb depth varied but generally ranged from 5 to 15 cm (2 to 6 in).

Site location, county, directions to the site, as well as site characteristics and associated vegetation were recorded, for study use and entry into the NPGS Germplasm Resources Information Network (GRIN) database (Figure 5). Latitude and longitude were recorded in decimal degrees centered on the collection area. All GPS coordinates were recorded using the World Geodetic System 1984 (WGS84) in order to minimize errors related to map datum (MANIS 2005). ArcPad® software (ESRI 2005) loaded on an iPAQ Pocket PC® was used to collect GIS data for Nevada sites (Figure 6).

COLLECTION RESULTS

The collection area spanned 1430 m (4692 ft) of elevation and covered approximately 620 km (385 mi) east–west and 445 km (277 mi) north–south, between N 39' to 44' latitude and W 114' to 119' longitude in the western US (Figure 7). A total of 3107 *A. acuminatum* bulbs were sampled throughout Idaho, Oregon, and Nevada. The bulbs were counted, measured (diameter), and assigned a shape description. They were then stored at the Western Regional Plant Introduction Station in a temperature-controlled room at 15 °C. Average bulb diameter was 1.0 cm (0.4 in) with a standard deviation of 0.2 cm (0.1 in) for the entire collection. The maximum bulb diameter was 2.1 cm (0.8 in) and minimum was 0.3 cm (0.1 in). The maximum and minimum site means were 1.2 cm (0.5 in) and 0.9 cm (0.4 in), respectively. Of the bulbs collected,



Figure 2. Large *A. acuminatum* population near Buchanan (Harney County, Oregon). Pink areas of the hillside haze are flowering *A. acuminatum*. Photo by RC Johnson



Figure 3. *Allium acuminatum* population growing near the North Fork of the Owyhee River (Owyhee County, Idaho). Photo by Walter Kaiser

91.1% were single bulbs, 8.7% were cloved bulbs (two attached sister bulbs), and 0.2% were 3-cloved bulbs (three attached sister bulbs). Most bulbs were globe-shaped (90.3%), 6.8% were classified as flat-globe, and 1.9% as high-globe (Figure 8).

Analysis of bulb diameter indicated a significant difference among the 55 collection sites ($F = 10.2$, $P < 0.05$), however, this analysis cannot separate the specific environmental and genetic factors related to bulb size. Despite statistical differences, the general uniformity in bulb size and morphology was striking given the large area and diversity of environmental conditions from which samples were collected.

Collection site coordinates were entered into a GIS database and a 30-m (93-ft) radius from the *A. acuminatum* population center was compared with Level III and IV ecoregions as described by Omernik (1987). *Allium acuminatum* populations were collected from 20 Level IV ecoregions (Table 1). Dissected High Lava Plateau was the most common ecoregion representing 24% of the 55 sites.

The use of GIS information allowed for efficient planning and organization of our fieldwork. Maps identifying possible collection sites provided a visual aid for route planning. Assigning coordi-

ates to Township/Range/Section data or general descriptive locations was useful when searching in remote areas with unmarked roads. GIS data such as ecoregions and land status (ownership) were helpful in determining priority and appropriateness of collection sites.

Although having predetermined coordinates for possible collection sites was generally useful, their value was limited by the quality of the source data. Some herbarium specimens were more than 40 y old, and location data from older specimens were often unreliable due to alteration of site condition. Land status changes were also important since our objective was to collect mainly from public and state land. In the field, determining land status from GIS-created maps or software was not always feasible. Consequently, BLM surface management maps (1:100 000) were consulted for increased resolution and ease of use.

Even though the utility of GIS-aided planning and analysis of germplasm collections has been described (Jones and others 2002; Hijmans and others 2001; del Rio and Bamberg 2004), this approach has not been widely implemented in ecological sampling for biodiversity assessments and germplasm conservation. Greene and others (1999) provide one example of an extensive

GIS application to field germplasm collection. For their study, a GIS consulting firm was hired to prepare data and provide maps based on elevation models, satellite imagery, digital soil maps, road maps, and climatic zones to aid in germplasm collection throughout the western Caucasus Mountains in southern Russia. Using site information based primarily on climatic zones and soil pH, the authors concluded that the GIS information minimized over-sampling of easily accessed or disturbed areas and facilitated identification of sample sites that would have been missed without spatial analysis (Greene and others 1999). The study also identified possible weaknesses in spatial analysis, such as precision of data. Analysis of on-site soil pH measurements showed that in complex and fragmented landscapes, higher precision than the available 1:1 million scale maps would be needed to use the GIS-derived soil maps to predict soil acidity (Greene and others 1999). It was noted that using satellite data to identify meadow patches was only suitable when GIS data was current and the site had not undergone recent anthropogenic disturbance (Greene and others 1999).

The use of GIS-derived maps and data for use in germplasm collection can function as an important tool for devel-



Figure 4. Collecting *A. acuminatum* bulbs in southern Idaho. Photo by RC Johnson

oping an effective sampling plan. With some introductory training on GIS software and mapping, members of the plant genetic resource community can benefit from this application. Many Internet and university-related educational opportunities are available (for example, ESRI™ Virtual Campus [ESRI 2006]), as are free mapping software programs from the International Potato Center at Lima, Peru, website (DIVA-GIS 2004).

COLLECTION UTILIZATION

In the fall of 2005, collected bulbs were planted in 2.54 cm (1 in) square x 12.70 cm (5 in) 4-cell, book-type starting containers with 50% Sunshine mix #4 soil and 50% perlite in the Western Regional Plant Introduction Station (WRPIS) greenhouses. The bulbs were then vernalized for 4 mo and were outplanted during spring 2006. Leaf tips from the greenhouse plantings have been collected for DNA extraction. DNA from selected populations will be analyzed by Sequence Related Amplified Polymorphisms (SRAP) (Li and Quiros 2001).

Phenotypic data collected from plants in common-garden studies will be used to complement the molecular data. Plants will be established at WRPIS farms in Pullman and Central

2005 *Allium acuminatum* Data Collection Sheet

Collector No. _____ Site Number _____ Date (DD/MM/YY) _____
 State (circle) OR ID NV County _____
 Latitude _____ N S Longitude _____ E W
 (WGS84, Decimal degrees)
 Directions _____

 Blooming phenology early mid late dry/with seed
 notes _____

 Collectors: BCH RTA WJK RCJ
 Population size _____ No. plants sampled _____ est. site size (m²) _____
 Population abundance: abundant frequent occasional rare
 Population Distribution: irregular uniform pure
SITE DESCRIPTION
 Exposure _____ Slope _____ Aspect _____
 Site Physical _____

 Site Vegetative _____

 Soil _____ Stoniness _____ Drainage (1=well, 4=poor) _____
 Invasive plant species present? (circle) Yes No _____

 Sage Grouse presence _____
 pygmy rabbit presence _____
 Other notes _____

Figure 5. *Allium acuminatum* data collection sheet showing site number, date, state, county, latitude, longitude, elevation, directions, blooming phenology, blooming notes, collectors, population size, number of plants sampled, site size, population abundance, population distribution, site description, associated vegetation, soil characteristics, invasive vegetation notes, and notes on species of concern.

Ferry, Washington. Data collected will include flower and anther color, leaf length and width, leaf number, scape length and diameter, flowers per umbel, umbel diameter, days to bolting, seeds per plant, average seed weight, and days to flowering. These data will be analyzed to characterize diversity using univariate and multivariate statistical analyses.

A major aim of this study is to investigate the patterns of diversity among and within populations of *A. acuminatum*. This, along with land status, ecoregions, and other environmental data, will be used to choose appropriate locations for

in situ conservation of *A. acuminatum* in the Great Basin. Methods employed by this study will provide a framework for utilizing genetic analysis, morphologic and environmental data, and geographic information systems to develop seed transfer protocols for ecological restoration of *A. acuminatum* and other native *Allium* species. This project in conjunction with other Great Basin native plant research may aid in habitat restoration efforts and provide an opportunity for recovery for threatened wildlife, such as the sage-grouse.



Figure 6. Robert Adair collecting *A. acuminatum* site data with i-PAQ GPS unit at Spruce Mountain site (Elko County, Nevada).

Photo by Barbara Hellier



Figure 7. Distribution of *A. acuminatum* collection sites across the Great Basin.

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TABLE 1

Number of *A. acuminatum* populations collected within Omernik Ecoregions (Omernik 1987). Ecoregion names in bold are Level III, others are Level IV.

Ecoregion	Level	Number of collection sites
NORTHERN BASIN AND RANGE	III	
Dissected High Lava Plateau	IV	13
Owyhee Uplands and Canyons	IV	8
Upper Humboldt Plains	IV	6
High Lava Plains	IV	5
Semiarid Uplands	IV	4
Semiarid Hills and Low Mountains	IV	1
Pluvial Lake Basins	IV	1
High Desert Wetlands	IV	1
CENTRAL BASIN AND RANGE	III	
Mid-Elevation Ruby Mountains	IV	3
Carbonate Woodland Zone	IV	2
Carbonate Sagebrush Valleys	IV	2
Central Nevada Mid-Slope Woodland and Brushland	IV	1
Central Nevada High Valleys	IV	1
IDAHO BATHOLITH	III	
Southern Forested Mountains/Dry Partly Wooded Mountains	IV	1
Southern Forested Mountains	IV	1
High Glacial Drift-Filled Valleys	IV	1
SNAKE RIVER PLAIN	III	
Unwooded Alkaline Foothills	IV	1
Semiarid Foothills	IV	1
Mountain Home Uplands	IV	1
BLUE MOUNTAINS	III	
Continental Zone Foothills	IV	1

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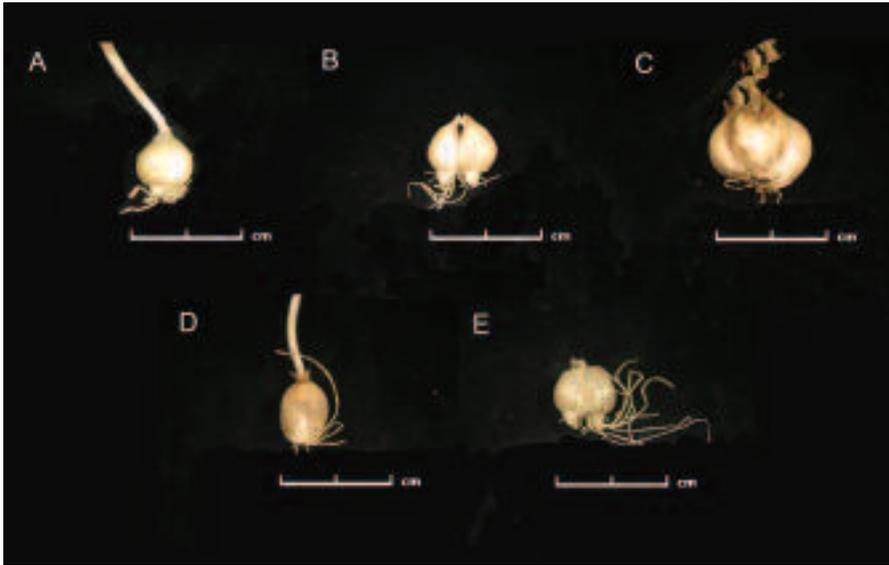


Figure 8. Bulb morphology. Single, globed (A), cloved (B), three-cloved (C), high-globed (D), flat-globed (E). Photo by Robert Adair

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